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OF ENGINEERING

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# ANNUAL 2005 OF THE CROATIAN ACADEMY OF ENGINEERING

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Zlatko Kniewald,
President of the Croatian
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# Foreword

Dear reader,

The past year 2005 will be written in the history of the Croatian Academy of Engineering due to a number of important events. The year has begun by the Euro-CASE decision on admission of the HATZ to its associate membership. Thus, our scientists were enabled to participate on the projects that are already being realized in the EU as well as those that are in preparation for the forthcoming programme agenda. The HATZ membership in the Euro-CASE, which has become possible only after the affirmative *avis* granted to the Republic of Croatia for its admission to the EU, was among the first initiatives taken by Croatian scientific institutions that has implemented this privilege granted to Croatia through the activities of establishing connections with the European scientists that had already been HATZ members since its foundation in 1993, or have become its members during the process of its admission to the Euro-CASE membership. This is particularly important because of the vicinity that enables a significant cooperation in the European area, which will, in the future decades, become a key area for maintenance of the technological and industrial step with the leading countries such as USA and Japan as well as the emerging technological focal areas such as China or India.

However, the Programme of our Academy must not close itself into narrow frames that, in time, would have lead to disabling wider cooperation also with the non-European nations and their scientists and entrepreneurs. Because of this, the past year has been directed not only to maintenance of HATZ activities within its membership in the CAETS, but also as HATZ contribution to strengthening the influence of this, the oldest, global association of engineering academies in realization of its partnership with the UN. In 2005 HATZ has accepted the offered chair in the CAETS Board of Directors and thus has contributed significantly to passing the documents that are the integral part of this "Annual": CAETS Development Strategy 2006-2010 and Statement on the future of the oceans as key factor for sustaining the life on the Earth, reflected upon from climatological, environmental, transport and food production viewpoint.

Our full openness to the world has been realized also due to our admission to full membership of the Croatian Academic and Research Network (CARNet) and transfer from temporary use of the server of the Faculty of Food Technology and Biotechnology and the Faculty of Geodesy in Zagreb, to our own server, and subsequent organization of the entire service network through the University

Computing Center (SRCE) and the HATZ. Thus the e-addresses in the form: Name.Surname@hatz.hr have been or are being assigned to all of our members. The existing web pages of the Academy in Croatian and English are being enhanced and updated daily, and I apologize to all visitors, almost 20 000 until now, who perhaps were not completely satisfied with our service in comparison to their expectations. However, all members of the HATZ are also personally obliged to update their data and to inform us on time about all forthcoming events in whose organization HATZ participates as co-organizer, and thus to contribute by their experience to the contents, quality and effectiveness of the HATZ web pages.

Within the results of the realization of the HATZ Programme during 2005 in Croatia, it is also necessary to emphasize a number of decisions passed at the HATZ Assembly in February, 2005. The Assembly was elective and the new Governing Board of the Academy has been elected. Many top scientists have been appointed to the HATZ membership, and a continuous successful cooperation with the economy has been realized, which means closer connections between the Academy and the economy and realization of the HATZ Programme with respect to the requirements of the economy. Since July 1, 2005, new Governing Board and Presidency of the Academy were introduced. They shall lead the Academy during the next four years and we have the honor to introduce them to our readers in this "Annual". The Foundation of the Academy has been established by donation of one of our Honorary Members from Canada, and we expect that it will become fully organized during the next year. Although the Managerial Board of the Foundation has been appointed, this year was particularly dedicated to strengthening the financial funds of the HATZ and realizing some previous obligations, which are the preconditions for maintaining constant funding of the Foundation of the Academy, aside from the funds for the Awards of the Academy that are being granted annually.

As you already know from the «Annual 2004 of the Croatian Academy of Engineering», during the previous year 2004, on the day of its Annual Assembly in February, the Academy had also organized a one-day Colloquium on specific requests of the engineering education with respect to various engineering professions. This initiative has given impulse also to the CAETS and the Euro-CASE to open discussion on this issue. The acknowledgement to our Academy's successful Colloquium was particularly visible at the 16th CAETS Convocation in Cairns, Australia, in July, 2005, where the organization of the discussion on engineering education was entrusted to our Academy in cooperation with the Korean Academy of Engineering.

In 2005, our Academy had organized a Colloquium on technologies that would help restarting production in Croatia, and in this "Annual" you will have the opportunity to learn on the technological solutions that can help starting SMEs and facilitate the new employment.

However, new technologies, new jobs, the existing production as well as the international surroundings and globalization of the market with the workforce migrations, open a series of ethical problems, which, in their final consequences, en-

danger more or less every man and threaten not only his physical and biological, but also his psychological balance. In its effort to reflect the seriousness of these problems that almost every inhabitant of the Earth is faced with one way or the other, the HATZ and its Committee for Ethics have organized a Round Table Discussion on these issues in June, 2005. The abstracts of the lectures delivered at this meeting are presented in this "Annual". Due to the fact that such complex ethical problems cannot be opened and solved in one day, and that all members and parts of the society as well as international institutions are responsible for their systematical analysis and solving, the HATZ intends to organize such discussions from time to time and make efforts that every member of the HATZ takes into account the consensus reached on these issues, at his working place as well as during his participation on the projects realized in cooperation with the economy.

I particularly wish to emphasize the activities of the Centers of the Academy, which either have developed close cooperation with the project holders or have started the projects themselves. I specially refer to the HATZ Center for Environmental Protection and Development of Sustainable Technologies that has signed the agreement with the Ministry of Environmental Protection and Spatial Planning of the Republic of Croatia. By this agreement the HATZ Programme for Life-Long Learning was also activated, and in the mid-2006 first seminar on this issue will take place. We hope that this event could become a permanent activity of the HATZ for the requirements of the entrepreneurs.

The "Annual" also contains the list of all Supporting Members of the HATZ - donors that have enabled the realization of the HATZ Programme during 2005. The Ministry of Science, Education and Sports of the Republic of Croatia has also supported some activities of the HATZ with the available funds. On behalf of all members of the HATZ I wish to express a cordial gratefulness to all mentioned institutions, and I am sure that our members have justified the invested funds by their quality work and results.

At the end, I wish to thank all members of the HATZ that have contributed to realization of the HATZ Programme according to her or his personal motivations and available time and energy. The adaptation of the House of the HATZ has successfully finished and its environment enhanced, the Library of the HATZ has started functioning, the banner of the HATZ was successfully designed by our distinguished members from the Department of Textile Technology. Having in mind all mentioned activities and results as well as positively finished financial year, I wish to thank all members of the HATZ as well as the Professional Staff of the HATZ with one permanent employee and financial, technical and legal services for their joint contribution to successful end of this year. I wish the following years to be at least as successful as the past year 2005.

President of the Croatian Academy of Engineering:

*Zlatko Kniewald*

# Contents

# CAETS Strategy 2006-10

Council Meeting July 14, 2005

## Preamble

CAETS is the International Council of Academies of Engineering and Technological Sciences, Inc. It consists of those national academies of engineering and technological sciences which have satisfied an agreed set of criteria for membership. It was established in 1978 and was incorporated as a charitable non-profit corporation in the District of Columbia (US) in 2000. Its Articles of Incorporation, By-laws and Operating Procedures set down its objectives and governance arrangements. Its membership and achievements are set down in the CAETS publication *The First 25 Years 1978-2003*.

## Mission

The mission of CAETS is to foster effective engineering and technological progress for the benefit of societies of all countries. Specifically, CAETS provides the mechanism through which the engineering and applied science academies of the world work together on internationally important issues in ways that enable each academy to draw on the total global experience and expertise of all member academies in addressing issues at the national level; and which ensure that the best technological and engineering expertise is made available to, and used to best advantage by, the key global intergovernmental institutions for the benefit of all the peoples of the world.

## Vision

The vision of CAETS is of a world in which national and international decision-making on economic, social, and environmental issues is properly informed on relevant scientific, technological and engineering considerations and in which the peoples of all countries benefit to the full from the capabilities of science, technology and engineering.

## Priorities

### Engagement with the United Nations specialized agencies and related international organizations

*Mission: Develop and implement an ongoing advisory/consultative role, with appropriate CAETS recognition, with the relevant scientific/technological organs of the United Nations(UN) System.*

The UN agencies/activities in need of informed, objective advice on scientific, technological and engineering matters include: UN Environment Programme (UNEP); UN Development Programme (UNDP); UN Commission on Sustainable Development (CSD); UN Educational, Scientific, and Cultural Organization (UNESCO); Food and Agriculture Organization (FAO); and World Meteorological Organization (WMO).

Member States and Territories of the UN, through their national delegations to sessions of these bodies have the opportunity for input and advice developed through their own domestic consultative arrangements, including that on scientific, technological and engineering issues from their own national academies. The envisaged role of CAETS over the next few years is to reinforce and complement the role of its member academies and provide consolidated input at the highest levels of the UN System by:

(i) Seeking Observer/Consultative status with key UN Agencies and Programmes with CAETS representation at the regular sessions of their governing bodies;

(ii) Encouraging and assisting CAETS member academies to be involved in the preparation of their national briefs and composition of national delegations to the governing sessions of these bodies;

(iii) Preparing a brief digest of major initiatives by CAETS and its member academies for input to the UN System and use by CAETS representatives in governing body sessions;

(iv) Inviting key relevant UN System Agencies and Programmes to be represented at CAETS Convocations; and

(v) Maintaining working relations on an equal basis with international, non-governmental engineering and scientific organizations, including the World Federation of Engineering Organisations (WFEO),Inter Academy Council (IAC), and the International Council for Science (ICSU), to facilitate cooperation and coordination in their input to UN System activities on engineering, technology, and scientific matters.

*Immediate goals: Over the next two years, CAETS will:*

- *identify and establish initial working contacts with at least two key UN System agencies;*
- *arrange CAETS representation, by invitation, at one or more UN System governing body sessions;*
- *provide all relevant UN System agencies with an introduction to CAETS and its activities;*
- *establish working relations with WFEO, IAC, ICSU and other relevant non-governmental bodies in respect of CAETS linkages with the UN.*

## Fostering and strengthening national academies of engineering and technological sciences

*Mission: Increase the number of academies to ensure that CAETS is a fully global organization*

Representatives of CAETS member academies need to be more proactive and contact appropriate engineering bodies and academies in other countries. CAETS should increase the number of member academies, especially from developing countries. We should encourage the creation of new academies of engineering in countries where none exists. In those countries where it is unlikely that separate engineering academies will be established, we should consider special arrangements with a view to enabling engineering subgroups of Academies of Science to be active in CAETS.

For many academies, which achieve their major income from personal membership, the dues to CAETS may be an important obstacle to active membership. CAETS should therefore maintain a dues structure which facilitates their membership.

*Immediate goals: Over the next two years CAETS will:*

- *Commence implementation of specific strategies to increase its membership by 50% by 2010, without altering its criteria for membership.*
- *Develop a list of possible candidate academies from Asia, Africa, the Middle East, South America and countries which were part of the former USSR based on member academy proactive contact with engineering bodies in these regions.*

## Convocations, symposia and reports - Support for member academy initiatives

*Mission: Join forces with member academies in order to better address global problems.*

Themes for the biennial Convocations reflect, to a significant extent, the host academy's view of its current national engineering and technological issue(s), and hosts of other year annual meetings schedule them to be in conjunction with a meeting of general interest to CAETS member academies. Also member academies of CAETS differ from one and other in financial resources and national and international impact and outreach. With a view to increasing the benefit of such CAETS activities, cooperation among member academies is encouraged, possibly including co-organization or co-hosting of meetings and collaboration on publications. A series of global technological foresights could provide useful input to the UN system, possibly in cooperation with Euro-CASE and similar regional organizations as well as with other international scientific and technological organizations with similar objectives. Issues for priority consideration by CAETS include:

- New Materials and Technologies
- Water management and production
- Transport
- Sustainable energy management, including the hydrogen economy
- Environment and Sustainable Growth

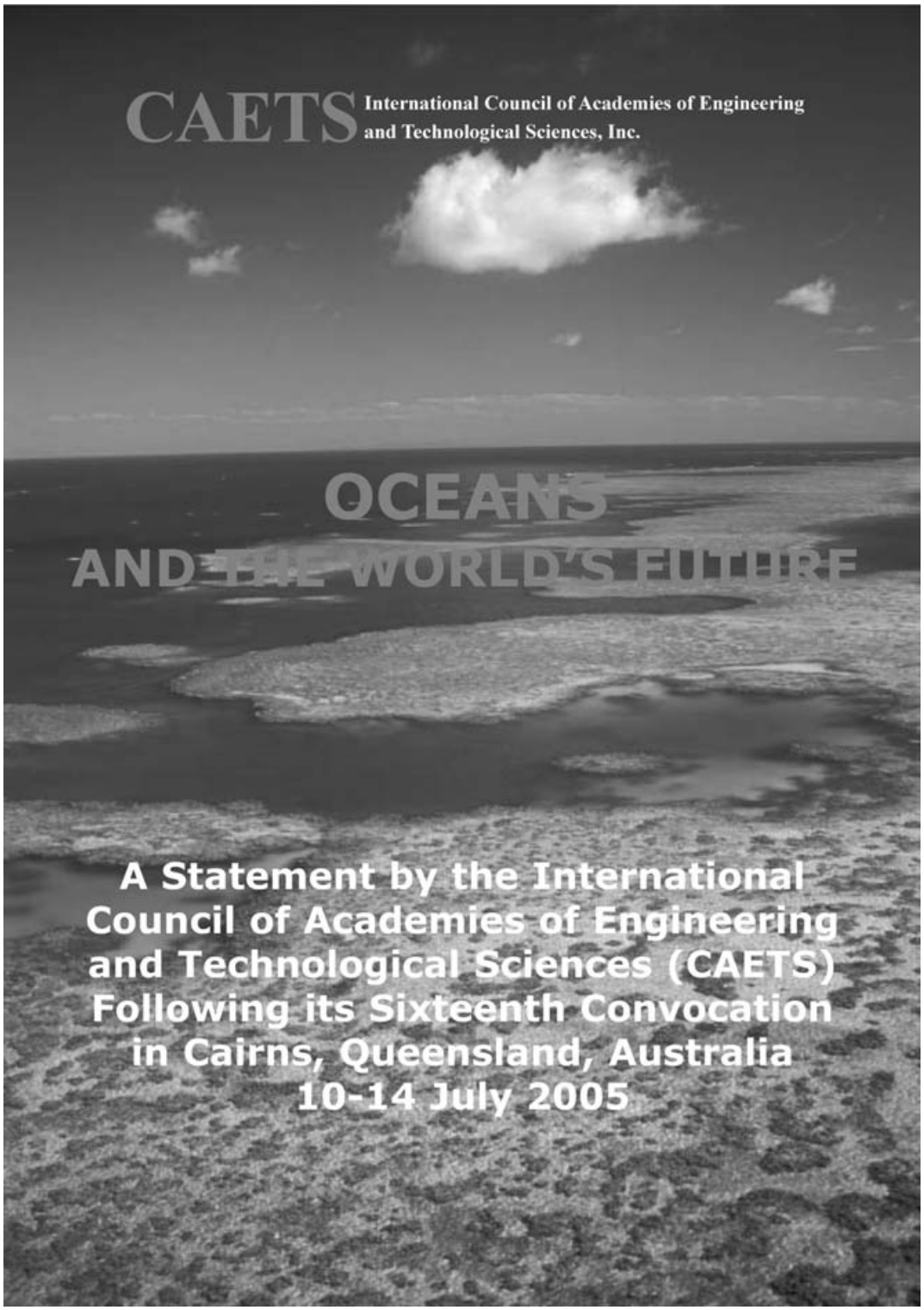
*Immediate goals: Preparation of a long term plan for a global technology foresight: Conduct of a successful Seventeenth Convocation in Japan in 2007.*

**Addressing issues of common concern** of the member academies at annual Council meetings and supporting workshops.

*Mission: Help member academies deal more effectively with their own national issues and academy operational issues through organized presentations and discussions at annual Council meetings.*

It has been shown that there are a number of issues of common concern among member academies, for example engineering education, which merit the attention of members of the Board of Directors with a view to organizing a portion of an annual meeting for discussion, possibly followed by a workshop, to assist participating member academies better deal with such issues in their own countries.

*Immediate Goals: Members of the Board of Directors will lead Council discussions on topics of common concern to benefit those member academies interested in the subject.*


CAETS
International Council of Academies of Engineering and Technological Sciences, Inc.
OCEANS
AND THE WORLD'S FUTURE
A Statement by the International Council of Academies of Engineering and Technological Sciences (CAETS) Following its Sixteenth Convocation in Cairns, Queensland, Australia 10-14 July 2005

# The International Council of Academies of Engineering and Technological Sciences

The International Council of Academies of Engineering and Technological Sciences, Inc. (CAETS) is an independent, non-political, non-governmental international organization of engineering and technological sciences academies, with one member academy per country. Its mission is to foster effective engineering and technological progress for the benefit of societies of all countries.

CAETS was established in 1978 with five founding Academies and held its first Convocation that year in Washington DC at the invitation of the US National Academy of Engineering (NAE). It consists of those national academies who have satisfied an agreed set of membership criteria designed to foster the highest standards of international excellence and who have sought admission and been elected to membership by the Council. Its current membership of 24 academies is listed, with contact details, on the back cover.

The administrative and policy body of CAETS, on which each academy has one representative, is the Council which elects the Officers (President, President-elect, Past President and Secretary/Treasurer) and the Board of Directors which consists of the Officers (the Executive Committee) and four other members each serving, except for the Secretary/Treasurer, for one year terms.

The President, President-elect, Past President and members of the Board of Directors during 2005 were:

- Dr John Zillman, Australian Academy of Technological Sciences and Engineering (ATSE), President
- Prof Achiel van Cauwenberghe, Royal Belgian Academy of Applied Sciences (BACAS), President-elect
- Prof Arne Bjørlykke, Norwegian Academy of Technological Sciences (NTVA), Past President
- Mr William C. Salmon, Secretary/Treasurer
- Prof Ben Veltman, Netherlands Society of Technological Sciences and Engineering (NFTW)
- Lord Alec Broers, Royal Academy of Engineering (RAEng)
- Dr Ki Jun Lee, The National Academy of Engineering of Korea (NAEK)
- Prof Zlatko Kniewald, Croatian Academy of Engineering (HATZ).

Recent Convocations have dealt with the following:

- Creating Wealth in Harmony with the Environment (Eleventh Convocation) Kiruna Sweden, 18-21 June 1995
- Engineering, Innovation and Society (Twelfth Convocation) Edinburgh, United Kingdom, 21-23 May 1997
- Technology and Health (Thirteenth Convocation) Sophia Antipolis, France, 24-27 May 1999
- World Forests and Technology (Fourteenth Convocation) Espo, Finland, 11-15 June 2001
- Entertaining Bytes (Fifteenth Convocation) Hollywood, United States, 18-22 May 2003.

The Sixteenth Convocation was hosted by the Australia Academy of Technological Sciences and Engineering (ATSE) in Cairns, Queensland, Australia on 10-14 July 2005. It was attended by delegations from eighteen CAETS academies and included an international Symposium on 'Oceans and the World's Future' with a total participation in the Symposium and associated events of 200 persons.

On the basis of the keynote address delivered by Dr Patricio Bernal, Executive Secretary of the Intergovernmental Oceanographic Commission (IOC) of UNESCO, invited presentations by 30 speakers and panelists, a closing address by Dr Meryl Williams and a synthesis by Symposium Rapporteurs Dr Greg Tegart, Dr Angus McEwan, Dr Russell Reicheldt and Mr Graeme Kelleher, the CAETS academy delegations reached consensus on the following statement and recomendations which were formally approved by the CAETS Council on 14 July and released on 28 July, 2005. This statement is also included in the Proceedings of the Convocation, copies of which are available from ATSE headquarters at:

The Australian Academy of Technological Sciences and Engineering (ATSE)
197 Royal Parade
Parkville VIC 3052
Australia
Ph: (+61 3) 9340 1200 Fax: (+61 3) 9347 8237 Email: andreww@atse.org.au

# OCEANS AND THE WORLD'S FUTURE

## A Statement by the International Council of Academies of Engineering and Technological Sciences (CAETS)

*The International Council of Academies of Engineering and Technological Sciences (CAETS) held its 16th Convocation in Cairns, Australia, from 10-14 July 2005, to examine the scientific, technological and engineering issues that link the world's future with the oceans. In the light of the presentations by the international experts assembled for the Convocation and review of the conclusions from the discussions during the Convocation sessions and an associated workshop on tsunamis, CAETS calls for urgent attention to the vital role of the oceans in the world's future. The following Statement, endorsed by the Council on 14 July 2005, sets out CAETS views and recommendations on the application of marine science, technology and engineering in planning for, and working towards, an environmentally, economically and socially sustainable future.*

**Introduction**

Although one third of the global ocean is divided into nationally controlled Exclusive Economic Zones, the ocean is a 'world commons' in which all of humanity has a stake, as set down in the United Nations Convention on the Law of the Sea. Humankind has used and exploited the ocean's resources extensively and sometimes destructively. Through the interconnectedness of the ocean's physical, geological and ecological systems, we all ultimately bear the consequences, good or bad. There is thus an inescapable international responsibility for what happens in and to the ocean.

The tsunami disaster of 26 December 2004 demonstrated the awesome destructive power of the ocean. More gradually, the oceans exert a profound impact on the global biosphere through their influence on weather and climate. At the same time, however, humans are changing the oceans on a comparable scale by, for example, depleting fish stocks and degrading the ecological condition of large parts of the coastal environment.

Science and engineering are the tools by which these interacting systems in the oceans can be understood and, to a significant extent, managed. The Convocation addressed the key issues relevant to the concerted and responsible action of the nations who are custodians of the world's oceans. Its main conclusions and recommendations are summarised below.

**Climate change in the ocean is a crucial issue for the future of mankind.**

The ocean and the atmosphere are intimately connected. Changes in the pattern of sea surface temperature are linked with changes in the atmospheric circulation. They affect the incidence of extreme weather and are precursors of climatic variability on inter-annual and longer timescales. The enormous thermal inertia of the ocean implies that any systematic change of climate will be of long duration.

With the development of ocean observing systems, the short-term prediction of climate variability is becoming practicable. The link between the El Niño-Southern Oscillation (ENSO) phenomena and inter-annual fluctuations of climate in many regions of the world is fairly well understood. Monitoring networks in the Pacific Ocean now give continuous data on sea surface temperature and subsurface heat content which, when used in numerical ocean-atmosphere models, allow extrapolation forward from the present state for periods of six months or more. Predictions diverge, but ensembles of outputs from different models improve the predictive capacity for a wide range of planning purposes.

The limits of predictability are yet to be tested for longer period fluctuations on the time scales of years to decades. Non linearity in marine and atmospheric systems may limit such predictability. The links between terrestrial climate and patterns of temperature and circulation in the adjacent oceans require more detailed understanding in many regions.

Long-term global warming due to the build up of greenhouse gases in the atmosphere and the increased release of fresh water in the polar regions are believed to have potential for altering the circulation of the entire world ocean, possibly bringing rapid alteration of the global climate patterns. This circulation may be sensitive to changes in particular regions such as the Indian Ocean, with widespread effects in both the ocean and the atmosphere.

The ocean may turn out to be the most reliable forward indicator of global climate change. Changes in the ocean climate are already observable and there is evidence that the human influence is separable from natural long-term variability. In wide regions, the deep ocean is perceptibly warmer and fresher. This warming can also be detected through its contribution to sea-level rise. In contrast, in some areas near the Arctic, there have been changes where the deep ocean is perceptibly cooler and fresher.

Warming can alter the viability of biological regimes, as evidenced by such events as coral bleaching. A rise in carbon dioxide concentration and acidity may seriously prejudice the shell-forming ability of biota, especially corals and modify other flora and fauna species. A drop in pH of 0.1 has been observed in surface waters and it is projected to fall by 0.5 by 2100.

Even modest increases in sea level, when superimposed on natural variability associated with shorter term meteorological influences including storm surges, can severely threaten coastal infrastructure. The water resources of small island communities are especially endangered through salt water contamination of the fresh water 'lenses' lying below the islands.

For all of these, and other, reasons, an improved understanding of the nature and mechanisms of climate change in the oceans is essential to properly informed policy development on all aspects of global climate change.

*CAETS recommends continued national and international investment in ocean monitoring and research as a vital input to national and international policy development on climate change and related issues. (Recommendation 1)*

**Human use of the marine environment must be made sustainable.**

Continental shelves and coastal zones comprise about 18% of the Earth's surface. They yield 90% of the fish catch and their margins are inhabited by 60% of the world human population. As spawning grounds, coastal zones and estuaries are vulnerable to land-sourced pollution and the legacy of agricultural and industrial practices. Even with vastly improved scientific data and knowledge, human exploitation and development in many regions, superimposed on natural change, challenges the sustainable future of coastal zones and requires a common understanding and concerted action by governments, industry and the community that transcends sectional interest.

Scientific monitoring and research, enhanced by modern technology and continuous scenario modelling, are essential to provide the tools and knowledge for sensitive and responsible national coastal management policies. As demand on ocean resources increases, the impact of multiple users in a given regional environment spreads to compound the pressure on species and to exacerbate conflicts of interest between the users as well as with those responsible for conservation in the broader public interest. In recent years, methodologies have evolved to reconcile the interests of multiple usage for a sustainable future. In some situations, novel technology such as the creation of artificial reefs can relieve environmental pressure.

Central to these methodologies is the concept of ecosystem management, wherein the effects of the external environment and man-made pressures upon the whole interacting biological system within a region are considered. Such methodologies require an expanded range of technical specialisations such as more sophisticated in-situ observing and quantitative data interpretation technology. Molecular biology will provide new tools for the rapid detection and quantification of environmentally forced change.

Classification of regional-scale habitats in terms of the types of flora and fauna populating them allows dynamic features common to different regions to be compared. The establishment of Marine Protected Areas not only protects zones of particular natural value or sensitivity but assists in separating the effects of naturally occurring change and human intervention.

These mechanisms and technologies must be used as the foundation for ensuring the long-term sustainability of the marine environment.

*CAETS recommends national and international endorsement for the commitment of various international organisations to the establishment of a comprehensive global network of Marine Protected Areas by 2012. (Recommendation 2)*

**Combined social and technological approaches are needed to ensure the future of world fisheries.**

Marine fisheries provide about 20% of world animal protein, half of which is diverted to animal or aquaculture feed. Most major wild fisheries are already fully exploited, overfished or exhausted. Technology including new types of ships and nets can increase quality and selectivity. However, national and international regulation of the size and scope of fleets, coupled with enforcement instruments against illegal operations , are essential for future viability of marine fisheries.

Aquaculture at present provides a quarter of fish production and is expected to provide virtually all the increase in supply of marine food in the coming decades. Species used in aquaculture are almost always fed on marine fauna lower in the food chain, placing greater pressure on wild marine ecosystems.

*CAETS recommends that effort be urgently applied to develop aquaculture systems that do not depend primarily on fish protein. (Recommendation 3)*

**New technologies are emerging to enhance the efficiency of marine transport**

Eighty percent of international trade is carried by ship and per capita tonnage has quadrupled in the last 50 years. The increased geographic separation of global supply and consumption requires vessels of ever-increasing size and capacity. Increasing global population and prosperity drive a trend to larger special purpose ships and are producing burgeoning growth in cruise shipping. Trends include significant increases in the size and specialization of container and bulk ships, and serious pressures in some high traffic regions. The growth of regional traffic and congestion and the need for access to difficult locations demand adequate ship management and new technical solutions to problems of manoeuvrability, drag reduction, propulsion efficiency and flexibility, ice going capability, marine antifouling and international dispersion of marine species as well as new challenges of terrorism and security.

*CAETS recommends an increased effort to ensure that future naval architects integrate engineering, environmental and social knowledge systems to design the ships of tomorrow. (Recommendation 4)*

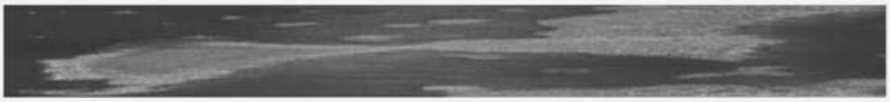
**Global petroleum demand is driving ambitious new offshore exploration and extraction technologies.**

The increased demand for energy resources will gradually move exploration activity to deeper waters and to environmentally difficult areas like the Arctic. Development of new and improved technology is important for sustainable and environmentally benign exploitation of oil and gas in these areas.

Deeper sites up to 2000 metres are planned to yield 30% of new production and sites to 3500 metres are being considered for the future. Ingenious new methods for remote exploration and extraction are pushing the boundaries of technology, including deviated and multiple drilling, ship and semi-submersible platforms, spars, and total sub-sea processing systems, coiled tube drilling, expandable casings and multilateral extended reach wells. Deep water production is feasible using artificial sub-surface well-heads, sub-sea down-hole processing, separation, re-injection, compression, riser-less light well intervention and multiphase flow simulation including the use of hydrates.

The cost and technical difficulty of developing offshore sites demands more accurate assessment of their prospectivity using numerical synthesis and analysis of vast quantities of seismic and other data. New techniques for exploration include electromagnetic seabed logging, seismic exploration and modelling of reservoirs and super-long seismic arrays.

*CAETS recommends continuing encouragement for innovative new technologies for remote exploration and extraction of oil and gas. (Recommendation 5)*



**The oceans can provide new resources of energy and minerals**

The increasingly high cost of energy derived from conventional sources will encourage commercial production of gas from gas hydrates. Some evaluations of future energy resources indicate that gas hydrate may be just as important a source of energy as oil and gas. Gas hydrates occur in the upper part of the sediments or on the seabed in oceans and the study of these deposits is just beginning.

Ocean currents, waves and tidal movements represent a vast amount of energy. If successfully exploited, they could contribute a substantial supply of electricity in coastal areas in many parts of the world.

On the seabed in the deeper ocean, manganese nodules occur over large areas and represent large resources of copper, cobalt and nickel for the future. These resources, together with sulphide deposits along spreading ridges and cobalt crust at some oceanic islands are now part of the resource management of the International Seabed Authority.

Our knowledge about the seabed is less than our knowledge of the surface of Mars, both in the high seas and in the Exclusive Economic Zones. We must increase the mapping of the seabed both in the deep oceans and on the continental shelves. A better geospatial knowledge base is necessary for monitoring and sustainable development of the resources in oceanic regions.

*CAETS recommends that more detailed mapping of the seabed be carried out as a basis for discovery and sustainable management of oil, gas, gas hydrate and mineral resources. (Recommendation 6)*

**To secure the sustainable future of the oceans and their resources, we must continue to develop new technologies for monitoring and data processing.**

In recent decades, there have been revolutionary technological advances in remote sensing, global positioning, miniaturization, automation and digital computation, with the capacity to acquire, assimilate, combine and distribute vast amounts of quantitative data using the Internet. It is now technically feasible to accumulate observations with sufficient coverage and accuracy to explore the ocean depths and below the seabed, to detect changes as they occur and to perform simulations and apply scientific knowledge to provide options for human intervention in the management and use of our ocean resources.

This capability is well advanced in pilot projects to describe the influence of ocean circulation on global and regional climate. We require a far greater national commitment to support the use of this technology in internationally coordinated programmes in the form of global "earth observing systems", of which the Global Ocean Observing System (GOOS), coordinated by the Intergovernmental Oceanographic Commission (IOC) of UNESCO and implemented through national observing programmes, is a key part. The gathering and assimilation of data in large quantities within 'operational' oceanographic systems (akin to, and linked with, meteorological service systems) should result in the routine generation of data products and the application of models and techniques that can be accessed and applied to questions involving the complex interaction between physical and biological processes.

*CAETS recommends the free and open international exchange of primary data in order to release the full power of global observations for a wide range of important economic and environmental applications in addition to climate research and prediction (Recommendation 7)*

*CAETS recommends the establishment of national oceanographic service organizations to facilitate participation in international data exchange and to deliver the benefits of operational oceanographic services to national communities. (Recommendation 8)*

**We must develop and exploit emerging technologies for disaster reduction.**

The South East Asian and Indian Ocean tsunami of 26 December 2004 provided a grim reminder of the vulnerability of human communities to the immense destructive power of the ocean in response to tectonic forces.

This event has provided forceful motivation for renewed international cooperation in the effective use of science and engineering to mitigate the impact of natural disasters and, in particular, to upgrade the systematic monitoring of both seismic and sea level characteristics to ensure rapid warning and community response, for tsunamis and other (more frequent) natural ocean hazards such as hurricanes and storm surges.

Through international cooperation, it is expected that the upgrading will involve improvements in both our physical observing systems and our communications systems. Working through existing international organizations such as the IOC and the World Meteorological Organization (WMO), the newly established Global Earth Observation System of Systems (GEOSS) will provide a framework to promote the development and worldwide implementation of the required observing and communications technologies.

Also required at national level is the development of much more sophisticated natural disaster mitigation plans drawing on available science (including social science) and technology and existing international systems of cooperation.

*CAETS recommends international support for the establishment of a global tsunami warning system, with initial priority for the Indian Ocean. (Recommendation 9)*

**The academies have a key role to play in ensuring the wise and sustainable use of the oceans.**

The Convocation concluded that the health and viability of ecological systems in the ocean are widely threatened by human pressures. Furthermore, human-induced greenhouse warming and associated changes in the ocean may bring serious consequences for mankind. However, with international will and cooperation, there is now great potential for nations, individually and collectively, to detect changes as they occur and a greater capacity than ever before to employ the capabilities of science, technology and engineering to ensure wise and prudent use of the oceans for the future of the world.

The academies can help in many ways through studies, information and advice. Capacity building through education and training in the area of ocean science and engineering should be a priority for national governments and multinational institutions like UNESCO, particularly in the third world. Special emphasis on sustainability and environmental implications should be made in such programmes.

*CAETS recommends that its Member academies increase their commitment to initiatives for raising public awareness of ocean issues, including scientific and technological solutions to the threats facing the oceans and their implications for society; and that they enhance their input to national governments and international organisations to ensure informed and balanced advice on ocean policy issues. (Recommendation 10)*

## Recommendations

In the light of its conclusions, as summarised above, CAETS commends, for consideration and action by all appropriate national and international organisations, the following consolidated set of ten recommendations from its 16th Convocation:

1 *CAETS recommends continued national and international investment in ocean monitoring and research as a vital input to national and international policy development on climate change and related issues.*

2 *CAETS recommends national and international endorsement for the commitment of various international organisations to the establishment of a comprehensive global network of Marine Protected Areas by 2012.*

3 *CAETS recommends that effort be urgently applied to develop aquaculture systems that do not depend primarily on fish protein.*

4 *CAETS recommends an increased effort to ensure that future naval architects integrate engineering, environmental and social knowledge systems to design the ships of tomorrow.*

5 *CAETS recommends continuing encouragement for innovative new technologies for remote exploration and extraction of oil and gas.*

6 *CAETS recommends that more detailed mapping of the seabed be carried out as a basis for discovery and sustainable management of oil, gas, gas hydrate and mineral resources.*

7 *CAETS recommends the free and open international exchange of primary data in order to release the full power of global observations for a wide range of important economic and environmental applications in addition to climate research and prediction.*

8 *CAETS recommends the establishment of national oceanographic service organizations to facilitate participation in international data exchange and to deliver the benefits of operational oceanographic services to national communities.*

9 *CAETS recommends international support for the establishment of a global tsunami warning system, with initial priority for the Indian Ocean.*

10 *CAETS recommends that its Member academies increase their commitment to initiatives for raising public awareness of ocean issues, including scientific and technological solutions to the threats facing the oceans and their implications for society; and that they enhance their input to national governments and international organisations to ensure informed and balanced advice on ocean policy issues.*

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## COLLOQUIUM

# DEVELOPMENT OF NEW TECHNOLOGIES AND PRODUCTS IN CROATIA

February 26, 2005

# Industrial Competence Centres and Networks in Austria

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*Abstract*

In this presentation a short review on a programme of the Austrian Ministry of Economics and Labour is given which successfully promotes the establishment of industrial competence centres and networks by a supporting by financial grants in order to meet the challenges of new technologies and international competition. The projects within the programme are subject to strict evaluations with respect to economical and scientific criteria. The overall idea is to generate new research findings as well as economically successful innovation.

## Introduction

It is an honour and pleasure for me to introduce a successful programme which has been established by the Austrian Federal Ministry of Economics and Labour (BMWA) in 1999 in order to respond to the problems and challenges faced by the Austrian industry as there are decreasing cycles in products, increasing complexity of new technologies and products and last not least globalization. This altogether requests a very selective processing of information and knowledge. The objectives of the programme are the promotion of cooperation of industry and science by clustering economics and technology know-how in Industrial Competence Centres of Excellence (Kind) and Competence Networks of Excellence (Knet), respectively. Over the years it turned out that this clustering became more and more important in order to be able to compete within a global environment.

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Beside of the Ministry of Economics and Labour the programme is administrated by two partner organizations which are involved in the evaluation process from the application to the end of the project in particular considering the science/technological and economic aspects of the project. The partner organizations of the BMWA are the Austrian Research Promotion Agency (FFG) and the Christian Doppler Research Association (CDG).

## The Partners of the BMWA

The Austrian Research Promotion Agency (FFG) was established in September 2004 and is "the central Austrian organisation for promotion of research and innovation". It is a result of consolidating the Industrial Research Promotion Fund (FFF), the Austrian Space Agency (ASA), the Bureau for International Research and Technology Cooperation (BIT), and the Technology Impulse Society (TIG) into one Agency.

With the Centres and Networks of Competence programme the FFG is handling the programme and takes care of the technical and economic evaluation. It represents the point of contact for the programme.

The Christian Doppler Research Association (CDG) is named after Christian Andreas Doppler (1803-1853), the Austrian physicist and mathematician well known due to the Doppler effect in acoustics he discovered. The Christian Doppler Research Association is a non-profit organization promoting developments in science, technology and economy and supports the economic transfer and application of new developments.

Its duty within the Centres and Networks of Competence programme is the scientific evaluation and to provide advisory services guarantying a high as possible scientific quality. It also evaluates the projects for its continuation based on quality assurance and scientific excellence.

## Industrial Centres ($K_{ind}$) and Networks ($K_{net}$) of Competence

Industrial Competence Centres serve the targeted development and strengthening of internationally competitive technology clusters. In general they build upon the existing technological competences of a number of enterprises with similar thematic or methodical R&D interests. They concentrate the R&D activities of a number of enterprises and the research activities of research institutes working in the same field. Their goal is to build up and develop application-oriented technical expertise followed by the promotion of dissemination into existing and new companies.

Competence networks consist of a number of nodes of research and industry in areas of technology where there is competence and/or demand at different locations while Industrial Centres of Competence are more or less locally clustered. The individual nodes must complement each other in the thematic orientation within the overall concept. In these networks existing regional R&D institutions (e.g. university institutes, Christian Doppler Laboratories, polytechnic colleges, joint venture research institutes) are included as partners.

For setting up Industrial Centres or Networks of Competence applications may be submitted by limited liability companies, societies or consortia. These entities are also members of the centres or networks. Foreign-based companies or research institutions, however, may also participate in the programme.

The programme itself can be set up by establishments and/or joint ventures with proven track record in R&D willingness of cooperation of industry and the scientific community provided. The programme must meet the objectives which are advancement, development and transfer of application-oriented technological knowledge. It can be set up anywhere where a thematic focus and intensification of research and development cooperation would increase existing industrial and scientific competence and where it would enhance its practical value to industry. However, the individual themes should be demand-oriented taking into account specifically local approaches. For the application the broad and long-term participation of both the enterprise and the scientists or the participating research institutes must be demonstrated.

The criteria to be met divide into two groups one are the scientific criteria (Table 1) and the other are the Technical & Economic Criteria (Table 2)

Table 1: *Scientific Criteria*

- Is the research project clearly defined according to high scientific standards?
- What academic standing do the participating universities have among their peers?
- How innovative are the approaches to solving problems and the methods that will be used to achieve the specified goals?
- Is the team (industrial, university and other partners) able to guarantee a continuous high standard of scientific quality.
- Will it be able to absorb new insights from outside?
- refine and implement them in an application-oriented form?
- Does the research programme offer clearly recognisable benefits for industry?
- Can an overall added value be recognised?

Table 2: *Technical and Economic Criteria*

- The Overall Concept
  - Does the programme meet BMWA requirements?
  - Is there a focus on an industrial technology cluster for technological innovation?
  - Have suitable possibilities for technology transfer been planned?
  - How will small and large enterprises benefit from the results?
- Possibilities for Technological Implementation
  - What technological competence do the partners from industry have and what possibilities exist for industrial implementation?
  - Can know-how be increased and what impact will it have on the R&D dynamics of the partners from the business sector?
- Economic Framework
  - Is the organisation structure suitable for the purpose?
  - Can the business plan be implemented with existing or planned resources?
  - Is sufficient financing guaranteed to complete the project?
  - How is the centre or network strategically positioned?
  - How are the implementation of the research results and the transfer of technology organised?
- Possibilities for Commercial Exploitation
  - What are the market prospects of the industrial partners in economic terms?
  - What impact will the project have on the national economy? (e.g. on the trade balance, employment market etc.)
  - Will it stimulate the creation of new businesses?
  - Will it have an additional impact on the region?

The application for financial support of a particular programme has to be submitted to the Research and Technology Department of the Federal Ministry where a primary evaluation of the overall concept takes place. In Fig. 1 it can be seen that after the programme passed this first evaluation the main review process is started involving the two external partners (FFG and CDG) who establish a panel of experts to examine the programme for its eligibility according to the scientific and economic criteria, respectively.

The final approval and the contract are submitted to the contractors by the BMWA.

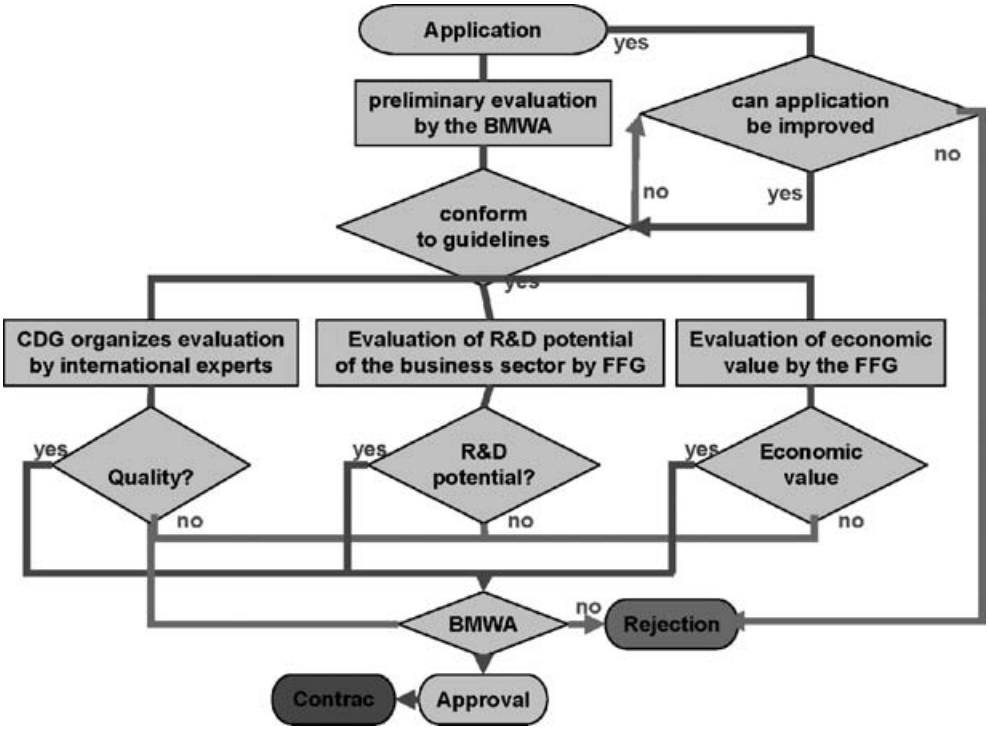


Fig. 1: *Evaluation Scheme*

The following costs may be covered by the grants:

– Personnel expenses including percentages of overhead costs
– Instruments, equipment
– Consulting and similar services
– Additional overhead costs
– Other operating costs
– Research work by third parties

The financial costs of each programme are shared by the BMWA, the particular federal province where the Centre of Competence is located as follows

| | |
|---|---|
| BMWA | up to 40 % |
| Province | up to 20 % (50 % of the support grated by the BMWA) |
| Centre/Network | at least 40 % |

For a four years runtime of a project the particular BMWA grants are typically between 1.4 and 7.7 million Euro depending upon the size of the programme.

For financing the grants the Austrian government provided a special fund called “Technological Offensive” from which about 91 million Euro are provided

until 2006 on top of which there are another 9 million Euro from the general budget.

From the cash flow scheme in Table 4 it can be seen that the total amount of a grant is not transferred to the Centre/Network at the beginning but is distributed over the term of the contract whereby the payment in instalment is subject to evaluations of the requirements accompanying the project.

Table 4: *Requirements and Cash Flow*

| Requirements | Cash Flow |
|---|---|
| Approval leads to a legally valid contract | 50% of 1st year funds |
| **1st year** | |
| Interim report & accounts | up to 50% of remaining 1st year funds |
| **2nd year** | |
| Schedule & cost plan | 50% of 2nd year funds |
| Interim report & interim accounts | up to 50% of remaining 2nd year funds |
| **3rd year** | |
| Positive scientific interim evaluation | |
| Schedule & cost plan | up to 50% of 3rd year funds |
| Interim report & interim accounts | up to up to 50% of remaining 3rd year funds |
| **4th year** | |
| Work schedule & cost plan for the 4th | 50% of 4th year funds |
| Interim report & interim accounts | up to 30% of remaining 4th year funds |
| Positive scientific interim evaluation and audit | up to 20% of remaining 4th year funds |

The maximum funding period is 4 years. Grants may be extended for further 3 years if the result of the 4 year evaluation is positive.

The programme “Centres and networks of excellence” is now closed for applications and wil be replaced by an improved funding scheme by 2007.

## Conclusion

We tried to give an overview over a programme which was initiated by the Ministry of Economics and Labour in order to optimize the links between business and science in order to increase competence and efficiency in research and development. Since its beginning 6 years before the programme described above has developed very rapidly and is considered as very successful. Until recently more than 225 million EURO were invested into 23 centres and networks and several new project are in the evaluation process of the applications. These centres and networks are listed in the appendix.

## References

Competence Centres Home Page <http://www.kompetenzzentren.biz>

Austrian Federal Ministry of Economics and Labour (BMWA) Homepage <http://www.bmwa.gv.at>

Austrian Research Promotion Agency (FFG) Homepage <http://www.ffg.at>

Christian Doppler Research Society (CDG) Homepage <http://www.cdg.ac.at>

## Appendix

| | |
|---|---|
| Industrial Centres of Competence in Austria | |
| ACC Kompetenzzentrum für Fahrzeugakustik | Graz |
| EC3 Electronic Commerce Competence Center | Vienna |
| Evolaris Kompetenzzentrum für interaktives eBusiness | Graz |
| HITT - health information technologies tirol | Innsbruck |
| IKMA Kompetenzzentrum Mechatronik und Automation | Linz |
| IMCC Kompetenzzentrum Industriemathematik | Linz |
| KERP Kompetenzzentrum für Elektro(nik)altgeräte -Recycling nachhaltige Produktentwicklung | Vienna |
| KMT Kompetenzzentrum Medizin Tirol | Innsbruck |
| Kompetenzzentrum holz.bau forschungs GmbH | Graz |
| Kompetenzzentrum Holztechnologie | Vienna |
| Kompetenzzentrum Licht | Innsbruck |
| Kompetenzzentrum für Neue Medien – Salzburg | Salzburg |
| Kompetenzzentrum für umweltfreundliche Stationärmotoren | Graz |
| Industrial Networks of Competence in Austria | |
| VResearch – Center for Tribotronics and Technical Logistics | Dornbirn |
| AAR Kompetenznetzwerk für Luftfahrttechnologie/ Verbund- und Leichtwerkstoffe | Seibersdorf |

| | |
|---|---|
| ACBT Kompetenznetzwerk Biotechnologie | Vienna |
| RENET Kompetenznetzwerk Energie aus Biomasse | Vienna |
| Kompetenznetzwerk für eTourism (anet) | Salzburg |
| Kompetenznetzwerk Fahrzeugantriebskonzepte der Zukunft | Vienna |
| Kompetenznetzwerk Holz | Vienna |
| KnetMET Kompetenznetzwerk für metallurgische und umwelttechnische Verfahrensentwicklung | Linz |
| Kompetenznetzwerk Verbrennungsmotoren der Zukunft | Vienna |
| Kompetenznetzwerk für Wasserressourcen und deren Bewirtschaftung | Graz |

# CROATIAN INNOVATION SYSTEM

# Contemporary Forms of the Spatial Organisation of Industrial Locations

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*Summary*

Contemporary production techniques, high standards of environmental protection, new methods of designing buildings and the environment, have enabled a higher degree of integrating production activities in the urban area. The advantages of using existing industrial locations are the following: retaining urban spatial organisation in the sense of the mixed use of space, slower urban expansion into unbuilt areas, an opportunity to arrange neglected and rundown areas because of smaller costs of preparing the land – existing traffic and public utility infrastructure, quality design and organisation of new buildings and their surroundings, employment increase, and slowing down processes of the encroachment of low-quality construction programmes. There are important unused areas of deserted or vacant industrial locations in towns that should be used to locate contemporary forms of production activities: technological, scientific and university-research parks, techno-units and business incubators.

*Key words*: town, planning, industry

## Problems of the spatial location of industry

The problems of spatial organisation from the aspect of stimulating economic development are the following:

- no clear concept of economic development,
- outdated ideas about how to lay out the area of production activities,
- undefined competence and lack of coordination between those who decide about spatial organisation,

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– frequent changes in local government and weaknesses in the legal system and practice,
– avoiding to accept the obligations of environmental protection and to effectively apply laws and regulations,
– strong pressure for spreading into unbuilt fringe urban areas,
– insufficient encouragement for better rationalisation in organising and using land for production activities.

The following have an adverse effect on solving problems of the spatial development of production activities:

- unsolved land management issues – especially stimulating rational and destimulating irrational use of building land,
- difficulties in setting up an investment programme system based on linking the property and capital of local government and natural persons,
- no regional development concept and no joint appearance of towns on the international market, resulting in disloyal competition and choosing identical developmental objectives,
- low development and quality of utility infrastructure,
- limiting spatial development potentials because of the high standard of environmental protection.

The bearers of economic development and the bodies that decide on spatial organisation approach their objectives in different ways, which is a result of the unbalanced system of authority in decision-making, disharmony in goals and priorities, political relations and the low level of coordination among participants. A parallel analysis of the spatial factors of production zoning in Croatia shows some special developmental characteristics:

- planning excessive increase of production areas based on unrealistic demographic and developmental assessments,
- accepting sustainable development principles and implementing measures for the protection of forests and agricultural land from construction, which leads to a scarcity of building land for production activities,
- changes of ownership while neglecting the protection of the public interest, and the unsuitable conversion and occupation of unbuilt land for housing and tertiary activities,
- moving production and shops to new unbuilt urban and suburban areas ("Greenfield"), thus avoiding the need to adapt existing neglected or abandoned areas and buildings suitable for economic use ("Brownfield" and "Greyfield").

Urban growth engulfs existing industrial locations. Industrial locations in towns are exposed to constant transformations because their compatibility with

other urban functions changes as a result of new standards of environmental organisation and protection. Industries that cannot satisfy new criteria of using and organising space are dislocated. The present resistance to dislocation is objective (construction expenses) and subjective (distance and laying out a new location).

Industry is still often treated as an offensive and unpleasant area, it is placed in fringe urban districts where the conditions for laying out the location are minimal. Thus dislocation does not solve the problem but only temporarily puts it off.

Industrial relocation makes it necessary to find new ways of using the areas and buildings that used to house production activities. Renewing production in existing locations pays better because of the high costs of laying out land for construction on new locations. At the same time, construction on new locations often does not lead to a higher quality of area use. Converting abandoned industrial locations and buildings opens up the question of how to preserve the industrial heritage, a recognised cultural good which we must protect.

The spatial and technological structure of production and the necessary utility infrastructure keep growing in complexity. This encourages the concentration of production activities, leading to the spread of building areas. Highly profitable production processes, high technology and highly skilled employees in an attractive environment lay down new requirements for zoning and using space.

## Planning the location of production activities

Planning the location of production activities is contingent on the optimal distribution of urban functions with the purpose of preserving, rationally using and protecting the urban environment. Urban development and environmental protection greatly affect the choice and size of areas given to production. The better qualification and social structure of industrial workers leads to higher criteria in laying out the surroundings Locating production in urban areas enables the contemporary design of production buildings, the layout of their surroundings and high standards of environmental protection. Quality design and arrangement of production locations shows the desire to affirm them as a pleasant and attractive work area.

Planning the location of production activities is based on scientific and professional research, analysis of the special features of spatial urban development, analysis of the scope and success of implementing earlier planning documents, demographic estimates and estimates of social and economic development. Only highly successful and high-income businesses can achieve the new and better-quality forms of spatial organisation, layout and use, and be a realistic factor of spatial development. One of the most significant factors of production development are modern technologies which change the number and social structure of workers, these are high-income production activities with highly skilled workers who have a

higher standard of living. Thus industrial transformation should aim at production units set up on contemporary forms of organising and using space:

- Technology parks – Physical or cybernetic areas organised by a specialist group that provides valuable services with the goal of: increasing economic competitiveness; innovation and product quality in business units and institutions that have the information and knowledge to achieve this advance; organising the transfer of knowledge and technology from the source to economic units on the market; actively encouraging new, feasible, creative entrepreneurship at the time of its establishment and nascent market independence. (Sanz, L.).
- Science parks – Forms of organising developmental research on the basis of ownership that forges links between university, research centres and other institutions of higher education. Their objective is to encourage the foundation and growth of production based on scientific research and to encourage existing high-quality economic units in the area in which they are organised.
- Research and university-research parks – a contract-based form of organisation which includes existing or planned land and buildings primarily built for public and private scientific research and the needs of development, an estate based on high technology and science with the accompanying activities. The owners and organisers include, by contract or formally, one or more universities and research institutions. The purpose is to promote scientific research at universities and forge connections with economic, production and accompanying activities, encouraging economic development and the transfer of technology and business skills between universities and the economy.
- Technocells – An area of undetermined size from several hundred to several thousand square metres, which accumulates technology within its boundaries, organises and stimulates overall development and promotes the competitive or traditional economy. Technocells are linked with the international market and depend on relations with it. (Romera, F.)
- Business incubators - support new economic units by helping them to find their feet on the market at the beginning of their work, when they are the most vulnerable. Incubators help organise management, provide access to financial resources and the market and accompanying technical services. They enable new firms to use premises and equipment “under the same roof” for very accessible prices, provide additional business and administrative services and links with other economic units within their field of interest. (Romera, F.)

## Conclusion

New economic activities should be selectively accepted depending on their contribution to future development, and an objective assessment made of how they can be applied in the existing system of deciding about the organisation and use of space. Research into and advancing development should aim at achieving a balance between economic interests and those of spatial protection, by limiting an out-of-date approach to the spatial organisation of production activities and selectively encouraging quality developmental programmes. Existing spatial and organisational structures of production activities should be steered to more modern forms of spatial organisation: technological, science and university-research parks, technocells and business incubators. In towns there are significant areas of abandoned or unused industrial locations, which are being transformed for other purposes, without making sufficient use of the advantages they have for the location of production activities spatially organised on contemporary models. The spatial distribution of production activities depends on adopting measures about managing building land, encouraging successful developmental programmes and limiting economic activities that use space irrationally and harm the environment.

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# Research and Development as a Business Activity

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*Abstract*

Current conditions in applied research and development in Croatia are outlined. It is shown that also in Croatia R&D as a business activity has a very good market position. It is pointed to inefficient investments in R&D on the part of the government, and also to inadequate appraisal of the results. The example of the independent scientific-research company Končar – Electrical Engineering Institute illustrates a possibility of efficient management of a company whose main business activity is R&D. The importance of watching key performance indicators of a scientific-research organization is stressed, and a possibility of its up-to-date implementation presented.

*Key words*: Intellectual capital; productivity; value added; research; development

## 1. Introduction

On the today's globalised market, with its ruthless competition, applied R&D plays the key role, and is more important than ever. The reason for that is that the results of R&D can give a company an essential competitive advantage, and ensure an increase of income and profit that is important not only for the owner of the capital, but also for the development and survival of the company.

According to standard ISO 9001, which applies to the quality management system, R&D is a part of process in every manufacturing and service company and institution. The first step in applied R&D is the contact with the customer, and the last is the product or service that suits best the customer's needs and that he/she is willing to buy at a reasonable price. Each product is expected to create added value both for the producer and the user.

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In the Republic of Croatia there are about 13,600 persons employed in R&D in the business and government sectors and in institutions of higher education, 45% of them with a doctor's degree and 22% with a master's degree [1]. According to the international methodology – Frascati Manual, OECD, Paris, 1994 – R&D is divided in basic research, applied research and experimental development. In 2003 the total expenditure summed about 2.2 billion kn, of which 47% for salaries, 36% for material costs, and 17% for investments [1].

Like at any financial investment in a certain activity, the case of R&D investments it is necessary to measure the efficiency of the investment, and eventually to determine the profit and the possible return on investment. One of the possible ways is to measure the investment in R&D expressed in percentage of the total income. This indicator gives only a general picture of a company, whether the management thinks about the future of the company, but it does not give any indication of the efficiency of such investments. The participation of products not older than x years in the annual income is certainly a better indicator. Of course, numerical indicators of both kinds of measurements, and the number of years in which a product can be considered new, both depend on the specific branch of industry and the specific area of a company's operations. Figure 1 shows what it looked like seven years ago.

Increasing competition on the market and accessibility of all the possible kinds of information drive companies to do their best to become more competitive in every respect than their competitors. Increasing specialization in all kinds of business activities and expansion of their scope can reduce costs essentially and improve price competitiveness, what consequently results in very frequent outsourcing.

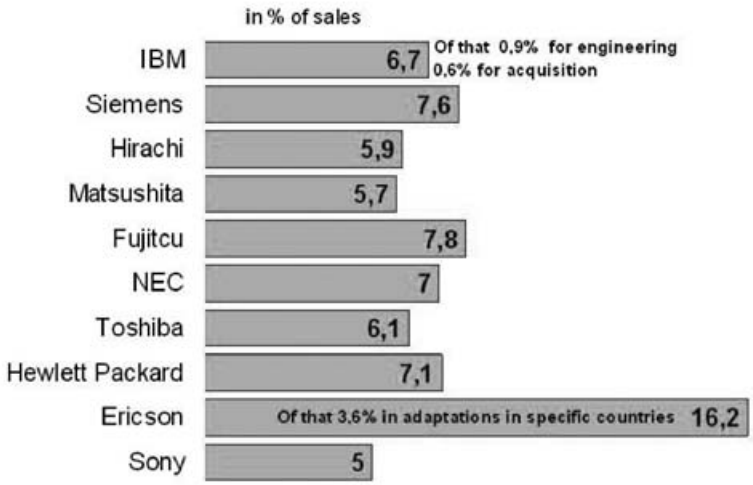



Figure 1: *Investments of electrical engineering companies in R&D in 1997*

In this sense, also the applied R&D can be bought on the market from specialized companies whose **main business activity is R&D**, and this option is widely used worldwide. The development of products and services organized in this way becomes exposed to the market, which is the best promoter of the improvement of efficiency.

## 2. Comments about the State in Croatia

In view of the relatively short period of market economy in Croatia, it is interesting to analyse the conditions in the area of R&D as a business activity. The analysis is based on the data provided by the Institute for Business Intelligence, [2] and [3], on newly created value and the number of employees in 1,000 most successful companies in 2002 and 2003, what means that the analysis does not cover the companies with negative business result, very small companies and R&D institutions. To put it simply, the newly created value in a business year represents for a legal entity the sum of gross and net salaries, with deduction of funds received from the national budget as donations or subventions. According to [2], it is actually less than the added value as defined in [7] only for the sum of depreciation. The newly created value divided with the average number of employees gives **the labour productivity**, which can be considered a good indicator of a company's efficiency and trends. The analysis of particular groups of activities is especially interesting (there are about 50 of them Croatia).

In Figure 2 there is a graphic representation of the productivity of about 20 leading activities with and above-average productivity and several of those with the least productivity. The representation of the trend in productivity in 2003/2002 is also interesting, with asterisked activities in which significant changes occurred (e.g. an essential change of the number of employees due to restructuring or exclusion of the some companies from the group because of negative business results).

The analysis shows that the activity RESEARCH AND DEVELOPMENT is an activity with above-average productivity of 272,000 kn per employee (about 40% higher than the average), which has been increased for almost 35% in 2003 in relation to 2002. In this activity there are about 1,550 employees in nine companies, with about 730 mill. kn total income in 2003, and about 16% increase of the number of employees. If all the business activities in all the nine companies are analysed in more detail, it becomes evident that those that are involved not only in applied R&D but also in other activities such as testing, technical supervision and consulting, which improve the stability of their business and efficiency of utilisation of their materials and human resources, and make them more successful. In Figure 3 there are graphic representations of the newly created value (a) and productivity (b) and their changes in the time period when these Croatian R&D companies have been observed.

