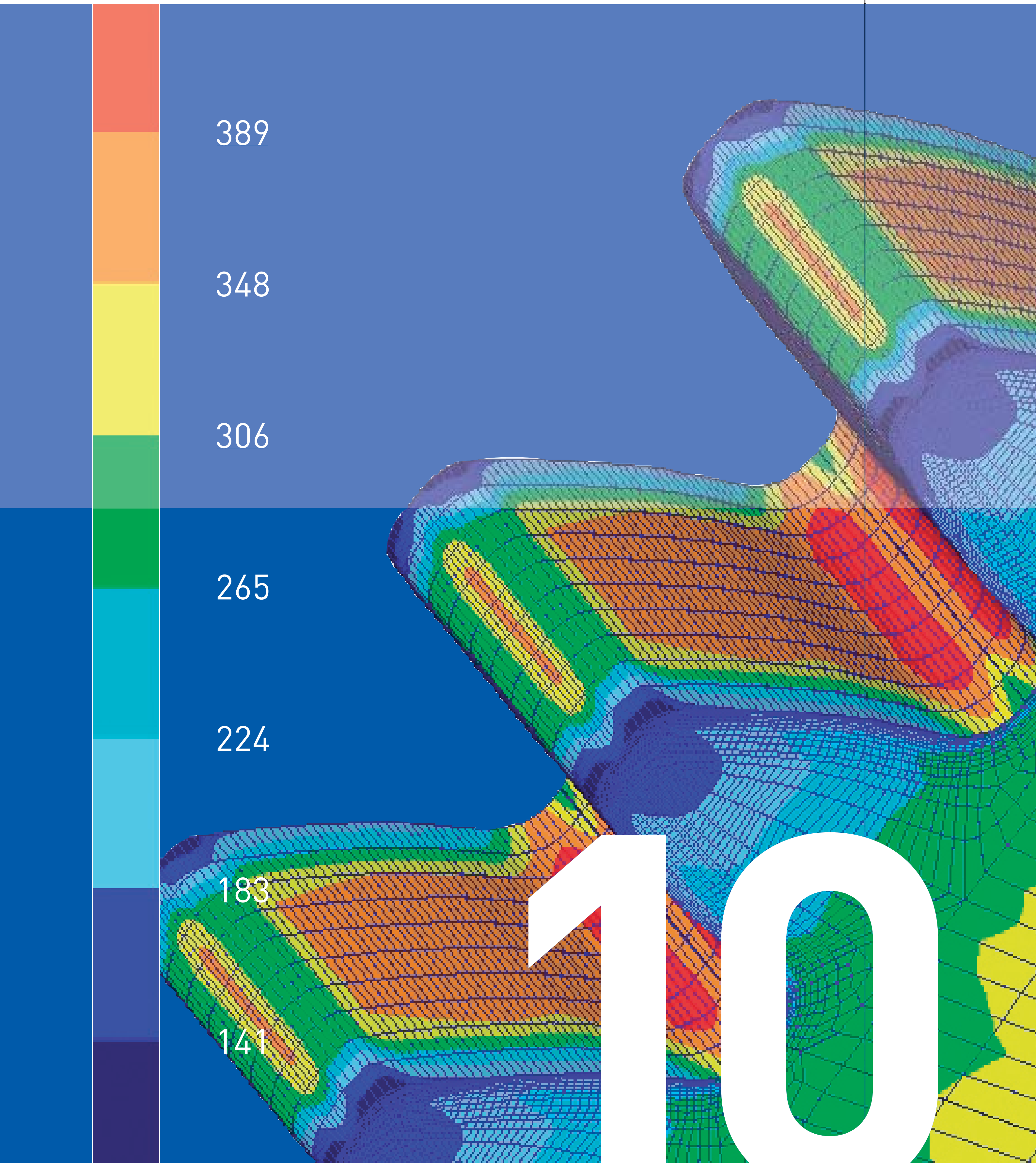
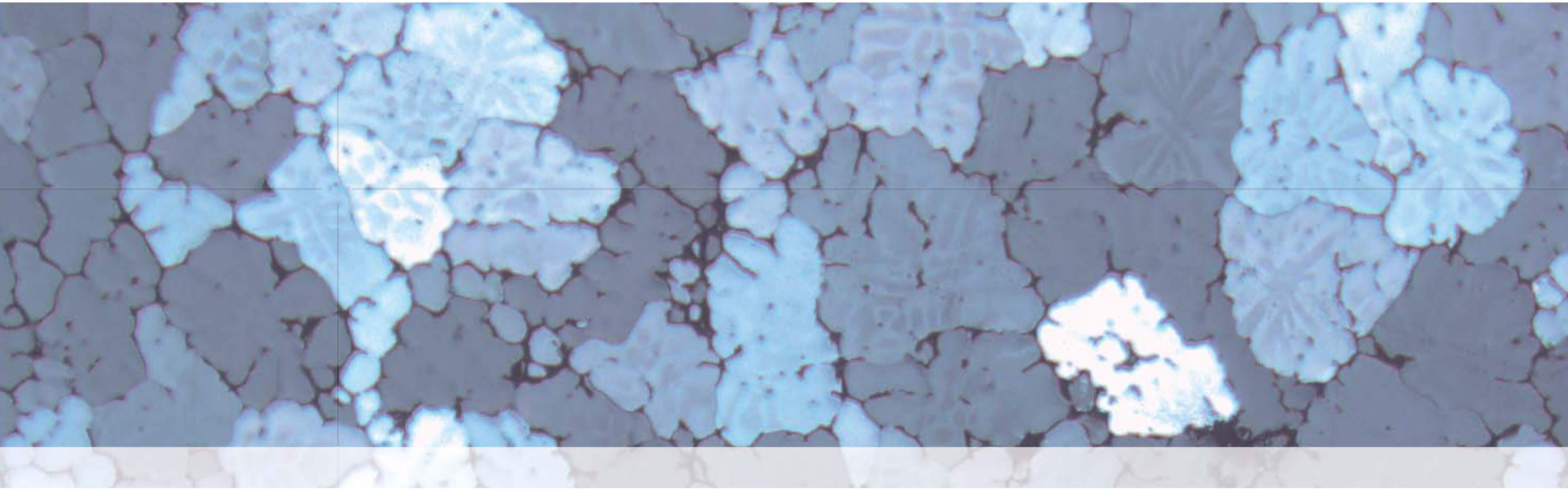
MATERIALS CENTER LEOBEN FORSCHUNG GMBH

ANNUAL REPORT 2010





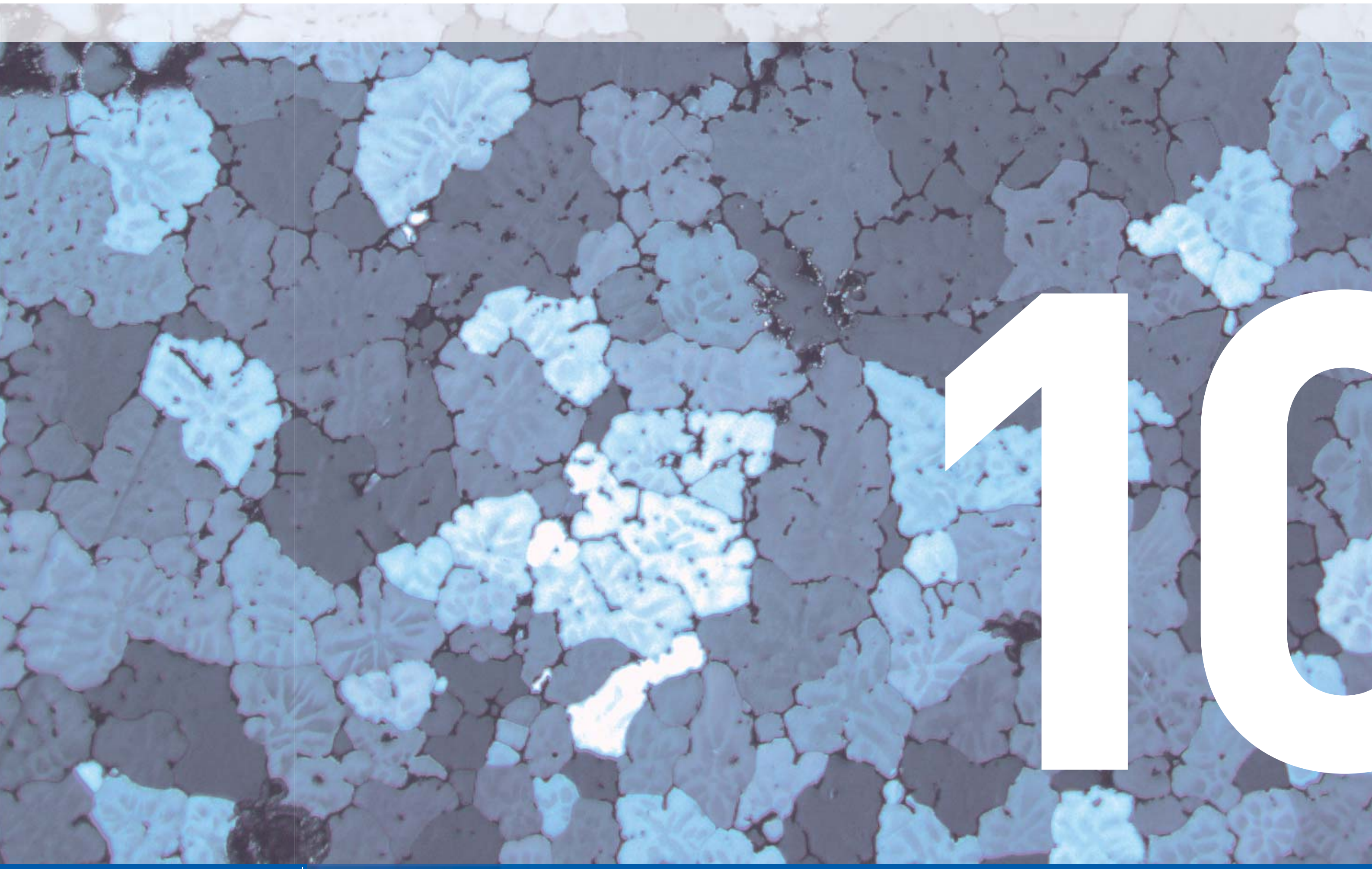
COMET

Competence Centers for
Excellent Technologies

COMET K2 Centre MPPE

The strategic objectives of COMET are: developing new expertise by initiating and supporting long-term research co-operations between science and industry in top-level research, and establishing and securing the technological leadership of companies. By advancing and concentrating existing strengths and by integrating international research expertise Austria is to be strengthened as a research location for the long term.

MPPE is grateful for funding from the Austrian Federal Government (especially the Federal Ministry for Transport, Innovation and Technology and the Federal Ministry of Economy, Family and Youth) represented by the Austrian Research Promotion Agency (FFG) and from the Styrian Regional Government represented by the Styrian Business Promotion Agency (SFG).



Our Expertise – Our Objectives

Material and processing technologies for the benefit of our customers

The Materials Center Leoben (MCL) is an internationally active research institution specialising in materials, production and processing engineering and innovative material applications.

MCL provides research services in the following areas together with its partners:

- **Metallic materials**, in particular **steels** – development, processing, design and innovative applications
- **Tooling,** tool materials as well as tool loading and service life
- **Material composites** – materials and component reliability (in particular for the **electronics industry**) and **ceramic materials**
- **Materials analysis** on all length scales
- **Materials mechanics and simulation** – processing, design and reliability, material models

MCL carries out cooperative research and development projects with partners from industry and offers a comprehensive range of services.

MCL also acts as the operating company and research partner of the COMET K2 Competence Center "MPPE – Integrated Research in Materials, Processing and Product Engineering", which provides a sound basis for solving complex research and development tasks.

MCL is Austria's leading cooperative materials research centre for industry and science, offering state-of-the-art research and development services.

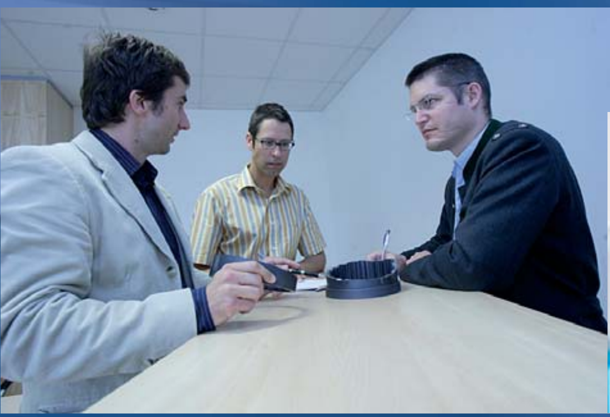
MCL is aimed at providing industry with sector-specific and scientifically sound knowledge in the field of materials research in order to strengthen the competitiveness of Austrian companies in this promising sector.

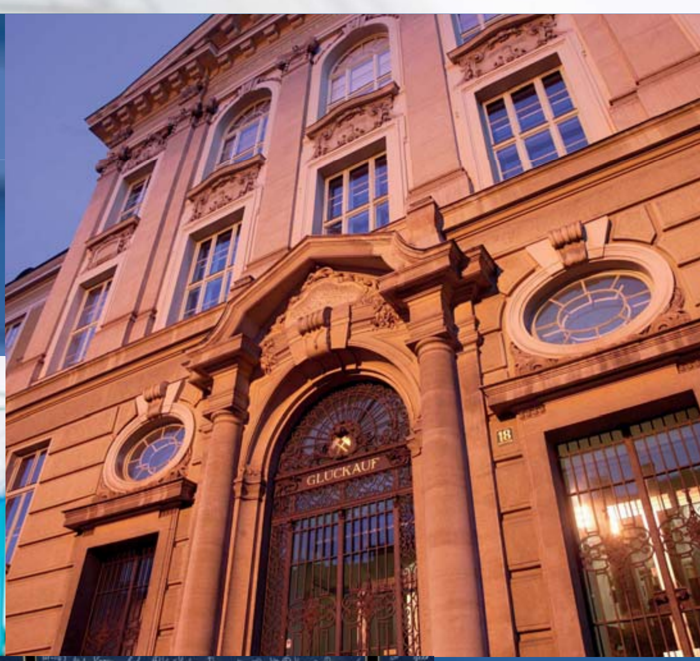
A professional team of over 115 highly trained experts is working on fundamental and innovative developments along the entire value chain of materials research by carrying out research and development projects in cooperation with a total of 120 industrial and scientific partners.

Industrial partners

COMET K2 Centre MPPE

Research projects





Scientific partners

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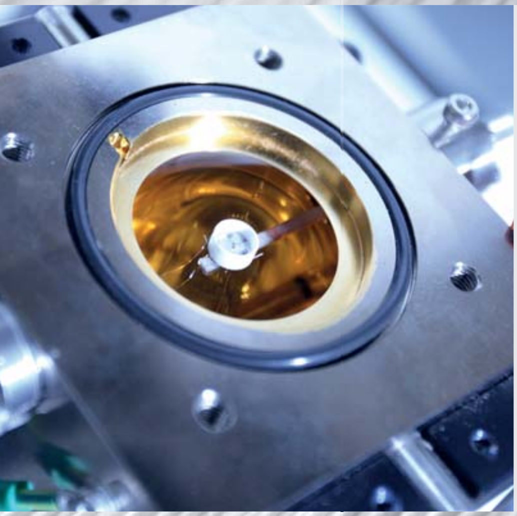

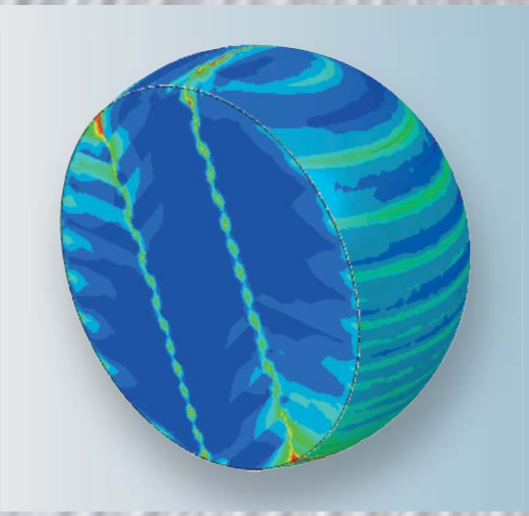

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Management Report

Economic crisis successfully overcome
In 2010, the general overall economic situation improved considerably compared with the previous year giving grounds for hope of sustainable economic recovery – despite initial signs of a further weakening in the economy. This improvement in the general economic situation was used to develop and implement new projects. A total of 13 new projects were launched in the 2010 financial year, which also compensated for the drop in orders in a difficult 2009.

Projects in new research fields and increase in staff
In this context, we would also like to point out that even in the economic crisis, existing partners remained loyal to the COMET research programme and to MCL and we would like to express our thanks and appreciation for this. The increase in new projects in the 2010 business year is mainly due to the fact that it was possible to acquire many new companies as partners. While most existing company partners are involved in materials production and materials processing, the new partners are mainly from the energy, mobility and environmental sectors. This clear extension of the portfolio was made possible through our comprehensive expertise in applied material mechanics and characterisation, which is of course transferable to new research fields. The new industrial partners include leading international companies from Styria, Austria and Germany. This enables us to meet our goal to strengthen the local economy through innovation while further intensifying our international activities. We are very proud to be able to cooperate within the COMET research programme with a total of 70 industrial partners and many companies in the non-K area.

Increased project volumes and the larger number of company partners has meant that the number of staff has also grown - at the end of 2010 MCL employed a total of 116 mostly scientific research staff, which represents an increase of 15% compared with 2009.

Successes and intellectual capital
The COMET research programme MPPE is now in its third year and important scientific progress has been made in the various fields. The main focus is on process chain simulation and optimisation, multi-scale materials design and production and properties of structural components, tools and electrical components made from graded materials or composite materials.

Over the last few years, extensive expertise has been built up in the field of process chain simulation. This means that in different fields of application, sequential manufacturing processes can be simulated in order to predict, for example, local property and residual stress distribution. The methods are already being used in industry in the optimisation of complex manufacturing processes as well as in the design and improvement of structural components, tools and electrical components. Multi-scale materials design from the atomic scale through to the component provides a new basis for the development of more efficient high-performance materials – mostly steel materials but also ceramics and composites, which are already at the stage of industrial implementation. There are increasing numbers of applications for graded materials with properties tailored to the local mechanical strain and which enable the manufacture of high-performance components combined with material saving and efficient use of resources.

These successes, which are of benefit to both industry and the environment, were made possible through the intensive research activities carried out by the 393 researchers involved in the COMET research programme. The impressive result of this research activity is reflected in the figures: a total of 183 publications and articles in journals as well as presentations and posters. The fact that their work also meets the highest scientific standards is demonstrated not only in the 52 publications in refereed journals but also in the numerous awards MCL staff have received for their research work over the last business year.

Univ.-Prof. Dr. Reinhold Ebner
Managing Director

Focus for 2011 – application for COMET Phase II

In 2010, the third year of research in the first funding period (2008 – 2012) in the COMET research programme MPPE was successfully concluded. Preparations for the second funding period (2013 – 2017), for which MCL will be applying in cooperation with its research partners, are already underway. In 2010, MCL submitted the relevant documents for the COMET review process, which was held on 26 January 2011. In a next step, the application for the second funding period will be submitted on 15 December 2011. We are therefore in the process of adapting current research fields, drafting project profiles for new research projects and establishing participation of companies in Letters of Commitment.

In this context, we would like to invite all existing company partners and scientific partners to participate in COMET Phase II and to contribute project proposals.

Dr. Richard Schanner
Managing Director

All other companies are of course also encouraged to join the programme. We are pleased to provide interested companies with further information on the opportunities provided by participation in the research programme and to support them in the drafting of project proposals aimed at developing solutions to complex R&D problems.

Further development and strategy for MCL

Since it was founded in 1999, MCL has grown and developed at a steady rate. To ensure we continue on this path over the coming years, MCL has introduced a comprehensive strategy process to keep us on track for meeting future goals. The focus for the coming years is primarily on steel manufacturing and application, materials for microelectronics and nanotechnology as well as tooling. We will also extend our research facilities and accelerate the build-up of our research staff in these fields.

The key to our success is our expert staff who, in cooperation with our partners in research and industry, did an excellent job in 2010. We would like to thank them all for their outstanding efforts. We therefore face the future with great confidence as we continue to develop innovative solutions for industry.

Shareholder Statement

Magn. Univ.-Prof.
Dr. Wolfhard Wegscheider
University of Leoben
Chairman of the
General Meeting

Materials research – crisis-resistant and future-proof
In the 2010 financial year, MCL succeeded in continuing to actively support existing company partners to meet their goals and in winning new partners for the COMET research programme to extend its research portfolio. This enabled MCL to further consolidate its position and perform well even during the economic crisis.

The basis for this was provided by the outstanding expertise of the scientific partners, owners and MCL in materials research, manufacturing and application. This basic research oriented and sector specific know-how is successfully applied and developed in the COMET research programme. As materials research has applications in almost all industrial sectors, it was also possible to win new business partners from a range of sectors and open up new fields of application.

Materials research plays a key role in providing solutions to current problems for example in process security, increasing material performance as well as design and reliability optimisation. Furthermore, it is also a key prerequisite for rising to future challenges. These include conservation of resources and environmental protection (availability of materials and recycling) as well as issues related to mobility, communication and the healthcare system. MCL has the means to actively address these topics and provide the relevant expertise. The research activities in these future-oriented areas aim to further strengthen Austrian industry and increase its competitiveness.

Report from the General Meeting
The General Meeting approved MCL's strategic focus on the fields of steel manufacturing and application, materials for electronic components and systems and tooling, thus securing MCL's long-term future. Two further General Meetings were also held in which the annual accounts 2009 were unanimously approved. Both the Management Board and the Supervisory Board have worked extremely hard and successfully over the past year.

The MCL shareholders would like to take this opportunity to thank all involved in MCL for their excellent support and cooperation. MCL will continue to work at the interface between industry and research developing innovative solutions in materials science and will thus make an important contribution to the future.

Shareholder structure of Materials Center Leoben Forschung GmbH:

- **47.5 %** University of Leoben
- **17.5 %** Joanneum Research
- **15.0 %** Municipality of Leoben
- **12.5 %** Austrian Academy of Sciences
- **5.0 %** Vienna University of Technology
- **2.5 %** Graz University of Technology

From the Supervisory Board

Dr. Martha Mühlburger
Chair of the Supervisory Board
delegated by the University of Leoben

MCL's future-oriented, independent and long-term focus
Since the end of the economic crisis, both the business volume and the number of employees have again been growing significantly. This positive development is primarily due to the fact that the company partners remained committed to the research programme and that MCL succeeded in opening up new research fields and industry sectors. The basis for this is MCL's extensive expertise in the field of materials characterisation and materials mechanics, which has a wide range of applications. This profound methodological knowledge combined with the relevant applied expertise should continue to be extended even further. The aim is to become established in further research fields and to provide valuable sector specific research in the interests of promoting competitiveness. This is true both for problems related to the "Old Economy" focusing on steel production and application as well as for the challenges posed by the "New Economy" with a focus on materials for use in microelectronics and nanotechnology.

Economically stable position
MCL survived the economic crisis and was, although slowed to some extent, able to continue to increase headcount and acquire further projects. MCL maintained its sound capital base and is thus able to proceed with its expansion plan. The research facilities will be expanded to meet requirements and will be accompanied by further recruitment of research staff.

The economic crisis was well negotiated through the careful yet future-oriented way in which all partners reacted. In view of this, we look forward to the successful application for COMET Phase II and would again ask for the cooperation of our partners and thank all involved in advance for their much appreciated support.

Additional members of the Supervisory Board:

- Dr. **Bruno Hribernik,** Deputy Chair
  elected by the General Meeting, until 23rd Supervisory Board Meeting in June 2011
- em. Univ.-Prof. Dr. **Horst Cerjak**
  delegated by Graz University of Technology
- Dr. **Knut Consemüller**
  appointed by the General Meeting, until 31st Supervisory Board Meeting in 2013
- Univ.-Prof. Dr. **Herbert Danninger**
  delegated by Vienna University of Technology
- Univ.-Prof. Dr. **Gerhard Dehm**
  delegated by the Austrian Academy of Sciences
- Mag. **Katharina Kocher-Lichem**
  appointed by the General Meeting, until 31st Supervisory Board Meeting in 2013
- Dipl.-Ing. **Erwin Kubista,** delegated by Joanneum Research
- SChef a.D. Senator h.c. Dr. **Norbert Rozsenich**
  delegated by the University of Leoben

From the COMET K2 Programme Committee

Large number of project applications

In the 2009 Annual Report, the Programme Committee expressed its hope that more projects would be submitted for scientific review. It was indeed possible, thanks to the efforts of all involved, to achieve this aim in the 2010 business year: a total of 15 projects with a total overall value of around € 11 million were presented in 5 Programme Committee meetings as compared with 8 projects in 2009.

All projects were recommended for inclusion in the COMET Programme. In the case of some project applications, members of the Programme Committee were able to draw on their extensive experience to provide important suggestions for improvements. Overall, the project applications were of a very high scientific quality and therefore fulfilled the strict criteria for scientific excellence demanded by the COMET K2 programme.

Extension of research topics

A trend had already emerged in 2009 towards more comprehensive research problems and new research topics. This development continued in 2010 and led to a very positive extension of the portfolio.

The new applications encompass the sectors of transport, energy production and distribution, industrial engineering as well as mining and extraction engineering. The combined expertise and know-how available in the MPPE research programme can be usefully transferred to other fields to support companies in finding solutions to their specific research problems.

First row (from left to right): Dr. R. Schanner, MCL; Dr. Ch. Hoffmann, EPCOS OHG; Dr. A. Sormann, voestalpine Stahl Donawitz GmbH & Co KG; Prof. R. Ebner, MCL; second row: DI J. Hagler, voestalpine Stahl GmbH; Dr. G. Jesner, Böhler Edelstahl GmbH & Co KG, designated member of the Programme Committee from mid-2011; Univ.-Prof. Dr. H. Antrekowitsch, MUL; Univ.-Prof. Dr. E. Kozeschnik, TUW; Univ.-Prof. Dr. W. Sitte, MUL; Dr. R. Ratzi, Miba AG; DI A. Retschnig, RHI AG; Univ.-Prof. Dr. W. Eichlseder, MUL; not shown: Dr. D. Caliskanoglu, Böhler Edelstahl GmbH & Co KG; Univ.-Prof. Dr. F. D. Fischer, MUL; Dr. Ch. Hinteregger, MAGNA Powertrain AG & Co KG; Univ.-Prof. Dr. A. Ludwig, MUL

From the COMET K2 Board

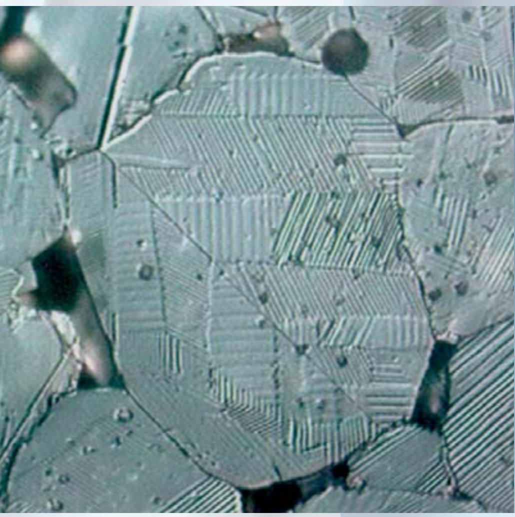
Scientific excellence for the benefit of industry
Since the very beginning, the MPPE research programme has been focused on achieving the highest possible standards of scientific excellence to fulfil the requirements demanded of a COMET K2 Centre. Great importance has always been attached to the economic value of the results. This most definitely promoted the companies' commitment to the programme even in economically difficult times in order to gain a competitive edge in the medium-term in the face of fierce competition. The large number of publications listed in the Intellectual Capital Report reflects the intensive research work carried out – particularly in the strategic projects – which provides the basis for future industrial projects. The strategic projects are described in more detail in the Annual Report.

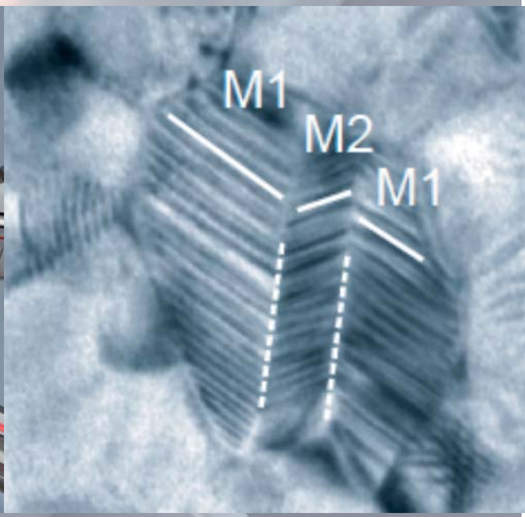
2011 – Submission of follow-up application for COMET Phase II
The year 2011 will be decisive for COMET Phase II, which runs from 2013 to 2017, as the application for this phase must be submitted by the end of the year. In preparation for submission, the scientific research programme for Phase II must be thoroughly revised. The focus will be on new research fields and on topics which did not develop as planned in the first phase due to the economic crisis. Furthermore, project profiles will be drafted in cooperation with industrial partners for around 60% of the target project volume. The individual companies will be required to declare their participation in the projects in a Letter of Commitment.

As we prepare for the follow-up application, we count on the active cooperation of our industrial and scientific partners and thank them in advance for their much appreciated support.

K2-Board (from left to right): Dr. H. Kestler, Plansee SE (member since 2010); Univ.-Prof. Dr. Ch. Mitterer, MUL; Dr. G. Gratzer, Styrian Regional Government; Ing. J. Seyrkammer, Miba Sinter Austria GmbH; Mag. A. Dirnberger, Municipality of Leoben; Mag. D. Hansmann, Styrian Regional Government; Dr. R. Schanner, MCL; Magn. Univ.-Prof. Dr. W. Wegscheider, MUL; Univ.-Prof. Dr. H. Mang, TUW, ÖAW; Univ.-Prof. Dr. R. Danzer, MUL; Univ.-Prof. Dr. H. Danninger, TUW; Univ.-Prof. Dr. R. Ebner, MCL; not shown: Univ.-Prof. Dr. B. Buchmayr, MUL; DI H. Lenger, Böhler Edelstahl GmbH & Co KG; Dr. K. Rabitsch, Treibacher Industrie AG; DI H. Schifferl, voestalpine Stahl Donawitz GmbH & Co KG; Univ.-Prof. Dr. Ch. Sommitsch, TUG

RESEARCH PROGRAMME COMET K2 MPPE



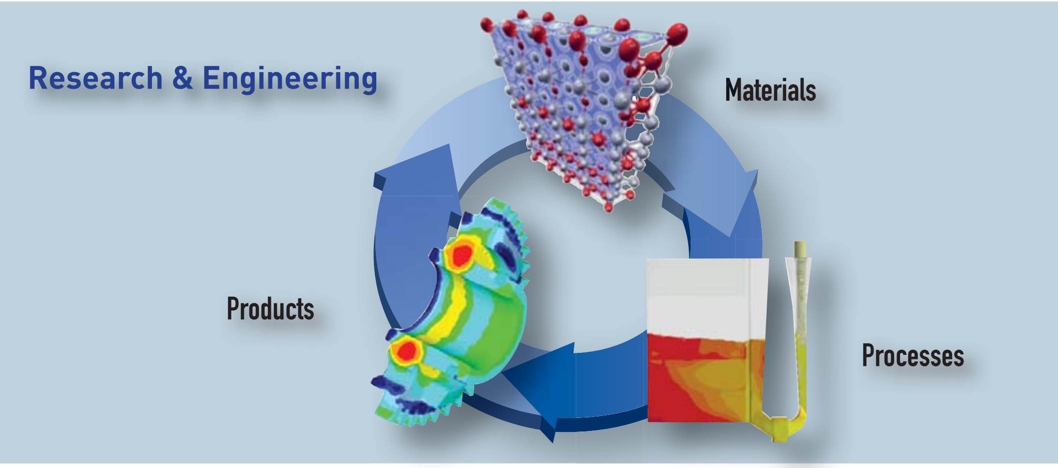


COMET K2 MPPE Research Programme

Innovation through integrated materials, process and product development

The COMET K2 Programme "Integrated Research in Materials, Processing and Product Engineering (MPPE)" provides a platform for MCL to carry out innovative research projects together with partners from industry and science.

Integrated materials, process and component engineering offers an enormous potential for innovation, cost reduction and resource efficiency, a potential that has scarcely been exploited to date due to the complex interactions involved.



An integrated approach is used to exploit and extend the load limits of materials and components and reduce both unit costs and time to market, resulting in innovative high-strength components.

