FRAUNHOFER INSTITUTE FOR MACHINE TOOLS AND FORMING TECHNOLOGY IWU

THE INSTITUTE AT A GLANCE

PROFILE

OVERVIEW

The Fraunhofer Institute for Machine Tools and Forming Technology IWU is part of the Fraunhofer-Gesellschaft, the leading organization for applied research in Europe. Its research activities are conducted by 66 institutes and research units at locations throughout Germany. The Fraunhofer-Gesellschaft employs a staff of more than 24,000, who work with an annual research budget totaling more than 2 billion euros. Of this sum, more than 1.7 billion euros is generated through contract research. More than 70 percent of the Fraunhofer-Gesellschaft's contract research revenue is derived from contracts with industry and from publicly financed research projects. International collaborations with excellent research partners and innovative companies around the world ensure direct access to regions of the greatest importance to present and future scientific progress and economic development.

Application-oriented research for the automotive and mechanical engineering industries

"Research for the Future" is the motto of the Fraunhofer IWU. For more than 20 years, the main focus of our work is on application-oriented research and development in the field of production technology for the automotive and mechanical engineering sectors.

We not only develop intelligent production systems for the manufacturing of car body and powertrain components, but we also optimize their related forming and cutting manufacturing processes. We create innovative solutions for continuous process chains, starting with the components, to assembly units, all the way up to complex machine systems with completely new kinematics. The use of lightweight structures and new materials is also playing an ever greater role.

Resource efficient production – a global issue

Facing the background of the increasing shortage of resources throughout the world, it is essential to make the most efficient use possible of raw materials and energy in the manufacturing sector. The development of both material-efficient and energy-efficient technologies and products, together with the optimization of the manufacturing process chains from a resource perspective constitute, is therefore a focal point in our research. We are continously devising solutions aimed at improving resource efficiency in cooperation with partners from the engineering sector and the automotive industry and preparing them for implementation on an industrial scale.

Scientific excellence guarantees research success

With an annual budget of about 37,2 million euros and over 650 highly qualified engineers and scientists, combined with laboratories in Chemnitz, Dresden, Augsburg and Zittau, Fraunhofer IWU is recognized as one of the leading contractual research and development institutions across Germany in our specialized fields of work.

The scientific expertise of our staff, together with state-of-the-art technical equipment, represents an optimum environment for research and development activities as well as industrial contract management. We partner not only with regional, trans-regional and international automotive manufacturers, their suppliers, and the mechanical and electrical engineering, precision and micro engineering sectors, but also with innovators in aerospace and medical technology.

1

RANGE OF SERVICES

Cooperative activities

Fraunhofer IWU works closely together with diverse partners from industry and research in various ways:

– Engaging in contract-based research with or without public funding
– Promoting collaborative involvement with companies and universities on publicly funded projects, aimed primarily at fundamental and advanced risk research
– Testing and performing research on behalf of machine suppliers who make available some of the most advanced machines and equipment to the Institute
– Providing outside firms the use of the technical equipment inside Fraunhofer IWU's own testing facilities in order to facilitate their access to new technologies

Through collaboration with other research institutions including the institutes of the Fraunhofer-Gesellschaft and other specialized organizations, we can provide our customers interdisciplinary solutions for individual needs, all within one institute, starting from the material and technical basics up to the manufacture of prototypes and final testing.

Our services

Fraunhofer IWU's development activities encompass products and processes right up to the point where they are ready to use. At the same time, individual solutions are created in direct contact with our customers.

We are constantly adapting our services in production technology and engineering to offer the most comprehensive, yet customizable solutions to best meet the needs of our customers – your needs. We are able to provide you with everything from feasibility studies and technological advances, to the actual development of entire machines and processes – all to suit your specifications. An overview of all the available technologies and an analysis of the current market situation may be your starting point. If so, Fraunhofer IWU is fully equipped to conduct thorough and exact feasibility studies, as well as market trend and cost analyses.

Perhaps you would like to have a new product developed? Not only do our services include product development and application, but we also provide the design and the creation of prototypes for an individual part, an assembled device or even a complete system.