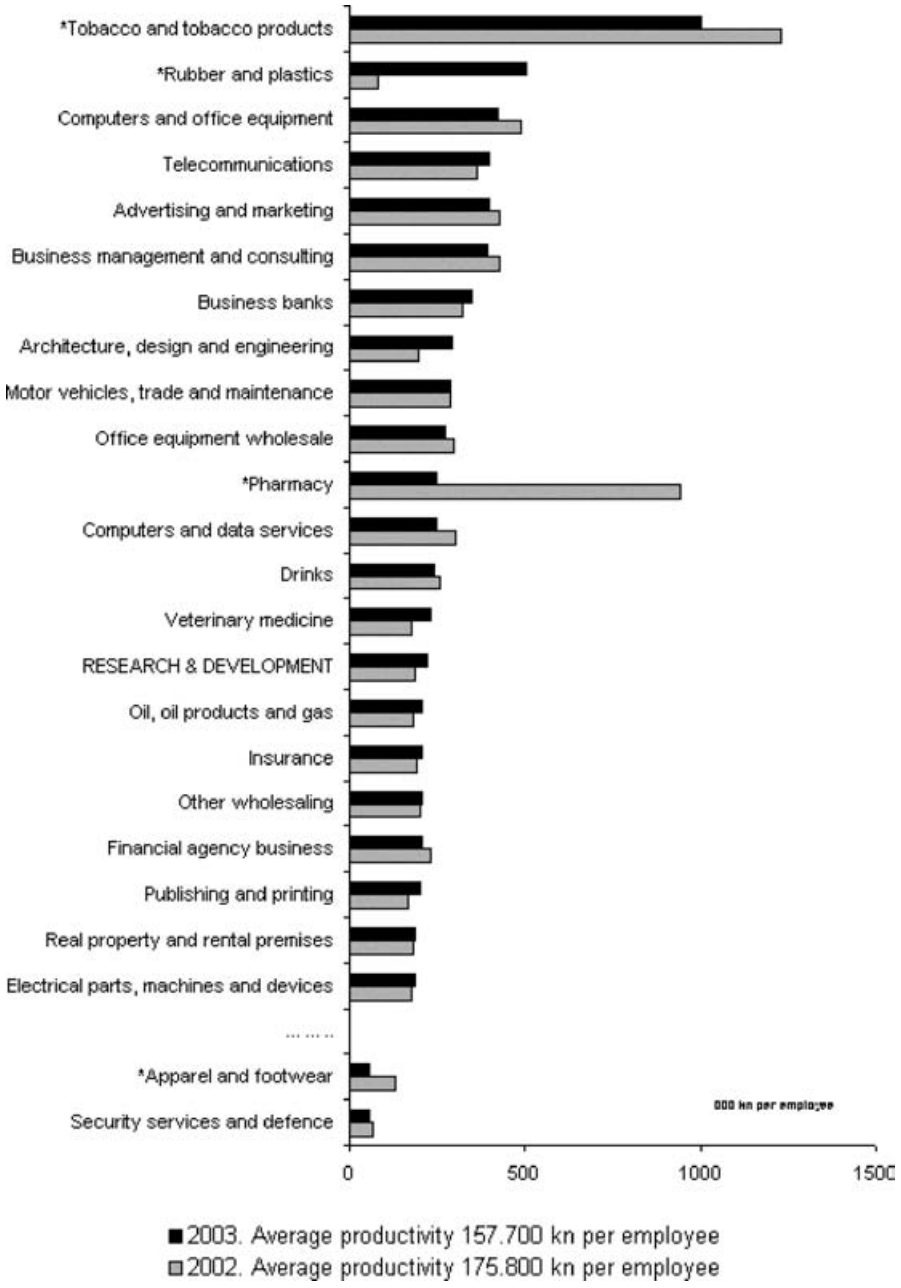
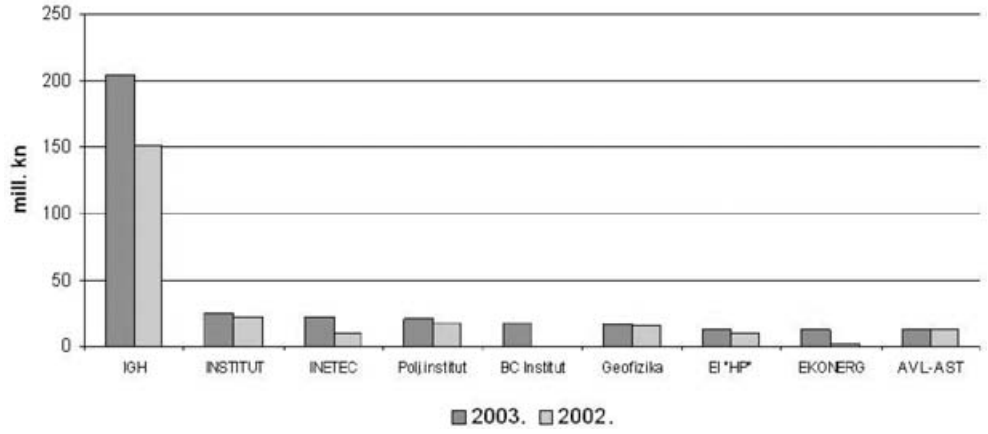
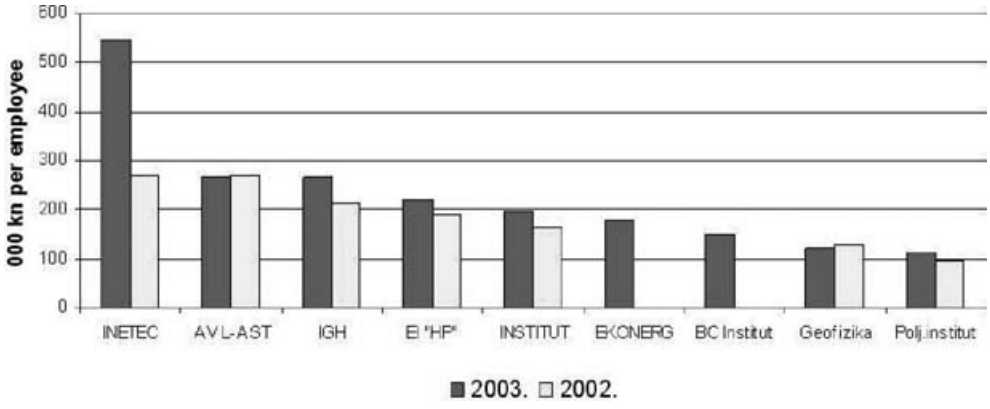



Figure 2: *Productivity of the best 1,000 companies in 2002 and 2003 grouped in 53 activities*

In conclusion it can be said that also in Croatia applied R&D is an attractive and expanding business activity, which has found its place also on foreign markets with as much as 30%, what is an indication of its large economic potential.




a)




b)

Figure 3: *Newly created value (a) and productivity (b) of R&D companies in 2002 and 2003*

Although most companies with R&D as the main business activity are privately owned, business indicators of those that are owned by the state and included in the best 1,000 are not worse than those of the private ones, so that it can be stated that the ownership is not decisive for the success of R&D as a business activity.

According to Eurostat, the knowledge-intensive high-tech services (KISHT) include: telecommunications, computers and accompanying activities, and R&D. If the data on participation of added value in total income of KISHT companies in EU countries that are interesting for us [4] are compared with those of Croatian R&D companies, Figure 4, it can be seen that the data are very similar.

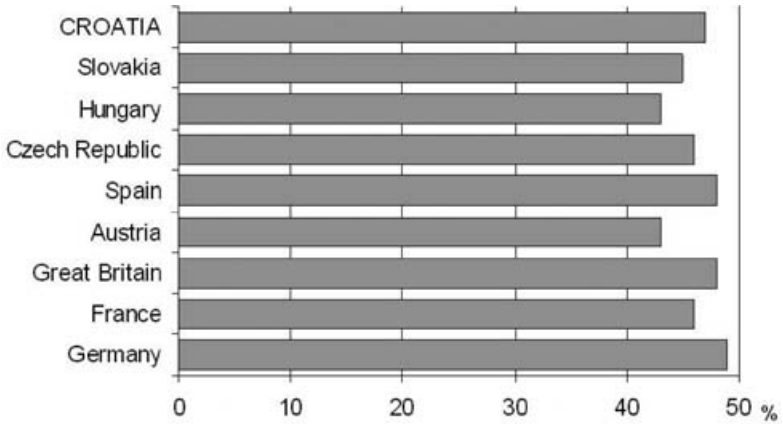



Figure 4: *Added value as a part of total income of KISHT companies in some EU countries and of Croatian companies with R&D as the main business activity*

From this analysis it follows that R&D in Croatia has taken a similar position in relation to other activities as its position in European countries, and in both cases the market is the regulator. Of course, we are talking here of a relative, not the absolute position.

## 3. Economy and Applied Research

Applied R&D as a business activity has a considerably stronger influence on the economic development that other activities, and it is more like the influence of the education or health care, which are concerned with human resource potentials.

If R&D operates in free market conditions, it will contribute considerably to its productivity as a separate activity, and it will also have a decisive influence on R&D in companies as a part of the process, because successful companies ask themselves whether it is better to have a process in their own house or to buy it on the market, and the decision is mostly made on the basis of the costs.

Countries with long market traditions have recognised long ago the importance of R&D. The governments of such countries direct considerable incentive funds to support R&D activities in a quality way, and thus encourage the economy to make more investments. All these investments will be returned in manifold ways back to the national budget through the economy, which will grow more rapidly and expand geographically.

According to [1], the sources of funds for R&D in 2003 were: 46% the companies' own funds, 44% (965 mill. kn) government and local administration, 7% private and public companies. In the same year the Government of the Republic of Croatia has invested almost 900 mill. kn through the Ministry of Science, Education and Sport, Table 1. Very similar sums for R&D were planned for 2004 and

2005, and the structure of investments e.g. in 2005 can be seen in Figure 5. Only 22% of the funds (192 mill. kn) are directed to concrete projects (more than 2,000 of them), 26% (230 mill. kn) to salaries of junior researchers, 6% (55 mill. kn) to the equipment, while **the infrastructure and other take as much as 46% or some more than 400 mill. kn**.

Table 1: *Distribution of funds from the Croatian budget for science and technology*

| | In mill. kn | TOTAL | | | |
|---|---|---|---|---|---|
| | | 2002 | 2003 | 2004 | **2005** |
| R&D<br>677,8 mill. kn..02<br>811,2 mill. kn...03<br>785,5 mill. kn...04<br>778,6 mill. kn...05 | R&D project | 153.5 | 196.6 | 151.2 | **130.0** |
| | Junior researchers | 153.4 | 173.7 | 218.6 | **229.9** |
| | Scientific equipment | 54.7 | 61.0 | 26.2 | **24.0** |
| | Foreign scientific journals | 38.0 | 35.0 | 31.0 | **31.0** |
| | Public institutes | 149.1 | 202.5 | 230.1 | **289.2** |
| | Other | 129.1 | 143.4 | 118.4 | **74.5** |
| Technological R&D activities<br>50,4 mill. kn...02<br>88,0 mill. kn...03<br>85,3 mill. kn...04<br>108,5 mill. kn.05 | Projects and programmes of technological R&D activity | 19.3 | 34.4 | 33.5 | **33.6** |
| | Development of knowledge--based technologies | 18.1 | 36.7 | 18.7 | **28.5** |
| | Incentives for technological infrastructure | 0 | 0 | 5.0 | **5.0** |
| | General administrative service | 5.8 | 3.7 | 1.2 | **1.1** |
| | Other / Capital investments | 7.2 | 13.2 | 26.9 | **40.3** |
| | T O T A L: | **728.2** | **899.2** | **860.8** | **887.1** |

This structure of government investments in R&D is very questionable, because there are no information and no evaluation of economic results of 2,000 projects except by the number of published and cited papers.

The number of projects should be considerably reduced and priorities in investigations set. Potential users of results of the investigations should be included in the projects. By all means the financing must become co-financing up to the maxi-

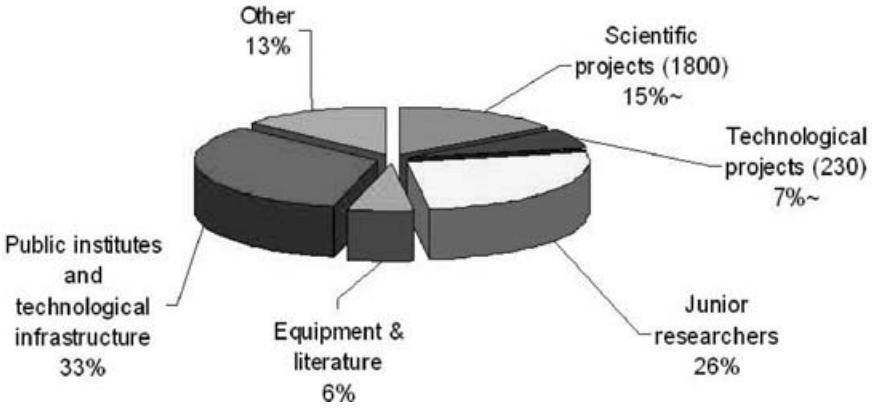



Figure 5: *Structure of government investments in R&D in 2005*

mum of 60%. This is extremely important, because in this way preconditions are created for implementation of only those products that have the chance to improve the competitiveness of our economy.

## 4. Position of KONČAR – Electrical Engineering Institute in R&D Activity

KONČAR – Electrical Engineering Institute is a stock company within KONČAR Group with the status of an independent company entered in the Register of Scientific-Research Legal Entities of the Ministry of Science, Education and Sport of the Republic of Croatia in the field of "science and technology". It operates in electric power sector and transport on:

- applied R&D
- diagnostics and systems for equipment monitoring
- safety tests, calibration and certification, and
- supervision of construction and consulting.

Trends in total income from sales per market segments in the last 10 years are shown in Figure 6. Figure 7 shows trends of added value and intellectual capital in the last 5 years. According to [7], intellectual capital is defined as the sum of total expenses for the employees, what means the sum of gross salaries, allowances and expenses for education of the employees. Added value according to [7] is defined as operating revenue reduced by the cost of products or services purchased on the market, or as the sum of profit and expenses for employees and depreciation. Constant growth of operating revenue and even added value is not a sufficient guarantee of business efficiency. Figure 8 shows sales and added value per employee, and Figure 9 profit per employee and added value to intellectual capital ratio (i.e. **the efficiency of intellectual capital**). So, the same standards can and should be ap-

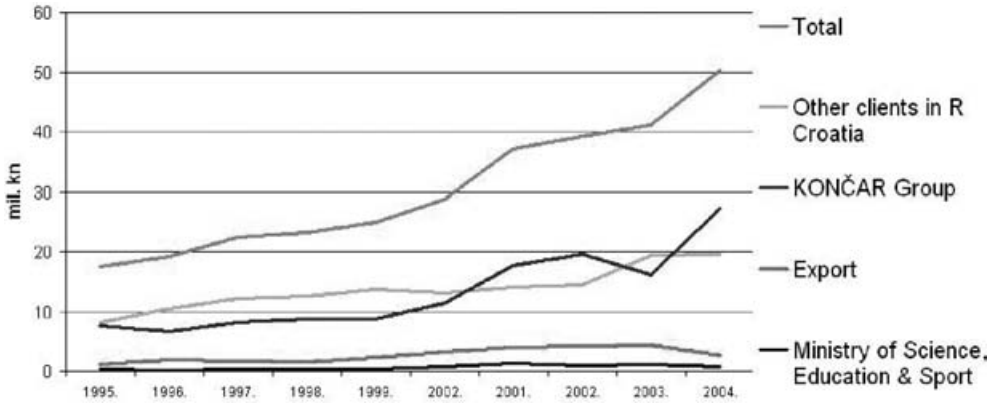



Figure 6: *Sales revenues of KONČAR – Electrical Engineering Institute*

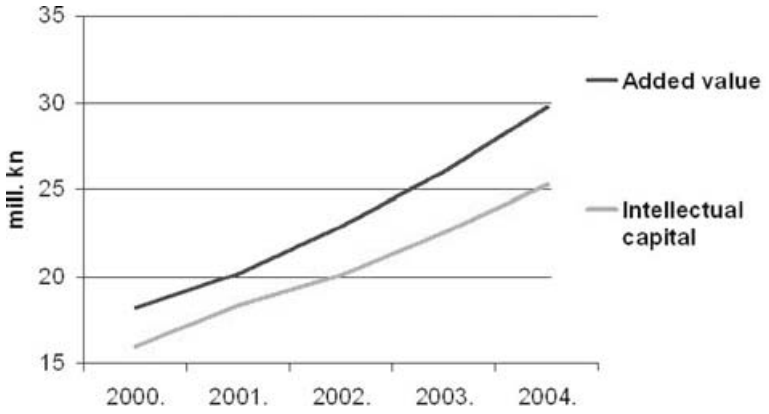



Figure 7: *Added value and intellectual capital in KONČAR – Electrical Engineering Institute*

plied to R&D as to other activities, and also the measures that lead towards permanent increase of business efficiency.

The parameters that should be tracked: sales per employee, added value per employee – labour productivity, profit per employee – labour profitability, and added value to intellectual capital ratio – efficiency of intellectual capital. Only if all these parameters grow in harmony, it can be said with sufficient certainty that a company's business is stable, and that all kinds of revenues and expenses are reasonably balanced. Of course, to be able to expand its business a company needs its retained profit. In the case of KONČAR – Electrical Engineering Institute the profit is retained in its full amount every year.

Although in most cases the objective of R&D as a business activity is not to make profit, the profit is nevertheless essential, because it is an indicator of the efficiency of utilisation of physical and financial capital, and it sustains the expansion of

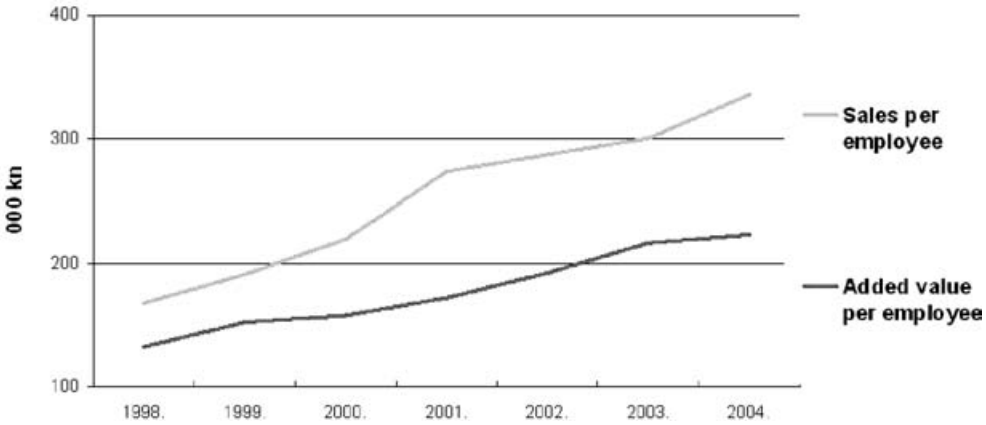



Figure 8: *Sales per employee and labour productivity in KONČAR – Electrical Engineering Institute*

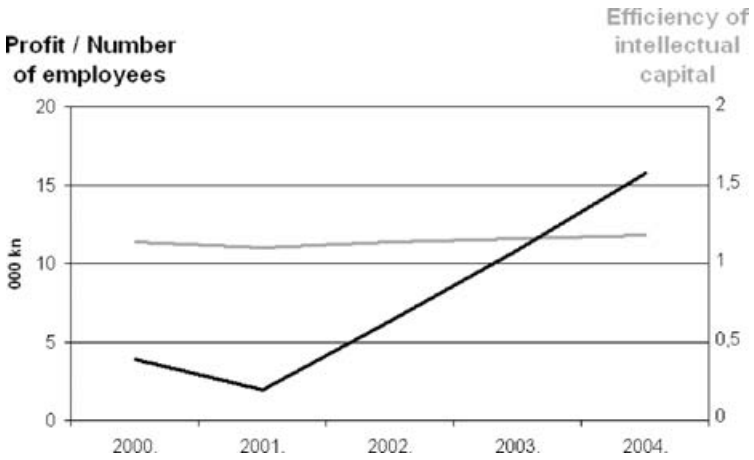



Figure 9: *Business efficiency of KONČAR – Electrical Engineering Institute*

operations. The most common objective of R&D is a new or innovated product or service that should in the future produce for the investor who has invested in R&D new revenues or preserve the present ones, and through that also **create new jobs** or **preserve the existing ones** as something most valuable for the society as a whole. Therefore investments in R&D are of great importance, but without a good tracking of operations of companies that implement it, and without watching the results of their work, there is no effective R&D. The best indicators of such tracking are the realised **total added value and the number of jobs per unit of capital invested** in R&D. These are the mechanisms that have to be established, and published papers and patents cannot be the criterion of the success of work in R&D – they are only side results important for a general picture of the people who perform R&D in the organisation in that the work, not indicators of efficiency of any kind.

So e.g. thanks to the results of R&D realised by KONČAR – Electrical Engineering Institute in the last ten years more than 350 people have been permanently employed, and more than 250 papers and patents published mostly not in u CC publications. Some of more important R&D results that bring KONČAR today additional revenues and new permanent jobs are:

- multisystem passenger car converters
- digital control systems for thyristorised locomotives
- controllers for electrical locomotives and cars
- passenger car fuses
- excitation systems for induction generators
- metal-enclosed busbars
- transformer monitoring systems

and important ones in progress:

- the development of electronic equipment and electric motor drive for the low-floor tramway
- generator monitoring system, and
- wind turbines.

It is evident that R&D organised in this way is very efficient, and its networking with the academic society and support by of initial government funds might ensure results that would be several times better than the ones achieved with the today's organisation and financing.

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# Some Specific Features of the Future Study for Training Forestry and Wood-Technology Engineers

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*Abstract*

To discuss the present education of graduated engineers means to consider the position of key factors of the Croatian economy. And to talk about forestry and wood industry, and hence also about the present study of forestry and wood-technology, by which engineers acquire the required education, means the obligation to take into consideration many specific features. In each individual case, each study component must be considered separately. Maybe then the answer will become clearer to the question: should the five-year study be divided in any case or, what should be the place of the second-degree study (graduated engineers) and first-degree study (undergraduate engineers). The analysis of programme structure of the higher forestry education at the verge of its 144th year of existence, and 57th year of existence of wood-technology, definitely shows some patterns. So, e.g. only during the period of four-year forestry study (1909 – 2004), which made part of bio-technological sciences, the biological component was doubled, while the technological one became 2.5 times lower. At the same time the natural-science component became approximately 1.6 times lower, while the other percentage shares of study (mathematical/graphical, economic/organisational, economic in general and others) ranged between 0 and 10 %. In the past, wood-technology study was about 2.6 or 1.6 times shorter compared to two-, three- and four-year study of forestry, which also shows two clear trends: 1.8 times higher share of the so-called wood-technology component and approximately 1.65 times lower share of engineering component. In this event, too, the share of other study components range between 0 and 10 %. These few data confirm the trends of university degree of forestry and wood-technology studies at the Faculty of Forestry, University of Zagreb, and possible guidelines for their restructuring and adaptation to the requirements for engineers in the 21st century.

*Keywords*: study of forestry, study of wood-technology, specific features, study curriculum and programme

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## 1. Introduction

The education of engineers in the 21st century, among other demands and maybe first of all, must also meet the requirements related to the production of goods, products, artefacts, and of course those related to new knowledge. In considering the education, as well as any other human activity, it is highly useful to be acquainted with the changes of such activity through the past and with its current position. As in many other human activities, when the education of engineers in forestry and wood-technology is concerned, it can be seen that sometimes some of the components of this process have a more conspicuous position in Croatia than elsewhere in the world, although sometimes the other way round occurs: some achievements are respected more in a broader environment, even globally, than in our own home. Anyhow, it should be noted that part of the basic education of the engineers in question stays unchanged, sometimes part of it has to be upgraded, and sometimes it has to be revised from the very beginning.

## 2. Some specific features of two bio-technological studies

When taking into consideration and trying to understand the two current bio-technological studies, the study of forestry and wood-technology, it is necessary to determine their key characteristics, by which their similarities or differences can be proved or denied. Several of such indicators are shown in the comparative survey in Table 1. Apart from the 87-year time difference between the beginnings of the two studies, it should be emphasised that the university-degree study of forestry also provided knowledge related to wood working and processing (sawmills, production of sawn timber and shingle, production of wood coal, material for drum production, etc.). Part of this production, and more than that, has remained part of forestry activities in many countries to date (portable sawmills, wood-cutting, etc.).

### *2.1. Development trend of forestry higher education*

**1860** – The School of Economy and Forestry in Križevci (Nowadays: Institution of Higher Economic Education in Križevci – *Visoko gospodarsko učilište u Križevcima*) started with a 2-year forestry programme at the newly established Forestry Department. In 1877 it became a three-year study.

**1894** – The School was partly restructured; a higher-level and a lower-level programme were established; the scope of the higher-level programme was the education in economics and forestry (Meštrović, chief editor, 1998, p. 116).

**1898** – After 39 years of activity of the School in Križevci, in October forestry training was transferred to the Royal Academy of Forestry (*Kraljevska šumarska akademija*) with the Faculty of Natural Sciences of the Royal University (*Mudro-*

Table 1: *Comparative survey of some characteristics of industrial branches for whose requirements forestry and wood-technology study was established*

| Characteristics | FORESTRY STUDY FOR FORESTRY | WOOD-TECHNOLOGY STUDY FOR WOOD INDUSTRY |
|---|---|---|
| Beginning of the study | 1860 | 1947 (1951/52) |
| Affected area | 43.5 % of the Croatian territory (Outside production: wood production, nursery production, silvicultural activities, forest protection, etc.) | Apart from logs and timber landing, everything else is outside production |
| Out-of-date knowledge | Several decades | 5-7 years |
| Type of market production | Production of raw material which can be directly processed (the so-called pre-production) | Production of artefacts, material goods |
| Products and goods | All forms of wood (technical, industrial, fuel, etc.) and the so-called general forest benefits along with many forest side products; the society must enhance these values and establish a national level of the forest eco-system benefit | Furniture, fancy goods, wood constructions, bridges, as well as cellulose and paper are made of wood, metal, plastics, textile and other material |
| Ecological benefits of economic branch | At present still the so-called non-market forest products highly exceed the value of wood, e.g. absorption of $CO_2$, emission of $O_2$, preservation and purification of water, landscape, etc. | Environmental pollution by industrial waste, gases, liquids (especially coming from processing procedures), but also the use of wood residues as energy source |

*slovni fakultet Kraljevskoga sveučilišta*) in Zagreb. It was the first engineering study of the University of Zagreb established following the studies of the so-called pure sciences such as philosophy, law and theology. The study was organised as a three-year education until the school year 1907/08, and after that as a four-year study (Matić, chief editor, 1998, p. 69). For almost a whole century forestry education remained organised as a four-year study with obligatory and optional subjects. Its aim was to provide adequate education to forestry engineers for the work in the economic branch called *forestry*. The forestry objective was the management of the Croatian forests and forestland, i.e. *general protection, care and silvicultural activities aimed at providing forest preservation, expansion and economic and other types of exploitation* (Šonje, chief editor, 2000). It should be noted that the Academy of Forestry achieved *a great independence in terms of administration, so that*

*it could be considered as an independent University institution* (Neidhardt and Androić, editors, 1963). The first head of the Academy of Forestry was Mr. F. Ž. Kesterčanek from April 1908, and the last one Mr. A Petračić in the school year 1917/18.

**1919** – The Faculty of Agriculture and Forestry was established as an independent institution of higher education within the University of Zagreb (*Gospodarsko-šumarski fakultet Sveučilišta u Zagrebu*). This was the end of a twenty-year period of the activity of the Academy of Forestry, and teaching started from the school year 1919/20 at the same time for all four generations of former attendees of the Academy of Forestry. Despite many provisory solutions, the Academy of Forestry marked an important period in the development of technical education (Neidhart and Androić, editors, 1963, p. 116). Its teachers did their best to initiate the foundation of a higher technical school in Croatia. In 1908, at the Academy, the so-called Geodetic Training Course (*Geodetski tečaj*) was established for the education of geodetic and technical experts. In 1918/19 the said Course was incorporated into the Higher Technical School in Zagreb. At the independent Faculty of Forestry and Economy teaching started in the school year 1919/20. Up to 1947 only minor changes of the school curriculum were recorded.

**1926/27** – One of the critical years in the lifetime of forestry education in Croatia. That year, the Faculty was left with no grants from the governmental budget. Nevertheless, the Faculty survived this trial of dissolution, i.e. the trial of its being moved out of Croatia.

**1960** – The year when the Faculty of Forestry became independent and got separated from the Higher School of Agriculture, with which it was closely connected for a whole century. The independence brought the establishment of two departments: Forestry Management and Wood Industry. This was the result of the crucial turning points in the past programme of the Forestry Department, especially the ones that occurred in 1947 and 1951.

### *2.2. Crucial past determinants for the establishment of wood-technology study*

In the past development of forestry education, two events preceded the establishment of an independent Wood-Industry Department upon the foundation of an independent Faculty. ***The first*** occurred in **1947** when the Forestry Department was divided into two study programmes: *forest-silviculture* and *forest-industry.* This division, the so-called bifurcation, colloquially called "*biological*" (**B**) and "technological" (**T**), marked almost fatally the development trends of the forestry study curriculum more than half a century ahead of time (see the Closing Considerations). Here is what is stated in reference of Neidhart and Androić, editors, at p. 128 on the reasons of such behaviour: *...however, the operational level started complaining first about this curriculum saying that foresters only trained in biol-*

*ogy could not fulfil the requirements met in practice. Young foresters who graduated from the biological programme were engaged in practice with civil engineering and other similar tasks although they had never attended technical courses* (end of quote from paragraph 3). It should be noted that this was the actual beginning of higher education for working and processing of wood in Croatia (Ljuljka, chief editor 1998, p. 7). Study programme "**B**" was intended for training the experts in silvicultural activities and forest management, so that the subjects had mainly biological and economic features. The programme "**T**" was intended for training the experts in all kinds of forestry technical operations (transportation vehicles, forestry machines, civil engineering, water construction, flood management, etc.) as well as in wood industry (Neidhart and Androić, editors, 1963, p. 125, last paragraph). Despite some changes of the curriculum of 1947, which were implemented in 1948 and 1950, in the school year **1951/52** the Forestry Department curriculum was adopted, with the so-called **second** division, which was the basis of the current and probably also future study of forestry and wood-technology: *...a special study was introduced for training wood-industry engineers. They should only be experts in wood industry and they are hardly supposed to enter the forest at all. They should take over the forest products from foresters by use of public transportation: this is the origin of the expression "to and from the axle"* (Neidhart and Androić, editors, p. 128, paragraph 5). This is the real beginning of the study of Wood--Industry Department of the then Faculty of Agriculture and Forestry, Forestry Department. The so-called general subjects were the same for both departments, while the four-year study involved a considerable part of field training (Vukelić, chief editor, 1998). The second division, the so-called bifurcation, within the Faculty of Agriculture and Forestry of the University of Zagreb had two departments: (**1**) *Forest-Management* and (**2**) *Wood -Industry*. The Forestry Programme, of course, now had to renounce the idea of the first bifurcation of being exclusively focused on issues of biology and economy: technical component of the curriculum became equally significant, as foresters were trained for carrying out all kinds of works met in this economic branch which dealt with forest management. Upon completing the study, the Faculty of Agriculture and Forestry awarded diplomas to ***forestry engineers****, for the study programme of forest-management and wood-industry, respectively.* After the Faculty of Forestry gained independence as an independent institution within the University of Zagreb in 1960, the two departments remained as they were formed in 1951/52. Apart from this another two changes should be noted when promoting wood-industry study: (**1**) In 1977/78 Wood- -Industry Department was renamed into Wood-Technology Department of the University of Zagreb and it awarded diplomas to *wood-industry enginers;* (**2**) In the school year 1997/98 Wood-Technology Department awarded diplomas to *graduated engineers in wood-technology.*

### *2.3. Scientific area pertaining to the study of Faculty of Forestry at the University of Zagreb*

Both studies of the Faculty of Forestry in Zagreb, *forestry* and *wood-technology*, originally come from the same area of *bio-technological science*. This has also been confirmed by the last announcement of the University of Zagreb for enrolling first-year students in the school year 2003/04 (Anon., 2003, p. 9), and nothing has been changed in the next school year 2004/05. In the group *BIO-TECHNOLOGICAL SCIENCES*, item 20 of the mentioned source, it is said: **Faculty of Forestry** – Graduated Engineer in Forestry, Graduated Engineer in Wood-Technology. So, the past scientific position of these two studies has remained unchanged. In the Croatian dictionaries no explanation has been found for the entry *bio-technology (Croatian, biotehnika)*. Generally, several dictionaries state that **bio**- [c*lass*. *eur.*] as the first part of the word, usually used in science, means that it applies to the life of what is named in the second part of the word (*in Greek* bios: life). There is no doubt that forestry deals with the technology of living trees or, in a broader sense, with the plant-life, as part of the forest eco-system. It should be noted that the expression *technology* can have one of the following meanings: means or group of means adapted to achieve a goal (e.g. technology of forest silviculture), special procedure used in order to carry out specific operations (wood skidding, etc.), group of all means of work and work procedures used, for example, in wood production (chain saws, skidders, etc.), skill or competence in performing some operations (technology of felling trees, etc.) or general work procedures, etc. In forestry there is a community of *technological and biological purposeful units* that represent a whole and are used as a whole: *Nature, natural technology and artificial technology (bio-technology and technology of things), belong to one and the same development process* (Čatić, 2003A). However, when it comes to cutting or processing wood, it can hardly be said that anything applies to the life of wood (not trees), studs, varnishes, plastics, textile, etc., material used in making wood-industrial products, even when speaking of wooden fancy goods, entirely made of wood. Here, we always deal with *technical procedures*, a certain group of operations applied on a material (sawing, milling, sanding, etc.), *technical material* by which certain tasks are realised, different *machines and devices* (different types of saws, milling machines, etc.) and *means of work* (tools) such as saws, moulders, abrasive paper and similar. All of these are included in some production procedure, the so-called technology, the expression used for working and processing techniques. This should be sufficient for analysing and establishing the facts related to the share of individual components in teaching curriculums and programs, which affected the crucial turning points in forestry and wood-technology study.

## 3. Analysis of study curriculums at the Faculty of Forestry

### *3.1. One hundred and forty years of forestry study*

In considering the changes and nature of higher forestry education, comparison has only been made between the periods of four-year study and moments of significant changes of study curriculums and programmes. These were the years, or school years, 1909, 1951/52, 1960 and 2001 (only obligatory subjects). For each of them the share of seven groups of subjects was determined in the same way in accordance with their scope: (**1**) the group covering the area of technical sciences, (**2**) group of natural sciences, (**3**) forest component (forestry sciences), (**4**) mathematical-graphic component, (**5**) economic-organisational component, (**6**) other branches or activities of economy and (**7**) subjects that could not be included in any of the said classes (uncategorised). So, in Figure 1 a column diagram shows the shares for each selected class in the years stated above. Their reference sources are under number 2 – 6 as well as the source for the last chosen reference year (Anon., 2001A). Without much analysis, general trends can be observed for some groups of subjects, for example, the growth of the share of forestry- -professional subjects from more than one fourth (1909) to more than a half (2001), and at the same time the drop of, for example, technical and natural science component of forestry study

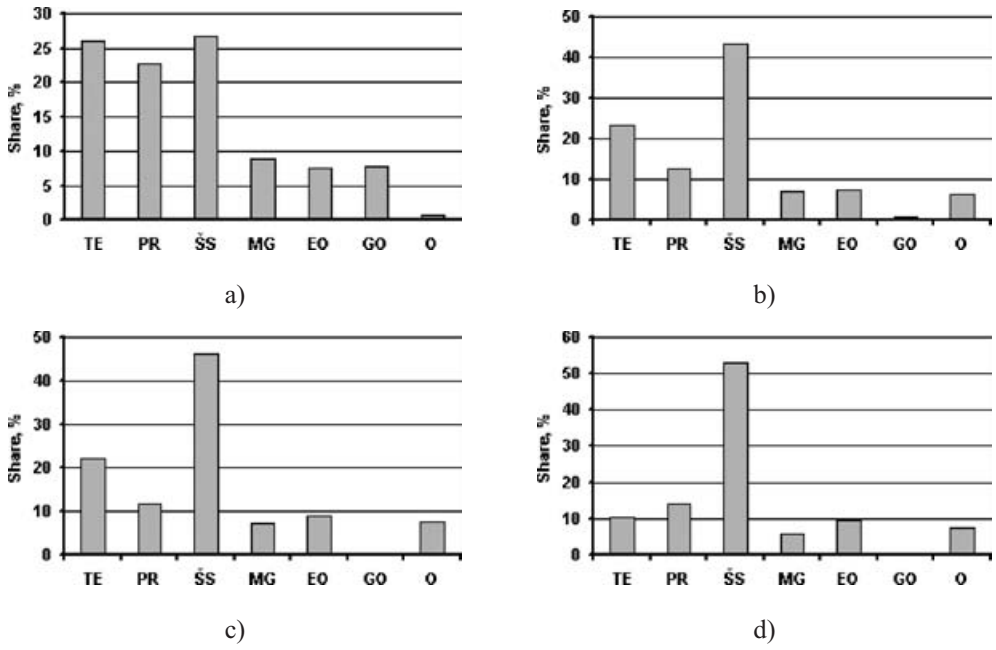


Figure 1: *Comparison between four-year forestry studies: (**a**) 1909; (**b**) 1951/52; (**c**) 1960; (**d**) 2001 (obligatory subjects). Legend: **1** – technical component (TE); **2** – natural sciences (PR); **3** – forestry-professional component (ŠS); **4** – mathematical-graphic component (MG); **5** – economic-organisational component (EO); **6** – other economy in general (GO);*

from approximately 26 % and 23 %, respectively, at the beginning to approximately 10 % and 13 %, respectively, at the end of the period. It should be noted that the biological component of the study is mostly made of forestry-professional subjects.

By restructuring the forestry study in 2001, along with the obligatory subjects, one of three offered modules had to be chosen. Figure 2 shows the share of the same seven groups of subjects for each module individually and all of them together. In two modules, **a** and **c**, (*silvicultural and environmental protection* and *organisation and forest economy in forestry and horticulture*) forestry-professional subjects of biological nature account for 70 % and 47 %, respectively, and the technical component for 11 % and 14 %, respectively. In module **b** *forest exploitation, forest operations and forest management*, the technical component accounts for about 52 %, owing to the share of the consideration of the skill of work and means of work, along with the share of approximately 16 % of forest- -professional subjects. The general share (Fig. 2d) of the technical component, thanks to the last (third) module, for all the three modules goes back to the starting one for the entire forestry study of 1909 (about 26 %).

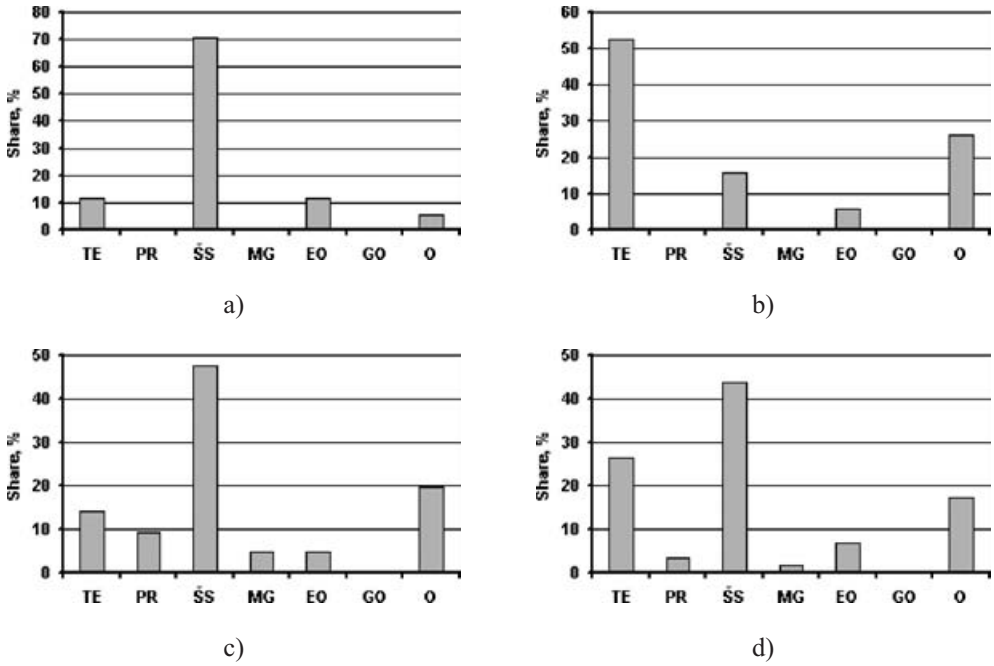


Figure 2: *Comparison between modules of forestry study 2001: module **a** Forest silvicultural activities; module **b** Forest exploitation, forest operation and forest management; module **c** Environmental protection, forest organisation and economy and horticulture; **d** –all modules together. Legend: **1** – technical component (TE); **2** – natural sciences (PR); **3** – forest-professional component (ŠS); **4** – mathematical-graphical component (MG); **5** – economic-organisational component (EO); **6** – other economy in general (GO); 7 – other uncategorised (O)*

In Figure 3, the shares of seven observed classes of subjects are put together related to four turning points and thus changes are vividly shown of changes of share of individual groups, i.e. *changes of character of forestry study*. Similarly as above, all data apply only to study curriculums and programmes of four year studies in crucial years.

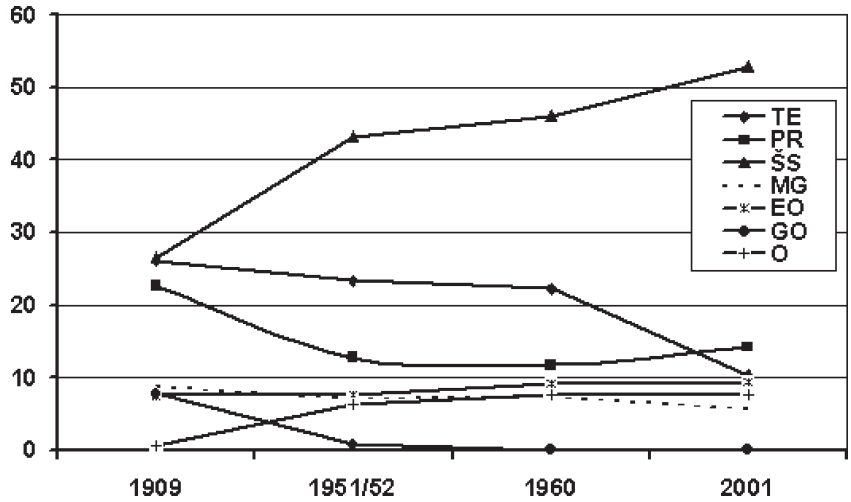


Figure 3: *Change of the components of four-year forestry study 1909 – 2001. Legend:* ***1*** *– technical component (TE);* ***2*** *– natural sciences (PR);* ***3*** *– forest-professional component (ŠS);* ***4*** *– mathematical-graphical component (MG);* ***5*** *– economic-organisational component (EO);* ***6*** *– other economy in general (GO); 7 – other uncategorised (O)*

The analysis of changes of higher education (university degree) curriculums and programmes of forestry study in Croatia shows beyond any doubt the changes of the nature of education of forestry engineers. At the beginning the curriculum involved the knowledge of that time in its broadest sense: starting with silviculture and forest protection, forest organisation, exploitation of wood and ending with processing of wood into market assortments of that time (logs, fuel wood, etc.), as well as some end products such as shingle or energy sources such as wooden coal. Right this was the beginning of the teaching programme of wood processing, at that time still within forestry study.

Furthermore, it should be emphasised that the most important, direct forestry product is the natural polymer *wood*, biomass used in wood industry or any other processing industry with the aim of obtaining useful products (furniture, fancy goods, etc.) or new products (cellulose fibres, paper, boards, tannin, furfural, acetic acid, etc.), or with the aim of turning it into some energy source such as briquettes, pellets, chips, etc. (Figurić and Risović, editors, 2003).

In each of the above cases, the comprehensiveness of forest production is manifested in introducing and expanding the technical component of forestry produc-

tion, forest management as well as the social component, by which forestry policy, strategy and forestry science and higher education are envisioned.

If bio-technology is the use of *knowledge and technical skills in studying the issues related to living organisms*, then forestry and forestry science, as general human activities related to forest as a natural phenomenon and economic factor, make part of bio-technological science in the same way as forestry higher education is made of a group of technical, biological and economic subjects, interconnected and always dependent on forestry as an economic branch.

### *3.2. Characteristics of wood-technology higher education study*

The *past dependence* of the higher wood-technology education on forestry and its gradual development into a completely separated study is the reason of the inherited dependence of the said study and science on the *class of bio-technological sciences.* Since there are a large number of dilemmas, only a few terminology issues should be noted here in view of this economic activity or higher education study. Uncertainties and seekings can be seen from changes of names of studies, departments and titles of the graduated engineers. The same occurs with the economic branch dealing with working and processing of wood, regardless of its value or quantity share in the end product. Due to great differences in the use of the expression *technology* in teaching curriculums and programmes, they will be discussed separately.

Some dilemmas were probably affected by the above emphasised joint development and partial overlapping of the margin activities of forestry and wood working/processing, in the economic branch as well as in higher education, but also by the influence of the assumed international standards and agreements literally translated into Croatian: this is not possible without being untrue to our own language. Thus, for example, already *in forestry* as an economic branch, the official Croatian statistics expressed data on *felling and the related services* ( p. 222). If Chapter 16 is entitled *Agriculture, Hunting and Forestry* (p. 220), and later on, data are discussed related to agriculture, forestry and fishing, there is no use in separating *felling and processing of wood* from forestry for at least two reasons: *firstly*, felling is only a component part of forestry production, but closely connected with others, especially with forest silviculture, and secondly, this is the part that employs 80 % of workers, realises almost the same income, this the part of activity in which almost the same percentage of all injuries at work occurs, etc.. Of course, such approach and seeking is still more obvious in expressing data related to the activity known as *wood industry* (Pavešić, editor, 1971, p. 69; Jojić, chief editor 2002, p. 277), *woodworking*, etc., the study of which has evolved from forestry higher education study. Thus in reference SLJH-99 , in Chapter 18 *Industry* (p. 267), data collected by *National classification of activities* of 1997 Wood Industry and cellulose-paper industry were classified in item 36 *Production of furniture, other pro-*

*cessing industry* (elsewhere mentioned), p. 281, in item 20 *Wood processing, production of wood and cork products, furniture excluded; production of straw goods and wicker material*, (p. 282), in item 21 *Production of cellulose, paper and paper products*, (p. 282), and as the source of raw material of any other production, e.g. *wood for dry distillation, packing material of all kinds* (item 24), *natron bags* (item 26), etc. Thus the name of the original study, *wood-industry programme,* got almost lost and the following has been said about it in ref. (Pavešić, editor, 1971) and (Jojić, chief editor, 2002): *...The expression is well formulated, it has its meaning, so there is no reason to pursue it…,* i.e. ***wood industry*** *is an economic branch dealing with mechanic and chemical processing of wood.* So, the first part of the compound *wood-technological, wood-,* (wood gas, wood product, wood industry, wood oil, etc.) are only adjectives, which show that something *relates* to wood; it is connected with wood and not made of wood, e.g. wood chair, etc. Similar division is also found in other languages, e.g. in English, where for wood industry the following expressions are used: *timber industry, wood industry, wood and lumber industry, wood-processing industry, woodworking industry, wood manufacturing industry, forest industry, forest-products sector, etc.*, and rarely (or not at all) the compounds with *technology*. This is mentioned because of the current name of the department (*Wood-Technology Department*), where the second part of the name – *technology* is disputable since it has been developed as a result of often misleading translation of the English word *technology.* If the well-known fact is taken into consideration that the type of used material is not crucial for a certain kind of processing, then the area which is ***not related*** to the life of what is named in the second part of the word, should belong to *technical sciences*, and on no account to *bio-technological sciences.*

### *3.2.1. Analysis of teaching curriculums of wood-technology study*

In order to determine the changes of the components of the teaching curriculums of wood-technology study from the actual establishment in 1951/52 up to the end of the last century, along with the initial curriculum, three other years have been selected as significant turning points: 1960 – the year when the Faculty of Forestry gained independence and an independent Wood-Industry Department was established, and two significant changes of the study curriculum, one in 1977/78 and the other in 1997/98.

Column diagrams in Figure 4 show the shares of 7 key components of the study curriculums for the said calendar year or school years. So as to show at least a general trend of changes of the observed groups of subjects, and in order to make a few comparisons with forestry study from which the subject department was developed, the same typical classes have been selected: only the forest-professional group of subjects has been replaced with the wood-technology component.

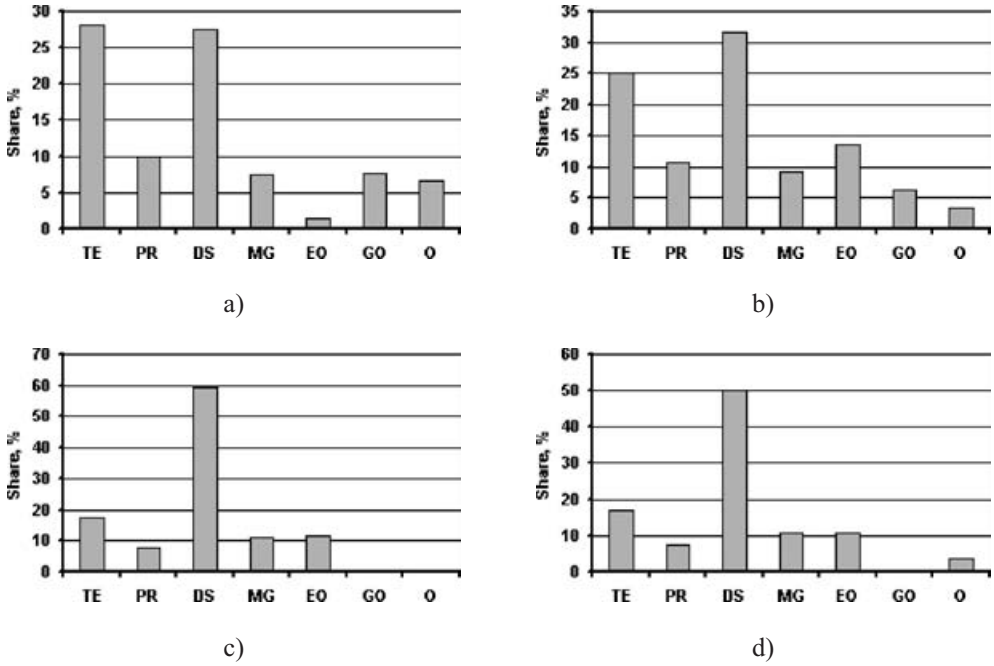


Figure 4: *Comparative survey of four typical components of wood-technology study for the period 1951 – 2001: (**a**) school year 1951/52; (**b**) 1960; (**c**) school year 1977/78 and (**d**) school year 1997/98. Legend: **1** – technical component (TE); **2** – natural sciences (PR); **3** – wood-technology component (DS); **4** – mathematical-graphic component (MG); **5** – economic-organisational component (EO); **6** – other economy in general (GO); 7 – other uncategorised (O)*

Similarly as forestry study, along with the obligatory subjects, the beginning of wood-technology study in the 21st century also brought three modules with optional courses. Figure 5 shows the shares of selected components of curriculums for the modules and their sum.

Figure 6 shows the shares of seven different observed subjects of wood-technology study put together, and in this way the changes of shares of individual groups can be clearly seen, i.e. the change of character of study in the second half of 20th century. Similarly as above, these data are related to the study in the years when crucial changes of teaching curriculums and programmes occurred.

Based on the analysis of curriculums and programmes of wood-technology study in the years of significant changes as well as on shares of groups of the related subjects in the entire teaching curriculum, it can be concluded that, e.g. the wood-technology component, which at the beginning accounted for a share slightly exceeding one fourth, was almost doubled at the end of the century, taking a half of the timetable (in mid 1970s its share increased to its maximum, almost 60 %). At the same time the technical component decreased by about 10 % (from 28 % to 18 % of share in the whole time-table). Although the other established classes

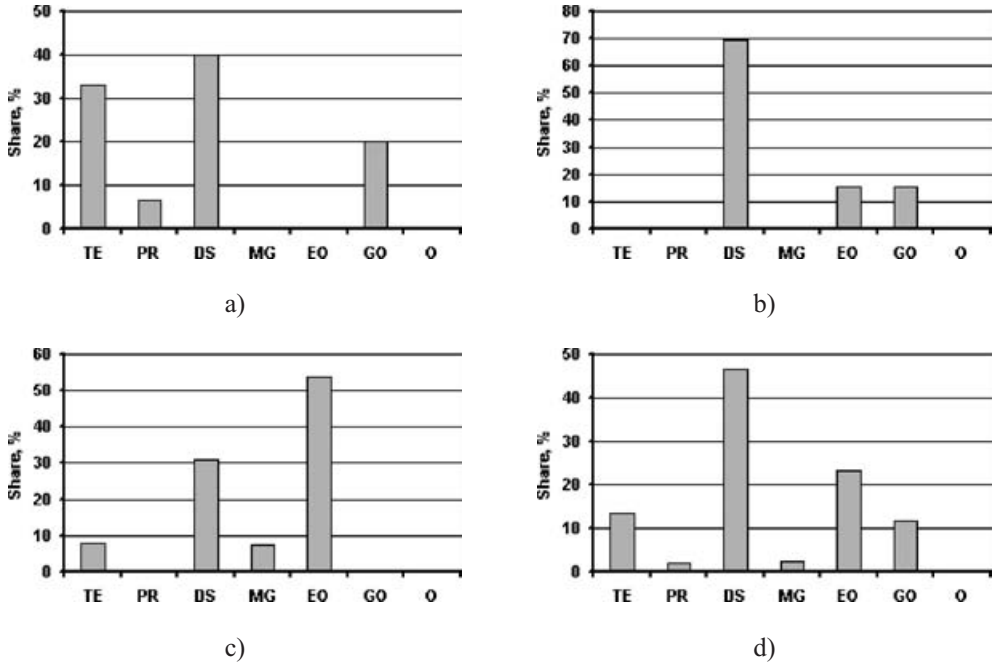


Figure 5: *Comparative survey of the module of wood-technology study 2001: module **a** – production technologies; module **b** – furniture design; module **c** – management; **d** – modules in total. Legend: **1** – technical component (TE); **2** – natural sciences (PR); **3** – wood-technology component (DS); **4** – mathematical-graphic component (MG); **5** – economic-organisational component (EO); **6** – other economy in general (GO); 7 – other uncategorised (O)*

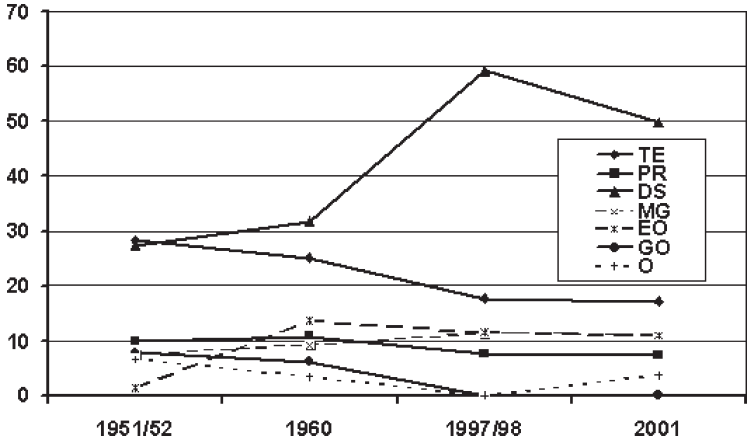


Figure 6: *Change of components of four-year wood-technology study in the period 1951 – 2001. Legend: **1** – technical component (TE); **2** – natural sciences (PR); **3** – wood-technology component (DS); **4** – mathematical-graphic component (MG); **5** – economic-organisational component (EO); **6** – other economy in general (GO); 7 – other uncategorised (O)*

changed their shares, they were always lower than 10 % of the total time-table (the sum of the remaining 5 components ranged between 29 and 43 %). As far as the module shares are concerned, the question should be posed whether a designer can develop successful designs without any additional technical training beside the obligatory one, or how a manager can run a company with less than fifty per cent wood-technological and technical knowledge in the area of management, etc., although it cannot be unconditionally and positively stated that such examples are not possible: there were cases of world- -wide known composers with no music education at all (G. P. Teleman learned to play piano with his teacher for only 14 days and at his time he was better known than Bach!). So, with design and management, too, natural talent and self education can, in some exceptional cases, be more important than the completion of the formal education, regardless of its programme. All changes stated above, established by the analysis of the characteristic crucial changes of curriculums and programmes, and established shares can be clearly seen in one of the diagrams: essential are the changes of wood-technology and technical component, while all the others depend on the currently available teaching staff, offered high-quality programmes, etc.

### *3.2.2. Terminology dilemmas of wood-technology curriculums and programmes*

Under the influence of English, the language prevailing world-wide, the last teaching curriculum of Wood-Technology Study of 2001 at the Faculty of Forestry, University of Zagreb, (Anon., 2001B) is not well adapted to the heritage of its origin. Here are several examples. Since this area doubtlessly makes part of *technical sciences*, it is very often almost impossible to understand professional names of subjects, areas and, of course, of the explanations of scopes. Indeed *...it is possible to find ways for providing better understanding or at least for establishing that we partly do not understand each other at all...*(Sever, 2003, p. 146), as stated and proved by many quotations in the said article. The same paper emphasises that the *terminological inaccuracy is fatal in many areas of human activity, but that its worst effects can be seen in education...* And the subject of this discussion is the education of wood-technology engineers in the 21st century.

In the papers dealing with general topics, the expressions like the following ones can be found ... *development of the principles of wood-technologies... areas of wood-technology ... development of wood-technology science ... technologies and engineering to come ... Zagreb School of Wood-Technology ...*, etc. It is not worth a vile to guess what the meaning is of the expressions *technology* and *technological*: one thing is sure though – it has nothing to do with the definition of J. G. Beckmann (1777) from the Faculty of Agriculture and Forestry in Göttingen, which says that *technology is a comprehensive science on interconnection between technical, economic and social issues* (in German: *Technologie ist eine übergreifende Wirtschaft, Gesellschaft und Technik verklammernde Wissenschaft*).

Along with the name of the study, department and graduated engineer (*graduated engineer in wood-technology / wood-technology study, wood-technology science, wood-technology department*), the names of many curriculum subjects, and also organisational units, are made of the noun *technology* and the adjective *technological*, as for example.: *Scientific and Teaching Wood-Technology Laboratory* (1984), *Institution for Wood-Technology* (1960), *Chair of Wood-Technology* (1975, 1997), *flexible technological systems* (2001), *gluing in end products technology* (2001), *mechanical wood-technology* (1978), *unconventional technology* (2001), *new technologies* (2001), *new technologies of wood protection* (1996/97), *new highly sophisticated technologies in wood processing* (2001), *basic wood-technology* (1987, 1989), *production technologies* (1996, 2001), *seminar of selected technology* (1989), *technical and technological development* (2001), *technology* (2001), *wood-technology* (1951), *technology of building wood products* (1989), *veneer and boards technology* (1963, 1978), *technology of veneer and multi-layer products* (1967), *technology of veneer and layered products* (1967), *technology of veneer and multi-layered wood* (2001), *particle boards technology* (1967, 1989, 2001), *technology of building products* (1978), *production technology of structural carpentry* (2001), *technology of furniture production* (2001), *technology(-ies) of end products* (1978, 1989), *mass wood-technology(-ies)* (1989), *furniture technology* (1978), *technological wood properties* (2001), *technological wood characteristics* (1989), *technological production processes* (1960), *technological processes in sawmill production* (2001), *higher education study of wood-technology* (2001) and other. Although it is not easy to conclude positivly in which case we actually deal with *technology* or *technological*, it can be guessed that we deal with procedures (production procedures, types of work, methods of control i.e. research or creative process), different processes, types of production, name of science, technique, mechanisation, properties/characteristics of material, teaching subject and many other unrecognisable meanings. These are great changes, especially at the beginning of the 21st century, e.g.: wood science or wood properties in wood-technology, production procedures or known productions in technology or production technologies or technologies of production, when the means of work became technological devices, etc. The curriculum language has remained without a meaningful inner connection between the written and read, read and spoken, and it makes no differentiation between the words with or without meaning. A little contribution can come from the understanding that *technology has always been and will always be a top science, side by side with theology,* and that it does not deserve the adjectival role in renewed curriculums and programs.

This consideration of names of study courses and of terminology used in defining the study (department, chairs, names of curriculum subjects...) is important in realising the Bologna Declaration and implementing the Bologna process, because each diploma shall very soon be accompanied by some supporting documents, the so-called *diploma supplement* and *supplement's appendix*, which must give unambiguous information to each user on the study, student and institution *for*

*which or by which the diploma has been issued*. The actual situation requires many substantial changes. Based on the assessment of the stated data in the supplement and its appendix, the equivalence of diplomas will be established as well as the inappropriate use of academic titles and their erroneous interpretation in the process of international verification of diplomas or their equivalence assessment.