Research projects, and especially the strategic projects, provide the industrial partners involved with fundamental expertise, simulation and experimental methods required for the development of new products. The participating companies thus gain access to the latest scientific findings and can implement funded research projects on complex issues in similar or complementary areas together with other industrial partners.

The MPPE Competence Centre receives funding under the COMET Programme "Competence Centers for Excellent Technologies" from the Federal Ministry for Transport, Innovation and Technology (BMVIT), the Federal Ministry of Economy, Family and Youth (BMWFJ), the Styrian Regional Government and the Styrian Business Promotion Agency (SFG). The COMET Programme is managed by the Austrian Research Promotion Agency (FFG).

The strategic objectives of COMET are: developing new expertise by initiating and supporting long-term research co-operations between science and industry in top-level research, and establishing and securing the technological leadership of companies. By advancing and concentrating existing strengths and by integrating international research expertise Austria is to be strengthened as a research location for the long term.

Development of the COMET K2 MPPE Programme

Science / Technology

The COMET K2 research programme MPPE was launched in 2008. The core objective is to build up expertise in (1) the integrated simulation of entire process chains and (2) simulation of the in-service behaviour of structural components, tools and functional components. MPPE's activities therefore aim to simulate materials all the way from manufacture through to the end of the service life of the finished product.

To accomplish this, nine strategic projects were launched and/or continued from the Kplus Programme to develop theoretical understanding and to improve scientific visibility at an international level. This resulted in major progress as detailed in the descriptions of the strategic projects (see pages 26 to 43).

The industrial projects are designed to investigate technological problems whilst also providing the basis for innovations within the companies themselves. Despite the economic crisis, the research projects outlined in the application were launched (with one exception) and successfully implemented, making a key contribution to meeting MPPE's goals.

The research projects also led to innovative solutions in the companies, a small selection of which are presented in the Intellectual Capital Report.

The scientific and technological progress of the research programme provides a sound basis for achieving the objectives set. The high scientific quality of the research work carried out is reflected in the large number of publications produced within the framework of COMET and listed in the Intellectual Capital Report. The technological achievements are described in more detail on pages 18 to 25.

Business / Staff

The entire funding volume of € 53 million earmarked for Phase I will be used for research projects. This is due to the fact that apart from the attractive range of research services and the interesting topics addressed, it is primarily the focus on basic research at MPPE which enables fast and efficient access to new thematic fields.

Network / Organisation

The establishment of a solid national and international network of industrial and scientific partners now enables complex research questions to be addressed. MPPE also succeeded in establishing an excellent network along the supply chain of the materials sector.

Internally, the splitting of management responsibilities into operative and scientific areas has created an efficient structure, which serves both the operative implementation as well as the future-oriented further development of the research programme.

COMET MPPE Phase I and Outlook on Phase II

Phase I of the COMET K2 Centre for "Integrated Research in Materials, Processing and Product Engineering" (MPPE) was launched in 2008 and has produced a number of excellent research results within the first three years of its operation.

In 2011, a follow-up application will be submitted for the second funding period, which runs from 2013 until 2017. Preparations for the application and evaluation began with a comprehensive review of MPPE on 26 January 2011. The follow-up application for COMET Phase II must be submitted by 15 December 2011 and evaluation will take place on 15/16 March 2012 in Leoben.

Based on the advances made in Phase I, several thematic adaptations will be made with regard to the second funding period. COMET Phase I concentrated primarily on the development of fundamentals and methods. The strategic projects with their strong focus on basic research made a major contribution in this respect, as is reflected in the large number of high quality scientific publications. In COMET Phase II, MPPE will also strengthen its focus on implementation in the companies and aims to further increase the number of innovations and patents considerably. Particular attention will be paid to the following issues:

- **Resource efficiency** (energy, alloying elements, recycling)
- **Material efficiency** and **utilization** (development, design, construction etc.)
- **Reliability** and **service life** (damage tolerant design, reliability of electronic components)
- **Innovative tooling solutions** (longer service life, flexibility)
- **Increased quality** and **reduced costs** (process chain optimisation, reduction in processing steps etc.)
- **Innovative materials** and **manufacturing processes** for new applications

MPPE's international focus is to be further enhanced through cooperations with scientific and industrial partners abroad in order to meet the exacting standards required of a COMET K2 Centre.

Research projects with a total volume of € 53 million are being carried out in COMET Phase I. In COMET Phase II, the project volume will be increased to € 65 million to be able to address the comprehensive research problems and tasks to be carried out in cooperation with a larger number of industrial partners.

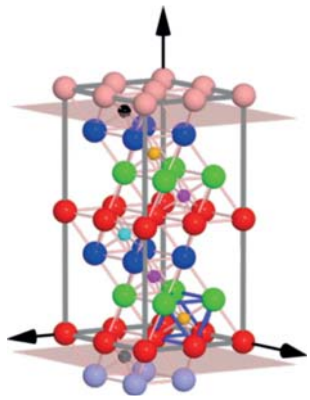
COMET

Competence Centers for
Excellent Technologies

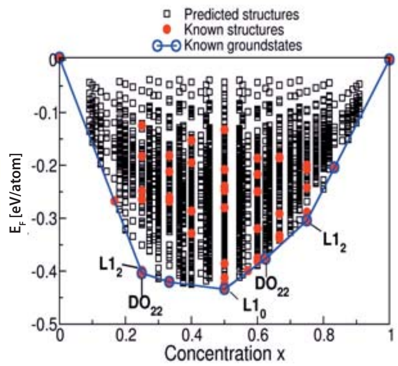
Technological Achievements

RESEARCH PROGRAMME
COMET K2 MPPE

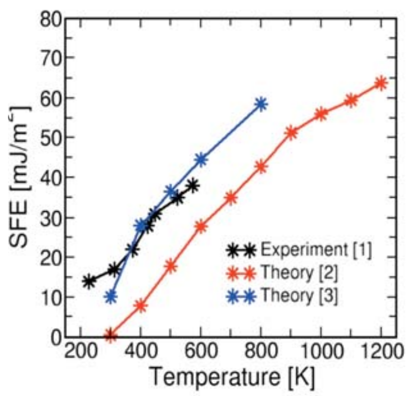
Technological
Achievements



Model of a face-centred cubic crystal with embedded interstitial atoms



Formation energy in a binary system, determined by automated structural variation



Stacking fault energy in a Fe-Mn system as a function of temperature (semi-empirical calculation)

Ab-initio calculations in materials design

Atomistic modelling using the density functional theory (DFT) is based on well-established fundamentals of quantum mechanics. The development of suitable calculation methods began as early as 30 years ago and has continued to date. The methods have become so powerful that they are gaining increasing significance as prediction methods in materials research.

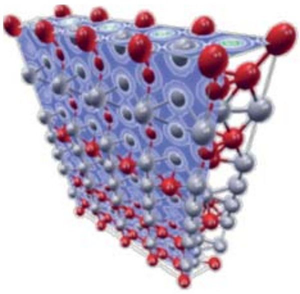
The properties of materials are substantially determined by their smallest units, which are mostly crystals. DFT calculations provide an in-depth insight into their structure. They can be used to derive, e.g., formation energy, electron energy states, electron density distribution and band structure and to determine mechanical (e.g. Young's modulus), electrical and other properties. The calculations are either based on the solution of the Schrödinger equation using only fundamental constants (ab-initio calculations) or including measurement values (semi-empirical calculations).

An important aim of the COMET K2 Centre MPPE is to encourage broader use of atomistic modelling in the development of materials and processes. Typical fields of application include the calculation of crystal structures, formation energies, stacking fault energies or elastic constants of binary and ternary alloys.

Multiscale material modelling for goal-oriented material and process design

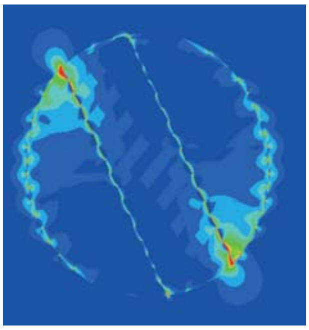
Multiscale materials design provides a detailed insight into the structure and thus also the resulting properties of materials at all length scales. In addition, it opens up new approaches in the application-oriented development of materials and processes.

The fatigue properties of components, for example, are mainly influenced by residual stresses at highly stressed points. These in turn result from temporally and spatially varying strains during quenching and in particular during phase transformation. Currently available models for the description of residual stress development during the hardening process usually provide good trend information but not sufficient quantitative results. The integration of material data from DFT calculations (atomic scale) in micromechanical models (micrometer scale) for example allows the development of material models which describe the influence of stress on strain during martensitic transformation more reliably than was previously possible. In future this will enable a more accurate prediction of residual stress distributions in hardened components.

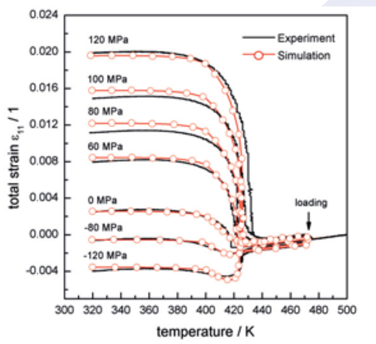


Model of a crystal for the calculation of the driving forces in martensitic phase transformation and elastic constants

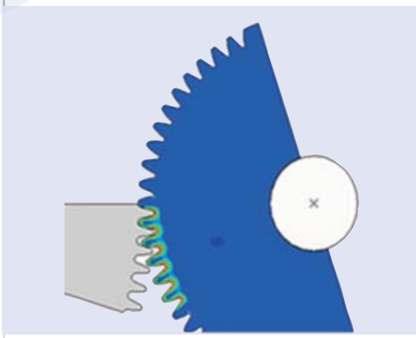
Simulated residual stress distribution in a component



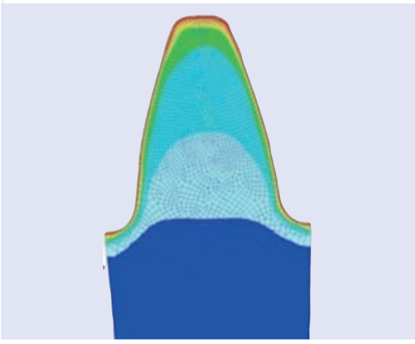
Micromechanical model for the calculation of inhibiting forces as a result of martensitic phase transformation



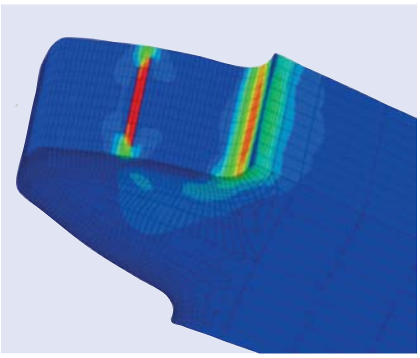
Improved model for predicting the influence of mechanical stress on strain during martensitic transformation



Simulation model for surface densification



Simulated carbon distribution in a surface densified gear tooth, taking the density dependence of carbon diffusion into account



Calculated local degree of usage due to local load and local fatigue strength

Implementation of through-process modelling

Many components are manufactured in a complex series of process steps. Taking a holistic view of such process chains opens up new potential for optimising components in terms of increasing performance, reducing weight and improving reliability.

Through-process modelling is an important basis for the optimal coordination of sequential process steps. For this purpose, the simulations of the individual process steps must be linked with each other, i.e. the relevant results of one process simulation serve as input data for the simulation of the subsequent process.

A major aim of the COMET K2 Centre MPPE is to identify, simulate and combine the key process steps affecting the properties of materials. This goal has been achieved for several process steps over the past few years.

One example is the simulation of the process chain of surface densified sintered steel gear wheels, consisting of

- surface densification
- carburisation
- hardening
- local operating strength analysis

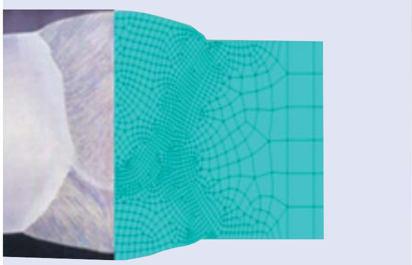
The analyses are based on detailed knowledge of local loads, residual stresses and properties.

Modelling the behaviour of inhomogeneous materials during service

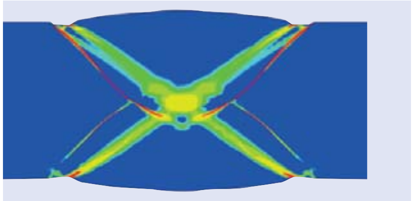
Practically all high-performance components are characterised by an inhomogeneous microstructure with locally varying properties, which substantially affect the behaviour of the component in terms of carrying capacity, fatigue strength and fracture resistance. The trend towards material saving and weight reductions leads to an increasing use of high-strength materials, but also higher utilisation levels. The safe use of such high-performance components requires in-depth knowledge of component behaviour based on local properties.

The COMET K2 Centre MPPE is developing FE-based methods to be able to investigate the deformation and fracture behaviour of inhomogeneous components in more detail. For this purpose, experimentally determined local properties, such as yield stress and ultimate strain, are translated into FE models. The simulation results provide valuable information about the global and local deformation behaviour and the carrying capacity of the component and can also be used to assess how closely local strains or crack driving forces approach the local parameters of yield stress or crack resistance.

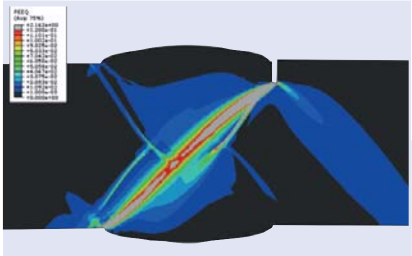
This methodology provides an important basis for assessing the safety and reliability of highly stressed components. It allows not only static loads but also dynamic and fatigue loads plus their effects on reliability to be taken into account.



Welded joint in a pipeline tube



Strain concentration in a welded joint with slight undermatching with reference to the pipe material



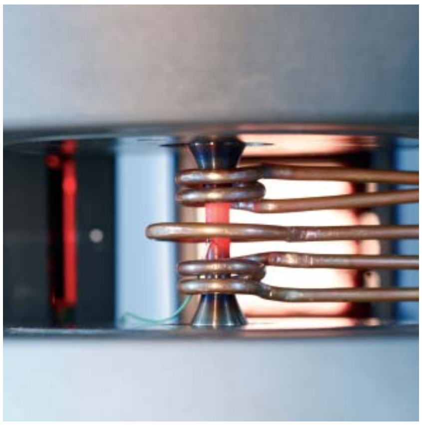
Strain concentration in a welded joint with slight undermatching with reference to the pipe material and crack initiation in the edge notch region

Testing and modelling of hard and brittle materials

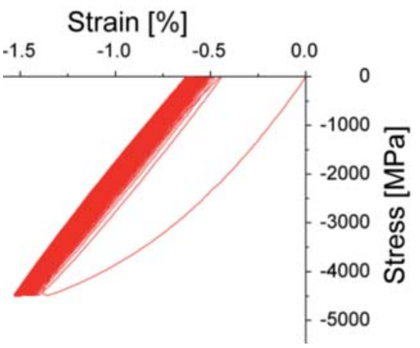
High-strength materials for structural and tool applications constitute an important focus of the research agenda at the COMET K2 Centre MPPE, and at MCL in particular. Special standardised testing methods have been developed for characterising the static and cyclic material parameters of high-strength materials at stresses up to approx. 10,000 MPa. These testing methods can be used to characterise the mechanical properties of hard metals, tool steels and other high-strength steels. The tests can be performed both at room temperature and at elevated temperatures of up to approx. 1000°C in air. Testing equipment for determining material parameters under inert gas or vacuum are currently being implemented. Tests at low temperatures down to approx. -150°C will also be possible in future.

In addition to property testing, MCL has special expertise in determining parameters for conventional material models, which can also be adapted and optimised according to requirements.

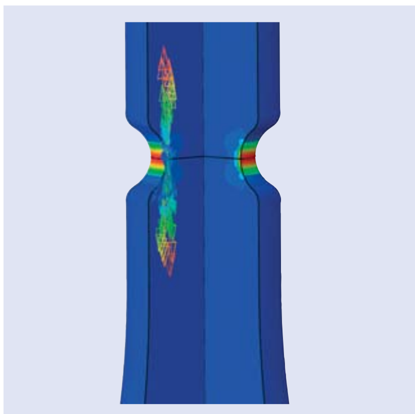
Specially adapted facility for standardised testing of materials at stresses of approx. 10,000 MPa



Measuring static and cyclic parameters at elevated temperatures



Stress-strain behaviour of a hard metal under cyclic loading (ratcheting)



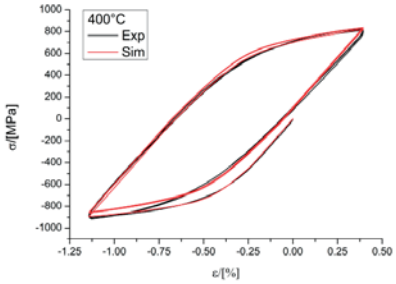
Optimisation of specimen geometry for analysing the build-up of local residual stresses at the notch root

Material models for FE calculations

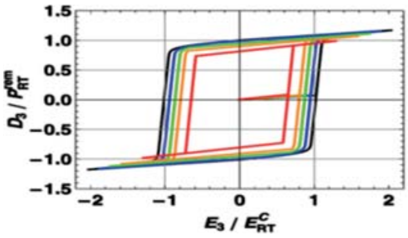
Modern structural and functional components are subjected to increasing loads in service. Excessive local yield stress leads to local plastic deformation and thus to residual stresses and distortion of the component. Residual stresses in particular have great influence on crack initiation and growth. Detailed knowledge of the development of residual stresses in service is thus a decisive factor in assessing the reliability and fracture behaviour of highly stressed components. This requires material models for calculating the elastic-plastic behaviour of materials under cyclic loading using FE methods.

Functional components pose additional challenges in the simulation of functional behaviour, e.g. the description of the electromechanical behaviour of piezoelectric materials.

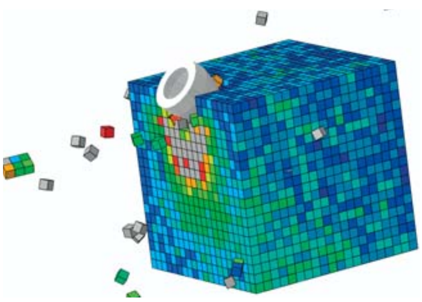
The COMET K2 Centre MPPE has developed special expertise in complex material models. A special focus is placed on the development of appropriate testing methods, the build-up of expertise in the determination of model parameters and the modification of existing material models.



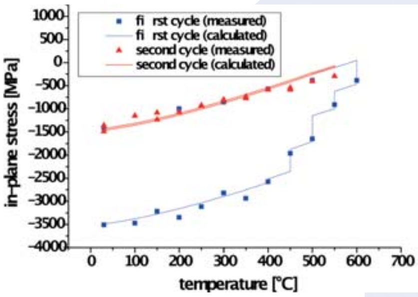
Measured and simulated stress-strain behaviour under cyclic loading



Simulated stress redistribution as a basis for calculating thermomechanical fatigue using an elastic-visco-plastic Chaboche model



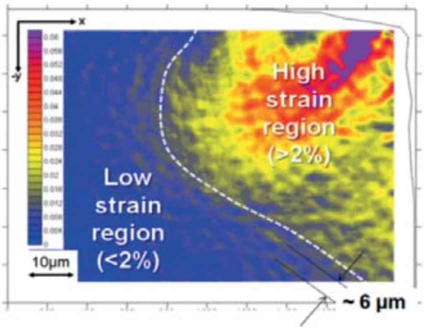
FE simulation of rock working using detailed models of material inelasticity and damage to sandstone and granite under local multi-axial tensile, compressive and shear loading



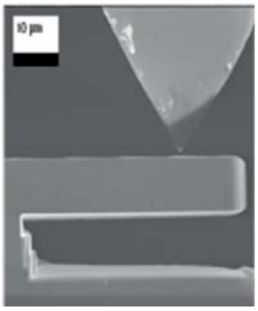
Comparison of measured and simulated stress relaxation in thin hard coatings due to cyclic thermal loading

RESEARCH PROGRAMME
COMET K2 MPPE

Technological Achievements



Local plastic strains at a highly stressed edge



Testing of material properties in small dimensions (micro bending test)

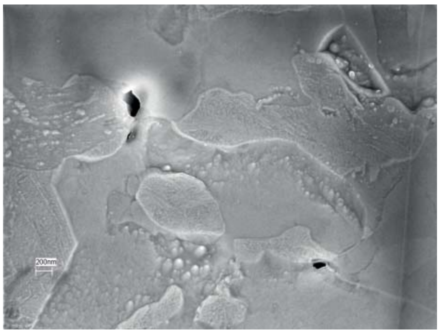
Local properties and testing of materials in small dimensions

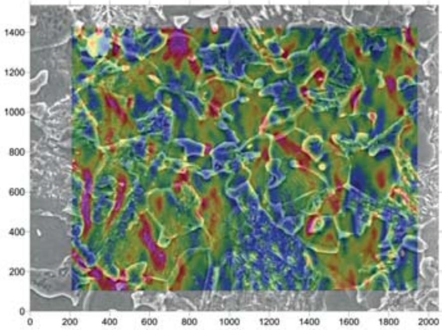
The macroscopic behaviour of materials and components is often determined by processes on the microscale. Many metal forming processes lead to excessive plastic deformation in some regions, while adjacent regions experience hardly any plastic deformation. Although local stress conditions also play a role in microscopic damage processes, an in-depth knowledge of strain distribution is essential for tailored materials design.

The COMET K2 Centre MPPE and its scientific partners offer advanced methods for investigating strain distributions in materials based on digital image correlation.

These techniques are used primarily for the investigation of the deformation and damage behaviour of materials. Regions of excessive plastic deformation are often prone to early damage, e.g. in the form of pores. In addition, the methods also allow local strains in highly stressed components to be investigated.

The COMET K2 Centre MPPE also develops testing methods for determining material properties in small dimensions, for example in order to characterise local material properties in electrical components and systems.





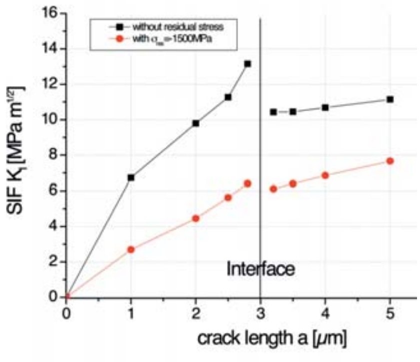
Microstructure of a multi-phase steel and corresponding strain distribution

The configurational forces concept in materials design

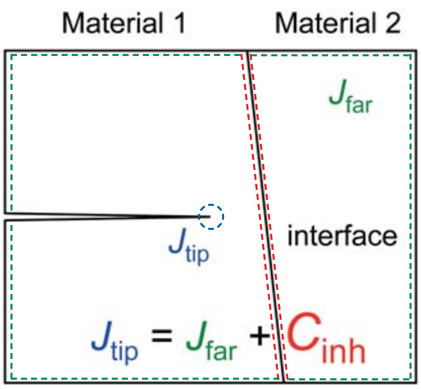
Multi-material systems and inhomogeneous materials are playing an increasingly important role in component design. Crack initiation and growth are of special interest for assessing the in-service behaviour of such components. Crack tip stress in this case depends not only on component geometry, crack length and external loading, but also on local structure, local properties and residual stress distribution.

The configurational forces concept advanced within the framework of the COMET K2 Centre is designed to illustrate the influence of the interior structure of multi-material systems on crack-driving forces at the crack tips. The new software allows parameter studies to be carried out in order to investigate the effect of internal material structure on fracture behaviour.

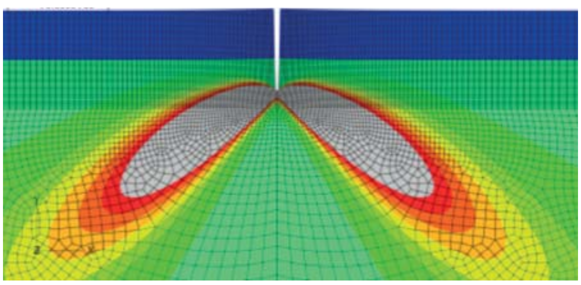
The methods developed have already been used to optimise coated surfaces and to analyse crack growth behaviour under RCF loading.



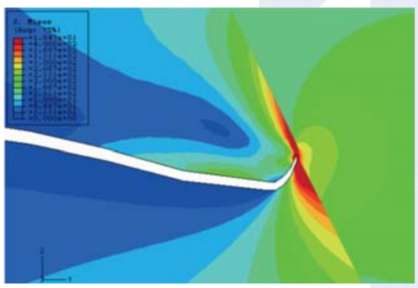
Crack tip stress as a function of crack length and residual stress in the coating: compressive residual stresses in the coating lead to a significant reduction in crack tip stress



Calculation of configurational forces, J-integral and material inhomogeneity term C_{inh} (FE simulation followed by post-processing)



Stress field around a crack in a coated surface (coating shown in blue)



Prediction of crack propagation path near an inclined interface

COMET K2 MPPE
RESEARCH PROGRAMME

Strategic Research
Projects

A 1.4

Strategic research projects

Tools for process chain simulation

This project applies a through-process modelling approach to simulate the manufacturing processes (gravity die casting, T6 heat treatment, mechanical machining) involved in the production of a cast aluminium component using multi-physical simulations. The calculations combine different physical disciplines and different simulation programs such as MAGMA, ProCast, ABAQUS and DEFORM. The aim of the project is to quantify the influence of these process steps on the lifetime of the component under isothermal cyclic loading. Process chain simulation will allow the component and subsequently also the entire manufacturing process to be optimised. This approach has the following benefits:

- Optimisation of the casting process through casting simulation
- Prediction of mechanical properties based on microstructure prediction
- Identification of process parameters for optimal heat treatment
- Adjustment of desired properties (e.g. strength) through targeted process control
- Minimisation of finishing operations (drilling, milling,..) through optimised dies
- High dimensional stability through prediction of deformation during the solidification process
- Minimisation of trial and error in development and fewer rejects
- Light-weight design and maximisation of lifetime through improved material usage

The simulation of the casting process consists of mould filling and solidification in order to investigate the influence of the cooling rate on the as-cast microstructure. Some sections of the castings were designed to have different thicknesses. Hence, each step of the plate has its own cooling characteristics. The simulation provides information about melt flow

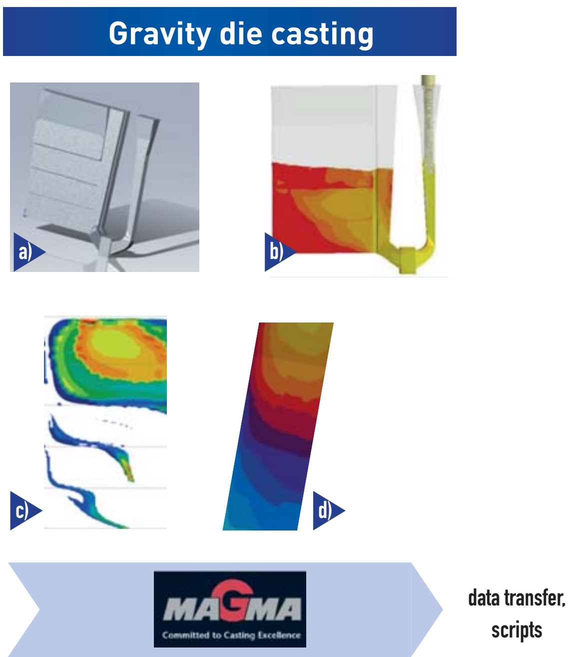


Fig. 1: a) Laboratory geometry of step plate for castings; b) Simulation of casting process; c) Simulation of pore distribution; d) Simulation of secondary dendrite arm spacing

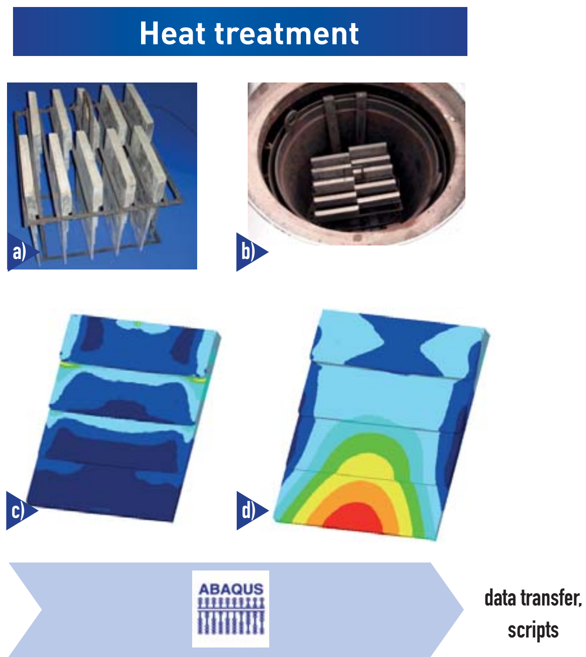


Fig. 2: a) Step plates prepared for heat treatment; b) Heat treatment of step plates; c) Simulation of residual stresses caused by heat treatment; d) Simulation of deformation caused by heat treatment

during the mould filling process, secondary dendrite arm spacing (SDAS), thermomechanical stresses and deformations. In order to validate the simulation results 65 castings with a configuration of a step geometry shown in Fig. 1 were poured and solidified in a steel die mould. A very critical parameter for the development of the microstructure during solidification is the heat transfer coefficient (HTC). For estimation of the order of the HTC the mould was instrumented with four K-type thermocouples. Special emphasis is placed on developing methods for data exchange between the individual simulation programs as there are currently no standardised interfaces and file formats available for this purpose. One of the challenges was to transfer the relevant process parameters to subsequent simulation steps performed by different software packages.
The mechanical properties of the material can be adjusted in the heat treatment process (Figure 2). Quenching is a very complex process (heat transfer coefficients), which causes residual stresses and distortions. On the other hand, it is essential for producing the supersaturated solid solution which leads to an increase in strength following heat treatment. To optimise heat treatment the precipitation kinetics of a heat-treatable aluminium alloy was calculated using MatCalc (Material Calculator). The simulation of machining operations (Figure 3) is a special challenge, especially when the residual stresses (elasto-plastic model) must be taken into account. The results obtained from the simulations are compared with experimental methods such as optical measurement, X-ray diffractometry (residual stresses on the surface) and hardness measurements (Figure 4).
The project was carried out in cooperation with the Chair of Simulation and Modelling of Metallurgical Processes and the Chair of Mechanical Engineering of the University of Leoben as well as the Institute for Materials Science and Welding of Graz University of Technology.

Machining

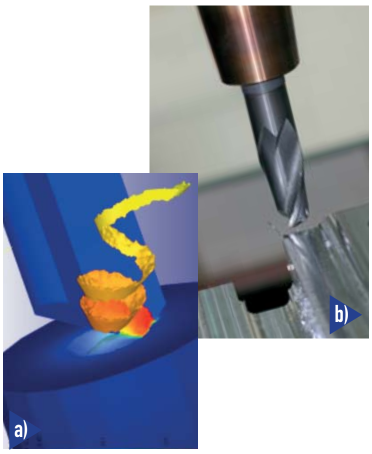
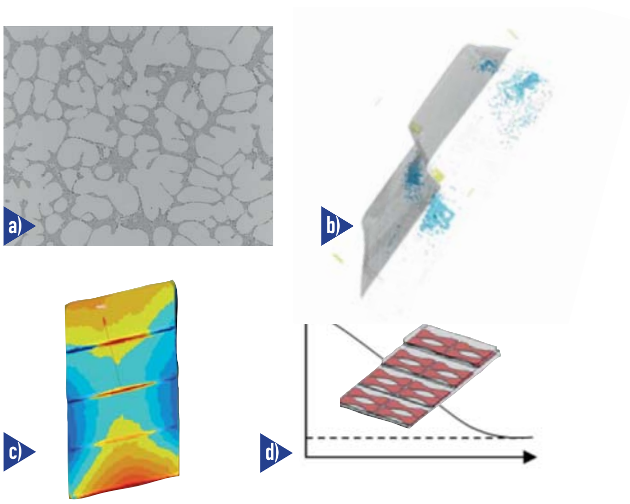


Fig. 3: a) Simulation of heat development and residual stresses during mechanical machining; b) Mechanical machining of step plate

Validation



Metallography, computer tomography, distortion measurement, residual stress measurement, cyclic materials testing

Fig. 4: a) Microstructure in step plates; b) Pore distribution measured by computer tomography; c) Measured distortion of heat treated step plates, d) Lifetime curve of specimens taken from the step plates

COMET K2 MPPE
RESEARCH PROGRAMME

Strategic Research
Projects

A 1.5

Modelling of martensitic phase transformations on different space and time scales

The project aims to characterise martensite formation at different hierarchical levels and to describe its effects in terms of continuum mechanics at the macroscopic level. Compared to most approaches described in the literature, the project is unique in covering a wide range of length scales (Figure 1).