Would you like to increase productivity and improve the quality of your products and services? We optimize existing production procedures, develop new technologies and processes, and we also provide assistance for their integration and implementation into your company.

If you need technical parameters and data for your products and processes, we possess a wide range of the most sophisticated metrological services available, from material testing to machine diagnosis.

Are you interested in keeping the experience and know-how of your personnel at the highest level? We regularly organize international conferences and workshops related to our numerous areas of research and expertise.

1 *"E3-Forschungsfabrik Resource-Efficient Production" at Fraunhofer IWU in Chemnitz.*

FIELDS OF ACTIVITY AND CONTACTS

Fraunhofer Institute for Machine Tools and Forming Technology IWU

Directors:
Prof. Dr.-Ing. Dirk Landgrebe (executive)
Prof. Dr.-Ing. Welf-Guntram Drossel
Prof. Dr.-Ing. Matthias Putz

Scientific Field Mechatronics and Lightweight Structures Prof. Dr.-Ing. Welf-Guntram Drossel	**Scientific Field Machine Tools, Production Systems and Machining** Prof. Dr.-Ing. Matthias Putz	**Scientific Field Forming Technology and Joining** Prof. Dr.-Ing. Dirk Landgrebe
Mechatronics	Machine Tools and Automation	Sheet Metal Forming
Functional Integration/ Lightweight Design	Production Systems	Bulk Metal Forming
Textile Lightweight Design	Machining and Removing	Joining
	Project Group Resource-efficient Mechatronic Processing Machines	

Research Management	
Research Planning	Public Relations

Services	
Technical Service	Administration

The Fraunhofer IWU stands for quality and innovation. We identify opportunities, work together with our partners in the engineering sector and automotive industry to devise solutions to improve resource efficiency, and prepare them for implementation on an industrial scale.

We are a one-stop shop with comprehensive expertise in developing products and processes to be ready for use by our customers.

Our services are managed within ten interdisciplinary divisions.

Scientific Field
Mechatronics and Lightweight Structures
Prof. Dr.-Ing. Welf-Guntram Drossel

Mechatronics

– Modeling and design of mechatronic systems
– Development of sensor-actuator systems based on piezo ceramics, shape memory alloys and active fluids
– Intelligent tools for forming, cutting and joining
– Acoustics and vibration technology
– Mechatronics in medical science
– Innovative prostheses and implants

Functional Integration / Lightweight Design

– Development and dimensioning of lightweight structures
– Dimensioning / application of hybrid components made from metal and fiber composites
– Application of metal foams (technology, prototypes, small series)
– Additive manufacturing technologies (3D laser beam melting, 3D printing, FDM technology)

Textile Lightweight Design

– Systems and technologies for textile structures
– Active textile compounds
– Textile production processes
– Integrative process chains
– Additive manufacturing of plastic components
– Function integrating plastic technologies

1 *Using array procedures for locating sound sources*

Contact
Dipl.-Ing. Holger Kunze
holger.kunze@iwu.fraunhofer.de

Contact
Dr.-Ing. Ines Dani
ines.dani@iwu.fraunhofer.de

Contact
Prof. Dr.-Ing. Lothar Kroll
lothar.kroll@iwu.fraunhofer.de


1


2

Scientific Field

Machine Tools, Production Systems and Machining

Prof. Dr.-Ing. Matthias Putz

Machine Tools and Automation

- Design and development of forming and cutting machines and their components
- Planning and design of production assemblies and drives
- Software development
- Analysis of static, dynamic and thermal behavior
- Application of Virtual Reality methods
- Optical and multi-sensorial quality control system

Contact

Dipl.-Ing. Peter Blau

peter.blau@iwu.fraunhofer.de

Machining and Removing

- Numerical simulation of cutting processes, tool design and component behavior
- Development of cutting and abrasive processes
- Design of process chains, combination and integration of processes
- Development of hybrid machining processes
- Micro structure and surface technologies
- Development of functionally optimized surfaces