## 4. Closing considerations

At the beginning of the 21st century, we are witnesses of many social, economic and even educational changes, be they related to higher education or just to a vertical series by which the faculty level is reached. The only question is whether the worn-out statements used by totalitarian politicians will be repeated and whether the educational system will be affected by use of many terminological distortions, or an up-to-date technical study will be developed on the grounds of the existing values of our own knowledge and experience, a comprehensive knowledge based on past activities. It is clear that higher education of both forestry and wood-technology should rely on our own past knowledge. And this means to make use of our own unused resources and to add to it all the richness of higher education studies already verified in practice. We are owners and proprietors of both of them, although sometimes we cannot say whether this ownership is real, objectified or only spiritual. Anyhow, the use of one's own experience is the only reasonable way toward the future forestry and wood-technology study and future fulfilment of our own expectations. However, when taking into consideration the two subject studies, the following should be noted: their setting is similar, but their environment is completely different. It should also be noted that their past knowledge is not a protected intellectual property, not even patent protected: this is general national knowledge, the basis of the future development of higher education at the only Croatian Faculty of Forestry.

However, all these considerations on the future of forestry and wood-technology engineering study are based on the assumption that the next teaching curriculums and programmes will be prepared by the same generation of teachers and scientists that created and directed the described trends not long ago. This is the only well-founded choice. Furthermore, it should be taken into account that forestry and the current wood-technology study were consistent and overlapping and that at the same time they supplemented each other and shared many inevitable time effects and circumstances typical of that time. Part of this heritage still affects each of the studies, as well as the economic branch for which the engineering education is being provided, and it acts as an inevitable factor having influence on events, growth and drops on the market as well as the market confrontation between goods and knowledge. Both studies have their own ***input*** (knowledge of enrolled students: *brought education* in mother tongue and foreign languages, and different levels of knowledge in mathematics, information technology, natural sciences, technical sci-

ences, etc.) and ***output***: post-graduation requirements with a comprehensive general education, type of knowledge hard to be foreseen today. Sometimes they overlap, sometimes they are somewhat different. The only sure thing is that both studies drew back from the area of *bio-technological sciences*: **forestry from the technology of living** inclining to its biological component, and partly also to natural sciences, **while wood-technology study has for a long time been present in this area only formally**, from outside, without being supported by its content. Adequate education of teachers should probably be provided so as to create the study of (wood) technical sciences with a more significant cultural supplement to both studies. The share of wood material or material in the products of wood industry still remains to be determined, as well as the share of engineering in environmental protection of the area managed by foresters in case of the first study.

Based on the review of the past study curriculums, in other words knowledge based on many years of practice in institutions of higher education, and based on the realisation of programmes for training of forestry and wood- -technology engineers, regardless of their name, it can be clearly seen that instead of aiming at providing closer connection between *bio-technology* (*technology of living*) and *technology of non-living*, in case of forestry the tendency is to *convert the technology of living into biology,* and in case of the so-called wood-technology it is acknowledged that it contains traces of the *technology of living*: *wood-technology studies technical procedures of non-living*, or in other words, it deals with the technique of wood working, processing and material realisation of some tasks aimed at producing material goods. Since wood is a relatively rare material that can be used as a working or processing material without any additional operations (moulding, pressing, injecting ...), it can be technically considered as a directly usable raw material, just like e.g. natural stone. The set objectives, possibilities and knowledge determine the type of processing or working technology to be applied along with the technology of trading and storaging, all with the aim of producing a well-designed product, artefact, or object with generally preset measures and defined properties for use. If, in case of forestry, interest remains focused on the production of the material, and pre-production without including wood production from wood, then the second part of the compound *bio-technology* suits better the description of the procedures of forest silviculture, thinning, reforestation, etc. If it is not perceived that these changes *leave the life somewhere else* (Čatić, 2003B), there will be no education of forestry and wood-technology engineers for the 21st century. If these requirements are not timely met, it will be very hard to catch up. Only engineers, who are able of transforming the ideas into the life of plants, as a tiny part of the forestry eco-system, or wood into a material product, shall be capable of solving every day engineering tasks. Both studies will continue their successful life in this *(bio-)technological age* in which humanity has lived, and is going to live for ever. It all means than in the 21st century, the issue of utmost importance shall still be the organisation of comprehensive production, procedures, measures of quality and suitability of means of work and personal protection of the production work-

ers, and others. And right this is the reason why the process of acquiring knowledge shall remain a continual educational process both in forestry and wood-technology. This is all the more so because the educational system is slow by its nature, and it should ensure to an individual successful work many years in advance when the knowledge acquired in school will have already been obsolete.

It should also be added to the above said that the international agreements as e.g. those reached by *Bologna Declaration, Lisbon Convention, Strasbourg Recommendation on Diplomas, European Cultural Convention of the Council of Europe and others,* first give the measures of comparative assessment of study programmes, level of students' load, etc. To that end, an ECTS (*European Credit Transfer System*) scoring system has been introduced by Bologna process aimed at simplifying inter-institutional agreements, changing the place of study, and especially enabling the comparison between the national (local) scales of marks and ECTS's. Apart from being used for the formal diploma verification, the system provides a just assessment of diploma equivalence. Everything else related to the study, its duration, curriculums and programmes, etc. is up to us, our wishes and possibilities. As the *Charter of European Identity* of 1995 deals with European heritage in education, each national entity should deal with its own legacy, regardless of its deficiencies and difficulties. This is why Mr. V. Havel says: *To be a European is not a matter of birth but rather of education!* And this cannot be achieved without serious restructuring of education.

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# TECHNOLOGIES AND PRODUCTS IN THE ENGINEERING AREA

## Part I.

# IOR and EOR – Chances for Increase of Oil Production and Recoveries in Existing, Mature Reservoirs

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*Abstract*

After the application of conventional oil extraction techniques, about 2/3 of discovered reserves still remain to be produced. In view of high probability for oil presence and oil price increases, investments in research of possibilities for higher recoveries and higher production with application of appropriate IOR and EOR methods are justified, naturally under economic conditions.

## Introduction

Let us assume the position of owner or at least oil company director, whose main task is renewal of reserves, and whose business success is measured by reserve replacement ratio.

New recoverable reserves of oil and gas can be obtained in the following manner[3]:

- Discovery of new reservoirs as a consequence of continuous pursuit of basic activity – exploration of domestic and foreign exploration areas;
- Improvement of reservoir models by application of new geophysical methods, state-of-the-art interpretation techniques and reinterpretation of all available data in combination with data obtained during reservoir exploitation (produced quantities of fluid and change in reservoir pressure);
- Application of EOR methods in reservoirs with inefficient displacement drives:
  - in the secondary stage of oil displacement by physical activity – injection of water or gas into the reservoir;
  - in the tertiary stage by freeing oil trapped in pore space after secondary stage by thermal or chemical activity – through application of EOR processes;

- Introduction of new technologies on existing fields: infill drilling, recompletions, fracturing, drilling of horizontal wells and sidetracking from existing holes to activate less permeable parts of the reservoir and catch the by-passed oil by IOR processes or reservoir management.

They can be defined as shown in Figure 1:

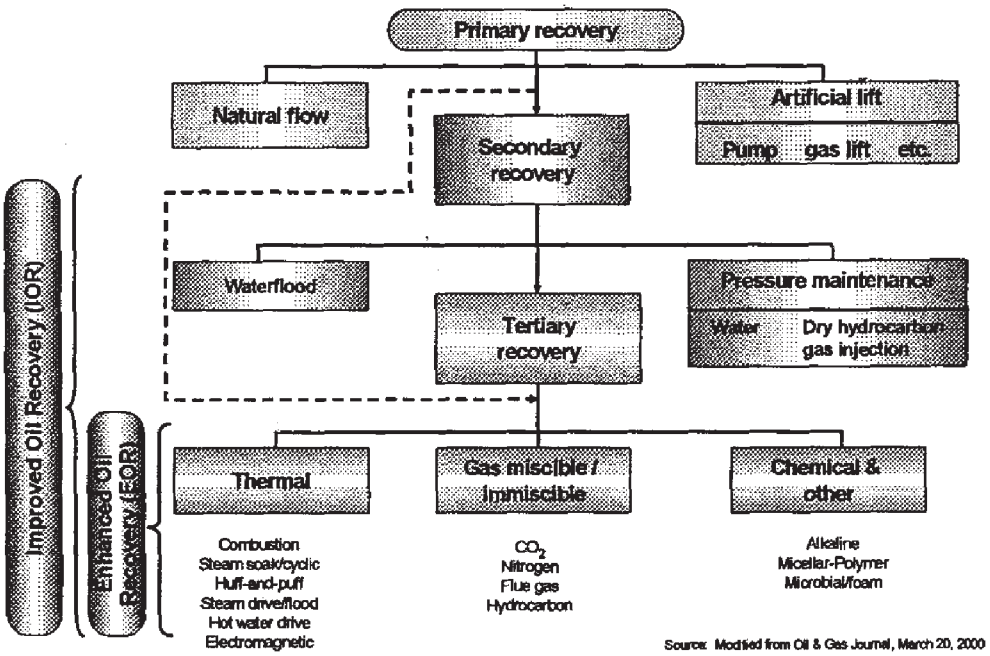


Figure 1: *Proposed definitions of the EOR and IOR terms*[8]

1. EOR methods, also known as tertiary recovery methods, mobilize oil trapped by capillary and viscosity forces during reservoir waterflooding in the secondary stage. Oil is freed by chemical and thermal activity, by injecting solvents and chemicals and heating of the reservoir.

2. IOR processes are applied mainly in the secondary and tertiary reservoir depletion stage to increase reservoir sweep efficiency coefficients by displacing fluids – looking for trapped oil by denser well spacing pattern, drilling of horizontal wells and sidetracking from existing holes, fracturing and use of polymers to improve fluid mobility ratio.

## 1. Exploration of domestic and foreign areas

Common problem of Central European oil companies is high degree of exploration of domestic exploration areas, without great probability for discovery of larger quantities of hydrocarbons. The situation in Croatia is a good example(1).

The territory of Croatia is divided in three exploration areas: the Pannonian basin, the Dinarides and the Adriatic offshore. A total of 332,6 million $m^3$ of oil and condensate and 129,8 billion $m^3$ of natural gas were discovered so far from 34 oil fields and 20 gas and gas-condensate fields. All oil was discovered in the Pannonian basin, and most of gas comes from the Pannonian basin and partly from the Adriatic offshore.

Despite great efforts, there were no major discoveries in the Pannonian basin in the last 20 years. We have to answer two important questions:

– Is the Pannonian basin sufficiently explored, and

– Is there a probability for discovery of new, larger quantities of hydrocarbons?

According to evaluations made within the framework of hydrocarbon potential investigation studies for the Croatian part of the Pannonian basin, two to four times more hydrocarbons were generated than they are discovered so far, which means that between 900 and 1 800 million $m^3$ of undiscovered quantities of oil equivalent could still be present in the subsurface. However, in spite of numerous seismic surveys and drilling of 850 exploratory and 2 780 production wells, these assumptions have not been confirmed.

Evaluation of possible discoveries of hydrocarbons were made applying the *Arps-Roberts* method. based on areas and reserves of hydrocarbons in already discovered fields. The data from 52 oil, gas and gas-condensate fields were processed.

Results of evaluations are shown in Table 1. According to analysis results, exploration targets were small and probability for discovery was low, but they could still be attractive due to available infrastructure for treatment and transportation of hydrocarbons.

Table 1. *Calculation of ultimate number of fields in each size class*

| *Class* | *Number of Fields* | *Number of Fields Smoothed* | *Total Area of Fields* | *Average Production Area* | *Original Oil in Place* | *Estimated Number of Fields* | *Total Productive Area* | *Original Oil in Place* |
|---|---|---|---|---|---|---|---|---|
| | | | ($km^2$) | ($km^2$) | (1000 $m^3$) | | ($km^2$) | (1000 $m^3$) |
| | $K_l$ | $K_i$ | $A_i$ | $A_l$ | $R_{ul}$ | $K_{ol}$ | $K_{ol}*A_i$ | $K_{ol}*R_{ul}$ |
| 1 | 4 | 2.78 | 1.19 | 0.43 | 1129 | 56.6 | 24.2 | 63883 |
| 2 | 7 | 6.61 | 6.90 | 1.04 | 1128 | 56.9 | 59.5 | 64227 |
| 3 | 10 | 10.89 | 23.92 | 2.20 | 2406 | 47.7 | 104.8 | 114781 |
| 4 | 13 | 12.48 | 55.27 | 4.43 | 4091 | 30.7 | 135.8 | 125440 |
| 5 | 11 | 9.94 | 97.56 | 9.82 | 14865 | 14.5 | 142.2 | 215314 |
| 6 | 5 | 5.50 | 82.71 | 15.04 | 25677 | 6.6 | 99.6 | 169976 |
| 7 | 2 | 2.11 | 90.11 | 42.63 | 30214 | 2.1 | 90.7 | 64294 |
| *Total* | 52 | 50.31 | 357.66 | 7.11 | 440612 | 215.1 | 656.7 | 817914 |

These results point out the only possible solution – exploration of insufficiently explored domestic exploration areas, in this case primarily the Dinarides, and foreign exploration areas. Will it be independently or jointly with other companies depends on the financial strength and company policy.

## 2. EOR methods

High depletion of oil reservoirs discovered several decades ago is attributable to high exploration of the larger part of the European continent. Conventional enhanced oil recovery methods, such as waterflooding and gas injection, were applied successfully in this area. We know about experiments with thermal processes in Romania and Hungary and displacement of oil with $CO_2$ was attempted in Austria, Hungary, etc.

According to natural depletion drives, recovery for all discovered oil reserves in Croatia was only about 25 %[(2)]. Recoveries were the smallest in the reservoirs with the largest reserves. Afterwards, following the world practice and effectiveness of natural water drive, reservoir pressure maintenance method by injection of water into 8 reservoirs/fields and gas injection into one field has been applied since 1972. Waterflooding is applied on 58 % of all discovered reserves. By this processes recoverable oil reserves were increased by approx. 30 million $m^3$, and recovery from earlier mentioned 25,00 to 34,45 %.

By the end of 2002 total production of oil at recovery of 32,5 % reached 102,0 million $m^3$ and remaining recoverable oil quantities are estimated at about 7,0 million $m^3$. The status of reserves, in percentages, is presented in Table 2.

Table 2. *Oil recovery rates and oil reservoir depletion methods, %*

| | |
|---|---|
| Recoverable | 34,45 |
| – recovered | 32,50 |
| – primary recovery | 50,91 |
| – secondary recovery | 49,09 |
| – tertiary recovery | 0,00 |
| – remainder | 1,90 |
| Unrecoverable | 65,55 |

In spite of such good results achieved by waterflooding, oil production has been constantly decreasing since 1981. The question is how to stop such production decrease. The solution lies in emerging of an idea how to recover a part of remaining 205,2 million $m^3$ of currently unrecoverable oil reserves.

The idea how to increase oil recovery from waterflooded reservoirs in tertiary stage of production has been developing for a long time. The solution was found in $CO_2$ injection as the most efficient method, since in addition to its positive characteristics and proved efficiency, $CO_2$ is available in high quantities, at present discharged into the atmosphere. Possible application is expected in the near future, primarily on Ivanić and Žutica fields. Numerous laboratory analyses, studies and numeric simulations were carried out and they indicate possibility for recovery increase by 12 to 14 % under miscibility or near miscibility conditions.

Economic valuation for one of the projects[6] was done for different variants:

- Variant A – extension of existing waterflooding system
- Variant B – oil displacement with $CO_2$.

with oil price at 20 \$/bbl (125,8 \$/$m^3$) and gas price at 0,12 \$/$m^3$ and discounted rate of 10 %. The obtained results are as follows:

- Positive project duration:
  - variant A – 10 years
  - variant B – 23 years or more
- Expected future total production:

| Variant | Oil tons | Gas $10^3$ $m^3$ |
|---|---|---|
| **A** | 1 538 295 | 445 018 |
| **B** | 5 462 283 | 1 302 620 |
| **Difference** | **3 923 988** | **866 602** |

- Net present value:
  - variant A – 32 264 000 \$
  - variant B – 50 144 000 \$
- Payout period:
  - variant A - 2 years
  - variant B – 12 years
- value of investments and production costs per unit of product, \$/BOE

| Variant | Capex | Opex | Total |
|---|---|---|---|
| **A** | 1,12 | 15,01 | 16,13 |
| **B** | 2,19 | 9,81 | 12,00 |

After application in these fields, the method could be extended to other fields in the same region.

## 3. IOR processes

Good results should also be expected from application of IOR processes, regardless of the manner of realization. The study on possibilities to search for by-passed oil in highly waterflooded part of the reservoir on Šandrovac[7] field was also prepared.

Analysis of sedimentation conditions, effective thicknesses, injected water flood front shifting as well as achieved recoveries from well drainage areas, helped locate the areas for 10 side-tracked holes and one horizontal well. They would double the quantity of oil in comparison with current production, with recovery rate increase by 5,8 %. Planned investments amount to approx. 500 000 $ per well. With oil price at 16 $/bbl and discounted rate of 10 %, net present value of 15,1 million $ was obtained, while payout time was one year and 10 months.

All such projects are burdened with high water cut in produced fluid. Hopefully, the problem will be solved in the near future. At a time when produced quantities of oil are accompanied by twice as large quantities of water, the problem is of global proportions and its solution would considerably reduce production costs.

## Conclusion

These considerations point out the need for exploration in new promising areas and applying of IOR processes and EOR methods on existing fields.

Produced indigenous oil is more valuable for domestic economy than imported oil and oil companies, scientists and experts from this sphere of activity face a permanent task how to maintain production levels and increase recovery from existing old fields in a profitable manner.

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# Technological Challenges at the Beginning of the Third Millennium

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*Abstract*

The paper describes situation in the science and technology at the end of 20th century. Technological achievements and advances in electrical engineering are listed. Especially the power engineering was analyzed. Beside the production and transmission of electrical energy the paper treats integrated electrical power engineering systems and big black-outs in them as well. The paper lists the news in electronics, communications and computing in short. The results of IEEE survey on the situation and technological development are described. The technological perspectives in electrical power engineering and transport are given. At the end, the possibility of the application of hydrogen as the energy-generating product in the near future is given.

*Key words:* technological development, electrical power engineering, integrated electrical power engineering system, big black-outs, fusion reactor, hybrid car, fuel cells, hydrogen

## 1. Introduction

In the whole last century Croatia and especially Zagreb was among leading European centers of cultural, educational and technological advancement. Due to recent Independence war stagnation occurred, but nowadays the industry progressively renews, and the technological development necessarily has to proceed and hasten.

In the developed world at the end of 20th and in the 21st century science and the technological development are advancing. According to the researches at the

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Stanford University (USA), the whole human knowledge is doubled every 5 to 8 years.

The consequences of such a development in science are the development and fast break-out of new high technologies, just to mention some of them: micro and nano technologies, informatics, power engineering, bio-engineering, exotic materials.

It caused the discovery of the human genome, virtual reality, quantum computers, hydrogen fuel cells, digital communications, fiber optics and lasers, high-temperature superconductivity, etc.

This paper, on the basis of the relevant reports, wish to point out some of those technological advances that reached almost unbelievable borders. The purpose was to give the contribution and an encouragement in the return to the tradition and in the new technological advance in our country.

The focus will be in the technological development in electrical engineering, electronics, computing and communications. At the end of the article we will point out the application and connection with the achievements in other areas.

## 2. Achievements and technological advances in electrical engineering

The survival of the modern society at the achieved level of the development, as well as the future progress, depends on the industrial production, transport of the persons and goods and the transmission of information, and above all it depends on the reliable supply of energy [1].

Mostly these areas include electrical engineering, i.e. its branches: electrical power engineering, mechatronics, electronics, communications and technical informatics, which treat production, transmission, processing and conversion of two key resources: energy and information.

### *2.1. Electrical power engineering*

Electrical energy is important and irreplaceable kind of energy. The production and transmission of electrical energy are relatively simple, and they do not cause any particular problems for natural environment.

The needs for electrical energy are doubled for every 10 years in developed countries. The significant increase is expected in future too. At the plenary opening of the 40$^{th}$ Conference of International Council on Large Electric Systems (CIGRE) in Paris in September of 2004, the information was brought that the world investments in electrical power engineering in 2030 will be 10000 billions of USD.

On the other side, the natural resources of energy as coal, crude oil, natural gas and energy of water are not unlimitedly available. The global deficit of energy is substituted by using nuclear power more and more. The research in the world is focused on inventing new sources of energy, and the alternative sources of energy are used as well.

### *2.1.1. Production and transmission of electrical energy*

The constant increase of the consumption of electrical energy demands the improvement and the new technological advances in production, transmission and distribution of electrical power. Water cooling generators are built up to the power of 1500 MW, and the possibility of 2500 MW is predicted. The generators with superconducting (exciting) winding point out the limit of 3000 MW, even more.

The alternative renewable sources of energy enable the production on the level of distribution of electrical power and introduce new challenges for the engineers. Solar energy, energy of wind, bio-power, fuel cells, etc. enable environmentally acceptable additional production of electrical power.

Institute of electrical engineering of Končar Group is commencing with the production of the prototype of the wind power plant with the power of 750 kW and a rotor with 51 m in diameter [2]. The information is given that the power of installed wind power plants in Europe till the end of 2003 was near 29000 MW, and that the production of electrical power from wind will until 2020 reach 12 % of the total production. In any case the spare is needed in conventional power plants to ensure the supply during no operation periods of wind power plants.

The transmission of electrical power has the essential role in connection of hydro-, thermo-, nuclear and alternative power plants and main nodes of integrated power system. Transmission lines are built for increased transmission voltages, reaching millions of volts and even more. Our high voltage transmission network (400, 220 and 110 kV) has overall length of 7200 km and contains 140 substations. The biggest power junction node in southeastern Europe is in Croatia – substation Ernestinovo, which was enlarged and renewed after the war. In October of 2004 the huge power system of EU was connected with the power system of the southeastern Europe using substation Ernestinovo. Besides that, Croatia is deficient in power and imports electrical power. The subsequent big increase in consumption is expected, and according to the analysis until 2010 in Croatia plans to build new power plants with the power of 1220 MW.

Apart from the introducing the new composite insulation materials in transmission systems, the new solutions for the more efficacious transmission of electrical power are researched. The technology of transmission of great powers using superconducting cables is researched.

A visible advance is reached using selective thyristor control in adaptive alternate transmission system (FACTS) that was developed by the Institute for the research in power engineering (EPRI – USA). This system optimizes the transmission of electrical power, ensures great stability of the system because it controls very quickly all the transient disturbances in the system etc.

### *2.1.2. Integrated electrical power system*

Nowadays the production, transmission, distribution and consumers in electrical power systems are more and more integrated and acting together. Besides classical power plants the additional production is introduced at the level of distribution. Integrated power system contains different sorts of new production technologies: cogeneration units, fuel cells, photovoltaic cells, wind generators, micro turbines etc.

The "tools" dedicated for the analysis of distributed production of power in such integrated systems exist, and the new "tools" are permanently developing [3]. Such tools contain systems for the analysis of the power flow, short circuits, protection systems, dynamic and transient stability, selectivity of protection, harmonics, as well as Monte-Carlo simulation, electromagnetic transient simulation, simulation and coordination of protection, calculation of flickers, probabilistic calculation of power flow, compatibility with other power systems etc.

Using a new software for calculation of electromagnetic fields developed at the Chair of electromagnetics of the Faculty of Electrical Engineering and Computing in Zagreb, E and B fields are calculated in substation Ernestinovo, Žerjavinec and Jarun, in order to determine the zones where electromagnetic fields exceed the values regulated by the law. Figs 1-5 present the distribution of the calculated fields in substation Žerjavinec [4].

### *2.1.3. Huge blackouts*

Contemporary investigations and advanced mathematical modeling of the integrated electrical power systems concluded that the big failures, i.e. huge blackouts are inevitable.

According to the statistics of big breakdowns during the period between 1984 and 2000, acting on the consumers greater than 2000 MW, it is concluded (according to Fairley [5]) that the probability of a breakdown expected in big integrated systems is every 15 years.

According to the informations of the US Department of Energy, one of the biggest blackouts in the history occurred at August 14, 2003, and cost between 4 and 6 billions of dollars.

There is lot of opinions how to avoid the problems of the huge blackouts in integrated power systems. Some of suggested measures are: make the network more robust, improve the simulation techniques, application of computer control in real time, improvement in regulation etc.

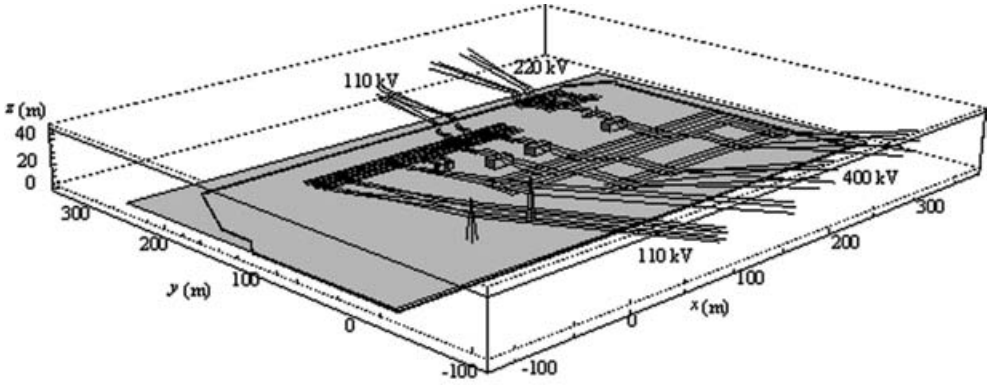



Figure 1: *Schematic diagram of substation Žerjavinec*

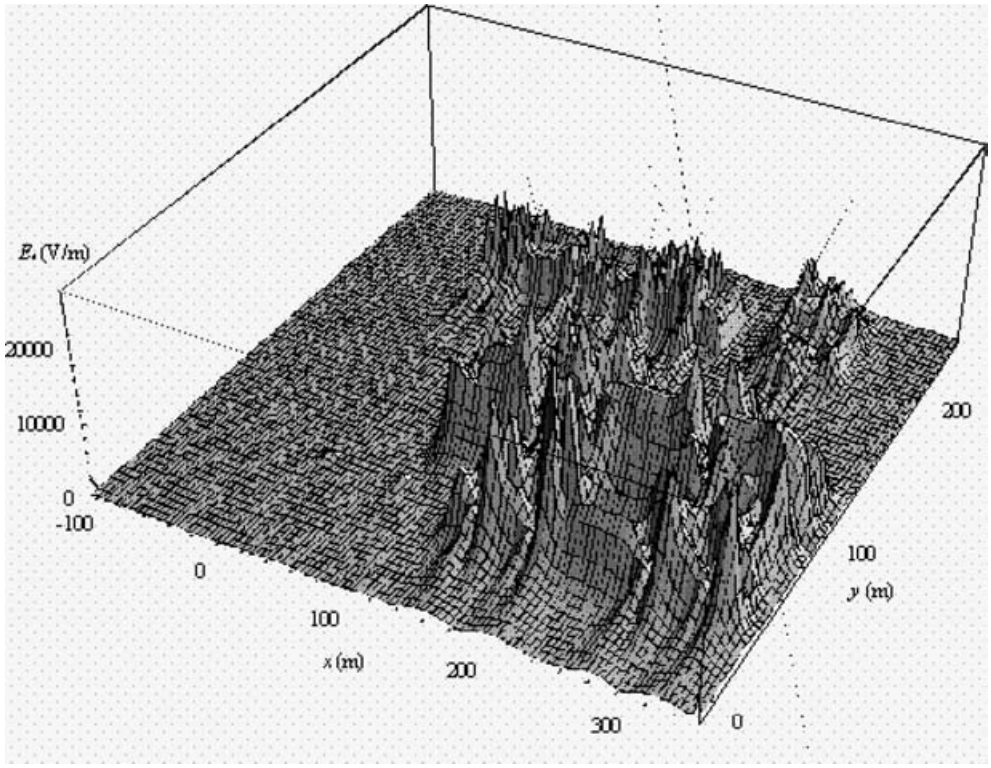



Figure 2: *Distribution of electric field in substation Žerjavinec*

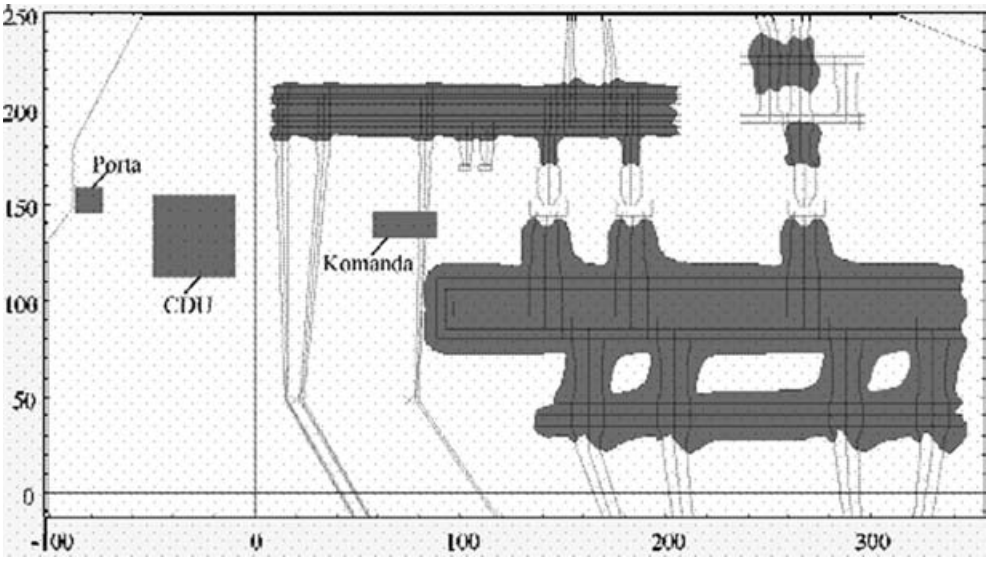



Figure 3: *Area of strong electric field in substation Žerjavinec*

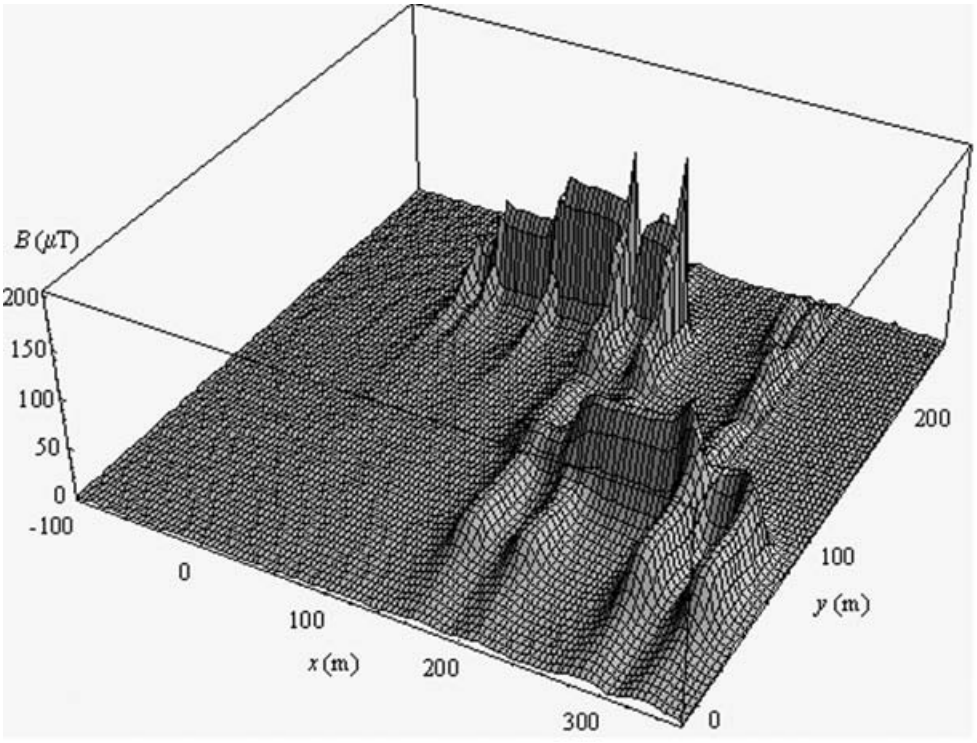



Figure 4: *Distribution of magnetic flux density in substation Žerjavinec*

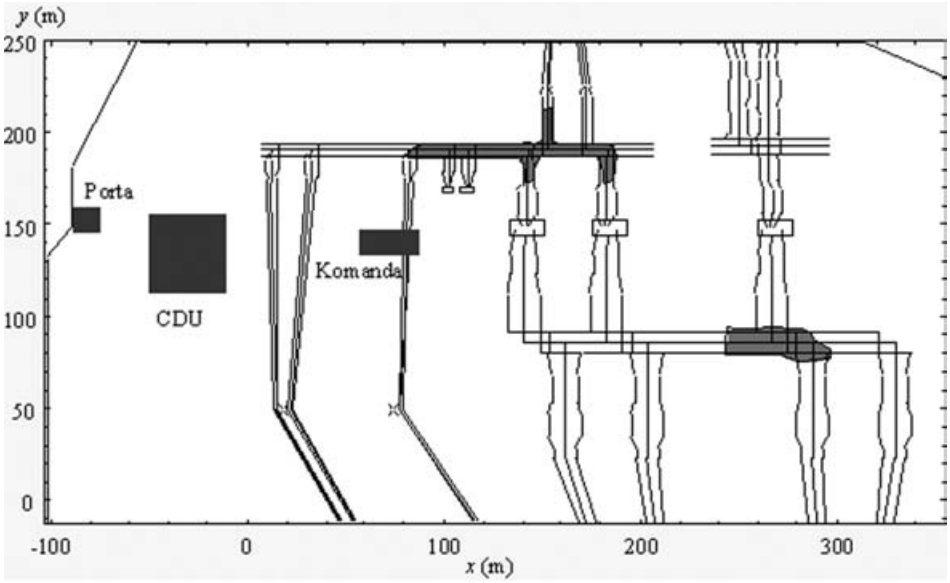



Figure 5: *Area of strong magnetic flux density in substation Žerjavinec*

### *2.2. Electronics, communications, computers*

According to the statement of the long-standing president of "Fraunhofer Gessellschaft" (57 institutes in Germany) prof. Hans Juergen Warnecke in his presentation at Croatian Academy of Sciences and Arts in May 2003 in Zagreb, microelectronics is doubled every 18 month, and the price is reduced two times. This is fastest development in technology until now [6].

More elaborated it was in presentation of Dalibor Vrsalović, PhD, vice-president of INTEL Corp. USA at MIPRO conference in Opatija during May 2003. According to Vrsalović, every 18 month integrated circuits can double the number of functions, so called packing, or speed. With the development of technology, he is convinced, speeds in processors can go to 20 GHz, and the global gap will continue to broaden. At this moment, global market of information technologies turns approximately 1300 billions of dollars every year. It is also predicted that the capacity of the biggest computer will reach the capacity of the human brain until 2014.

Communications (tele, radio, computer) at the beginning of the third millennium also have an unbelievable fast development. This development is contributed by fixed, mobile and satellite communication. News are coming all around. Fixed communications use semiconductor lasers and fiber optics without electronic amplifiers (dark fiber). There are also erbium doped distributed amplifiers. Asynchronous transmission mode at the photonic level is optimal for fixed global telecommunication networks.

Since 1980, the capacity of photonic transmission lines is doubled every year.

## 3. Situation and technological development according to the expert opinion in ieee survey

According to the judgment of IEEE, the situation in 2003 in many technological areas is not satisfying, despite to its fast development.

What has to be improved? The list is long, and only two important areas are listed: telecommunications (jammed) and the lack of energy. Engineering education is bulky and different, and the politics is without vision.

The key issue is how to use the knowledge and technological resources to give technological answers that lead us to the next millennium. To answer this question, IEEE contacted a group consisted of 565 elite technological experts in areas that contained computers, telecommunications, power engineering, semiconductors and processors, transport and education. The results of the survey are published in [7].

### *3.1. Answers and opinions*

Here are listed only some of the questions and shorted answers:

1. Which is the group of problems that demands biggest technological challenges in the subsequent years? The experts judged that the development in power engineering has the highest priority. Too strong dependence on fossil fuel concerns them all, and they connect it with the environmental pollution
2. What is expected in transmission and processing of information? Most of experts expect subsequent progress in production of mobile phones, laptops, digital television (HDTV) etc.
3. What contributes a successful production and distribution of electrical power? 70 % of them identified the alternative sources of energy
4. There is a spread spectrum of the answers to the question: which are promisable sources of the energy in the next decade? The placing is surprising: hydrogen power, nuclear power, photovoltaic cells, fossil fuel, hydraulic energy and power of wind.
5. On the question what is next, IEEE experts predict the most important technological development in the next years in the field of alternative sources of power, super fast wireless communication and molecular computers.

In [7] is listed a number of interesting questions and answers. It predicts a cheap wideband access and interconnects, all the things that Internet promised, and didn't achieve. The next internet revolution will be “high-speed wireless” access.

It is expected that alternative gate-dielectrics will replace silicon. The utilization of cheap artificial intelligence is predicted, intelligent computers that can drive

some kind of vehicles or act as research assistance, etc. Very much is expected from representation and application of genomic research as well as from the integration of biology and technology (genetic engineering and bioinformatics).

## 4. TECHNOLOGICAL PERSPECTIVES IN 2004

A special IEEE report [8] describes the results achieved in 6 big technological project in the fields of communications, electrical power engineering, semiconductors, transport, computers and bioengineering. Some of the solutions in these projects are called "high-technology dreams" that will become reality in our life-age. We will here show some of the expectations in electrical power engineering and transport, based on [7] and [8].

Picture 6 shows a proposal of tokamak reactor. Inside such a reactor plasma is heated and depressed using the magnetic fields produced by a superconducting coil placed all around. This way a self-sustainable fusion reaction is generated. This favorable approach to the production of electrical power using strong magnetic fields in thoroidal machines (fusion reactors) is tested in prior large experiments at Joint European Torus, Abingdon, UK , and at Princeton Plasma Physics Laboratory,

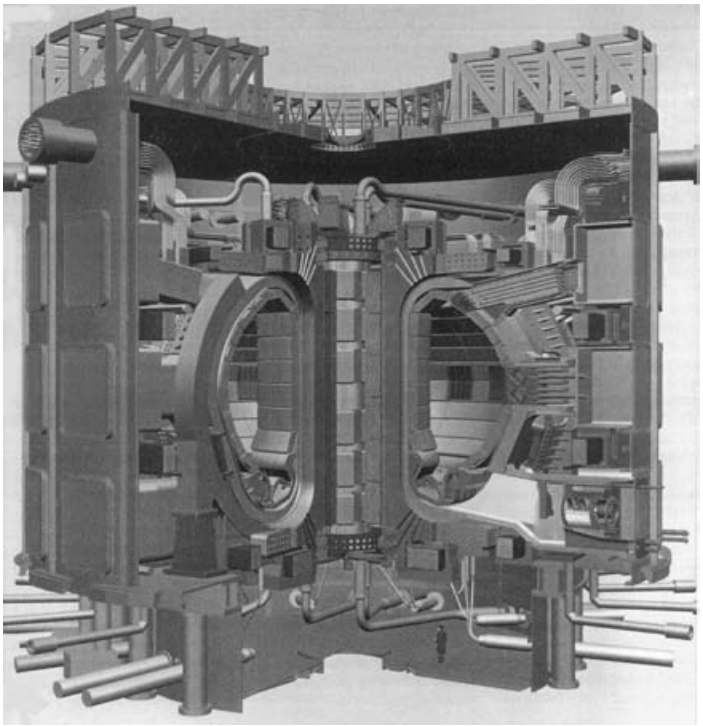


Figure 6: *Fusion reactor*

New Jersey in the mid of 1990's. The next important event will be design and completing of the International Thermonuclear Experimental Reactor (ITER). This international cooperation with the investment of 5 billions of dollars has a goal to produce a permanent (uninterruptible) self-sustainable reaction in so called burning plasma. USA, EU and Japan participate in such projects.

New superconducting electrical motors dedicated to ship propulsion represent a revolution in shipbuilding and navigation [8]. U. S. Office of Naval Research (ONR) has in the program the testing of a 5 MW and 23 tons weighting superconducting ship motor (Picture 7). Rotor with a superconducting winding was developed in American Superconductor in Westborough, Mass. It is sustained in superconducting condition at the temperature of 23 K by a helium cooling plant. It was built at Alstom Power Conversion in Rugby, UK. ONR already prepares the development of the next-generation 36.5 MW motor. All research in naval transportation leads toward a 36.5 MW motor as the optimal one. This motor is in a special shielding directly connected to the ship screw.

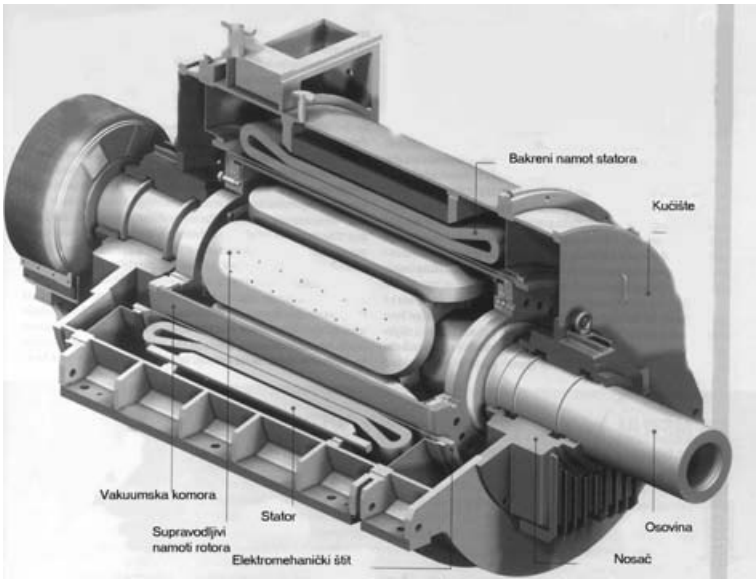



Figure 7: *Motor with superconducting rotor winding (5 MW)*

Electromotive operation of cars becomes reality too. In reference [9] the examples of hybrid Toyotas, Fords and Chevrolets are described under the title “hybrids are coming”. A hybrid car with the plug (dedicated to the supply with electrical power) contains a petrol-driven machine and an electrical motor equipped with an electronic converter for the charging of the batteries that drive electrical motor (Picture 8). Reference [8] describes a hybrid car that is developing at Daimler Chrysler in Mannheim, Germany.

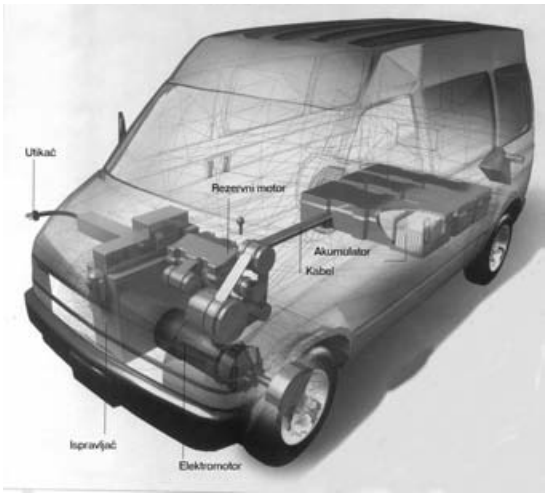



Figure 8: *Hybrid vehicle (with plug)*

There is a rapid research on the development of magnetic levitation extremely fast trains, that reach greater and greater velocities. The wagons of such kind of trains contain superconducting electromagnets cooled by fluent helium, enabling the train to move and in the same time to "levitate" above the rails. One of this super fast trains composed of three parts (Picture 9), reached at the end of 2003 maximal speed of 581 km/h in the region Yamanashi, west of Tokyo [8]. Table 1 presents the figures of the project of such or similar super fast trains that are to be built in the world.

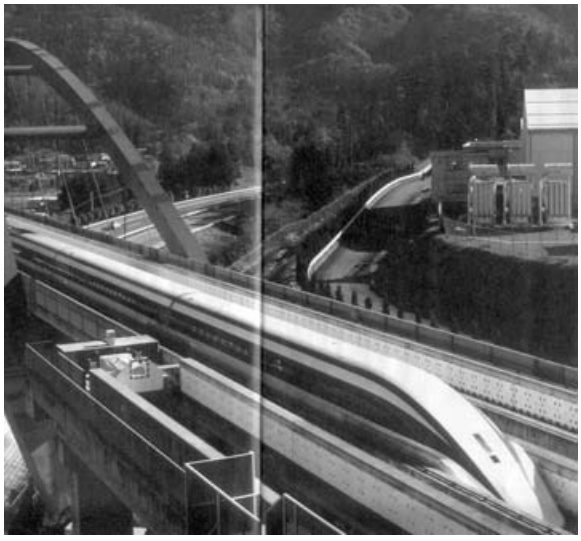


Figure 9: *Super fast levitating train with linear motor*

Table 1: *Projects of super fast trains in the world*

| | **In testing** | **In development** | | | **Elaborating** | | |
|---|---|---|---|---|---|---|---|
| Location | Shangai | Munich | Pittsburgh | Washing-ton | Las Vegas – LA | LA-Palmdale | Atlanta |
| Purpose | Airport-subway | Center-Airport | Center-Airport | Center-Airport | Las Vegas Airport | Center-Airport | Airport-Center |
| Distance | 30 km | 37 km | 76 km | 64 km | 56 km | 115 km | 51 km |
| Travel time | 8 min | 10 min | 23 min | 18 min | 12 min | Depend-ing | 23 min |
| Velocity | 500 km/h | 400 km/h | 400 km/h | 430 km/h | 500 km/h | 400 km/h | 400 km/h |
| In use from | 2003. | 2008. | 2012. | 2012. | 2010. | 2010. | 2010. |

## 5. Future hydrogen era

Almost 50 years ago scientific and technical literature announced the application of hydrogen as the primary source of power in transportation and electrical power engineering. In late 1960's, NASA Apollo program used hydrogen fuel cell as the source of energy [10]. Nowadays the vision of hydrogen as the future's energy-generating product is confirmed in many authorized committees in the developed world. In 2003 USA president Bush and EU president Prodi confirmed the vision of “hydrogen economics” [11]. The vision appeals to change the global economics of the energy transport depending on the crude oil into that based on the hydrogen. The main reason is pollution caused by the fossil fuel (hydrocarbons) driven cars. Only in USA, in 2001 the emission from the vehicles was more than 500 million tons of equivalent carbon. In 2003 two thirds of $CO_2$ emission from fossil fuel was generated in the areas of transport and energy production. US Department of Energy initiated the use of hydrogen fuel (Table 2, [10]), that suggested start of the hydrogen era in 2024. One of their judgments is that we need 40 million tons of hydrogen to supply 100 millions of fuel cell vehicles and 25 millions of households.

Fuel cells (elements) were developed for several purposes in the fields where we need electric power. Pictures 10, 11 and 12 depict fuel cells (according to [10]). Picture 10 shows a schematic diagram of the cell with polymeric diaphragm charged by hydrogen, which seems to be most appropriate for hybrid and electric vehicles. Picture 11 shows a fuel cell charged by natural gas that serves as a sta-

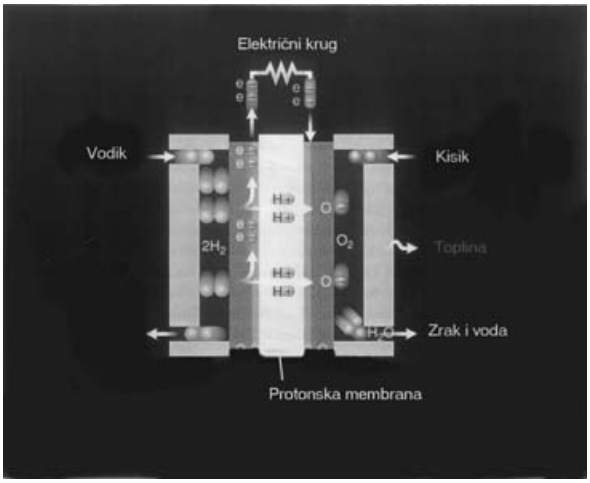
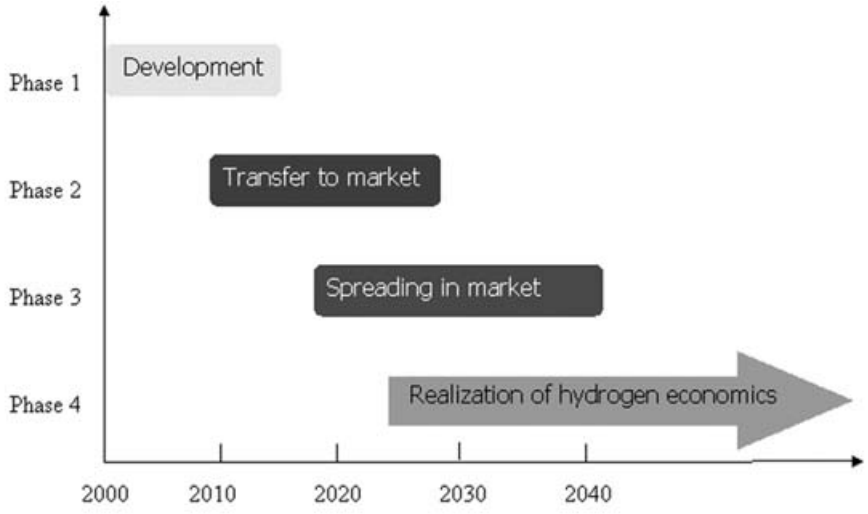



Figure 10: *Fuel cell with polymeric diaphragm*


Figure 11: *250 kW fuel cell charged by natural gas*


Figure 12: *A fuel cell Ford in front of hydrogen fuel station (350 bars)*

Table 2: *Time diagram of research and development of "Hydrogen economics" (source: US Department of Energy)*




tionary source of energy with rated power 250 kW. Picture 12 shows a Ford fuel cell electric car, standing in the front of a hydrogen fuel station working at the pressure of 250 bars.

At the end, according to the above facts, and according to many recently published professional papers, we may conclude:

Immediate replacement for the crude oil is not possible for vehicles. One of the solutions for today and for the near future is a hybrid vehicle containing both internal combustion machine and a fuel cell, gradual transition to the vehicles driven by fuel cells only. On the other side, application of fuel cells in transportation is a key for the realization of the hydrogen economics.

Power system based on the fuel cells would be a very expensive way of producing electric power. Besides all the advantages of the hydrogen, arguments against widely hydrogen-based power system is hydrogen production itself, as well as the high building price of the hydrogen distribution system. Critical point is electric power needed for the hydrogen production, which is lately used in production of electric power. This "twofold conversion" substantially increases usage cost of fuel cells as the primary source of power. Possible way is to combine all new sources of energy in the production in one unique power system. Raissi and Block quote in [11] that the hydrogen and electricity are ideal partners and that they together constitute an integrated power system based on the distributed energy production.

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# Energy and Ground Vehicles in the Near and Distant Future

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*Abstract*

The subject of the theme is a problem of a great concern of the contemporary world: sustainable mobility under the threat of disappearance of fossil fuels and environmental and global pollution. In the focus of the lecture are: the importance of mobility for the economy, the harmful threats to mobility, alternative drives for ground vehicles that enable decrease of the dependence on petroleum and better protection of the environment and the earth, the prospect of the technology development for alternative drives for ground vehicles, solutions for alternative drives on which the developed countries like Japan, USA and EU count, and should Croatia wait for a final solution or should it act itself and grab the opportunity of opening of a new developing area for its own technological renewal.

*Key words:* ground vehicles, alternative drives, alternative energy

## Introduction

The awareness of the fossil energy and earth pollution problems marked the end of the last century and let us hope that the solution to these problems will mark the beginning of this century. Vehicles in general are particularly vulnerable to the threat of the final dead of fossil fuels, which is as close as the development speed increases. The use of fossil fuels is the biggest enemy for the environment and the globe, and ground vehicles in the urban centers affect the health of the biggest part of the global population. On the other hand, mobility is of a paramount importance for further development of the world economy.

Having in mind that this lecture was prepared for the Colloquium "*Development Of New Technologies And Products In Croatia"* organized by *the Croatian Academy of Engineering,* its purpose was to point out: first, that looking for solutions for sustainable mobility is of a crucial importance of the contemporary world

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which means that it concerns every country and which testifies that a new market need is opening, second, the question of alternative energy for ground vehicles represents an extremely vast technology platform which offers opportunity to new players, and third, since any country including Croatia has ultimately to take car of its own development, they'd better grab the opportunity for their own involvement and technological renewal.

Following the intention of the lecture, this article will point out the increasing need for mobility and accordingly increasing petroleum use, the direction of technology development for alternative drive for ground vehicles, the way the developed countries like Japan, USA and EU are trying to find appropriate solutions for decrease of the petroleum dependence and the way how developing countries like Croatia should act in order to decrease the dependence on petroleum and to protect the environment, and eventually to prevent an increasing possibility for a petroleum crisis.

## Mobility and Economy

There is a strong link between the economy development and mobility. According to the European Road Statistics 2004 of the European Union Road Federation, Figure 1, from 1990 to 2001 the GDP of the EU 15 increased for about 33% and the transport of goods and passengers increased for about 22 – 25 % respectively. Growing transport, far beyond the economic development planners prevision, provokes numerous problems, starting from the congestion caused by inability of the infrastructure to digest the number of vehicles up to the degradation of the environment and climate change. European Commission White Paper (2001) "*European transport policy for 2010 : time to decide*" stated that unless major new measures are taken by 2010 in the European Union so that the Fifteen can use the advantages of each mode of transport more rationally, heavy goods vehicle traffic alone will increase by nearly 50% over its 1998 level. Now we are in 2005 but nothing spectacular happened concerning redistribution of the transport on various traffic modes, and EU consists of much more then the Fifteen, which ultimately will provoke further increase of the need for transport. Economic growth expected in the new EU members, and even more in the new candidate countries, will certainly need further increase of the transport flows.

The Gothenburg European Council has placed **breaking the link between economic growth and transport growth** at the heart of the sustainable development strategy. Is it possible to break the link between the economic growth and the increase of the mobility? The Growth of the transport is due to the new economy which moved from a "stock" economy to a "flow" economy, as the EUC White Paper recognizes it. Globalization is rapidly changing the production system and relocation of the industry from developed countries towards cheaper workforce will even more influence the growth of the transport due to the dispersion of the pro-

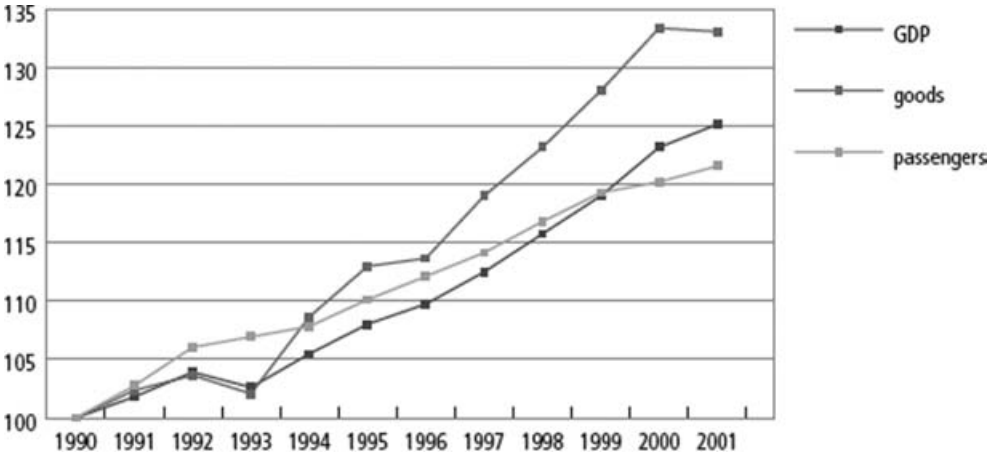


Figure 1: *Passengers, Goods and GDP from 1990 to 2001 in EU 15 (1990=100)*

duction plants for a single product, which finally travels thousands kilometers to reach the assembly plant and after that to the reach the users. Further more, developing countries can not develop on their own and a large cooperation is an imperative which also needs increasing mobility. Besides, the transportation on itself is a part of the economy – vehicle industry, roads infrastructure, various services, etc. The part of the road vehicles industry and road transport, according to the Road Statistics 2004 of the EU Road Federation, in 2002 represented 11% of the EU 15 GDP and 8% of the total employment. Therefore it is difficult to imagine that the economic growth can happen independently of the mobility. But it is much more easier to imagine a brake to the development model in which a favorite source of energy enabling rapid increase of wealth, has taken the monopole and nowadays makes us expect unimaginable crises.

## Mobility and Its Impact on the Petroleum Matter, Environment and Global Pollution

In the EUC White Paper (2001) is said that the roads carry 44% of freight and 79% of passenger transport. Figure 2 shows the trend of transport mode in EU from 1970 to 1998. The car fleet is expanding by 3 million vehicles a year in the Union.

In 2002 in China there were 20 million motor vehicles (Wan 2004). It is estimated that there will be more than 50 million such vehicles by 2010, and 100 million by 2020. With an estimated 1500 million people in China by 2020, for every thousand people 67 will own cars, far behind the world wide average level of 126 cars in 2001. It means that China will see an increase of road vehicles at a rate of about 15.000 vehicles a day.

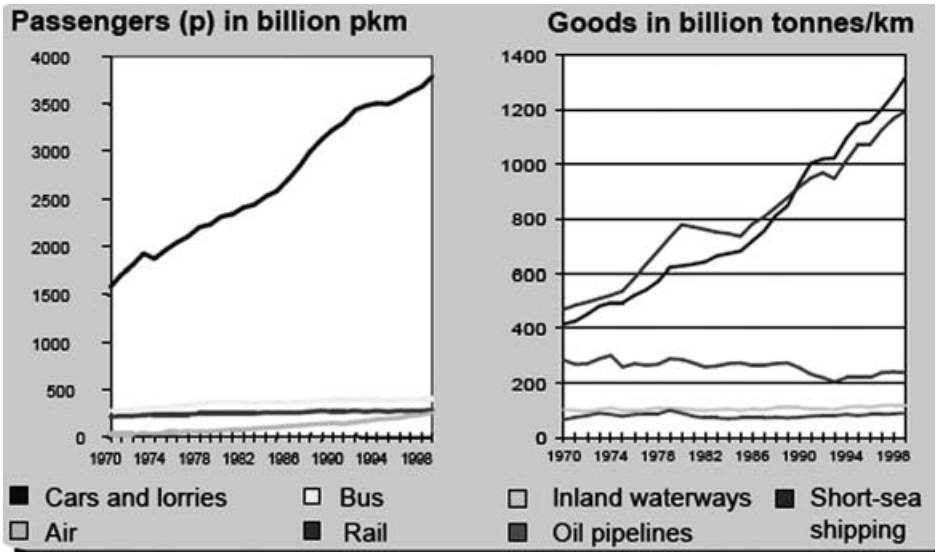


Figure 2: *Mode of transport in EU from 1970 to 1998*

In a EU document (European Union Oil Supply, 2000) the following estimations are given: world energy demand is expected to increase from 9,3 billion tones oil equivalent (toe) in 2000 to 15 billion toe in 2020. World oil consumption is expected to be 115 million barrels a day in 2020, as compared to about 77 million barrels in 2000, an increase of more than 50%.

Concerning EU, in this document is said that in 2000 the oil consumption in EU was 12 million barrels a day (*600 million toe*) where 270 million toe (about 45%) belonged to the transport sector. The estimation for 2020 are that the part of the transport sector will increase up to 71% of the total oil demand in EU.

Concerning the oil prices, in the cited document is said: "Oil prices in the last few weeks have reached historical levels since the Gulf War." The price of the oil in 2000 was around $30 a barrel. Two years before, in 1998, the price for a barrel was $10. The expectation were that it will fall down to $5. But four years later (in 2004) the price of the oil reached $50. Can anybody dare to forecast the price of the oil in 2020, given the estimation of oil demand? On the other hand, the estimates for the crude oil reserves are 30 to 40 years (Stan 2002) which gives additional and indisputable arguments to the rare oil producers for further speculation on the oil prices.

Concerning environment and global pollution, in the EUC's November 2000 Green Paper on security of supply is said that Each day 10 hectares are covered over by road infrastructure. In 1998 energy consumption in the transport sector was to blame for 28 % of emissions of $CO_2$, the leading greenhouse gas. The estimates are that, if the traffic trend continues, $CO_2$ emissions from transport can be expected to increase by around 50 % to reach 1 113 billion tones in 2010, compared with the 739 million tones recorded in 1990. Once again, road transport is the main

culprit since it alone accounts for 84 % of the $CO_2$ emissions attributable to the transport sector. These figures raise the question: Is the deaths of estimated 50,000 people across Europe in the summer of 2003 due to unusually high temperatures a consequence of climate change?