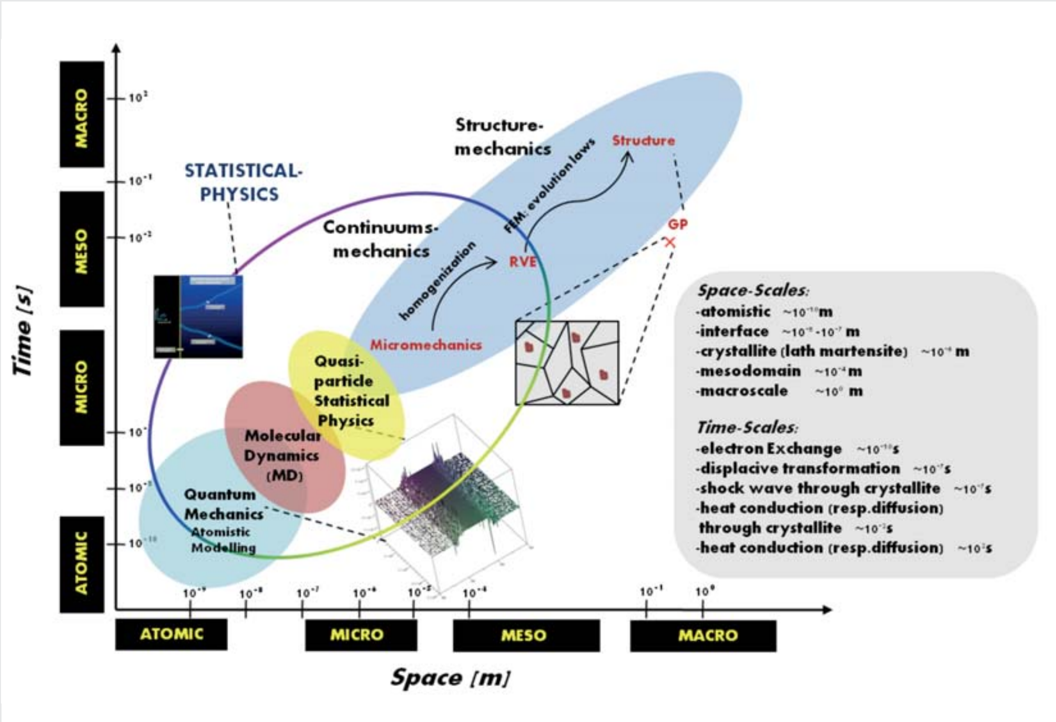


Fig. 1: Different time and length scales and corresponding numerical methods

This wide range of length scales must be considered because many effects on the macroscopic level can be explained by details that become visible only at higher resolutions at lower hierarchical levels. The determination of transformation kinetics, for example, requires sound knowledge of the thermodynamic barriers and inhibiting forces involved in martensite formation – a question that can only be answered one length scale below by a detailed energetic analysis of the individual grain. This in turn requires a "handshake" with a still lower length scale, for example, for determining the elastic constants of the phases involved. Within the scope of the project, the Chair for Atomistic Modelling and Design of Materials has developed a custom-tailored software module for calculating the elastic properties of a NiTi shape memory alloy. This material is ideal for this purpose as it already contains all relevant phenomena of martensite formation.

Energetic analysis makes it possible to predict the martensite structure and compare it with HRTEM images provided by the Physics of Nanostructured Materials research group from the University of Vienna. This requires complex finite element studies, which were carried out in a three-dimensional and fully parameterised way. A key result of this analysis, the distribution of strain energy density, is shown in Figure 2a, while Figure 2b shows the experimentally determined morphology for comparison.

Energetic analysis provides valuable information about the development of the product phase in a martensitically transforming steel based on comprehensive data from previous thermomechanical experiments with this material. The transformation produces an effect that is known as transformation induced plasticity. The macroscopic part of the project seeks to correctly model this effect under arbitrary loading conditions. The required description in terms of continuum mechanics must be implemented in a module suitable for integration in a FE program. The relevant R&D is partly carried out at the Centre des Matériaux of the Ecole des Mines de Paris, an internationally leading research institution in the field of thermomechanical materials characterisation.

The key to accurate material modelling is to formulate a potential function for phase transformation, which can then be used to derive transformation-induced strains. Figure 3a shows a three-dimensional representation of such a transformation potential. The resulting strains are compared with existing experimental data in Figure 3b. As can be seen, the simulation gives very satisfactory results. Complex temperature and stress paths can be simulated by formulating the relevant constitutive relationships. This distinguishes the new model from the wide variety of models published in the literature and thus constitutes a novel scientific approach. In addition to its scientific relevance the project provides the basis for the precise prediction of residual stresses as a result of manufacturing-induced phase transformations.

The project was carried out in cooperation with the Institute for Mechanics and the Chair of Atomistic Modelling and Design of Materials of the University of Leoben, the Physics of Nanostructured Materials research group of the University of Vienna, the Centre des Matériaux of the Ecole des Mines de Paris and the Department of Materials Physics of the Swedish Royal Institute of Technology.

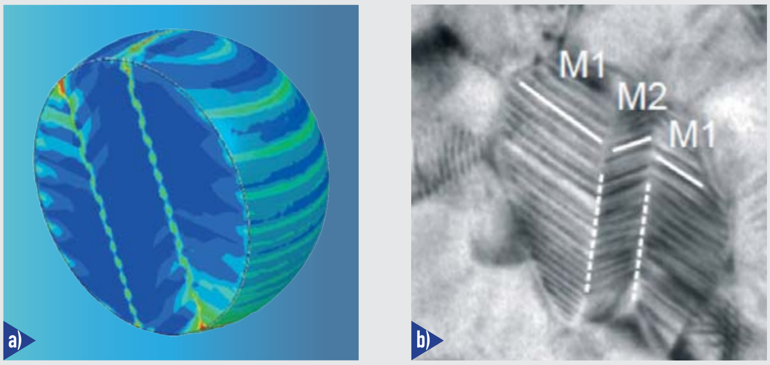


Fig. 2: Energetic analysis of martensite structure of a NiTi grain a) using the FE method, b) using HRTEM

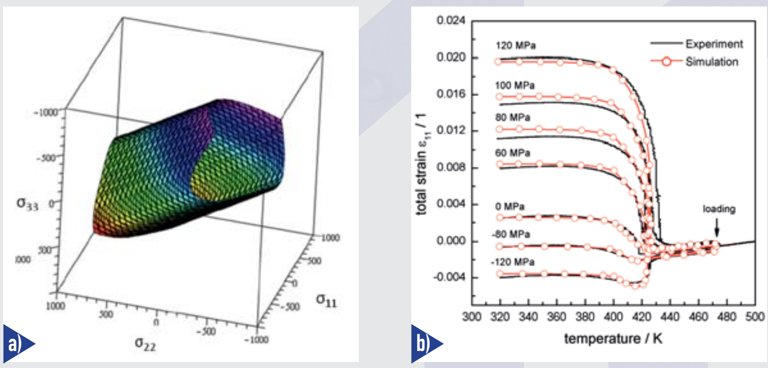


Fig. 3: a) Transformation potential, b) comparison of numerically and experimentally determined strains

Modelling and simulation of precipitation processes

The focus of this strategic project is to develop a theory and methodology for the description and prediction of simultaneous precipitation and diffusion in technologically relevant processes. The concepts for describing precipitation in multi-phase multi-component systems have already been developed in a previous MCL project (SP16). This project aims to use the results in practical application of surface treatment processes. This required fundamental model development to extend the original precipitation kinetics approach to complex material microstructures.

The latter issue was solved by developing a new model for precipitation at grain boundaries, as can be observed for instance during precipitation of AlN in steel. The nucleation of AlN precipitates in steel is known to be rather difficult due to large volumetric differences between AlN and the steel matrix. This mismatch causes high elastic stresses in the nucleation stage, which suppress homogeneous nucleation in the undisturbed crystal. Nucleation of AlN occurs only at heterogeneous nucleation sites, such as dislocations and grain boundaries. Due to the lack of an appropriate theoretical description, the project set out to develop a theory for these lattice locations.

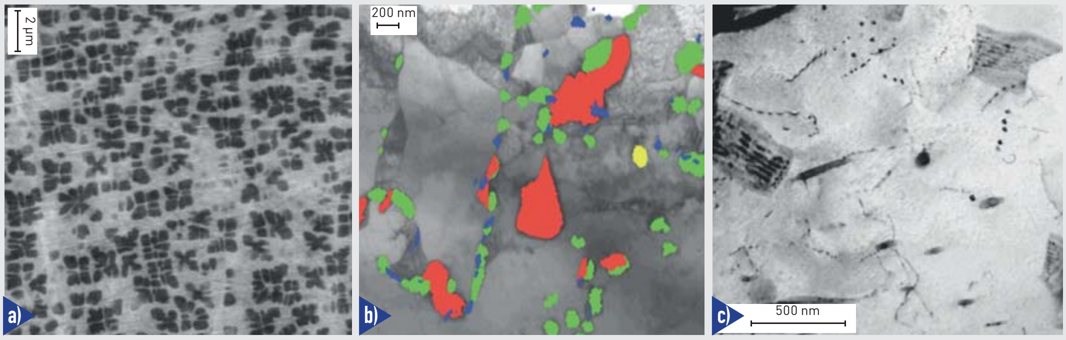


Fig. 1: a) γ-precipitation of Ni-base superalloy; b) precipitations of 9-12% Cr-steel for power plant application; c) microalloying precipitation of steel

Figure 2 (a, b) shows the assumptions for the diffusion fields for precipitate growth in the original model and the new model taking into account grain boundary diffusion. The models developed in the project are implemented into the MatCalc software (http://matcalc.at), which is available in combination with general CALPHAD-type thermodynamic and mobility databases for various precipitation-related projects at MCL. The project has recently moved its focus to the complex situation of simultaneous diffusion and precipitation. This situation typically occurs during carburization and nitridation of materials for the improvement of surface properties. The approach that has been implemented in the MatCalc software is based on a solution of the second Fick's law for multi-component systems and coupling with the precipitation kinetics module. Figure 2 c) shows a sketch of the approach taken in this project, with the real situation being represented in discrete volumes. The diffusion equation is solved between each individual layer, simultaneously with the precipitation reaction.

Diffusion and precipitation has already been coupled using the classical 'local equilibrium' hypothesis. In the next project stage, this coupling will be extended to the actual kinetics of surface treatment processes. The fully coupled model will finally represent a modelling approach that can be applied to numerous important surface treatment processes in practice. In the scientific community, this approach represents a unique modelling tool for the interactive precipitation of particles and long-range diffusion of solute atoms. In addition to our modelling activities, experimental work has started with the aim of quantifying the amount of diffusion and precipitation experimentally. Equipment is currently being designed and implemented, which allows us to perform interrupted surface treatment processes with various types of process gases. These investigations will deliver important experimental information for verification of the models developed.

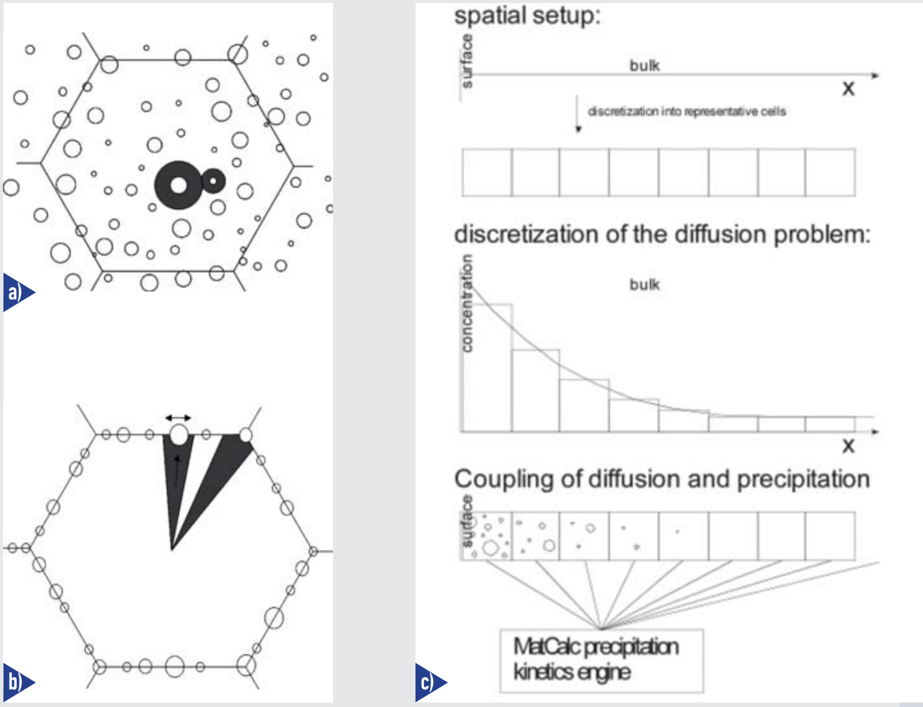


Fig. 2: a) Random precipitation in a poly-crystalline microstructure and corresponding spherical diffusion fields; b) diffusion from the grain interior to the grain boundary and precipitate in the new model; diffusion fields are conical; c) modelling approach for the representation of simultaneous diffusion and precipitation

This project was carried out in cooperation with the Institute of Materials Science and Technology of Vienna University of Technology, the Chair of Physical Metallurgy and Materials Testing and the Institute for Mechanics of the University of Leoben, the Institute for Materials Science and Welding of Graz University of Technology and the Academy of Sciences of the Czech Republic.

COMET K2 MPPE
RESEARCH PROGRAMME

Strategic Research
Projects

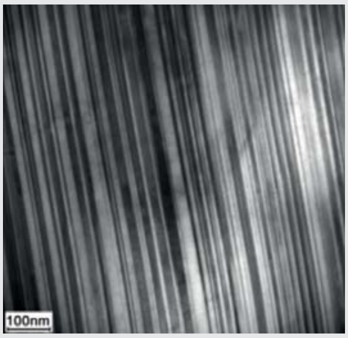
A 2.3

Interface engineering in modern materials design

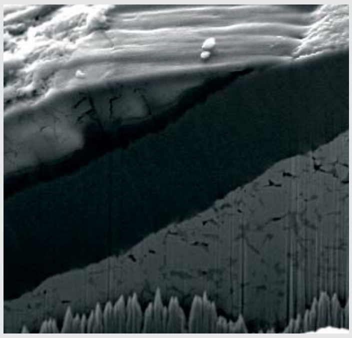
The aim of the project was to develop methods for the design and characterisation of interfaces in multi-phase materials. These interfaces are often used to tailor the properties of modern structural and functional materials, including strength, ductility or electrical conductivity. The project is designed to provide the scientific basis for tailoring interface-related mechanical and physical properties – the range extending from hardness and ductility of high-temperature materials through to electrical transport properties of electroceramics.

Experimental methods for the manufacture and characterisation of interfaces at high resolutions are combined with simulation methods describing the interface structure from the atomic scale through to the macroscopic component in order to develop tailored interface designs for different applications.

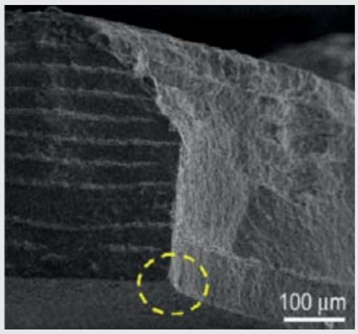
The following model systems were investigated in the project: intermetallic lightweight materials (γ-TiAl), electroceramic materials ($BaTiO_3$) and hard coatings (TiO_2, Al_2O_3). These materials were used for developing the experimental and theoretical methods and for analysing the relationships between interface formation, the resulting interface structure and the corresponding mechanical and electrical properties.



Interfaces in an intermetallic TiAl-based material used in aircraft turbine blades at elevated temperatures



Interfaces in a hard-coated tool for high-performance cutting (FIB section)

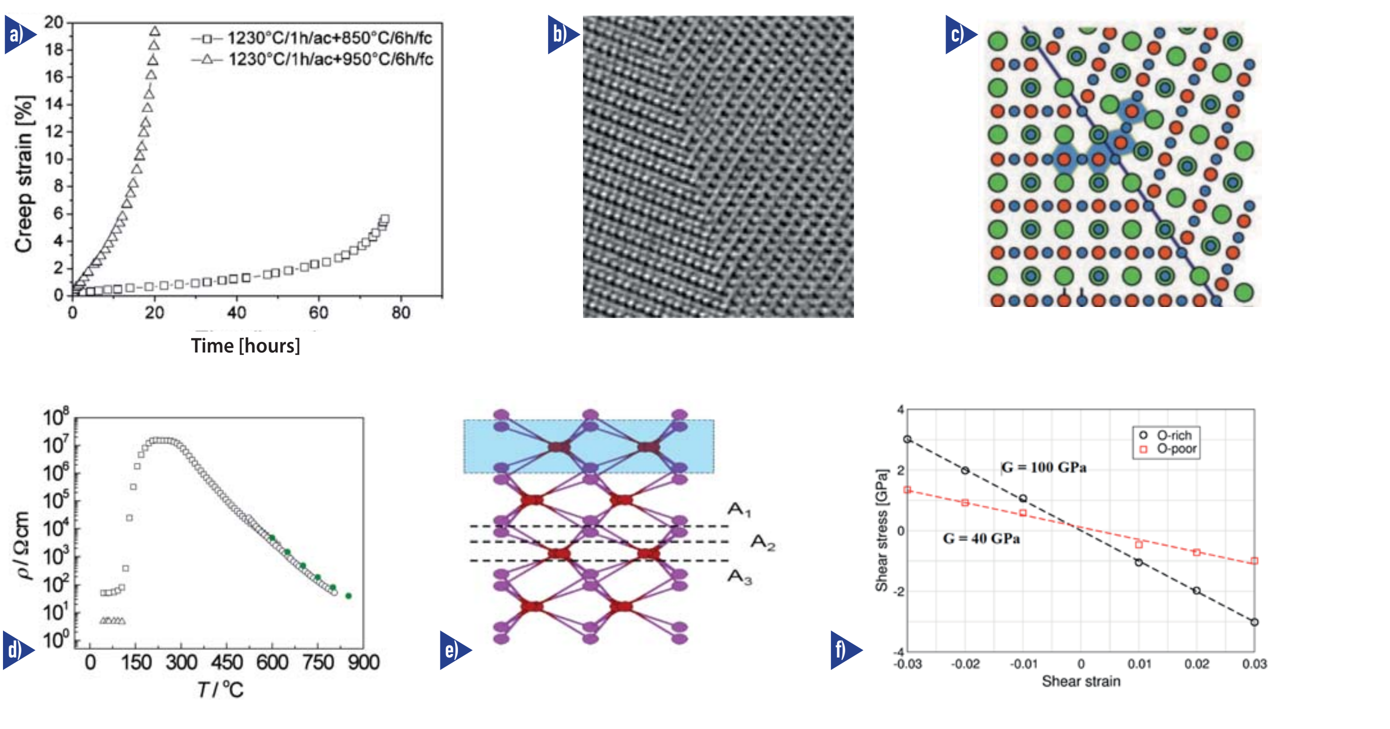


Interfaces in a multi-layer electroceramic material used in electronic circuits

Ab-initio methods provide the numerical basis for the prediction of stable interface structures and their properties. Materials with well-defined interfaces were produced by heat treatment or synthesis methods, e.g. powder metallurgy for electroceramics or plasma-assisted deposition of epitaxial layers for hard coatings. These interfaces and adjacent crystals were characterised using high-resolution transmission electron microscopy, which provides resolutions down to the atomic level when combined with image simulation techniques.

This enables the validation of the numerical simulations and provides the basis for a deeper understanding of the interface formation process. The coupling of the interface structure obtained by numerical and experimental methods with the properties determined by these interfaces offers a deep insight into the materials investigated. It is now possible, for example, to explain the specific electrical conductivity of electroceramics based on their interfaces and doping profiles or to control growth of hard coatings based on their epitaxial relationships to their substrates. The methods developed in the project thus provide fundamental data on interface structure and properties, which can be implemented in finite element methods to predict the behaviour of modern interface-controlled materials up to the macroscopic scale.

The strategic project of Area 2 "Multi-Scale Materials Design" has provided both analytical and numerical methods for the structural and property characterisation of interface-controlled materials, which will allow the properties of structural and functional materials to be tailored to the application at hand.



a) Creep strain of TiAl with identical phase volumes, but different grain boundaries; (b, c) Mn-segregation at a twin grain boundary in a $BaTiO_3$ electroceramic material; d) PTC effect – conductivity in the bulk material and at the interface as a function of temperature; e) ab-initio modelling of the Al_2O_3-TiO_2 interface; f) calculated sheer stress/strain diagram of a TiO_2-Al_2O_3 interface

The project was carried out in cooperation with the Chair of Physical Chemistry, the Chair of Functional Materials and Materials Systems, the Chair of Physical Metallurgy and Materials Testing and the Chair of Atomistic Modelling and Design of Materials of the University of Leoben.

COMET K2 MPPE
RESEARCH PROGRAMME

Strategic Research
Projects

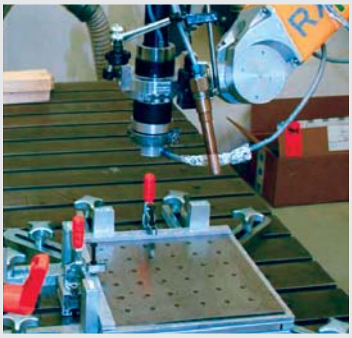
A 3.9

Improving stability and dynamic behaviour of thin-walled structures

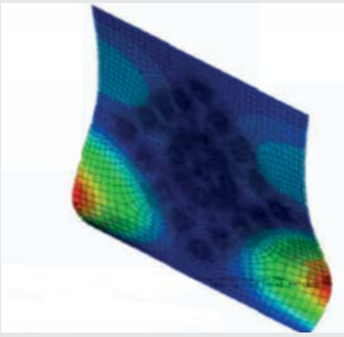
Light weight materials, design and construction are gaining increasing significance in automotive engineering. Light weight construction is aimed at enhancing the static and/or dynamic properties of a component or its material characteristics during the manufacturing process without increasing its weight. The project was focused on improving the stability (increased buckling resistance) and dynamic behaviour (increased fundamental frequency) of thin-walled components without increasing the component mass.

Stability and dynamic behaviour are key criteria in the design of light-weight components, with buckling strength playing a major role for thin-walled structures.

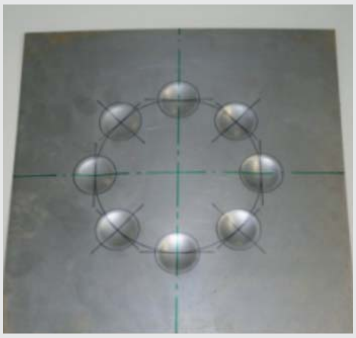
The project was aimed at improving the stability and dynamic behaviour of thin-walled components. Several concepts were developed to enhance the static and dynamic properties of the component without increasing its mass. The approach was to enhance stability by introducing residual stresses through laser treatment and to improve stiffness by the targeted introduction of beads and embossing patterns. Alternative methods such as the application of additional structural material were not considered, since these would lead to an increase in weight and manufacturing costs.



Introducing residual stresses into steel plates through local laser treatment using a Nd-YAG laser



Simulation of the first buckling mode of a steel plate with laser-induced residual stresses, without stiffening measures

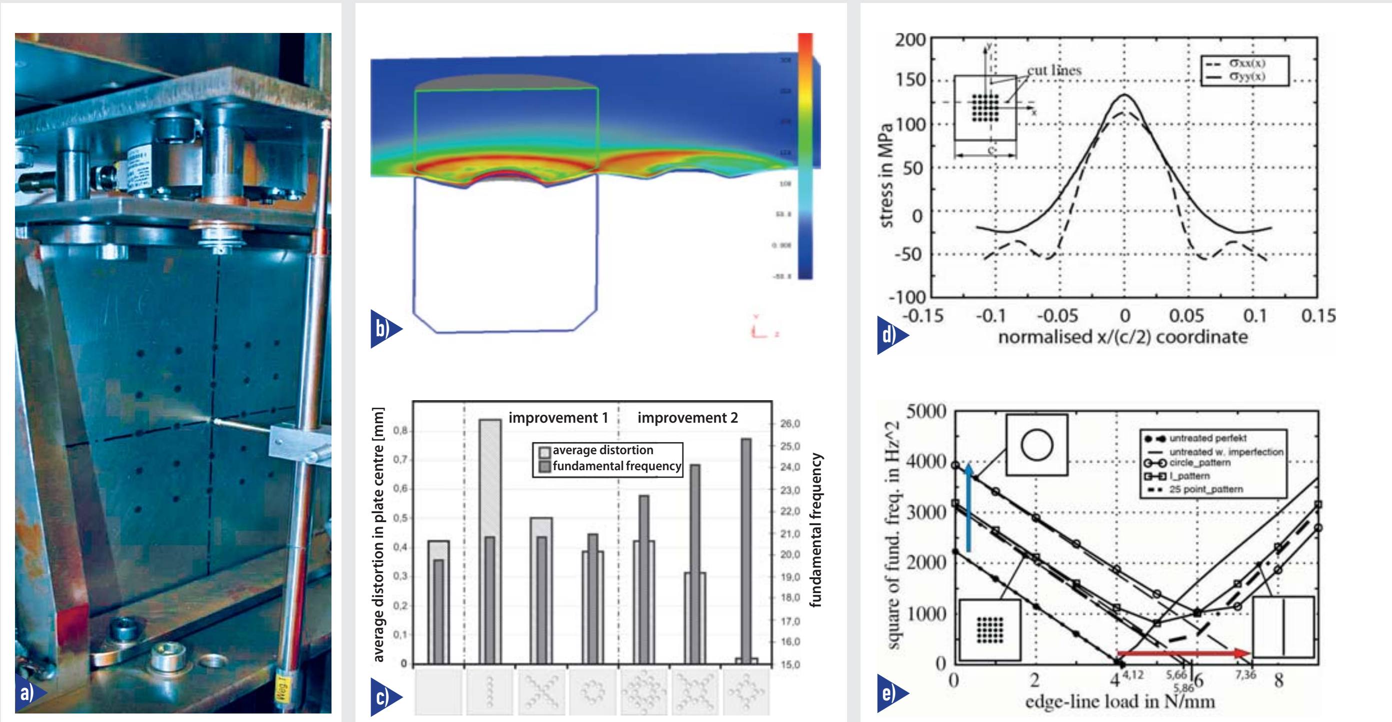


Embossing patterns in a plate for improved stiffness

Local laser spots and lines are introduced to induce residual stresses through local thermomechanical plasticizing, which enhance buckling resistance and/or the fundamental frequency of the component. The degree of improvement largely depends on the form and position (circle, line, point) of the pattern as well as the intensity of laser treatment. Simulations were carried out to analyse these parameters for the purpose of optimisation. The method has the advantage that it does not increase component mass and requires no change in geometry as it enhances the stability and dynamic behaviour without altering the outer appearance of the component.

Figure e) below shows the effect of laser treatment in terms of increase in theoretical buckling load and/or fundamental frequency depending on the patterns used.

The second approach was to analyse a mechanical method based on the introduction of embossing patterns in order to increase global stiffness and thus also the stability of thin-walled structures. Various embossing patterns were tested for their effectiveness. These patterns also led to a significant improvement in stability and dynamic behaviour, but involve geometric shape changes which are often undesirable or impossible to implement from a design perspective.



a) Testing facility for measuring buckling resistance and eigenfrequencies; b) Simulation of embossing process; c) Average buckling in the centre of the plate and fundamental frequency of original and improved plates with different embossing patterns; d) Residual stresses around a laser spot determined by hole drilling method; e) Simulation results for laser-treated plates – the red horizontal arrow indicates the increase in theoretical buckling load, the blue arrow indicates the increase in fundamental frequency for different patterns

The project was carried out in cooperation with the Chair of Metal Forming (LUT) of the University of Leoben and the Institute of Lightweight Design and Structural Biomechanics (ILSB) of Vienna University of Technology. ILSB was responsible for the simulations, i.e. the numerical modelling of the manufacturing processes as well as the analysis of stability and dynamic behaviour. LUT analysed and verified the simulation results by laboratory experiments and developed new strategies to further increase the efficiency of the improvement measures.

COMET K2 MPPE
RESEARCH PROGRAMME

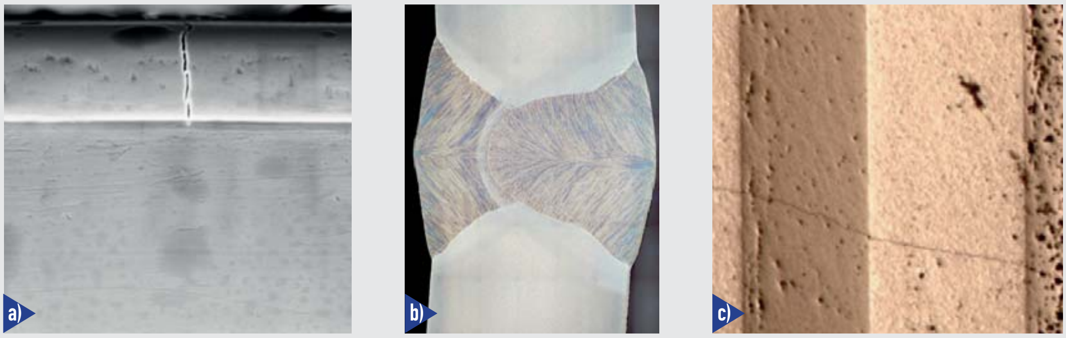
Strategic Research Projects

A 4.11

Description of crack propagation in heterogeneous materials using the configurational forces model

This strategic project focuses on the following subjects: (1) damage evolution up to the point of crack initiation, (2) crack propagation in heterogeneous materials, (3) damage evolution in small structures and (4) development of physically reasonable models for damage evolution. Much progress has been made in the work packages. Work package WP2 deals with the modelling of the behaviour of cracks in multi-phase and composite materials using the configurational forces concept. Configurational forces are forces derived from thermodynamics that act on all kinds of defects in materials.

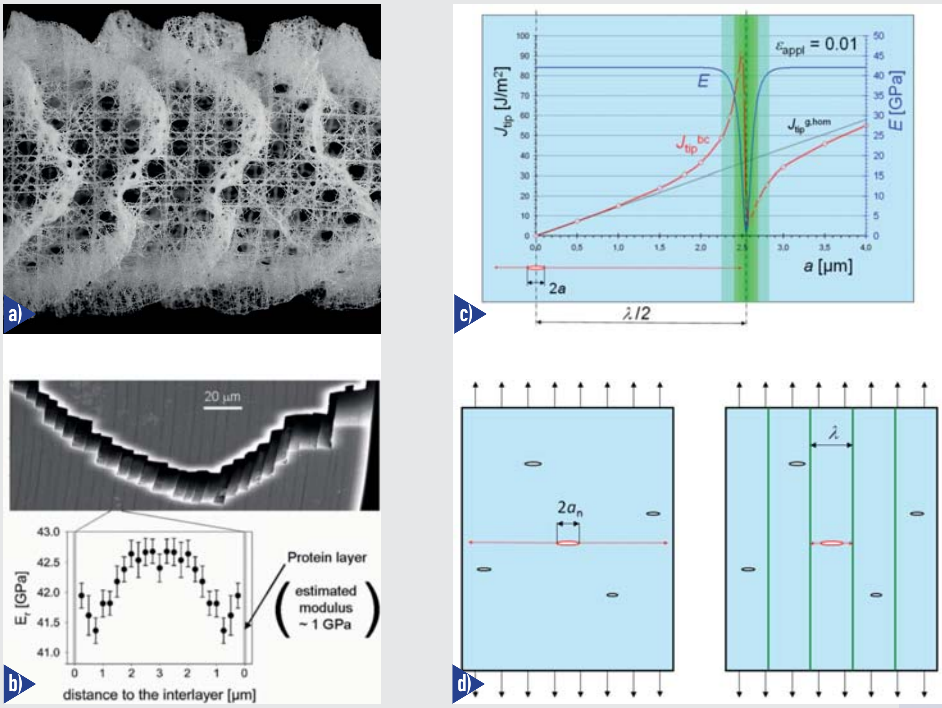
A material inhomogeneity can either shield the crack tip from the external loading or amplify the external loading (anti-shielding). The configurational forces concept takes this into account by introducing an additional crack driving force term, denominated as "material inhomogeneity term". A post-processing procedure for the commercial FE software package ABAQUS was developed to evaluate this term and the effective crack-driving force. The results reveal that the crack-driving force falls below the level shown by a homogeneous material when a crack grows from a material with low yield stress and/or Young's modulus towards a material with higher yield stress and/or Young's modulus, and vice versa. Compared to other methods, the configurational forces concept has the advantage that it can be used for any material with continuous or discontinuous spatial variations in properties. The influence of thermal residual stresses or strains induced by phase transformations can also be taken into account. The configurational forces concept also allows the evaluation of the crack propagation path, using the principle of maximum dissipation.



a) Tool steel W300 with a crack in a 3 µm thick CrN-layer, which grows into the substrate under cyclic loading; optimised coatings can be designed so that the crack stops; b) Inhomogeneous welding seam, c) Fracture in a multi-layer ceramic composite

In addition to new fundamental theoretical knowledge, e.g. on the application of the J-integral for elastic-plastic materials, the project also has already provided valuable results for concrete technical applications. Examples are the optimisation of coated steels or ceramic multi-layer composites, or the growth of fatigue cracks near interfaces. The project has thus generated world-wide leading expertise in the modelling of the behaviour of cracks in inhomogeneous materials and components.