Contact

Dipl.-Ing. Peter Blau

peter.blau@iwu.fraunhofer.de

Production Systems

- Planning and control of energy- and resource efficiency
- Application and further development of integrative production management systems
- Analyzing/evaluation of production-, logistic- and factory concepts
- Solutions and applications for modern energy- and data management
- Joining and assembling systems; sensitive robotics
- Flexible equipment and gripper
- Software for automating planning tasks

Contact

Prof. Dr.-Ing. Matthias Putz

matthias.putz@iwu.fraunhofer.de

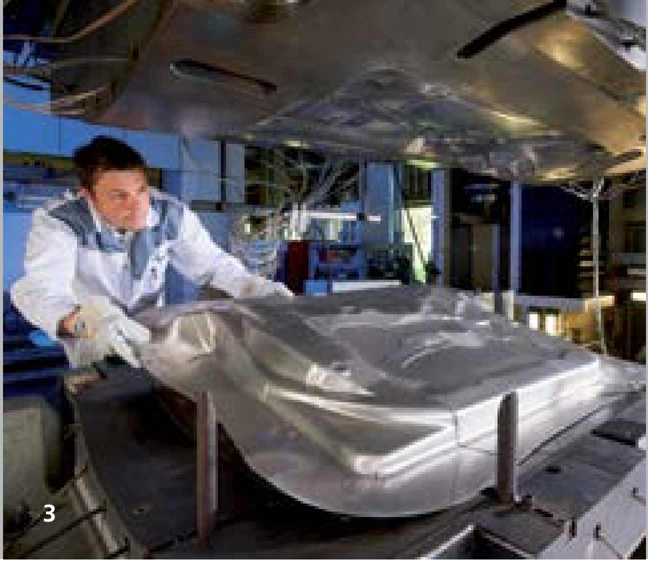
Project Group Resource-efficient Production Processing Machines

- Resource-efficient factories: planning, evaluation and operation
- Resource-efficient order processing and added value
- Flexible processing machines
- System development and plant simulation
- Functionally-integrated lightweight design
- Intelligent cleaning
- Industrial biotechnology

Contact

Prof. Dr.-Ing. Gunther Reinhart

gunther.reinhart@iwu.fraunhofer.de



Scientific Field

Forming Technology and Joining

Prof. Dr.-Ing. Dirk Landgrebe

Sheet Metal Forming

- Process chains and method planning
- Technologies for sheet metal processing
- Hot sheet metal forming of steel, aluminum, magnesium and titanium
- Media-based-, energy-based- and incremental forming
- Tool and die design and concepts
- Simulation of forming processes
- Material-physical basics

Bulk Metal Forming

- Process chains and method planning
- Cold, warm and hot bulk metal forming
- Technologies for hollow shaft geometries
- Forming manufacturing of various types of toothing
- Tool and die design and concepts
- Simulation of forming processes
- Material-physical basics

Joining

- Thermal joining technologies (laser-, arc- and press welding, hybrid- and material mix)
- Mechanical joining technologies (clinching, self-piercing riveting, hybrid joining with bonding)
- Tolerance analysis in the car body process chain
- Experimental and numerical process description
- Testing of individual processes and components

Contact
Dipl.-Ing. Frank Schieck
frank.schieck@iwu.fraunhofer.de

Contact
Dr.-Ing. Andreas Sterzing
andreas.sterzing@iwu.fraunhofer.de

Contact
Dr.-Ing. Reinhard Mauermann
mauermann@iwu.fraunhofer.de

1 *Machining center for tool and mold making*
2 *High-speed cutting with flexible kinematics*
3 *Heated forming tool for forming of a magnesium blank*
4 *Cold forming of high toothings*

LOCATIONS

Chemnitz

The principal facilities of Fraunhofer IWU are located in Chemnitz, Germany, close to the Technische Universität Chemnitz. The campus "E3-Production", a production technology research complex with an area of about 9,500 m², includes the brand-new "E3-Forschungsfabrik Resource-efficient Production" as well as large-scale test facilities for forming and cutting technology, machine tools and precision technology, a metal foam center and a Virtual Reality Center.

Fraunhofer IWU in Chemnitz deals with research topics in the field of machine tools and production systems, forming and assembling technologies, precision machining and production management.