An EU document about urban transport says that more than 75% of the population of the European Union lives in urban areas. Therefore urban transport accounts for a significant part of total mobility, and an even greater proportion of damage to the health of citizens and to buildings. For example, one-fifth of all EU kilometers traveled are urban trips of under 15 km. **Between 1995 and 2030, total kilometers traveled in EU urban areas are expected to increase by 40%.**

The car is dominant, contributing about 75% of kilometers traveled in EU conurbations. Cars cause so much congestion that, **in some European cities, average traffic speeds at peak times are lower than in the days of the horse-drawn carriage**. Urban transport contributes to global warming. More than 10% of all carbon dioxide emissions in the EU come from road traffic in urban areas which is also the main source of carbon monoxide and fine particulates in European cities. These emissions pollute the immediate area and pose serious health hazards.

## Technologies and Solutions for Sustainable Mobility

There are two main directions which can help to decrease dependence on petroleum and eventually get rid of it: alternative fuels or alternative energy for driving the vehicles and increasing energetic efficiency, Figure 3.

There is a large spectrum of various possibilities concerning alternative fuels and alternative energy (Ilijevski 2005).

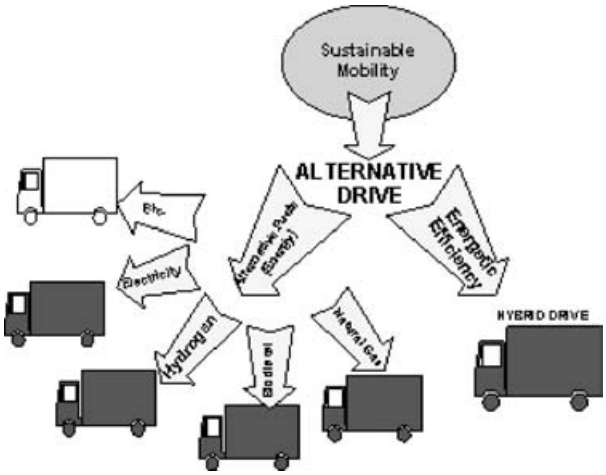


Figure 3: *Alternative Drives for Sustainable Mobility*

Concerning the increase of the energetic efficiency, the internal combustion engine producers have made significant improvement since the first petroleum crisis at the beginning of the 70's. New technologies for IC engines will bring more improvements on both efficiency and gas emission. Still, the IC engines devour the enormous part of the fuel energy in the chain thank-to-wheel. New drive technologies as hybrid-electric drives offer a jump in the fuel economy of over 50% in some driving conditions. However, when talking about energy efficiency one should be open eyes and mind. A hybrid-electric drive adds to the conventional drive chain fuel tank-IC engine-transmission-wheels new components: electric motors/generators, energy storage and power electronics devices. Each of them consumes one part of the energy passing through, which totalizes at least 25% of the energy passing through them. Nevertheless this driving system helps the IC engine to operate in a more efficient way so that the overall efficiency thank-to-wheel may be significantly improved.

The spectrum of various possibilities for alternative drives and in addition to that a vide range of different kind of vehicles that need an alternative drive generate confusion about the right answer to the problem of sustainable mobility. To clear up this mess, one should look at the problem with due diligence. An alternative fuel, like hydrogen for instance, needs new drive technologies, production facilities, appropriate transport and new distribution infrastructure, Figure 4. Its implementation will take time and enormous investment. Development of new drive technologies for implementation of hydrogen has already taken at least two decades (Metz and Cozzarini, 2003) and a lot of investment. In the long run, hydrogen generated from various renewable sources such as wind and water power, biomass or solar energy has the most promising potential for supplementing fossil fu-

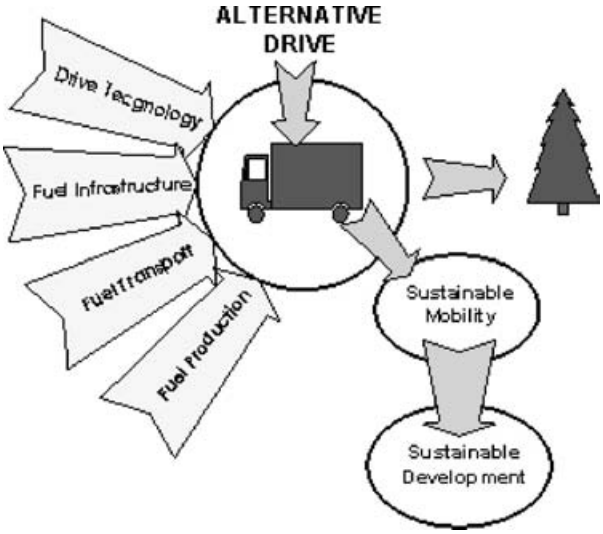


Figure 4: *Some Alternative Drives need not only new drive technology but a new infrastructure from fuel production up to the distribution infrastructure*

els. Although hydrogen technology is advancing everyday (Diem, 2003), how much more time and investment will it take before a mass implementation starts? What is the final answer for sustainable mobility then?

The world (read developed countries) took the easiest way for making wealth and has wasted a lot of time before the problem of sustainable development becomes obvious. Concerning sustainable mobility, there is no time to wait for a universal solution. There will not be such a solution any more, at least not for a foreseeable future. Therefore it seems reasonable to emphasize:

- we need pragmatic solutions that will match local conditions – available energy sources, needs, requirements, etc.,
- diversification of solutions and evolutionary but fast changes are the final answer to the problem of sustainable mobility,
- increasing fuel efficiency has no alternative.

Speaking of fuel efficiency, the hybrid-electric drives are proven technology with ability to double fuel economy and to delay the death of the IC engines, without loosing the comfort and the behavior of the users. Toyota with its *Toyota Prius* car has shown that that kind of car can enter the market easily if the awareness for protection of the nature and oil independence is highly promoted and supported. Other car makers, and policy makers too, should be aware that Toyota has put significant effort to implement not only a hybrid-electric concept, but to develop a new and more efficient IC engine and many other improvements with it in order to double the efficiency of the energy chain tank-to-wheel compared to an ordinary similar car.

Development of new energy storage technology in terms of better performances and life cycle of batteries (Kruger, 2005) will enable development of the hybrid drives towards plug-in hybrids, Figure 5. It means that while the vehicle is off use, the batteries can be recharged from the electric grid. Since many car users do not drive more than 50 km a day, relatively small batteries capacity could substitute the biggest part of the needed fossil fuel energy. This type of drive system for cars and even for other light vehicles may enable substitution of an important part of the oil with electricity and to eliminate almost entirely the pollution of urban areas.

## Japan, USA and EU for Sustainable Mobility

Japan, which must import all its fuel, started very early looking for alternative fuels and drive technology. In 1995, there were 11,043 of these vehicles on the road. In 2002, the number had reached 130,329 vehicles fuelled by CNG, electric, hybrid technology, diesel-alternative LPG and methanol (Diem, 2003). The government action plan target is to bring this to over 3.48 million by 2010.

Japanese hybrid-electric vehicles Honda Insight, a light hybrid, and Toyota Prius, a full hybrid, were the first commercialized hybrids that entered the world

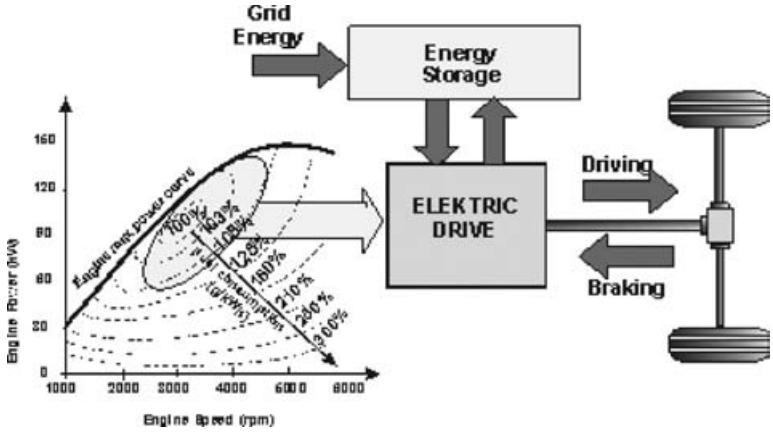


Figure 5: *Hybrid-electric drives and plug-in hybrids an efficient bridge towards petroleum independence*

market. Toyota Prius is a hybrid-electric car which represents a benchmark for hybrids fuel efficiency that will not be easy to attain (Hermance, 2003).

Japan pushes forwards also with electric and hydrogen drive technology. Several Toyota's full cells vehicles have been on the road for several years. Hydrogen presents challenges of production, storage and safe delivery, but Japan is already subsidizing research and the construction of several hydrogen fuelling stations.

USA, a country of high fuel consumption and large vehicles is at the centre of a debate over which alternative powertrain will dominate: modern direct injection diesels or gasoline-electric hybrids (Burns, 2004). However its a debate which concerns car manufacturers among which General Motors and Ford are working hard on hydrogen technologies. GM has the ambition to be first to sell one million full cells hydrogen cars, although it is not certain when this technology will be ready for mass implementation - in 10 or 30 years.

USA is very concerned about oil dependence and it subsidizes introduction of alternative fuels and alternative drive technologies. Toyota Prius has had $2,000 incentives since its introduction in the USA market. There are all kind of vehicles using alternative fuels, but since 2002 hybrid-electric vehicles started entering the market and in 2003 there were about 60,000 Japanese hybrids. The market research estimations are that in 2013 in USA there will be about 4,000,000 hybrid-electric vehicles on the road (Miller, 2003).

California is a State which succeeded the highest standard (SULEV, ZEV) for protection of the environment, especially urban areas, combining incentives and restrictions.

In the European Union biodiesel and compressed natural gas seem to be getting the largest push. EU has named both of them as the favored mid-term alternative fuels, with biofuels – those made from cultivating and processing biomass – coming first, with 5,75 % of the market by 2010 (Directive 2003/30/EC).

The EU Commission Green Paper 'Towards a European strategy for the security of energy supply' sets the objective of 20 % substitution of conventional fuels by alternative fuels in the road transport sector by the year 2020.

Development of diesel engines and small cars, and their substantial market share in Europe, has softened the problem of fossil fuels so that EU counted on hydrogen technology as a long-term substitute. But latest development and estimations concerning oil consumption and prices push EU to speed up research of alternative drive technologies. The United States and the European Union together have committed $3.7 billion in research funds for alternative technologies (Diem, 2003). Reuters' report on December 13th 2004 from Frankfurt "DaimlerChrysler and General Motors will jointly develop new hybrid motors to compete against Japanese rivals on the fuel-saving technology that reduces harmful emissions, the companies said Monday" is indicative concerning EU orientation for development of drive technology.

## Developing Countries and Sustainable Mobility

Most developing countries do not probably suffer from environmental pollution problems, although their urban areas are also congested. But the global worming will strike everybody. Still, those who must import their fuels, are already stricken hard by the excessive increase of the oil prices since 1998 and they will not be able to carry the burden of further oil prices increase. Increasing fuel prices creates a paradox for the goverments of any country – fuel prices increase favors tax collection and the economy suffers. Isn't it a boomerang for the governements of the developing countries? There are all kinds of weaknesses in current energy supply for the developing countries and their development needs even more energy. Therefore unless they start a consistent program for an accelerated decrease of the oil dependence, further increase of the oil prices could provoke their economic collapse.

In Croatia in 2001 (Ilijevski, 2005) road transport spent 25,54 % of the total energy, and oil products participated with 99,1 % of the road transport energy – the rest of 0,9% only belongs to CNG. Its industry faced a fall down at the beginning of 90's. It needs an accelerated development to stop some negative processes (as brain drain, fore instance) and to reverse them. The recovery of its industry will need an increase of energy at much greater rate than developed countries in EU, which means a much greater rate of energy increase. Croatia has potential for alternative fuels and renewable energy. It has even potential to participate in the development of alternative drive technology. A consistent program for import oil independence could be multifunctional: substitution of oil import, new technology development for a new market need which could increase its export, development of new SMEs, and finally a much safer future. Besides, Croatia is a country of a great potential for development of tourist industry. Safeguard of its urban areas, coast region and islands is of a paramount importance for further development of tourism. In that sense Croatia should follow the example of California.

## Conclusion

The oil dependence is threatening all the countries oil importer. On the other hand, use of fossil fuels increases the pollution of the place we live in. Instability of the oil market is striking the most vulnerable ones – developing countries. Developed countries can not avoid their responsibility for further development of the matter. They have means to react much faster in the sense of curbing the oil demand. Even a slight trend towards decrease of oil dependence could stabilize the oil market and to get breath to reimagine the future. Short and midterm solutions should be put into effect at galloping pace. There is not much time for long discussions.

The governments of developing countries oil importers should avoid the trap of collecting taxes on the increasing fuel prices. They should act immediately in the direction of decrease of import oil dependence. Croatia should harness all its resources in order to put its renewable energy potential, alternative fuels and any other option into effect as soon as possible, and to catch the pace towards a safer future.

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# Building of a Prototype of a Poly-Valent Vessel of a Generic Hull Form

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*Abstract*

This report presents the idea for revival of boat building on Croatian Adriatic coast supported by governmental funds. The scope of the contract among the Ministry, Faculty and cooperating shipyard Punat on island of Krk, the main particulars of the boat and the appropriately illustrated design and production of the boat are part of this report.

*Key words:* boat building, boat design, governmentally supported project, Croatia

## 1. Introduction

The Ministry of Science, Education and Sports decided to add impetus to the revival of shipbuilding on Adriatic cost and islands. Therefore one of the governmentally supported projects contracted in the year 2003. was the building of a prototype of a multipurpose boat of generic hull form. The background motivation was found in the fact that boat building on the Adriatic coast has a very long tradition inheriting different types of specific old-time boats. Numerous very specific and well known boats pertinent to local conditions have been developing through centuries. During the last decade or so, many activities, including boat building badly suffered due to the war on the territory of the Republic of Croatia. The idea of revival of the boat building combining modern international trends and local tradition, supported by experience in maritime research and new technologies, was ignited by the ever increasing interest towards nautical tourism on the Croatian part of the Adriatic coast and islands.

## 2. The scope of the contract

The contract obligates the involved parties to participate on a joint project including conception, research, development, design, production and marketing of a boat whose maritime characteristics are particularly suited to Adriatic Sea and service conditions in the Croatian coastal region. The principal points in the contract were the following:

- Development of a conceptual design of a multipurpose boat for personal, heavy duty works and public services, using former broad experience on similar vessels.
- Design of a family of boats with same hull and three virtual digital models in order to facilitate design, production and marketing.
- Establishment of a common platform for a generic boat hull using earlier research and experience in towing tanks and on sea.
- Building and testing of a prototype boat in shipyard Punat on island of Krk.
- Supporting the builder in his international marketing efforts of the new boat.
- Supporting the builder for omplementation of a series and modular production in his yard with his own skills and workmanship.

## 3. Design features

The general arrangement plan of the boat is shown in Figure 1. The arrangement is based upon a number of considerations including aesthetics appeal, operational requirements, habitability and equipment maintainability.

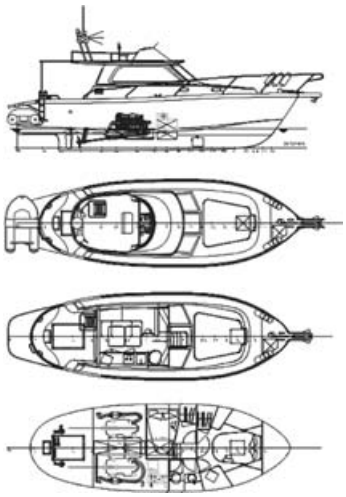

Figure 1: *General arrangement plan of the boat*

The maximum speed of the craft is planned 24 knots and the range 300 Nm at 21 knots of cruising speed providing good seakeeping and maneuverability. The GRP hull is divided into three watertight compartments: fore peak, crew compartment and machinery compartment.

The hull is of the round bilge form with a fine forward entry, flat run aft and oversised inovative integral swim platform. The hull is moulded using a combination of chopped strand matt and woven rovings and stiffened by a system of girders, frames and stringers. The cockpit is integrally moulded as a part of deck and is watertight and self draining. The lids to the seat/lockers are laid with teak and the sole is fitted with a teak grating. A GRP weathertight cockpit hatch gives access to the stowage space beneath. Machinery room and crew watertight compartment are equipped with an independent electric bilge pump operated by level switch. A hand operated diaphragm pump is fitted and connected to a valve chest with suction points to each bilge compartment.

The wheelhouse/saloon contains the helm position to starboard with full engine controls and instrumentation and a crew seat to port. Situated aft of the helm/crew positions is a dining table and seating to port and the galley to starboard. Windows to the wheelhouse/saloon are fitted with temper glass and entrance to wheelhouse/saloon is through aft sliding door, see front and end view on Fig. 2.

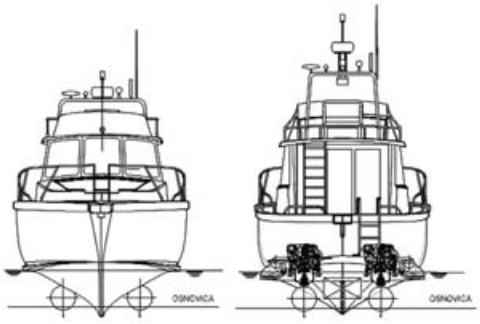

Figure 2: *Front and aft view of the boat*

Wood finished are in classic cherry, cream leather upholstery and Cerock galley worktop. Deck equipment includes hydraulic passerelle with remote control, reversible electric anchor windlass, 16 kg anchor with 40 m chain, foredeck sun cushions and bimini top to flybridge.Flanking the steps down from the saloon are fore and port cabin and starboard toilet. Cabins are equipped with double berths, shelves and lockers. Skylight/escape hatches are fitted to the fore-cabin.

The machinery compartment houses main propulsion engines consisting of two high speed marine diesels each developing appropriate power for the pertinent boat usage at approximatelly 2600 rpm coupled via flexible couplings to the reverse reduction gearbox. The exhaust system is of the wet type with GRP mufflers

and transom outlets. The steering gear in wheelhouse and open bridge are hand hydraulic. The vessel is fitted with a soil holding tank to the toilet with facilities for pumping out to either shore or overboard.

The main boats system is 12 volt DC supplied by four heavy duty lead acid batteries arranged in two banks of two batteries each. A parallel switch is fitted for emergency engine starting. The 12 volt DC system is supplied via a distribution panel fitted with DC rated circuit breakers. The vessel is wired for AC shore supply and includes a 40A battery charger. The boat is fitted with marine quality light fittings including overhead lights throughout, reading lights to the berths in side and aft cabins, bulkhead lights to the engine compartment and external lights to the cockpit and open bridge. The main particulars of the boat are listed in Table 1.

Table 1: *Main particulars of the boat*

| | |
|---|---|
| Length, over all | 11,95 m |
| Length, waterline | 10,25 m |
| Breadth | 3,50 m |
| Draft | 0,87 m |
| Depth | 2,28 |
| Material | GRP |
| Passenger | 10 |
| Cabins | 2 |
| Power | 2 x 315 KS |
| Electric systems | 12 V DC / 220 V AC |
| Speed, max | 27 knots |
| Speed, cruising | 22 knots |
| Fuel tanks | 650 l |
| Holding tank | 88 l |
| Water | 215 l |

## 4. Design and production

Since the contract was signed by all parties, intensive work was carried out. The activities performed with respect to research, development and design are listed and illustrated in the sequel.

Conceptual design development in several steps accounting for relevant expert suggestions, Fig.3.

Figure 3: *Conceptual design*

Comparison with recent international trends detected on international fairs, Fig. 4.

Figure 4: *Recent trends in boat design*

Completion of technical documentation, Fig. 1. and 2, followed by the marketing presentation virtual 3D and animated model. Fig. 5.

Figure 5: *Marketing presentation model*

Completion of the digital model for CNC model preparation, Fig. 6.

Figure 6: *Production digital model*

The preparation for production involves first the preparation of a 1:10 test model, Fig 7.

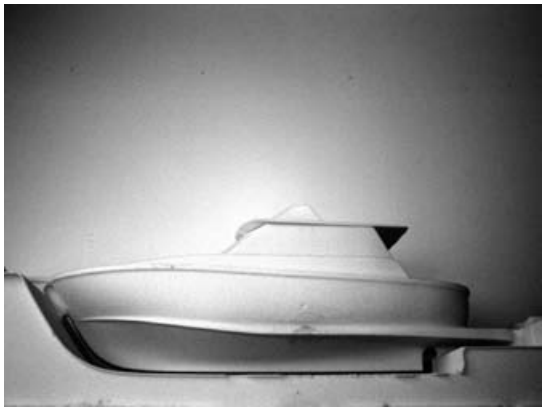

Figure 7: *Physical model in scale 1:10*

Completion of the full scale model on CNC equipment was the next step, Fig 8.

Photogrametry testing of the hull form indicates high accuracy in model preparation, Fig. 9.

Significant time was spent in survey and completion of the technical documentation together with the shipyards's technical staff, as well as in purchasing of outfit, equipment and engines.

The activities with respect to production included first the transportation of the full scale model to the shipyard and finishing of the model, Fig. 10.

Completion of the moulds were done in shipyard Punat using their fabricationa faciilities, Fig. 11.

Figure 8: *Full scale physical model*

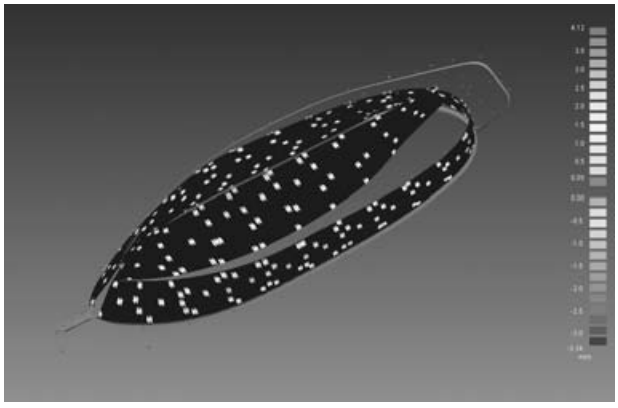

Figure 9: *Photogrametry checking of the shape*

Figure 10: *Finishing of the model*

Figure 11: *Completion of the moulds*

Production of the prototype structural elements in shipyard Punat, Fig. 12. and fitting the parts together, Fig. 13. and 14.

Figure 12: *Production of the prototype hull*

Figure 13: *Prototype end view after assembly*

Figure 14: *Prototype front view after assembly*

The design, virtual presentation and production documentation for the boat's interior arrangement is carefully revised, Fig. 15.

Virtual models provide useful guidelines for interior arrangement, Fig. 16.

The works to be performed to completion of the project are the following:

- Final outfitting of the boat, Fig. 17.
- Engine room, electrical and other systems mounting and testing

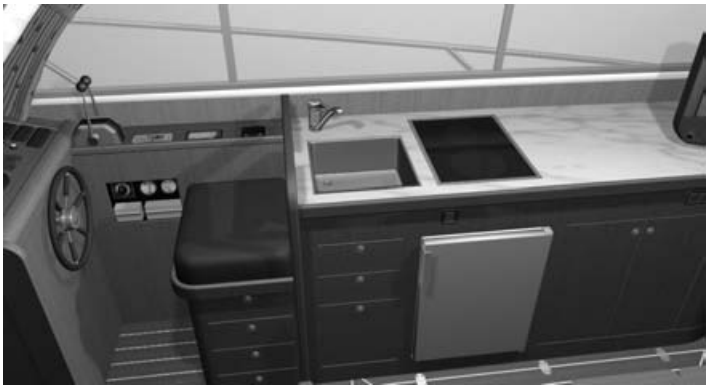

Figure 15: *Interior design*

Figure 16: *Virtual view forward from the cabin*

Figure 17: *Prototype top view during outfitting* (compared to virtual model to view)

- Trials in harbour and sea conditions
- International certificate *CE* achievement
- Marketing, advertising, participation on domestic and unternational fairs
- Preparation for series production

## 5. Conclusion

The idea of governmental support of complex project involving investigation pertinent to academic community as well as research institutes, together with the cooperating production industrial companies, may be a successful model of development at present and in the future. Such an integrating model may provide a solid background for revival of industrial activities in earlier known industrial sites, wherever exists enthusiasm, traditiona and production capacities. During the two years of project duration vivid interest and enthusiasm were encountered in achieving a higher level of production practice and standards in employment of new technologies available in addition to former tradition in boat building.

## Acknowledgement

The authors wish to acknowledge the support of the Ministry of Science, Education and Sports. The works on 1:10 and full scale models were performed on CNC facilities by Seaway, Bled - Slovenia.

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# Dynamic Simulator for Numeric Analysis of Landing Transport Aircraft

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*Abstract*

Dynamical model and numerical procedures for dynamic simulation of landing and taxi of large transport aircraft are shortly presented. The simulator allows for dynamic response determination of landing aircraft for different flight and touch-down parameters. The mathematical model and computational procedures are based on non-linear dynamical model of landing aircraft, which is synthesised via modelling of aircraft structural subsystems using multibody dynamics approach. The model includes discontinuous dynamics of landing gear oleo-pneumatic shock-absorber with friction and hydraulic/thermodynamic processes as well as non-linear tire contact dynamics and unilateral dynamics of nose gear elastic leg assembly. The longitudinal and lateral aerodynamic loads are estimated by considering aircraft various system configurations (landing gears in up and down position, different control surfaces in active/inactive modes). 'Solver' of dynamic simulator is based on the numerical processing of nonlinear dynamics of aircraft structural subsystems with variable kinematical structure, derived as differential-algebraic (DAE) system. The developed numerical tools are modularly shaped and efficient numerical integration methods, as well as original procedures for MBS constraint stabilization, are applied for dynamical response determination. On the basis of the presented model, dynamic simulations of landing cases of large transport aircraft were performed for different initial descent velocities and different lateral wind conditions.

*Key words:* dynamics of landing aircraft, aircraft multibody model, non-linear landing gear dynamics, shock absorber model.

## 1. Introduction

During landing and taxi, a transport aircraft landing gear and parts of an airframe can be exposed to high dynamical loading. In the extreme situations even damages and loss of the stability of an airplane may be expected. During large airplane tail-down landing, all of dynamical loads are carried on the main gear first: dynamical characteristics of the main gear are of the most significant importance for the safe touchdown and landing during which an airframe load factors should be kept in the prescribed range [1], [2], [3]. However, when the aircraft critical landing conditions and structural loads are being determined, the simplifications are often made: aerodynamic loads are oversimplified, aircraft pitching and rolling motion are neglected or tire dynamics and wheel spin-up forces are not taken into consideration [2]. Although some basic characteristics of landing aircraft dynamical response can be determined by linear dynamic analysis [4], dynamic simulation of landing airplane for the sake of its stability analysis or determination of landing structural loads requires full-scale non-linear multibody approach.

In the paper, a non-linear dynamical model of large transport aircraft that allows for dynamic simulation of airplane landing cases is shortly described. The model includes aircraft aerodynamic loads, discontinuous dynamics of shock absorbers oleo-pneumatic elements (main and nose landing gear) and aircraft tires 3D dynamics including longitudinal and lateral loading. Because of its great influence on the aircraft ground dynamical behaviour and structural loads determination, dynamical model of the main gear shock absorber is presented in more details. Based on the developed model, landing cases of the large transport aircraft for different 3D flight-landing parameters are simulated and presented.

## 2. Landing aircraft dynamical model

### *2.1. Multibody dynamical model*

The aircraft dynamical model that allows for non-linear dynamic simulation of 3D landing is designed as a multibody system with variable kinematical structure. The ‘global’ model comprises aircraft main body, main landing gear consisting of two elastic legs with the upper part (upper part of shock absorber + additional masses) and the lower part (lower part of shock absorber + wheel and tire + additional masses) and nose gear consisting of the upper and lower part of the same structure. The ‘local’ structural subsystems of different parts and mechanisms are independently modelled and incorporated in the ‘global’ scheme (*Fig. 1*).

The gears’ upper and lower parts are connected *via* non-linear force couplers, modelled according to the shock absorbers dynamical characteristics. With this aim in view, main elastic leg and shock-absorber subassemblies as well as nose gear elastic leg mechanism are modelled in detail using *CAD* tools (*Fig. 1*, *Fig. 3*). After

defining geometry, non-linear models of their dynamical behaviour are numerically tested (*Fig. 2*) and built into the 'global' dynamical model.

The additional non-linear force couplers are added to model aircraft tires dynamics: it is assumed that the aircraft main gear is equipped with four tires of the conventional type and two conventional tires are mounted on the aircraft nose gear. Mechanical properties of the tires are estimated after [7] and manufacturer data [8] and dynamical model considers tire non-linear dynamical behaviour (inertia effects, centrifugal growth of tire radius, side loads). The calculation of tire contact dynamics spin-up force is based on variable slip-friction characteristics and a slippage factor defined according to [8] (*Fig. 3c*). It is assumed (and verified by the simulation results) that tire-bottoming deflections will not occur during analysed motion.

Generally, dynamical response of landing aircraft includes unsteady aspects, not only because of the external landing impact, but also with regard to the unilateral contact phenomena within landing gear mechanism. A full *3D* aerodynamic loads are estimated by considering aircraft various system configurations (landing gears in up and down position, different control surfaces in active/inactive modes). The whole aircraft ('global' model) and parts of main shock absorber assembly are depicted in *Fig. 1*.

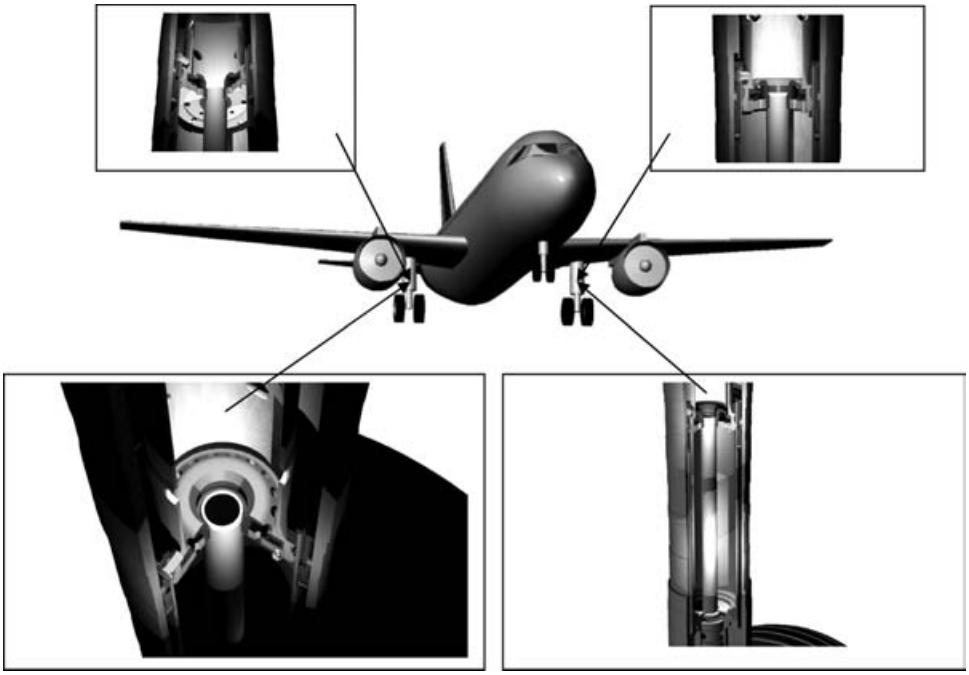

Figure 1: *Schematic landing aircraft global multibody model and details of shock absorber assembly model – low pressure gas chamber / oil chamber, upper and lower bearings, systems of orifices.*

### *2.2. Mathematical model*

The configuration space $\mathrm{R}^n$ of an airborne aircraft is considered to be a manifold $\mathrm{M}^n$ covered by coordinate system (local chart) $\mathbf{q}(t)$ and equipped with Riemannian metrics *via* system generalized mass $\mathbf{M}(\mathbf{q}) = [M_{ab}]$. The system kinetic energy $T(\mathbf{q},\dot{\mathbf{q}}) : T\mathrm{M}^n \to \mathrm{R}$ is defined on tangent bundle $T\mathrm{M}^n$ covered by the coordinates $(\mathbf{q},\dot{\mathbf{q}}) : T\mathrm{M}^n = \{(\mathbf{q},\dot{\mathbf{q}}) : \mathbf{q} \in \mathrm{M}^n, \dot{\mathbf{q}} \in T_{\mathrm{q}}\mathrm{M}^n\}$, or explicitly $T = \frac{1}{2} M_{ab} \dot{q}^a \dot{q}^b$ and manifold kinematical line element is $\mathrm{d}s^2 = M_{ab} \mathrm{d}q^a \mathrm{d}q^b$.

Consequently, the dynamical equations of the unconstrained system are given in the form

$$M_{ab}\ddot{q}^b + \Gamma_{a,bc}\dot{q}^b\dot{q}^c = F_a(\mathbf{q},\dot{\mathbf{q}},t), \tag{1}$$

where generalized mass (metric tensor) is defined as

$$M_{ab} = \sum_{k=1}^{N}\left[ \underset{k}{m} \partial_{q^a} \underset{k}{X^{i}} \partial_{q^b} \underset{k}{X^{i}} + \underset{k}{\psi^{ij}} \partial_{q^a} \underset{k}{R^{i_i}} \partial_{q^b} \underset{k}{R^{i_j}} \right], \tag{2}$$

and Christoffel symbols of the first kind $\Gamma_{a,bc} = \frac{1}{2}(\partial_{q^b} M_{ac} + \partial_{q^c} M_{ab} - \partial_{q^a} M_{bc})$

$$\Gamma_{a,bc} = \sum_{k=1}^{N}\left[ \underset{k}{m} \partial_{q^a} \underset{k}{X^{i}} \partial_{q^b}\partial_{q^c} \underset{k}{X^{i}} + \underset{k}{\psi^{ij}} \partial_{q^a} \underset{k}{R^{i_i}} \partial_{q^b}\partial_{q^c} \underset{k}{R^{i_j}} \right], \tag{3}$$

define non-linear velocity terms (centrifugal, gyroscopic, Coriolis); symmetric Riemannian connection on $\mathrm{M}^n$ is defined by $\Gamma^a_{bc} = M^{ad}\Gamma_{d,bc}$. Inertial frame $\mathrm{E}^3$ coordinates of mass centre of the body $B_k$ ($N$, number of bodies) are given by $\underset{k}{X^{(i)}}$. Mass and Binet's inertia tensor of the body $B_k$ are $\underset{k}{m}$ and $\underset{k}{\psi^{ij}}$ and $\underset{k}{R^{i_i}}$ is the rotation matrix of the body, where underlined indices refer to the inertial frame; generalized applied forces are given by $F_a$. By imposing system kinematical constraints (landing gear external contacts, elastic leg extension constraints [9]):

$$\Phi(q,t) = 0,\ \Phi(q,t) : \mathrm{R}^n \times \mathrm{R} \to \mathrm{R}^r, \tag{4}$$

the system is forced to move on the configuration submanifold:

$$\mathrm{S}^{n-r}(t) = \{\mathbf{q} \in \mathrm{M}^n,\ \Phi(\mathbf{q},t) = 0\},$$

and velocities and accelerations of the system are given by:

$$\Phi_{\mathrm{q}}(\mathbf{q},t)\dot{\mathrm{q}} = -\Phi_t,\ \Phi_{\mathrm{q}}(\mathrm{q},t)\ddot{\mathbf{q}} = \zeta. \tag{5), (6}$$

The mathematical model of the aircraft multibody system is shaped as differential-algebraic system (DAE) of index 1 (redundant coordinates formulation) [6], where Lagrangian equations of the first type (7) and the kinematical constraint equations at the acceleration level (8) are put together in matrix form:

$$\mathbf{M}(\mathbf{q})\ddot{\mathbf{q}} + \Phi_{\mathrm{q}}^{\mathrm{T}}(\mathbf{q},t)\lambda = \mathbf{Q}(\mathbf{q},\dot{\mathbf{q}},t), \quad \Phi_{\mathrm{q}}(\mathbf{q},t)\ddot{\mathbf{q}} = \xi. \qquad (7), (8)$$

$\mathbf{M}(\mathbf{q})$ is positive-definite inertia matrix, $\Phi_{\mathrm{q}}(\mathbf{q}, t)$ is the system's Jacobian (kinematical constraint matrix) and $\mathbf{Q}(\mathbf{q},\dot{\mathbf{q}},t)$ represents the applied forces and centrifugal and gyroscopic terms [6, 9]. Since the system has variable kinematical configuration (during motion several kinematical constraints change form active to inactive mode and reverse), it is integrated using DAE numerical routines and constraint violation stabilization procedures [6].

## 3. Landing gear shock absorber

Most commonly, a telescopic main landing gear of a transport aircraft comprises a shock absorber of oleo-pneumatic type [5], [8]. Considering a contemporary design, it is a several stage unit and contains four chambers: a first-stage oleo-pneumatic chamber containing low pressure gas and hydraulic fluid, a recoil chamber and compression chamber containing hydraulic fluid and a second-stage pneumatic chamber that contains high pressure gas (nitrogen) (*Fig.* 2).

The floating piston in the second-stage cylinder separates hydraulic fluid and high pressured nitrogen. During a compression stroke, the floating piston does not become active until the gas pressures of the first-stage and second-stage chambers are equal, which happens during system increased dynamical loading. Dynamical characteristics of the shock absorber are strongly influenced by the systems of orifices that control a hydraulic flow and by means of which net hydraulic resistance can be tuned. Considering different possibilities of the activation of floating piston and orifices as the absorber closes, it can be shown that four operation stages can be identified during the compression stroke.

During return stroke, primary control of the shock absorber recoil consists of the fluid flow from the recoil chamber into the oleo-pneumatic chamber and from the oleo-pneumatic chamber to the compression chamber. To prevent unit (and airplane!) excessive rebound, the orifices hydraulic resistance increases significantly during the absorber recoil stroke.

### *3.1. Dynamical model*

Since mechanical properties of the landing gear shock absorber are mainly determined by the pneumatic spring force and oleo (hydraulic) damping force, dy-

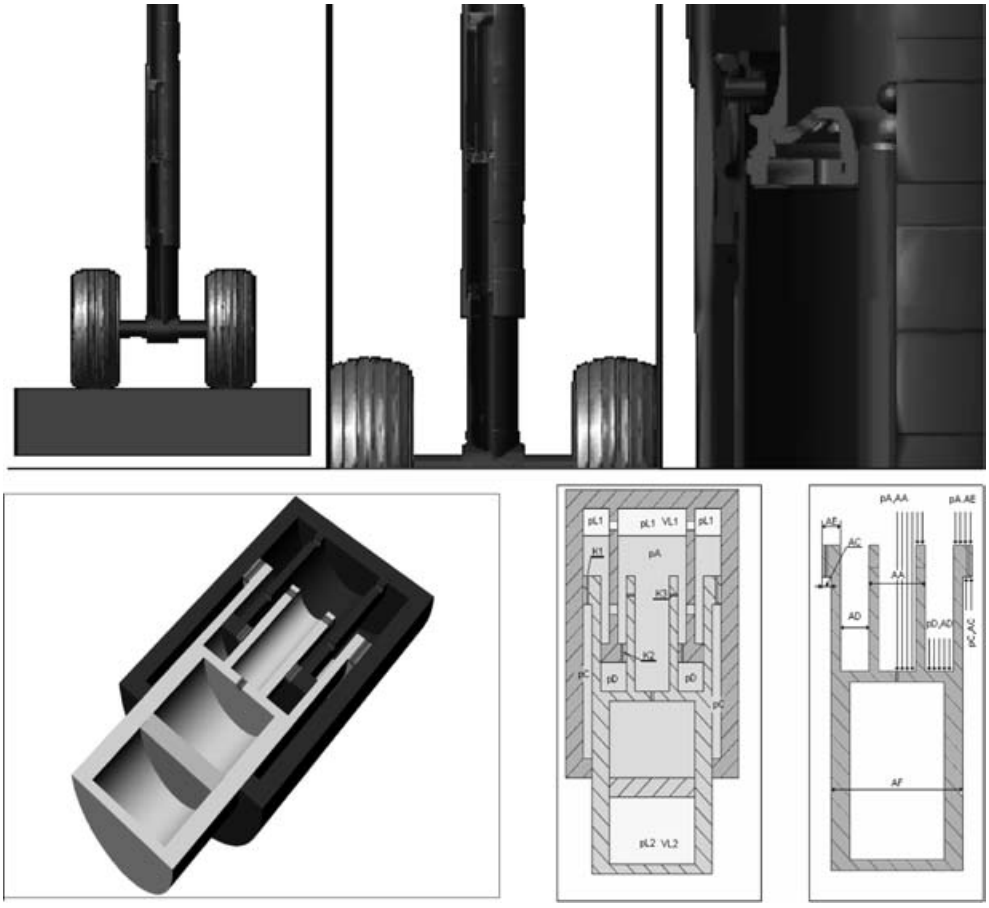


Figure 2: *Main landing gear elastic leg multibody model and schematic oleo-pneumatic shock absorber. The animation of dynamical simulation of 'drop-test' – numerical testing of elastic leg dynamical characteristics and data validation (JAR-25).*

namical model of the absorber are presented in the overall multibody system as a force coupling element (highly non-linear!) consisting of these terms. All mechanical characteristics and geometrical data (AA, AC, AD etc., *Fig.* 2), needed to establish the mathematical model, are determined on the basis of *CAD* modelling according to [8]. The cylinder-piston stick-slip friction phenomenon and internal seal friction are also introduced. The floating piston inertia effect is neglected in the absorber dynamical model presented here.

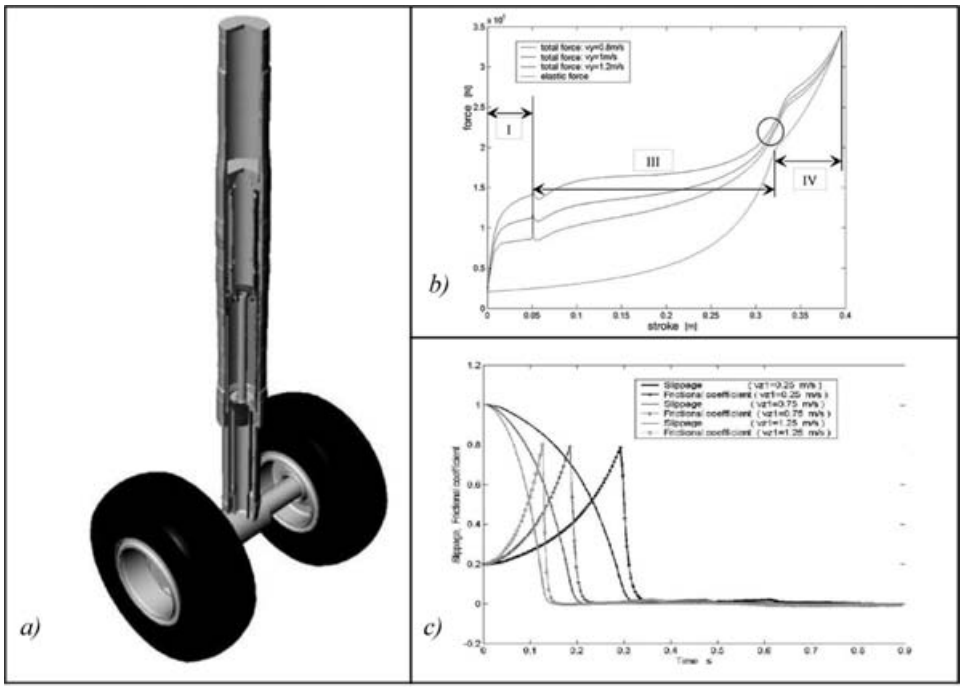


Figure 3. *Main gear elastic leg – shock absorber load characteristics and variable slip-friction characteristics of tire contact spin-up force.*

### *Pneumatic spring force*

Depending on the unit operation stage, the pneumatic spring force is defined by the initial inflation pressure in two nitrogen chambers and by the change of volume of the shock absorber (unit current kinematical configuration).

During modelling, it is assumed instantaneous gas compression ratio in accordance with the polytrophic law for compression [10], [11]. Since absorber high rate of compression is to occur during landing impact, the polytrophic exponential term is chosen as $n = 1.3$ during modelling of all internal processes [12]. Having considered geometrical determinations of the gas chambers (volumes *VL1, VL2*, *Fig. 2*) in dependence of unit kinematical configuration and after determination of initial gas inflation pressure [8], the net pneumatic force is expressed as a non-linear function of shock absorber stroke.

### *Hydraulic damping force*

The hydraulic damping force results from the pressure difference associated with the flow through the systems of orifices. It is assumed that jet velocities and

Reynolds numbers are sufficiently large that the flow is fully turbulent (the orifice area is small in relation to the absorber diameter) [8]. As a result, the net damping force is expressed as a function of the stroke velocity. Since during the compression stroke some orifices become active/inactive (orifices *K3* change their position as the absorber closes), the net hydraulic damping force is modelled *via* two stage discontinuous function of the absorber stroke velocity (*Fig. 3b*).

The orifice hydraulic resistance damping coefficients *K1, K2, K3* (*Fig. 2*) are estimated on the basis of orifice geometry and hydraulic fluid density according to [8]. Prior to dynamic simulations of landing aircraft, the dynamical model of shock absorber has been validated by numerical dynamical simulations (*Fig. 2*) of landing gear drop test ([1] paragraphs 25.723-25.727).

## 4. Dynamic simulation procedures

The schematic layout of dynamic simulator 'global' architecture is shown in *Fig. 4.* Dynamic simulator is modularly designed: numerical algorithms and procedures for dynamical response determination of different structural subsystems are decoupled during development. They are independently validated on the basis of measurements taken on the airplane and characteristic data provided by manufacturer. After partial numerical tests are successfully performed, the algorithms that control particular as-

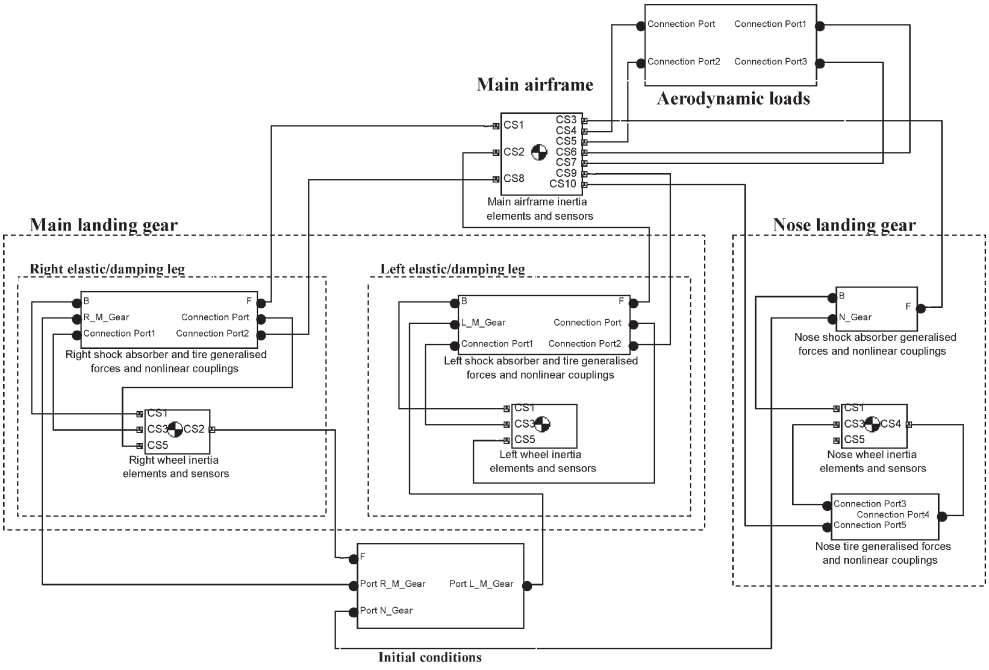


Figure 4. *The schematic layout of dynamic simulator 'global' architecture.*

sembly units are mutually coupled and incorporated into the global simulation procedures, where additional tests and data validation are made for the whole system.

On the basis of the aircraft dynamical model, dynamic simulations of landing cases of large transport aircraft were performed for different initial descent velocities and different lateral wind conditions. Mass of the aircraft is set as 64500 kg and the

Figure 5: *The animation sequence of landing airplane with present lateral wind – one gear landing case*

horizontal velocity equals $v_{x1} = 67.5$ m s$^{-1}$. The initial aircraft pitch and roll angles prior to touchdown are 10° and 3° respectively, while the aircraft pitching and rolling velocity at the instant of touchdown is assumed to be approximately zero. The animation sequence of landing airplane with present lateral wind is shown in *Fig. 5*. Time evolution of the shock absorber stroke and total force in the left and right elastic leg during different landing cases, when descent velocity is varied in the range from $v_{z1} = 0.25$ m s$^{-1}$ to $v_{z1} = 1.25$ m s$^{-1}$ is presented in *Fig. 6.-9.*

The landing cases with the indicated touchdown parameters do not represent demanding landing scenarios for a modern transport airplane. During simulated landing impacts the absorber stroke time evolution is well within a range of 0.45 m (max. stroke) and no upper-point cylinder-piston collision occurred during analysed landing cases (which does not mean that stick-slip transitions can not occur within shock-absorber mechanism). The undercarriage load factors are also well in the prescribed range.

It is evident that time diagrams of the shock absorbers' stroke and total force evolution are almost flat immediately after the touchdown. This is due to the fact that, since the shock absorber pneumatics acts as a set-up spring, it is still not active during this period and the tire dynamics affects the overall system motion dominantly. This is more emphasised for the lower initial descent velocities.

In the cases of landing impacts with larger touchdown descent velocities the set-up value is quickly reached and damping hydraulic component builds up very

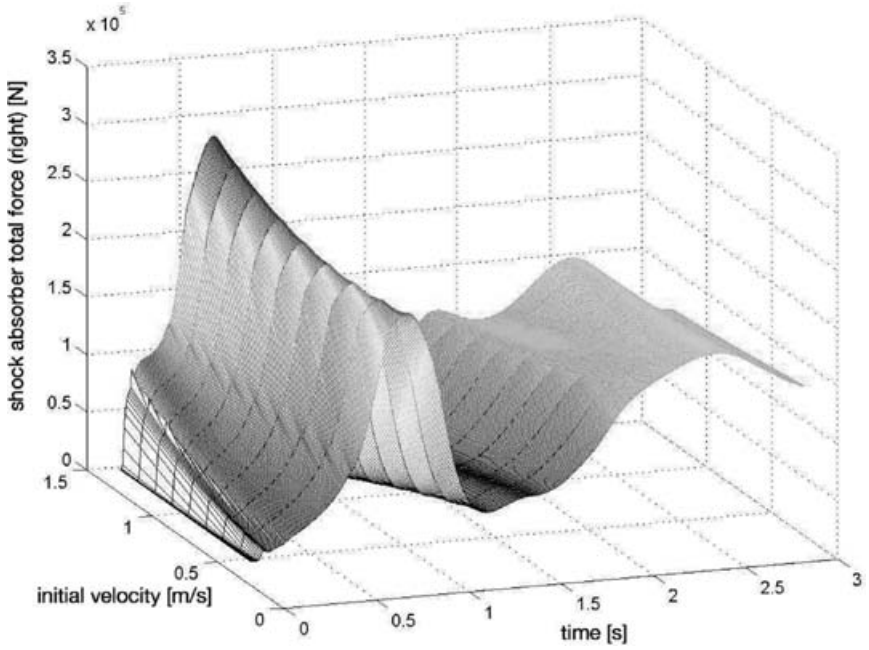


Figure 6: *Shock absorber total force vs time (right elastic leg).*

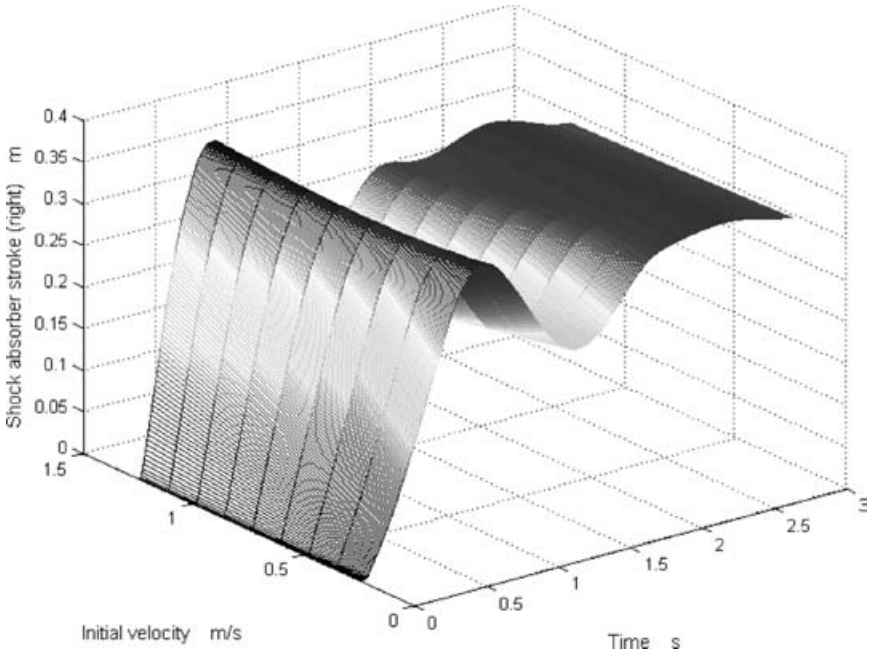


Figure 7: *Shock absorber stroke vs time (right elastic leg).*

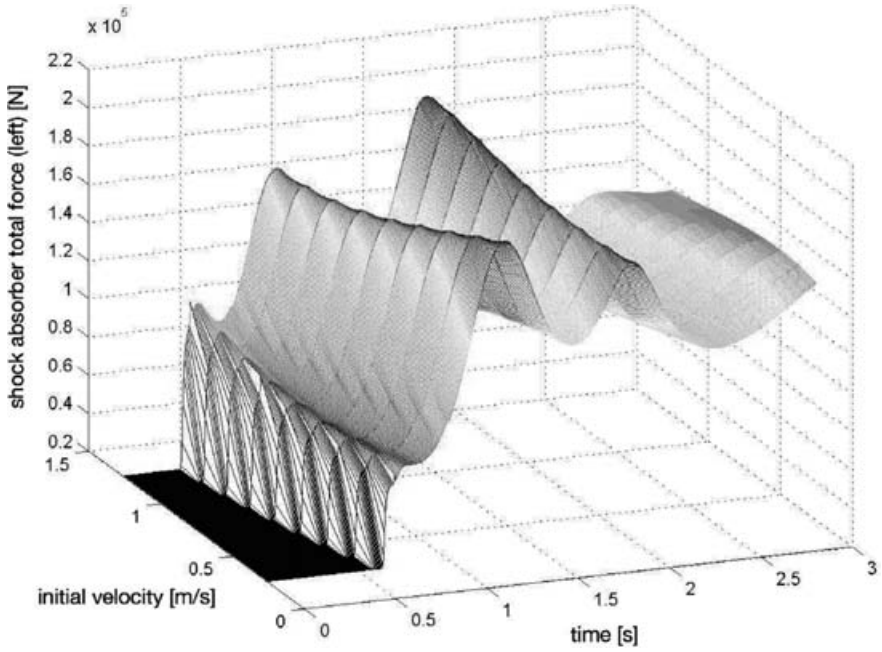


Figure 8: *Shock absorber total force vs time (left elastic leg).*

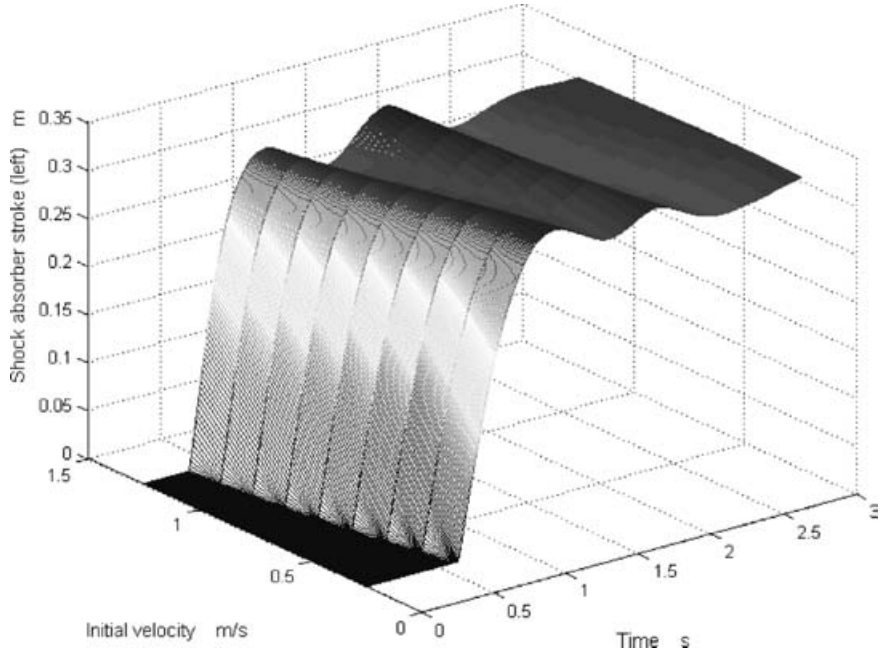


Figure 9: *Shock absorber stroke vs time (left elastic leg).*

fast after the impact, provoking thus a big gradient of the absorber total force soon after the moment of touchdown.

Of course, left shock absorber values have an additional time delay due to the fact that left elastic leg comes to the contact with the ground later on during landing process, depending on the aircraft geometry and rolling motion.

The discontinuities visible at the shock absorber total force characteristics in *Fig. 6* and *Fig. 8* are due to the orifices different working regime (inactive/active K3 orifices, *Fig. 2, Fig. 3b*) and due to the change of the absorber's pneumatic force at the point where floating piston of the second-stage pneumatic cylinder becomes active (*Fig. 3b*).

As presented shortly here, dynamic simulator is based on the dynamical response determination of the modelled aircraft for specified initial conditions, airplane aerodynamic configuration and generalized loads. Results are validated by comparing them to the technical documentation characteristic values, *JAA* requirements and measured data. Considering numerical results and required tolerances, the developed mathematical model and computational procedures can successfully serve as a core of the flight navigation procedure trainer for different landing routines in the framework of which additional *'man-in-the-loop'* simulation routines have to be incorporated.

## Acknowledgement

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# TECHNOLOGIES AND PRODUCTS IN THE ENGINEERING AREA

## Part II.

# The Comminution of Solid Waste

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*Abstract*

The demand for secondary materials, primarily steel, glass and plastics, has led to the significant development and application of new techniques, equipments and plants used in recycling. The paper describes the basic techniques for solid waste comminution and presents the typical machines and equipment used for this purpose. The aim of the paper is to draw domestic industry's and contractor's attention to the production area which in spite of certain production potentials still doesn't exist in Croatia.

*Key words:* recycling, solid waste, comminution.

## 1. Introduction

Waste recycling is nowadays one of the most dynamic economic activities especially in developed countries. The main reason is increasingly strict legislation influencing directly the increase in waste management costs. Besides, the demand for raw materials increases year after year while their production becomes technologically more complex and expensive. Consequently, the producers of industrial goods are more and more frequently oriented to the suppliers of secondary materials. The metal producers, primarily steel producers, then glass producers, plastic producers etc., take the initiative therein.

Influenced by the mentioned factors, significant development and application of new techniques, equipments and plants used in recycling has occurred in the last 15 years. Equipment for waste comminution and separation is of particular importance. The paper describes the basic comminution techniques and presents typical machines and equipment used for this purpose. The aim of the paper is to draw the attention of domestic industry and contractors to the production area which, in spite of certain production potentials, still does not exist in Croatia.

## 2. Waste management

Waste is any substance or object that a possessor discards, intends to or has to discard. According to the Regulations on waste types, waste is classified by its properties and the place of generation into 20 groups. Waste groups and respective waste terms are found in Waste Catalogue and denoted by six-digit numbers. The first two digits indicate the activity from which the waste originates, the second two digits indicate the process in which the waste is generated, and the last two indicate the part of the process from which it originates. Beside each waste type term there is also the denotation for possible waste processing procedure (Waste Management Act, 2004).

Waste differs according to the source of generation and waste properties. According to the source of generation it can be classified as municipal or as industrial waste, and according to the properties as inert, hazardous or non-hazardous waste.

Waste management is the integration of all activities, decisions and measures oriented to:

- the prevention of waste generation, reduction of waste quantity and/or adverse waste impact on the environment,
- the implementation of collecting, transport, recycling, disposal and other activities concerning waste management, and monitoring of those activities
- the after care of closed disposal sites

Waste management should be implemented in such way that human health is not jeopardized and without applying the processes and/or methods which could have adverse impact on environment, especially in order to avoid:

- the risk of water, air and soil pollution,
- noise pollution,
- bad odor occurrence,
- jeopardizing the flora and fauna,
- adverse impact on areas of cultural-historical, aesthetic and natural values,
- explosion and fire occurences.