Our work with the configurational forces concept opens up new possibilities for developing novel damage-tolerant and fracture-resistant materials and components. Of special interest in this context are various biological materials, such as mother-of-pearl or the skeletons of some deep-sea sponges, which are characterised by high stiffness and strength, whilst also being extremely fracture resistant. This latter property is especially noteworthy because these materials are made up mainly of brittle ceramic substances. We have shown that one of the key reasons for these properties is a periodical microstructure consisting of hard and soft layers. Fracture mechanics analysis was applied to derive a criterion for the potential design of these structures: for a combination of high stiffness and high fracture toughness, the wavelength λ of the structure must not exceed a critical value, depending on the relationship of the Young's moduli.



a) Skeleton of a deep-sea sponge; b) Structure consists of thin glass layers with soft protein interlayers; (c, d) Finite element simulations and the configurational forces concept were applied to study the behaviour of short cracks in this structure. The thin protein layers impede crack propagation by strongly reducing the crack driving force J_{tip}^{bc}, thus stopping the crack. This mechanism is fundamentally different from the mechanisms of interface decohesion and crack curvature observed in composite materials

The project was carried out at the Erich Schmid Institute of the Austrian Academy of Sciences, the Institute for Mechanics of the University of Leoben and MCL in cooperation with the University of Minnesota, Minneapolis, USA, the University of Maribor, Slovenia and the Max Planck Institute for Colloids and Interfaces, Potsdam.

COMET K2 MPPE
RESEARCH PROGRAMME

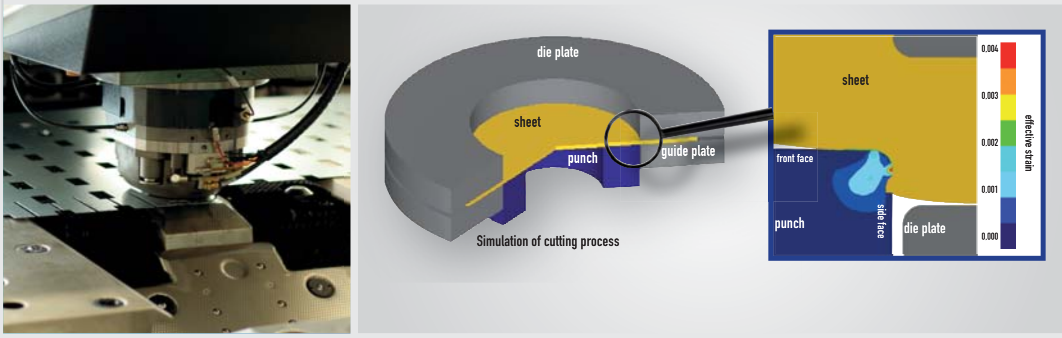
Strategic Research
Projects

A 5.2

Tool loading during forming operations

The project is aimed at designing forming tools like mechanical components by determining the loads in forming simulations and then using the results for design against fatigue. This approach provides new knowledge about how the forming process influences the life-time of forming tools and about the influence of the tool material and its microstructure on deformation, damage and crack growth.

Tool life-time is primarily determined by the loads resulting from construction, forming and operation. In addition, however, tool properties such as material, heat treatment or surface characteristics also have a major influence.



Stamping/fine blanking of steel sheet and simulation of the cutting process and local tool loading

The life-time prediction for tools constitutes a great challenge. The reasons for this can be found in the diversity of influences acting on the tool during operation, a lack of understanding of the underlying damage mechanisms and a lack of adequate numerical models for transient tool loading.

The mechanical loads acting on cutting, punching and forming tools in service often lead to high local stresses and cyclic plastic deformation. Local plastic deformation is accompanied by a build-up of residual stresses which lead to tensile stresses at critical points, which in turn accelerates damage. The growth of short cracks of several micrometers is of special importance when considering damage development in tools, as cracks in this size range have a major influence on tool life-time.

The 2D tool loading simulations were carried out in a fully coupled way, while the 3D simulations were calculated via a resultant forces model. The 2D simulations are carried out using a software tool developed within the project, which, combined with the commercial finite element (FE) software package ABAQUS, allows detailed modelling of transient tool loading. For the 3D simulations the forming process was first modelled in a separate FE model. The contact forces acting on the tool are then transferred as loads to a subsequent FE simulation in order to determine local tool loading. This procedure allows the calculation of complex tool geometries.

In the FE simulations, the modular phenomenological plasticity model by Chaboche was used to model stress redistribution due to cyclic plastification. In this model a significant number of parameters must be adjusted to the respective application. The project thus focuses on developing both a universal model for tool steels with the parameters hardness and Young's modulus and a physical macroscopic material model based on crystal plastic approaches.

In highly stressed tools, the major part of tool life lies in the propagation of cracks with initial lengths of several micrometers (which often arise already during tool manufacture or the first loading cycles) to several ten micrometers. In cracks of this size range the structure of plasticity induced crack closure and interaction with the carbide phases in the tool steel play an essential role. These effects are investigated experimentally for different materials in order to derive fracture mechanics based life-time models.

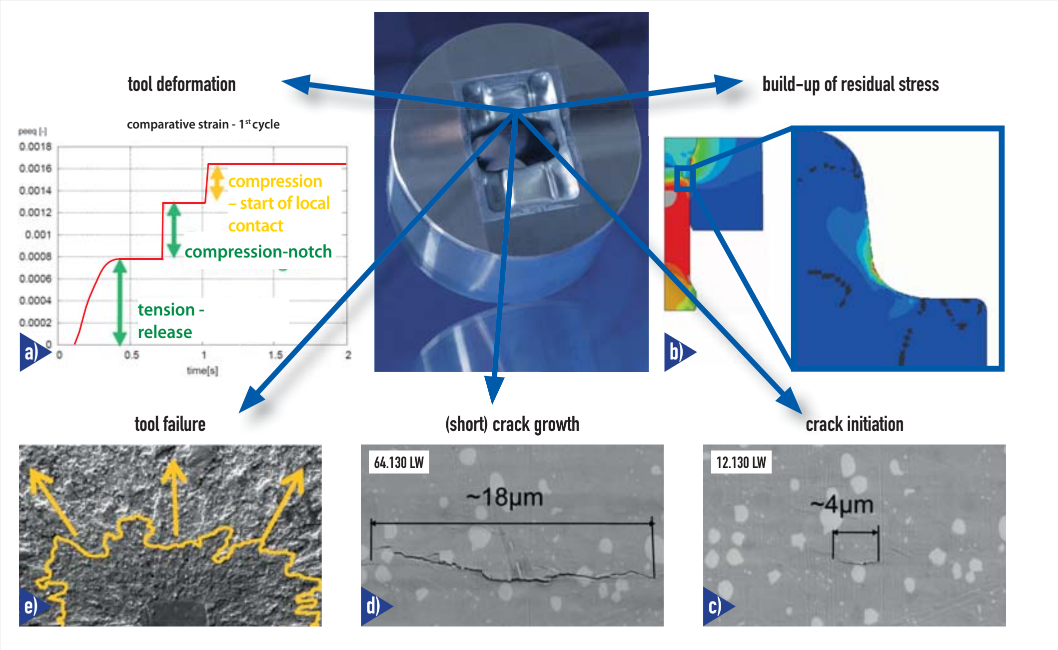


Fig.: Stages of material fatigue in forming tools – a) cyclic plastic deformation due to process loading; b) build-up of residual stresses due to cyclic plastification; c) crack initiation, e.g. through carbide fracture, partly occurs in first loading cycle; d) growth of short cracks from 5 µm to 20 µm determines tool life-time; e) unstable crack propagation leads to damage and tool failure

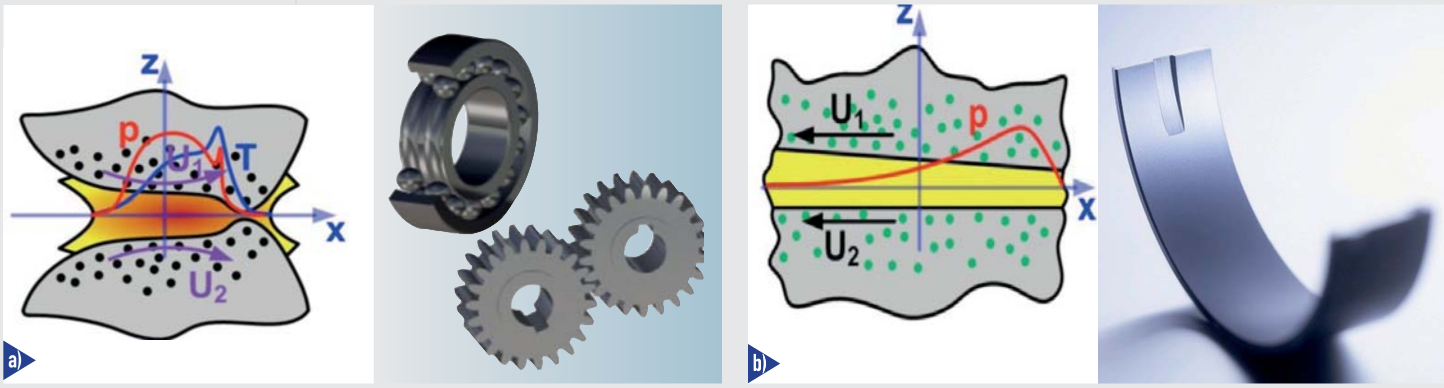
The strategic project provides numerical methods for the design of forming and punching tools for related projects and enhances expertise in the key research fields of MCL, i.e. material modelling and fracture mechanics based life-time modelling.

The project is carried out in cooperation with the Erich Schmid Institute of the Austrian Academy of Sciences, the Institute for Mechanics of the University of Leoben, the Institute for Materials Science and Welding of Graz University of Technology and the Centre des Matériaux of the Ecole des Mines de Paris in Evry, France.

Coupled simulation of the load-bearing capacity of materials with heterogeneous microstructure in lubricated contacts

Contact mechanics plays a major role in many areas: for journal and roller bearings, couplings, brakes, combustion engines, joints and seals as well as in forming and machining operations. It is primarily influenced by the material properties and determines reliability, energy efficiency and service life.

Contacts between machine components moving relative to each other are usually lubricated. Highly stressed Hertzian contacts result in pressures of up to 20,000 bar, subjecting the material to significant stress. The project is aimed at assessing lubricating film formation and local material stress of lubricated systems. This approach far exceeds conventional simulation methods by taking a heterogeneous microstructure into account. Another focus was placed on modelling the tribological behaviour of heterogeneous tribomaterials for large-area contacts using simulations and experiments.

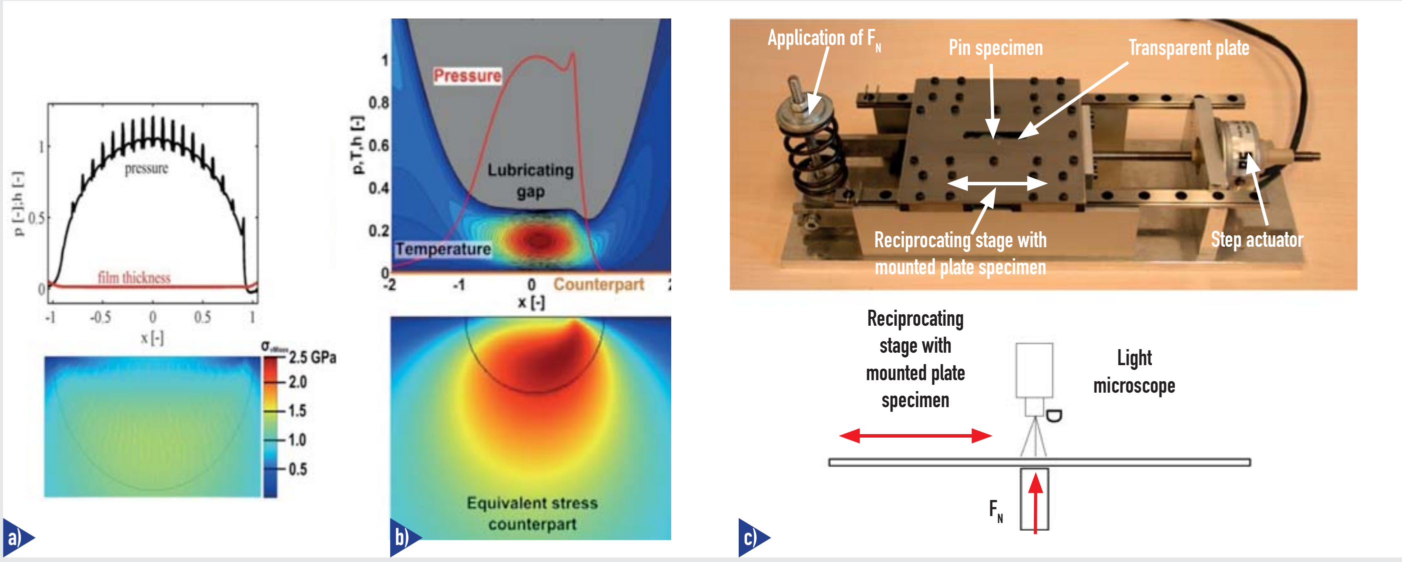


a) Hertzian contact, thermo-elasto-hydrodynamic (TEHD) simulation of heterogeneous tribomaterials; b) large-area contacts of roller bearings, hydrodynamic (HD) simulation

A thermo-elasto-hydrodynamic (TEHD) simulation based on COMSOL Multiphysics was developed to assess true local loadings and lubricating film formation for heterogeneous materials in Hertzian contacts. This simulation enables the determination of local lubricating film thickness, pressure, material loading and temperature distribution. The influence of temperature on lubricating film thickness must be taken into account in particular for gear contacts. The method allows not only the analysis of components such as journal bearings, camshafts, roller bearings and gears but also makes it possible to assess tribological analogous models, thus significantly improving the evaluation and transfer of the results obtained.

The friction forces caused by thermo-elasto-hydrodynamic contact (friction power, friction loss) were described using established equations taking into account the physical fluid properties. High-pressure measurements were carried out on selected lubricating oils to determine the rheological properties. Tribometric validation was done by measuring friction force, contact potential, wear and temperature for different operating parameters using a specially developed two-disc test rig. The results obtained led to a better understanding of the system interactions and enable the targeted improvement of lubricated contacts.

The addition of hard and soft phases can significantly improve the bearing capacity, emergency running operation and wear resistance of tribomaterials, in particular for friction applications such as dynamic seals, journal bearings or cylinder/piston ring systems. Targeted optimisation requires an in-depth understanding of the tribological mechanisms involved.



a) TEHD contact, influence of heterogeneous material structure on lubricating film formation and local loading of a steel with hard phases under rolling contact loading; b) TEHD contact, pressure and temperature distribution and component loading; c) in-situ tribometer

The novel in-situ tribometer developed within the project enables light microscopic analysis of the lubricating gap using transparent counterparts and thus allows fundamental tribological wear mechanisms such as micro-ploughing and micro-cracking to be investigated. The project also involved analysing the tribological mechanisms of hard particles for a heterogeneous tribomaterial in order to obtain basic knowledge about the optimal structure of tribomaterials for different applications.

The project is carried out at the Chair of Mechanical Engineering of the University of Leoben in cooperation with the Bay Zoltan Foundation for Applied Research

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COMET K2 MPPE
RESEARCH PROGRAMME

Strategic Research
Projects

A 7.7

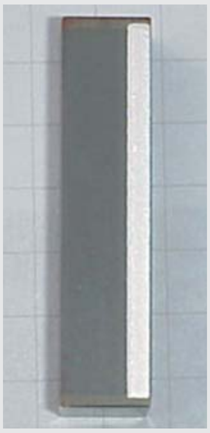
Constitutive laws for piezoceramic materials

Piezoceramic components are used in a wide range of sensor and actuator applications. The most important material in this area is sintered lead zirconate titanate (PZT). Because of its high strain rates PZT is also used for injection control systems in the automotive industry. The underlying "giant piezoelectric effect" in this ferroelectric material is caused by a complex interaction between the intrinsic and extrinsic piezoelectric effect, the latter being enabled by domain movement and re-orientation.

The development of a constitutive material law is a key prerequisite for gaining a detailed insight into the material dynamics and thus for the design of reliable components. The implementation of coupled ferroelectric and ferroelastic effects is essential for obtaining a sufficiently realistic material model. This was achieved in a phenomenological-continuum mechanical approach using a novel finite element method. Consistent tangent modules were calculated quasi-analytically using automated differentiation of the FORTRAN code to achieve rapid and robust convergence of the highly non-linear problem. As the FEAP-based code can be accessed from within the commercial FE program ANSYS, we can thus provide a sophisticated FE tool with pre- and post-processing capabilities. The model has already been used for predicting field distributions in realistic component sections. This knowledge is of major significance for example for robust "crack management".

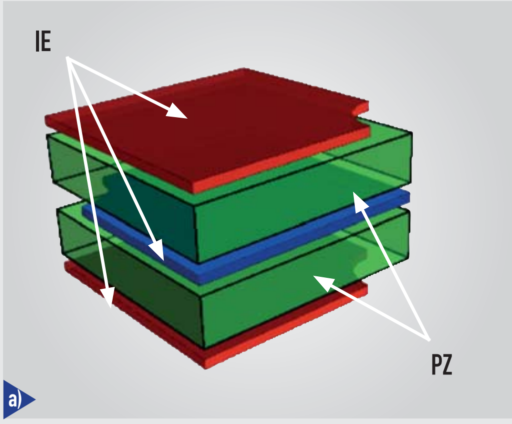
Common rail system of a vehicle diesel engine

Common rail injection elements

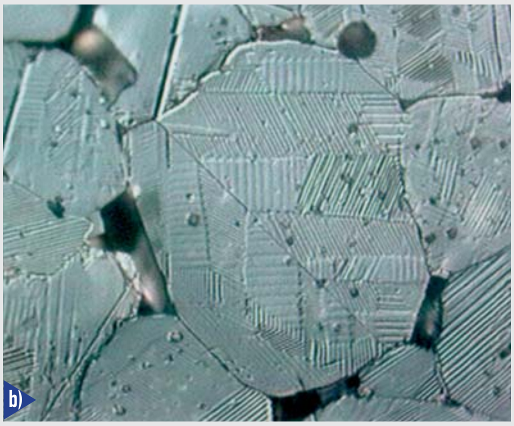


Piezoelectric actuator

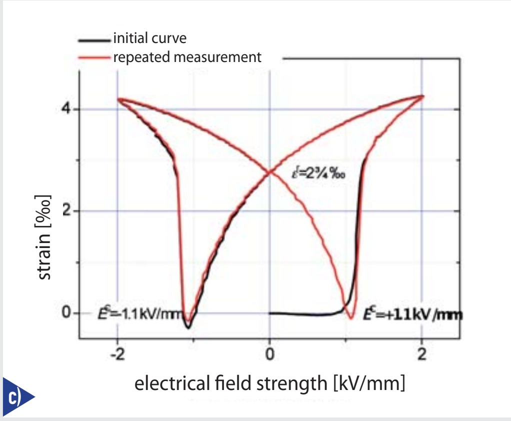
The new simulation model is designed to contribute to enhancing expertise in piezoelectric materials in order to be able to open up new fields of application. The knowledge obtained about special simulation techniques can also be translated to other non-linear problems concerning functional ceramics.



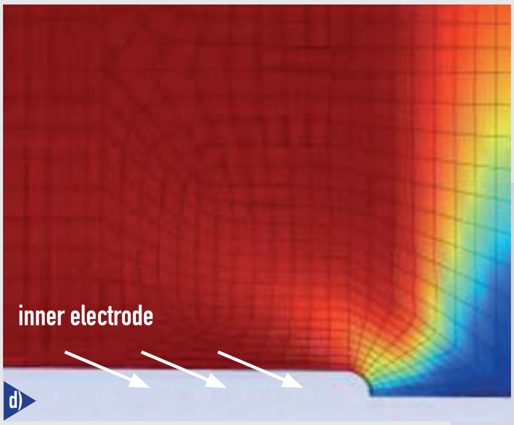
Schematic structure of a multilayer actuator: the piezoceramic layers (PZ, green) are sandwiched between alternatingly electrically connected inner electrodes (IE: red, blue)



Etched microsection showing the typical domain structure of a ferroelectric ceramic (ca. 100x70 µm)



Integral strain behaviour of a PZT material as a function of electrical field strength



Inhomogeneous polarisation around the tip of an inner electrode (see design in structure in Figure a)) calculated with the new material model

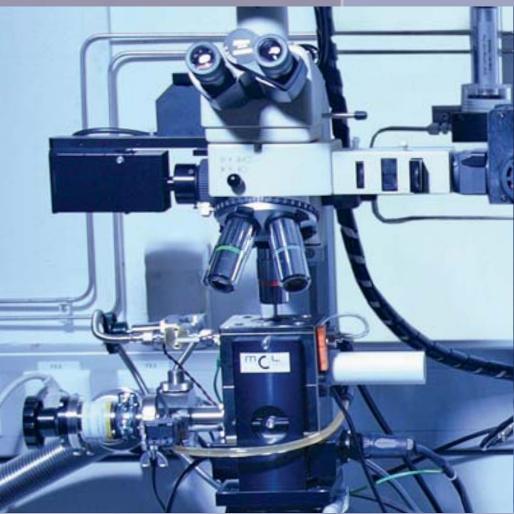
The project was carried out in cooperation with the Institut für Struktur- und Funktionskeramik.

LABORATORY EQUIPMENT AND BUSINESS FIELDS OF MCL

MCL Business Fields

New Laboratory Equipment at MCL:

- High-temperature laser scanning confocal microscope
- Crack growth measurement of short cracks at high/low temperatures
- High-temperature chamber and extension of XRD laboratory



MCL Business Fields

LABORATORY EQUIPMENT AND BUSINESS FIELDS OF MCL

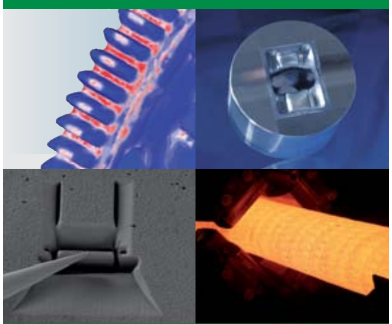
The Materials Center Leoben acts as a center for materials, process engineering and product development offering development support and services in addition to the COMET K2 MPPE research programme.

The Materials Center Leoben offers a strong mix of theoretical and practical expertise and state-of-the-art facilities, making it a flexible and experienced partner for demanding research, development and application tasks in the areas of materials engineering, process engineering, quality assurance and component design. MCL offers the following services:

RESEARCH

Research in the areas of materials, process and product engineering

DEVELOPMENT



Development and optimisation of materials, processes and products

SERVICES

Consulting services, materials analysis, simulation and damage analysis

For more detailed information on these topics, please visit our website www.mcl.at. Our brochures are also available for download or can be requested directly from MCL.

MCL offers services mainly in the field of materials analysis with a focus on microstructure characterisation and determination of mechanical and physical properties. State-of-the-art laboratory equipment and advanced analytical methods are made available both to companies and scientific partners to carry out application-oriented non-K projects or complex academic research. Considerable investments were made in new laboratory equipment to adapt the service range to future requirements:

- High-temperature laser scanning confocal microscope
- Crack growth measurement of short cracks at high/low temperatures
- Extension of XRD laboratory (X-ray diffractometry) with a high-temperature chamber and an analysis system for in-situ investigations

High-temperature laser scanning confocal microscope

MCL decided to purchase a high-temperature laser scanning confocal microscope (HT LSCM) in the course of COMET K2 Project 3.1 "In-situ observation of metallurgical processes by means of High-Temperature Laser Scanning Confocal Microscopy". The VL 2000DX microscope from Yonekura (Japan) was installed at the Chair of Metallurgy of the University of Leoben in December 2010.

High-temperature laser scanning confocal microscopes are today widely used for the in-situ observation of materials at temperatures of up to 1700°C. Phase transformations in the solid state, melting and solidification as well as surface reactions like oxidation and reduction become visible. The behaviour of non-metallic inclusions in liquid alloys and at the interface between alloys and slags as well as the interface alloys/refractories are also a matter of interest. HT-LSCM is thus an essential tool for contemporary iron and steel research.


Installation of the high-temperature laser scanning confocal microscope by experts from Yonekura

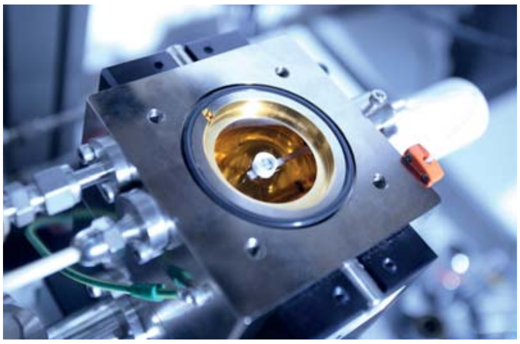
The 408nm laser enables the observation of glowing surfaces because the reflected near UV light is not outshined by the self-radiation of the sample.

The infrared furnace provides heating rates of up to 1200°C per minute and cooling rates of 1000°C per minute down to a temperature of 900°C in conventional cooling mode. The optional rapid quenching system uses helium to achieve quenching rates of several 1000°C per minute to near room temperature.

The furnace is gas tight and thus allows observations to be performed under defined atmospheres (oxidising/reducing conditions) as well as under vacuum conditions.

The free choice of test parameters significantly extends the measurement and analysis methods available at MCL.

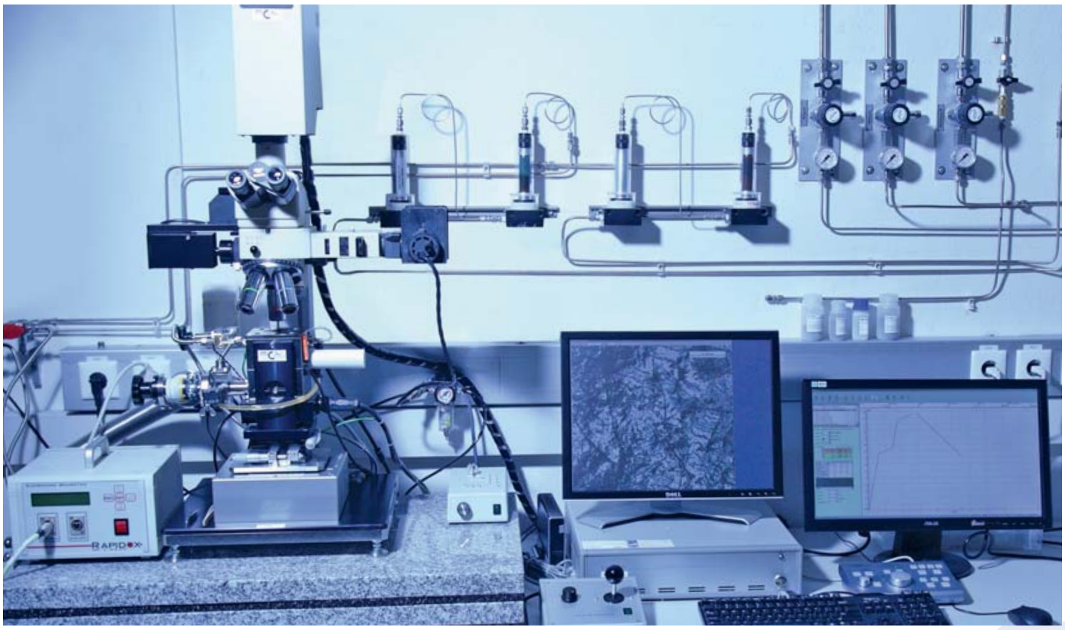
The new microscope enables direct analysis of the melting and solidification behaviour of metallic and non-metallic melts and inclusions, oxidation and reduction processes as well as phase transformations and relationships between liquid and solid phases.


Open infrared furnace with standard specimen in Al_2O_3 crucible

The results of the measurements are integrated into simulations for the further development of materials and processes.

The team of Professor Rian Dipenaar from the University of Wollongong in Australia is an invaluable project partner with over 12 years expertise in high-temperature laser scanning confocal microscopy. A team member, Mark Reid, also provided invaluable support in installing the new equipment.

Over 100 Yonekura HT laser scanning confocal microscopes are installed worldwide, thus giving MCL access to the scientific community, which includes not only the University of Wollongong, but also prominent steel manufacturers and research institutes, especially in Asia, as well as universities in the USA and Europe.



The high-temperature laser scanning confocal microscope

Additional subjects of analysis include phase transformations during heating and cooling, the behaviour of materials, interactions of metallic melts with non-metals such as refractories and non-metallic inclusions as well as thermochemical reactions on metallic and non-metallic surfaces.

LEHRSTUHL FÜR METALLURGIE
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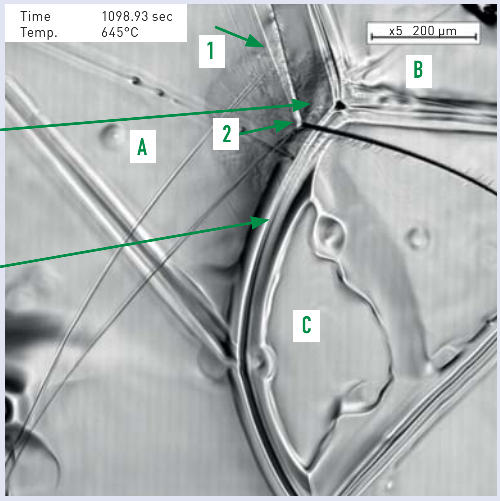
HT laser scanning confocal microscope

Analysis examples

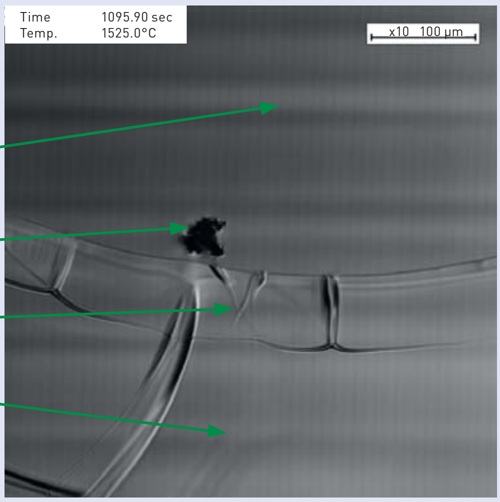
Steel with 0.05% C heated to 884°C:

Surface tensions cause grooves to form at the grain boundaries at elevated temperatures, thus making the grains visible ("thermal etching"). Continued heating above the alpha-gamma transformation temperature leads to the formation of austenite with the grain boundaries again emerging through thermal etching and the ferrite grain pattern remaining visible in the background.



Steel with 0.42% C cooled to 645°C:

After superficial melting of the specimen, the relief of the former delta grains remained visible during cooling. The austenite grains A and B have grown at the expense of C, causing the triple point where bainite formation occurs to move from 1 to 2. The in-situ observation of the velocity of grain boundary migration provides valuable information for the targeted heat treatment of materials.