Dresden

Fraunhofer IWU has maintained a presence in Dresden since 2006. Situated close to the campus of the Dresden University of Technology, this complex features offices, laboratories, and a 1,000 m² technical testing facility. Research subjects are adaptronics and acoustics, lightweight design, additive manufacturing, joining technology and medical engineering.

Augsburg

In 2009, the Fraunhofer IWU Project Group "Resource-efficient Mechatronic Processing Machines" was set up at the Augsburg iwb (Institute for Machine Tools and Industrial Management) Technology Transfer Center under the leadership of Professor Gunther Reinhart. The basic objective of the Project Group has been to devise innovative solutions for components, assemblies and complex systems aimed at ensuring the efficient use of resources in the operation of processing machinery.

Zittau

In 2011, a Fraunhofer IWU Project Group began its operation in Zittau. The strategic objective of the "Fraunhofer-Kunststoffzentrum Oberlausitz" is the development of resource and energy efficient technologies for the regional automotive and mechanical industry and their small- and medium-sized suppliers. Lightweight construction is also a major focus in Zittau.

1 *The campus "E3-Production" of Fraunhofer IWU in Chemnitz.*

TOWARDS GLOBAL COOPERATION

By providing research solutions for international clients, Fraunhofer IWU is continuously increasing and strengthening its position as a top tier provider for research and development in the field of production technology.

The importance of European-funded collaborative research has greatly increased. In particular, the funding of European Union (EU) framework programs has continually increased, whereas the national budget for research and development is declining. Research projects are realized within numerous international university and industrial partnerships, and include collaborative exchange of researchers and students. The projects are supported mainly by the European Commission, the German Research Foundation (DFG) and the Fraunhofer-Gesellschaft.

The Fraunhofer IWU has strengthened its position in the European research landscape. We are involved in a number of EU projects within the 7th Framework Programme as a research partner. After finishing the successful collaborative project "LearnForm – Self-Learning Sheet Metal Forming System" we have taken on the challenging responsibility of coordinating the joint iMain project "A Novel Decision Support System for Intelligent Maintenance." With funding of around 7 million euros, eight partners from four different countries are developing an innovative system which has the potential to revolutionize preventative maintenance in production.

Fraunhofer IWU is also partner in the REEMAIN project "Resource and Energy Efficient Manufacturing" where sixteen partners from six countries combine their cutting edge knowledge and experience from production processes, energy simulation software tools, energy and resource planning and renewable energy and storage to develop and demonstrate a methodology and platform likely to boost the efficiency of both energy and material resources.

Fraunhofer IWU's proficiency and the successful results stemming from industrial research for the automotive and machine tool manufacturers have recently led to a number of projects which we are currently coordinating with companies in India, South Africa, Turkey, Israel, Canada and Brazil.

In South Africa, the University Stellenbosch has been our cooperation partner since 2006 for projects in the automobile and aircraft industry. Currently, our researchers are working on a project promoted by the South African government for the precision machining of light metals. In addition, we are part of the South African "Advanced Manufacturing Initiative" as a coordinator for the value chain "Titanium."

Our cooperation with the University of Naples Frederico II in Italy has also been taken to the next level. By founding the Joint Laboratory of Excellence on Advanced Production Technology (J_LEAPT), we are now in a position to be active in the market together with our Italian research partner. The focus of the partnership is on projects looking into machining materials that are difficult to process and producing CFRP components. With the backing of the Fraunhofer IWU, J_LEAPT has applied to the European Union and Campanian authorities for permission to construct a production technology laboratory as research base for these projects.

Our close cooperation with other European neighbors is a benefit of our geographic proximity. Therefore, companies and universities from Switzerland, especially the Swiss Federal Institute of Technology Zurich (ETH Zurich), Austria, the Czech Rebublic, Slovakia and Slovenia are important network partners of our Institute.

CORE COMPETENCIES

E3: ENERGY AND RESOURCE-EFFICIENT PRODUCTION ON A NEW LEVEL

"E3" stands for the three central areas of study where we are looking to turn visions into real technological innovations in the coming years: Aside from **E**nergy and resource efficiency in production through development of new machines and technologies, the concept includes the idea of an **E**mission-neutral factory as well as rethinking the way of **E**mbedding human into the manufacturing processes.