The objectives of waste management are:

- to avoid and reduce waste generation and to reduce dangerous properties of waste, esppecially through:
  - the development of clean technologies which utilize the natural sources to a lesser extent,
  - the technical development and promotion of products which do not contribute, or contribute in minimal degree, to the increase of adverse impact of waste and to pollution risk,

  - the development of appropriate methods for disposal of hazardous substances contained in waste intended for recycling,
- waste recycling or another process which enables recovery of secondary raw materials or use of waste for power supply purposes,
- proper waste disposal,
- reclamation of waste polluted environment.

In Croatia there have been registered 257 municipal waste disposals having total capacity of 71,234,000 $m^3$, where about 35,491,000 $m^3$ of waste have been disposed of up to now (Schaller *et al*, 2004). Approximate waste composition: combustible waste (dry fraction) 50%, biodegradable waste 33%, metal waste 3% and inert waste 14%. According to estimates, in Croatia in 2000 there were generated 4,100,000 t of waste (without forestry and mining waste) of which municipal waste accounts for about 1,200,000 t. During 2003 the company "Čistoća" collected 266,475 t of waste (Radović *et al*, 2004): municipal waste 190.210 t, bulk waste 65,476 t, street waste 10,790 t and waste from illegal landfills 6,293 t. Of the total amount of municipal waste, only 8% were recycled or collected separately: paper 6,500 t, glass 4,650 t, metal 5,300 t, PET containers 275 t, tyres 530 t, biowaste 220 t, batteries 8.5 t and medicines 200 kg.

In Croatia the price of waste disposal in sanitary landfills ranges from 18 to 54 EUR/t (in Zagreb 1 t of waste is disposed of at the price of 325 kn + tax). Those prices are up to six times higher in Austria and Germany.

## 3. Waste recycling

Waste recycling is the reuse of waste in a production process excluding energy recovery. (Waste Management Act, 2004.).

Recycling is practiced because of three main reasons:

- altruistic – awareness of environment and natural resources protection as a common interest
- economic – reduction of the increasingly high costs of waste disposal
- legal – because of lack of alternative disposal methods, the government stimulates waste recycling by implementing statutory and economic measures and other initiatives.

Raw materials used for the production of new goods and energy can be primary and secondary.

Primary raw materials – raw materials cultivated for the needs of the food, wood and textile industry, and mineral raw materials extracted by mining operations for the needs of the metal and nonmetal industry, chemical industry, energy production, etc. Primary mineral raw materials, e.g. ores, after excavation pass

through the benefication procedure where the useful component (e.g. metal) is separated from tailings. In this way separated metal concentrate is further processed by some of the metallurgical procedures.

Secondary raw materials – by recycling produced raw materials used for making new products or energy production. E.g. if it is not polluted by some other metal or plastics, scrap metal should only be reduced to the appropriate size (to comminute) and charge directly into melting furnace. However, recycling processes especially sorting and separation may be very complex and sometimes even impossible that is, nonprofitable.

During 2003 in drop-off centers in Zagreb there were collected 694 t of paper, 120 t of glass (container and flat glass), 9.6 t of PET container, 734 t of waste metal sheet (white goods), 107 t of non-ferrous metals, 37 t of tyres, 31 t of electronic waste. According to estimates of the company "Čistoća" d.o.o., about 50,000 t of paper per year gets to the landfill "Jakuševec". The disposal of 1 t of paper costs 331 kn, and collected paper is sold at the price of 290 kn/t. Besides, in landfills there are discarded about 90,000 t of glass containers per year and recycled about 14% (in Switzerland, Belgium and Finland there are recycled more then 90% of the total consumption).

In the period from 1998 to 2003, the average annual export from Croatia was about 102,000 t of steel and 13,300 t of other metals in the form of metal waste. C.I.O.S., a company for metal waste recycling from Zagreb, produces monthly at the plant for old car recycling 1400-1600 t of steel, 80-90 t of aluminium, 11 t of copper + brass, 0.7 t of zink, 5 t of Cu-PVC cables, 6 t of stainless steel and about 200 t of waste (dust, etc.) (Salopek and Bedeković, 2001).

The process of recycling involves the following operations:

- collection;
- comminution;
- classifying;
- sorting/separation;
- smelting (metal)

Additional operations are baling (metal, plastics, paper, textile), pressing or compacting (cars) and briquetting (metal scraps).

**Collection** is gathering, sorting and/or mixing of waste for the purpose of transportation. Municipal waste collection can be generally realized in three ways:

- collecting mixed waste without sorting at the generation site;
- collecting waste previously sorted to "dry" and "wet" and disposed of in separate containers (before disposal or incineration dry waste may be recycled, and wet waste used for compost production);
- collecting the part of solid waste previously sorted in special containers (paper, glass bottles, plastic bottles, alu-cans).

In that way collected waste is periodically transported by companies dealing with the collection and/or processing of individual types of waste.

*Bulk waste* (white goods, old furniture, textile) and hazardous waste (old paints and solvents, medicines, batteries) from households are transported to drop-off centers by citizens themselves.

*Industrial waste* generated e.g. by metal processing or treatment is sorted at the site of generation, disposed of in containers and transported directly to smelting plants and foundries or to waste collectors. At collectors waste is compacted/baled and afterwards delivered to the buyer.

*Construction waste* is usually transported to the recycling plant or it is recycled at the site of generation, for which stationary and mobile plants are used.

**Comminution** or change into dispersion state of solids is carried out in order to make easier the manipulation and transport, to separate the "intergrown" waste components as preparation for some of the sorting or separation operations, and to reduce to the required size according to buyer's requirements.

**Classifying** is a process used to divide coarser or finer fragments (grains) of waste into "classes" according to size and shape or the same terminal velocity.

The aim of classifying is to separate classes prior to certain sorting or separation operations, to separate classes as final products according to buyer's requirements, and to separate a certain class prior to separation operations.

**Sorting** is the separation of individual waste components on the basis of their optical properties.

**Separation** is the separation of individual waste components on the basis of differences in their density, magnetic and electric properties and wettability.

**Smelting** is a waste treatment in melting furnaces in metal production plants and foundries.

## 4. Comminution

The classification of comminution machines and devices has been done according to the physico-mechanical properties of waste (strenght, toughness, brittleness) and comminution mechanism (cutting, impact, pressing).

### *4.1. Cutting – gas, plasma, laser-beam, water-jet and abrasive disc cutting*

The mixture of acetylene, $C_2H_2$ and oxygen (1:1.5), propane, $C_3H_8$ and other gas mixtures (e.g. Mappgas) are used for gas cutting. One man ("the cutter") can produce up to 5-10 t of scrap in a day. The combustion temperature when cutting with acetylene-oxygen mixture is around 3,160 °C, and around 2,820 °C when cut-

ting with propane. When higher temperatures are needed, e.g. for cutting alloy steels containing Ni and/or Cr, plasma torches working at extremly high temperatures up to 25,000 °C are used. Laser beam torches are commonly used for cutting plastics (with the aid of added nitrogen), and less often for cutting metals (with the aid of oxygen – combustion). Water jets are used for cutting plastics, leather, rubber, in general for applications where thermal cutting is not acceptable. Jet pressures are up to 4000 Bar. Besides extremely high jet pressures, the disadvantages are noise and waste water generation during water-jet cutting. Abrasive-disc cutters are used for cutting metals, concrete, electric cables, paper bales, etc. (Nijkerk and Dalmijn, 2001).

Figure 1: *Abrasive disc cutting*

### *4.2. Alligator shears mechanically- or hydraulically-driven, mounted on a pedestal or crane-attached*

The “alligator” shears mounted on a pedestal are used for cutting short steel for foundries and for cutting non-ferrous metals. When hand-fed, no more than 1-2 t/h can be cut. By introducing a vibrating conveyor feeder the alligator shear capacity is increased and the danger of injuries is reduced. Nowadays, common shear drive is hydraulic.

Crane-attached shears are used for cutting metal and reinforced-concrete constructions, chimneys, etc. They can be remote-controlled when mounted on special vehicle. They are produced in three main variations: with scrap “shearing” jaws, concrete “pulverising” jaws or concrete “cracking” jaws. Cutting power ranges from around 100 t to 2000 t.


Figure 2: *Hidraulically-driven alligator shear (STRA spol.sr.o., 2005)*

Figure 3: *Crane-attached shear*

### *4.3. Hydraulic guillotine shears*

Nowadays hydraulic guillotine shears are in operation in every larger plant for bulk scrap metal recycling. They can be stationary and mobile. The cutting power ranges from around 125 t to 2000-3000 t, or more. The largest hydraulic guillotine shears weigh more than 250 t and can cut heavy beams a metre thick. They consist of charging or shear box (also called precompression or press box) usually sized around 600x100 (to 200) x 50 (to 100) cm with hydraulic cylinders, feed cylinder (pusher or gathering ram for pushing the scrap), cutting head and drive (electric motors, pumps, etc.). The cutting head includes the vertical cutting cylinder above the blade head, the guide-rails for the blade unit and the blade unit with bolted hard steel blades themselves.

Figure 4: *Hydraulic guillotine shear (Sierra Europe Recycling Ltd)*

The operation of machine is totally automatized and often controlled remotely by the crane operator filling the charging box. The machine capacity is usually 10-20 t/h and sometimes more then 50 t/h. Hydraulic guillotine shears are also used for cutting waste intended for incineration, which is too large to be fed directly into an incinerator. Their cutting power is far less than that of guillotine shears for cutting metals and their capacity ranges from 80 to 150 $m^3$/h. Similar shear designs are used for cutting old railway and tram rails, old textiles and paper bales.

### *4.4. Rotary shears and shredders*

Rotary shears consist of one, two or four horizontal shafts to which circular disks with hard steel teeth are fixed. Commonly they have two or four counter-ro-

tating shafts. In rotary shears having only one shaft, the material is shredded against the wall protected by lining whose configuration enhances the comminution process. The size of comminuted material depends on the gap between shafts. Rotary shears are driven by an electric or hydraulic motor, power of 10 to 100 kW. Their capacity is 5-50 t/day depending on the type of material. They are used for the comminution of softer and tougher materials (rubber, wood, plastics, cans).

Shredders consist of rotor equipped with free-swinging hammers (10-36 reversible hammers, each weighing around 100 kg or more). During the rotor turning (around 500-600 rpm) hammers comminute the metal material against an alloy steel breaker bar or anvil fixed to the input section of housing. The breaker bar (anvil) serves as a baffle and helps fragmentation and further comminution of material. Usually there is a grid under the rotor which predetermines the piece size of comminuted material. Above the rotor there is an emergency door for ejecting non-shreddable parts. The dry shredders include dedusting system. Shredders are used for the comminution of bulk metal waste (cars, white goods, etc.).

Depending on the power of driving motor and capacity, shredders are classified in four categories:

- small, 1-300kW, capacity of several hundreds kilos to several tonnes a day,
- medium, 300-700 kW, capacity 10.000-40.000 t/year,
- large, 700-2000 kW, capacity 40.000-125.000, t/year,
- very large, 2000-45000 kW, capacity can exceed 600.000 t/year.

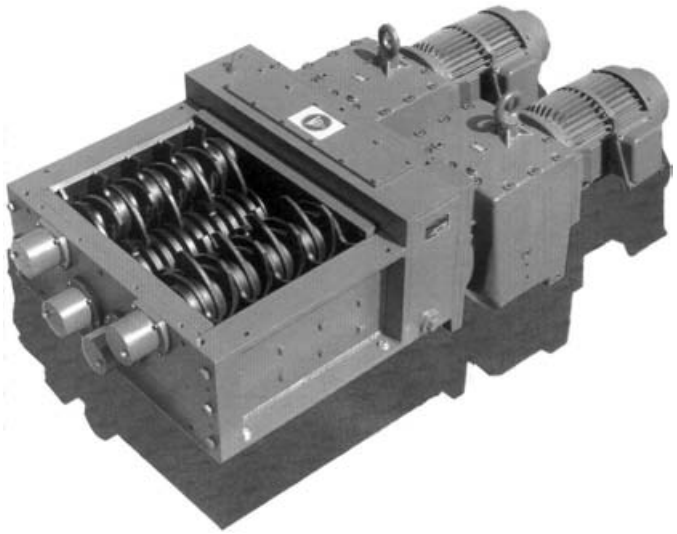

Figure 5: *A slow-speed, high-torque rotary shear/shredder (MOCO Maschinen- und Apparatebau GmbH & Co. KG)*

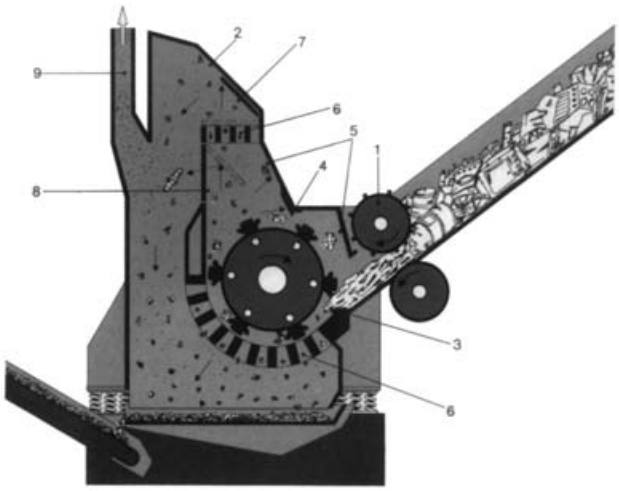


Figure 6: *Top-bottom discharge (TBD) automobile shredder (Nijkerk and Dalmijn, 2001)*
1 - Feeder rolls, 2 - Rotor housing, 3 - Anvil, 4 - Baffle plate edge for further fragmentation and pre-compression, 5 - Baffle plate, 6 - Top and bottom grates, 7 - Top lid, 8 - Emergency ejection door, 9 - Duct to dust collection unit

### *4.5. Shredders for construction and demolition debris, slag, etc.*

Shredders originally developed for crushing rocks and ores in mineral processing processes are also used for the comminution of construction and demolition debris. These are usually different types of jaw and impact crushers and hammer mills. The cone (gyratory) and roll crushers are less often used. Jaw crushers comminute the material by pressing it between fixed and mobile jaw. Impact crush-

Figure 7: *Mobile rubble crushing installation with crushing and screening unit*

ers have impact bars fixed to the horizontal rotor and hammer mills have free-swinging hammers attached to the rotor. Material is comminuted due to the impacts of bars and hammers respectively, the impacts of material against baffle plates and inner housing lining, and interparticle impacts.

Jaw crushers can be fed with concrete pieces up to 800 mm in diameter, while material fed into the impact crushers and hammer mills is not usually larger than 500 mm in diameter. Motor power usually ranges from 30 to 250 kW, and capacity from 50 to 500 (1000) t/h.

## 5. Conclusions

According to the data of the company "Čistoća" for 2003, in Zagreb there were collected 190,210 t of municipal waste, and recycled only 8% (paper, glass, metal, etc.). According to the same data there were disposed of around 50,000 t of paper in landfill "Jakuševec" and recycled only 6,500 t or 11.5 %.

In Croatia, around 90,000 t of glass containers are annually disposed of in landfills and only 14% are recycled.

The proportion of recycled waste in Croatia has been planned to be increased up to 30% till 2010 and up to 40% till 2020. In Germany the disposal of previously untreated waste (thermal, mechanical, mechanical-biological treatment) will not be allowed after June 1, 2005.

The EU directives regulate that at least 60% of marketed glass should be recycled till June 30, 2006.

From the above it is obvious that waste recycling in Croatia is underdeveloped, not only at the collection level, but also at the level of mechanical waste treatment. There is not a single producer of equipment for mechanical waste treatment athough its production is nowadays one of the most dynamic economic activities.

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# Microwave Device for Thermal Treatment of Cellulose Materials

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*Abstract*

Planar microwave (MW) device for thermal treatment of cellulose material (textile and wood) was constructed, tested and patented. The device is based on a magnetron-fed travelling wave applicator with meandered waveguide. The treated material, which is in a wide state, is horizontally passed through the slots of the applicator. The feasibility of use of developed device for textile treatment was tested on cellulose materials impregnated with different finishes. Obtained effects of microwave treatments were compared with conventional drying and curing method and significant improvements of physical and mechanical properties were found.

This might pave a way toward use of proposed technology for drying and curing of textiles, as well as for chemical wood modification.

*Key words:* microwaves, planar treatment, cellulose material

## Introduction

In the electromagnetic radiation spectrum, microwaves (300 MHz – 300 GHz) lie between radiowave (RF) and infrared (IR) frequencies, with relatively large wavelength (1m-1mm).

The energy of microwave photons is very low (0,125 kJ/mol) relative to the typical energies for chemical bonds (335-84 kJ/mol); thus MW will not directly affect the molecular structure. They cannot change the electronic structure around atoms or among them, but they can interact with the electronic differences between atoms.

However, chemical reactions can be accelerated due to selective absorption of MW energy by polar molecules, while non-polar molecules are inert to the MW radiation.

Some important applications of microwaves come from their interaction with various types of material. The interaction of microwaves with dielectric materials causes a net polarization of the substance. There are several different mechanisms of polarization: electronic polarization, ionic, molecular (dipole) polarization and interfacial (space-charge) polarization. The overall net polarization creates a dipole moment.

For a microwave electromagnetic field oscillating at 2.5 GHz, which is preferred frequency for heating applications, the charge changes polarity nearly 5 billion times per second. Under the influence of high frequency alternating electrical field the particles that oscillate about their axes creates intermolecular friction associated with the dissipation of energy in a form of heat.

The oscillating microwave energy is not absorbed to any degree by nonpolar materials. These include most polymeric materials and most fibers of interest to the textile and nonwoven industries. Different materials can be divided according to their response on microwave radiation:

– The materials that reflect MW radiation (stayed cold)
– The materials that are transparent to MW radiation (non-heated)
– The materials that absorb MW energy (being heated).

The main difference between conventional heating with hot air and microwave heating is the heating mechanism. During the conventional heating, the heat is generated outside the treated product and conveyed by conduction or convection. Hence, the surface is heated at first and afterwards the heat flows toward the inside, which always remains colder than the surface. The required internal temperature can be reached only by sufficient increase of the surface temperature of the material above the temperature needed for particular treatment.

On the contrary, in MW treatment, the heat is generated in a distributed manner inside of the material, allowing more uniform and faster heating. While conventional techniques heat a surface, the microwaves heat the whole volume of the treated object. The result is almost instantaneous heating of any material that responds to microwave radiation with either dipole rotation or ionic conduction. Dipole rotation is an interaction, in which polar molecules or species try to align themselves with the rapidly changing electric field of applied radiation. The motion of the molecule as it tries to orient to the field results in a transfer of energy. The second way to transfer energy is ionic conduction, that occurs if there are free ions or ionic species present in the substance being heated.

Additional advantage of MW treatment lies in a fact that the energy (heat) and the mass (water) flow are travelling in same direction. According to the literature, the energy consumption is 60-70 % lower than in a case of conventional heating.

During the Second World War microwaves were used in radiocommunication and radar technology. The heating effects of microwave radiation were discovered accidentally during the radar-related research project. After more than 50 years of investigation and development, the MW heating technology is nowadays widely used in a number of fields – from food preparation, chemical sludge, medical waste, organic synthesis, analytics, curing of hi-tech polymers, to industrial drying processes. There are also other various applications of microwaves in various aspects s of human life varying from mobile phones, radiocommunications and wireless computer networks to some special applications such as rocket engines.

First idea of MW application for textile finishing processes originated in 1970-es when cellulose fabrics were treated with Durable Press (DP) finishing agents and cured in MW oven. Although these first results were promising, the idea was abandoned till 1995, when Miller patented his Pre-set process without awareness of the earlier patent. Both cases involved garment microwave treatment, but they were abandoned because the efforts to control the process failed.

Until now, MW irradiation for textile finishing has been used for the combined desizing, scouring and bleaching processes, dyeing and drying processes, as well as for eradication of insects from wool textiles (Reagan 1982).

Majority of the experiments used a cavity-based applicator. However, American company Industrial Microwave Systems (IMS) uses a meander type of travelling wave applicator for planar drying of materials in a rope state. This system offers uniform heat distribution across the treated material.

## Apparatus

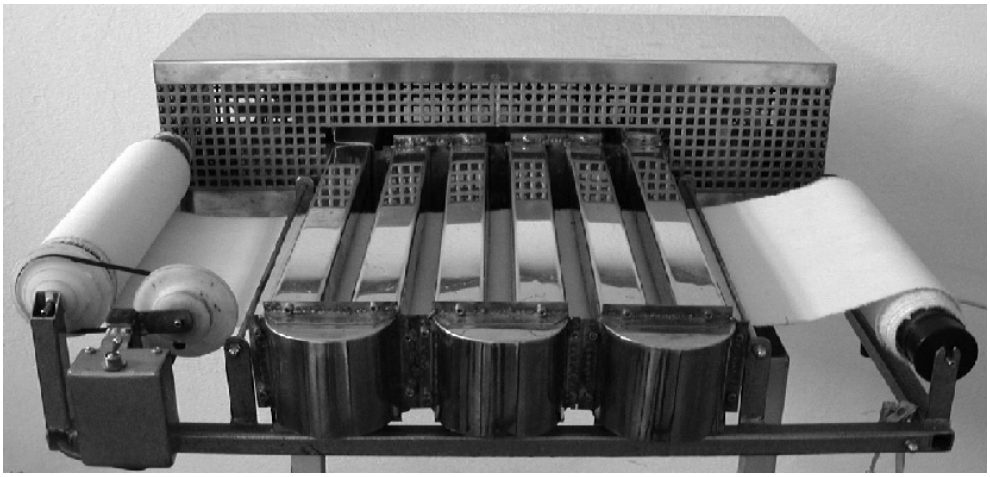

Figure 1: *Planar microwave device constructed at Faculty of Textile Technology*

Laboratory microwave device, shown in Fig. 1, was constructed at the Department for Textile Chemistry and Material Testing of Faculty of Textile Technology, University of Zagreb. This novel system is completely different from the resonant cavity used in domestic ovens and offers more uniform energy distribution. The idea was to treat textile material on a continuous flow basis. It is achieved by passing the textile material through the slots of waveguide-based applicator. With proper design of the waveguides and supporting equipment, a specific environment (at the particular wavelength) can be created in order to provide controlled distribution of the microwave energy, making it possible to achieve uniform exposure to material passed through a channel.

The applicator was fed by two 500 W magnetrons and the waveguide is terminated with water-based dummy load that prevents leakage of residual microwave energy. The system consists of 6 rectangular waveguides (4 x 8 cm) centrally slotted in order to obtain planar passage of textile material in a wide state. The leakage of microwave energy is inherently small due to fact that waveguide slots are oriented along the waveguide line of symmetry, and therefore they cannot act as efficient slot antennas. Furthermore, in this way the material lies in the maximum of the electric field that assures effective coupling to the flowing microwave energy.

Before this novel device comes into commercial use, the unintentional leakage of microwave energy must be checked in order to comply with existing safety regulations (Ministry Regulations 2003). The upper limit of tolerable microwave irradiation for professional exposure is 10 $W/m^2$ (1 $W/m^2$ in higher sensibility range). Preliminary determination of irradiation level has been performed at Department of Radiocommunications and Microwave Engineering at Faculty of Electrical Engineering and Computing.

Meander type of travelling wave applicators provides uniform energy distribution accros the treated material. In a case of single pass applicator, exponential decay of electric field might cause non-uniform heat distribution. To prevent this negative tendency, the material is passed through a number of waveguide passes (the present device uses six passes). Additionally, the level of applied microwave energy is increased by the use of the second magnetron, that feeds the applicator at the other end. The amount of microwave energy is absorbed by the textile (or other) material in each waveguide pass depends on the material thickness and moisture content. (Ministry Regulations 2003).

## Conclusions

From the results of textile finishing treatment with different finishing agents further conclusions can be made:

1) Application of microwaves in Durable Press finishing treatments offers significant improvement in comparison to the classical curing method performed at tenter frame.

2) In water and oil-repellent finishing with fluorocarbon polymers microwave treatment have offered minor improvements
3) In flame retardant finishing with organophosphorus agents microwave treatment obtained equal and durable treatment effects.
4) In chemical modification of wood with different environment safe reactants improvement of dimensional stability was obtained.

Application of microwave irradiation for drying and curing processes of cellulose materials showed significant improvements of treatment effects, but as a measure of precaution, the preliminary tests have to be performed for each reagent.

A fact that MW radiation can be successfully applied for drying, as well as curing of cellulose materials (textile and wood), is stressed as a final conclusion. Favourable and economical conditions are the best reference for future investigations and application of microwave technology in practice. After this preliminary laboratory investigations further experiments should be performed for the purpose of construction of semi-industrial or industrial microwave device.

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# Cartography and New Technologies

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*Abstract*

At the beginning of the article, there is a review of the remote sensing method, which is soon going to be the most important data gathering method in cartography. It is followed by a review of products of contemporary cartography, paper, multimedia and electronic maps, and 3D landscape visualizations and a representation of relations of Global Positioning Systems (GPS), Location Based Services (LBS), the Internet and cartography. Special consideration was given to the role of Croatian experts in the development and application of new technologies in cartography and geoinformatics.

## 1. Introduction

Maps have a fundamental and indispensable role as one of the underpinnings of civilization. Most human activities related to space are hard to realise without adequate cartographic representations. Some of them are land use planning, property ownership, weather forecasting, road construction, locational analysis, emergency response, forest management, mineral prospecting, navigation etc. (URL 1).

## 2. Remote sensing and cartography

Remote sensing is a method of gathering and interpreting information about remote objects without a physical contact with them. Airplanes, satellites, and space probes are usual platforms for observation in remote sensing.

The possibility of applying remote sensing data in cartography was significantly improved with the successful launching of the IKONOS-2 satellite of the American company Space Imagine in September 1999. Data from that satellite with spatial resolution of 1 m in panchromatic channel and 4 m in multispectral channel have been commercially available since March 2000 (URL 2).

In October 2001 DigitalGlobe (former EarthWatch), a private American company, launched the Quickbird (2) satellite with spatial resolution of 0,61 m in panchromatic channel and 2,44 m in multispectral channel. For civil needs, this is so far the best spatial resolution for recording the Earth from space (Oluić 2002).

Croatian company GISDATA and Naklada Ljevak published in 2001 the *Satellite Atlas of Croatia* 1:100 000 by using Landsat ETM 7 digital satellite images supplemented with cartographic data for the state border, roads, railways, airports, marinas etc. and geographic names. At the moment of its publishing, it was the most up-to-date atlas of Croatia (Fig. 1).

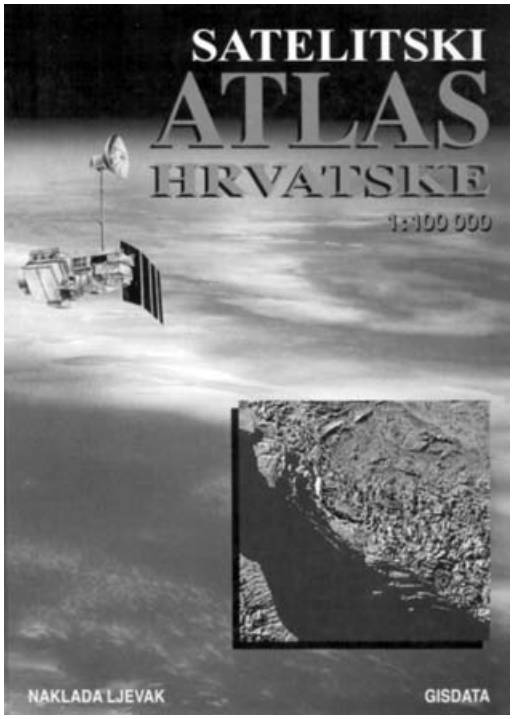


Figure 1: *Satellite Atlas of Croatia 1:100 000*

## 3. Paper maps

Today, paper maps are almost exclusively produced by digital technology. The equipment required - a personal computer and cartographic software are inexpensive and available to everyone. The Department for Cartography of the Faculty of Geodesy in Zagreb acquired the OCAD software in 1998. The software has since been applied in teaching and for the production of various maps, in the more recent times also Internet maps (Fig. 2) (Župan, Frangeš 2003). A copy of OCAD 8 Professional, which supports working with a database, costs 853 euros (URL 3).

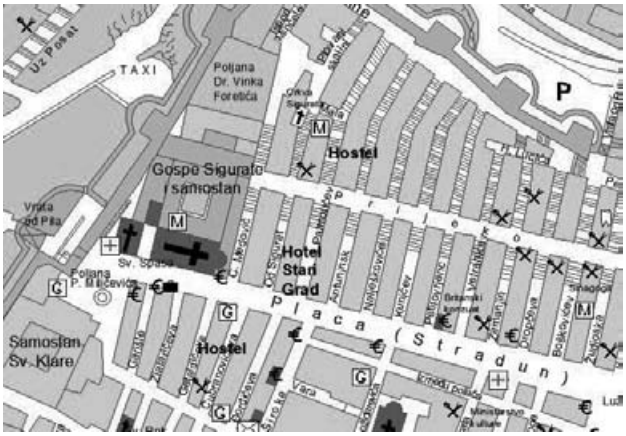


Figure 2: *A section of a map produced with OCAD*

The production of maps is going to be facili-

tated even more when most of the required data is in digital form. For the area of Croatia, we especially point out the need for the creation a base of geographic names. That is a project within the scope of the work of the Croatian Geodetic Institute (URL 4).

## 4. Electronic maps

Electronic map is a map connected with texts, graphs, photographs, pictures, satellite or aerial images, other maps, sound or motion picture etc. into multimedia in order to provide an additional level of information and a more complete view of reality (State Geodetic Administration 2003).

The end of the 20th century is the time of creating electronic navigation. At first with the help of unofficial *Electronic Chart Systems* (ECS), and today, finally, with a significant use of official system of the *International Maritime Organization* (IMO) titled *Electronic Chart Display and Information System* (ECDIS) (Fig. 3), and *Electronic Navigational Charts* (ENC) related to it (Racetin 2004).

Electronic navigational charts are databases with standardised content, structure and format. For use with ECDIS, they are published by official and authorized hydrographic offices. ENC contains all information of a chart required for safe navigation. It may also contain information other than those included by paper maps (e.g. navigation directions), which can be deemed necessary for safe navigation (Racetin 2004).

Figure 3: *ECDIS installation in the ship (URL 5)*

Norwegian Hydrographic Service (NHS) and Hydrographic Institute of the Republic of Croatia (HHI) signed an agreement on implementation of a jointly funded project CRONO HIP in January 2005. CRONO HIP project's goal is to provide Hydrographic Institute of the Republic of Croatia with new technology and methods for data collection, data management and electronic chart production.

## 5. 3D-visualization of landscape

There is an increasing number of requests for three-dimensional models for various analyses, simulations and visualizations. One method of producing such models is to combine existing data (digital elevation models, topographic maps) and corresponding modelling procedures. The procedure includes following phases:

1. relief visualization on the basis of digital elevation models
2. visualization of three-dimensional situation (combination of relief and a map)
3. 3D-object visualization.

The Croatian company GISDATA produced in this manner 3D representations of cities of Zagreb, Rijeka, Split and Osijek (Fig. 4).

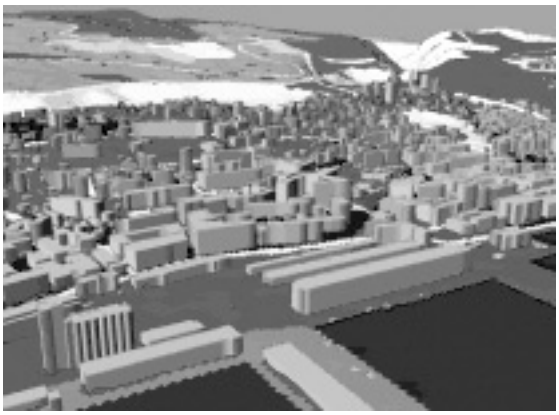

Figure 4: *3D model of city*

3D landscape models can also be produced by surveying with laser scanners (LIDARs) from an airplane or a helicopter. The position of a LIDAR in space is determined by a GPS and inertial measuring units, and the LIDAR measures horizontal and vertical angles and distances to a large number of points on the Earth's surface enabling the determination of spatial coordinates of those points.

Most of today's geoinformation systems are 2D GIS, because they were created on the basis of digitalisation of existing maps. Rapid development of com-

puter technology, graphics and data gathering methods (GPS, LIDAR) stimulate the production of 3D GIS. Since the landscape is a three-dimensional object, landscape modelling also requires a 3D-approach. 3D GIS will enable, among other things, 3D landscape visualization in real time (URL 7).

## 6. GPS and cartography

GPS (**G**lobal **P**ositioning **S**ystem) is a network of satellites which continuously transmits encoded information, which enables precise positioning on the Earth. GPS is based on a group of satellites of the Ministry of Defence of the USA that orbit the Earth. Satellites transmit very weak radio signals enabling the GPS receiver to determine its position on the Earth. GPS has various applications on land, sea and in the air. Basically, GPS enables the precise positioning and facilitate navigation.

There are also small handheld GPS receivers with the possibility of saving a detailed map from a CD-ROM. Map data can be integrated into the receiver either by using a data card or loading directly from a CD to a GPS receiver. Some receivers can have data saved directly into internal memory without the need of a data card (Fig. 5) (URL 8).

Figure 5: *GPS GARMIN with the integrated digital map*

The Croatian company Navigo Sistem d.o.o. produced the first digital map of Croatia in a format suitable for GPS-receivers produced by GARMIN.

GPS is slowly becoming a usual tool in automobiles. Sophisticated systems are able to indicate the position of a vehicle on an electronic map enabling the drivers to mark their positions and look for an address, for example a street, a restaurant, a hotel or another destination. Some systems can even automatically create a route and provide instructions for each turning, until the desired position is reached (Lapaine et al. 2004).

The company Mireo d.o.o. (URL 9) produced a digital map of Croatian roads in a format suitable for Microsoft Pocket PC (Fig. 6). Pocket PC with an integrated GPS or connected with it via Bluetooth wireless technology provides driving instructions from the current position to any address in Croatia. It is not necessary to look at the map during the drive, it is sufficient to follow vocal instructions in Croatian.

Using a GPS receiver and a handheld computer with adequate cartographic or GIS software, one is able to undertake a topographic survey of a small area. They can also efficiently be applied to the terrain work on topographic map revision on the basis of an aerophotogrammetric survey.


Figure 6: *Pocket PC with an integrated digital map of Croatia (URL 9)*

## 7. Location based services and cartography

Location Based Services (LBS) and telecartography belong to the field of newest research in cartography. Location Based Services include all the information a user can obtain via a cell phone or a handheld computer and are related to the position (location) he or she is currently at. For example, the user is in a certain city and would like to find the nearest hotel, hospital or a bank etc. A lot of such information can be transferred to the user most efficiently in the form of cartographic representations on the display of the cell phone or the handheld computer. The goal of cartography is to create cartographic representations suitable for small displays of those devices. Because of very small displays of portable devices, it is necessary to integrate multimedia elements into the cartographic communication process (Gartner 2004).

The company GISDATA is a pioneer in the field of Location Based Services in Croatia. For Zagreb, Rijeka, Split, and Osijek, they provide information about restaurants, gas stations, post offices, cinemas, theatres, hotels, banks, rent-a-cars, public garages, pharmacies, and pizza parlours (URL 6).

The company VIP.net d.o.o. offers the VIP.navigator service. Data at VIP.navigator's disposal, and that is more than 200 object categories (restaurants, hotels, cinemas, theatres, museums, banks etc.) and 270 thousand addresses for 34 Croatian cities and 7000 settlements are available over the Internet free of charge, and

via a cell phone for a fee. Digital geographic maps with plotted locations of objects (for the entire territory of Croatia) and much additional object information are also available (URL 10). If we are at the Josip Jelačić square and we would like information about Privredna banka, we are going to get the locations of two nearest banks (Fig. 7).

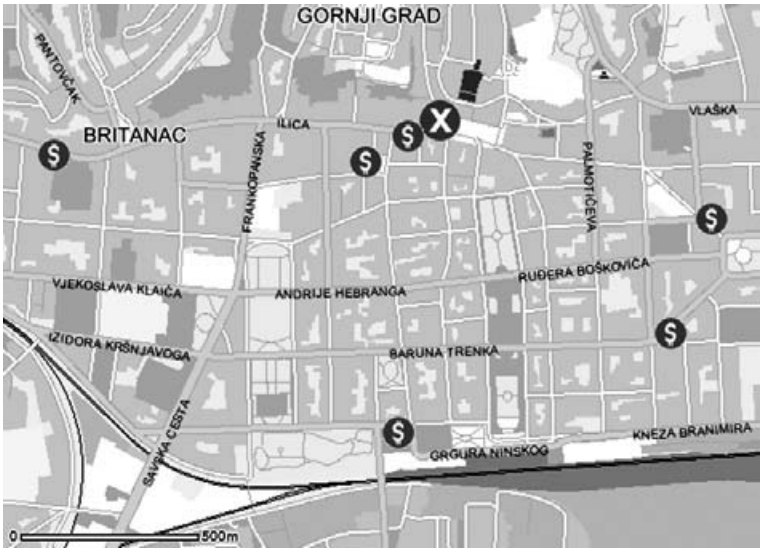


Figure 7: *VIP.navigator*

Another proof for the statement that contemporary technology provides extraordinary possibilities to gifted young people is an application for cell phones titled *mobyMAP*, produced by two students of a high school from Karlovac (URL 11). mobyMAP (Fig. 8) enables viewing maps on the cell phone, has an integrated street search, can show the direction of the nearest object you are looking for (pharmacy, bank, gas station). Maps of Zagreb and Karlovac are available at this moment. Maps of other cities are being produced. The authors offer companies the production of personalized city maps, which only contain the main streets and ways to access the company, and they plot the route to the company from any location in the city. In contrast to the on-line service VIP.navigator, mobyMAP is a Java application, which means that we only have to load it into a cell phone once, and are able to constantly use it afterwards. This makes it quicker and cheaper.


Figure 8: *mobyMAP (URL 11)*

## 8. Internet and cartography

Maps on the Internet are also called web maps. There are static and dynamic web maps. Both groups include maps which can only be viewed and those that are interactive. Today, most maps on the Internet are still static and aren't interactive. Examples of such maps are scanned maps put on the Internet. Some very old maps difficult to access become available to many people this way. Static maps can also be interactive. It may have a link to another web page with another map or some data, interaction also encompasses the possibility to zoom in and out, move around the map, and define cartographic content by turning various layers on and off. Dynamic maps are characterised by various animations, for example moving clouds on meteorological maps. Interactive dynamics enable three dimensional representations and moving through space.

Creating maps for the web is an extension of cartographers' activities, and it requires new creating methods. Cartographers have to dedicate themselves to this new work vigorously or professionals of other professions will seize that important part of the market (Frančula, Tutić 2002).

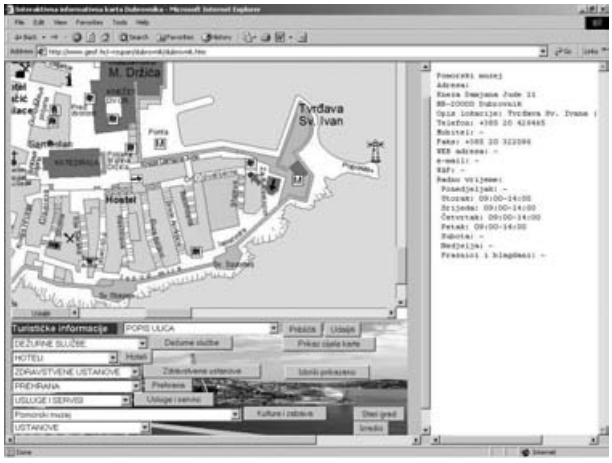


Figure 9: *Interactive web map of Dubrovnik*

Fig. 9. shows an interactive web map of Dubrovnik and its surroundings (URL 12). The map (city plan) was produced within the scope of a diploma thesis at the Faculty of Geodesy (mentor Prof. S. Frangeš), and the interactive map was put on the Internet by MSc. Robert Župan, assistant at the Department for Cartography. The map contains this information: a list of streets, services on duty, hotels, health services, food, services and repair shops, culture and entertainment, public institutions. If, for example, we are looking for the *Maritime Museum* among institutions of *Culture and Entertainment*, we are going to look for it in the list on the left, and

clicking on it a section of the city plan at a large scale will show up, with an arrow pointing at the museum. The textual window at the right shows the name of the institution, its address, phone number, and other useful information.

Internet interactive maps are also produced by students of the Faculty of Geodesy (URL 13).

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URL 12: Interactive plan of the city of Dubrovnik http://www.geof.hr/~rzupan/dubrovnik/dubrovnik.htm (January 27, 2005)

URL 13: Students of the Faculty of Geodesy, University of Zagreb http://www.geof.hr/kartogra/studenti.htm (January 27, 2005)

# Perspectives of Designing with New Concrete Types

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*Abstract*

Concrete is the most widely used material in civil engineering. During the last decade our conceptual thinking about concrete has changed. It is more and more understood that one can influence the properties of concrete quite considerably by minor changes on the concrete composition. By altering its composition and following some of the basic principles innovative types of concretes were developed. This paper intends to testify and illustrate the possibilities for designing structures by designing new concrete types. The results of testing properties of new concrete types are presented. In selecting the components to be used for preparing a concrete mixtures attention was given to cost-effectiveness. Thus, all the concrete components that were used are available on the Croatian market.

*Key words:* design, high performance concrete (HPC), high strength concrete (HSC), structural application

## 1. Introduction

Concrete is the most often used building material. Every year, more than 1 $m^3$ of concrete is produced per person on planet Earth. (Bjegović, 2004) Evidently, concrete is one of rare materials that can potentially meet human needs for remediation of the existing structures and construction of new, modern ones. This explains why experts and researchers in the field work persistently on further improvement of the properties of existing concrete types. This aim can be achieved only provided that development of concrete microstructure, concrete technology and performance are correlated in a proper way. Thanks to such an approach, development of new materials based on cement binders and improvement of properties of the existing materials have made considerable strides over the last few decades. (Skazlić, 2003)

Development of new concrete types started as early as in the middle of the last century with the invention and development of high strength concretes (HSC). In the middle of the twentieth century concrete compressive strengths could reach a maximum of 40 N/mm$^2$, while those of the concrete types whose production was started in the 60s were up to 60 N/mm$^2$. Until recently, concretes having compressive strengths of over 40 MPa (ACI Technical Committee 363, 1992) fell under high strength concretes. Today, the term high strength concrete mostly refers to concretes with compressive strengths of more than 55 MPa. If those concretes also exhibit other improved properties except compressive strength, then they are called high performance concretes (HPC). Under the coming Croatian laws and regulations the classes of compressive strength will cover concrete types up to C 100/115.

By modifying some of the existing rules for designing concrete composition and selecting materials in high strength concrete types, at the end of the last century ultra-high strength concretes were invented. This type of concrete has not only characteristic compressive strengths of over 150 MPa, and mainly even above 200 MPa, but also considerably improved tensile behaviour, stiffness and durability in relation to other concrete types. Their good mechanical and durability properties enable their structural application also in some areas in which concrete has not been widely used so far. (Collepardi et al, 2002)

Unexpected invention and sudden development of concrete with compressive strength of above 200 MPa hogged the limelight of the parallel development of concrete having compressive strength higher than 100 MPa. This concrete type can be also termed very-high strength concretes. Although they exhibit somewhat poorer mechanical properties than ultra-high strength concretes do, they are much more cost-effective. However, the application of these concrete types has not been fully investigated yet. (Walraven, 2004)

In Table 1 the classification of concretes is shown with regard to the values of their compressive strengths and thus they are classified as high strength, very-high strength and ultra-high strength concretes.

Table 1: *Classification of high-performance concrete types into high strength, very-high strength and ultra-high strength concretes (Nawy, 2001)*

| Parameter | High strength | Extra-high strength | Ultra-high strength |
|---|---|---|---|
| Compressive strength (MPa) | 42-100 | 100-150 | > 150 |
| Water/binder ratio | 0.45-0.30 | 0.30-0.24 | < 0.24 |

In this paper the rules are given for designing the composition of high strength and high performance concretes and for selecting their components.

The illustration is given of the results of experimental laboratory work carried out at the Department of Materials, Faculty of Civil Engineering in Zagreb. This research, in which components available in the Croatian market were used, produced new concrete types with improved mechanical and durability properties in relation to high-performance concretes that have been used in the Croatian construction industry up to today. Prospects were assessed of possible uses of these concrete technologies in the world and Croatian construction industry.

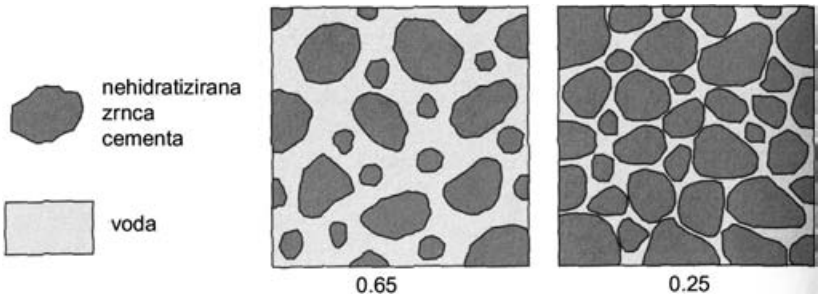


Figure 1. *Illustration of two mixtures of fresh concrete with different water/cement ratio: 0.65 and 0.25 (Aitcin, 1998)*

## 2. Rules for designing compositions and selecting components

Adherence to special rules for designing compositions and selecting components is crucial in high strength concretes and high performance concretes. The higher category of concrete types with regard to compressive strength values and other serviceability properties the more complicated the selection of components and concrete technology is.

The design of the concrete composition and production of high strength concretes is more complicated work than design of plain concrete since with the increase of compressive strength the concrete properties are in correlation not only with water/cement ratio - as it is the case in plain concrete - but also with several other parameters (this especially goes for porosity of concrete). (Aitcin, 1998)

To get higher strength values or to improve other properties, special attention should be given to the selection and compatibility of components (cement, superplasticizer, aggregate, mineral additives, fibres, etc.) and technology (production, placement, curing, transport, and quality control).

In comparison to plain concrete, high strength concretes are much more homogenous and less porous. Strength and other serviceability properties of these concrete types grow with the number of contacts among particles, reduction of porosity and defects within the structure. Considering that they contain high quantities of binders, the size of maximum aggregate grain should also be reduced.

Reduction of porosity is achieved by using a low water/binder ratio and by adding superplasticizer, and provided that sufficient workability in fresh state is ensured and a portion of cement is replaced with pozzolanic additives. By using much less water in the composition of these concretes than in plain concrete, the space between cement grains and mineral additives in the fresh state (see Figure 1) is reduced. In this way capillary porosity is also reduced and so is the space to be filled with the products of hydration. (Aitcin, 1998)

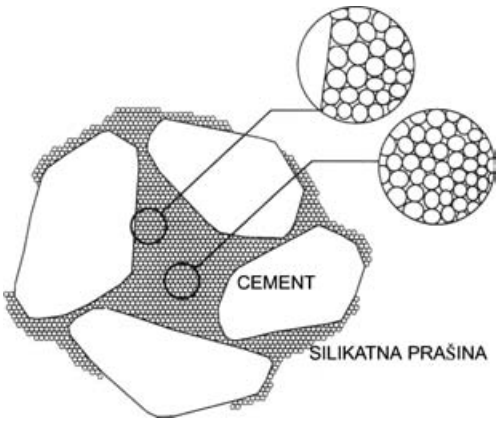


Figure 2: *The thickening of concrete structure by filling in the space between cement grains with the addition of silica fume (Aitcin, 1998)*

A reduction in water/binder ratio and the use of mineral additives have a positive effect on an improvement in the interface between cement stone and aggregates as the weakest link in the concrete structure. The most efficient admixture to cement is silica fume. Owing to its very small grains (about 10 times smaller than a cement grain) and large specific area, silica fume has a positive effect on an increase in density of the area surrounding cement particles and, because of higher reactivity, on accelerated hydration (see Figure 2). What is more, silica fume reacts with free lime - the poorest component of cement – thereby making CSH gel. (Skazlić, 2003)

Concrete brittleness grows with an increase in its compressive strength and hence high strength concretes are much more brittle than those exhibiting less strength. The main reason for the use of fibres in a weak, brittle matrix is to improve ductility of the cement matrix. The degree of improvement resulting from fibre reinforcement varies depending on the amount and kind of fibres admixed, adhesion of fibres and cement matrix, and the quality of the cement matrix itself. (Skazlić, 2005)

Besides taking into account the facts mentioned above, to obtain ultra-high strength concretes the concrete designer should adhere to the basic principles as follows:

- increase of homogeneity by eliminating coarse aggregate,
- increase of density of the placed concrete by optimizing grain size distribution in such a way to achieve maximum packing of particles,
- improvement to the structure of placed concrete by heat treatment,
- water quantity in concrete is maximally reduced and, because of this, its quantity is insufficient for cement hydration; this principle results in the reduced quantity of free water, which can result in the formation of micro cracks because of desiccation; non-hydrated cement acts as reactive micro aggregate of high modulus of elasticity that can hydrate subsequently,
- improvement to ductility by adding higher quantity of fibres.

By adhering to the first four principles high compressive strengths can be achieved, while by adding fibres tensile strength and ductility are improved. This has an effect on the ductility of the cross-section and structural elements, thereby ensuring deformation and redestribution of cutting forces and prevention of brittle failure of the structure or the test element. (Skazlić, 2005)

Table 2: *Compositions of the mixtures tested*

| Composition components (kg/m$^3$) | **C 60** | **C 130** | **C 200** |
|---|---|---|---|
| Cement PC 30dz 45S | 400 | - | - |
| Cement PC 55 | - | 600 | 1115 |
| Silica fume | 30 | 59 | 169 |
| Quartz sand | - | - | 1073 |
| Fine aggregate (fluvial) | 919 | - | - |
| Coarse aggregate (fluvial) | 883 | - | - |
| Fine aggregate (diabase) | - | 944 | - |
| Coarse aggregate (diabase) | - | 648 | - |
| Superplasticizer | 3 | 5 | 37 |
| Water | 151 | 145 | 204 |
| Steel fibres | - | 100 | 234 |
| Water/binder ratio | 0.35 | 0.22 | 0.16 |
| Maximum aggregate grain (mm) | 16 | 11 | 0.5 |
| Aggregate mass/binder ration | 4.2 | 2.4 | 0.8 |
| Silica fume quantity (% $m_{cem}$) | 7.5 | 9.8 | 15.2 |
| Superplasticizer quantity (% $m_{cem+sil}$) | 0.7 | 0.8 | 2.9 |

## 3. Experimental work in the field of ultra high strength concrete

In the laboratory of the Department of Materials at the Faculty of Civil Engineering, University of Zagreb, experimental researches have been conducted into new types of concrete. These researches have been carried out by investigating, in parallel, properties, structure and technology of concrete. The aim of the researches is to get new types of concrete that exhibit improved mechanical and durability properties in relation to other concrete types. At the same time, they need to also fulfil the condition that the obtained concrete types can be prepared at the existing concrete production plants. The preceding researches yielded the components for these concretes which were used in the subject researches. (Skazlić, 2003) In order that the production price of the new concretes is as favourable as possible the components available in the Croatian market were used.

Table 2 shows the compositions of the mixtures tested. Test were carried out on three various concrete types that, according to classification given in Table 1, can fall under high strength (C 60), very-high strength (C 130) and ultra-high strength (C 200) concretes.

Figure 3: *Testing of mechanical properties of ultra-high strength concrete in the laboratory of the Department of Materials, Faculty of Civil Engineering in Zagreb*

The design of the compositions of the mixtures, selection of their components and production were governed by the principles described in previous chapter.

All the mixtures had plastic consistency in fresh state. In hardened state, they were tested for the following properties:

- Compressive strength (HRN.EN.12390-3 or HRN EN 196-1)
- Flexural strength (HRN.EN.12390-5 or HRN EN 196-1)
- Static modulus of elasticity (HRN.U.M1.025)
- Dynamic modulus of elasticity (HRN.U.M1.O26)
- Toughness (according to (AFGC/SETRA working group, 2002), and analysis of results according to Japanese standard JCI-SF 4)
- Gas permeability (EN 993-4)
- Capillary water absorption (HRN.U.M8.300)
- Diffusion of chloride ions (ASTM C 1202)

The results of testing mechanical and durability properties are shown in Tables 3 and 4. Statistical analysis of the results obtained by the single-parameter model of analysis of variance showed that they are repeatable for all three concrete types.

Table 3: *Average values of the results obtained from mechanical properties testing*

| Mechanical properties | **C 60** | **C 130** | **C 200** |
|---|---|---|---|
| Compressive strength (MPa) | 71.5 | 141.7 | 211.3 |
| Bending strength (MPa) | 7.1 | 13.3 | 40.1 |
| Static modulus of elasticity (GPa) | 34.4 | 40.8 | 48.7 |
| Dynamic modulus of elasticity (GPa) | 40.8 | 55.7 | 55.6 |
| Toughness (Nm) | 3.7 | 44.8 | 133.9 |

Concrete marked C 60 is categorized as high strength concrete and this is the concrete type with the highest strength currently used in the construction industry in Croatia. Concrete having a very similar composition to the one mentioned above was used in construction of the arch of Krka Bridge on the Zagreb-Split Motorway (Borzić, 2005). One of rare cases in which concrete of higher quality (fibre reinforced concrete MB 75) was used is the case of rehabilitation of above-arch structure of Krk Bridge (Beslać et al, 2003). Also, on several structures (e.g. precast viaduct girders or high-rise building column) concretes of C 50 or C 55 were used.

Table 4: *Average values of the results of testing durability properties*

| Durability properties | **C 60** | **C 130** | **C 200** |
|---|---|---|---|
| Coefficient of gas permeability ($m^2$) | $1.3 \cdot 10^{-17}$ | $1.3 \cdot 10^{-18}$ | $1.3 \cdot 10^{-19}$ |
| Coefficient of capillary water absorption ($kg/m^2h^{1/2}$) | 0.138 | 0.06 | 0.023 |
| Diffusion of chlorine ions (Coulomb) | 766 | 416 | 150 |

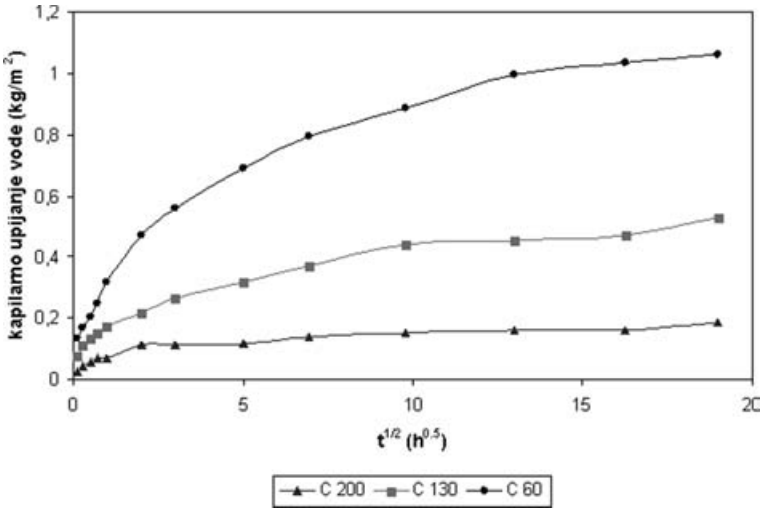


Figure 4: *Diagrams showing capillary water absorption in concrete types tested*

If the comparison is made among average values of the mechanical properties given in Table 3, it can be seen that concrete types marked C 130 and C 200 have much better mechanical properties than the concrete marked C 60. Except increased values of compressive strengths in comparison with the other two concrete types, concrete C 200 has also high flexural strength and toughness owing to high quantities of steel fibres contained in its composition. With the increase in concrete homogeneity, their stiffness grows too. As for the values of static and dynamic modulus of elasticity, the Table 3 shows that concrete types C 200 and C 130 have higher values of modulus of elasticity compared to C 60.

The results of testing durability properties, as shown in Table 4 and Figure 4, illustrate that the concrete type C 200 exhibits the best durability properties, and then follow concretes C 130 and C60 in this order. Such results are primarily due to significantly reduced capillary and total porosity of concrete C 200 compared to the other two concrete types.

## 4. Possible structural application

For the time being, high strength concretes, of which C 60 is also one, are mainly used in precast or in situ construction of load bearing elements of viaducts and bridges, as well as for high-rise building columns. Maximum values of compressive strengths of concrete types that are used in Croatian construction industry are the same or somewhat higher than the values achieved with concrete C 60.

The use of very-high and ultra-high concretes for structures allows the designer to reduce the sizes of structural elements. Modulus of elasticity of these con-

crete types does not rise proportionally to the strength values. For this reason, in structural application of high-strength and ultra-high strength concretes, slim cross-sections are used; however, deformations of these structures are also more serious, and thereby their spans are limited. Owing to the use of high-strength concretes less reinforcement is necessary, which makes it possible to install slimmer structural elements.

On the basis of the above facts, it can be concluded that very-high strength concretes such as C 130 can be used for high-building construction, for bridge construction, and for the construction of slim and lightweight structures such as for example thin-walled roof structures for roofs having wide spans or for girders of low self-weight intended for building additional storey or raising. It should be pointed out that these concrete types cannot be used without traditional reinforcement, although in certain cases concrete C 200 can. However, concrete types C 130 are more cost-effective than concrete C 200, and their compressive strength and other mechanical properties are sufficient for the majority of structural applications.

Because of good workability of concretes C 130, their composition can be further modified with the purpose to use them as shotcrete in placing primary tunnel lining. In this manner the thickness of the placed shotcrete would be reduced thus ensuring flexibility of the primary tunnel support. Rapid growth in strengths would allow shotcrete to immediately take over a large portion of load; additionally, because of a large binder quantity, rebound, i.e. the loss of material during installation would be reduced.

High ductility and energy absorption capability, along with small self-weight of not only concrete C 200 but also of C 130, allow their application in the case when structures are built in seismically active area or for strengthening existing structures.

Good durability properties exhibited by C 200 and C 130 prolong the service life of structures in unfavourable and chemically aggressive environments and also reduce maintenance and remediation costs to a minimum.

Figure 5: *Production of girders made of ultra-high strength concrete*

When concretes have high flexural strengths - as it is the case with concrete C 200 - in certain applications it is possible to eliminate ordinary reinforcement and to only pre-stress cross-sections of structural elements. As a result, structural engineers have gained freedom in structural shaping of load-bearing elements.

Due to the fact that ultra-high strength concretes contain very fine (mainly not exceeding 1 mm) particles which make the structure of a material especially fine, and with the possibility for admixing colour pigments and replacing steel fibres with polymer ones, fabrication of more complicated architectural elements is possible.

Figure 6: *The view of Bourg-Les-Valence Bridge in France, the first European bridge to be constructed of ultra-high strength concrete*

In most current applications in the world, good use has been made of the suitability of concrete types having similar properties to those of C 200. These properties are high strength, durability and/or architectural aspects that allow great freedom in structural shaping, and high-quality surface finishing. In all the applications mentioned, ultra-high concrete types have been used for construction using precast elements.

That is why ultra-high strength concretes have been used worldwide for construction of bridges, lightweight and slim structures such as roof structures; for strengthening structural elements; for architectural façade panels; as structural elements in highly aggressive environments, etc. (Skazlić, 2005)

Considering its properties, this concrete type could be also used for bridge plates, precast segments of secondary tunnel linings, impact protection panels

against missiles and explosion, containers intended for storage of radioactive and other non-degradable waste, waste water pipes, vaults in which valuable things are kept safely, etc.

At present, the highest reinforced concrete structure is 508 m high, and certain experts have plans to construct a new high building as high as 1 kilometre. Load-bearing elements will be steel pipes filled with ultra-high strength concrete. (Pu et al, 2004)

Competitive advantage of ultra-high strength concrete over other kinds of structural concretes was analysed on the example of high-building columns. Thus three different concrete types were analysed, namely C40/50, C80/95 and C 180. The comparison was made of their price of production, transport and installation costs, their environmental acceptability, maintenance and rehabilitation costs over their predicted service life. The results of the comparison showed that ultra-high strength concretes can compete with other concrete types on price. (Racky, 2004)

In the world, very-high strength and ultra-high strength concretes have been applied for the last five to ten years. However, the first structures built of these concrete types were test structures aimed primary to monitoring material and structure behaviour with time. So it can be generally said that the real structural application is yet to take hold. As a result, the properties and production technology of these concretes have been further improved with the aim to use them in the structures in which the properties of material will be used optimally.

At present, very-high strength and ultra-high-strength concretes are not used in Croatia. Considering that this research and some other researches into this material proved that such concretes can be produced in the country using the components available in the home market, and taking into account considerable expertise and skill of Croatian civil engineers, it is to be expected that these concrete types will come to use in practice in the near future.

## 5. Conclusion

Rapid development of new materials based on cement binder and great improvement of properties of existing materials took place at the end of last century and at the beginning of this century. Concretes having very-high strength and ultra-high strength are among other new concrete types that were developed during the said period. They exhibit much better mechanical and durability properties than other concrete types. Outstanding characteristics of these materials enable their structural application in various fields of civil engineering.

To this day, a small number of structures have been constructed using these concretes in the world. However, further investigation into their properties and structure is being carried out and possible future application analysed.