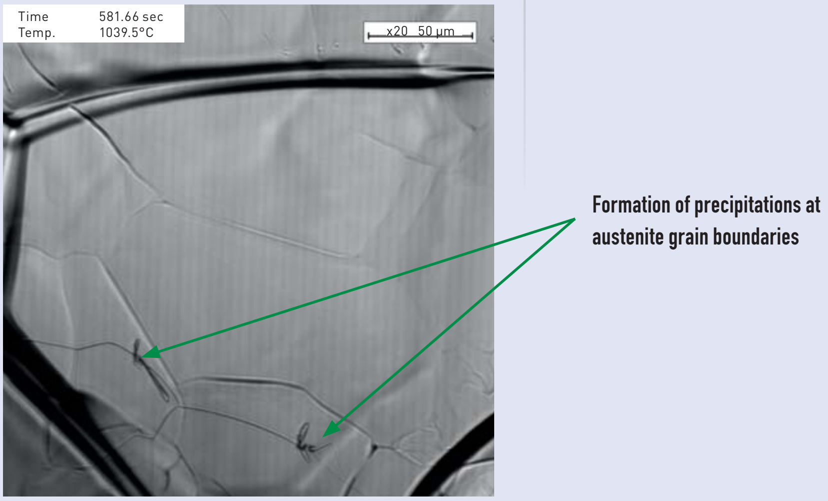


Steel with 0.18% C heated to 1525°:

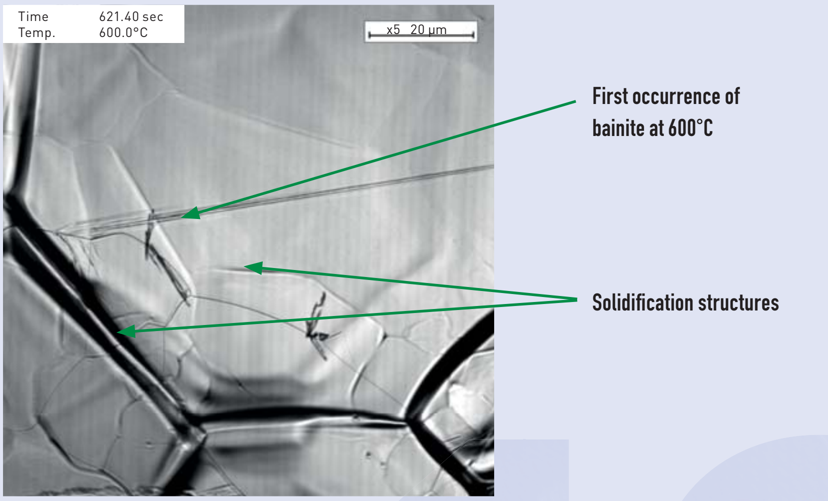
The design of the infrared furnace leads to a radial temperature gradient. The temperature in the centre of the specimen is slightly higher than at the edges, thus causing a pool to form which is in direct contact with the solid specimen material. This opens the opportunity to observe interactions between several thermodynamically stable phases in one image.

Micro-alloyed steel:

After superficial melting, the specimen was cooled at a rate of approx. 1000°C/minute. The image shows former grain boundaries visible as relief structures as well as current austenite grain boundaries with pre-eutectoid precipitations growing into the austenite. Both the solidification structures and the precipitations are the subject of further analysis.



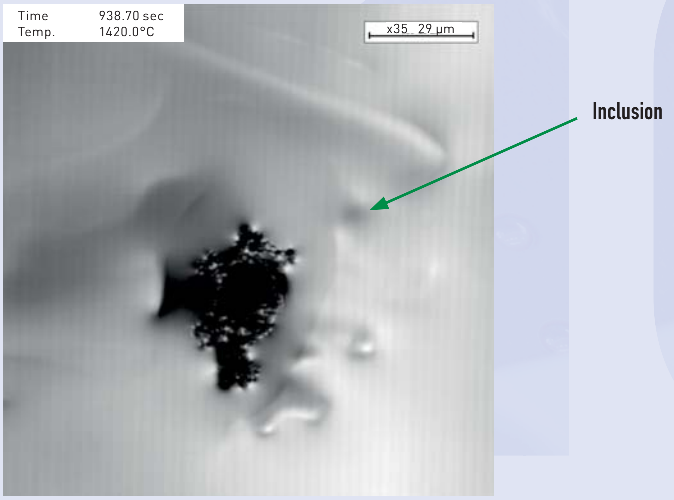
Continued cooling of the steel causes the first bainite to form slightly above 600°C, which is helpful in the allocation of structures on the specimen surface. The observation of the growth of bainitic and martensitic structures allows conclusions to be drawn about nucleation and segregation processes, which in turn have a major influence on heat treatment.



Floating inclusion on CrMo steel:

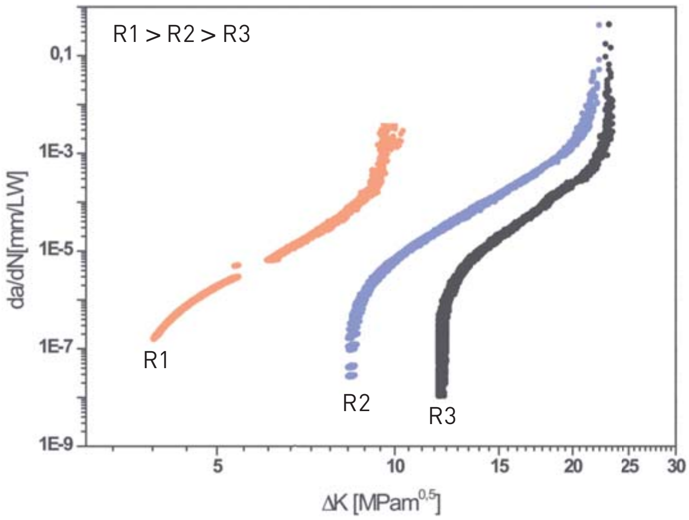
A key research focus is on the analysis of inclusions and their modification during solidification and remelting of steels as well as their interactions with each other and with ceramic materials.

The image shows a ZrO_2 inclusion floating on a CrMo alloyed steel melt at 1420°C.



Crack growth measurement of short cracks at high/low temperatures

Fracture mechanics analysis of component failure and reliability has proven to be indispensable in many areas of component design. Proper validation requires material parameters from fracture mechanics and crack propagation tests. The quality of these material parameters depends substantially on the quality of the crack growth measurement. The direct current potential drop technique is the most widely used method for measuring crack length in fracture mechanics experiments. It is a very robust method, where currents from 50 to 100 Ampere are passed through the specimen.

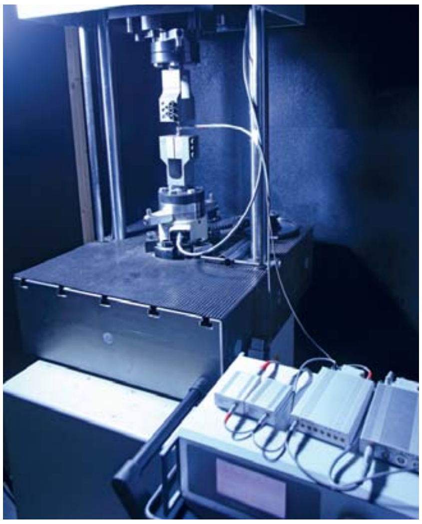


Crack growth curves as a function of the R values of a steel specimen (measured on CT specimens using the alternating current potential drop technique)

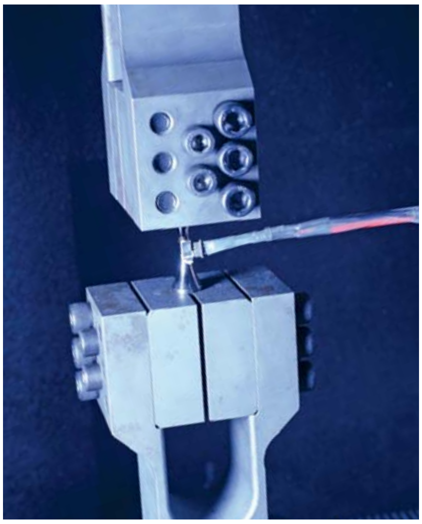
The method has the disadvantage, however, that it carries the risk of component overheating due to the high current loads involved, thus making tests at elevated temperatures difficult. Another drawback is that it is not suitable for measuring the growth of small and short cracks (several µm to tenths of mm).

An alternative method is the alternating current potential drop technique, which is ideally suitable for measurements at high and low temperatures and also for short cracks. This technique employs very low currents of approx. 0.5 Ampere and thus reduces component heating to a minimum. The skin effect (currents flow very close to the surface) allows even very small cracks close to the surface to be detected.

At the end of 2010, new instruments for crack growth measurement based on the alternating current method were installed at MCL. The new equipment includes a CGM-7 crack growth monitor (Matelect Ltd.) and a high-precision spot welder for connecting the contact wires to the specimen. In 2011 the portfolio will be further complemented with a direct current potential drop unit (Matelect Ltd.). These crack growth measurement systems can be integrated with all mechanical testing equipment (electromechanical, electrodynamic and hydraulic) currently available at MCL.



Electrodynamic resonance test machine with tensile specimen of high-strength tool steel, connected to an alternating current potential probe with integrated measurement system



Detail: Tensile specimen with introduced small crack (approx. 25x10 µm) and Pt contact wires for the alternating current potential drop unit

These new measurement systems are primarily used in fracture mechanics tests such as:

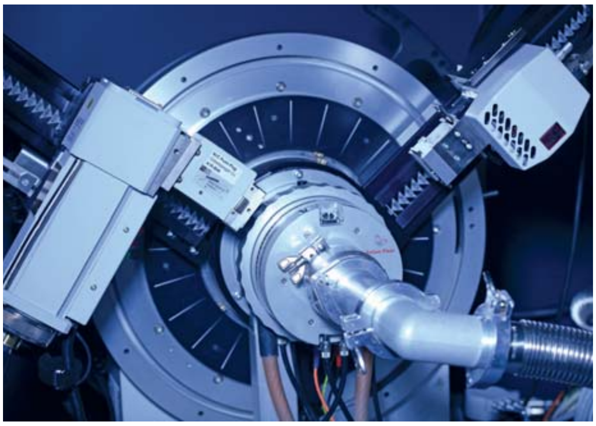
- J-integral test
- CTOD test
- recording of cyclic crack growth curves (da/dN curves)
- recording of crack growth curves and crack resistance curves for small and short cracks (e.g. using artificially introduced microdefects)

Another servohydraulic testing machine including a controlled test chamber will be installed in 2011. This system will enable fracture mechanics tests to be carried out at low (down to -150°C) and elevated (up to 600°C) temperatures.

High-temperature chamber and extension of XRD laboratory

In 2011, MCL extended its capabilities in high-temperature X-ray structure analysis by implementation of a new high-temperature chamber and new fast detector. These new facilities allow for characterizations of phase transformations and thermal expansion coefficients in crystalline materials. The measurement system (D8-Advance, Bruker AXS, Karlsruhe) is now equipped with parallel optics (Goebel mirrors) for different wavelengths (Mo $K\alpha$, Cu $K\alpha$) and a linear detector system (Lynx Eye, Bruker AXS, Karlsruhe) which allows for short measuring times. The new HTK 2000 high-temperature chamber (Anton Paar, Graz) enables XRD analysis at temperatures of up to 2000°C and provides fast heating and cooling rates. Measurements can be carried out both in air and in inert gas atmosphere (N_2, He, Ar) at calibrated (current state) temperatures of up to 1500°C. The highest temperatures can be achieved under vacuum conditions ($<10^{-4}$ mbar).

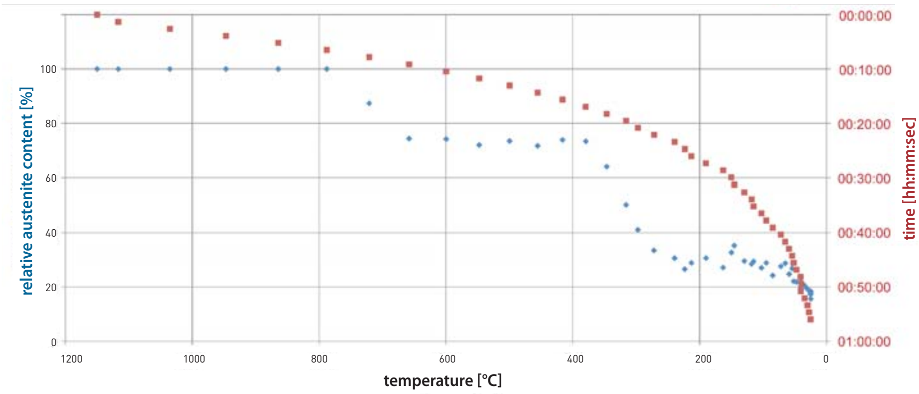
HTK 2000 high-temperature chamber (Anton Paar)



D8 Advance measurement system including 1D LynxEye detector (Bruker AXS)

The new measurement procedures are typically used for monitoring phase transformations in steel samples during controlled cooling from the austenitisation temperature. The accurate measurement of the phase transformation temperatures and precise monitoring of the phase transformation kinetics provides invaluable support in the calculation of time-temperature-transformation diagrams.

The new equipment complements the high-temperature XRD portfolio of MCL Leoben. The range from room temperature to 900°C is covered by a reactor chamber for measurements under process gases at working pressures of up to 10 bar (XRK 900, Anton Paar, Graz), which allows for chemical reaction monitoring by investigations of crystalline phase development. In addition, a domed high temperature stage for the 4-circle diffractometer up to 900°C (DHS 900, Anton Paar, Graz) in air or inert gas (N_2, He) is available for characterising residual stress development during thermal loading.



Relative austenite content of a powder metallurgical high-speed steel during exponential cooling (Lambda= 4) from 1200°C to room temperature (simulation of hardening process). A significant proportion of residual austenite remains after cooling

Advanced evaluation routines are available for all methods.

MCL analysis portfolio:

- **HTK 2000 NEW**
  Phase transformations (quantitative), solidification from the melt, time-temperature-transformation diagrams, phase diagrams (equilibrium)
- **XRK 900**
  Phase transformations (quantitative), chemical reactions on surfaces
- **HS 900**
  Build-up/relaxation of residual stresses in coatings and treated surfaces

INTELLECTUAL CAPITAL REPORT

Intellectual Capital Report

I. Scope, Goals and Strategies

2008 was the first year in which the intellectual capital report was included in the annual report. We were inspired by the universities who, in contrast to MCL, are obliged to draw up an intellectual capital report as a means of illustrating their multifaceted scientific output. Like the universities, MCL measures its primary business success not in terms of financial success, but rather in terms of its scientific output as well as its contribution to the economy. Therefore we have decided to adapt the specified structure of the intellectual capital report for our own purposes, enabling us to use it more intensively as a control instrument for the company.

The majority of the data included in the intellectual capital report does not have to be freshly generated, but is taken largely from the comprehensive set of reports submitted to the FFG and SFG. However, it is the preparation and interpretation of this data that provides a new perspective on how the past business year has developed.

During the past years a further reason has emerged for drawing up an intellectual capital report. Competence centres are largely funded from the public purse and, in view of the ever more limited financial resources available at state and regional level, are also obliged to account precisely for the proper use of tax money. Our research programme aims at generating scientific output, for example innovations or patents, to provide benefits for the companies involved. These benefits can be measured in any number of complex ways. We have chosen to present concrete examples of the successful transfer of knowledge from science to business. Since 2008, MCL has used its annual intellectual capital report to present several highlights from the research projects which have led to innovations at the partner companies. These success stories are also published on our homepage.

II. INTELLECTUAL CAPITAL

A) Staff

MCL had 116 staff members at the end of 2010. This represents a significant increase over the 2009 figure of 101 employees.

The majority of these new staff members are qualified scientific employees who have contributed to strengthening and expanding the following areas:

- 1 key scientist, researcher with a proven international track record.
- 4 senior scientists, experienced researchers with the ability to actively develop specific subject areas.
- 8 junior scientists, young researchers currently in training (e.g. students currently working on degree theses).

MCL takes the subject of gender very seriously. We have succeeded in increasing the proportion of women from 20% in 2009 to 23% in 2010. Female employees at MCL enjoy the same basic conditions as their male colleagues. We also offer childcare support and help women returning to work after maternity leave by means of special working models. MCL will increase its efforts to raise the proportion of female staff members further. There is most room for improvement amongst the doctoral students.

Personnel at MCL/MPPE 2010

as of: 31/12/2010

	Employees		
	male	female	total
Research	**82**	**18**	**100**
Competence Centre Management	1		1
Key scientists	6	1	7
Senior scientists	15	2	17
Junior scientists	60	15	75
Administration	**1**	**8**	**9**
Technicians / Skilled staff	**6**	**1**	**7**
Total MCL	**89**	**27**	**116**

Personnel at COMET Partners

	male	female	total
Industrial partners	252	15	267
Scientific partners	111	15	126
Total MCL	**363**	**30**	**393**

Amongst our industrial and scientific partners, a further 400 researchers are working on projects in the COMET programme. With a total of around 500 employees, the COMET programme offers enormous potential for taking on highly complex scientific challenges.

1. Special research equipment

MCL has extensive laboratory equipment in the fields of metallography, physical/ chemical and thermal analysis, mechanical testing, heat treatment and tribology.

The laboratory infrastructure had already been significantly extended in 2009 by the installation of a scanning electron microscopy laboratory. The focus of 2010 was on the development of new analytical methods such as cut&slice methods for microstructure tomography, which are available on a permanent basis thanks to a tailored personnel concept.

The lion's share of capital expenditure went into the purchase of a high-temperature laser scanning confocal microscope, which was delivered in December 2010 and was immediately put into operation. The instrument at MCL is one of only three such microscopes in Europe. The microscope quickly showed its enormous potential for materials research and has attracted great interest from the scientific community and industry. A detailed description of the system can be found on page 46 of this annual report, which also includes details on the new measurement system for short cracks (page 50) and the high-temperature chamber for X-ray diffractometry (page 52).

Two other major investments in equipment were originally scheduled for 2010. One was the purchase and commissioning of a servohydraulic testing facility including a controlled test chamber for dynamic materials tests, especially fracture mechanics tests, at low (down to -150°C) and elevated (up to 600°C) temperatures. Also planned was the commissioning of a thermomechanical simulator to determine complex mechanical materials parameters under mechanical and thermal loads. Due to delivery problems on the part of the manufacturers, however, these two investments were postponed to 2011.

Various other smaller investments were made in 2010 to complement the laboratory infrastructure and to purchase equipment for specific research projects. The focus in 2011 will again be on extending and complementing the existing laboratory equipment.

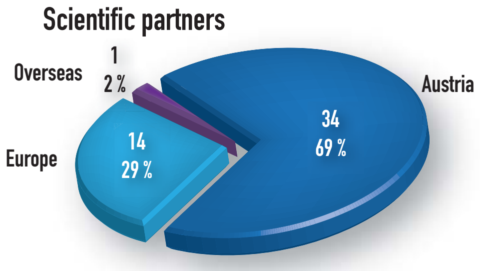
2. Relational capital

Building up and maintaining a comprehensive network of partners is an essential prerequisite for a cooperative research organisation, enabling complex problems to be handled quickly and competently.

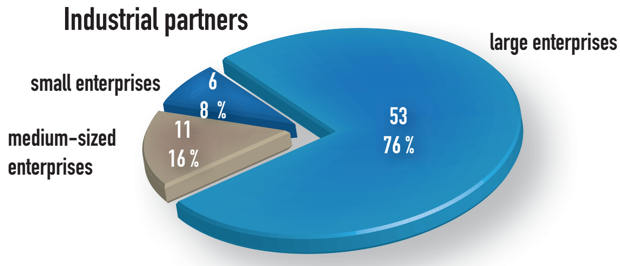
As the figures show, the number of partners has consistently risen over the past years. Since 2008 the number of industrial partners has almost doubled from 40 to 70. We have also registered a significant rise in the number of scientific partners, which increased from 36 to 49.

There is a certain need to catch up in terms of attracting partners from the USA, Canada, Japan and China. However, because of differences in legal systems, recommendations to increase cooperation with organisations in these countries have proven very complicated to implement. Collaboration with partners from these countries thus currently remains largely at an informal level.

Over the past two years a large number of new industrial and scientific partners have joined the research programme. However, this cooperation is often limited to a particular project or work package. Therefore we will make increasing efforts to integrate partners into long term cooperative agreements and to bind them to the centre by means of additional activities over the coming years. Of course not every company, especially from the small and medium-sized enterprise sector, has the financial and personnel resources to allow them to be involved in the research programme on a permanent basis. Therefore MCL must use its output to establish itself as the first port of call for these partners when they are looking for solutions to complex problems. By organising subject-specific workshops and events, MCL will increasingly act as a driver of technology, offering businesses a platform through which to access the centre's expertise.



Number and origin of the scientific partners involved in the COMET programme



Number of industrial partners by size

COMET scientific partners

Seven new research partners have been accepted to the MPPE research programme in order to enable complex research problems to be tackled with the greatest possible levels of competence. The following scientific partners have recently joined the COMET research programme:

- ARMINES, France
- Bay Zoltán Foundation for Applied Research, Institute for Logistics and Production Systems, Department of Structural Integrity, Hungary
- KTH Royal Institute of Technology, Department of Materials Physics, Sweden
- University of Leoben, Institute of Materials Science and Testing of Polymers, Austria
- Polymer Competence Center Leoben GmbH, Austria
- University of Wollongong, Australia
- Testing Institute for Mechanical Engineering at HTL Innsbruck, Austria

The University of Wollongong, which contributes experience in the field of laser scanning confocal microscopy, is the first overseas scientific partner joining the research programme. We also enjoy intensive cooperation with other scientific partners abroad although, due to very different legal systems, this cooperation is often required to take place at a more informal level.

Our efforts for the immediate future will be focused on deepening cooperation with existing partners.

Company partners in the non-K area

In the non-K area, i.e. for funded projects outside the COMET programme as well as laboratory, computational and advisory services, MCL has a comprehensive customer base of around 100 companies. Orders and project volumes for conducting specific investigations range from several hundred to several hundred thousand euros.

COMET company partners

In 2010, a total of 70 industrial partners were involved in the COMET research programme, of whom no less than 19 joined in the past year. A key motivation for this was the large Pipeline project in which ten, primarily new, company partners are taking part. As a result we have succeeded in involving almost all major Austrian and Styrian companies in our field in the COMET K2 programme.

- AMSC Windtec GmbH, Carinthia
- Andritz AG, Styria
- Böhler Schweisstechnik Deutschland GmbH, Germany
- Buderus Edelstahl GmbH, Germany
- Europipe GmbH, Germany
- Faiveley Transport Witten GmbH, Germany
- Hegenscheidt-MFD GmbH & Co. KG, Germany
- Krenhof AG, Styria
- BIS VAM Anlagentechnik GmbH (formerly: MCE Industrietechnik GmbH), Upper Austria
- OMV Exploration & Production GmbH, Vienna
- OMV Gas GmbH, Vienna
- Schoeller-Bleckmann Edelstahlrohr GmbH, Lower Austria
- SHW Casting Technologies GmbH, Germany
- Siemens Österreich Aktiengesellschaft, Vienna/Styria
- Stahl Judenburg GmbH, Styria
- Thales Corporate Services, France
- TIWAG Tiroler Wasserkraft AG, Tyrol
- voestalpine Grobblech GmbH, Upper Austria
- voestalpine Tubulars GmbH & Co KG, Styria

This is the largest number of industrial partners yet achieved, but more will certainly follow. Industrial partners include large organisations as well as SMEs and micro-businesses who are strengthened technologically through their involvement in research projects. It is above all small and medium-sized enterprises who are often unable to take part in research programmes on a permanent basis and on a large scale. These SMEs are therefore supported on a project basis. In this context, we will focus on establishing a tight network in order to be able to provide the relevant scientific and technological expertise quickly and efficiently.

On closer examination it becomes clear that very few industrial partners within the network are competitors. Rather, they take up different positions along the value chain, allowing each to play a key role in contributing to solving complex problems by means of cooperative research

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III. Core Prozesses

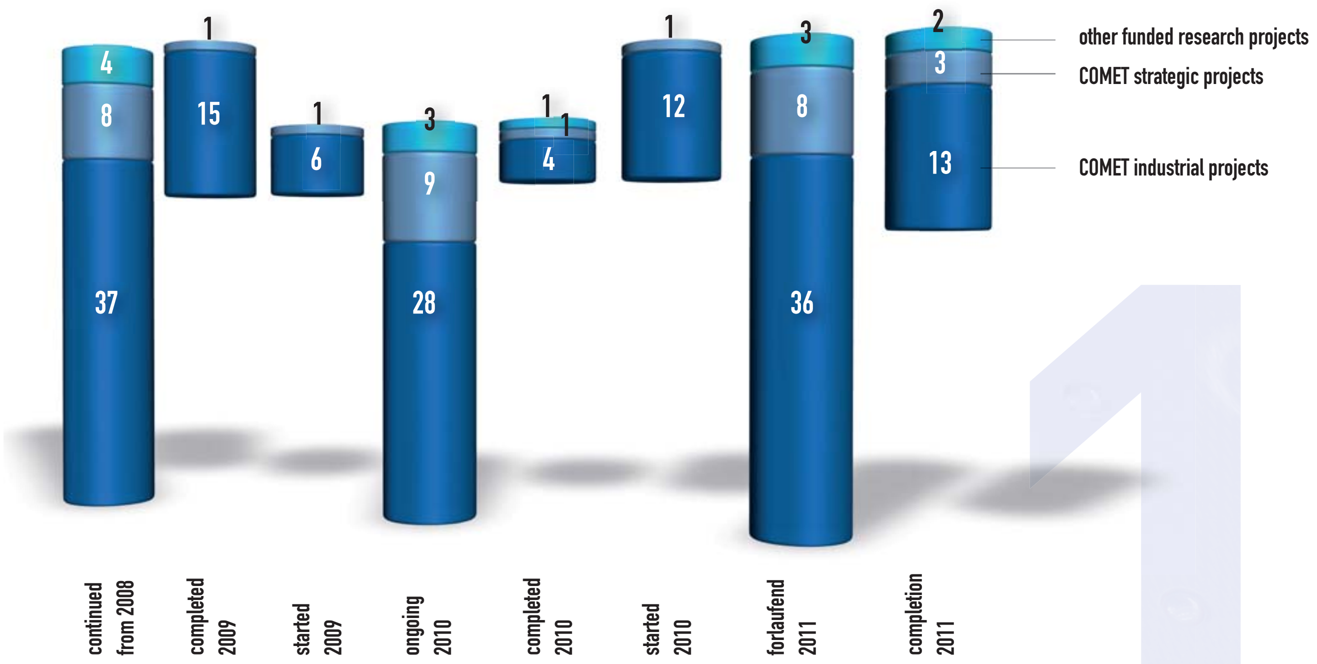
A) Research and development

There was a significant increase in the number of new projects in 2010 compared to the previous year. In addition to numerous smaller projects, we have been able to start a total of twelve new COMET projects and a large project in the non-K area. By doing so, we have almost managed to make up for the project losses of 2009, which were the consequence of the economic crisis.

Projects usually run for three years and as many of them began during the 2008 research year, a lot of projects will be concluded in 2011, with new ones needing to take their place. During 2011 we must also generate projects for COMET Phase II which can already be launched in Phase I. Therefore the coming year will see strengthened efforts in the development of new projects. Sufficient funding is still available from COMET Phase I to start new projects in 2011 and 2012, and so businesses are invited to submit new projects in order to fully make use of the EUR 53 million of project funding available.

In addition, three further funded research projects in the non-K area were carried out at MCL, one of which was concluded and a new one started.

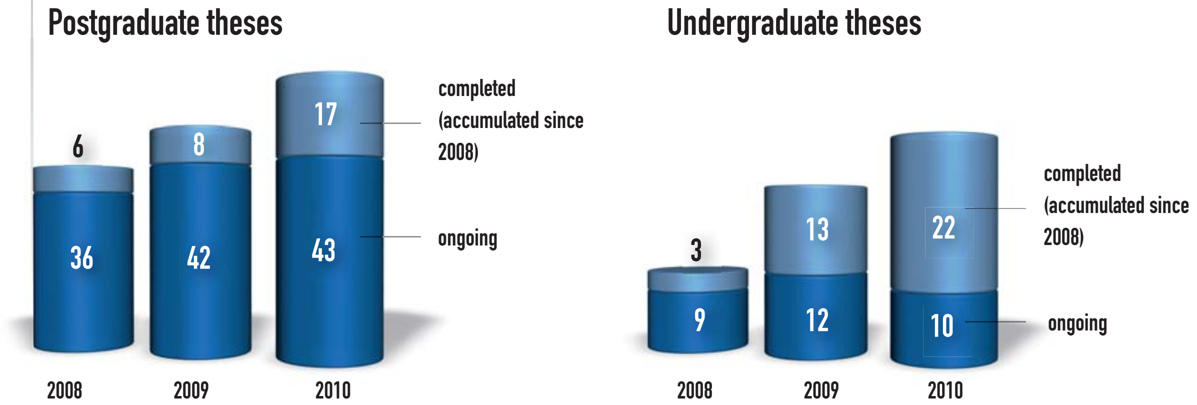
Number of research projects



Change in number of ongoing MCL research projects by project type

B) Undergraduate and postgraduate theses

Many activities in the COMET research projects are carried out by undergraduate and postgraduate students. These colleagues have the advantage of being able to fully concentrate on problems whilst under the direction of highly qualified scientific staff. This also plays a key role in educating future generations of scientists and engineers.



Number of ongoing and completed undergraduate and postgraduate theses in COMET

As the above diagram shows, the number of postgraduate theses is about twice that of undergraduate theses.

Women account for around 23% of undergraduate theses, which is in direct correlation with the proportion of female students at the University of Leoben (approx. 25%). In contrast, women account for only 11% of postgraduate theses. While the reasons for this relatively low proportion are not yet entirely clear, we aim to significantly increase this figure.

In addition, a large number of students were employed in 2010, giving them early insight into current research topics, with their work very often leading to later undergraduate or postgraduate work. Furthermore, one Bachelor's thesis was concluded during the reporting year.

Qualification measures

Some 60 training courses were carried out for MCL employees in the course of 2010. This figure does not include participation in workshops or congresses or obligatory lectures as part of postgraduate theses. These courses covered topics such as software, training on equipment use and user meetings, and are designed to supplement sound university education with application-oriented knowledge, thereby ensuring high standards of qualification.

MCL employees also provide training and education for others. This includes practical training as well as lectures and exercises at universities and secondary technical colleges (HTL).

IV. Output & Impact

A. Prizes and Highlights / Innovations

1. Prizes received by MCL/MPPE researchers for scientific work

Association of the Austrian Vehicle Industry awards 1st prize to Dr. Christian Oberwinkler

On 29 June 2010, the Association of the Austrian Vehicle Industry awarded prizes for undergraduate and postgraduate theses that are of special interest to the automotive industry.

A total of twelve awards with a total prize money of 30,000 euros were presented to graduates from Vienna and Graz Universities of Technology and the Universities of Leoben and Linz.

The Association of the Austrian Vehicle Industry uses the annual awards ceremony to draw attention to the enormous significance of top-level engineering education for the sector and continued high demand for expertly trained graduates.

Dipl.-Ing. Dr. mont. Christian Oberwinkler received the first prize for graduates of the University of Leoben with his postgraduate thesis on virtual fatigue proof design of aluminium high-pressure die cast components. The thesis was researched and written as part of the COMET Project A6.1 at the Chair of Mechanical Engineering under the supervision of Prof. W. Eichlseder.

This project will be described in more detail in the Section "Highlights/Innovations".

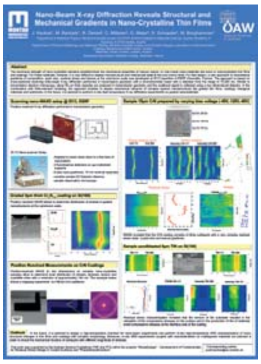
Best Poster Award for Dr. Günther Maier at the Denver X-Ray Conference

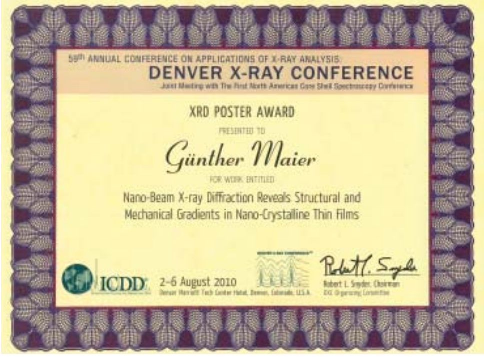
The 59th Denver X-Ray Conference took place from 2 to 6 August 2010. Over 400 scientists attended the world's largest annual conference on X-ray based materials characterisation, which featured a total of 17 workshops, 56 poster presentations and 113 lectures.

A total of 36 posters were presented in the field of X-ray diffraction (XRD). The coveted Best Poster Award went to "Nano-Beam X-ray Diffraction Reveals Structural and Mechanical Gradients in Nano-Crystalline Thin Films" (J. Keckes, M. Bartosik, R. Daniel, C. Mitterer, G. Maier, S. Schoeder and M. Burghammer). The poster co-authored by Dr. Günther Maier presented results of the StressDesign research project.

Dr. Maier, who joined MCL in 2003, has special expertise in materials characterisation using X-ray and synchrotron based methods.

The StressDesign research project carried out under the Austrian NanoInitiative deals with the production of thin films with defined residual stresses. The development and application of measurement methods for stress characterisation make a decisive contribution to the targeted design of coatings for extended service life of tools and components in the electronics industry.