The "E3-Forschungsfabrik Resource-efficient Production" at our location in Chemnitz focuses on new technical innovations, engineering processes and factory planning concepts. Together with industrial partners, solutions are being studied and tested in three main fields of research: "Powertrain", "Car Body Construction", and "Data- and Energy Management 2.0".

The design and implementation of ultra-short process chains is the area of focus in the competence field "Powertrain". By replacing manufacturing and machining processes with more resource-efficient technologies or by saving process steps, we can reduce energy use, material consumption, and overall process time. Potential savings are being investigated and demonstrated, for example on a sample production line for a gear shaft.

The competence field "Car Body Construction" focuses on the future of automotive manufacturing. In close cooperation with Volkswagen AG, we conduct research using a state-of-the-art assembly line for a car door, similar to what is used in series production. We are researching how energy, time, and costs can be reduced under realistic conditions. One of our aims is to design a completely flexible body construction operation, meaning a production line that could be rapidly reconfigured for any number of different models of one manufacturer. Furthermore, the development of software tools and training concepts for supporting the technical staff are topics of our research.

The vision of the third competence field "Data- and Energy Management 2.0" is to shift the factory of the future from an energy consumer into a more active player on the energy market. Based on the volatility of energy supply, more flexibility in the demand can help industry not only save but earn money. Therefore solutions for a more intelligent load, storage, monitoring and forecasting system need to be developed and tested.

A fourth important research focus is to strengthen the role of human in future industrial production. Challenges arise as a result of demographic trends, increasing automation and flexibility as well as new opportunities offered by information and communication technologies. Age-appropriate production environments, new designs for human-machine interaction, and strategies for strengthen the creative and problem solving potential of human in the production process are some of the key research fields being addressed in the model factory.

In order to uncover and leverage existing potential savings, processes needs to be observed in their entirety, and manufacturing steps will first have to be broken down into individual increases in efficiency: starting from individual processes, and proceeding to process chains all the way to the factory level and even beyond, e.g. logistics and environmentally friendly generation and storage of energy. A holistic analysis and optimization depends on the availability and utilization of information about all necessary resources as well as material and energy flows in the factory. This data is being collected in the "Factory Cloud" of the E3-Forschungsfabrik. Here we can visualize and assess this data in real time using state of the art devices and develop even new concepts for information and communication technology.

All data of resources needed, such as compressed air, water, electrical energy, and machines and process data come together at the factory level in the "Factory Cloud".

CORE COMPETENCIES

FORMING TECHNOLOGIES

The increased demand for safety and comfort has led to cars becoming much heavier in recent years. Engines have become more powerful, leading to increased fuel consumption. Lightweight construction is a key technology in the struggle to counteract these trends and protect our resources and environment, while still producing safe, comfortable and powerful vehicles. The automobile manufacturing process is the focus of particular attention here, with the aim of reducing defects by driving up process stability, improving how materials are implemented to reduce cutting and waste, and shortening process chains in order to minimize material and energy consumption.

We have set for ourselves the challenge of looking at the entire process chain of sheet and bulk metal forming, as well as the design of factory and logistics systems. Our research focus is on car body and powertrain components. With a view to optimizing energy and material efficiency, we are developing solutions which systematically shorten the process chains involved in forming technology, e.g. by the application of innovative technologies, implement innovative processing technologies and ensure that forming tools are fit for their purpose and capable of handling the workload required of them.

In order to meet the demands facing the car of the future, we need to implement lightweight construction strategies that involve an optimal interplay between materials, construction and production processes. It only makes sense to use lightweight materials if their mechanical properties are better than traditional steel. This also has an impact on costs, and so we are currently researching forming and joining methods to find the optimal blend of high-strength steel, aluminum, magnesium and fiber-reinforced materials.

In the future, a number of different materials will go into the construction of mass-produced cars. The important thing is to use the right material in the right place. The choice of materials depends on a variety of different factors – chemical and physical properties, weight, the production facilities at one's disposal, the intended quality of the finished product, and last, but by no means least, recycling options. This makes it extremely important to both improve tried and tested hybrid construction joining methods and develop new ones.