Very-high strength and ultra-high strength concretes have not been used in Croatia yet. Experimental work on the subject materials performed at the Faculty of Civil Engineering in Zagreb is a stepping stone to their future applications. On the basis of the results obtained, an analysis was made of possible applications of extra-high strength and ultra-high strength concretes.

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# Soil Improvement by Deep Vibro Compaction

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*Summary*

Deep vibro compaction is often used to improve bearing capacity and settlement of soft soils that are otherwise unsuitable for foundation of structures. The method has quite successfully been used at several motorway projects in Croatia in the last five years. By compaction, soil is transformed into a new material upon which characteristics depends the future safety of above laying structures. Two deep vibro compaction techniques have been developed: one that compacts soil by means of a vibrator that penetrates into deeper soil layers, and the other, when in addition to vibrations, a charge of stone or coarse gravel is added into the hole formed by the vibrator and compacted by the vibrator. The former technique, known solely as vibro compaction, is used for coarse-grained soils like sands and gravels, while the later, known as vibro replacement, is used for fine-grained soils with low permeability that cannot compact under vibrating action. By vibro replacement, stone columns are formed in the foundation soil. Stone columns, depending on their stiffness and spacing, are capable of carrying considerable proportion of structural loads.

A serious problem related to any soil improvement technique is quality control. The Geotechnical department of the Civil Engineering faculty of the University of Zagreb used a technique measuring the average soil stiffness increase obtained by vibro compaction and vibro replacement successfully. The technique employs the spectral analysis of surface waves (SASW) generated by induced impact on the soil surface.

The paper describes experiences of using SASW in quality control of soil improvement by vibro compaction and vibro replacement in Croatia. SASW is a particularly suitable since, in contrast to some other geophysical methods, it can measure stiffness of softer layers found under stiffer soil layers. The method is non-destructive, measurements are taken at soil surface, and the need for expensive borings and uncertain quality of recovered soil samples is avoided. Therefore the method is rapid, relatively inexpensive, and commercially competitive.

## 1. Introduction

In modern civil engineering, civil engineers are more and more often faced with the situations in which foundation works for heavy structures and infrastructure facilities are being carried out in the soil of low stiffness, i.e. of insufficient bearing capacity. In such situations the problem of making foundation in poor soil can be solved using several techniques.

The oldest technique is the simple replacement of existing soil with new, stiffer and firmer soil in which then a new structure is to be founded. By using this technique, the "geotechnical" solution to this problem is practically avoided since it is based on the new "man-made" soil of predefined stiffness and bearing capacity. Although the costs are high, the risk of excessive settlements and the loss of bearing capacity were reduced to a minimum, i.e. brought under control.

A geotechnical solution to this problem would be the design of the structure that takes into account low stiffness and bearing capacity of the soil. A geotechnical engineer defines the foundation structure that can take on the given load. The foundation costs under such conditions are in most cases lower than that of soil replacement. They are, however, inversely proportional to the risk, and the risk itself is never under full control.

The third solution, which is presented in this research work, is soil improvement. This solution is a compromise among the solutions described above. By the use of various techniques for compacting and mixing the in situ soil with new soil, natural soil taken on the characteristics of the new material. The desired degree of soil improvement and the selection of suitable foundation structure can result in optimum relation between costs and a reduction of risks, which is in this case under control.

In the cases when costs do not justify the adoption of any of the above solutions, and in the conditions of a high and uncontrollable risk, engineers resort to "non-engineering" solutions such as the relocation of the structure to the other site with soil of higher stiffness and bearing capacity or, in the most extreme case, the withdrawal from the project. The soil improvement techniques make it possible to: increase soil bearing capacity; to reduce and keep under control total and differential settlements; to reduce the time required for deformations to occur; to reduce soil permeability; to completely remove water from the soil by formation of internal drainage system; and to increase soil stability to erosion.

Soil improvement can be achieved using different techniques. Owing to the fact that solutions to making foundations in extremely difficult conditions are badly needed, improvement techniques have been rapidly developed.

When selecting suitable soil improvement technique, there are a number of considerations that must be taken into account. The most important ones are the following:

1. The aim of improvement, i.e. the level of an increase in stiffness, bearing capacity or water impermeability
2. Surface, depth and total volume of soil to be improved
3. Soil type and its mechanical properties
4. Availability of materials for improvement (sand, gravel, mixtures)
5. Environmental factors and local experience
6. Time spent for compaction
7. Costs
8. Analysis of the risk of inefficient improvement.

In Croatia, the GeoTechnik Company of Varaždin, operating in the Keller Group, has been applying and developing - in collaboration with the Department of Geotechnics of the Faculty of Civil Engineering in Zagreb - ground improvement using deep vibro compaction technique for the past few years. Depending on soil particle sizes, the distinction is made between two deep vibro techniques. Thus, a *vibro compaction technique* is used in the case of non-cohesive soil, while a *vibro replacement technique* is more suitable for cohesive and mixed soils. In the vibro compaction technique, the pore volume of the soil particles is decreased by means of vibration, which results in higher compaction and hence also soil stiffness. The vibro replacement technique – often also called *vibro stone columns* – involves the installation of columns of gravel and stone that, proportionally to their stiffness and volume, take over a significant portion of load of building structures.

In both techniques, a vibrator is lowered to penetrate the ground to required depth and, depending on the kind of the technique to be used, soil is compacted or gravel columns installed. Soil improvement technologies by means of the deep vibro compaction technique are much more cost-effective than conventional methods of making foundations. The time required for completion of foundation work is relatively short, and the procedure is easily adjustable to site conditions. The construction of foundation for the future structure can follow immediately after the soil improvement is completed. Soil is improved using only natural materials and thus this technique is very environmentally acceptable.

## 2. Vibro compaction

*In situ* non-cohesive soils and mixed soils with low content of fines have lower density than maximum. Under the action of deep oscillations and vibrations in soil, soil particles can be “rearranged” thereby increasing soil density, i.e. compaction, the angle of internal friction, and modulus of compressibility (Figure 1).

The effectiveness of this soil improvement technique depends on soil particle size distribution. Figure 2. shows the ranges in a particle size diagram in which vibro compaction can be used. Range 1, mostly covering coarse sand, is the range

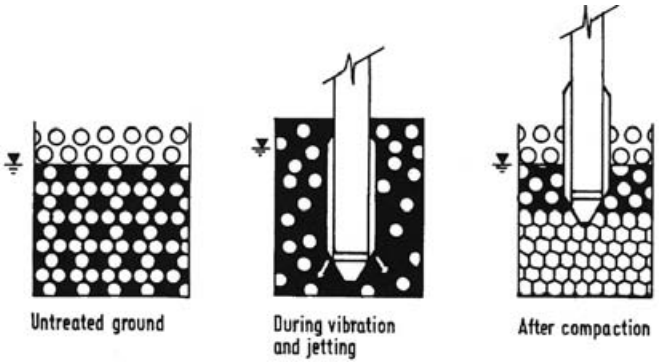


Figure 1: *Principle of vibro compaction*

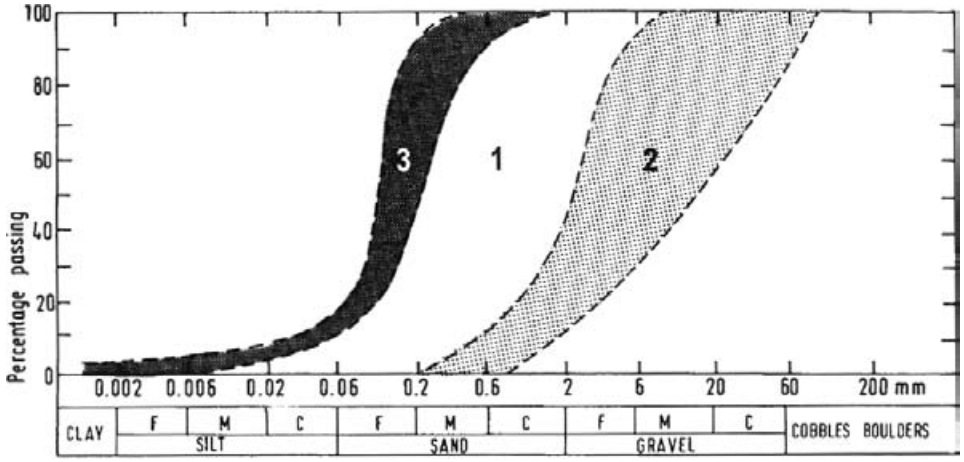


Figure 2: *The grain size distribution curves showing where vibro compaction can be applied*

in which this technique is most effective. Somewhat poorer results are achieved in Range 2 in which gravel prevails, while the effect of treatment is the lowest in the soil consisting of fine sand with a low content of silt, i.e. Range 3 (Brown, 1977).

The process of vibro compaction work is shown in Figure 3. The vibrator head vibrates and, assisted by jetting water that also washes down fine particles, penetrates to the designed depth. Once the designed depth has been reached, the water jets are reduced and compaction process is started. The compaction process takes place in steps from the required depth up to ground level, and the influence of the vibrator is up to 5 meters. The effect of compaction is recorded based on power consumption of the vibrator electric motor. On the ground surface around the vibrator, a funnel is formed which is filled with backfill material. After deep vibro compaction is completed, the surface layer is removed and the surface of the foundation soil compacted by rolling.

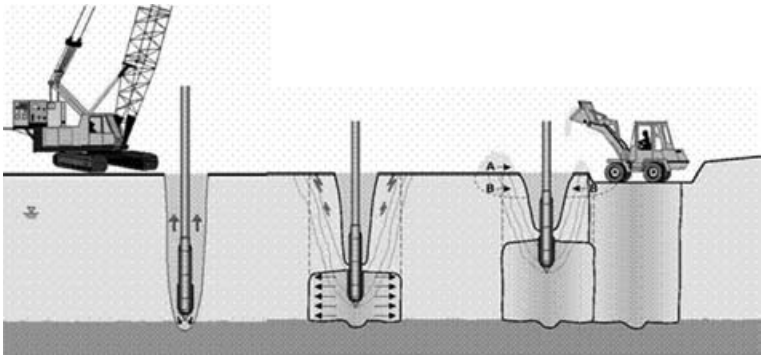

Figure 3: *Deep vibro compaction – sequence of compaction operations*

The use of this technique is limited by the fact that cohesive and mixed soils with silt and clay content of more than 20% cannot be efficiently compacted only employing deep vibro compaction technique.

## 3. Vibro replacement

In cohesive and mixed soils with silt or clay content exceeding 20%, gravel or crashed stone are pressed into the ground and by means of vibrations columns are installed which then take over additional loads (Figure 4). Both the surrounding soil and such granular materials installed by means of a vibrator exhibit higher stiffness and shear resistance. As a result, bearing capacity of foundation soil is increased and settlements are reduced. Owing to high water permeability of gravel columns consolidation is significantly accelerated and because of this a successive increase in shear strength of natural soil is more rapid. The potential of liquefaction is also reduced (Watts, 2000).

The efficiency of this soil improvement technique also depends on grain-size distribution of soil. In Figure 5. grain size distribution curves show the ranges in

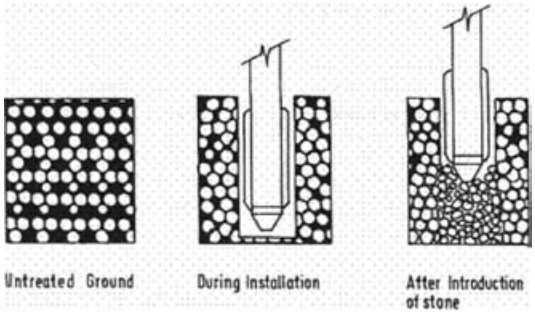


Figure 4: *Principle of vibro replacement or vibro stone columns*

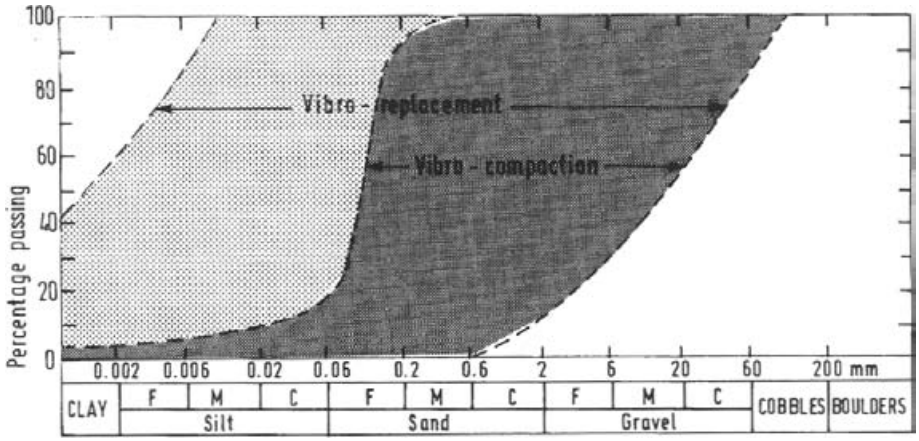


Figure 5: *The grain size distribution curves showing where vibro replacement technique can be applied*

which vibro replacement can be applied. From the diagram it can be seen that vibro replacement techniques can be applied in the wide range of grain size distribution and that its application also extends over the ranges in which vibro compaction is also used. However, vibro replacement is used in the cases in which rearrangement of soil particles by means of vibro compaction cannot result in required soil stiffness and consequently the soil must be partly replaced.

The process of vibro replacement technique is illustrated in Figure 6. The vibrator with a feed device is stabilized on hydraulic outriggers and located on the ground at the marked point position. The skip is charged with the material by a special loader. Then it travels up the leaders and discharges its content into the feed device. After the device is closed by special hinged lid, compressed air forces the material towards the outlet nozzle on the vibrator tip. The vibrator presses out the surrounding soil and penetrates to the desired depth assisted by water or air pressure and a downward vertical force of the machine itself. When the final depth is reached, the vibrator is raised by 30 to 50 cm to make a hole into which material is pressed. By moving the vibrator in small steps up and down, the material is compacted and laterally pressed into the surrounding soil. In this way, gravel column is continuously installed from the bottom up to the ground surface or to the design height.

The drawbacks of this technique are primarily the loss of lateral resistance in the case of very soft silt clays or silt sand and failure to install in the soil the column of desired shape and volume because of the cavities in the soil, tree roots and the like.

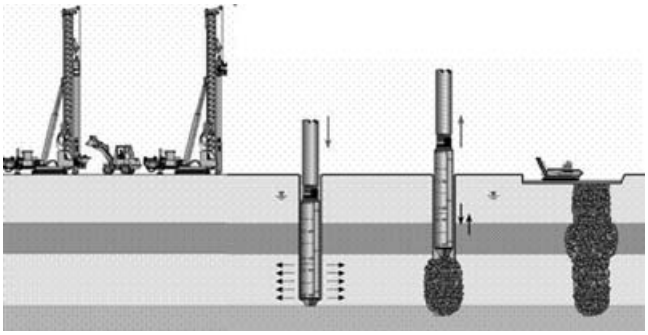

Figure 6: *Deep vibro replacement – sequence of operations*

## 4. Technology for soil improvement quality control by spectral analysis of surface waves

When executing works on soil improvement, full attention is given to the quality control of the improvement achieved. Typically, for the quality control of soil improvement by deep vibro compaction technique the so-called *heavy impact probe* is used (Figure 7). The device consists of a 50 kg weight dropping from the height of 1 metre. The weight transfers energy through a special adaptor to a rod with an irreversible tip. The result obtained from the test is the number of impacts required for the rod to be driven into the soil by 10 cm. Thus, the test result illustrates well the degree of soil improvement achieved using vibro compaction technique. In the case of vibro replacement technique, stiffness, i.e. bearing capacity of the gravel column or the surrounding soil determined well. However, the result of this test cannot, without reservations, be used for determining the degree of improvement in average stiffness properties of all the new soil. Consequently, the test

Figure 7: *Soil improvement quality control by heavy impact probe*

result cannot be compared with design assumptions. The complicated state of stress and interaction between the gravel columns and the surrounding soil make it impossible to establish the stiffness of composites. To determine the degree of soil improvement, it is necessary to carry out tests that will cover a larger volume of the improved soil based on which average newly created stiffness properties will be determined.

An average increase in soil stiffness improved using vibro replacement technique can be brought about successfully and reliably by means of the *Spectral Analysis of Surface Waves (SASW)* (Figure 8). This method for measuring soil stiffness properties on various structures is employed in Croatia by the Department of Geotechnics of the Faculty of Civil Engineering in Zagreb. The process takes place on the ground surface and consequently this method can be classified as non-destructive seismic measurements. Surface waves are generated by mechanical vertical impulse on the ground surface. Vertical sensors, geophones are placed at predetermined distances to measure the velocity of wave propagation. By Fourier's analysis the received signal is converted from the time domain to the frequency domain, and it is on the converted signal that further spectral analysis is made. The cross power spectrum and coherence are used to determine dispersive characteristics of the input wave. On the basis of dispersive characteristics of the surface wave using back-analysis the values of stiffness for individual layers in the layered soil are obtained.

Apart from quality control of the soil stiffness improvement by gravel columns and jet injection techniques, this method is efficiently used for quality control of compaction of road embankment and reinforced concrete embankments, and for determining the thickness of the layers of pavement structure and concrete lining in road and water transfer tunnels.

More detailed information about the SASW method can be found in the references as follows: Nazarian, and Stokoe,1983; Nazarian, 1984; Addo and Robert-

Figure 8: *Quality control of soil improvement by the Spectral Analysis of Surface Waves method*

son, 1992; Hiltunen, and Gucunski, 1994 and Stokoe et al., 1994. Experience in the use of this method in Croatia is described in the research works of Szavits-Nossan A., Mavar and Kovačević, 1998; Kovačević, 1999; Mulabdić, Szavits-Nossan A. and Kovačević, 1999; Stanić, Kovačević, and Szavits-Nossan V., 2001, Stanić, Kovačević and Gjetvaj, 2002; and Kovčavić and Skorić, 2003.

## 5. Croatian experiences

Up to the present, a long series of structures on which not only construction techniques but also quality control of the degree of soil improvements have been successfully tested and improved. In Table 1. the achieved degrees of soil stiffness properties are given. Figure 9. shows a stage in execution of works on soil improvement, and Figure 10. illustrates only a few of the existing structures whose foundation soils have been improved using the technologies described above.

Table1: *Average degrees of improvements in soil stiffness properties*

| Structure | Year of construction | Degree of improvement |
|---|---|---|
| The port of Ploče, Ploče | 1998 | 3.12 |
| Potable water treatment plant, Slavonski Brod | 1999 | 3.82 |
| Housing and hotel complex HIT Marina, Novi Vinodolski | 2001 | 3.47 |
| Overpass on the Zagreb-Goričan Motorway | 2002 | 3.11 |
| Kaufland Shopping centre in Zagreb, | 2003 | 4.14 |
| Residential buildings, Government subsidized housing projects, Rijeka | 2003 | 3.34 |
| Welfare Centre Building, Ploče | 2003 | 3.75 |
| Warehouse and boiler room at the Uljanik Shipyard, Pula | 2003 | 4.25 |
| BOKŠIĆ Apartment Hotel, Makarska | 2004 | 3.42 |
| SRZIĆ Hospitality and Tourism Building, Makarska | 2004 | 3.87 |
| ZLOPAŠA Apartment Hotel, Makarska | 2004 | 3.87 |
| Residential and office building OMING, Omiš | 2004 | 4.11 |
| Office Building PORR – ZAGREB TOWER, Zagreb | 2005 | 3.61 |
| Embankments on the Zagreb-Macelj Motorway | 2005 | 3.56 |

Figure 9: *Stage of compaction work operations*

Figure 10: *Examples of structures built in the improved soil*

## 6. Conclusion

The technology for soil improvement using deep vibro technique has been applied and developed in Croatia by the GeoTechnik Company of Varaždin, a member of the Keller Group. The technology for quality control of soil improvement by means of the Spectral Analysis of Surface Waves method was developed in cooperation with the Department of Geotechnics of the Faculty of Civil Engineering in Zagreb.

The described technologies for deep soil vibro compaction are sure to make it possible for the engineer to obtain significant improvement in stiffness and bearing capacity of natural soil. The quality control of soil improvement can be made efficiently using a method called Spectral Analysis of Surface Waves (SASW). This method is classified as non-destructive testing method. It is used on the ground surface and does not require expensive borings. Measurement is reliable because soil disturbances due to boring, sampling, and installation of samples in laboratory equipment are avoided. This method solves some of the fundamental problems of surface refraction as it can detect a softer layer that is located under a stiffer layer. The technique is rapid and enables the engineer to make a large number of measurements during one site visit.

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# TECHNOLOGIES AND PRODUCTS IN THE BIOENGINEERING AREA

# The Novel Technologies for the Use of Biocatalyst and Biotransformations

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*Summary*

Throughout the history of mankind, microorganisms have been of tremendous social and economic importance. In the course of time, it was discovered that microorganisms could modify certain compounds by simple, chemically well-defined reactions, which were further catalyzed by enzymes. Nowadays, these processes are called "**biotransformations".** Biotransformations are reactions in "one or two-steps" where the chemical structures of the substrate and product resemble one another. The reactions are catalyzed by isolated enzymes or enzymes in whole cells. These enzyme forms are named biocatalysts (Vasić-Rački, 2000)

In comparison to fermentation processes fewer side-products are formed in enzymatic biotransformations, complex expensive fermentors are not required, aeration, agitation and sterility need not necessarily be maintained and substrate is not diverted into the formation of *de novo* cellular biomass. Isolated biocatalysts are especially useful if the reaction they catalyze is about to be completed, if they are resistant to product inhibition, and if they are active in the presence of low concentration of substrate (such as in detoxification reaction where pollutants are present in the waste stream). "One-pot" multi-enzyme reactions are much more feasible than a combined use of several chemical catalysts or reagents, especially as the latter often have be used in reactors made of special resistant materials to tolerate extreme conditions, such as the use of concentrated acids under elevated temperatures and pressures.

*Key words:* biocatalysts, biotransformations, malic acid, pyruvic acid, L-*tert* leucine

## Introduction

Since early 1970s the use of biotransformations in industry for the "fine" as well as for the traditional chemicals, pharmaceutical and agrochemical intermediates production has steadily increased. Presently, approximately 100 different biotransformations are carried out in industry (Liese *at al*, 2000). Without doubt, there will be an increase in the industrial use of biocatalysts over the next 10 years because the biotransformations had led to a reduction in waste generation from 10 to 2 tones per ton of product. In the fine chemical sector, it would be in order of one million tones of waste per annum. Biotransformations can be carried out at ambient temperature and neutral pH without need for high pressure and extreme conditions thereby saving process energy. The use of biocatalysts has proven to be supplementary technology for the chemical industry too allowing in some case reactions, which are not easily conducted by classical reactions or in other cases allowing reactions, which can replace several chemical steps. Thus, highly chemo-, regio- and steroselective biotransformations can simplify manufacturing processes and make them even more economically attractive and environmentally acceptable. Recombinant DNA technology has dramatically changed enzyme production, because enzymes are synthesized in cells by the normal protein synthesis methods. A 5-10 year period required for classical enzyme development can be reduced to 1-2 years. Protein engineering, in combination with recombinant expression systems allows to plug in a new enzyme variant and to be very quick and cheaper at manufacturing levels. It is now well-known that enzymes do function in various forms, in organic solvents, and many in neat (pure) solvents or in supercritical fluids in the absence of added water, and finally in gas phases. Until now, mainly isolated hydrolases are used industrially with water as solvent (penicillin G splitting, hydrolysis of acrylonitrile, hydrolysis of methyl-p-methoxyphenyl-gycidate). On another hand, oxidoreductases were used from whole cells in the industrial biotransformations (sorbit-sorbose oxidation, biocatalytic steroid hydroxylation). A considerable amount of time elapsed before the first isolated oxidoreductases were used in industry (synthesis of L-*tert*- leucine (Kragl et al.1996)). The development of the continuous coenzyme regenerating system by means of the isolated formate dehydrogenase had made it possible (Wichmann and Vasić-Rački, 2005).

The biotransformations at mild conditions with high regio- and enantio-selective biocatalysts are green and economical alternative in chemical, pharmaceutical and agrochemical industry, because highly chemo-, regio- and stereoselective biotransformations can simplify manufacturing processes and make them even more economically attractive and environmentally acceptable. The range of customers considering the utilization of enzymes, as a replacement to conventional chemical methods, appears to be growing. It appears that enzyme-based processes are gradually replacing conventional chemical-based catalyst e.g. the use of enzymes as catalyst provides a very new way of polymer synthesis; most of these polymers are otherwise very difficult to synthesize by conventional chemical catalysts (ESAB, 2005).

It is no longer the case that biotransformations are relevant only to high added-value products such as pharmaceuticals. Bulk chemicals including polymers may have biotransformations such as conversion of methane to methanol (Chevron Research and Technology and Maxygen) or conversion of sugars to 3-hydroxy-propionic acid (Cargill Inc. USA) or dehalogenation step in Dow's alkene oxide process. The next generation of biotransformations based process will target large volume chemicals and polymers and will compete directly with petroleum-based products.

Biotransformations are becoming competitive with conventional routes, but industry expert believe that further improvements in enzymatic catalysis and fermentation engineering may be required before many companies are prepared to announce world-scale bioprocess plants. Bioprocessing proponents see a future in which micro-organisms are replaced by purified enzymes, synthetic cells or crop plants.

Today, both the academic and the industrial community see biocatalysis as a highly promising area of research, especially for the development of sustainable technologies for the production of chemicals and more selective and complex active ingredients in pharmaceuticals and agrochemicals.

## Production of pyruvate

Pyruvic acid and its salts serve as an effective starting material for the synthesis of drugs, agrochemicals and fat burners (Zelić, 2003). It is also a valuable substrate for the enzymatic production of amino acids such as L-dihydroxyphenylalanine (L-DOPA) (Li *et al*, 2001).

There are two different approaches for the production of pyruvate: a) the classical chemical routes and b) biotechnological routes.

### *a) The classical chemical routes:*

There are several chemical syntheses for pyruvate production. In the oldest one, which is described, pyruvate is produced by the dehydration and decarboxylation of tartaric acid in the presence of potassium hydrogen sulfates at 220 °C (Howard and Fraser, 1932). Decarboxylation of diethyltartarate (Sugiyama *et al*, 1992), oxidation of propylen glycol (Tsujino *et al*, 1992) and oxidative dehydrogenation of lactic (Ai and Ohdan, 1995), in the presence of heavy metals as catalysts and high temperature are also recently described. These chemical processes have in common that they are energy-intensive and that they use a heavy metals. Accordingly, these processes are not environmentally friendly. Therefore, more sustainable "green" process alternatives have been developed in the last two decades.

***b) Biotechnological routes:***

These process alternatives can be divided into three different approaches using: 1) isolated enzymes (Burdick and Schaeffer, 1987; Eisenberg *et al*, 1997); 2) resting cells (Izumi *et al*, 1982; Ogawa *et al*, 2001; Schinschel and Simon, 1993); and 3) fermentation (Li *et al*, 2001; Yokota *et al*, 1994).

The bioconversion of glucose to pyruvate with non-growing, acetate auxotrophic cells of *Escherichia coli* YYC202 *ldhA::Kan* (Gerharz *et al*, 2002; Zelić, 2003; Zelić *et al*, 2003a; Zelić *et al*, 2004; Zelić *et al*, 2004a,), which is presented in Figure 1., offers the opportunity to produce pyruvate from sustainable, low cost substrate, glucose, with high product/substrate yield ($Y_{P/G}$=1.78 mol/mol), high volumetric productivity ($Q_P$=145 $g_{pyruvate}$/L/d and high product titers of about 65 g/L.

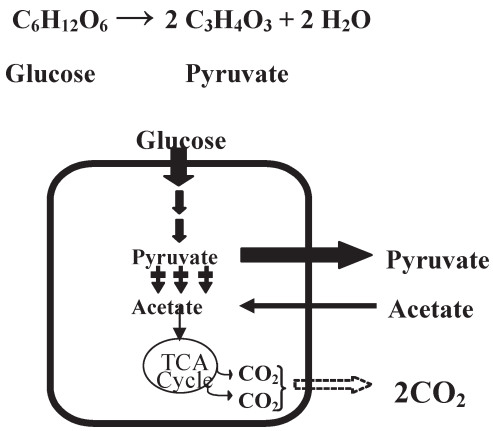


Figure 1: *Non-growing, acetate auxotrophic cells of Escherichia coli YYC202 ldhA::Kan (Gerharz et al, 2002, Zelić, 2003)*

**Production of L-malic acid**

The production of malic acid has received great interest because this four carbon dicarboxylic acid is commonly used as a food and beverage acidulant, mainly as the D, L-racemate mixture, in food industry (Giacobbe *et al*, 1980). Moreover, to a lesser extent, the L-isomer of the acid, which holds about 10 % of malic acid market (Bressler *et al*, 2002), is used as a component of amino acid infusions and in the treatment of hyperammonemia and liver dysfunction (Goldberg *et al*, 1991). L-malic acid is incorporated in powdered soft drinks in conjunction with aspartame, as a flavor fixative and is used as an emulsifier for the manufacture of margarine and mayonnaise. L-malic acid as a monomer is used in synthesis of biodegrad-

able polymers (Rossignol *at al*, 1999; Wada *et al*, 1996). It is presumed, that about 40 000 t of malic acid are used worldwide annually.

The traditional method for preparing L-malic acid was by extraction from apple juice which has 0.4-0.7 % of L-malic acid and therefore it is not economical. Hence, today malic acid is produced by two additional processes: 1) chemical synthesis via hydratation of maleic or fumaric acid at high temperature and high pressure, yielding the racemic mixture, and 2) enzymatic synthesis, whereby fumaric acid is transformed to L-malic acid. Direct fermentation of carbohydrates to L-malic acid by *Aspergillus flavus*, though well-know, is not used in industry because of moderate productivity and the potential toxicity of the producing organism (Peleg *et al*, 1988).

In the current industrial enzymatic process, fumaric acid is continuously converted to L-malic acid by immobilized whole cells of *Brevibacterium ammoniagenes* or *Brevibacterium flavum* (Takata and Tosa, 1993), containing the enzyme fumarase with high activity. The yield of L-malic acid reaches about 70 % of theoretical. The unconverted fumarate is recycled. The enzymatic reaction is carried out at neutral pH and results in L-malic acid salts. Thus, downstream processing involves separation of the un-reacted substrate as well as isolation of free acid. The enzymatic batch process using *Corynebacterium glutamicum* (Daneel and Faurie, 1994) also exists, but continuous process is more economical.

The reaction catalyzed by fumarase is as follows:

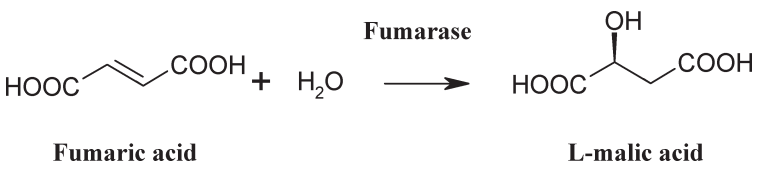


Figure 2. *Enzymatic process for L-malic acid synthesis.*

Fumaric acid is transformed into L-malic acid by addition of water molecule to the double bond. The process is a typical equilibrium reaction. The enzyme is highly stereospecific.

Fumaric acid is obtained using byproducts resulting from the production of phthalic anhydride. The application of fumaric acid in the industrial field is limited by its low solubility therefore the conversion to L-malic acid is a solution.

Even though the enzymatic process is environmentally more acceptable, the cost of L-malic acid produced by fumarase reaction from fumaric acid is higher than chemically synthesized acid. Therefore, the attempt to make it more economically is needed.

Thus, a strain *Saccharomyces cerevisiae* was engineered to overproduce fumarase (Bressler *et al*, 2002). The advantage of this microorganism lies in in-

creased productivity; lack of succinate accumulation and of course, compatibility with the requirements of food product safety. The yeast was immobilized in small glasslike beads of the composite alginate-silicate matrix ensuring the long-time stability. It was found (Vrsalović Presečki and Vasić-Rački, 2005) that *Saccharomyces bayanus* (UVAFERM BC) had the high activity of fumarase. Cells was permeabilized with 0.2 % (w/v) CTAB for 5 min. The average achieved conversion of fumaric acid of up to 82 % gives 21, 40, 83 and 175 mM of l-malic acid respectively from 25, 50, 100 and 210 mM fumaric acid.

## Production of L-*tert*-leucine

The synthesis of L-*tert*-leucine is an example of the application of oxidoreductases with cofactor regeneration in an industrial continuous process (Kragl *et al,* 1992; 1993*;* Kragl *et al,* 1996; Bommarius *et al.,* 1998). This chiral amino acid is important building block for drug synthesis (Fig. 3). Its chemical synthesis is not known.

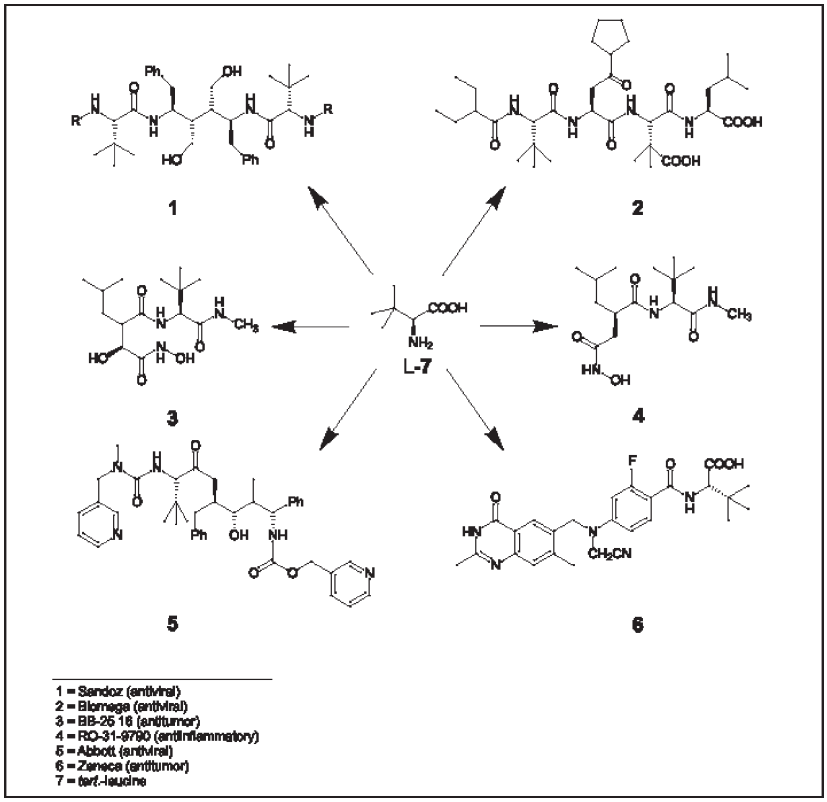


Figure 3. *L-tert-leucine a building block for drug synthesis (Liese et al, 2000).*

Therefore, only the enzymatic synthesis by oxidoreductase is available.

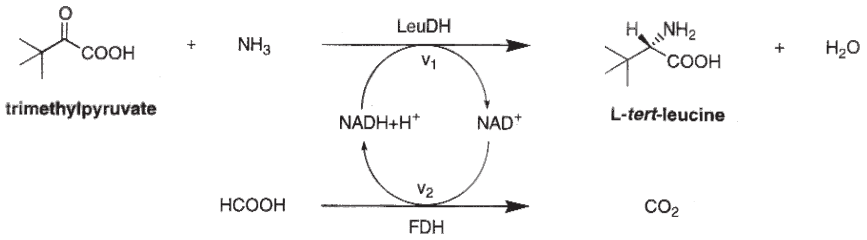


Figure 4. *The enzymatic synthesis of L-tert-leucine from trimethyl-pyruvate catalyzed by leucine dehydrogenase with simultaneous regeneration of cofactor by formate dehydrogenase (Kragl et al, 1996).*

The kinetics of the substrate and the cofactor of this reaction can be described by Michaelis-Menten double substrate kinetics (Kragl *et al,* 1996*,* Vasić-Rački *et al*, 2003), taking into consideration a competitive product inhibition.

The calculations for this synthesis (Kragl *et al.,* 1992) indicated the way in which the total turnover number depends on the cofactor concentration. The dependence shown is valid for a conversion of 90 % adjusted by the corresponding variation of the residence period. Whereas the space-time yield rises with an increasing cofactor concentration, the total turnover number achievable simultaneously drops. This behaviour is found both for the polymer-enlarged and for the native cofactor. The space-time yield is somewhat higher for the native cofactor since a higher reaction rate is achieved due to favourable kinetic parameters. From the economic point of view, a compromise must be made between space-time-yield and total turnover number, which directly determines the cost of the cofactor. Due to the low price now achieved, the native cofactor can be used economically in the continuous process for the smaller achievable total turnover numbers.

The understanding of the enzyme reaction engineering of such systems is useful in determining the optimum reaction conditions.

The overall reaction rate for the formation of L-*tert*-leucine as a function of the concentration of trimethylpyruvate and the cofactor concentration for 90 % substrate conversion rises with the increasing cofactor concentration whereas it drops with the rising substrate concentration. At the given conversion of 90 %, this drop can be attributed to increasing product inhibition. The activity ratio of the two enzymes applied also influences the achievable space-time yield. Different conversions are achieved at a constant enzyme ratio by varying the residence time. In calculating the enzyme molar fraction, the enzyme activities determined under the initial reaction rate conditions are used. At low conversions, the maximum space-time yield must therefore be found at the molar fraction of 0.5. As the conversion increases, the maximum of the achievable space-time yield is shifted towards smaller enzyme molar fractions since the production enzyme and the regeneration enzyme

are influenced to a different extent by the concentrations of the reactants, which are changed with increasing conversion. To achieve the same reaction rates for both enzymes under the concentration conditions prevailing in the reactor, the production enzyme must be applied in larger quantities due to the very strong product inhibition.

The CSTR with the ultra filtration membrane is by far one of the simplest reactor configurations for continuous process realisation and is widely used in many biochemical reactions.

While being advantageous for reactions with substrate inhibition, this reactor is disadvantageous in cases of severe product inhibition as in the synthesis of L-*tert*-leucine from trimethylpyruvic acid. A system of two membrane reactors in series can be proposed as a solution for the reaction in question (Kragl *et al,* 1996).

From the economic point of view, a compromise has to be made between the space-time yield, the conversion and the activity of two enzymes that are used. Different conversions at a constant enzyme ratio are achieved by varying the residence time. A comparison among the three types of reactors shows that the maximum space-time yield is found in the batch reactor at the enzyme activity fraction of 0.5. The maximum of the achievable space-time yield in the batch reactor is shifted towards smaller values in the CSTRs in series. The smallest enzyme activity fraction is found for the single CSTR. This can be explained by the fact that the production enzyme (LeuDH) and the regenerating enzyme (FDH) are influenced to a different extent by the concentrations of the reactant and the product. These concentrations are changed according to the different increase of conversion in each reactor type. The main reason responsible is the product inhibition by L-*tert*-leucine. Therefore, with increasing conversion the maximum of the space-time yield is shifted to lower enzyme activity fractions for all three reactors. It is therefore possible to minimise the biocatalyst cost in the reactor by maximising the space-time yield if other destabilising effects are excluded. The minimal biocatalyst cost is achieved in the batch reactor. Even at the highest conversion of 98 % required from the practical point of view, the difference in the biocatalyst cost in the batch and two CSTRs in series is negligible. At that conversion, a single CSTR cannot compete with the batch reactor any more.

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# Development of Furniture in Croatia

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*Summary*

In the furniture sector of industrialized countries development of furniture design, constructions, technologies and knowledge along with the use of innovative materials has advanced in recent years so much that many professionally and technologically lagging countries cannot consistently follow this upward trend. Croatia is one of the countries that in the past few years has neither systematically invested into nor developed this strategically important sector, which resulted in its stagnation. With the aim to revitalize and develop the entire furniture industry, local experts are facing a difficult task of finding out a model and generating the operative plan for development of this industrial branch. At the same time they must focus on designing and distribution of a well-known local finished brand that incorporates the lasting, nationally and internationally distinguishable values.

In order to identify development strategy of the national furniture industry, the Croatian Government has, at the recommendation of the Ministry of Agriculture, Forestry and Water Management, passed the *National Forestry Policy and Strategy* (Official Gazette No. 120/03) and *Development Strategy of Wood and Paper Processing* (Official Gazette No. 114/04). They both deal with market research and development of high-quality finished products of a well-known domestic design, and with the promotion and use of domestic timber and wood resources in local produces to be ranked globally among highly priced products. Sustainable development and competitiveness of furniture production require investments into development and adoption of new technological solutions, investment-encouraging environment, innovativeness, research, new products development, entrepreneurship as well as rapid programmatic and market reforms, unimaginable without financial and expert support.

Operationalization of these principles brings a long-lasting success to both the individual and the unit product and creates identity of the Croatian furniture sector.

*Key words:* furniture, timber and wood industry, development, design, new technologies

## 1. Introduction

Furniture is the product of human creative activity. Its shape, construction, material and technological design have reflected living conditions, habits and taste of its makers as well as manufacturing conditions and social development of a country. For centuries furniture has been a unique masterpiece of its artisans (later of other craftsmen too) and has reflected specific style, habits and needs of its users. Wood, metals, stone and other natural materials of specific aesthetic, mechanical and other properties are the commonest material make. Industrial development, new technologies and novel materials have increased the use of non-wood and synthetic materials treated by the state-of-the-art technologies. At the same time design loses national attributes and becomes global.

Recent technological growth and development of furniture industry in industrialized countries has been so rapid owing to the fast development of innovative materials, technologies, knowledge and design. Many countries cannot consistently follow this upward trend. Croatia is among the states which are not professionally and technologically equipped and which during past years has not systematically invested into this branch or thought about this issue. On the other hand, latest foreign investments into local companies have prevented generation of a well-known domestic brand because the products are being designed by foreign designers and are intended mostly for export. Such subordination of local producers cannot guarantee longevity and recognition of companies or products. Consequently, local experts are facing a difficult task of finding out a model for development of this industrial branch. At the same time they must focus on designing and distribution of a well-known local finished brand so as to create the products that incorporate the lasting, nationally and internationally distinguishable values.

Current development of furniture in Croatia is a very complex issue. This is partly due to the overall timber and wood-processing sector (based on high-quality wood trees, primarily oak, beech and ash trees) having markedly overcapacitated primary part (saw-mill production) and to organizationally-technologically uncompetitive furniture manufacture, still requiring unambiguous programmatic orientation.

The question is how to increase competitiveness of the final Croatian product – furniture – and how to create its well-known *brand*?

In order to define major issues in the Croatian forestry sector, to specify main strategic directives of its further development and accommodation to the open market and, thus, to determine furniture industry development, at the recommendation of the Ministry of Agriculture, Forestry and Water Management, the Croatian Government has brought *National Forestry Policy and Strategy* (Official Gazette No. 120/03) and *Development Strategy of Wood and Paper Processing* (Official Gazette No. 114/04).

## 2. Analysis of the Croatian Furniture Industry

Furniture industry as the branch of timber and wood industry has always been a significant factor of the Croatian economy. With introduction of the open market many relations within the sector have undergone fundamental changes, manifested as structural changes of timber and wood processing companies, changes in their production programmes, significant deployment, losses of markets and other untoward trends. According to economic indicators and philosophy of the Croatian manufacturing companies, furniture production has been dealing for years with structural and transitional crisis.

Croatia today manufactures wood of all types and dimensions, veneer and veneer boards, chopped wood boards, parquet, floor and wall linings, wooden construction elements, wooden packaging, wooden furniture or wooden furniture combined with other materials, impregnated wood for various purposes (sleeper timber and poles) and many fancy goods made of wood (musical instruments, sports equipment, brushes, etc.). The companies comprising industrial processing of timber, wood and paper sector are officially classified in three main groups: wood and timber processing and manufacture of wood products (DD-20), furniture industry and other processing industries (DN-361) and production of cellulose, paper and paper products (DE-21).

In 2004 the Croatian furniture manufacturers produced 4.1 billion pieces of furniture. Chairs accounted for majority of these products (59%), domestic furniture for 24%, office furniture for 9%, upholstered furniture (armchairs and two- and three-seaters) for 5% and kitchen furniture for 3% (figure 1).

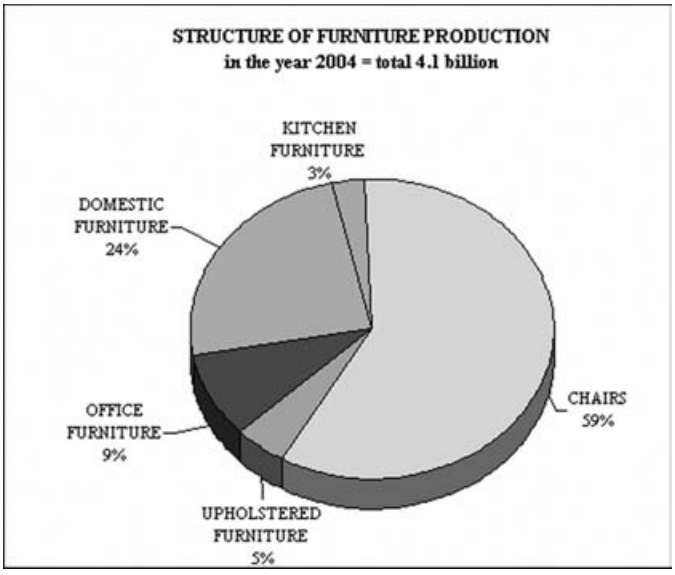


Fig. 1. *Structure of furniture production in the Republic of Croatia in the year 2004*
*Source: The Croatian Chamber of Economy*

Big export of the raw material has a negative effect on domestic production of finished products by causing shortage in good-quality raw materials on the local market. This impairs due development of finished products manufacture (in 2003 there were 346 furniture manufacturers) and reduces the employment rate (in 1990 furniture sector (DN-361) employed 13,600 people and in 2003 this number fell to 10,800). Current structure of finished products production (excluding a few praiseworthy examples) requires urgent reprogramming and ability to sell locally designed products (at this point the supply is hardly available) on the market of high-quality finished products.

### *2.1. SWOT analysis of the national wood sector*

Recognition of own strengths, weaknesses, opportunities and threats of this sector is the important precondition for realistic and sound forecast of furniture industry prospects. SWOT analysis (strengths – S; weaknesses – W; opportunities – O and threats, limitations – T) is one of the methods for objective evaluation of the situation and for analysis of the sectoral development strategy. It has yielded valuable results in the analysis of the Croatian wood sector. Nowadays, with globalization, new technological achievements and productivity increased by new models, techniques and management organizations, the Croatian furniture industry (according to SWOT analysis) shows marked **weaknesses**. It is disintegrated, mismanaged, fragmented, disconnected, has inappropriate qualification structure, practically incompetent people, undeveloped quality assurance system, improper public relations and overall investments into marketing and promotion, poor substitution of finished products and export of sawn raw materials and semi-finished products. All these weaknesses make it poor, technologically outdated, programmatically undefined and, consequently, increasingly uncompetitive. Despite significant **strengths** of the whole timber and wood processing sector (e.g. marked processing potentials, available infrastructure and technological capacities which require modernization) it has good-quality and certified raw materials, it is export-oriented for its finished products, has experience and tradition in the manufacture of good-quality products and outstanding growth potentials. **Opportunities** are great and relate to increased competitiveness, export of high-quality finished products, complexity and establishment of new cooperative links within the sector. There are limitations indeed, primarily in the competent people (mostly designers and constructors) which can contribute to better placement of a future finished product. **Threats** are unfavourable economic and investment policy, uncontrolled expansion of saw-mill capacities, poor use of wood raw material (e.g. in recent years the investments into saw-mill processing of timber and wood have increased – in 2003 there were 722 wood and timber processing companies!) due to which saw-mill capacities are more than three times above the available wood and timber mass that Hrvatske šume d.o.o. can supply, sectoral structure is inappropriate, there are no brands and

structural changes (such as those going on in the competitive East-European countries) are absent.

### *2.2. Forecasts*

Given the intensive negotiations about inclusion into the above mentioned world and full EU membership, Croatia will very soon share equal rights with other EU member states. Current traditional local production will inevitably change its development strategy. The Croatian wood industry, particularly furniture production and marketing, failing to invest into development and to adopt new technologies will not be able to compete with the neighbouring industries. Simultaneously, the united and unique market will have equal rules for all stakeholders – competitors. What to do and how to act?

According to FAO 2010- 2020 year forecast Croatia is among the countries that will have a surplus of sawn timber. In other words, it will be the exporter of sawn timber and elements rather than the exporter of finished wood products.

To make this forecast fail, this sector must be developed and restructured; employment, production and export increased and regional development and development of other related economic activities initiated. It is very important to redefine export strategy because its current structure increases the demand in raw materials and semi-finished products. Locally manufactured finished products must meet the needs of global market, whereas marketing activities of domestic stakeholders need to be intensified. Interdisciplinary activities of all stakeholders, particularly of designers, constructors, technologists, manufacturers and distributors must be aimed at designing a competitive, export-oriented, indigenous and high-quality Croatian finished product.

## 3. Global directives for designing and manufacture of furniture

What should be Croatia's approach to new products development aimed at global and local competitiveness? A sound reply to this question requires consideration of world trends in furniture development and consideration of furniture models.

Global furniture industry is systematically investing into interdisciplinary research, new technologies and technological innovations, improvement of materials, production, processing know-how, design, visual communication, advertising and marketing.

The industrialized countries have realized long time ago that development, innovations and design are strategic stimulators of a sound production development. Design is being increasingly recognized as the main carrier of products development. Linking of conceptually different directives and national modelling patterns

creates foundations for new solutions development in furniture design and production. Systematic investments into interdisciplinary research and knowledge along with development-technological innovations in materials and processing techniques facilitate designing inventiveness and creativity. This brings novel approach to furniture design and determines new trends in exterior design and quality of make and finish. Innovations in design and construction also influence development of new technologies and production. Design is becoming a key to products' development. *Brand* of a product and, consequently, brand of a company have become inevitable marketing parameters.

There is a marked consistency in the production of furniture showing paramount design, very sophisticated aesthetics and functionality, high production and processing technology and concealed internal values. Visual design and novelty are in the first plane. New materials, technologies and products are eye-catching. Whole wood is being replaced by new wooden materials (combinations of wood-plastics or wood with other synthetic materials), plastics, glass or metal. Regardless of furniture quality, design maintains its position.

On the other hand, the number of less flexible manufacturing companies is increasing (in Croatia, with their equipment and management they can be major carriers and designers of the Croatian quality and ingenious national product). They are characterized by individual production of a paramount product (carrying in its design and construction national characteristics and emotions). This product has special design and construction, it is made of uncontaminated raw material (most commonly of wood) and in small batches.

## 4. Challenges to the croatian furniture industry in the near future

Sustainable development of furniture sector (as a markedly prospective branch of the Croatian timber and wood industry on a long-term basis) and its international competitiveness require speeding up of the programmatic and market reformation. Financial and professional support is indispensable to achieve this goal. Only by investing into development and with new technological solutions furniture industry can become competitive on the unique European market which has equal rules for all.

Appropriate relations between the forestry and wood and timber processing sector, productive participation of relevant institutions and engagement of other state entities can help establish the environment which would encourage investments, innovations, research and new products development. Easier access to financial institutions and reduced operational costs would also encourage entrepreneurship. Comparative advantages of wood and furniture industry are the quality and available raw materials, production tradition, well-established business links with foreign partners and demands of the local market.

### *4.1. The measures to upgrade furniture quality and production*

Operative programme for development of wood and timber processing sector implies specific measures for upgrading of furniture quality and production.

#### *4.1.1. Changes in the current production structure*

Changes in the current production structure of semi-finished products and raw materials in the favour of finished products along with the use of local wood and timber resources can increase furniture competitiveness and its availability on the local and foreign markets. Consequently, export of the higher- and high-quality products and services must be increased so that these goods are classified as such and that the profit is generated for encouragement of further development.

##### 4.1.1.1. Raw material

Irrespective of many substitutes and other synthetic materials developed, wood is still a dominant raw material in the worldwide furniture production. Biologically uncontaminated raw materials and natural materials ("biomaterials"), whole timber, glued constructions and wood materials (particularly chopped wood boards and laminates made with nature-friendly glues) are current trends, so very important for the Croatian economy.

As much as 44% of Croatia's surface is woodland (i.e. 2,485,111,000 ha) which must be preserved and rationally exploited. Nearly 88% of total wood stocks (estimated to cover 324,256 million sq.m.) are state-owned. *Hrvatske šume d.o.o*. and other legal entities manage 86% and 2% respectively. Private forests account for 12% of wood inventory. These facts are very important for the future of national wood and timber industry, particularly as regards furniture sector. Already now Europe is scarce in wood as the raw material, especially in uncontaminated and healthy timber, which is still available in Croatia. Channelling of production to export of the finished product, rather than of the semi-finished or even more dramatically a green log is the key to Croatia's presence on the global market.

*Hrvatske šume d.o.o.* has a prestigious FSC certificate (Forest Stewardship Council) for forest management. In other words, forests are managed under strict ecological, social and economic standards. This certificate is one of the key tools for forest sustainability and contributes to increasing users' awareness about this issue. FSC programme is aimed at promotion of ecologically accountable and socially and economically sustainable management of global forests through implementation of the generally approved *Principle of Accountable Forestry*. FSC certification carries its weight, inasmuch as it applies to the whole state-owned wooded area, which is a unique case in the world. It also suggests indisputable quality of

the raw material and possession of a biologically renewable raw material for further processing, particularly in the manufacture of finished products.

Accordingly, certified wood is available to the local wood and timber processing industry which sells its products on the local and foreign markets. Regretfully, local market lacks sufficient awareness about sustainable management of woods and about compulsory FSC labelling of the finished wood products. However, to approach foreign markets and to gain competitive advantage it is very important that both the raw material and finished products are certified.

### *4.1.2. Technological modernization*

Introduction of new technologies and upgrading of the available industrial capacities can grossly increase competitiveness of the production. Rapid modernization of the existing capacities requires cooperation between the research-development institutions and production companies, importation of innovative technologies and investing through rationalized administrative management.

#### 4.1.2.1. Technological innovations and modernization

Investments into new technologies bring innovations to the production of furniture industry worldwide. Most frequently the innovations are generated from the struggle for competitiveness and costs reduction. They can also be market- or user-based, in which case they indirectly influence development of new technologies. The first type implies automation, CAD/CAM and sophisticated CNC systems with the use of new, considerably low-priced materials and significant use of Internet services, particularly in the products sale. Market-based innovations are determined mostly by (re)design and changes in the object's shape or function. A demanding customer can significantly determine further course of production development by interfering with the use of new materials (e.g. natural biologically uncontaminated raw materials, recycling, etc.), ecological awareness (the use of biomass), ergonomic requirements (safety and health), etc.

### *4.1.3. Cooperation between local and furniture manufacturers (establishment of clusters)*

With the aim of establishing and selling the Croatian well-known brand on the local and foreign markets, which implies increasing of the employment rate, wood and timber processing sector has initiated establishment of cluster organizations in wood and timber sector. Generally speaking, they are the trend in global economy and mark the linkage of various economic entities on the regional level. Philosophical framework of clustering is based on the connections between societies and in-

dustries and societies and related institutions under mutual understanding and the use of available economical base as well as on the links between small- and medium-sized economy, public sector and associations. The aim is to exchange knowledge and information and to upgrade proficiency and cooperation. They base their activity on innovations and education.

Clusters in the Croatian wood industry, and thus in furniture industry, are economically justified by availability of natural resources of raw materials, experience and knowledge of the work force, inclusion and development of local suppliers and cooperants, and availability of technical infrastructure. As already witnessed worldwide, clusters in the Croatian wood and timber processing, furniture and paper sectors will increase the employment rate and export of finished products, especially of furniture.

### *4.1.4. Development of the local (stock) market with raw material and semi-finished products as a precondition for development of finished products market*

Organization of the stock market and its operations requires defined operating regulations and rules, a designed long-term national balance sheet of available wood raw material and a manufacturing balance sheet of the wooden finished products (furniture, parquet, window frames, doors, etc.). Without reliable long-term forecasts of commercial woods (with all sorts of trees) the investments into production capacities and continuous development of the wood and timber processing sector, especially of the furniture sector, are not economically sound and safe. Only these forecasts can give a realistic picture of production potentials for exported finished products made of wood and of the potentials of wood and timber processing capacities based on domestic raw material.

### *4.1.5. Investments into new qualified human resources*

Technology nowadays is the product of science and its systematic fundamental and applied research. Irrespective of the increasingly automated furniture production, the need in the qualified human resources is the imperative. Education of the work force at any level is indispensable. World trends in furniture design have shown the need in manual finishing of products, consequently in the respectively skilled resources. On the other hand, a supreme-quality product of nearly paramount make results from the investments into development and the use of new sophisticated technologies, manageable only by highly qualified people who are indispensable for sectoral restructuring in Croatia.

The Croatian wood and furniture industries as well as many other branches being retarded in their development and research are very dependent on technologies and knowledge from abroad. Frequently, the existing resources are not capable of

mastering the imported technologies and of their further development. This fact underlines the importance of their education and training.

Vigorous technological advancement along with significant and rapid political, social and economic changes in Europe and worldwide have brought dramatic changes to educational systems in which Croatian is included as well.

Current national educational system, comprising kindergarten, primary, secondary, tertiary and life-long education must be reformed to accommodate to the needs of labour market. Consequently, systematic curricula must be implemented already at the secondary educational level (especially at woodworker and related schools and at schools of applied architecture and design) and at all respective Faculties (Forestry, Architecture, Administration and Design). The measures for better motivation of students must be proposed and Faculties must be continuously evaluated internally and externally. Premises, qualified staff and equipment must be provided and developed. All this will give a better picture of trends in wood and timber processing sectors already during academic period. The students will then be able to channel their interest on mastering either production organization or production management. For example, elsewhere in the world the projects which link students' works with furniture manufacturers have become traditional form of cooperation between academic institutions and economy. Their benefit is mutual and twofold – the students detect their creative potentials whereas the companies can select much in advance their future employees and prepare them for real world of intellectual and production competition. Figure 2 shows one of such cooperation between future designers and Tvin d.d. Virovitica.

Fig. 2. *OWELL – office furniture system, design by Danijela Domljan, student project, produced by Tvin d.d. Virovitica, 1993*

The structure of managing staff in companies shows the need for development of specific educational systems that will enable mastering of new knowledge and skills. Education of technical staff is one of priorities because of rapid changes arising from frequent novelties in the use of reproduction materials. Foreign languages must be studied at all educational levels.

### *4.1.6. Investments into research, development and design*

Majority of the worldwide development strategies in furniture production are channelled towards innovativeness, technologies and costs reduction and particularly to products design. Tough market competition and furniture marketing strategies impose special requirements upon this production. The Croatian furniture development strategies should be focused on market research, development of high-quality finished products with well-known local design and on recognition and implementation of local wood resources in local produces to help our listing among the global high-ranked classes. After being familiarized with construction, technology and furniture raw material (wood) the Croatian designers should be systematically included in all development stages of a product. Given the differences in basic assumptions of designers, constructors, technologists, manufacturers and sellers, all entities must be involved in interdisciplinary cooperation so that each and every of them understands methodology of other professions and their mutual dependence. Education about the importance of interdisciplinarity and cooperativeness is the important step in further teamwork.

#### 4.1.6.1. The role of design in furniture development

For many experts design is the solution, although it is only one of determinants of a product successful launch. No matter how outstandingly good it is, it can fail at one of unbridgeable steps of its development – in marketing. Design in Croatia has not been recognized yet as a significant segment in competitiveness and international acknowledgement nor has its potential been fully exploited as it is, for example, in Italy and Finland. These two countries build up their national image on a well-known design of their products. Moreover, Finland additionally does it by using its local raw material.

How about Croatia? It is not only that it exports its good quality raw material at a low price, but it also exports its designers who then work for celebrity brands but under a fictitious name. Croatia has many young designers (about 150 highly qualified product designers) requiring vocational training in this field and, vice versa, users of design must be taught about designer's role in the product's life and designer's contribution to product's successful launch (provided the designer is familiar with all standards of a future product). This is a complex and mutual process aimed at creating a finished, well-known indigenous product for export.

Accomplishment of this goal needs the preconditions for marketing, design, product development and a new *brand*. Currently, the Croatian wood and timber processing industry does not play any significant role on the global market of finished wood products. This must arise from the absence of marketing activities at various levels.

A finished product gives an added value to product unit and enables better utilization of raw material resources. All the way to the finished product is time-con-

suming and a hard-working process. *Brand* development implies permanent involvement of institutional and production entities for familiarization with political and legal environment of potential markets. Based on these information target markets and main production programmes are identified and the analyses of financial operations and *benchmarking* of local products and sectoral manufacturers competitiveness are analysed.

Croatian manufacturers of finished wood products must be encouraged to apply for the *"Croatian Quality"* and *"Croatian Creation"* label which the Croatian Chamber of Economy gives to the products compliant with high worldwide standards and which are the result of development-research works and innovations.

## Conclusion

Furniture development nowadays faces many challenges coming from various areas - design, construction, manufacture, marketing and sale. Primary goal of furniture industry (satisfaction of changeable and individual tastes, habits and needs of increasingly demanding customers) asks for development of new cooperation schemes, based on different marketing strategies. They are major support to the trends in design and production. The art of furniture design and production is now mostly design, innovation, technology with relevant development and education of the respective resources.