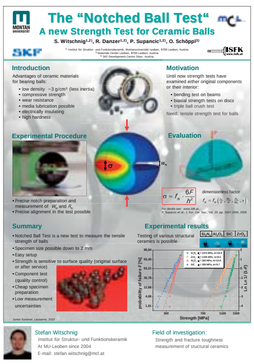
Stefan Witschnig takes 3rd place in the Hans-Walter Hennicke Speech Contest

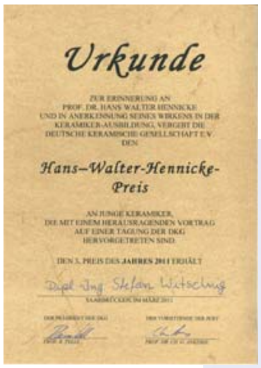
The German Ceramic Society (DKG) held its annual meeting on the campus of Saarbrücken University from 28 to 30 March 2011.

This year's annual meeting, which featured some 50 lectures and 27 poster presentations, also provided the stage for the Hans-Walter Hennicke Speech Contest, which is held annually as part of the plenary session. Young scientists from all the German-speaking countries are invited to present their undergraduate theses at the contest.

MCL employee Stefan Witschnig presented his thesis on testing methods for mechanical strength and toughness of ceramic balls and received 3rd place. The research was carried out as part of a MCL project in cooperation with industrial partner SKF at the Institut für Struktur- und Funktionskeramik.

Dipl.-Ing. Stefan Witschnig joined MCL in 2007. He started work on his postgraduate thesis on the reliability of highly-stressed ceramic rolling elements for hybrid bearings in 2011 in cooperation with SKF Steyr (COMET K2 Project A4.14). This is the second prize Stefan Witschnig has won recently.



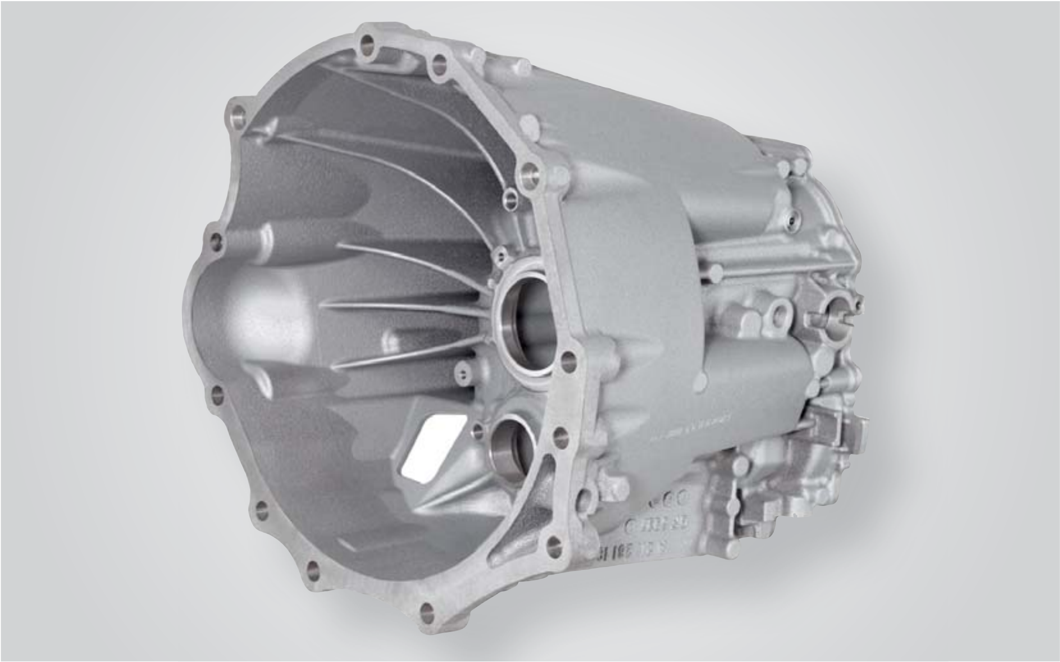


2. Highlights/Innovationen

Improved component design: fatigue proof design of aluminium high-pressure die cast components

The aim of the project is to develop an improved method for computing the fatigue lifetime of aluminium high-pressure die cast components. Conventional computations have been shown to underestimate the component potential by a factor of 2. These large deviations result from a lack of adequate models which take into account the inhomogeneous pore distribution in the component. The combination of a fracture-mechanics material model and a statistical porosity model allows the influence of inhomogeneous pore distribution to be taken into account in the computation of cyclic fatigue resistance.

Through-process simulation has gained increasing significance over the past few years. It spans the entire life of the component, from the manufacturing process including all process steps to the resulting mechanical properties and finally through to material and component failure.



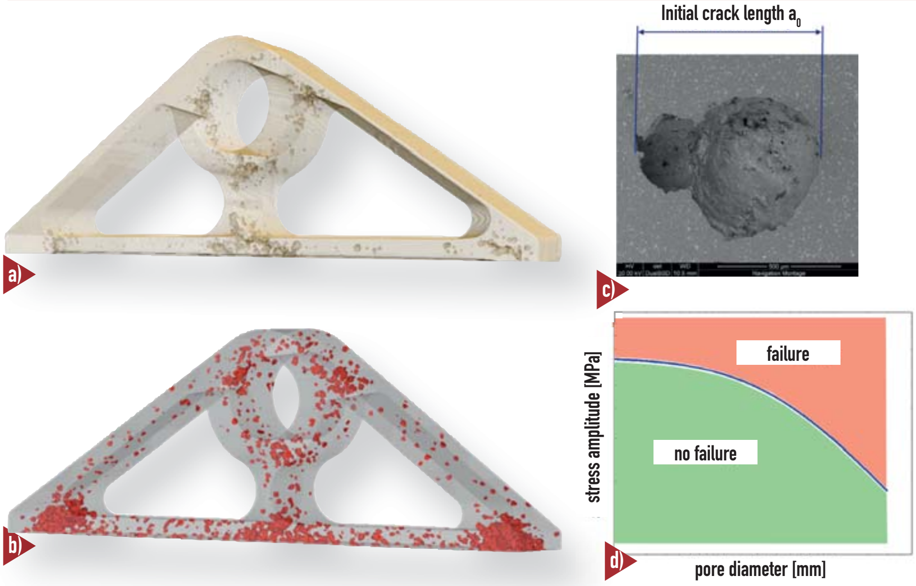
High-pressure die casting components are widely used in automotive engineering, e.g. transmission casings

The first part of the project was to develop a material model to calculate the fatigue strength as a function of pore size. It was shown that the lifetime of a specimen can be described in fracture mechanics terms. It is assumed that the crack is initiated at a pore within the first few cycles and that the lifetime is then determined by the velocity of crack growth through the microstructure. A correlation between fatigue strength and pore size was found using the El-Haddad equation. The fracture mechanics parameters required were derived from crack growth curves. The approach was finally verified through fatigue testing and crack growth analysis.

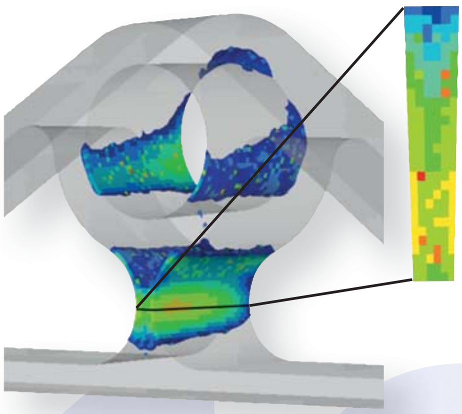
The second part focused on deriving a statistical porosity model to estimate pore distribution in a high-pressure die cast component based on the results of a casting simulation. Aluminium alloy plates of different qualities (different dwell pressures and plunger speeds) were cast to identify the correlations between measured pore distribution and casting simulation parameters. The plates were then cut into pieces to measure pore distribution.

The casting simulations were subsequently compared with the real pore distributions in the cast plates using self-organizing maps. These comparisons revealed a strong correlation between the temperature from the solidification simulation and the porosity. The statistical porosity model thus allows the pore distribution to be computed for a defined temperature range as a function of dwell pressure.

The combination of a fracture mechanics model and a statistical porosity model improves the calculation of cyclic fatigue strength taking into account the results of the casting simulation. A comparison of the results obtained using the new methodology with those from conventional calculations showed a significant increase (approx. by a factor of 2) in calculated safety.



a) pore distribution measured by computer tomography, b) computed / simulated pore distribution in the component, c) pore as an initial crack, d) modified Kitagawa diagram according to El Haddad for describing permissible fatigue strength as a function of pore size



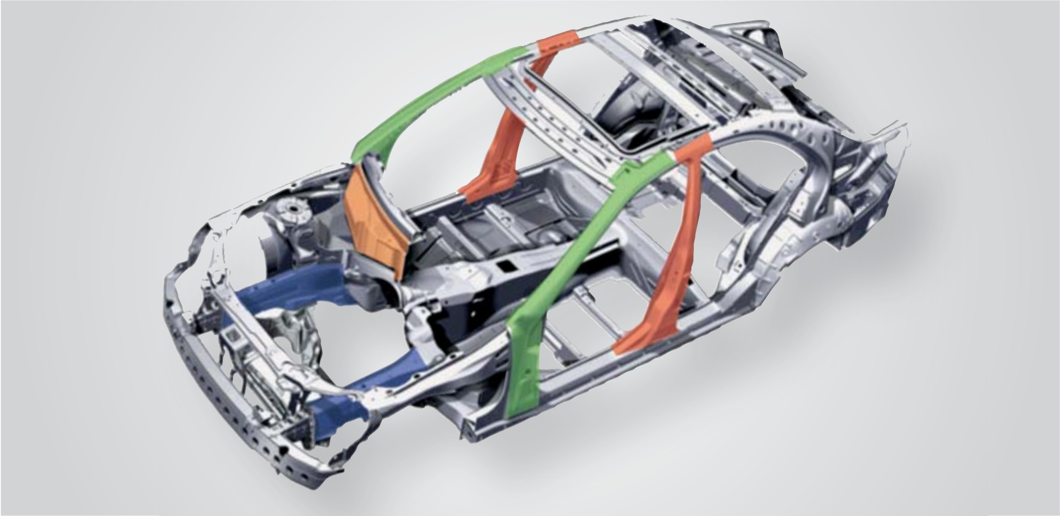
Distribution of fatigue strength in a component for a calculated pore distribution

The project was carried out by the Chair of Mechanical Engineering in close cooperation with MAN Nutzfahrzeuge, Georg Fischer and MCL.

Steels for the automotive industry: deformation and fracture of modern high-strength multi-phase steels

The recent definition of ambitious goals for the reduction of CO2 emissions has been accompanied by legally binding guidelines for car manufacturers to reduce fuel consumption and thus also the CO_2 emissions of their vehicles to a significant extent. One way to achieve this is to reduce vehicle weight, for example by using thinner body sheets, which in turn requires high-strength steels. The strength of traditional steel can usually be increased only at the expense of other important properties such as ductility and fracture toughness. These properties prevent the formation of cracks during the manufacturing of complex body parts and are necessary to meet ever more stringent crash safety requirements. In the event of an accident, the components must not break but should deform to absorb energy. The aim is thus to develop high-strength steels which are both ductile and fracture tough.

These intensive efforts have led to the development of high-strength multi-phase steels such as for example DP steels (dual phase steels). They have a ferritic/martensitic microstructure and provide an excellent combination of strength and ductility.

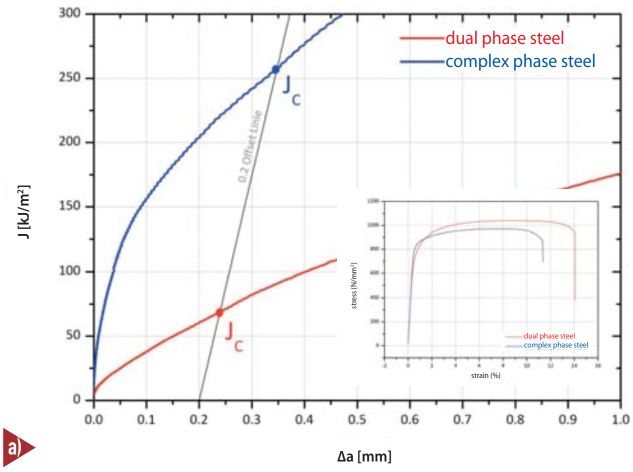


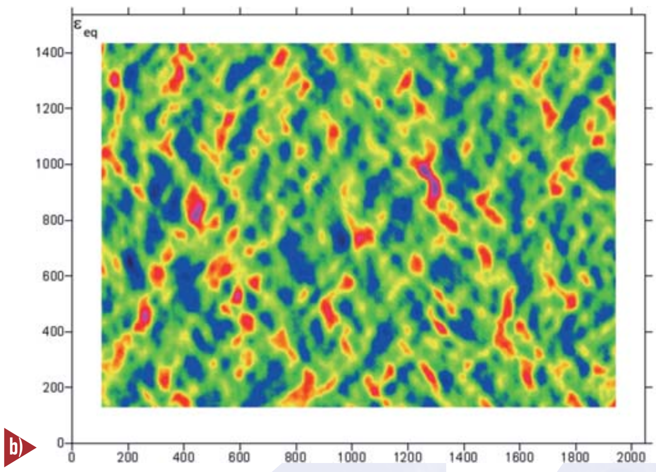
Car body with integrated multi-phase steel sheets

The highest-strength grades, however, are prone to cracking during the forming process, especially at sharp angles and edges. CP steels (complex phase steels) on the other hand, have a bainitic matrix with only small amounts of ferrite and martensite, and show slightly lower ductility in the tensile tests but significantly better formability at sharp angles and edges.

Two high-strength DP and CP steels with similar yield strength and the same chemical composition were investigated to obtain a better understanding of the relationships between the microstructure and deformation or fracture behaviour. Two methods were used for this purpose.

1. Adapted fracture mechanics tests were carried out to determine the fracture toughness of the steels. The two chemically identical materials showed similar ductility properties but significant differences in fracture toughness.
2. The local deformation behaviour was investigated by means of local deformation analysis. For this purpose the sheet specimens were subjected to tensile loading in a scanning electron microscope and the strains were observed in-situ. Images were taken of each step and subsequently compared using special software (Digital Image Correlation). The resulting displacement field allows the strains to be determined. The microstructure components are best visible at a magnification of about 5000x. This makes it possible to distinguish the individual phases, which are only several micrometers in size, and to identify the microstructure components which experience the largest strains. It has been shown that deformation at the microstructure level is strongly inhomogeneous and that strongly deformed regions can be found next to practically undeformed regions. The degree and spatial distribution of this inhomogeneous strain distribution substantially influences subsequent damage. The results of this analysis give an indication of where cracks originate and the most suitable phase combinations.





a) Comparison in terms of fracture toughness and strength properties of two multi-phase steels. b) Spatial distribution of strains in a multi-phase steel

By combining the two methods it was possible to obtain new information about the relationship between microstructure and deformation or formability which provides a sound knowledge base for the further development of sheets for lightweight and safe cars.

This project was carried out together with voestalpine Stahl GmbH and in cooperation with the Erich Schmid Institute of Materials Science (ESI) of the Austrian Academy of Sciences (ÖAW).

Hard metal tools with multi-layer hard coating for the turning of steel

The newly developed MT-TiCN coating (MT-TiCN = medium temperature titanium carbonitride) with fine grained columnar structure is a key component of hard metal coatings for the turning of steel. A coating with maximum hardness and minimum residual stress was achieved by targeted adjustment of process parameters and oxide integration.

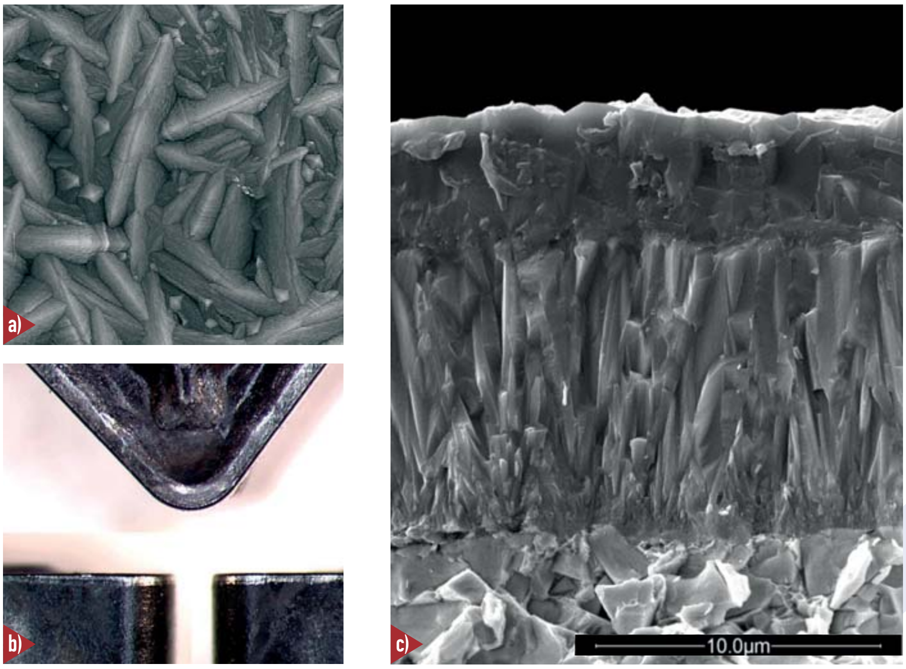
The newly developed TiCN layer forms an integral part of multi-layer wear coatings on hard metal for the turning of steel. These coating systems comprise a sequence of titanium nitride (TiN), titanium carbonitride (TiCN) and aluminium oxide and are produced by chemical vapour deposition (CVD) at temperatures of 900 to 1000 °C and pressures between 50 and 300 mbar. Typical coating thicknesses are in the range of 10-25 µm, with 10 µm TiCN and 5 µm Al_2O_3 for ISO P25 applications. While the aluminium oxide is characterised by low thermal conductivity, high-temperature hardness and oxidation resistance, TiCN is designed as a bonding layer between the hard

Turning with a hard metal tool

metal and the ceramic Al_2O_3 and reduces flank and crater wear due to its high abrasion resistance. The wear resistance and toughness of the tools is above all influenced by the layer architecture.

The combination of high deposition temperatures and different expansion coefficients leads to thermal mismatch in the tool interior, which can by minimised by an appropriate layer architecture and targeted process parameter setting. The project team succeeded in achieving a fine-grained columnar TiCN structure with maximum hardness and minimum residual stresses by optimal adjustment of the coating parameters and targeted integration of oxygen. The approach led to an increase in indentation hardness and a reduction in tensile stresses determined with the XRD-$\sin^2\Psi$ method. Combined with the optimised aluminium oxide this resulted in enhanced tool life and improved process reliability in service.

The optimisation of the TiCN layer extends the application of the insert, enhances tool life through increased hardness, improves process stability and reduces the probability of failure during machining operations. This layer has already been integrated in commercially available grades for the turning of steel.



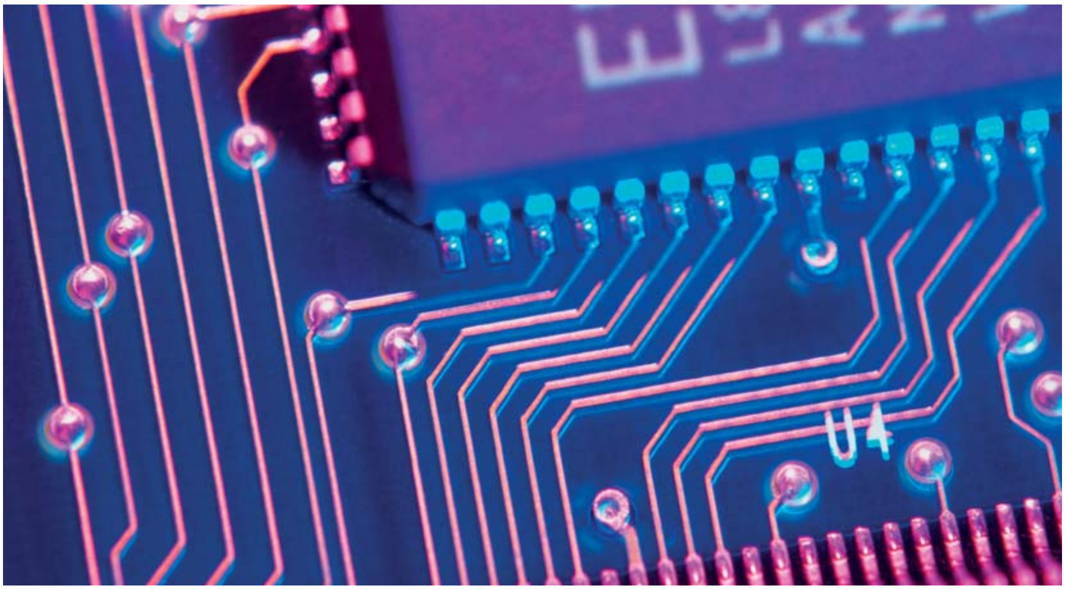
a) SEM surface image of the TiCN layer; b) wear behaviour of the overall coating at 50% of tool life; c) SEM fracture image of a CVD coating for the turning of steel

The project was carried out in close cooperation with Ceratizit Austria and the Chair of Functional Materials and Materials Systems of the University of Leoben.

Integration of ceramic components into printed circuit boards

The printed circuit board industry is facing enormous cost pressure from low price competitors in Asia. In order to assure the future of our manufacturing facilities in Austria and Europe we must compete in high tech markets. One way to add value to PCB is to directly integrate functions by embedding functional components. The FE model developed during this project is able to describe the embedding process. It has thus contributed to the establishment of the Embedding Component Packaging (ECP) technology at AT&S and the opening of new facilities for mass production using this concept.

The new trends towards miniaturisation and integration of functional components into printed circuit boards are a challenge for microelectronic companies competing in the market. Profound knowledge of the embedding process provides the design parameters and rules for the production of more reliable boards.



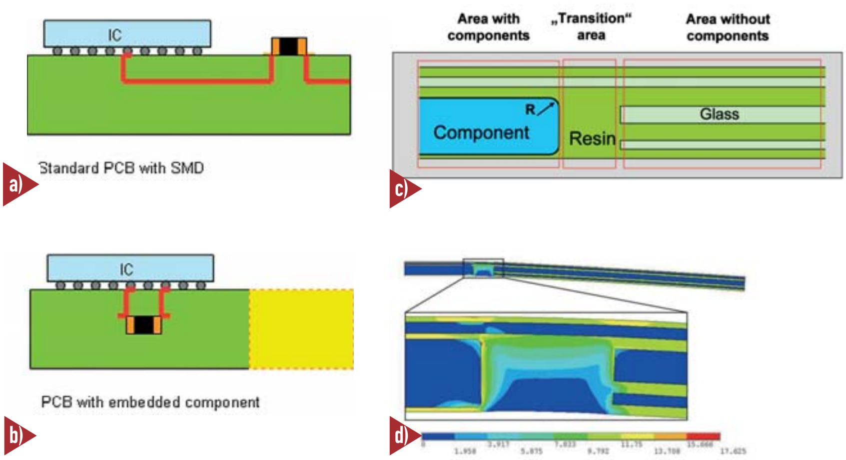
Printed circuit board

The embedding of components (e.g. ceramic capacitors, silicon semiconductors) into the inner parts of the PCB saves space on the surface and also reduces the necessary length of interconnections. This new approach can be used to increase the functionality of the system and thus convert it into a high-tech system. The integration of components plays an important role in the ongoing trend of miniaturising electronic devices.

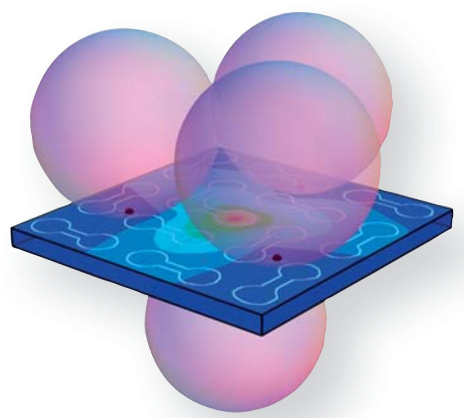
The description of the embedding process (deformations and stresses during hot pressing of the components and cool down of the board) provides the manufacturer with design parameters and rules for the production of more reliable boards (i.e.

where all components survive the embedding process). The focus of the project was on developing a Finite Element model to describe the embedding process and on determining the strength of the miniaturised components used.

The scientific achievement has been to clarify the damage mechanisms which can lead to failure of miniaturised brittle components during embedding. This was achieved by combining FE modelling and micro-analytical techniques (i.e. focused ion beam, SEM). Another challenge was the development of testing methods to determine the mechanical properties of the embedding components on a length scale of only a few millimetres. From the technological viewpoint the generation of a parametric 2D FE model to describe the deformation and stresses in the board during embedding (i.e. pressing and cooling down) has helped the company partners (especially AT&S) in establishing the ECP technology.



(a, b) Integration of components saves space on the surface, reduces the necessary length of interconnects and helps to miniaturise electronic devices (the yellow space is saved by the new technique); c) schematic structure of an ECP printed circuit board, d) FE model and simulation results of stress and deformation of the PCB with embedded components



Testing methodology for determining the biaxial strength of brittle embedding components with special features (contacts)

This new embedding technology has enormous potential for use in microelectronic systems where integration and miniaturisation can add considerable value to the end product.

The project was carried out in close cooperation with the companies AT&S (Leoben-Hinterberg) and THALES (Paris, France) as well as the Institut für Struktur- und Funktionskeramik of the University of Leoben.

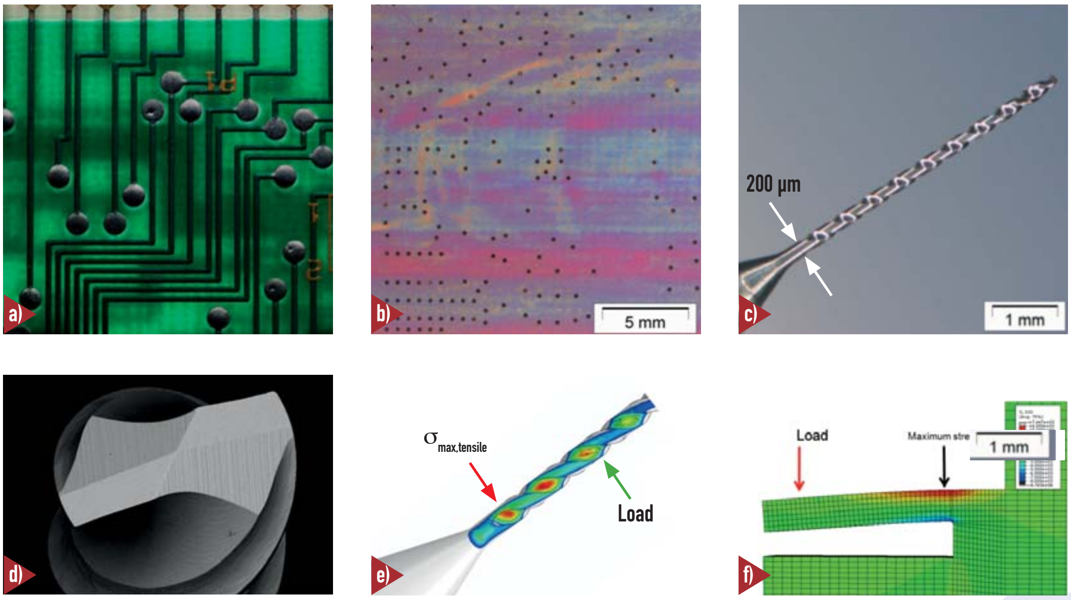
Microtools made from high-strength and ultra-fine grain tungsten carbide (WC-Co) hard metal

Tungsten carbide cobalt (WC-Co) is a hard metal widely used in wear applications and in metal machining. A sound knowledge of its material properties under mechanical loading is a key prerequisite for extending its application range and for the safe design of highly stressed components and tools. The research project was aimed at the determination of properties such as Young's modulus, yield strength, ultimate strength and fatigue strength as well as crack initiation and cyclic behaviour for different hard metals. The testing methods required for the characterisation of these high-strength brittle materials were developed within the project.

Microdrills for printed circuit boards

The yield strength level of modern hard metal grades is about twice as high as that of high-speed steels and can be tuned by the appropriate selection of binder content and carbide grain size. They have an enormous potential for use in components subjected to high cyclic-mechanical loads, which is largely determined by the existence of microdefects and material inhomogeneities as well as their size and frequency. In microtools such as PCB drills with 200 µm diameter the volumes subjected to the highest tensile loads are usually very small. The capability of a tool to withstand such tensile stresses increases with decreasing loaded volume. The limits of this increase in tensile strength, which can be described by the well-known size effect, have so far not been investigated for hard metals.

Specimens of different sizes were subjected to various strength tests to highlight the enormous tensile strength potential of ultra-fine grain WC-Co hard metal. The loaded volume ranged from 100 mm³ for large-volume tools to a few µm³ for extremely small components and tools. The low probability of a fracture-inducing defect resulting from the reduction in the tested volume led to extremely high tensile strength values. Tensile strength was found to increase from about 2000 MPa in the macroscopic specimens to 6000 MPa in the smallest specimens. The fracture surfaces of the micrometer sized specimens showed no material inhomogeneities, indicating that cracks originate from natural stress concentrations at the phase boundaries between WC and the cobalt binder. The immense inherent tensile strength of the material is a



a) Printed circuit board and b) drill pattern in a PCB; c) PCB drill and its dimensions; d) scanning electron microscopy image of cutting edge geometry; e) stress simulation of a microdrill during the drilling process; f) stress simulation of an ultra-fine grained WC-Co hard metal in a very small loaded volume during tensile test

great stimulus for the project team to further improve the manufacturing technology in order to reduce the number and size of inhomogeneities in the material and thus exploit its full potential.

The project was carried out in cooperation with AT&S Austria Technologie & Systemtechnik Aktiengesellschaft, Ceratizit Österreich, HPTec GmbH, the Erich Schmid Institute of the Austrian Academy of Sciences and the Institut für Struktur- und Funktionskeramik of the University of Leoben.

B. Final degrees

The following undergraduate and postgraduate theses were completed within the COMET Programme in 2010.

Postgraduate theses:

Burzic Denijel
Analysis of oxidation and decarburization of spring steel, Vienna University of Technology, May 2010

Gruber Peter
Charakterisierung des Verhaltens von Kanten aus hochfestem Werkzeugstahl unter zyklischer Belastung, University of Leoben, February 2010

Haberer Christoph
Methode zur Optimierung der Zahnfußtragfähigkeit einsatzgehärteter Zahnräder,
University of Leoben, May 2010

Hochauer David
New high-performance oxide-based CVD coatings, University of Leoben, February 2010

Paulitsch Jörg
Structural development and interfacial engineering of hard coatings by HIPIMS, University of Leoben, January 2010

Schöngrundner Ronald
Numerische Studien zur Ermittlung der risstreibenden Kraft in elastisch plastischen Materialien bei unterschiedlichen Belastungsbedingungen, University of Leoben, October 2010

Wurmbauer Harald
Kurzzeitkriechverhalten von Warmarbeitsstählen,
University of Leoben, June 2010

Zuber Michael
Werkzeugstähle mit höchster Festigkeit und Zähigkeit, University of Leoben, February 2010

Zunko Horst
Untersuchung des Mikrorissverhaltens von Zn-Al-Mg Überzügen auf Stahlbändern,
University of Leoben, July 2010

Undergraduate theses:

Brettner Elisabeth
Contact Modeling of CVD coatings for cutting tools, University of Leoben, June 2010

Eßl Werner
Bestimmung und Validierung eines Materialmodells zur numerischen Simulation des Eigenspannungsabbaus in CrN Schichten, University of Leoben, June 2010

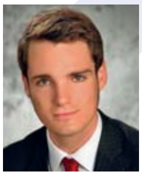
Janko Mariann
Numerische Simulation des Risswachstums mit dem Kohäsivzonenmodell: Untersuchungen für Stahl, Polyethylen und Polyethylenverbunde, University of Leoben, May 2010

Krampl Herbert
Rechnerische und experimentelle Untersuchung der Schmierfilmbildung in geschmierten Tribokontakten, University of Leoben, January 2010

Ognianov Miloslaw
Einfluss von Silizium auf Struktur und mechanische Eigenschaften von nitrierten Randzonen in 5% Cr martensitischen Stählen, University of Leoben, September 2010

Oschgan Manuel
Diffusion Simulation in Metals with Moving Phase Boundaries, Vienna University of Technology, November 2010

Polaczek Erich
Lock-in Thermographie an elektronischen Vielschichtbauteilen, University of Leoben, February 2010



Sailer Wolfgang
Methodenfindung zur Beschreibung der Vorgänge im Kontaktbereich bei Composite-Werkstoffen unter tribologischer Beanspruchung, University of Leoben, February 2010

Witschnig Stefan
Zähigkeitsmessung an keramischen Kugeln, University of Leoben, February 2010

We'd like to offer our undergraduate and postgraduate students our hearty congratulations on their achievements and degrees. Their work has made an important contribution to achieving the aims of the research programme.