Temperature-supported hydroforming is a process for producing complex components from materials that are difficult to work with at room temperature.

CORE COMPETENCIES

PRODUCTION SYSTEMS

Reducing processing times and increasing manufacturing precision are as important in the cost-efficient manufacture of tools for sheet metal and bulk metal forming as they are for the highly productive mass manufacture of components in the motor vehicle powertrain. The identification and implementation of the subsequent requirements, as far as the machine tool and its main sub-assemblies are concerned, represent a central focus of work at Fraunhofer IWU. These include increased acceleration and higher feed axis speeds, increasing the speed for HSC (high speed cutting) as well as machining operations, self-optimizing precision control and re-configurability.

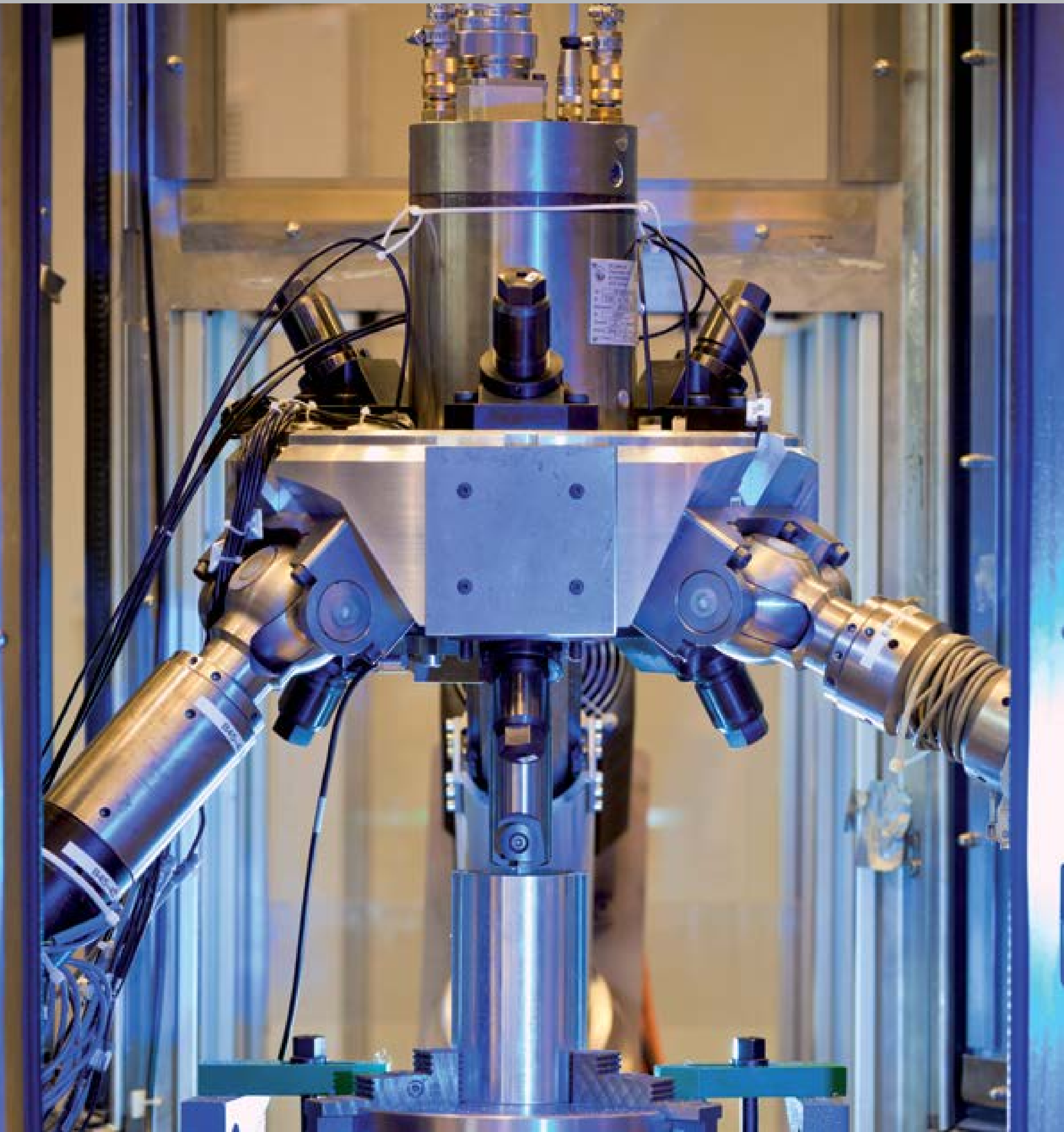
When it comes to achieving high dynamics, the most important factor is maintaining small loads. This objective can be realized both by applying new structural principles to the machines and through the consistent use of lightweight design techniques – for example, by using metal foams for sub-assemblies. In addition to the pre-emptive determination of characteristics by means of experimental investigations and finite element (FE) analysis, important areas of research include the simulation of movement and collision behavior in relation to machines, something that for example can be achieved with the help of Virtual Reality (VR).