Many various parameters show that Croatia has much human potential for furniture design and production. Development strategy for large-scale production and competitiveness should be focused on sophisticated technology and trained local human resources. With indigenous certified raw material and national design of the products with lifetime values these people would gain competitiveness on the global market. The approach based on the investments into individual development and smaller-scale production companies that employ their traditional and highly sophisticated materials manufacture and processing skills, use biologically uncontaminated raw materials and designer's ideas and create well-known national design should be considered. With such an approach global furniture market can be enriched with and recognize a well-known quality design of Croatian origin.

Apparently, in line with global turbulences, traditional viewpoints and philosophy of the Croatian manufacturers will be changed as well, because large-scale production and success of the low-priced products of poorer quality at the mass markets are not sufficient indicators of their business success. Market globalization requires in the first place restructuring of the long-established viewpoints and of the overall management concept, technologies, design implementation and more investments into research and development. As regards technology, higher level of wood processing accommodated to contemporary design additionally encourages

innovation of constructional solutions. New requirements and initiatives for novel products and technologies are then set accordingly.

The above principles are being operationalized. Still, the question is whether new production programmes are the investments and how to design financial construction in the phase of product development?

For survival of the Croatian manufacturers it is important that every company in any wood industry sector, especially in the furniture sector, first establishes how much it has changed its development strategy, goals and products, and how much time and money it spends on own cultural development and style identity. Furniture of the renowned worldwide producers and designers incorporates functionality, reliability and quality as integral parts of their tradition and cultural achievements. Being that, they are the generators of new trends in design. Therefore, every company must develop its own culture, present it on the market and use it not only for profit accumulation but also for re-investment into the culture as the basis for new production development. This is the key to a long-time success of an individual and of the individual product as well as to strategically comprehensive identification of the Croatian furniture.

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# Improvements of Wood Surface Layers by Modifications

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*Abstract*

An intensive research on the development of materials and methods of application which can improve the durability of wood and woodcoatings is being performed in recent years. Wood properties such as dimensional stability, water repellency, resistance to biological attack, UV- and visible light stability and even mechanical properties can be significantly improved by applying chemical and thermal treatments which are briefly presented in this work.

Wood properties can be improved by heat treatment, acetylation, and plasma treatment or by application of nanocoatings. Heat treated and acetylated wood are commercially applied abroad, while possibilities for commercial usage of other modification methods need yet to be confirmed.

Because the properties of modified wood are significantly improved, it can be successfully used for cladding and fencing, for noise reduction barriers, for joinery and furniture in exterior, and also for flooring and furniture in interior applications.

*Key words:* wood modification, durability, water repellency, dimensional stability, UV- and visible light stability

## 1. Introduction

Wood is widely used as a constructive as much as decorative material, thanks to its excellent properties. Like other biological materials, it is degradable under inifluences of exterior factors. Wood is in exterior use exposed to various chemical, mechanical and biological factors, and ultraviolet and visible light. To ensure its durability and integrity, wood must be protected with materials like stains, varnishes and lacquers. Transparent coatings are used to emphasize aesthetical value

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of wood. However, their durability is relatively poor. The biggest effect onto the degradation of the coating have synergistic actions of elements that cause the changes of colour and mechanical changes (the coating becoming brittle) introducing stresses in the coating, which results in its degradation.

That is why the durability of the wood – coating system needs to be improved by reducing these stresses and by improving its light stability. Thermal and chemical modifications of wood surface lead to improvement of wood properties, but generally reduce adhesion at the same time.

Better durability of the coating can be achieved by improving resistance of the wood – coating system to water and light.

## 2. Thermal treatment

Thermal treatment of wood should improve dimensional stability, enable better water repellency, enhance resistance against biological deterioration and minimize the colour changes. Thermal – treated wood is most often used in exteriors for wall claddings and fencing, garden furniture, doors and windows, and flooring and furniture in interior applications.

In thermal treatment process the temperature usually varies from 120 °C to 280 °C, while treatment time ranges between 15 minutes and 24 hours, depending on the type of the process, wood species, dimensions, moisture content, mechanical properties that want to be obtained, resistance against biological deterioration, and dimensional stability of the product. The presence of air or other oxidative medium can accelerate the degradation process of wooden components during heat treatment and this is why the process is usually carried out in a protective medium (in atmosphere of nitrogen, in steam or in different oils) (Rep, Pohleven, 2001).

Colour changes during heat treatment depend onto the temperature (the higher the temperature, the more intensive colour change – figure 1). Softwoods become dark brown when heated to 240 °C (Kollmann, 1975). At the beginning of the application of this method, the colour change was considered as a shortcoming, but today it is one of the reasons for its application, because it is possible to achieve the effect of appearance of other wood species over the entire cross section of the element (Sundquist, 2004).

Chemical analysis after natural exposure of thermal treated wood showed less lignin destruction in comparison with untreated wood, which indicates possible enhancement of wood durability during weathering (Jämsä and Viitaniemi, 2004).

However, the increasement of diffusion coefficient of water along the tracheid axis shows that it is necessary to pay a special attention when protecting end grain surfaces (Jämsä and Viitaniemi, 2004). Increased coefficient of diffusion indicates the degradation of basic wood components, but acetic acid that forms in the pro-

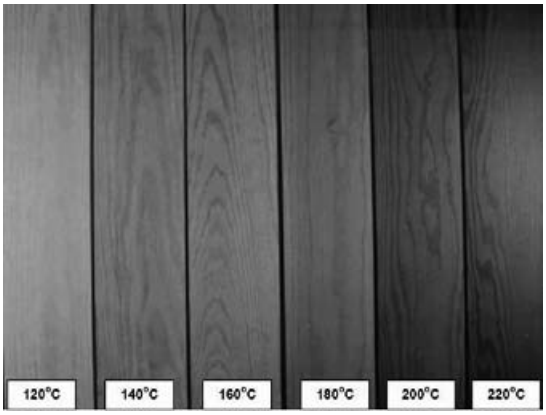


Figure 1: *The colour of heat – treated pine*

cess can cause at the same time the increase in acidity to such extent that the possibility of mould growth or rot formation would be impaired. (Sandquist, 2004).

Results of the weathering during last 10 years showed very small dimensional changes (cupping, twisting and other distortions) on heat treated wood comparing to untreated. Equilibrium moisture content on heat treated specimens even after 3 years of natural exposure was 40 – 60 % lower than in untreated specimens, regardless of the surface protection system. That indicates that permanent improvement in dimensional stability was obtained (Jämsä and Viitaniemi, 1998). However, reduction of equilibrium moisture content and dimensional instability did not prevent cracking on heat treated wood (Jämsä and Viitaniemi, 2004). If heat treated wood is finished, then the type of coating has got a significant influence on reduction of cracking. Heat treated wood is an excellent substrate for finishes as it is dry and free of resins, which exude during heating. At temperatures above 180 °C oils and waxes are extracting from sapwood and later don't cause problems with adhesion. Mechanical properties decrease regardless of process parameters. Wood becomes brittle, especially when high temperatures are applied (bending and tensile strength decreases up to 30 %), mass loss ammounts up to 15 %, and colour becomes brownish (the higher the temperature, the more intensive the colour change)(Jämsä and Viitaniemi, 2004).

Unfavorable consequences could be reduced by combining various process parameters and keeping careful control over it. For example, very high temperature at the end of the process results in very high durability of the product, but the mechanical properties of such wood are low. On the other hand, low temperature at the end of the process only slightly improves durability of the product, but also slightly reduces its mechanical properties.

Subsequent treatment with protective coating is necessary to keep acceptable aesthetical appearance of wood, because thermal treated wood is susceptible to colour changes (Ayadi, N. et al., 2003).

Heat treatment systems are still under research. However, present results are not very encouragint regarding the possible improvement in wood properties, since the treatment does not ensure high durability in the ground contact, the dimensional stability is not sufficiently improved to enable the application of wood species with low durability (like willow and poplar) for products that require high dimensional stability (e.g. windows). Even the specific dark colour of heat-treated wood is not stable for longer than 6 months if not protected with finish coating.

## 3. Acetylation

The main purpose of acetylation with acetic anhydride is to improve the dimensional stability of wood and its resistance to biological attack. The tendency of wood to absorb moisture is reduced as a consequence of reaction of hydroxyl groups in wood with reagent (acetic anhydride) which forms covalent bonding of acetic groups (which are resistant to hydrolytic degradation, figure 2). Equilibrium moisture content is reduced with the increase of the degree of acetylation.

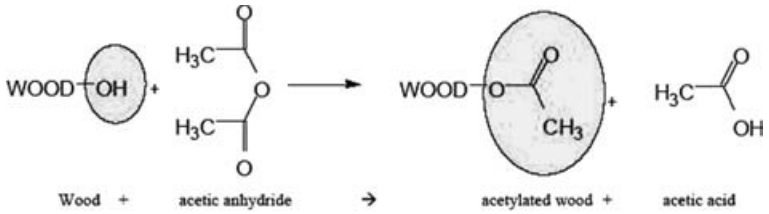


Figure 2: *Acetylation: replacement of OH-groups by larger and heavier $CH_3$-groups*

To achieve a fairly rapid acetylation, the wood impregnated with acetic anhydride must be heated to a temperatures exceeding 100 °C. Heat is usually supplied to the exterior of the reactor and is transported into the reactor and into the wood by convection, which prolongs the process and can have negative effect on the quality of the final product, since certain level of thermal degradation of the wood can not be avoided. By using microwave energy instead of conventional heating, the heat is generated within the whole impregnated wood object, but in this case it is necessary to establish the microwave absorption capability and penetration depth including any temperature dependence of the process (Larsson Brelid et al., 1999). The research of the above mentioned authors showed that penetration depth of microwaves at frequency of 2450 MHz amounts to 10 cm, which means that this type of process is applicable only for the specimens with a dimensions 20 by 20 cm (tangential × radial). Microwave energy was shown to heat up acetic anhydride and impregnated wood efficiently, because it enables fairly rapid heating to a desired level of temperature (120 – 130 °C). During the removal of excess acetic anhydride and byproducts the acetic acid is extracted by evaporation in vacuum. During the

vacuum phase, about 70 % of the chemicals could be removed within the first 30 minutes, and after evacuation of 2 hours at 120 °C the content of residual chemicals is reduced to 2 –3 %.

Results presented by Larsson Brelid and Simonson (1999) showed that acetylation increases the content of acetic groups to about 20 %, compared to 1 – 2 % in unmodified wood. The introduction of new acetyl groups into wood polymers leads to a certain degree of bulking of the wood cell walls, which in combination with reduced ability of attracting water molecules, results in the improvement of dimensional stability and biological resistance against wood destroying fungi which is comparable to wood impregnated with preservatives that contain copper, chromium or arsenic salts. It is necessary to emphasize that the improvement of physical and biological properties is achieved without altering mechanical properties of the wood material.

## 4. Plasma treatment

Podgorski et al. (2004) tried to apply the plasma technology, which is already successfully utilized in textile industries for production of water-repellent fibers, in the wood research area, with intention to obtain the same modification effects. Plasma can be defined as partially ionized gas, containing charged and neutral particles, including electrons, positive or negative ions, radicals, excited atoms and molecules.

In the wood industry the use of plasma technology may have different applications. The first one consists in increasing the wettability in order to achieve better adhesion of coatings and, therefore, better performance of these coatings. The second one consists in decreasing the wettability to make the wood water-repellent. The third possibility is to use plasma technology in testing the coatings durability. If this new water-repellent coating turns out to be sufficiently resistant, it could be applied directly to bare wood (Podgorski et al. 2004). As the coating is invisible, the unfinished, natural wood appearance would be retained. In case when plasma coating itself is not sufficient to obtain a desired effect on the bare wood surface, its application to subsequently coated wood surface might help to extend the service life of traditional coatings.

Surface treatment can be carried out using different gases (argon, methane, ethene, and silane/nitrogen) to create such layers. There are two groups of gases – *working gas* and *processing gas*. In the first step of the plasma process the working gas activates the surface, which is important for further treatment. In the second step both gases (working gas and protective gas) are used simultaneously. The protective gas itself creates the actual protective layer. The function of the working gas in the second step is to create homogeneity of the discharge (Bente et al. 2004 according to Grünwald 2000).

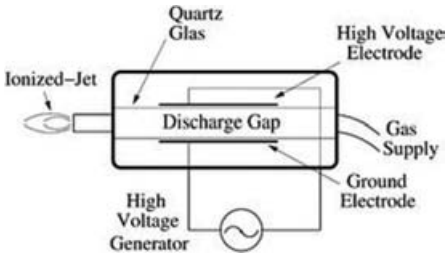


Figure 3: *Scheme of a hand-held plasma unit*

Plasma (ionized gas), in general, is generated if high voltage is applied to the electrodes. In order to generate the required plasma (e.g. silane/nitrogen) a gas mixture has to be injected between the two dielectric barrier electrodes. That can be done by a hand – held Ionized – Jet – Generator (shown in figure 3), which is easy to handle and can be readily applied to all shapes and sizes of wood (Bente et al. 2004). When gases (methane, ethane and silane/nitrogen (2 % silane, 98 % nitrogen)) are injected into a dielectric barrier discharge thin hydrophobic layers are created on the wood surface. The layer created in silane/nitrogen plasma has a contact angle of 145°, whereas the contact angle of untreated wood is 72°, when measured 10 s after application of the drop. Water absorption tests of 50 µl water drops on a wood surface showed that the time the water needed to penetrate the plasma treated wood was 145 times more compared to untreated wood (Bente et al. 2004). Rehn and Viöl (2003) were using a gas mixture of argon and methane ($Ar:CH_4$=80:20) for 1 minute duration, and measured contact angle values of 155 ± 3°.

To produce hydrophilic wood surface, the wood board needs to be exposed to gases like helium, argon, nitrogen and air. In this case the contact angle can not be measured, because the water absorption happens in a few seconds. A plasma treatment time of just 1 second is sufficient to produce hydrophilic surface. This phenomenon can be used to increase the fracture strength of glued woods, which can be improved by 68 % with plasma treatment in air (Rehn and Viöl, 2003).

As mentioned before, plasma treatment can produce hydrophilic and hydrophobic wood surfaces, but only when treated with gas discharge that achieve good homogeneity.

## 5. Nanocoatings

Nanocoatings are the materials with particle sizes measured in nanometers (usually 10 to 100 nm), whose properties are currently in research worldwide.

Results of researches made so far imply that various properties of polymers like stiffness, hardness, UV –stability, biostability and many more can be modified or enhanced by the use of nanoparticles. The main challenge is to disperse and sta-

bilize nanoparticles so that they can be incorporated into different polymeric materials like paints, coatings or plastics. Using a novel combination of nanoparticles made using gas phase together with surface – active ingredients allows the formation of nanoparticle batches that can be easily applied to various types of polymers. Small amounts (usually less than 5 %) of those additives enhance significantly for example scratch resistance of polymeric coatings, without any influence on other important properties like flexibility, transparency or gloss (Sawitowski and Schulte, 2004).

The introduction of small amounts of organophilic clay was found to improve some of the properties of UV – cured coatings (impact resistance, tensile strength, hydrophobicity). Clay also imparts some surface roughness which reduces the gloss of such nanocomposite coating and makes it work as a matting agent. The scratch resistance was substantially enhanced by the addition of silica nanoparticles (Decker, 2004).

## 6. Conclusion

Facing fierce competition of alternative materials, the use of wood must be based on improvement and promotion of natural properties and advantages of that natural, ecologically acceptable and aesthetically attractive material. The methods for modification of wood and, in particular, of its surface, exhibit important advantages in comparison with convenient protective methods, since they offer better durability of wood along with the improved properties such as water repellency, dimensional stability and other. Further extensive research is required to introduce modified wood to the wide utilization levels.

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# Third Generation Medium-Size Forest Skidder TIBOTRAC FM 03[1]

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*Abstract*

In the last twenty years many facts have determined the design of Croatian domestic-produced forest machines and equipment, particularly small-scale tractors, s.c. medium-size skidders suitable for thinning operations. Wood skidding is a part of wood production that accounts for a half of the total costs of this work procedure. Generally, the manufacturing of forest tractors designed for wood skidding, as a replacement for large-series adapted tractors or animals, started in the 1960s. Since smaller assortments represent a part of the main felling, the intent was to continue the skidding process by adapted farming tractors. In the event that large articulated tractors, the so-called skidders, were not fully engaged, they would be used for skidding small roundwood or thinned wood as a different small-scale technical wood too. In the mid 1980s the Croatian forestry clearly expressed the need to create a Croatian medium-size forest tractor with a mass of up to 4 t. After the first production of about fifty ECOTRAC TV skidders and following the interruption of production caused by newly arisen circumstances in the Croatian economy, manufacturing was resumed with second generation skidders whose ergonomic characteristics were significantly upgraded. Many circumstances contributed to the quick appearance of the design of the third generation of skidders. It was introduced to the public in mid 2005.

*Key words:* medium-size forest skidder, third generation

[1] The construction of the third generation medium-sized forest skidder prototype was partly financed by the Ministry of Science, Education and Sports of the Republic of Croatia. This particular project was chosen by the Council for Technology within the TEST-HITRA programme. Brodarski Institute, the institute of the main researcher and "3. MAJ" – TIBO d.d., Matulji participated in the realisation of this project.

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## 1. Introduction

The development of logging machines in an industrial, technological and semi-developed country like Croatia is closely connected with its general economic conditions; low inland prices of wood, a relatively low degree of wood product finalization, considerable dependency on imported equipment, rising national debts, high level of the national currency inflation. These circumstances combined determined the design and production of domestic-produced forest machines, tools and supplements, especially of the harvesting and skidding vehicles and its additional equipment (Sever and Knežević, 1989).

Vehicles used for the extraction of small-scale wood are the most important. Namely, the part of small-size wood from thinning operations ranges between 10 % and 60 % of the annual cut, in different forestry enterprises, (Tomičić, 1986; Štefančić, 1989). Tomanić (1989) reports that thinning operations of the forest represent about two thirds of all operations in even-aged forests, in terms of work duration, workers employed and means of work. Sometimes 65 % of all annually cut wood in even-aged forests, is thinning wood. In its annual report for 2003 (Kunstić i Dundović, editors, 2004) "Croatian Forests" Ltd., which accounts for the management of more than 80 % of Croatian forests, contains more complete data on the share of so-called thinning wood in the budget. Profits of even-aged forests consist of previous profits by 31 % and 41 % main profits, in the average annual budget between the 1996-2005 period. The remaining part of the budget relates to various aged forests that do not account for previous profits, simply general profits. In the total amount of realized previous profit, regular profits represent ¾ and unplanned represent ¼ of the budget. When deciding a part of the assortment, roundwood or thinned wood, intended for a medium-sized or perhaps even a small-sized tractor prove to be good production assortments. In 2003, 1 861 940 $m^3$ (48, 4 %) roundwood and 1 950 146 $m^3$ (51, 2 %) thinned wood was manufactured in "Croatian Forests" Ltd. The business plan proposal of the company for 2005 (Anon., 2004B) offers insight into one more part of the products, other than thinned wood, adequate for skidding by medium sized-tractors, the so-called thin roundwood. Trunks of categories F, L, I, II and III amount to 1 804 263 $m^3$ (48,5 %) and usually have to be skidded by tractors over 5 t in mass while thin roundwood and thinning wood (used for either recycling or fuel wood ) together amount to 1 915 830 $m^3$ (51,5 %). 126 tractors of the company weighing less than 5 t (115 of them are ECOTRAC TV – 1033F skidders) and 187 tractors weighing more than 5 t are envisaged for the entire workload. Part of the hauling of the mentioned assortments is serviced by companies as well (in 2003 they accounted for 43 % of the skidded lumber). It is certain that *forest harvesting* of small assortments (industrial wood, roundwood, fuel wood, etc.) makes up half of the annual cut. The whole skidding process, from transporting the lumber from its felling position to the assisting unloading point, has to be executed using adequate mechanization and procedures of high quality for ergonomic, ecological environmental-protection reasons, being that the process is carried out in one of the most complex natural ecosystems: the forest.

## 2. The development of Croatian medium-size skidders

Wood skidding itself, as a part of wood production, accounts for a half of the total costs of forest harvesting. It is a work procedure which has a share of approximately 80 % in forestry management in terms of costs, employment, income and work risk. Due to the value of produced wood, during mechanization of work processes, a special interest has always been focused on the most valuable assortments, because of the highest profit and highest efficiency it achieves in producing the most valuable assortments. Up until the 1980s, special forest skidders were built mainly for skidding large timber. As smaller assortments also comprise the main felling, the intent for thinning operations of products was to continue the skidding activity by adapted farming tractors or in the event that large skidders with masses over 6 t were not fully engaged, use them for skidding small roundwood.

### *2.1. First generation of medium-size forest skidders*

In the mid 1980s, this was the main reason why the Croatian forestry clearly expressed the need to create a Croatian medium-size forest skidder with a mass of up to 4 t, which had to meet at least two requirements: (**a**) entail features suitable for skidding wood from regular thinning and small-sized roundwood in the final cutting, from random thinning and salvage felling (dry trees, trees broken by snow, wind, ice...) to processing fuel wood and industrial wood, (**b**) help in the division of wood extraction carried out by ground skidding using a winch or by suspending one end between medium-size and heavy skidders. Thus, in the late 1980s the *first generation* of the Croatian skidders was constructed, having a mass of 3460 kg (front axle 56 %, rear axle 44 %). It was almost entirely manufactured from Croatian components (engine, gearbox, transmission, axles, winch...) and consisted of a 33 kW power engine, with a mechanical transmission gearbox (6 speed forward, 2 speed reverse), steering angle ±42°, center brake type on front axles, safety frame and atmospheric cabin, two drum winch (every drum with line pull 35 kN), width 1600 mm, wheel base 1900 mm, length 4400 mm, height ground clearance 400 mm, max. turning radius 3,5 m (outside tire), etc. After about the first 50 productions of the first generation medium-size skidder, and following the interruption of production in the factory where tractor design was started, renewal began on a new location in the same town.

### *2.2. Second generation of medium-size forest skidders*

Manufacturing resumed with *second generation skidders* in a factory specialized for the production of special ship equipment whose ergonomic characteristics

were significantly upgraded (new cabin, radio remote control of the winch, new type of oil for lubrication of engine and transmission, some new mechanical features...). Work conditions for the operator of the skidder were more humane and occupational safety was on a higher level.

While maintaining the basic purpose for use – hauling wood medium and late aged timber, the so-called dry trees and final-cut roundwood – the dimensions, conducting of the skidding and speed schedule (forward-reverse) enabled the maintenance of efficient mobility on tractor roads or even areas with no roads, decreased destruction of other trees and unnecessary trampling in the forest was maintained. The two-drum winch which has the drums in opposite positions, differing from the first generation prototype that had drums in parallel positions (this model was abandoned in serial production) is delivered upon choice of the buyer. The on-off button activates the tractor is connected to the winch reducer via the engine and gearbox to the universal crankshaft. The winch can be operated from the cabin or via radio remote control. The front loader which is a common feature on skidders or the frontal lifting-thrusting rotating axle (rotates about 90°) can load skidded wood in limited amounts to the assisting unloading point. The rear loader can be tied tightly to the tractor or hydraulically lifted and is used for anchorage or for the protection of other lumber from leaning on the tractor wheels during the skidding of lumber using the winch. This would protect it from the felling point or chopping point to the tractor point, forming the load and lifting its frontal, thinner and thicker ends during the skidding. The tractor can be conducted by joints using the gearbox and two hydraulic cylinders for dual rotation of the front and rear parts of the tractor's chassis (±36°). While skidding using the winch, the stability of the tractor is increased by the cylinder blockade, by assuming an upright position (the hook is not bent) and by automatically shutting of the possibility of activating the tractor. The opposing bumps during operations in the forest are overcome using the frontal fluctuating bridge (±19°). The cabin of the tractor is sound and heat proof elastically connected to the chassis by to four airbags on a freestanding chassis. The solidity of the cabin is ensured by the protective frame and protective profiles located in front of the cabin to protect it from strikes of branches. The safety nets at the front and sides of the windows with 40 cm × 40 cm openings in size are also used for protection. The new cabin and motor hood designs were completed under the leadership of Z. Novak and M.T.A. Ltd. and the construction department of TIBO Inc., Matulji, manufacturer of tractors (August-September 2001). Air-conditioning was also built into the cabin. The rear windows, the so-called safety windows as well as the side windows are protected by a removable net. The 3-cylinder Diesel engine HATZ 3 M 41 has a volume of 2574 $cm^3$ and is cooled aerially. The largest engine power at 3000 $min^{-1}$ is 42 kW, and the highest moment of 164 Nm is achieved at 2000 $min^{-1}$. The multi-regime regulator used for measuring engine frequency is not built in; instead a dual-regime regulator is used. The categorization of tractors for wood skidding is divided according to KWF into three groups: (Backhaus and Bandt, 2003): (**I**) small-sized tractors <50 kW, (**II**) medium-sized

tractors >50 – 80 kW, (**III**) large-sized tractors >80 kW. The reason why the type of tractor of any generation examined here is placed in the group of medium-sized tractors and not in small-sized tractors, which is probably the more adequate category according to its engine power, is to distinguish it from the mini skidder once developed in Croatia. All prior skidding tractors with winches were divided as follows: (**i**) specialized forest tractors, (**ii**) forest tractors based on the conventional agricultural tractor, (**iii**) caterpillar tractors and (**iv**) agricultural tractors or "caterpillar" with a built-in rope winch. Taking into consideration most of its characteristics, the tractor examined here falls into group (ii). From the time of large scale prototype production of the tractor, the internal combustion engine (ICE) engine and transmission gearbox remained components for this tractor but underwent necessary adjustments to enable its work in the forest. The adjustments to the tractor encompass four unsynchronized forward speeds and one reverse speed doubled with the reducer for enabling a fast/slow pace. Therefore, that totals 8 + 2 speeds and differential gears that can automatically be blocked and manually turned on again. The final reduction of transmission in all the tires is carried out with a universal reducer (planetary gear) with a transmission ratio of 1:8. There is no crossing over of tractor bridges. The hydraulics system functions by two pumps with the pressure of 120 bar (12 MPa), 16 $cm^3$/rotation in width (48 L/min) with the purpose of steering the tractor and functioning of the front and rear blades or 4 $cm^3$/rotation for the joint blockade. The operating and parking brakes are turned on by hand and foot, two by two lamellas in the front bridge are dipped in oil and are placed between the differential gears and final planetary universal reducer. The length of the tractor in motion is 4700 mm, the largest is 4850 mm, 1740 mm in width, 2400 mm in height and the wheel base 1900 mm long. The total mass of an unloaded tractor is 3843 kg; 65, 4 % of the weight is burdened by the front tires and 34,6 % by the back tires. The turning radius is 3,77 m. The force of the empty drum of the winch is the largest at 34 kN. Test results of some technical and ergonomic characteristics of the generation of tractors examined here are laid out in the June 2002 report (Goglia et al., 2002), based on the Rulebook on the basic conditions for tractors in agriculture and forestry (DZNM, 2001). This examination encompasses certifying features of the tractor except for specific cabin safety checks, engine feature checks (otherwise given by the engine manufacturer) and skidding power of the vehicle. Special attention was paid to the examination of cabin safety of third generation tractors according to ISO standards. It is important to note that the mentioned Croatian Rulebook is based on the OECD Rulebook for Official Examinations of Agricultural and Forest Tractors (OECD, 1998). The forest winch was examined and graded based on corresponding ISO norms. Noise and vibrations were measured and graded according to the Act on Safety at Work of the Republic of Croatia and corresponding Croatian norms, since their requests were more demanding that those of the OECD Rulebook. Ergonomic evaluations were based on examiners, namely German, Canadian and Scandinavian (ex. Frumerie, G. editor, 1999).

## 3. TIBOTRAC FM 03 – the third generation medium-size skidders

Many circumstances contributed to the quick appearance of the design of *the third generation* of skidders, e.g.: (**i**) *environmental protection* has become an important factor in the decision making of work processes and selection of means of work, (**ii**) demands requiring *humanization of forest work* were getting close to those of the (best) developed countries, (**iii**) many Croatian ecosystems have been *protected by various degrees of protection* for more than fifty years; e.g., there are currently 8 national parks and 10 natural parks, which together with other forms of protection cover approximately 11 % of the Croatian territory, and more than 60 % of this area is forestland that should be managed under much stricter rules if they are not excluded from management, (**iv**) Croatia is required to *harmonise its laws with European Union laws and regulations* during the preparatory period for the beginning of accession negotiations before getting the *avis* and the known date for the commencement of negotiations as a candidate country (in the meantime negotiations started), including other Acts related to the *responsibility for environmental protection, use of renewable energy sources* enhanced by EU directives, *use of biodegradable fuels and oils* for everyday vehicles and particularly for those traveling off-road, etc.

All this, and many other things not-mentioned, is comprised in the joint *technology project* (PT) of the TEST programme of the former Ministry of Science and Technology, the actual Ministry of Science, Education and Sport, that financially supported the *project of construction of prototype of medium-size third-generation forest skidder*, with two major requirements: (**1**) the so-called *bio-diesel fuel* to be used as propulsive fuel, and engine or hydraulic oil to be biodegradable (non-fossil) both for lubrication and hydraulic transmission systems, all pursuant to EU directives, (**2**) *humanisation of the workplace* in the cabin by providing work conditions as close as possible to those achieved by tractors having several times the mass of these skidders (more favourable seats, double steering – joystick and steering-wheel, further improvement of ergonomic characteristics of the work environment, especially in view of noise, vibrations, climate, conditions, etc.). This generation of skidders is a result of a close connection between society (state), science, (university, institutes) and economy, which is well known in current universal activities (s.c. *triple helix*). Preconditions for the success of this project are adjustment of all participants and exposure of the new work to the market. Even though there is a great scientific potential that can be revealed on the market, one main challenge remains for the systems of science and production: to direct the riches of scientific research knowledge to various economically sustainable products and services. This is Croatia's current and future challenge.

### *3.1. Defining the Strategy for Small Scale Wood Skidding Mechanisation*

Small scale techniques for thinning operations cause a number of construction problems which had to be solved in the course of their adaptation, e.g. choosing the suitable engine, tires, tracks, transmission components, etc., strengthening the chassis and axles, securing a particular degree of stability, realizing the most favourable arrangement of graded gear box speeds, etc.

The next task is taking part in organization of equipment manufacturing, optimization of work regime, level of control, energetic consumption, etc., as well as legislation of products (certification, occupational safety, typing...).

It is always the wish to combine power, economy, and environmental preservation in logging. For more efficient future generation machines, it is desirable to make the equipment that will not damage the soil, which is energy-saving and does not pollute the environment (Sever and Knežević, 1989).

### *3.2. Ecological and Environmental Views of Operating Mechanization with the Purpose of Obtaining Wood*

Environmental consequences of operations in forestry need to be established especially in the process of mechanization. But, even spontaneous and natural grown forests must be maintained and harvested for its well being and growth (Abeels, 1994). As a resource of wood, energy or by products, the forest is managed and several operations, manual or mechanical, must be conducted during the life of the stand. As a result of third generation medium-sized skidders, thinning should occur in the planted or regenerated forest in order to open the crown canopy and offer more light to the remaining stems for their improvement in growth and quality. On the site, preparation of the products from planting to harvesting, different machines and tools, all of the above-mentioned tractors travel through the stand. As mechanized operations are normal ergonomic necessities for man, it must be ecologically based. The harvesting and site preparations rules meet, among others, the following requirements: operationally feasible and socially acceptable. This enables the decrease of different hazards, e.g. soil compaction and disturbance, biomass wasting, damage to vegetation like bark peel, stem damage, breakage of a stem, etc., that are always in correlation with the depth of the damage or location of the damage. Different tree harvesting operations incorporate many machines with several more or less extensible tools to each process. Overall height, length and width define vehicle gauge which is related to spacing, tree height and maneuverability between the trees. Wheel bases, swing of the axles, front and rear cantilevers of the frame and so the angles of clearance control the stability and trafficability of the equipment. Loading capacity in dimensions, volume and weight will define pressure impacts on the soil (Abeels, 1994). These and other particularities of Croatian forests, the economy and technical capacity are considered in the

framework of possibilities for the creation of a suitable new generation tractor harmonized with current and future EU directives. The FORSITRISK Assembly (summer 1994), FAO/ECE/ILO wrote: *Soil, tree, machine interactions in forest operations*, have taken into consideration the following various aspects: *soil and vegetation face mechanization, impacts-disturbances-alterations-changes and damages to the forest, tools and machinery in the mechanization of the operations, measurement methods and restoration techniques.* While preparing the project task (Sever et al., 1985 and 1986) fundamental analysis has come to systematic statements (see item 3.3).

Ergonomic parameters of forestry mechanization, its measuring and evaluation, is a complex problem. Sometimes, e.g. for emergency usage of chain saws and skidders, it is necessary to define what is the procedure of measuring results. The prototype of the medium-size skidder was tested, except for the measuring of sound and vibration, cabin safety test, choice of seat characteristics, tractor driving system, remote control of winch and front or rear blade, etc., This must be included in the ergonomic program because the operator of the skidder is usually exposed to sound and vibration and other risks of steering with working systems. As it is well known, the risk of noise can induce hearing damage and is determined by the level of sound, frequency and exposure time (Goglia, 1997). The task was to reach a sound level exceeding 85 dB(A) during a typical working day. The same author divided exposure to vibrations in two separate areas: the vibration of the whole body and hand-arm transmitted vibration. Measurement procedure of all these values is defined in the international standards of ISO, or in OECD rules, etc.

Achievements made in determining noise for different work scenarios of third generation tractors is the reason why research on the first generation skidder ECOTRAC V-1033 F was mentioned in the introduction (Goglia and Gnjilac, 1997). One of the concluded proposals in this abstract, connected to the value of the tractor, based on the confirmed noise it makes that burdens the operator and atmosphere around it, is “everything leads to the fact that it is necessary to work on a number of improvements so that the examined tractor would be considered recommendable for use, from an ergonomic standpoint.” This was accomplished in two steps: (**1**) construction of a second generation tractor with a renewed (not reconstructed) cabin and engine (**2**) third generation skidders with interior designed cabin, changed seat, operating method, etc. In order to be able to compare the improvements, the mentioned abstract states the noise testing results. Medium level of noise was measured next the operators ear in the cabin in three operating regimes of the engine (neutral gear, full gas, actual mode) and totaled 82,42 dB(A) / 100,67 dB(A) / 98,00 dB(A). For second generation tractors, the level of noise was decreased from 14 do 22 %. The noise produced in the surroundings of the first generation tractor for the same working regime of the engine were approximately 62 / 81 / 79 dB(A), which was for third generation tractors in two of the cases (in neutral gear the results were almost identical) less by 11 to 15 %. The level of noise for second degree tractors was 13 % less in comparison to first generation tractors.

### *3.3. Particularities of constructing and designing forest mechanisation for small assortments*

In many countries like Croatia, the development of forestry machines is closely connected with its current general economic conditions: really low inland prices of wood, a relatively low degree of wood products finalization, considerable dependency on imported equipment, possible increase of national debts. All these circumstances make the design of home-produced forest machines and equipment more difficult, particularly the small-scale techniques suitable for thinning operations. The vehicles for extraction of small-size wood are the most important here.

Small-scale technology and techniques have been characterized the same as thinning operations by the following (Moberg et al., 1988):

- low level of capital investment resulting in low unit capital costs is required (it is usually compared to some small-scale techniques like horse skidding, from cutting area to strip road);
- unsophisticated technology which is easy to learn and apply;
- a high degree of manual intensive work is required but less than motor-manual system (cutting and bunching from cutter);
- ease of maintenance, etc.

In order to reach a decision on building new small-scale techniques for thinning operations, some common well-known goals are set:

- elimination of unsuitable equipment and vehicles used in the final cut and for hauling thinned wood;
- designing the machines that will damage forest soil;
- building energy-saving machines;
- less pollution of the environment;
- machines with good stability, maneuverability, traffic ability, flotation, etc.
- building of robust and high-quality machines strictly intended for forest work;
- other high performance, e.g. a very maneuverable system, high ground clearance, etc. (Sever and Knežević, 1989).

### *3.4. Announcements of the skidder prototype*

At the end of 2003, the construction of the third generation medium-sized skidder prototype began under the HITRA-TEST technological project. The Ministry of Science and Technology (currently known as the Ministry of Science, Education and Sports) helped with financing the project. The deadline envisaged for construction of the prototype was 18 months. 2005 marked the completion of assem-

bling all the components and imported parts and the test run in the laboratory of the manufacturer. This enabled presenting the tractor to expert associations, mandatory reports to the Ministry in the framework of their first colloquium, presenting the skidding procedure, presentation on the Croatian Academy of Engineering (HATZ) web site, etc. Data is displayed in the basic report.

**(1)** S. Klak, V. Koroman, B. Milković, S. Krivičić, S. Puljak, S. Sever (2005) Third Generation Medium-Sized Forest Skidder TIBOTRAC FM 03. " Development of New Technologies and Products in Croatia" presentation at the Croatian Academy for Engineering – HATZ (In Croatian) Zagreb, 26 February 2005. pp 1-33.

**(2)** S. Klak, V. Koroman, B. Milković, S. Krivičić, S. Puljak, S. Sever (2005) Treća generacija srednjega šumskoga zglobnika TIBOTRAC FM 03 / Third generation of medium-size forest skidder TIBOTRAC FM 03. Bilingual, Croatian-English Razvoj novih tehnologija i proizvoda u Hrvatskoj / Colloquium Development of new technologies and products in Croatia, February 26, 2005, No: P-35, pp 84-86.

**(3)** HATZ (2005) Croatian Academy of Engineering, http://www.hatz.hr/hrv/tehnika/p35_ppt.html Accessed 7 June 2005. Amended presentation under (1) (in Croatian), pp 1-33

**(4)** S. Klak (2005) / Third generation of medium-size forest skidder – TIBOTRAC FM 03 (in Croatian). Innovation Centre, bulletin of the technology development Unit within the Ministry of Science, Education and Sports of Croatia Vol. 2(2) 2005, pp. 8-9.

**(5)** S. Sever, S. Klak (2005) / Third generation of medium-size forest skidder TIBOTRAC FM 03 (in Croatian). First ministerial colloquium for technology projects, Zagreb, 5 May 2005. pp 1-32.

**(6)** S. Klak (2005) HITRA Project – First Croatian medium-size forest skidder (in Croatian). Periscope **19**(2005), br. 76, June 2005, pp 16-17. Web site announcement www.hrbi.hr (editorial).

**(7)** S. Sever (2005) medium-size forest skidder: yesterday, today and tomorrow (in Croatian). Presentation on the Medium-size forest skidder TIBOTRAC FM 03, Crni Lug, 15 July 2005. pp 1-32.

**(8)** Other announcements, for example: Croatian Forests web site; Croatian Forests monthly bulletin no. 76, p 39; HINA news (16 July 2005), newspaper dailies Novi list and Jutarnji list (16 July2005) etc. Furthermore, the TIBOTRAC FM 03 was first presented in 2002 at the Slovenian Forestry Days Fair in Kočev and the third generation tractor was first presented to the public at the Croatian Forestry Days on 18 June 2005, in Karlovac.

**(9)** Pleše V. (2005) new forest tractor TIBOTRAC FM 03 – bio-diesel will be used as fuel! (In Croatian) *Croatian Forests*, no. 106, October 2005, pp 14-15.

**(10)** Other than the continuation of laboratory testing on Croatia and the EU as well as exploitation of skidding conditions, a preparation of a more detailed prototype showcase is underway within the expert work in the *Annual 2005 of the Croatian Academy of Engineering*, *Forestry Mechanization* (in Croatian), etc.

### *3.5. Technical Features of the TIBOTRAC FM 03 Skidder*

The third generation tractor engine with the transmission gearbox is identical to the one installed in the second generation model. All the changes made, except for the repairs or faults noticed during the test run in the forest, were directed towards harmonization with EU directives in terms of ecological and ergonomic requirements. So, for example, the engine and its additions used in the second generation model were improved by changing the pumps and razors so that bio-diesel fuel could be used. This resulted in a change of the instruction manual and behavioral guide in the case of a more permanent break (unemployment of the engine during holidays, weekends, etc…). This enabled utilization of bio-diesel fuel without greater problems, except for the already identified ones: weaker power, a more significant need for materials such as pumps and razors, sensitivity to temperature change, usage of an adequate filter, etc. With the aim of a more simple management of the hydraulics system, apart from the use of bio-oil, specific oil was chosen for the lubrication of the engine, transmission gearbox and hydraulic components. With the aim of decreasing damage to soil, forest tires and chains were chosen to ensure better tracking. Technical features in terms of meeting ergonomic requirements influenced changing the operating method of the tractor and equipment, more precisely of the winch and the front and rear loaders. The newly chosen tractor seat is a top achievement for medium category tractors that enables operating the tractor, all its working components and the engine (winch, both blades, etc.) with the joystick which is attached to the seat. This allows for operating the tractor and steering the wheel at a speed of over 20 km/h (in compliance with EU directives). In comparison with the previous generation, the connection between the cabin and chassis is improved by the selection of four improved rubber shock-absorbers. Other improvements worth mentioning are: development of the joining element, the selection of a more reliable producer of the hydraulic head of the wheel, attempt to change the rope speed of the winch (decrease will be possible only with the modification of the reducer box of the winch), exchange of hydraulic valves on the axles, additionally installed bars for turning on and off the universal shaft of the winch, additionally installed cooler with a thermostat for cooling oil in the system for operating the tractor and its working parts, modernized remote control operation winch and tractor (two transmitters are always at disposal for safety reasons), etc.

In comparison to the second generation TIBOTRAC, the center of gravity the blockaded joint tractor (ISO 789-6:1993) is located near the longitudinal axis of

the tractor, approximately 1246 mm from the axis of the rear bridge at a height of 906 mm. The joint blockade mechanism is important during hauling the load by winch to the tractor, because it enables the increase of stability. This procedure can be accomplished while the manual brake handle is locked, onto which a switch is installed that regulates turning off of the electromagnetic valve power supply in which case the joint blockade will not be able to be turned on during the operation of the tractor (lowered manual brake). The center is not determined in the case that the front and rear longitudinal axes of the tractor do not concur, when for example; it is bent to the furthest bending angle of 36°. In the first decade of skidder utilization in forestry, it was clear that control of the joint enables splitting the turning radius but also presents problems of stability in relation to tractors that are operated by its front tires. That was the exact reason for special training and preparation of the skidder operator, even tough the operator previously worked on wood hauling using an agricultural tractor. The stability of the tractor determines space between the tires, road trail and position of the center (Krohn, 1979; Sever and Horvat, 1987). During construction, the following has to be taken into consideration: the height of the swinging axle (usually the front axle), the positions of individual centers of the front and rear parts of the tractor, the type of machine, dynamic influence during operation, winch work while the tractor is stationed, etc.

The clearance, the lowest point of the box, remained the same as the one from the second generation model at a distance of 370 mm from the ground.

In comparison with first and second generation skidders, the total mass of the third generation has increased: The second generation model is 11 % heavier and the third generation model is 22 % heavier than the first generation model. The burdening of the bridge remained the same: around 34 % of and unloaded tractor burdens the rear bridge and 66 % burdens the front bridge. The definition of forest tractors (Backhaus and Bandt, 2003) states that an inappropriate ratio of burdening the front and rear bridges is 40 : 60 (common with agriculture tractors). The reason for this is that apart from the winch, installment of a crane is envisaged in the rear. The ratio of the front and rear of the skidder's bridge is 2/3 : 1/3.

The chassis of the tractor remained the same, where the connection of all the outlets of the important parts of the transmission box comprise a mobile entity of other components (it does not have an independent individual chassis like larger skidders). Figure 1 illustrates how the chassis connects the transmission outlets from and to the joint

Aside from the features of the chassis taken from the first generation skidder (ECOTRAC – V), kinematical transmission features were also adopted (Figure 2). Individual promotion is composed from a varied choice of material, quality and control of the construction and a few of the results improved the application features of the skidder (winch, joint blockade, etc.)

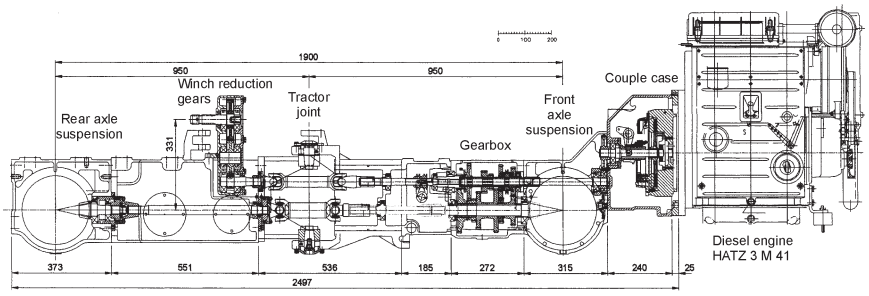


Figure 1. *Longitudinal sectional view of the engine and installed boxes that create a tractor chassis*

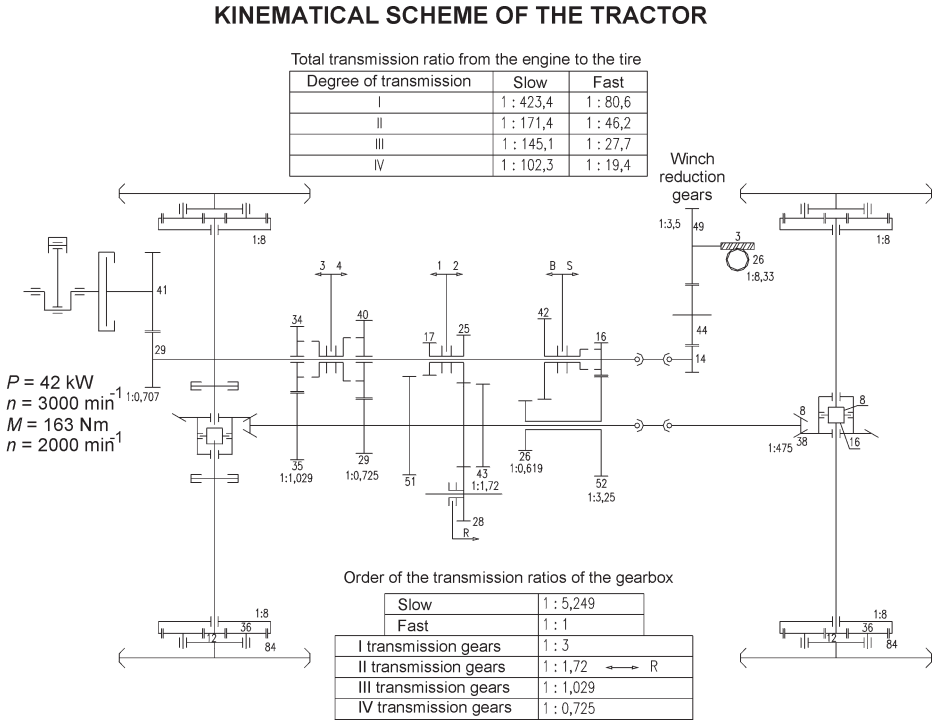


Figure 2. *Schematic illustration of the tractor's transmission from the engine to the tires*

### *3.6. Position of the TIBOTRAC FM 03 skidder in the category of medium-sized skidders*

In the mid 50s of the last century, the evaluation of transporters for various purposes, began based on morphological studies, as a specific aspect of applying dimensional analyses of forms and dimensions to their masses and motor features, most of all the power of the tractor engine. Following road and rail vehicles, this analysis was used for the first time on vehicles that operate off roads (Bekker,

1956). The forest tractor historically stemmed from working, most often tractive vehicles, maintaining their shape, dimensions and connections between the two, but not its connection to ecology, especially to forest ground. The tractor had to be changed quickly and adapted to the sensitive ecosystems of the forest. This caused and continues to cause constant changes to specific groups of self-paced motor working vehicles. Every morphological analysis determines characteristics and laws of the current state and demonstrates development trends. The examined tractor-medium-sized forest skidder belongs to a subtype of tractor for wood skidding and its hauling from the chopping to the assisting point. In more narrow terms, it is intended for accumulating small scale wood from shafts, dry wood, lumber that was broken in a storm (wind, ice…) Two correlations were chosen for the examined third generation tractor TIBOTRAC FM 03: engine power versus tractor mass and two index forms; the width and length quotient in relation to the height and length quotient $B/L = f(H/L)$. The second correlation indicates two groups of tractors in relation to the B = H link (line of equal width and height of the tractor): above the line are tractors whose width dominates the height, beneath the line are an area where the height dominates the width. The historical trend represents moving the large series tractors from are A to area B, adapting a stocky form. It is not as accentuated with large forest tractors but is present with medium and small-sized skidders. Furthermore, this analysis confirms the well-known fact that for this type of vehicle, air resistance is not significant which is not the case for the next phase of assorting lumber and its transportation to the final customer. The first known similar type analyses of forest tractors date from the mid 70s of the last century (Sever, 1974).

Further research continued throughout the 80s, marked the increase in the number of researched parameters and adequate data processing (Sever, 1980). In the next quarter century more than ten abstracts covered the morphological features of various forest mechanizations, mostly the tractor for hauling lumber. Only two are mentioned that contributed to dividing the so-called adapted agricultural tractors and two groups of skidders (Horvat, 1999; Horvat and Sever, 1999). Figures 3 and 4 demonstrate the mentioned correlations.

The medium-sized skidder according to its place in the diagram $P = f(m)$ lies right next to the line of equalization. Subgroups of skidders that weigh less than 5 tons, are located in the upper half (see figure 3). In comparison to the first generation, as it was earlier mentioned, its mass increased by 22 % as did the power of the tractor engine. The correlation of the shape index shows deviation from the B = H line in the area where height dominates width. This is a result of maintaining an unaltered length of the tractor and a slight increase in the width as well as changes in the cabin with the aim of increasing it ergonomics and safety (see figure 4).

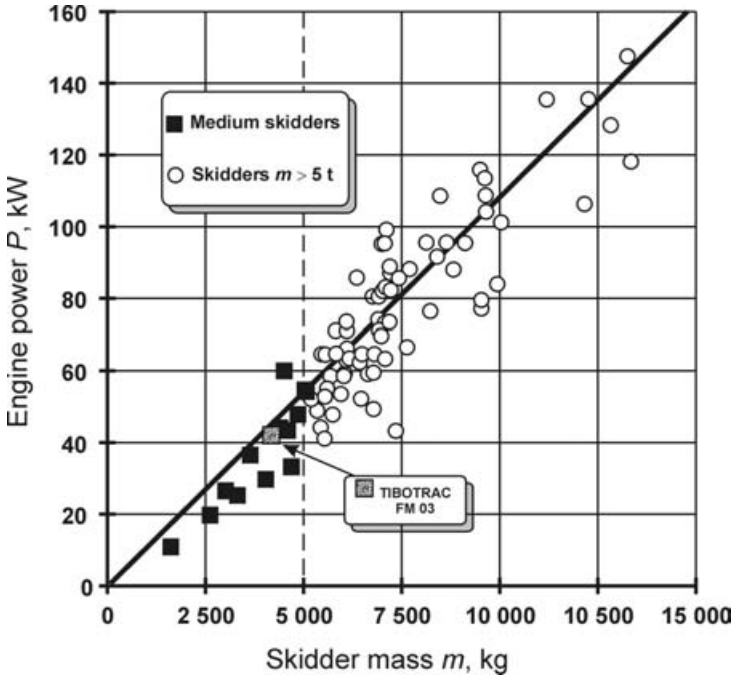


Figure 3. *Diagram demonstration of the place of the forest skidder TIBOTRAC FM 03 in the family of forest skidders in P = f(m) correlation*

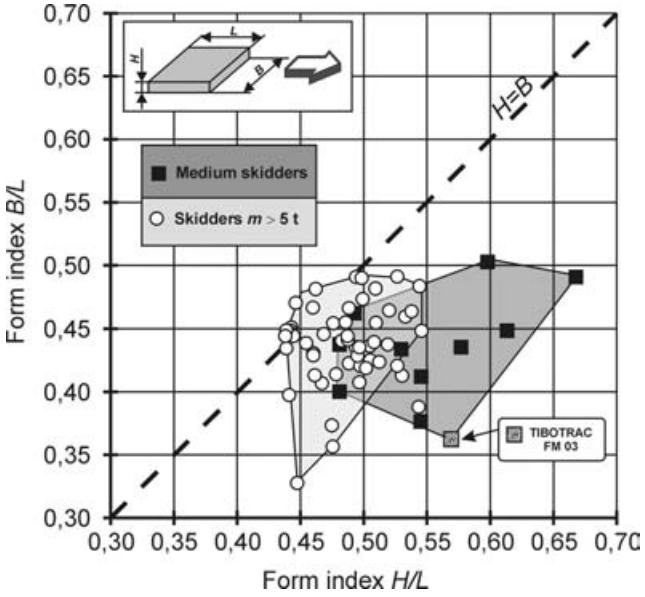


Figure 4. *Correlation between the width and length indexes of the forest skidder's shape and certification of the third generation TIBOTRAC FM 03 prototype position*

### *3.7. Tractor fuel and lubrication for tractor components*

The tractor engine, transmission gearbox, hydraulic components of the tractor (operating the tractor as well as front and rear axles) and hydraulic components of the winch are all lubricated using a specific biodegradable oil (Planto hydramot SL SAE 5W-40). Around 85 L of oil is required for a single change. The operating hydraulic system for operating the winch requires API GL-3 oil, with a single fill-up of 4 L. It is trying to be replaced by the unique Planto hydromat oil. Multi-purpose mast LIS 3, with numerous lubricants is used for the lubrication of mobile parts: chassis 18, front axle 12 and rear axle 14. Undoubtedly, it is the task to replace fossil fuels that are difficult to degrade in protected areas with degradable bio-oils that are environmentally friendly to the forest (Auguštin et al., 2000).

The tractor engine can use fossil fuel like crude oil but also other renewable fuels colloquially know as bio-diesel fuels (produced from rapeseed, sunflower and similar oil sources as well as fuel derived from remaining food oil). Among others, this can be considered as adapting the engine to renewable biodegradable fuel that is based on the EU strategy on reorganization of the EU energy sector. It began with the publishing of the co-called *White Book* and adoption of a number of EU directives on the growth in share of renewable energy-generating products, for example, Directive 2003/30/EC on the promotion of bio-fuel in transport. Another reason for the enhancement and improvement of the tractor was the significance of environmental protection and energetic efficiency. The manufacturer of the tractor engine requested fulfillment of the fuel components with norms DIN EN 14214 and DIN EN 51606 (or DIN 51605). The manufacturer prepared the engine for consuming bio-diesel fuel (by installing a special filter, changing the pump, razor and other parts that are related to fuel). Since the terrain work of the tractor began in May 2005 in National Park Risnjak, the adequate fuel was acquired for its use. The fuel is changed four specific times of the year in Croatia: (1) 16 April. – 30 September ▸ point of filterability 0 °C; (2) 1. October – 15 November ▸ –10 °C; (3) 16 November – 29. February ▸ –15 °C; (4) 1 March – 15. April ▸ –10 °C (Anon., 2004A). Considering the climatic characteristics of mountainous Croatia, fuel is used at a filterability point of up to –20 °C in the third period, because leaving the tractor out at night in the open or in unheated closed spaces may affect its operation (this is regulated by norm DIN EN 14214). The standardized check up of the blackness of the built-in HATZ 3 M 41 engine showed it totals 0,63 $m^{-1}$, which is nearly one fourth of the permitted value, while the so-called belt width totaled 16 % of the permitted amount. It is believed that small soot particles (all particles smaller than 10 μm) will be less present in exhaust fumes. Directive 2003/30/EC of the EU Parliament and Council on promoting bio-fuels and other renewable fuels for transport, is a directive regulating the future behavior of the EU in view of renewable energy-generating products, permitted emission of glasshouse fumes, replacement of fossil fuels with renewable ones, etc. Article 2 of this directive offers useful definitions of bio-fuels, bio-masses, other renewable sources, heat factors,

and a list of possible bio-fuels: bio-ethanol, bio-diesel, bio-gas, methanol, methyl ether, t ethyl cyan butyl ether, t methyl cyan butyl ether, synthetic bio-fuels, hydrogen and pure vegetable oil. When constructing the third generation medium-sized skidder prototype, bio-diesel fuel was planned to run the skidder. The engine of the second generation skidder was activated by fossil fuel, so-called crude oil. The emission of hazardous substances amounted to 0,3 % (hard particles of sulphur dioxide, hydrocarbons, carbon monoxide and nitric oxides), with over ¾ nitrogen, close to 10 % oxygen and approximately 7 % water steam and just as much carbon dioxide. If using bio-diesel fuel which derived from rapeseed oil, it can be expected that $CO_2$ will decrease by 80 %, CO will decrease by 10 %, hydrocarbons by around 35 %, hard soot particles by around 50 %, sulphur will be evident while nitric oxides will present a problem because its emission in using bio-fuels is around 13 % higher, but a part of nitric oxides sometimes transforms into harmless nitrogen. Certainly, some of the hazardous and even ozone fuels that derive from bio-diesel fuels disappear in the plant photosynthesis process. Due to its biodegradability, bio-diesel fuel belongs in class 1 of dangerous fluids for underground waters, with no specially regulated conditions for its transport and storage. The engine is better lubricated and its duration is prolonged, which is verified on road vehicles (bus with 270 000 km) and forest tractors that have been engaged by diesel engines for ten years straight, 15 forest tractors or special forest machines and other vehicles (trucks…) (Rakel, 2005). The EU directive from May 2004 regulates for the period between Jul 2005 and 2014, gradual intensification of the permitted emission of diesel engines (Sever et al., 2005). For the forest and its needs, changes are important for tractors that operate off –road (all tractors that haul wood), unloading points, forest rail vehicles (forest rail) and vessels (tugboats of aquatic barges), (Weise, 2005). Limitations are regulated according to categories of engine power (H....R) and degrees: III A, III B i IV. The starting point, are acts of the so-called II degree, with limitations for CO, $NO_x$, HC and small particles of soot. For degree III B, the permitted amount of nitric oxide emission will be split in half as will the permitted amount of hydrocarbon emission, soot particles will be permitted at 5 % of the actual value up until the finally envisaged permitted values. In many cases filters for small particles will have to be built in as will a system for the processing of exhaust fumes and diesel fuel will have to be prepared using a smaller percentage of sulphur (2009 is envisaged with a sulphur content of less than 10 ppm). All of this will require a change in the testing procedure, adapted to the working method. All forest transport of goods and materials will have to decrease its emission of $CO_2$ by 50 %, as is the case with other modes of transport! EU rules require domestic production of 35 700 t bio-diesel fuel (2,75 % of the total consumption of fossil fuel) in 2006, and this has to be doubled by 2010 so that the total consumption of engine fuel with internal burning will amount to 5,75 %. In the next 10 years, up to 2020, the share of bio-diesel fuel will have to participate in transport with a consumption of 20 %. Momentarily, there is no production of domestic bio-fuel (according to estimations, domestic production should amount to

260 000 t in 2020). In this moment, Croatian forestry consumes 30 000 t crude oil for its needs.

### *3.8 Verification of basic technical and applicative features of the tractor*

The first check up of the medium-sized prototype of the skidder marked a number of its features that determined its applicative features and ergonomic and environmental friendliness. The directive for determining the privilege for confirming the order of verified measurements was the Croatian Rulebook on the fundamental requirements for agriculture and forest tractors (DZNM, 2001). The observed forest tractor according to provisions from article 2 belongs in *category T1* as a wheel tractor, with a speed from 6 to 40 km/h, a gap between tires with at least one axle larger for 1150 mm, mass of an empty tractor in operating mode more than 600 kg and a gap from the ground less than 1000 mm. The same Rulebook determines basic requirements relating to safety structure, brakes, components for lighting and light signalization, safety glass, rear-view mirrors and permitted level of noise (article 4). Legal entities certified according to provisions from the Rulebook performed the verification of standard fulfillment with the basic requirements for second and third generation tractors.

#### *3.8.1. Approximate measurements and other features of the skidder*

The total length of the tractor is 5038 mm, wheel base is 1900 mm, the largest width is 1740 mm, and the height of the noose is 2380 mm.

The radius of the tractor's turning is an important indicator of its working benefits in shafts. Since the skidder is not envisaged by the ISO norm, or the OECD rulebook on tractor examination for confirming the smallest radius/diameter of turning while using the brakes, the same examination was implemented for two motion directions, the so-called left and right (counter clockwise and clockwise) and for the activation from the motionless state of the tractor or at a beginning speed (usually operating at 7 – 9 km/h). Furthermore, the smallest radius/diameter was measured as was the largest, confirmed at the most exposed part of the tractor, the so-called clearance radius/diameter. The Global Positioning System (GPS) was used for establishing the position of a specific point on the ground, as it was used for determining the speed of the tractor and breaking speed and for determining the rotation radius limitations (Figures 5 and 6). The steering wheel was held in the extreme left/right position during the entire course of the operation of the tractor.

Table 1 displays the results of determining the radius/diameter of the tractor's turning in two observed cases.