C. Publications and presentations

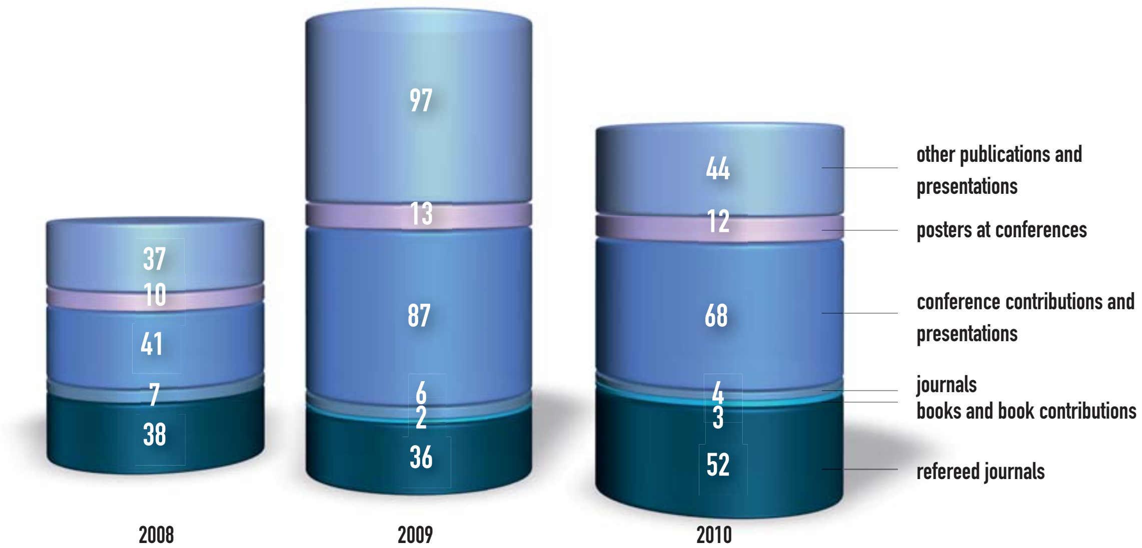
The aim of our research activities is to apply the highest levels of scientific excellence to generate innovations for our industrial partners. It is, however, no simple task to quantify these innovations and their impact on these companies, particularly as the number of registered intellectual property rights is not a significant parameter due to the different patent strategies followed.

In contrast, the number of publications and presentations can very well be evaluated, even though their allocation to the different categories allows certain room for interpretation.

After the start of research work for COMET K2 MPPE in 2008, the number of publications in 2009 increased significantly, remaining at this high level in 2010. The continually increasing number of publications in refereed journals confirms the high scientific standards of our staff and research partners. In future we will also place a stronger focus on application-oriented journals, where there still remains some catching up to do. It should be noted, however, that a very large number of application-oriented workshops and papers are already included in other publications.

All in all, the centre is well on its way to achieving the planned number of publications in the COMET programme. Due to increasing project volumes, we can expect a slight increase in the number of publications over the coming years.

Publications and presentations



Number of publications and presentations per year

D. Completed projects

A total of six research projects were concluded in 2010. The following five COMET projects, including one strategic project, were finalised in the period under review:

A3.5: Neue Verfahren zum Oberflächenverdichten von hoch belasteten Bauteilen aus P/M-Werkstoffen; Miba Sinter Austria GmbH, University of Leoben, Materials Center Leoben Forschung GmbH

A3.8: Zn-Mg-X Alloy Coatings on Sheet Steel; voestalpine Stahl GmbH, Wuppermann Engineering GesmbH, University of Leoben, Austrian Academy of Sciences, Materials Center Leoben Forschung GmbH

A3.9: Metal Forming Concepts for Manufacturing of Light Weight Structures; University of Leoben, Vienna University of Technology, Materials Center Leoben Forschung GmbH, Strategic Project

A6.1: Virtual Design of Fatigue Proof Aluminium Pressure Die Casting Parts; MAN Nutzfahrzeuge Aktiengesellschaft, Georg Fischer Verwaltungs GmbH, University of Leoben, Austrian Foundry Institute, Austrian Academy of Sciences, Materials Center Leoben Forschung GmbH

A7.6: Re-oxidation Kinetics of Grain Boundary Regions in PTC Ceramics; EPCOS OHG, University of Leoben, Materials Center Leoben Forschung GmbH

One non-K research project was concluded in 2010: the large-scale project "Early Recognition, Monitoring and Integrated Management of Emerging, New Technology Related Risks (iNTeg-Risk)" was carried out under the 7th EU Framework Programme and included over 60 partners. MCL was involved in Subproject 1: "Technology cases - Identifying specific emerging risks and developing solutions for iNTeg-Risk framework", where it investigated the formation of ultra-fine particulate matter in the development and production of CVD and PVD coatings. Several different nanoparticles were found in the dust collectors. These nanoparticles formed clusters which were removed from the exhaust air by the filter systems.

E. Workshops/Conferences

The researchers involved in the COMET K2 MPPE Programme take part in national and international workshops and conferences to present the results obtained in the projects and to exchange information with colleagues. This active participation in knowledge transfer is demonstrated by the large number of contributions and poster presentations given at conferences and the poster awards received for outstanding achievements.

MCL also fulfils its role as a cooperative research company by organising and co-organising a range of workshops. These workshops are not only designed to improve contact between the research teams, but also serve to present the research achievements and the COMET Research Programme in general to a wider public and the scientific community.

The annual MCL/MPPE workshop again served to advance cooperation and exchange of ideas within the MPPE Research Programme. A total of some 75 colleagues took part in the workshop, which was held on 25/26 March 2010 in the Semmering/Stuhleck region. MCL Managing Directors, Prof. Reinhold Ebner and Dr. Richard Schanner, opened the workshop by providing an overview of the most recent developments and current challenges. This was followed by presentations and discussions of projects from the individual research areas and a presentation of the new laboratory methods and equipment available. The evening and the next day provided ample opportunity for skiing, informal networking and sharing of ideas.

MCL also participated in the organisation of another three workshops, which will be presented in the following. Additional events and a two-day COMET workshop are scheduled for 2011. All industrial and scientific partners are invited to take this opportunity to present their research results and discuss the thematic focus for COMET Phase II

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1st Austrian Symposium on Carbon Based Coatings

The 1st Austrian Symposium on Carbon Based Coatings was held at the Leoben Congress Centre on 19 and 20 May 2010. The event was organised by JOANNEUM RESEARCH Forschungsgesellschaft mbH in cooperation with the Austrian Society for Metallurgy and Materials (ASMET) and Materials Center Leoben Forschung GmbH (MCL) with financial support from NANONETStyria.

A total of 22 30-minute presentations were held to present and discuss the current state of the art and latest developments in the manufacture, development, characterisation and application of carbon based coatings (diamond coatings, amorphous carbon coatings, DLC (diamond-like carbon) coatings). The programme was complemented by a tour of the MCL and the laboratory facilities of the nanoSurface Engineering Center Leoben (nSEC), which is jointly run by the University of Leoben and JOANNEUM RESEARCH, as well as a panel discussion. Some 70 experts from five European countries took part in the event. Due to the positive feedback received from participants, the symposium will be held every two years in the future.

Welcome address by Dr. W. Waldhauser (JOANNEUM RESEARCH)

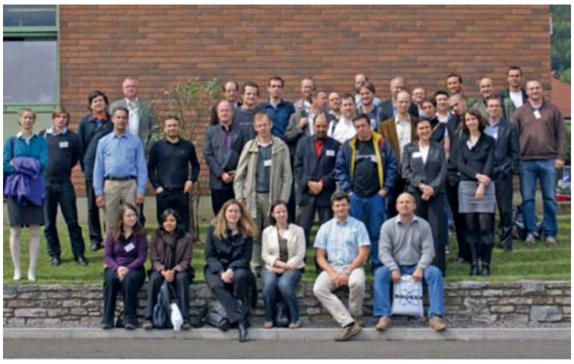
Auditorium of the Austrian Symposium on Carbon Based Coatings

4th International SAXS / GISAXS Workshop – Advanced Small Angle X-ray Scattering in Biology, Chemistry , Polymer and Materials Science

This international workshop took place in Leoben from 9 to 11 September 2010 and was organised by Bruker AXS GmbH (Karlsruhe, Germany), the Materials Center Leoben and the Erich Schmid Institute of the Austrian Academy of Sciences (Leoben). The workshop was organised by Dr. Günther Maier from MCL Leoben together with Dr. Geert Vanhoyland from Bruker AXS.

A total of 42 participants from 7 countries attended this workshop, making it the largest SAXS workshop ever held in Leoben. 14 presentations and 3 workshops were held to provide an introduction to the method of small angle X-ray scattering from theory to application. The first section dealt with the principles of small angle scattering and highlighted its application to systems in solution, especially micelles and liquid crystals. The second section was dedicated to the structural analysis of solids with a focus on complex materials such as bones and carbon fibres. The third section provided an introduction to the surface characterisation method of grazing incidence SAXS (GISAXS) and a presentation of scanning probe microscopy, which is often used as a complementary method. The last section was designed to discuss practical aspects of evaluation with a special focus on the characterisation of porous systems.

Prof. Dr. Jan Skov Pedersen from the University of Aarhus in Denmark, one of the world's leading experts in small angle X-ray scattering, presented methods for SAXS data evaluation and also talked about the application of small angle X-ray scattering to the characterisation of complex solutions.



4th International SAXS / GISAXS Workshop in Leoben

HoW exciting – Hands-on Workshop on Excitations in Solids Employing the exciting Code

The "HoW exciting - Hands-on Workshop on Excitations in Solids Employing the exciting Code" was held at the Centre Européen de Calcul Atomique et Moléculaire (CECAM) in Lausanne from 11 to 17 November 2010. The workshop was organised by Prof. Claudia Ambrosch-Draxl from the Chair for Atomistic Modelling and Design of Materials at the University of Leoben (AMDM) in cooperation with Dr. Pasquale Pavone and Dr. Jürgen Spitaler from the Materials Center Leoben (MCL) and Dr. Clas Persson from the Royal Institute of Technology in Stockholm. The workshop offered young scientists the opportunity to learn the theoretical fundamentals of ab-initio calculations from prominent experts in the field.

Ab-initio codes, which calculate the material properties based on physical laws without the use of experimental input data, have become an indispensable tool for research at the cutting edge of materials science. The "exciting" code developed in Leoben represents an advanced ab-initio implementation, which is characterised by high reliability and can be used for a wide range of materials.

The intensive programme included presentations, tutorials and computer exercises. The workshop was attended by a total of some 50 researchers from eleven European countries, the USA, Japan and Mexico.

Kieron Burke gave two presentations on the fundamentals of density functional theory. Prof. Burke, Professor for Physical and Computational Chemistry at the University of California, Irvine, was prominently involved in the development of the PBE density functional. His publication on this topic has been cited over 12,000 times.

The workshop participants in Lausanne with Prof. Ambrosch-Draxl

INTELLECTUAL CAPITAL REPORT APPENDIX

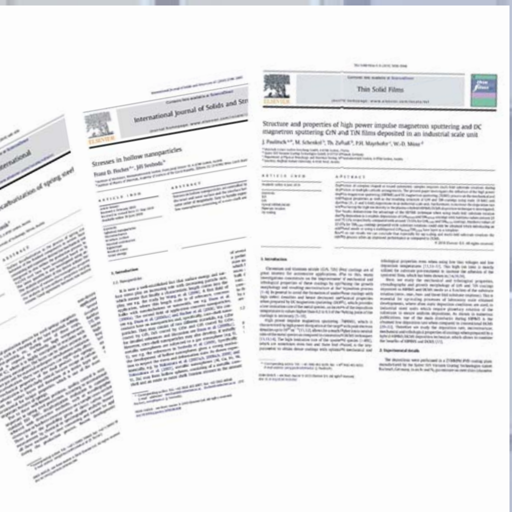
Publications in refereed journals

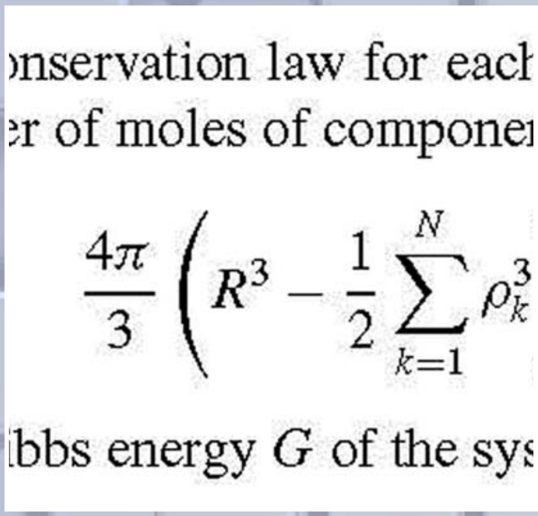
Conference contributions

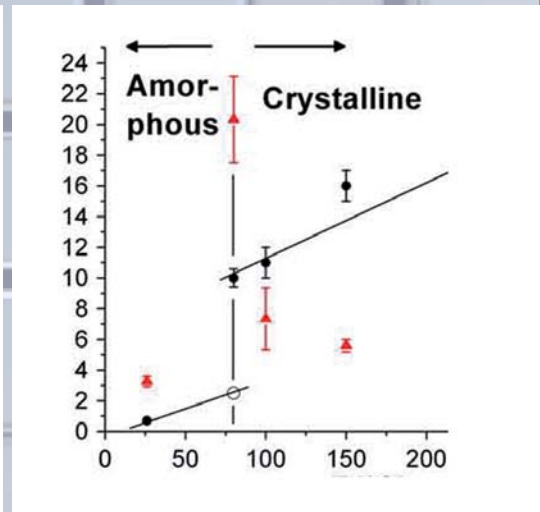
Posters

Journals

Books







APPENDIX

A) Publications in refereed journals

Author Co-author	Title	Journal	Edition/ Year
Anghelina, D.; Kienreich, R.; Zamberger, S.; Zamberger, J.; Kozeschnik, E.; Schneider, R.	**Kinetics and control of scaling for reduced surface decarburization of spring steels**	Metalurgia International	15 / 2010
Bermejo, R.; Grünbichler, H.; Kreith, J.; Auer, C.	**Fracture resistance of a doped PZT ceramic for multilayer piezoelectric actuators: Effect of mechanical load and temperature**	Journal of the European Ceramic Society	30 / 2010
Budna, K. P.; Mitterer, C.; Spicak R.; Walter C.	**Synthesis and characterisation of sputtered hard coatings within the system Cr-N/WS_x**	Surface Engineering	26 / 2010
Burzic, D.; Zamberger, J.; Kozeschnik, E.	**Non-destructive evaluation of decarburization of spring steel using electromagnetic measurement**	NDT & E International	43 / 2010
Chakraborty, M.; Spitaler, J.; Puschnig, P.; Ambrosch-Draxl, C.	**ATAT@WIEN2k: An interface for cluster expansion based on the linearized augmented planewave method**	Computer Physics Communications	181 / 2010
Chen, C.R.; Bermejo, R.; Kolednik, O.	**Numerical analysis on special cracking phenomena of residual compressive inter-layers in ceramic laminates**	Engineering Fracture Mechanics	77 / 2010
Christiner, T.; Reiser, J.; Gódor, I.; Maderbacher, H.; Eichlseder, W.; Trieb, F.; Stühlinger, R.	**Combined numerical and experimental investigations on fretting wear**	Procedia Engineering	2 / 2010
Danninger, H.; Harold, C.; Gierl, C.; Ponemayr, H.; Daxelmüller,M.; Simancik, F.; Izdinsky, K.	**Powder metallurgy manufacturing of carbon-free precipitation hardened high speed steels**	Acta Physica Polonica A	117 / 2010
Deluca, M.; Bermejo, R.; Grünbichler, H.; Presser, V.; Danzer, R.; Nickel, K. G.	**Raman spectroscopy for the investigation of indentation-induced domain texturing in lead zirconate titanate piezoceramics**	Scripta Materialia	63 / 2010

APPENDIX

A) Publications in refereed journals

Author Co-author	Title	Journal	Edition/ Year
Deluca, M.; Fukumura, H.; Tonari, N.; Capiani, C.; Hasuike, N.; Kisoda, K.; Galassi, C. et al.	**Raman spectroscopic study of phase transitions in undoped morphotropic $PbZr_{1-x}Ti_xO_3$**	Journal of Raman Spectroscopy	published online / 2010
Ebner, R.; Gruber, P.; Ecker, W.; Kolednik, O.; Krobath, M.; Jesner, G.	**Fatigue damage mechanisms and damage evolution near cyclically loaded edges**	Bulletin of the Polish Academy of Sciences	58 / 2010
Fischer, F.D.; Cha, L.; Dehm, G.; Clemens, H.	**Can local hot spots induce α_2/γ lamellae during incomplete massive transformation of γ-TiAl alloys?**	Intermetallics	18 / 2010
Fischer, F.D.; Svoboda, J.	**Stresses in hollow nanoparticles**	International Journal of Solids and Structures	47 / 2010
Fischer, F.D.; Svoboda, J.	**Substitutional diffusion in multicomponent solids with non-ideal sources and sinks for vacancies**	Acta Materialia	58 / 2010
Fischer, F.D.; Waitz, T.; Scheu, C.; Cha, L.; Dehm, G.; Antretter, T.; Clemens, H.	**Study of nanometer-scaled lamellar microstructure in a Ti-45Al-7.5Nb alloy - Experiments and modeling**	Intermetallics	18 / 2010
Fratzl, P.; Fischer, F.D.; Svoboda, J.; Aizenberg, J.	**A kinetic model of the transformation of a micropatterned amorphous precursor into a porous single crystal**	Acta Biomaterialia	6 / 2010
Gardini, D.; Deluca, M.; Nagliati, M.; Galassi, C.	**Flow properties of PLZTN aqueous suspensions for tape casting**	Ceramics International	36 / 2010
Grün, F.; Gódor, I.; Javidi, A.; Pondicherry, K.; Offenbecher, M.; Bertram, R.	**Model scale generation and microscopic characterisation of tribofilms formed on Fe and Cu alloys**	Lubrication Science Published online	22 / 2010

Author Co-author	Title	Journal	Edition/ Year
Grünbichler, H.; Kreith, J.; Bermejo, R.; Supancic, P.; Danzer, R.	**Modelling of the ferroic material behaviour of piezoelectrics: Characterisation of temperature-sensitive functional properties**	Journal of the European Ceramic Society	30 / 2010
Gänser, H.P.; Javidi, A.	**A simple engineering estimate of the fatigue notch factor of arbitrary stress concentrators**	Advanced Engineering Materials	12 / 2010
Hackl, K.; Fischer, F.D.; Svoboda, J.	**A study on the principle of maximum dissipation for coupled and non-coupled non-isothermal processes in materials**	Proceedings of the Royal Society A	published online / 2010
Hatzenbichler,T.; Buchmayr, B.; Weiss, S.	**FEM-simulation of high-speed corrugation process with Abaqus/ Explicit**	Steel Research International	81 / 2010
Hochauer, D.; Mitterer, C.; Penoy, M.; Michotte, C.; Martinz, H.P.; Kathrein, M.	**Thermal stability of doped CVD κ-Al_2O_3 coatings**	Surface and Coatings Technology	204 / 2010
Holzer, I.; Kozeschnik, E.; Cerjak, H.	**New approach to predict the long-term creep behaviour and evolution of precipitate back-stress of 9-12% chromium steels**	Transactions of the Indian Institute of Metals	63 / 2010
Klünsner, T.; Marsoner, S.; Ebner, R.; Pippan, R.; Glätzle, J.; Püschel, A.	**Effect of microstructure on fatigue properties of WC-Co hard metals**	Procedia Engineering	2 / 2010
Klünsner, T.; Shen, Q.; Hlawacek, G.; Teichert, C.; Fateh, N.; Fontalvo, G.A.; Mitterer, C.	**Morphology characterization and friction coefficient determination of sputtered V_2O_5 films**	Thin Solid Films	519 / 2010
Kolednik, O.; Predan, J.; Fischer, F.D.	**Cracks in inhomogeneous materials: Comprehensive assessment using the configurational forces concept**	Engineering Fracture Mechanics	77 / 2010
Kozeschnik, E.; Svoboda, J.; Radis, R.; Fischer, F.D.	**Mean-field model for the growth and coarsening of stoichiometric precipitates at grain boundaries**	Modelling and Simulation in Materials Science and Engineering	18 / 2010

APPENDIX

A) Publications in refereed journals

Author Co-author	Title	Journal	Edition/ Year
Náhlík, L.; Šestáková, L.; Hutař, P.; Bermejo, R.	**Prediction of crack propagation in layered ceramics with strong interfaces**	Engineering Fracture Mechanics	77 / 2010
Paulitsch, J.; Schenkel, M.; Schintlmeister, A.; Hutter, H.; Mayrhofer, P.H.	**Low friction CrN/TiN multilayer coatings prepared by a hybrid high power impulse magnetron sputtering/DC magnetron sputtering deposition technique**	Thin Solid Films	518 / 2010
Paulitsch, J.; Schenkel, M.; Zufraß, T.; Mayrhofer, P.H.; Münz, W.-D.	**Structure and properties of high power impulse magnetron sputtering and DC magnetron sputtering CrN and TiN films deposited in an industrial scale unit**	Thin Solid Films	518 / 2010
Peterlechner, M.; Bokeloh, J.; Wilde, G.; Waitz, T.	**Study of relaxation and crystallization kinetics of NiTi made amorphous by repeated cold rolling**	Acta Materialia	58 / 2010
Roschger, P.; Lombardi, A.; Misof, B.M.; Maier, G.; Fratzl-Zelman, N.; Fratzl, P.; Klaushofer, K.	**Mineralization density distribution of postmenopausal osteoporotic bone is restored to normal after long-term alendronate treatment: qBEI and sSAXS data from the Fracture Intervention Trial Long-Term Extension (FLEX)**	Journal of Bone and Mineral Research	25 / 2010
Sabirov, I.; Kolednik, O.	**Local and global measures of the fracture toughness of metal matrix composites**	Materials Science and Engineering A	527 / 2010
Schloffer, M.; Teichert, C.; Supancic, P.; Andreev, A.; Hou, Y.; Wang, Z.	**Electrical characterization of ZnO multilayer varistors on the nanometre scale with conductive atomic force microscopy**	Journal of the European Ceramic Society	30 / 2010
Schöngrundner, R.; Kolednik, O.; Fischer, F.D.	**The configurational force concept in elastic-plastic fracture mechanics - Instructive examples**	Key Engineering Materials	417-418 / 2010
Siffalovic, P.; Chitu, L.; Majkova, E.; Vegso, K.; Jergel, M.; Luby, S.; Capek, I. et al.	**Kinetics of nanoparticle reassembly mediated by UV-photolysis of surfactant**	Langmuir	26 / 2010

Author Co-author	Title	Journal	Edition/ Year
Siffalovic, P.; Chitu, L.; Vegso, K.; Majkova, E.; Jergel, M.; Weis, M.; Luby, S. et al.	**Towards strain gauges based on a self-assembled nanoparticle monolayer - SAXS study**	Nanotechnology	21 / 2010
Siffalovic, P.; Jergel, M.; Chitu, L.; Majkova, E.; Matko, I.; Luby, S.; Timmann, A. et al.	**Interface study of a high-performance W/B_4C X-ray mirror**	Journal of Applied Crystallography	43 / 2010
Siffalovic, P.; Majkova, E.; Chitu, L.; Jergel, M.; Luby, S.; Keckes, J.; Maier, G. et al.	**Characterization of Mo/Si soft X-ray multilayer mirrors by grazing-incidence small-angle X-ray scattering**	Vacuum	84 / 2010
Sonderegger, B.; Holzer, I.; Kozeschnik, E.	**Calculation of energies of coherent interfaces and application to the nucleation, growth and coarsening of precipitates**	Materials Science Forum	638-642 / 2010
Sonderegger, B.; Kozeschnik, E.; Leitner, H.; Clemens, H.; Svoboda, J.; Fischer, F.D.; Staron, P.	**Kinetics of precipitation in a complex hot-work tool steel**	Steel Research International	81 / 2010
Stoschka, M.; Leitner, M.; Fössl, T.; Leitner, H.; Eichlseder, W.	**Application of fatigue approaches on fillet welds of high strength steel**	Materialwissenschaft und Werkstofftechnik	41 / 2010
Svoboda, J.; Fischer, F.D.	**Model for coarsening of intergranular precipitates in multicomponent systems**	Scripta Materialia	62 / 2010
Svoboda, J.; Fischer, F.D.; Abart, R.	**Modeling of diffusional phase transformation in multi-component systems with stoichiometric phases**	Acta Materialia	58 / 2010

APPENDIX

A) Publications in refereed journals

Author Co-author	Title	Journal	Edition/ Year
Witschnigg, A.; Laske, S.; Kracalik, M.; Feuchter, M.; Pinter, G.; Maier, G.; Märzinger, W. et al.	**In-line characterization of polypropylene nanocomposites using FT-NIR**	Journal of Applied Polymer Science	117 / 2010
Wurmbauer, H.; Leitner, H.; Panzenböck, M.; Scheu, C.; Clemens, H.	**Short-term creep behavior of an X 37 Cr Mo V 5-1 hot-work tool steel with almost bainitic and fully martensitic microstructures**	Steel Research International	81 / 2010
Wurmbauer, H.; Panzenböck, M.; Leitner, H.; Scheu, C.; Clemens, H.	**Short-term creep behavior of chromium rich hot-work tool steels**	Materialwissenschaft und Werkstofftechnik	41 / 2010
Yang, B.; Motz, C.; Grosinger, W.; Dehm, G.	**Cyclic loading behavior of micro-sized polycrystalline copper wires**	Procedia Engineering	2 / 2010
Yang, B.; Vehoff, H.; Pippan, R.	**Overview of the grain size effects on the mechanical and deformation behaviour of electrodeposited nanocrystalline nickel - from nanoindentation to high pressure torsion**	Materials Science Forum	633-634 / 2010
Zehetbauer, M.; Grössinger, R.; Krenn, H.; Krystian, M.; Pippan, R.; Rogl, P.; Waitz, T. et al.	**Bulk nanostructured functional materials by severe plastic deformation**	Advanced Engineering Materials	12 / 2010
Özkol, E.; Wätjen, A.M.; Bermejo, R.; Deluca, M.; Ebert, J.; Danzer, R.; Telle, R.	**Mechanical characterisation of miniaturised direct inkjet printed 3Y-TZP specimens for microelectronic applications**	Journal of the European Ceramic Society	30 / 2010

B) Conference contributions

Author Co-author	Title	Conference
Ambrosch-Draxl, C.	**Stacking fault energies of metals and metal alloys**	Ab-Initio Description of Iron and Steel: Mechanical Properties (International Scientific Seminar)
Antretter, T.; Pranger, W.; Waitz, T.; Fischer, F.D.	**Martensitische Phasenumwandlung in nanostrukturierten Materialien**	8. Werkstoffkongress "High Performance Metals"
Auer, T.	**Thermomechanical simulations of ladle preheating**	RHI-GHI Research Conference
Bermejo, R.; Kraleva, I.; Morrell, R.; Aldrian, F.; Supancic, P.; Danzer, R.	**Fracture behaviour of low temperature co-fired ceramics under biaxial loading: Influence of metal-ceramic internal architecture**	18th European Conference on Fracture (ECF18)
Bermejo, R.; Šestáková, L.; Grünbichler, H. Lube, T.; Supancic, P.; Danzer, R.	**Fracture mechanisms of structural and functional multilayer ceramic structures**	6th International Conference on Materials Structure and Micromechanisms of Fracture
Bermejo, R.; Šestáková, L.; Lube, T.; Danzer, R.	**Optimization of strength and fracture toughness of damage tolerant multilayer ceramics**	9th International Conference on Sandwich Structures (ICSS)
Bilik, C.; Pahr, D.H.; Rammerstorfer,F.G.	**A bead laying algorithm for enhancing the dynamic and stability behaviour of thin shell structures**	37th Solid Mechanics Conference
Bilik, C.; Rammerstorfer,F.G.; Figala, G.; Buchmayr, B.	**Investigation of the stability and dynamic behaviour of plates subjected to laser treatment**	Junior Scientist Conference 2010
Buchmayr, B.; Figala, G.; Wunsch, L.	**Lokale fertigungstechnische Verstärkungskonzepte zur Erhöhung der Materialeffizienz**	ASMET Forum für Metallurgie und Werkstofftechnik 2010

Author Co-author	Title	Conference
Cha, L.	**In-situ heating experiments on TiAl alloys: Lamellae formation temperature**	International Conference on Advances in Materials and Manufacturing Processes (ICAMMP 2010)
Christiner, T.; Reiser, J.; Gódor, I.; Eichlseder, W.; Trieb, F.; Stühlinger, R.	**Numerical approach to fretting wear**	20th International Conference on Water Jetting
Christiner, T.; Reiser, J.; Gódor, I.; Eichlseder, W.; Trieb, F.; Stühlinger, R.	**Numerischer und experimenteller Ansatz zur Frettingbewertung: Materialabtrag und Ermüdung**	Tribologie-Fachtagung 2010
Czettl, C.; Mitterer, C.; Penoy, M.; Michotte, C.; Kathrein, M.	**Stress state of CVD TiCN/κ-Al_2O_3 hard coatings**	24th International Conference on Surface Modification Technologies (SMT 24)
Dahlem, E.	**Determination of cohesion and friction angle of refractories at room temperature and at 1400°C**	RHI-GHI Research Conference
Dahlem, E.; Gruber, D.; Auer, T.; Harmuth, H.; Huger, M.; Chotard, T.	**New method to determine the cohesion and the friction angle of refractory materials at room temperature and at elevated temperature**	COM Vancouver 2010
Dahlem, E.; Gruber, D.; Auer, T.; Harmuth, H.; Huger, M.; Chotard, T.	**Optimisation d'une géométrie éprouvette pour essai sous sollicitation combinée compression-cisaillement de matériaux réfractaires**	Materiaux 2010
Deluca, M.; Bermejo, R.; Pletz, M.; Supancic, P.; Danzer, R.	**Strength and fracture analysis of silicon chips to be embedded into printed circuit boards**	18th European Conference on Fracture (ECF18)
Deluca, M.; Fukumura, H.; Galassi, C.; Harima, H.	**Phase transformations of $PbZr_{1-x}Ti_xO_3$ in the morphotropic region analysed by temperature-dependent Raman spectroscopy**	Electroceramics XII

Author Co-author	Title	Conference
Deluca, M.; Galassi, C.; Fukumura, H.; Harima, H.	**Raman spectroscopic study of undoped morphotropic $PbZr_{1-x}Ti_xO_3$**	1st Joint Workshop COST Action MP0904 SIMUFER
Deluca, M.; Grünbichler, H.; Bermejo, R.; Supancic, P.; Nickel, K.G.; Danzer, R.	**Measurement of domain orientation in piezoceramics by microprobe polarised Raman spectroscopy**	6th International Workshop on Direct and Inverse Problems in Piezoelectricity
Dietrich, A.; Haberer, C.	**Herstellen von Planetenzahnrädern mittels Kaltmassivumformung**	25. Jahrestreffen der Kaltmassivumformer 2010
Eck, S.; Wlanis, T.; Gänser, H.	**FE simulation of heat treatment of surface densified powder metallurgical gears**	DEFORM Anwendertreffen 2010
Figala, G.; Buchmayr, B.	**Improvement of buckling resistance of thin sheets by local laser treatment**	13th International ESAFORM Conference on Material Forming
Fischer, F.D.; Svoboda, J.; Hackl, K.	**Variational concepts with applications to microstructural evolution**	IUTAM bochum on variational concepts with application to the mechanics of materials
Fischlschweiger, M.; Cailletaud, G.; Antretter, T.; Oberaigner; E. R.	**Modelling of martensitic phase transformations in steels**	8. Werkstoffkongress "High Performance Metals"
Forstner, K.; Figala, G.; Hatzenbichler, T.; Buchmayr, B.	**Analyse und Diskussion verschiedener Verfahren der Eigenspannungsmessung anhand von laserbehandelten dünnwandigen Blechen**	XXIX Verformungskundliches Kolloquium
Fössl, T.; Leitner, M.; Eichlseder, W.	**Evaluation of fillet weld properties in dependence of weld manufacturing parameters**	27th DANUBIA-Adria Symposium 2010
Fössl, T.; Stoschka, M.; Eichlseder, W.; Posch, G.	**Characterization of weld toe design by arc welding process parameters**	63rd Annual Assembly & International Conference of the International Institute of Welding
Grasset-Bourdel, R.; Alzina, A.; Huger, M.; Chotard, T.; Emler, R.; Gruber, D.; Harmuth, H.	**Development of a microstructural methodology to establish structure/property relations of refractories and first results for magnesia spinel materials**	COM Vancouver 2010