VR allows us to view objects in three dimensions. This enables us to evaluate and assess engineering projects in a way that mirrors reality, even in the early stages of development. VR also gives us a virtual presentation of machines and plants while they are still in their early stages. The earlier we can incorporate changes into virtual prototypes, the lower our costs will be. Components can be integrated into control systems to improve accuracy. We are developing methods and tools for systematically designing and optimizing parallel kinematic machines. Electro-mechanical drives for generating principal and feed movements are the key sub-assemblies of machine tools which bear the crucial know-how for the entire system. The demand for resource efficiency is also making it increasingly important to be able to tailor the design of drives and structures to requirements. The use of large servo drives as the main drives for forming tools is evidence of this current trend.

Increasing manufacturing precision and eliminating cooling lubrication in dry machining are development trends that are of considerable importance in the area of thermal research. A thermally robust machine design and compensation for misalignments on machine tools resulting from thermal influences represent the most important challenges in this area.

This convertible servo press test rig, developed by the Fraunhofer IWU in partnership with Anchor Lamina GmbH, can be used to test different drive modules and assemblies, as well as methods for linking them together.

CORE COMPETENCIES



MECHATRONICS AND LIGHTWEIGHT DESIGN

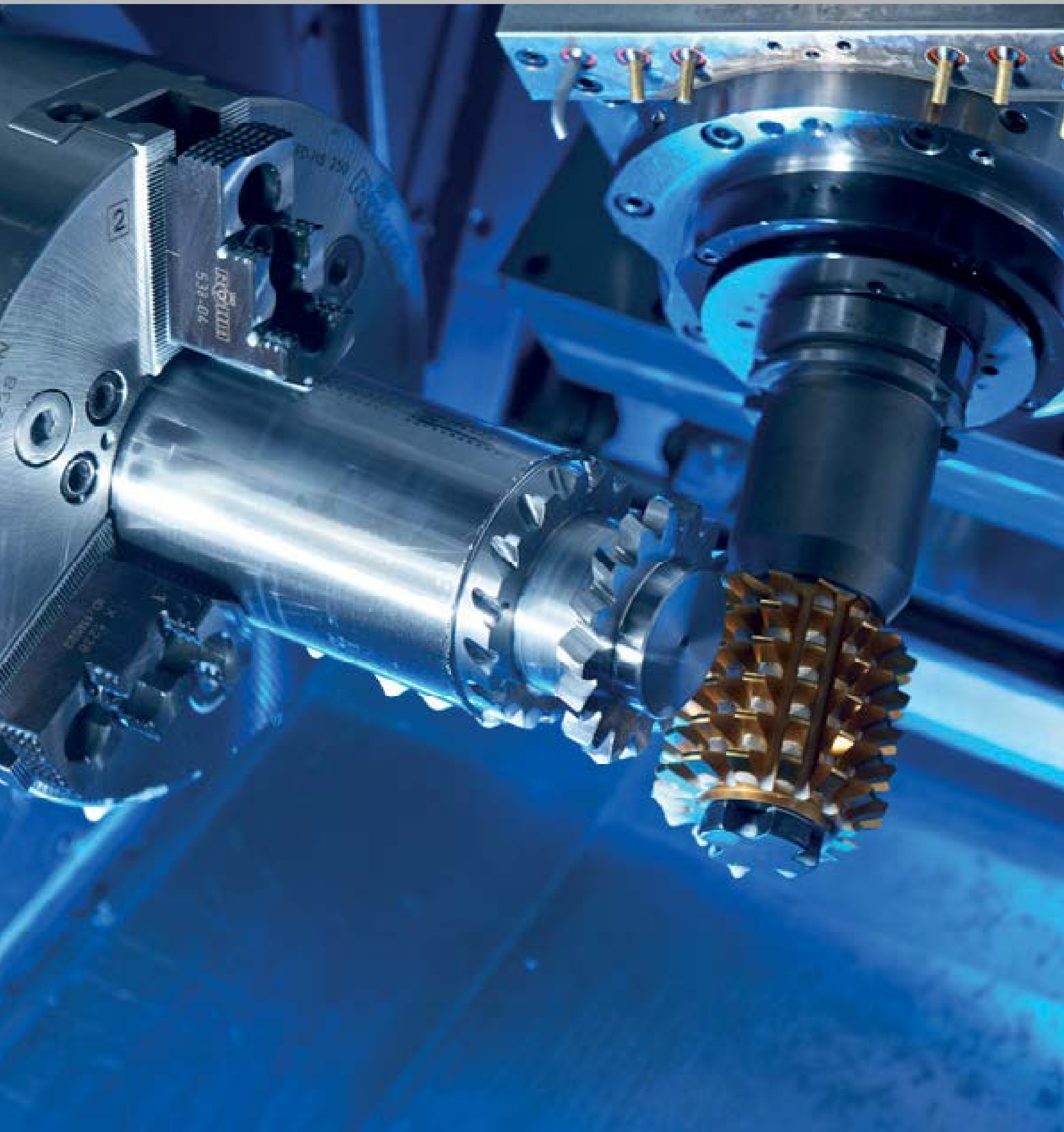
Mechatronics is an interdisciplinary field of activity related to mechanical engineering, electrical engineering and computer engineering. Sensors are integrated into production systems to record the current status of process and machine. The data is matched with open and closed loop control models; the optimum operating status is ultimately set by actuators. This means that a high level of efficiency can be guaranteed, even while taking into account variations in process and environmental conditions. A prerequisite for this is that the design of mechanical components, drives and open and closed loop electronics be coordinated down to the last detail.