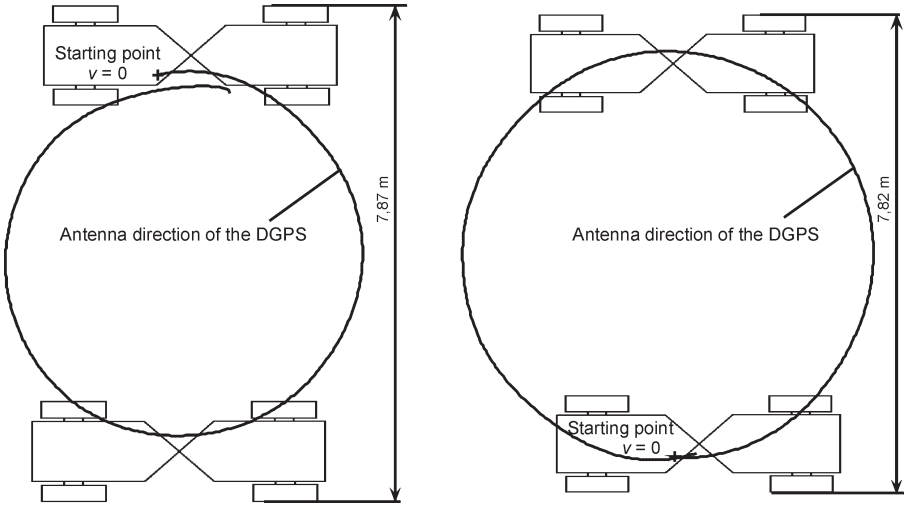


Figure 5. *Determining the rotation circle of the TIBOTRAC FM 03 skidder while operating when stationed (motionless mode); (**a**) clockwise motion of the tractor (towards the right), (**b**) counter-clockwise motion of the tractor (towards the left)*

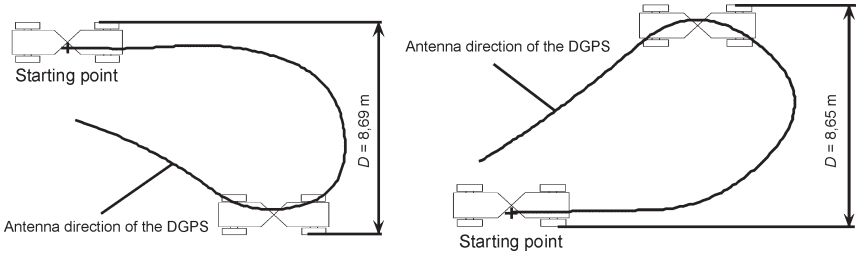


Figure 6. *Determining the rotation circle of the TIBOTRAC FM 03 skidder while operating at a specific speed; (**a**) beginning speed 2,2 m/s (7,92 km/h), motion towards the right (**b**) beginning speed 2,5 m/s (9 km/h), motion towards the left*

Table 1. *Radiuses of the tractor's turning in starting mode while motionless or at a beginning speed*

| | Starting point stationed | | Starting point at a specific speed | |
|---|---|---|---|---|
| | Left circle | Right circle | Left circle | Right circle |
| | m | | | |
| Smallest radius of rotation | 3,71 | 3,74 | 4,11 | 4,15 |
| Largest clearance radius | 3,91 | 3,94 | 4,33 | 4,35 |

Breaking the tractor using cold brakes was also examined. Figure 7 shows the course of the examinations with notes on the correlation between speed and breaking time and the amount of time of turning the vehicle from the direction while breaking.

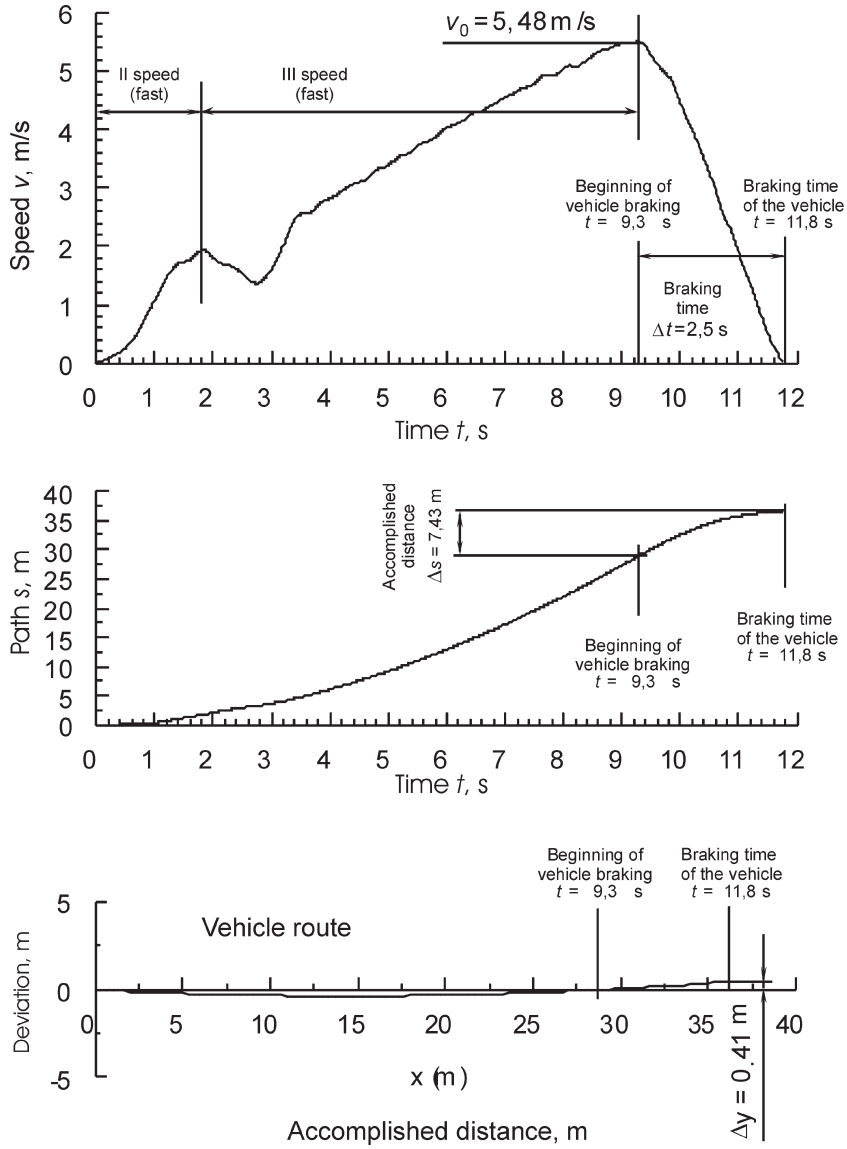


Figure 7. *Braking test using cold brakes: v = f(t), s = f(t) i y = f(x)*

In table 2 the evaluations for braking of the tractor with cold brakes on a flat path are displayed

Table 2. *Measured data of braking the tractor using cold brakes*

| Starting speed | Braking time | Achieved distance | Medium deceleration | Largest deviation from the motion direction |
|---|---|---|---|---|
| km/h | s | m | $m/s^2$ | m |
| 19,73 | 2,5 | 7,43 | 2,02 | 0,41 |

*3.8.2. Engine characteristics of the tractor and transmission gearbox*

While checking the eight forward speeds of the tractor and two reverse speeds for all the transmission gears, fast and slow paces, the frequency of the rotation of the main universal valve was also measured. The results of this additional examination are displayed in table 3. The frequency of the rotation of the main universal valve for the two fastest groups was not measured due to technical reasons. From the measured results, it is evident that the realized speeds were smaller than the calculated ones due to not being able to achieve the fastest calculated frequency of engine rotation at 3000 $min^{-1}$. As a result, the ratios of the calculated speed measured at the highest engine frequency and the actual speed of the tractor are displayed in the table.

Table 3. Tractor speeds for all gears during forward and reverse driving

| Transmission Gear | Speed Group | Frequency of the rotation of the main universal valve | Tractor speed | Ratio of the calculated and actual speed |
|---|---|---|---|---|
| – | – | $min^{-1}$ | km/h | – |
| 1 | slow | 233 | 1,30 | 1,15 |
| 2 | slow | 402 | 2,23 | 1,17 |
| 3 | slow | 685 | 3,78 | 1,14 |
| 4 | slow | 946 | 5,22 | 1,17 |
| 1 | fast | 1222 | 6,77 | 1,15 |
| 2 | fast | 1890 | 11,95 | 1,14 |
| 3 | fast | – | 18,36 | 1,24 |
| 4 | fast | – | 25,67 | 1,25 |
| Reverse | slow | 400 | 2,23 | 1,17 |
| Reverse | slow | 1830 | 11,52 | 1,18 |

### *3.8.3. Ergonomic characteristics of the skidder*

The ergonomic indicator specifying humanization of the work is important. This is an indicator of the necessary amount of human work force needed for pulling in/out the steel rope from the location of the tractor to the location of assembling the load. This is of much more importance if the wood is being hauled from downhill (meaning the rope is being pulled from up hill). Apart from he technical features of the winch, the mass of the steel rope in terms of meters in length and friction of the rope on the surface, the pulling force of taking out the rope depends on the state and type of surface, obstacles on the terrain, etc. Figure 8 illustrates the measurements of the changes in the amount of necessary human force which obviously oscillates. The pulling force did not reach the most permissible forces for similar tasks (the best measured forces reached approximately 8,5 daN at a distance of 30 m, and the average value reached close to 5,5 daN).

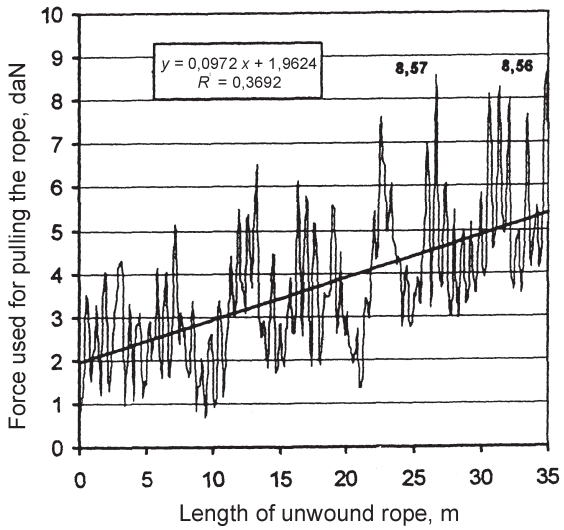


Figure 8. *Correlation between the worker's pulling force for pulling out the rope and its length when it is unwound*

The newly chosen tractor seat is one of the top accomplishments for the medium-sized skidder. The only obvious problem is that it is located in a rather small cabin space. The seat (Figure 9) enables left-right movements for half a circle, π radian (±90°), different adjustments of the seatback and sitting surface and operating the tractor and all its components as well as the engine (winch, both blades, etc.) joystick, and operating the tractor and steering wheel at a speed over, all in accordance with EU directives (Figure 10),. The connection with the chassis and cabin in comparison to the previous generation of tractors is improved by a choice of four enhanced rubber shock-absorbers.


Figure 9. *Tractor seat Grammer- ACTIMO XXL 12. 1 – Adjustable headrest, 2 – Foldable armrests adjustable height and angle, 3 – Adjustable seatback, 4 – Adjustable seat angle, 5 – Height adjustment, 6 – Fore/aft adjustment, 7 – Variable seat length, 8 – Adjustable airbag, 9 – longitudinal muffler*

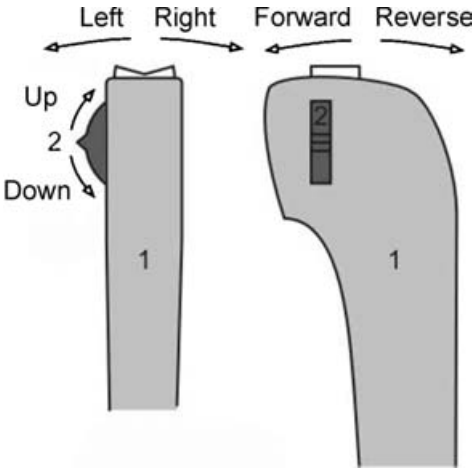


Figure 10. *Joystick for conducting the tractor and its working components. Handle 1: forward- turning the front axle downward: reverse – turning the front axle upward; left – lowering of the front axle; right – lifting the front axle. Wheel 2: up – lifting the rear axle; down – lowering the rear axle*

Measuring of the vibrations that affect the operator of the tractor was executed by the certified Croatian laboratory of the Ship Institute on third generation skidders in accordance with HRN ISO norms (Radić and Beatović, 2005). The most important purpose of measuring and evaluating the vibrations is determining the affect it has on the operator's health during the working period. The examination was implemented while operating the tractor on a rough asphalted path that was partly damaged and repaired. It was established that the vibrations traveled through the seat to the operator's entire body and hands/fists via the steering wheel. In principle, the measuring chain for determining the vibration that is transferred to the operator's entire body began with a tri-direction inter-vertical accelerators and a magnetic tape recorder for recording the vibration accelerations. Apart from the computer, all the instruments were from B&K Company. In accordance with the adequate norm, following the third analysis the measured accelerations, were evaluated by coefficients of a basic method for very individual direction in the frequency area of 1 to 80 Hz. Their results were calculated $a_w$, as was the entire value of acceleration $a_u$. The measured results are displayed in Table 4. The driving and motor working regimes during the experiment are not stated.

Table 4. *Analysis Results of measuring vibrations of the entire body of the operator of the skidder*

| Terrain | $a_{wx}$ | $a_{wy}$ | $a_{wz}$ | $a_u$ | Category of working capability |
|---|---|---|---|---|---|
| | m/s$^2$ | | | | |
| Driving on rough asphalt | 0,357 | 0,357 | 0,627 | 0,945 | B |

Since category B according to norm HRN ISO 2631-1:1997 EN ($1{,}11 \geq a_u \geq 0{,}64$) confirms the possibility of decreasing working possibility, the results of all the experiments are compared with those of the same second generation tractor (TIBOTRAC FM 02), only possessing a seat of a lower category (Goglia et al., 2002). There is a main difference in the functioning of the tractor and engine regimes: all of the vibration measurements transferred to the operator are proven when the tractor is not in motion (not during operation) and during the least, medium and most number of engine rotations. Measuring the acceleration of the vibrations was executed for average frequencies from 1,3 to 100 Hz. Without displaying the measurement results, the conclusion in accordance with norms ISO 2631:1986 and HRN ISO 2631:1997 is interesting: all three levels of vibrations on the seat of the tractor are significantly beneath the permitted limitations of daily exposure and there are no limitations-the level of vibrations do not exceed the permitted limitations of daily exposure (8 hours) and enables comfort with no signs of tiredness. The fact that these two institutions did come up with the same conclusions and consequences calls for the need to examine the tractor by a third party.

Radić and Beatović (2005) under the same conditions (tractor operating on rough asphalt with damages and minor repairs) estimated that the vibrations that are transferred to the operator's hand via the steering wheel (table 5).

Table 5. *Analysis results of measuring vibrations transferred to the operator's hands*

| Terrain | $a_{x,h}$ | $a_{y,h}$ | $a_{z,h}$ | $a_{h,w}$ | Category |
|---|---|---|---|---|---|
| | m/s$^2$ | | | | years |
| Operating on rough asphalt | 0,872 | 1,059 | 0,532 | 1,472 | 20 |

The evaluation is done according to ISO 5349:1986 for a 4 hour per day exposure to the vibrations. Therefore, after 20 years, there is a possibility of the appearance of so-called white fingers for 10 % of the tractor operators.

The comparison with the results of the vibration measurements that are transferred to the operator's hands from the steering wheel on a second generation skidder (Goglia et al., 2002), by all earlier mentioned measuring conditions (functioning of tractor and engine regimes), the level of vibrations are below the permitted level for 8 hours-a-day exposure, with no risk to the operator's health and for a full working period (proven in accordance with ISO 5349-2:2001EN) .

Noise in the cabin in the place of the skidder operator is established according to HRN ISO norms (Mučnjak, 2005). In the event of a motionless tractor, noise next to the operator's head was established for three different frequencies of rotations of a working engine: neutral gear 980 min$^{-1}$ (minimal number of rotations), for an average number of rotations it totaled 2000 min$^{-1}$ (normal at a rotating frequency at the biggest rotating moment) and at the largest number of rotations of the engine it totaled 2700 min$^{-1}$. The noise was measured from the left and right sides of the operator's head in each case (table 6).

Table 6. *Measuring noise near the operator's ear, from the left and right sides for all three regimes of the working engine and during motionlessness of the tractor*

| Working regime of the engine | Level of sound $L_{pA}$ | |
|---|---|---|
| | dB(A) | |
| | Left | Right |
| • Neutral Gear | 79,1 | 78,8 |
| • Rotation Frequency in the highest moment | 83,6 | 83,5 |
| • Working at full gas | 88,2 | 87,5 |

Measuring noise in the cabin while operating an unloaded tractor, for 4 gears for transmission and 2 gears for multiplying the speed, so-called fast and slow speed (pace), are shown in table 7.

Table 7. *Measuring noise near the operators head at different speeds of operating the tractor*

| Gear | $L_{pA}$, dB(A) | |
|---|---|---|
| | Fast speed | Slow speed |
| I | 88,9 | 86,9 |
| II | 89,0 | 87,2 |
| III | 89,7 | 86,9 |
| IV | 90,0 | 87,5 |

The other results are not displayed due to obvious technical and measuring problems.

Goglia et al. (2002) proved burdening of the operator with noise under different conditions and norms envisaged by work regimes for the same engine type and applied norms for the second generation skidder. Similar to the vibrations, the frequency of engine rotation altered in three degrees: the lowest number of rotations, the so-called neutral gear at 780 $min^{-1}$, medium number of rotations which equals half the amount of the highest number of rotations at which time the engine achieves the highest moment and the so-called highest number of rotations at which point the engine achieves the highest power (measured at 2580 $min^{-1}$). The number of measurements completed from the left and right sides of the operators head is regulated. As was the situation with measuring vibrations, the working regime of the engine altered when the tractor rested in one place (was stationed).

Due to the comparison and confirmation of the unreliability of data from measuring noise of the engine which is possibly the cause of deviation of the measured levels of noise in the cabin and surroundings of the tractor, data is displayed for the same technical measurements of noise for second generation skidders (table 8).

Table 8. *Measuring Results of the level of noise in a cabin against the ear of the operator of a second generation skidder*

| Working regime of the engine | Level of sound $L$ dB(A) | |
|---|---|---|
| | Left side | Right side |
| Neutral gear | 75,75 | 75,25 |
| Average no. of rotations | 80,25 | 78,00 |
| Maximum no. of rotations | 85,00 | 84,75 |

It is now obvious that the operator of the tractor does not need to use hearing protection during the 8-hour-a-day working time for the estimated noise in the cabin.

Among the standardized experiments is also the situation when the stationed tractor transfers sounds to its surroundings. Norms HRN ISO 4872:2000EN and HRN ISO 6393:2000EN regulate this type of measuring by placing microphones in specific measuring places shaped like a semi-sphere with the tractor in the centre of the space. The measuring is done in six measuring points for three working regimes of the tractor engine, as was done in the prior estimation. The level of noise produced where the tractor was located was as follows:

(**a**) neutral gear of the engine – $L_{pA}$ = 62,8 dB(A)
(**b**) average number of rotations (the biggest moment) – $L_{pA}$ = 67,4 dB(A)
(**c**) full gas (most number of rotations) – $L_{pA}$ = 72,2 dB(A).

The established level of noise produced in the immediate surrounding conformed to the limitations of the EU norms and also enabled fluent communication of the operator with the assistants at the cutting ground or unloading point. There are significant differences between the two certified laboratories in the prior measuring [a so-called A-value sonic power level of the tractor of 127 dB(A) was established], as well as similar problems in proving vibrations using the same standardized procedures by the two certified institutions that are evident when examining forest machines for which a great deal of parameters influence the sought measurements. For one group of forest mechanization, chain saws, the problem was researched and reported to the IUFRO Congress as an incentive for change and amendments to adequate ISO norms (Goglia, 1995). In the mentioned abstract, it is emphasized that reoccurrence and newly produced identical measuring conditions in forestry are very difficult at today's level while enforcing general standards created for more areas.

The third measuring of noise was the situation in the forest surrounding during tractor acceleration, in accordance with norm HRN ISO 362:2000 EN. Along prior stationary measuring, this is also important due to the frequent tractor motion from the state of motionlessness to working speed, especially while loading lumber at an assisting point.

The measuring results are displayed in table 9.

Table 9. The level of noise [dB(A)] of a skidder during acceleration

| Gear | Left side | | Right side | |
|---|---|---|---|---|
| | Slow speed | Fast speed | Slow speed | Fast speed |
| 1 | 73,25 | 73,5 | 73,5 | 71,5 |
| 2 | 72,5 | 72 | 72,5 | 72,5 |
| 3 | 72,5 | 73,5 | 71,5 | 72,5 |
| 4 | 73 | 76 | 72,5 | 74 |

All confirmed evaluations of noise produced during the acceleration of a skidder are below permitted levels.

### *3.8.4. Standard testing of the cabin stability*

As already mentioned, a new cabin and engine hood were designed in relation to the first generation of middle forest tractors. Considering the complexity of the redesign of the cabin and tractor exterior, the job was designated to M.T.A. Ltd., Rijeka, and to the company president and project leader Z. Novak. The contract was signed mid August 2001, documentation was handed in by October and cooperation was completed in February 2002 which marked the completion of the cabin and all the exterior and interior tractor components. In order to prove the stability of the cabin in accordance with the three components of the standardized examinations, the tractor manufacturer verified the stability of the cabin on its own temporary prototype. The results were positive for all three examinations; protection from the tractor turning over, protection from falling objects and actual protection safety: (**a**) ROPS – ISO 8082 *Roll-over protective structures*, (**b**) FOPS – ISO 8083 *Felling-object protective structures*, (**c**) OPS – ISO 4252 *Objective protection safety and other* instructions for ergonomic evaluation of the benefits of skidders (Frumerie, editor, 1999; Rehschuh and Tzschöckel, 1977; Sundquist, editor, 1990; Hansson and Pettersson, 1980; Zerbe, 1979), according to which the second generation skidder TIBOTRAC-a was evaluated (Goglia et al., 2002). The request for cabin testing at the DLG laboratory (*Deutsche Landwirtschafts-Gesellschaft e.V. – Prüfstelle für Landmaschinen, Gross-Umstadt, Germany*), one of the most prominent in Europe and the world was also a request that after receiving the evaluation report no further certification or approval would be necessary for certifying the compliance of the products with the mentioned standards. Fulfillment of all requirements to ISO standards was confirmed in the report for the testing of the cabin DLG Test Nr.: 2004 – 426 , evaluations ROPS i FOPS (DLG, 2004). FOPS-Test on the safety cab fitted on forest tractor, s.c. skidder, TIBOTRAC FM 03 was made with a standard laboratory drop test object, level 1: diameter 290 mm, length 570 mm, mass 288, 40 kg, drop height in the test 2,05 m. The energy applied on the FOPS-Test by the drop test object (level 1) without intrusion of any structural members into the **d**eflection-**l**imiting **v**olume (DLV – orthogonal approximation of a large, seated, male operator as defined in ISO 3411 wearing normal clothing and a protective helmet) was 5,80 kJ. Determination position of DLV (manufacturer's information) is 235 mm in front of the C-posts and 105 mm below the roof. Cab construction is characterized by six-post-frame made of square tube and sheet steel and a metal sheet roof, longitudinal and transversal bracing, mounted to the chassis. ROPS-Test calculation of minimum performance was as follows: (**a**) *lateral load* – force 19,68 kN and energy 3,91 kJ; (**b**) *vertical load* – force 79,0 kN; (**c**) *longitudinal load* – force 15,75 kN. As ROPS-test results in test report for the (**i**)

*lateral loading* it is quoted as maximum applied force or exceeded without intrusion of structural ROPS parts or the **s**imulated **g**round **p**lane (SGP – flat surface on which, after rolling, a forestry machine is assumed to come to rest) into the DLV was 29,31 kN, and the absorbed energy without intrusion of structural ROPS parts or the SGP into the DLV was 3,92 kJ. In the same test (**ii**) for the *vertical loading* the maximum supported force without intrusion of structural ROPS parts or the SGP into the DLV was 81,15 kN, and (**iii**) for the *longitudinal loading to rear,* the maximum applied force after the required load was attained or exceeded without intrusion of structural ROPS parts or the SGP into the DLV was 16,57 kN, and in the same time the absorbed energy without intrusion of structural ROPS parts or the SGP into the DLV was 0,34 kJ. Figures 14 (**11**) and 15 (**12**) show two examples of force/energy vs deflection curves (original from Test Report). At the end as certification of test results as follows: (**1**) *Minimum performance according to ISO 8083:1989 level 1 fulfilled by this test*, and (**2**) *Minimum performance according to ISO 8082:1994 and longitudinal load fulfilled by this test for a machine of maximum gross mass of 3950 kg.*

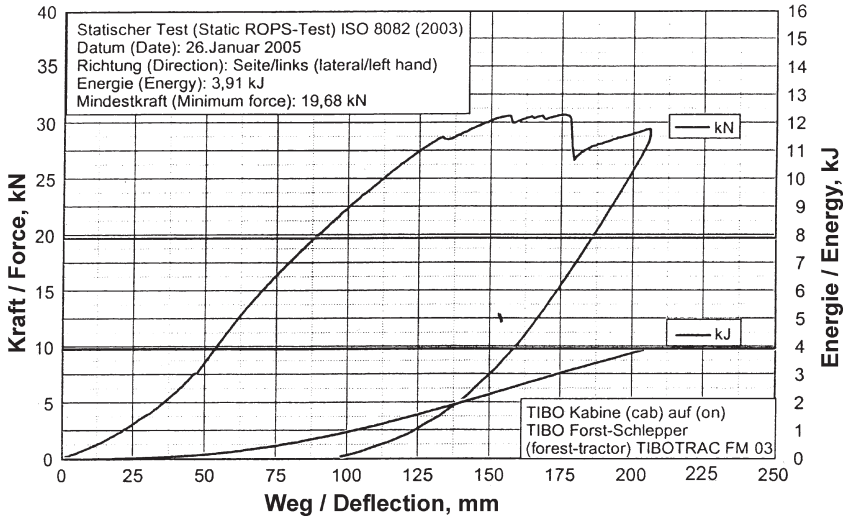


Figure 11. *Static ROPS-Test ISO 8082:2003, direction lateral/left hand, force/energy vs deflection*

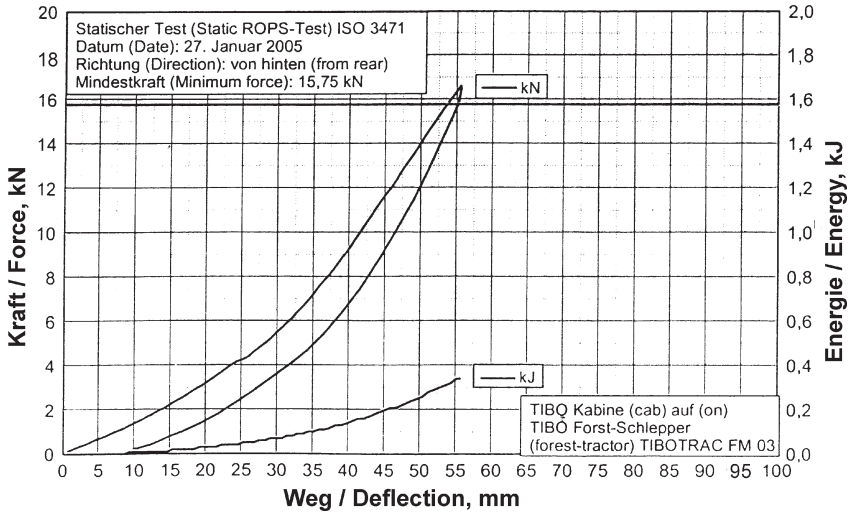


Figure 12. *Static ROPS-Test ISO 3471:1994, direction from rear, force/energy vs deflection*

### *3.9. Basic working components of the skidder*

The selection of working components of the skidder used for hauling wood is equipped differently: the timber is usually assembled by the mechanical winch from the cutting location to the possible tractor station. But, in the event that the terrain is appropriate so that the tractor can reach the assortment that is prepared for hauling, like long roundwood, the *grapple skidder* or even the *clam bunk skidder with knuckle boom hydraulic crane* can be used. When necessary, the front axle is mantled or dismantled, for example: an additional crane loads the hauled lumber at the loading point. The same situation applies to the rear axle which is necessary only as an alternative to the winch tractor.

#### *3.9.1. The Double drum winch tractor*

The manufacturer of the medium-sized forest skidder, 3 MAJ TIBO d.d., Matulji, when constructing the second generation model offered its own double drum winch (2 × 35 kN) which is offered in the third generation as a 2 × 40 kN version, but can also utilize any winch produced by other manufacturers. The first winch was evaluated in accordance with the ISO standards 6816:1984, 6687:1994 and certified safety of the winch according to ISO standard 4254-4:1990.

The speed of collecting the rope remained unchanged (1,2 – 2,1 m/s during a rotation frequency of the engine at 2200 $min^{-1}$), a selection of diameter of the steel rope (∅10 mm or ∅12 mm, 54 m in length or 35 m, rope performance 6[1 + 6 + 12

+18]). For the third generation, the rope operating system was altered: alongside rotating pulleys (not steel rollers) on the exit side towards the pulled load, the bending angle from the inner side of the winch drums is softened by adjustable pulleys. Examination of the winch at an actual pulling force of 2 × 40 kN was published in 2005 (Radaković, 2005). The experimentation confirmed that the largest pulling force is when the rope is completely loose, the left drum is 45,1 kN and the right one is 42,3 kN), where if the rope is tied around the drum (around 10 m of its length) it is established that the left drum is 31, 4 kN and the right one is 36,3 kN. In this situation, problems were determined with tying the end of the rope to the drum of the winch and with the quality of the rope which resulted in the selection of a new manufacturer.

Alongside these modifications, and during selection of the components, especially of the hydraulic and electro hydraulic valves etc. only those tested on forest machines were chosen. Operating the winch can be done manually from the cabin or via remote control. The hydraulic pump remained the same capacity (4 $cm^3$/rotation, actual pressure 12 MPa).

Goglia et al. (2002) calculated by standardized verification in accordance with the ISO standard the marginal (largest) pulled amount of load that can be still pulled by a winch on terrain slopes up to 50° (119,2 %) (Figure 13). The tractor was not stationed on a flat surface at this point from which it was hauling the calculated load upwards, while using the greatest force it can. Expressing this action in calculation mode would be: the resistance of haulage = (weight) hauled load ($f_v$ = 1).

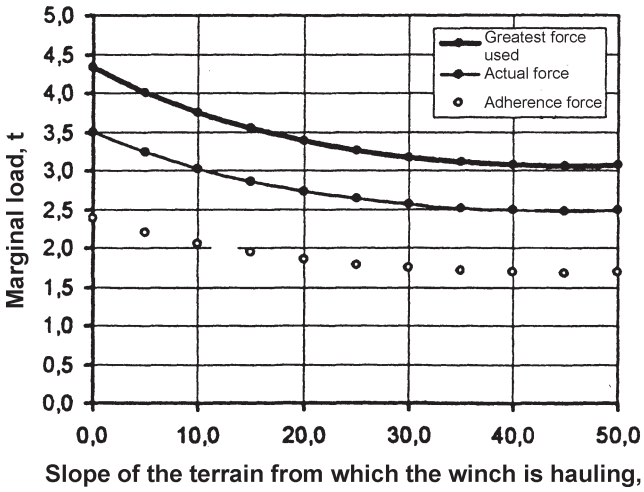


Figure 13. *Marginal hauled loads for three case of hauling force (Goglia et al., 2002)*

### *3.9.2. The frontal thrusting and lifting loader*

As an alternative to the thrusting loader, skidder TIBOTRAC FM 03 (and the earlier 02) offers a replacement by a diverse functioning thrusting and lifting loader (Figure 14). The main aim of the broader application is to facilitate loading of the hauled roundwood in spatially confined assisting loading points, by increasing the height of the stack. Naturally, this will decrease the damage of the working surface of the loading point or the tractor trails. It will also decrease the resistance while pushing the lumber, therefore saving fuel, tires, chains, etc.

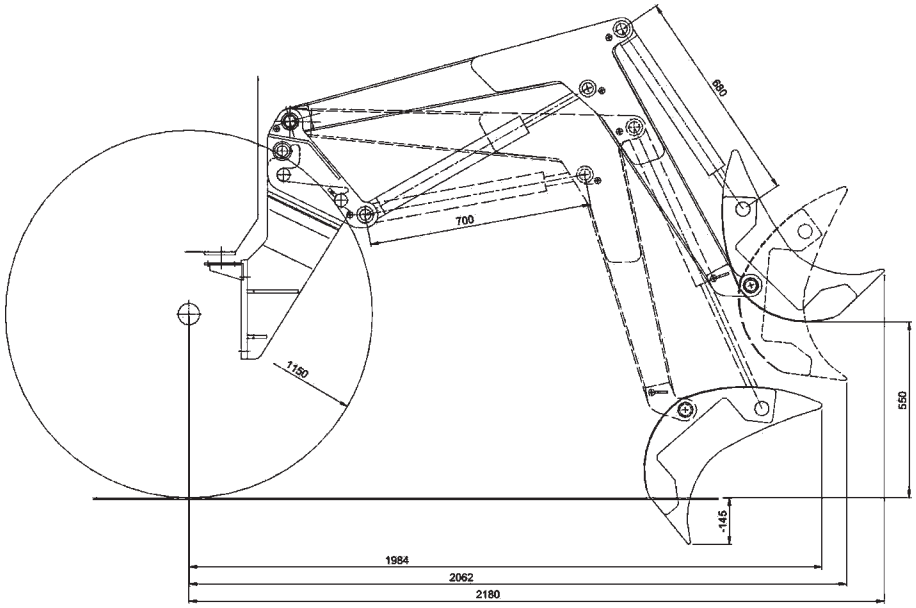


Figure 14. *New alternative to the frontal thrusting and lifting loader of the skidder*

### *3.9.3. Rear lifting/leaning loader*

Since using the method of tightly tying the axle to the chassis, throughout development a new lifting anchor loader with which the tractor resists the pulling force while hauling and after collecting the load, it lifts it and leans the loader, skidding the load with one lifted end (leaning on the tractor wheels). With the remaining load it pushes it against the ground and creates resistance of the skidding which the tractor has to overcome with its traction (Figure 15). Pampel (1985) states that at that moment the skidding force is decreased by 31 % in comparison to the situation when the load is being skidded by it entire length on the ground.

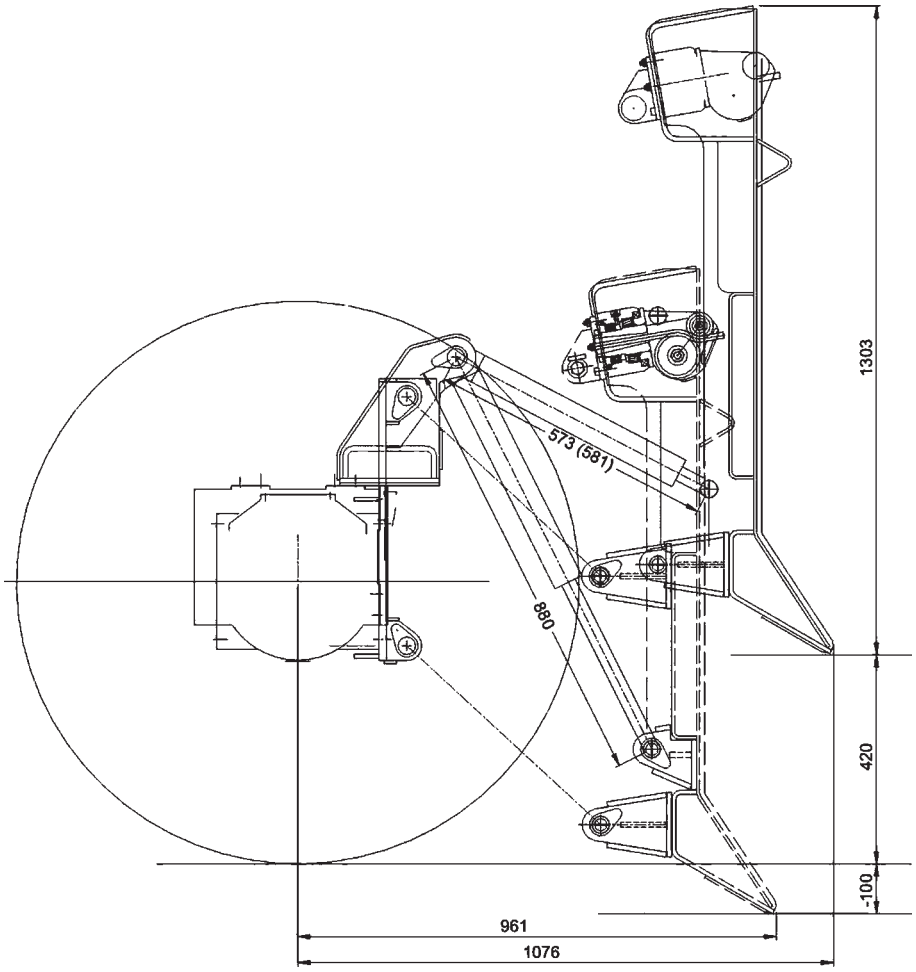


Figure 15. *Two extreme positions of the rear anchor/leaning loader of the skidder*

## 4. Further steps

The construction of the medium-sized third generation prototype of the skidder is a natural next step of constructing Croatian tractors for hauling thinning wood, a process that started twenty years ago with the creation of a project of a first generation tractor. Every decreased effort of forestry experts to deal with forestry mechanization at any level, the non-preparedness to manage national forests as a public or private company when once when there were 16 forest managements that were willingly ready to invest in the community, somehow influenced the answer to the posed question: What is the next step?

The first step to of any further decision on beginning a serial production is to look into the cabin evaluation in one of the most prestigious laboratories in Ger-

many, DLG. The next step should be the verification of the complexity of the tractor and its elements: using bio-diesel fuel, operating with the assistance of the joystick and engine, oil selection for lubrication of the transmission gearbox and hydraulic elements, etc. Apart from knowing the reliability of these experiments and evaluations, while selecting the valuation criteria, measurement procedures definition of the procedure, evaluation method and interpretation of the results with a final evaluation should all be verified. The entire procedure of confirming the compliance of the tractor as a whole will be executed according to article 11 of the Rulebook (DZNM, 2001). The suggested examination should be executed in accordance with the procedure of European certification. Any discoveries about schools for the mechanization of forestry work should be taken into consideration, such as the Central European, Scandinavian and Northern American schools. Their school of thought and accomplished levels can make it more difficult to give an objective picture of the Croatian accomplishments in this field. The tractor has to operate in actual Croatian conditions for the flaws to be noticed and subjectivity to be divided especially, that of the leading participants into professional/unprofessional, researched/unresearched, worthy/unworthy. It would not be worth not mentioning the unfriendly attitude of the society towards a creation that brings something new.

When examination in a neutral laboratory is finished, it is useful to find the resources and begin a small-series production for the domestic and international market. It is hopeful that conservation of the complex forest ecosystems will become livelier through working elements used in Croatian forests space, be there forests or not, be fertile or infertile. Besides the fact that Croatia can receive certified elements, for example CE stamp with a signature of a certified body, the grade of a product from the standpoint of work protection, test mark, Euro Test, environmentally friendly oils it is important to have a third party grade the product. And remain among the best using personal judgment.

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# THE AWARDS

## OF THE CROATIAN ACADEMY OF ENGINEERING IN 2005

# The Awards of the Croatian Academy of Engineering in 2005

Once a year the Croatian Academy of Engineering presents awards for extraordinary contributions to science and to the profession, for the realisation of the goals and programmes of the HATZ, and for the dedicated work, which has contributed to the social affirmation of the HATZ. The awards are presented in the form of written certificates and are of a pecuniary nature in certain amount. The awards are presented as:

– one Award for Life Achievement "Power of Knowledge",
– up to five Annual Awards "Rikard Podhorsky",
– up to five Awards to the Young Scientists "Vera Johanides"

The procedure of applying for awards and decisions on them are specified in the Bylaws on Awards.

On July 7, 2004, the HATZ has published its annual Call for Nominations for the HATZ Awards, which was concluded on November 25, 2004. According to the proposal of the HATZ Committee for Awards, supported by the Governing Board and the Presidency of the HATZ, the Assembly of the HATZ has decided, at its session held on February 26, 2005, upon the Academy's Awards Laureates for 2004:

**1. one Award for Life Achievement "Power of Knowledge":**

– **Prof. Marijan Bošnjak, Ph. D**., for his scientific and research results in total and for their application in and impact on the Croatian economy as well as for his permanent contribution to the development and promotion of the HATZ,

**2. five Annual Awards "Rikard Podhorsky":**

– **Prof. Hildegard Auf-Franić, Ph. D**., for the significant scientific achievements in elementary schools planning, programming and designing,

– **Prof. Jasna Franekić-Čolić, Ph. D**., for the research in the field of ecotoxicology and substances, which enable successful pollution removal without harmful impact on the ecosystem,

– **Prof. Gojko Nikolić, Ph. D.**, for four patents: P20030642 (2003), P20030727A (2003), P20030987A (2003) and P20031024 (2003), which promote founding of the new enterprises and production processes in the Croatian textile industry,

– **Prof. Nedjeljko Perić, Ph. D**., for the outstanding contribution to research, development and employment of the new strategies of complex engineering systems management,

– **Prof. Stanislav Sever, Ph. D**., for the eminent scientific work in the field of forest utilization, particularly in the mechanization of cutting, manufacturing and drawing processes.

**3. five Awards to the Young Scientists "Vera Johanides":**

– **Ksenija Durgo, M. Sc.,** for the scientific research in the field of environmental protection, the results of which are published in the scientific journals,

– **Ivica Garašić, B. Sc.,** for the scientific and professional contribution in the field of welding and non-destructive underwater inspection,

– **Assist. Prof. Mislav Grgić, Ph. D.**, for the scientific contribution in the field of multimedia communications,

– **Ante Jukić, Ph. D.**, for the scientific activity in the field of chemical engineering,

– **Vedran Slačanac, Ph. D.**, for the published papers and the scientific activity in the field of food technology.

The HATZ hereby expresses its acknowledgements to the sponsors of the Awards:

– **Končar Institute for Electrical Engineering, Inc., Zagreb**, for the Award for Life Achievement "Power of Knowledge",
– **PLIVA Croatia, Ltd., Zagreb**, for the Annual Award "Rikard Podhorsky",
– **Zagreb Brewery, Inc**., **Zagreb,** for the Award to the Young Scientists "Vera Johanides".

# ETHICS IN APPLICATION AND DEVELOPMENT OF THE ENGINEERING SCIENCES

## Abstracts from the Round Table Discussion

# Ethics in Application and Development of the Engineering Sciences

The Round Table Discussion "Ethics in Application and Development of the Engineering Sciences", organized by HATZ, was held on June 3, 2005 at the Faculty of Food Technology and Biotechnology, University of Zagreb, Croatia. The meeting was attended by approximately 25 participants, including 14 lecturers.

The Program of the meeting was divided into two parts: Major Issues and Special Issues. Herein we present the authors and the abstracts of their lectures delivered at the meeting. The extended abstracts of the lectures in English and papers in Croatian will be encompassed by a special publication – Proceedings of the Round Table Discussion.

## MAJOR ISSUES

Zlatko Kniewald
**Ethics in Knowledge and Technology Transfer**

Marijan Bošnjak
**Trend of Ethics as a Reflection of Science and Technology Developments**

Mislav Ježić
**World views and Ethical Principles**

Tonči Matulić
**Application and Development of the Engineering Sciences: A Christian Ethics Viewpoint**

Ivan Koprek
**Wisdom of the West and the Relation to Ethics**

Melanija Strika
**Sociological Aspects of the Role of Ethics in Application and Development of the Engineering Sciences**

Juraj Božičević
**Code of Ethics in the Field of Engineering Sciences**,
(The lecturer cancelled his participation at the Round Table Discussion)

**SPECIAL ISSUES**

Srečko Pegan
**Reflections on Ethics in the Architecture and Urban Planning**

Ivo Soljačić and Tanja Pušić
**Ethics and Ecology in Textile Finishing and Textile Care**

Hrvoje Domitrović
**Ethics and the Internet**

Miljenko Lapaine and Nedjeljko Frančula
**Ethics in Geodesy**

Ivan Ilić
**Ethical Vertical of the Application of Fuel Cells in Energy Conversion**

Zoran Zgaga
**Ethics in Biotechnical Sciences**

Zvonimir Janović
**Ethics in Chemical Engineering**

Milan Glavaš
**Forest Fires in the Republic of Croatia**

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## ETHICS IN KNOWLEDGE AND TECHNOLOGY TRANSFER

*Abstract*

Every scientific discovery that is intended for direct application, while on its way to the market, may as well put into question some ethical standards. The question is: Who is responsible in the process? The scientists that have achieved the discovery, for which they usually are not rewarded at all, or those that turn the scientific discovery into a market product with its commercial value? Are the scientists in the position to influence the producer, who, for instance, deliberately maintains an obsolete technology that not only pollutes the environment, but is also on the verge of rentability, not to mention the decrease of profit, while the existing production may still maintain the profit at the constant level? And, if they are in

such position, in what way can they make the influence? Are the scientists in the position to influence the decisions made by the “state” or the “politics” in cases when the demands of growth of the population standard is likely to change the appearance of the environment that has been preserved by traditional way of life? And, if they are in such position, in what way can they make the influence? Every day we face the derogation of the ethical standards, only the question is whether the one who derogates them is convinced thet he does that with the aim of obtaining a greater good for his fellow men, or he does that for the sake of his own interest that ignores the ethical standards. Being ethical is a wisdom that we learn as long as we live, but we have to admit that the individual point of view is often crucial for ethical evaluation of someone's deeds. The world could hardly achieve a fast development if being ethical would be a wide-spread effort, obligatory everywhere and towards everyone. Thus this discussion does not aim to the final solutions, but instead it aims to reconsider the problem and make the personal framework for what is ethical or unethical. It also aims to keeping our deeds within the limits of a generally accepted behaviour during our lifetime.

*Key words:* science, technology and ethics, market and ethics, life-long ethical approaches

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## TREND OF ETHICS AS A REFLECTION OF SCIENCE AND TECHNOLOGY DEVELOPMENTS

*Abstract*

Modern progress of the science with an especially fast development in the field of biological and technical sciences, catalyzed with a more and more efficient informatics, advanced potentials of human population tremendously. Therefore, we could hope for a safer future of the people that is characterized with an efficient environmental protection and better living conditions for all people. However, there is no guaranty for the increased knowledge and better technical and other possibilities to bring the benefit. We are witnesses of more and more frequent bad or even tragic consequences of science and technology advances, markedly caused by neglecting moral principles in people’s activities. Because of still present hidden dangers, and especially of those unpredictable, which can arrive with uncontrolled progress, the processes of enhancing the ethical component of human community have been initiated, and one can expect that these processes would direct knowledge and technical

advances to be applied undoubtedly for benefit, harmony and a maintainable and safe development. Actually, one can observe very pronounced activities of such a character worldwide. Being expressed through the organization of scientific and professional meetings, adaptation of education programmes for ethical behavior, spontaneous protests of people against defects or imperfections of new products and technologies, and especially through an efficient organization of adequate institutions and working groups with a strong influence in favor to ethics and with an authority to ethically control the deviations with possible dangers for people and environment, these activities encourage us for our actions in the right direction. Now is the moment to enhance the activities in Croatia, especially since Croatia could fulfill the strongest ethical criteria if Croatian people, government and other relevant institutions would be systematically and efficiently engaged in this direction.

*Key words:* trend of ethics, science, technology, development, worldwide activities

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## WORLD VIEWS AND ETHICAL PRINCIPLES

*Abstract*

Ethical systems are far more numerous than world views or especially than great cultures in which they appear. However, they can be systematized according to their main approaches. In this way we can notice that in different great cultures we can find congenial ethical approaches.

A theory of virtues was developed by Plato, and later elaborated by Aristotle, but it can be equally found in Hinduism or Buddhism.

A list of moral principles or commandments can be found in the Bible, but also in the Yoga, Buddhism or Jinism, and more than half of the list is practically identical.

A formulation of a universal categorical imperative demanded by our reason was attempted by Kant in the 18th century. A similar principle of universal legislation based upon duty and disregarding any interest was formulated in the Bhagavadgita two millenia ago.

The axiological foundation of ethics can be found in Old Indian lawbooks, as well as in Christian scholastic philosophy, moreover with the same list of values. A more recent example is the ethics of Max Scheller.

Utilitarian ethics can have a greater appeal to modern consumer societies. It will lack the deductive strictness, but will address human interests. Based on

intersts is the ethical approach of Peter Singer, who defends the interests of sentient beings, bringing our attitude to animals into the ethical sphere.

Modern ethics can be based on the principle of resposibility for life. It is endangered by our technology and therefore this approach is appropriate for our epoch. Hans Jonas formulates it as a universal imperative, resembling Kant's, but replacing its formalism with content.

Concerning the astonishing progress of our technology and its power today, the principle of responsability may teach us that ethical consciousness, bioethical concerns and ecological responsibility should be all the more important for technology, medicine and biotechnology the greater progress they make. If that proportion between ethics and technology cannot be maintained, human dignity can be crushed, and the living world can be destroyed.

*Key words:* ethics, technology, responsibility, ecology, bioethics

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## APPLICATION AND DEVELOPMENT OF TECHNOLOGY: A CHRISTIAN ETHICS PERSPECTIVE

*Abstract*

In his contribution the author provides a systematic reflection on the epistemological, historical and philosophical as well as sociological implications of the development of technology with a special emphasis on the implications of the Christian ethics. Having as aim a clearer understanding of the essence of the transformed epistemological paradigm with respect to interpretation and understanding of technology, the issue is elaborated in the paper in five subsequent parts. In the first part, certain essential features of the historical metamorphosis of scientific and technological enterprise are reflected upon from their original culturological perspective, e. g. antique understanding of reality. In the second part, and opposing to the cosmological order of antiquity, certain intra-secular implications of God's creative will are reflected upon from a Biblical and Christian perspective. A series of important aspects of the modernity metamorphoses with respect to interpretation and understanding of the world, the man, the nature, the ethics and the technology, are reflected upon in the third part. In the fourth part, certain aspects of philosophical and ethical metamorphosis of the essential understanding of the relation between a purpose and a means are reflected upon. In the fifth part of the paper the

author reflects upon certain aspects of social metamorphosis, stipulated and embraced by the idea of social progress in the materialistic sense of the word, which is supported by a technological conquest of the nature, including man himself. In the last, sixth part of the article, certain principal suggestions on the (pre)conditions for the realization of a partnership dialogue between the technology and the Christian ethics are presented. In the realization of this dialogue, certain essential theological pre-suppositions of the Christian ethics have to be particularly emphasized, because without their clear recognition it is both unconceivable and unfeasible to realize a fruitful and partnership dialogue of the Christian ethics and technology.

*Key words:* cosmos, nature, (bio)technology, natural science, metamorphoses, Christianity, creation, salvation, culture, dialogue, Christian ethics

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## WISDOM OF THE WEST AND THE RELATION TO ETHICS

*Abstract*

According to B. Russell, the philosophical tradition of the West differs firstly by its practical wisdom of the Greek genius from the speculations of the spirit of the East. The concept of **wisdom** – *σοφια* sofia (Greek), *sapientia* (Latin) – for the Greek meant a way of living, thinking and acting in accordance with the supreme moral principles – the philosophy, "love for the wisdom", the science of wisdom. The first Greek philosophers were inventors, mathematicians, physicists, chemists, teachers, pedagogues… They studied the motion of the celestial bodies, state governance, social relations…

The practical and theoretical thought of the Greek has set a basis for all subsequent scientific systems of the West. It may as well be said that the Western civilization has been created under the influence of the "Greek miracle".

There is no doubt that Socrates is a personalized image, an ideal of philosopher and sage who is a theorist and a practitioner at the same time. Yet only the philosophy of Aristotle became crucial for the principal differentiation between the *theoretical philosophy* that encompassed sciences (such as mathematics and physics) and the *practical philosophy* that, according to Aristotle's classification, encompassed politics (ethics), dialectics and rhetorics. However, he did not consider the theoretical and practical philosophy to be divided by an insurmount-

able divide, but was convinced that they differ only in their ways of reaching the truth.

In most general terms, today we consider philosophy a scientific discipline that seeks to answer the essential questions on the world, the man and his cognition, the society… a discipline that ought to lead from knowledge to wisdom. The author of this paper shall demonstrate the development of the Western ethical thought (wisdom), starting with classical theses of ethics all the way to the newest attempts of its founding. His intention is to point at the necessary elements of the "science of wisdom", which today's sophisticated techniques and the contemporary sciences need the most.

*Key words:* philosophy, theoretical and practical philosophy, ethics, practical wisdom, moral principles, Socrates, Aristotle, virtues, moral responsibility

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## SOCIOLOGICAL ASPECTS OF THE ROLE OF ETHICS IN THE APPLICATION AND DEVELOPMENT OF ENGINEERING SCIENCES

*Abstract*

A sociological reflection on the double role of ethics in engineering sciences will be presented in the paper. The absence of ethics in its meaning of philosophical discipline is implied by a growing distance between philosophy and the engineering sciences. The affirmation of ethics in the engineering sciences is also implied, but in the meaning of reduction of ethics to "practical ethics" that lacks a unique theoretical foundation. The rise of the engineering sciences overlaps with the idea of progress as a key idea that marked the age of modernity and might well be detected in the etymological definition of the terms "technique" and "technology", with particular emphasis on performance-oriented knowledge and practice as their constitutive elements.

*Key words:* sociology, ethics, philosophy, engineering sciences, progress, modernity, technique, technology, performance-oriented knowledge, practice

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## ETHICS AND ECOLOGY IN TEXTILE FINISHING AND TEXTILE CARE

*Abstract*

Plenty of water and chemicals are used in textile finishing and care, which can pollute environment to a great extent. For years possibilities of substituting harmful chemicals by less aggressive and biodegradable chemicals have been investigated intensely. Stronger regulations have been passed. Many chemicals were banned or their maximum quantities being used are limited. New dye groups have been introduced and potentially carcinogenic dyes and dyestuffs containing harmful ions of heavy metals have been displaced. Energy and water consumption is reduced.

The same can be stated about the processes of textile care. By introducing enzymes and bleach activators, efficient washing at lower temperatures with a lower detergent consumption is enabled. The permitted perchlorethylene consumption must not exceed 2 % of the amount of dry cleaned textiles.

Hydrocarbon solvents partly substitute perchlorethylene. The possibilities of the application of new solvents are being investigated, of which liquid carbon dioxide has the best prospects.

The sewn-in labels prescribe care regulations, label textile quality and sometimes environmental values (Eco labels). They determine whether the textile product is manufactured in an environmentally friendly manner and whether harmful substances are contained.

*Key words:* textiles, ethics, ecology, finishing, texcare, eco-labels

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## ETHICS AND THE INTERNET

*Abstract*

In the growing line of media, the Internet is the latest and in many respects the most powerful one. Its decentralized nature and two-way flow of information gives

all the users the opportunity to be both the source and the end point of information, thus enabling the elimination of time and space as barriers in communication. Omnipresence and availability of Internet have long overcome its limitations as a strictly professional and scientific medium. Nowadays, the internet has become a new *Forum Romanum*, the place where social, political, business as well as cultural life take place. Due to progress in technology, human privacy and intimacy is exposed on this virtual *Forum*. Therefore, the Internet is truly a place where all the good and the bad things man does are exposed to the public eye and judgment.

The human person and the human community are the object and the measure of social communication, so it is necessary to evaluate this medium not only by its technical potential or financial effect, but by the ethical values as well. In this paper the author deals with some ethical areas of concern by analyzing the phenomena related to the possibilities the Internet gives, the ways of using it and the types of information published on it.

*Key words:* ethics, Internet, social communication

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## ETHICS IN GEODESY

*Abstract*

The paper first discusses the issue of existence of ethical codes in the geodetic profession in Croatia. Although there is the *Croatian Geodetic Society*, it does not have a code of ethics. There is the *Code of Professional Ethics of Croatian Architects and Engineers in Civil Engineering* created in 1998, which is valid for geodesists who are members of the *Croatian Chamber of Architects and Engineers in Civil Engineering*. The Faculty of Geodesy is a part of the University of Zagreb, but the University does not have its ethical code yet. According to the *High Education Law*, the Croatian parliament was supposed to nominate the *Committee for Ethics in Science and High Education*, but as far as the authors know, such a committee has not been established yet. We also have not found a code of conduct of officials in public or state service in Croatia.

Furthermore, the paper considers the ethical codes for geodesists in other countries, such as e.g. Australia, USA and Slovenia, and in professional societies (*Fédération Européenne d'Associations Nationales d'Ingénieurs European* –

FEANI, *International Federation of Surveyors* – FIG, *American Society for Photogrammetry and Remote Sensing* – ASPRS). The example of research of ethics in public services in countries members of the European Union shows an increase in interest for that subject.

Finally, the paper describes in details the Code of Ethics of FIG. The authors recommend its adoption in Croatia.

**Key words**: *ethics, geodesy, surveying, Croatia*

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## ETHICAL VERTICAL OF THE APPLICATION OF FUEL CELLS IN ENERGY CONVERSION

*Abstract*

By directly converting chemical energy into electrical, with the aids of fuel cells, environment pollution with toxic nusproduct of incineration is avoided in whole. Except of avoiding the toxic effect on environment, fuel cells have much higher efficiency, what corresponds to extra quality of ethical vertical. It is already built and in use in power units of couple of MW, which allows the distributed production of electrical energy directly to the consumer.

In the past approximately 15 years, major world's car industries invested huge assets in exploration of application of fuel cells in electromobile's drive engine, and thus already critical pollution of urban centres by exhaust gasses of classic engine vehicles would be avoided.

It might be concluded that we are on the doorstep of a new and, from the ecological point of view, a clean era in energy conversion. It may be expected that with time this technology would overcome technological and economical problems in amount high enough that its key ecological advantages would greatly influence decision of replacing old, ecologically toxic technology with new, ecologically clean fuel cells technology.

*Key words:* ethics in technics, fuel cells, energy conversion, ecology, electromobile

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# CHEMICAL ENGINEERING ETHICS

*Abstract*

Judging by the previous developments, production capacity and growth and its influence on the other production branches, chemical industry belongs to the leading manufacturing enterprises. The development of chemical industry is based on knoweledge and scientific achivements and is able to materialize most of the innovative challenges. It is also a driving force for the development of many similar productions and therefore is a headstone of the overall breakthrough and the achievements of our material civilization. Also, chemical industry in the developed countries belongs to the most propulsive and profitable ones, having direct influence on the value of all production, investment and new employment.

However, besides new developments, particularly sustainable and environmental acceptable processes and products, the chemical engineer in his practice should also recognize and obey the ethical principles.

The fundamental principles of conduct of engineers include truth, honesty and trustworthiness in their service to society, and honorable and ethical practice showing fairness, courtesy and good faith towards clients, colleagues and others. The engineers take societal, cultural, economic, environmental and safety aspects into consideration, and strive for the efficient use of the world's resources to meet long-term human needs. The engineers should examine the societal and environmental impact of their actions and projects, including the wise use and conservation of resources and energy, in order to make well-informed recommendations and decisions. Chemistry end chemical engineering will have to respond to them. They should perform practice only in their areas of competence, in a careful and dilligent manner and in accordance with standards, laws, codes of ethics, and rules and regulations applicable to the engineering practice.

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## FOREST FIRES IN THE REPUBLIC OF CROATIA

*Abstract*

The majority of forest fires appear in karst areas, primarily in the coastal and island regions. The Mediterranean and sub-Mediterranean belt of our forests covers an area of approximately 870,000 ha. In Croatia, computer assisted monitoring and analysis of forest fires began back in 1975. Since then, there have been several years (1983, 1985, 1988, 1998, 2000 and 2003) in which numerous forest fires occurred and large areas of state and private forests and uncultivated lands were burnt in the fires. The greatest catastrophe occurred in the exceptionally dry year 2000, when 706 forest fires broke out, and 68,106 ha of forests were burnt. The average burnt area per fire is very high in Croatia. The annual average is from 29 to 90 ha per fire. In Europe, a fire is considered to cause great damage when the average per fire is greater than 10 ha.

In terms of the time period in which forest fires occur, there are two peaks in Croatia: a smaller spring peak (usually resulting from weed burning) and a larger summer peak when the majority of fires occur.

The Canadian meteorological index of forest fire danger is applied in Croatia. Hrvatske šume d.o.o. (Croatian Forests) has divided all our forests into 4 levels of danger from forest fires:

Level I – very great danger, encompassing about 50,000 ha, Level II – great danger, about 142,000 ha, Level III – intermediate danger, about 625,000 ha and Level IV – low danger, almost 1 million ha.

Hrvatske šume d.o.o. invests great efforts in forest fire protection. Professional firefighters, volunteer firefighting associations, Hrvatske šume d.o.o. and citizens participate in extinguishing forest fires, with Kanader aircraft and helicopters of special significance in forest fire fighting. The greatest measure of protection is the education of all citizens, and their contributions to prevent forest fires from occurring.

*Key words:* forest fires, forest areas, number of fires, human factor, protection measures