Author Co-author	Title	Conference
Grasset-Bourdel, R.; Emler, R.; Gruber, D.; Harmuth, H.; Alzina, A.; Huger, M.; Chotard, T.	**Propriétés thermomécaniques de réfractaires magnésie/spinelle modèles**	Materiaux 2010
Grasset-Bourdel, R.; Gruber, D.; Harmuth, H.; Schmitt, N.; Alzina, A.; Huger, M.; Chotard, T.	**Modélisation des propriétés d'élasticité de matériaux réfractaires modèles par homogénéisation périodique**	Journées Annuelles du GFC (French Group of Ceramics)
Gruber, D.	**Investigation of relationship between the microstructure of refractories and their mechanical properties: case of magnesia-spinel materials**	RHI-GHI Research Conference
Gruber, D.	**Laser induced cracking of ZrO_2 discs**	RHI-GHI Research Conference
Grün, F.; Gódor, I.; Sailer, W.; Schiffer, J.	**Characterization and simulation of tribological functionality of heterogeneous tribomaterials**	37th Leeds-Lyon Symposium on Tribology
Grünbichler, H.; Bermejo, R.; Deluca, M.; Danzer, R.	**Strength and fracture characteristics of metal-piezoceramic multilayers for actuator applications**	Electroceramics XII
Grünbichler, H.; Bermejo, R.; Deluca, M.; Supancic, P.	**Fracture features of piezoceramic materials for actuator components**	18th European Conference on Fracture (ECF18)
Grünbichler,H.; Deluca, M.; Presser, V.; Nickel, K.G.; Danzer, R.	**Influence of domain orientation on the electro-mechanical properties of multilayer piezoelectric actuators**	DKG-Jahrestagung und Symposium Hochleistungskeramik 2010
Harmuth, H.	**Characterisation of the fracture path in "flexible" refractories**	12th International Ceramic Congress (CIMTEC)
Harmuth, H.	**Characterisation of the fracture path in "flexible" refractories**	RHI-GHI Research Conference
Harmuth, H.	**"Flexibility" of refractories – fracture mechanical and microscopic investigations**	VI International Scientific Conference Refractories - Furnaces and Thermal Insulations

Author Co-author	Title	Conference
Dahlem, E.	**Geometry optimisation for a torsion-compression test**	RHI-GHI Research Conference
Hatzenbichler, T.; Buchmayr, B.; Weiss, S.	**FEM-simulation of high-speed corrugation process with Abaqus/Explicit**	Metal Forming 2010
Hatzenbichler, T.; Buchmayr, B.; Walzl, A.	**Simulation of cold forging under consideration of residual stresses induced by preceding drawing**	Advances in Materials and Processing Technologies (AMPT)
Hölzl, C.; Kharicha, A.; Ludwig, A.; Domitner, J.; Pusztai, T.	**Lattice Boltzmann simulation of a metallic dendritic structure**	19th International Conference on the Discrete Simulation of Fluid Dynamics
Janko, M.; Kolednik, O.; Pinter, G.; Ecker, W.	**Numerical simulation of crack growth with the cohesive zone model: Investigations for steel, polyethylene and polyethylene composites**	Austrian Slovenian Polymer Meeting, ASPM10
Kapp, M.; Hebesberger, T.; Pichler, A.; Kolednik, O.	**Characterization of the deformation and fracture behaviour of multiphase steels at the micro and macro scale**	18th European Conference on Fracture (ECF18)
Kapp, M.; Hebesberger, T.; Pichler, A.; Kolednik, O.	**Multiphase steel: A microscale study on deformation and fracture behaviour**	Material Science and Technology Conference
Klünsner, T.; Marsoner, S.; Ebner, R.; Pippan, R.; Glätzle, J.; Püschel, A.	**Effect of microstructure on fatigue properties of WC-Co hard metals**	Fatigue 2010
Klünsner, T.; Wurster, S.; Pippan, R.; Ebner, R.; Supancic, P.; Jenko, M.; Glätzle, J.; et al.	**Comparison of bending strength of WC-Co hard metal in millimeter and micrometer sized specimens**	18th European Conference on Fracture (ECF18)
Kolednik, O.; Gruber, P.J.; Krobath, M.; Ecker, W.; Ebner, R.	**Plasticity and damage evolution of ultra high-strength materials**	16th International Symposium on Plasticity and its Current Applications
Krajewski, P.	**Experimental simulation of crack formation of steels in the temperature range of second ductility trough**	Junior Euromat 2010

Author Co-author	Title	Conference
Krampl, H.; Grün, F.; Gódor, I.	**Analyse der Schmierfilmbildung tribologischer Modellsysteme mithilfe kommerzieller Softwarepakete**	Symposium der Österreichischen Tribologischen Gesellschaft (ÖTG) 2010
Legut, D.; Spitaler, J.; Ambrosch-Draxl, C.	**The influence of interstitial carbon on the elasticity of the TiAl system in the γ and α_2 and the formation energy of octahedral cavities in the γ-phase**	Frühjahrstagung der Deutschen Physikalischen Gesellschaft (DPG) 2010
Lube, T.; Witschnig, S.; Supancic, P.	**Fracture toughness of ceramic balls**	18th European Conference on Fracture (ECF18)
Mangler, C.; Kerber, M.; Schafler, E.; Müllner, P.; Waitz, T.	**Effects of severe plastic deformation on the high temperature magnetic shape memory alloy Ni-Mn-Ga**	Joint European Magnetic Symposia JEMS 2010
Oberaigner, E. R.; Fischlschweiger, M.	**A novel method taking advantage of statistical mechanics for the description of martensitic phase transformation**	20th International Workshop on Computational Mechanics of Materials (IWCMM 20)
Oberaigner, E. R.; Leindl, M.; Antretter, T.	**An integral-equation approach to solve time-dependent heat conduction problems**	International Congress of Mathematicians
Peterlechner, M.; Bokeloh, J.; Waitz, T.; Wilde, G.	**Crystallization kinetics of NiTi shape memory alloys made amorphous by repeated rolling and folding**	Solid-Solid Phase Transformations in Inorganic Materials (PTM2010)
Pierer, R.; Bernhard, C.	**Die Besonderheiten der Fehlerbildung im Zweiphasengebiet fest/flüssig beim Stranggießen von Stahl**	Hot Cracking Workshop
Pierer, R.; Bernhard, C.	**The nature of internal defects in continuously cast steel and their impact on final product quality**	The Iron and Steel Technology Conference and Exposition (AISTech)
Planitzer, F.; Hatzenbichler, T.; Buchmayr, B.	**Surface densification of P/M gears by radial forging - FEM feasibility study**	Metal Forming Meeting 2010
Pletz, M.; Daves, W.; Ossberger, H.	**A dynamic finite element model of a wheel passing a crossing nose**	10th International Conference on Computational Structures Technology
Pondicherry, K.; Grün, F.; Gódor, I.; Bertram, R.; Offenbecher, M.	**Understanding the differences between ring on disc and pin on plate test configurations**	37th Leeds-Lyon Symposium on Tribology

Author Co-author	Title	Conference
Pondicherry, K.; Grün, F.; Gódor, I.; Bertram, R.; Offenbecher, M.	**Elucidating the differences between ring-on-disc and pin-on-plate tribometric test approaches**	37th Leeds-Lyon Symposium on Tribology
Pranger, W.; Antretter, T.; Waitz, T.; Fischer, F.D.	**Numerical analysis of the role of interface energies in the context of martensite formation in NiTi nanograins**	IV European Congress on Computational Mechanics (ECCM 2010)
Predan, J.; Gubeljak, N.; Fischer, F.D.; Kolednik, O.	**Local crack driving force in materials with yield stress inhomogeneity**	6th International Conference on Materials Structure and Micromechanisms of Fracture
Presoly, P.	**Experimental characterisation of new peritectic steel grades**	Junior Euromat 2010
Presoly, P.	**Simulation of peritectic steels - DICTRA and Sulfur**	ThermoCalc User Meeting
Presser, V.; Deluca, M.; Berthold, C.; Nickel, K.G.	**Sliding wear of silicon carbide: Measurement of the thermal conductivity via Raman spectroscopy**	XXII International Conference on Raman Spectroscopy
Reyes-Huamantinco, A.; Ruban, A.; Puschnig, P.; Ambrosch-Draxl, C.	**DFT-based calculation of the temperature-dependent stacking fault energy in the Fe-Mn alloy**	Frühjahrstagung der Deutschen Physikalischen Gesellschaft (DPG) 2010
Sailer, W.; Grün, F.; Gódor, I.; Gänser, H.-P.	**Design of a novel methodology for in-situ investigation of contact conditions**	14th Nordic Symposium on Tribology - Nordtrib 2010
Schöngrundner, R.; Endler, S.B.; Daniel, R.; Ebner, R.; Mitterer, C.; Kolednik, O.	**A numerical study on the fatigue resistance of a coated tool steel**	18th European Conference on Fracture (ECF18)
Schöngrundner, R.; Endler, S.B.; Daniel, R.; Kolednik, O.; Ebner, R.	**Endurance limit of Chromium Nitride coated tool steels – Experimental and numerical studies**	4th European Conference on Computational Mechanics (ECCM4)

Author Co-author	Title	Conference
Schwaab, H.; Grünbichler, H.; Krautgasser,C.; Kamlah, M.; Supancic, P.	**Assessment of different compression test setups for the (electro-) mechanical characterization of piezo-ceramics and multilayer actuators**	Electroceramics XII
Spitaler, J.	**Phase stability, energetics, and elastic properties of Ni-Ti-Hf shape-memory alloys**	PSI-K Conference 2010
Stoschka, M.; Fössl, T.; Leitner, M.; Posch, G.	**Contribution to the capability of filler metals to influence pulsating fatigue life**	63rd Annual Assembly & International Conference of the International Institute of Welding
Stoschka, M.; Leitner, M.; Fössl, T.; Schanner, R.	**Contribution to the use of local fatigue approaches focussing on finishes of complete welds**	63rd Annual Assembly & International Conference of the International Institute of Welding
Stoschka, M.; Leitner, M.; Fössl, T.; Leitner, H.; Eichlseder, W.	**Application of fatigue approaches on fillet welds of high-strength steel**	Materials Science and Engineering (MSE 2010)
Supancic, P.; Witschnig, S.; Polaczek, E.; Danzer, R.	**The strength of ceramic balls - The notched ball test**	18th European Conference on Fracture (ECF18)
Trausmuth, A.; Gódor, I.; Stoschka, M.; Dietrich, A.; Eichlseder, W.	**Life fatigue prediction of different plasma nitrided and case hardened specimens under rolling contact loading**	AWT 2010
Trausmuth, A.; Gódor, I.; Stoschka, M.; Dietrich, A.; Eichlseder, W.	**Tragfähigkeitsuntersuchungen von unterschiedlich gehärteten Werkstoffen unter Kontaktbeanspruchung**	Symposium der Österreichischen Tribologischen Gesellschaft (ÖTG) 2010
Unterreiter, G.; Wlanis, T.; Ludwig, A.; Wu, M.; Sommitsch, C.; Mayer, F.	**Through-process simulation of aluminium casting A356 - simulation of solidification and stress analysis during heat treatment**	1st International Conference on Multiphysics Simulation - Advanced Methods for Industrial Engineering

Author Co-author	Title	Conference
Waitz, T.; Mangler, C.; Steiner, G.; Peterlechner, M.; Antretter, T.; Fischer, F.D.; Pranger, W. et al.	**Multifunctional shape memory alloys processed by SPD**	International Symposium on Giant Straining Process for Advanced Materials (GSAM 2010)
Waitz, T.; Pranger, W.; Antretter, T.; Fischer, F.D.; Steiner, G.; Peterlechner, M.	**Nanostructured shape memory alloys**	Special Workshop on Shape Memory Alloys
Wallner, S.; Harrer, O.; Buchmayr, B.; Hofer, F.	**Manufacturing of precision forgings by radial forging**	International Conference on Advances in Materials and Processing Technologies (AMPT)
Walter, C.; Mitterer, C.	**Roughness influence on nanoindentation measurements**	International Conference on Metallurgical Coatings and Thin Films
Wlanis, T.; Sommitsch, C.	**Heat treatment of the aluminium alloy AlSi7MgCu05 - simulation of the process and precipitation evolution**	5th Seminar for PhD Students
Yang, B.; Motz, C.; Dehm, G.	**Tensile and fatigue behaviour of micro-sized copper wires studied by a fibre tensile loading frame**	International Conference on Mechanical Properties of Materials
Yang, B.; Motz, C.; Grosinger, W.; Dehm, G.	**Cyclic loading behaviour of micro-sized copper wires**	Fatigue 2010
Zechner, J.; Kolednik, O.	**Fracture toughness testing of single sheets and multilayers of paper**	18th European Conference on Fracture (ECF18)
Zechner, J.; Kolednik, O.	**Single sheets and multilayers of paper - fracture toughness testing**	Workshop Prospects for Bionics for Functional Materials Science and Engineering

APPENDIX

C) Posters

C) Posters

Author Co-author	Title	Conference
Bermejo, R.; Šestáková, L.; Kraleva, I.; Supancic, P.; Danzer, R.	**Influence of metallisation on the mechanical behaviour of low temperature co-fired ceramics under biaxial loading**	DKG-Jahrestagung und Symposium Hochleistungskeramik 2010
Bilik, C.; Rammerstorfer,F.G.; Figala, G.; Buchmayr, B.	**Investigation of the stability and dynamic behaviour of plates subjected to laser treatment**	Junior Scientist Conference 2010
Deluca, M.; Bermejo, R.; Pletz, M.; Supancic, P.; Danzer, R.	**Characterisation and modelling of the mechanical reliability of semiconductor components for printed circuit boards**	Electroceramics XII
Gholizadeh, H.; Puschnig, P.; Ambrosch-Draxl, C.	**The influence of interstitial carbon on the γ surface in iron-carbon alloys**	PSI-K Conference 2010
Gholizadeh, H.; Puschnig, P.; Ambrosch-Draxl, C.	**The influence of interstitial carbon on the γ surface in iron-carbon alloys**	Ab-Initio Description of Iron and Steel: Mechanical Properties (International Scientific Seminar)
Golesorkhtabar, R.; Pavone, P.; Puschnig, P.; Spitaler, J.; Ambrosch-Draxl, C.	**ElaStic: A universal tool for calculating elastic constants from first principles**	Frühjahrstagung der Deutschen Physikalischen Gesellschaft (DPG) 2010
Golesorkhtabar, R.; Pavone, P.; Puschnig, P.; Spitaler, J.; Ambrosch-Draxl, C.	**ElaStic: A universal tool for calculating elastic constants from first principles**	PSI-K Conference 2010
Grünbichler, H.; Deluca, M.; Presser, V.; Nickel, K.G.; Danzer, R.	**Influence of domain orientation on the electro-mechanical properties of multilayer piezoelectric actuators**	DKG-Jahrestagung und Symposium Hochleistungskeramik 2010
Keckes, J.; Bartosik, M.; Daniel, R.; Mitterer, C.; Maier, G.; Schoeder, S.; Burghammer, M.	**Nano-beam X-ray diffraction reveals structural and mechanical gradients in nano-crystalline thin films**	59^{th} Annual Conference on Applications of X-ray Analysis

Author Co-author	Title	Conference
Krajewski, P.; Pierer, R.	**Experimental simulation of crack formation of steels in the temperature range of second ductility trough**	Junior Euromat 2010
Kreith, J.; Keckes, J.; Chitu, L.; Resel, R.; Neuhold, A.; Maier, G.A.	**Reflectivity measurements on 2D detectors in omega geometry**	XTOP 2010
Legut, D.; Spitaler, J.; Pavone, P.; Ambrosch-Draxl, C.	**The role of carbon in Nb-alloyed Ti-Al compounds**	PSI-K Conference 2010
Leitner, M.; Fössl, T.; Stoschka, M.	**Steigerung der Schwingfestigkeit geschweißter Strukturen durch die Pneumatic Impact Technology (PIT)**	Fachkongress Join-Ex
Oberaigner, E.R.; Leindl, M.; Antretter, T.	**Time-dependent heat conduction problems solved by an integral-equation approach**	60^{th} Annual Meeting Austrian Physical Society
Pavone, P.; Golesorkhtabar, R.; Spitaler, J.; Ambrosch-Draxl, C.	**Nonlinear elasticity of graphene and other hexagonal carbon allotropes**	PSI-K Conference 2010
Popov, M.; Spitaler, J.; Walter, C.; Ambrosch-Draxl, C.	**Ab-initio investigation of the interface structure of TiO_2 grown on Al_2O_3**	Frühjahrstagung der Deutschen Physikalischen Gesellschaft (DPG) 2010
Pranger, W.; Antretter, T.; Waitz, T.; Fischer, F.D.	**The correlation between grain size and martensite morphology in nanostructured NiTi shape memory alloys**	Solid-Solid Phase Transformations in Inorganic Materials (PTM2010)
Presoly, P.; Pierer, R.	**Experimental characterisation of new peritectic steel grades**	Junior Euromat 2010
Reyes-Huamantinco, A.; Ruban, A.; Puschnig, P.; Ambrosch-Draxl, C.; Wießner, M.; Wiener, J.; Ebner, R.	**DFT-based stacking fault energy in the Fe-22.5at.%Mn random alloy above room temperature**	Ab-Initio Description of Iron and Steel: Mechanical Properties (International Scientific Seminar)

Author Co-author	Title	Conference
Reyes-Huamantinco, A.; Ruban, A.; Puschnig, P.; Ambrosch-Draxl, C.; Wießner, M.; Wiener, J.; Ebner, R.	**DFT-based stacking fault energy in the Fe-22.5at.%Mn random alloy above room temperature**	PSI-K Conference 2010
Sagmeister, S.; Glantschnig, K.; Kothleitner, G.; Hebert, C.; Ambrosch-Draxl, C.	**TDDFT study of the momentum-dependent loss function of palladium**	PSI-K Conference 2010
Sifallovic, P. et al.	**GISAXS on self assembled nano-particles**	XTOP 2010
Steiner, G.; Waitz, T.; Karnthaler, H.P.	**Martensitic phase transformations of NiTiHf high temperature shape memory alloys processed by severe plastic deformation**	Solid-Solid Phase Transformations in Inorganic Materials (PTM2010)
Unterreiter, G.; Wlanis, T.; Oberwinkler, C.; Redik, S.; Pabel, T.; Kneißl, C.	**Durchgängige Simulation des Herstellungsprozesses eines A356-Gussteils**	54. Österreichische Gießereitagung
Walter, C.; Mühlbacher, M.; Mitterer, C.	**Control of phase formation during synthesis of ZrO_2 coatings by magnetron sputtering**	International Conference on Metallurgical Coatings and Thin Films
Witschnig, S.; Danzer, R.; Supancic, P.; Schöppl, O.	**The "notched ball test" - a new strength test for ceramic balls**	Junior Euromat 2010
Ženíšek, J.; Kozeschnik, E.; Svoboda, J.; Fischer, F.D.	**Impact of microscopic chemical fluctuations on precipitation in interstitial / substitutional systems**	Solid-Solid Phase Transformations in Inorganic Materials (PTM2010)

D) Journals

Author Co-author	Title	Journal	Edition/ Year
Buchmayr, B.; Figala, G.; Wunsch, L.	**Lokale fertigungstechnische Verstärkungskonzepte zur Erhöhung der Materialeffizienz**	BHM	155 / 2010
Grün, F.; Gódor, I.; Javidi, A.; Pondicherry, K.	**Tribometrie von Grenzschichten in großflächigen Kontakten - Methodik zur Erzeugung von Tribofilmen und begleitende Analytik**	Tribologie + Schmierungstechnik	57 / 2010
Oberwinkler, C.; Leitner, H.; Eichlseder, W.; Schönfeld, F.; Schmidt, S.	**Fatigue proof design of aluminium high-pressure die casting components taking into consideration the defect distribution (Schädigungstolerante Auslegung von Aluminium-Druckgusskomponenten)**	Materials Testing / Materialprüfung	52 / 2010
Zuber, M.J.; Winkler, H.; Schweiger, H.; Leitner, H.	**Einfluss der Pulverfraktion auf die Eigenschaften von pulvermetallurgisch hergestelltem Schnellarbeitsstahl**	BHM	155 / 2010

E) Books

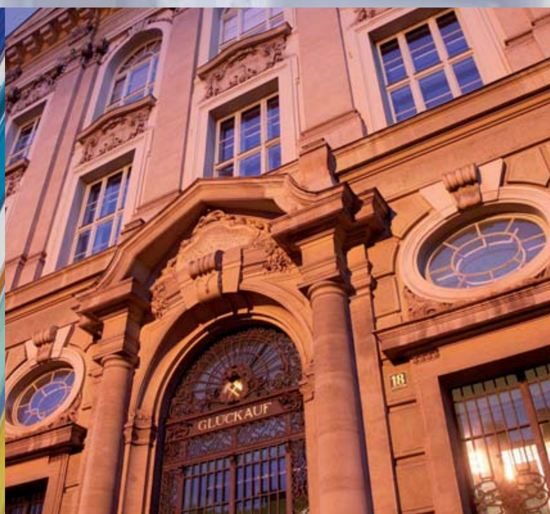
Author	Book / Contribution	Year of publication ISBN
Danzer, R.; Lube, T.; Supancic, P.; Damani, R.; Chen I.-W. (Hrsg.)	**Fracture of Ceramics in: Ceramics Science and Technology, Volume 2**	2010 978-3-527-31156-9
Schöngrundner, R.	**Numerische Studien zur Ermittlung der risstreibenden Kraft in elastisch-plastischen Materialien bei unterschiedlichen Belastungsbedingungen in: Fortschrittsberichte VDI Reihe 18: Mechanik / Bruchmechanik; 329**	2010 978-3-18-332918-2
Wießner, M.	**Hochtemperatur-Phasenanalyse am Beispiel martensitischer Edelstähle**	2010 978-3-86931-536-2

BUSINESS FIGURES 2010

Business Development

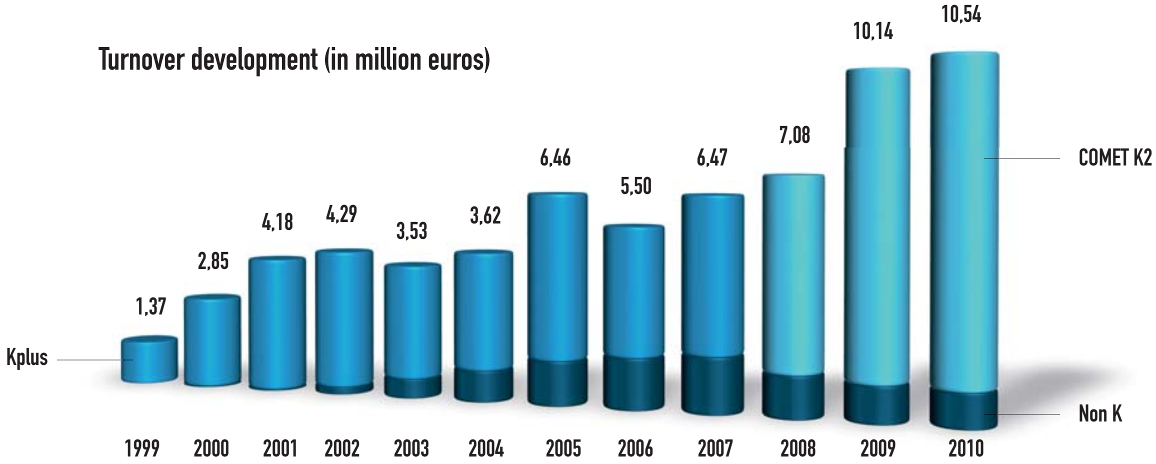
Profit and Loss Account

Balance Sheet

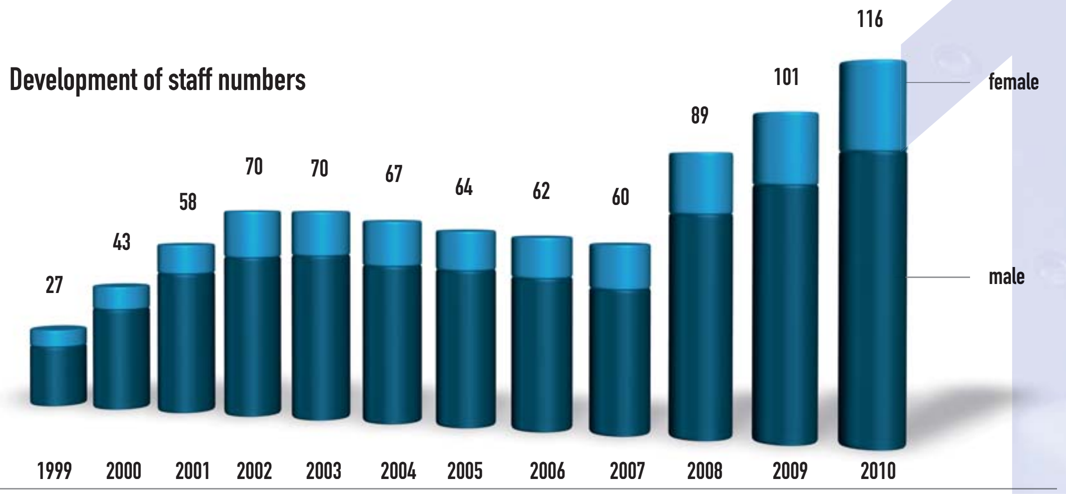
Business Figures

Development of business results and project volume:
The COMET project volume once again increased in 2010, although this increase was not as significant as had been planned. The reasons for this are to be found in the effects of the economic crisis and in the delayed implementation of investments. Overall, the development of the turnover volume is highly satisfactory, allowing us to look to the future with confidence.



Staff development

With the establishment of the COMET K2 Centre MPPE, the number of staff has grown considerably since 2008. In 2010, the headcount grew more rapidly than the turnover volume. This is due to the fact that an increasing number of project activities are carried out by MCL staff, while the contributions provided by the institutes involved remain constant. This shift of workload to MCL is fully in line with the character of a K2 Centre.



General economic conditions:
In the 2010 financial year, projects were completed both in the COMET area as well as in the Non-COMET area.

The project volume with regard to COMET K2 MPPE totalled € 9,495,824 including financing of the COMET investments. This is a slight increase compared with the previous year, with a further increase to be expected.

In the Non-COMET area, the project volume for the same period was € 1,045,272, including service and development contracts as well as research projects from other funding sources. This means that the Non-COMET project volume remained below the level reached before the economic crisis, but it is expected to reach that level within the next few years.

Capital spending:
Delivery delays meant that only relatively small investments could be made in 2010. The largest investment made in the course of this financial year was the high-temperature laser scanning confocal microscope, followed by the high temperature chamber for x-ray diffractometry.

Total investments, including advance payments for equipment, amounted to € 453,202.30, while depreciations totalled € 842,555.91. It should however be noted that very large investments were made in 2009 and increased investment is planned for COMET Phase II. Overall, the preservation and further accumulation of investment assets is secured.

Results:
With regard to the results situation, the 2010 financial year can be considered to have been a very good year. With the profit from the Non-COMET area and the research and training premium it was possible to generate a net income of € 484,216.80. With the profit carried forward this resulted in a balance sheet profit of € 538,809.28.

As MCL operates in the public interest and does not distribute profits, capital and reserves increased to € 2,558,846.06. This solid cash situation means that MCL is well-placed to deal with any fluctuations occurring as a result of the transition between COMET Phase I and COMET Phase II in the period 2012/13.

Outlook for 2010:
The COMET K2 MPPE programme accounts for a major proportion of MCL's business volume. COMET Phase I is due to expire at the end of 2012. MCL will therefore take up the option of extending until 2017 and will submit a follow-up proposal in 2011. Activities in 2011 will thus focus mainly on updating the research programme as well as on the development and procurement of new projects for COMET Phase II.

MCL aims at achieving a break-even result in 2011. The generated earnings will be used to advance in-house research and method development in order to open up new research fields for MCL.

Profit and Loss Account

	2010 in EUR	2009 in EUR
1. Turnover	990,656.09	1,013,713.08
2. Services not yet billable	66,523.76	-86,474.47
3. Income from cash and in-kind contributions by partners	4,808,435.25	4,117,966.40
4. Public funding and allowances	4,508,188.00	3,797,057.16
5. Other operating income		
a) release of investment allowances	744,488.96	714,748.76
b) income from the disposal of fixed assets	5,000.00	0.00
c) income from the reversal of accruals	176,475.22	190,732.56
d) other	553,200.23	1,747,263.75
	1,479,164.41	2,652,745.07
6. Raw material expense and expenditure for services received		
a) raw material expense	707,970.25	705,185.21
b) expenditure for services received	5,013,206.46	3,810,067.21
	5,721,176.71	4,515,252.42
7. Staff expenses		
a) Wages	15,347.58	12,337.89
b) Salaries	2,881,678.38	2,584,676.74
c) Employee income provision fund	41,211.44	37,659.13
d) Expenses for social security payment prescribed by law as well as taxes and mandatory contributions dependent on compensation	781,353.71	704,048.18
e) Expenses for other employee benefits	15,883.14	9,780.89
	3,735,474.25	3,348,502.83
8. Amortization		
a) of fixed assets	842,555.91	799,421.54
9. Other operating expenses		
a) taxes, in so far as they are not on income or on revenue	7,097.17	6,363.38
b) other	1,090,081.32	1,094,087.30
	1,097,178.49	1,100,450.68
10. Operating result	456,582.15	1,731,379.77
11. Other interest income and similar income	42,651.01	40,143.26
12. Financial result	42,651.01	40,143.26
13. Profit from operating activities	499,233.16	1,771,523.03
14. Taxes on income and revenue	15,016.36	1,758.50
15. Net income	484,216.80	1,769,764.53
16. Profit for the year	484,216.80	1,769,764.53
17. Profit carried forward from the previous years	54,592.48	12,864.73
18. **Balance sheet profit**	538,809.28	**1,782,629.26**

Profit and Loss Account as at 31/12/2010 Materials Center Leoben Forschung GmbH

Balance Sheet

BUSINESS FIGURES

Balance Sheet as at 31/12/2010 Materials Center Leoben Forschung GmbH

as at 31/12	2010 in EUR	2009 in EUR
Assets		
A. Fixed Assets		
I. Intangible Assets		
1. Licences and software	12,275.61	5,804.76
II. Tangible Assets		
1. Equipment	1,780,529.12	2,159,979.32
2. Tools, fixtures and fittings	115,328.64	141,673.27
3. Payments made on account	264,378.37	254,408.00
	2,160,236.13	2,556,060.59
	2,172,511.74	2,561,865.35
B. Current Assets		
I. Inventories		
1. Services not yet billable	87,602.48	21,078.72
2. Payments made on account	99,519.92	136,966.80
	187,122.40	158,045.52
II. Receivables and other Assets		
1. Receivables arising from deliveries and services	245,812.50	143,554.95
2. Receivables of cash and in-kind contributions from partner companies	687,931.00	588,266.89
3. Receivables from subsidies und project subsidies	193,168.62	155,164.26
4. Other receivables and assets	696,259.62	617,189.74
	1,823,171.74	1,504,175.84
III. Cash on hand and bank deposits	4,230,786.88	4,085,862.12
	6,241,081.02	5,748,083.48
C Prepaid expenses, deferred charges	102,133.69	111,813.58
Total Assets	**8,515,726.45**	**8,421,762.41**

BUSINESS FIGURES

Balance Sheet as at 31/12/2010 Materials Center Leoben Forschung GmbH

as at 31/12	2010 in EUR	2009 in EUR
Liabilities and Shareholders' Equity		
A. Capital and Reserves		
I. Share capital	292,000.00	292,000.00
II. Revenue reserves		
1. Other reserves (free reserves)	1,728,036.78	0.00
III. Balance sheet profit	538,809.28	1,782,629.26
thereof profit carried forward from the previous years	54,592.48	12,864.73
	2,558,846.06	2,074,629.26
B. Investment Allowances	1,483,954.27	1,952,160.90
C. Accruals		
1. Other accruals	829,195.58	649,504.41
D. Liabilities		
1. Payments received on account for orders	36,680.84	36,680.84
2. Liabilities arising from deliveries and services	1,187,453.71	1,693,380.23
3. Other liabilities	530,530.13	436,164.99
thereof taxes	-2,822.23	34,842.54
thereof social security	82,839.22	73,344.44
	1,754,664.68	2,166,226.06
E. Prepaid expenses, deferred charges	1,889,065.86	1,579,241.78
Total Liabilities and Shareholders' Equity	**8,515,726.45**	**8,421,762.41**

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