Lightweight design offers enormous potential for resource-efficient mechatronic systems. Lightweight design means less weight in terms of the sub-assemblies to be moved and, in addition, is a synonym for the optimum application of materials and design principles that manage the load. At the same time bionic design, such as cellular structures, is emulated by means of metal foams or composite constructions such as sandwich structures and fiber composites for a bionic layout incorporating mechanical sub-assemblies. Additive manufacturing technologies, such as 3D laser beam melting or 3D printing, simultaneously provide additional scope in terms of geometry, material and quantities.

Adaptronics transforms the system methodology of mechatronics, targeting a high degree of functional compression through the integration of sensors and actuators in the material level. This calls for the use of composites such as piezo ceramics, shape memory alloys or active polymers with construction materials such as steel, aluminum or fiber plastic composites. The intentions are active components for machines and motor vehicles that will prevent faults such as distortions, vibrations or acoustic emissions at the point of onset. These measures are considerably more effective than pure design improvements and, since they are only active at the time and at the location of the fault, significantly more energy-efficient.

An adaptive spindle holder based on piezo actuators supports the vibration compensation in machine tools.

CORE COMPETENCIES



PRECISION IN MICRO AND MACRO

Improving the stability as well as the material and energy efficiency of machining processes while meeting the demand for finished components to involve less friction, be harder wearing and consume less energy are some of the challenges facing us today. This gives us a complex set of factors to look at, ranging from energy used in production processes, designing resource-efficient process chains, pushing process limits to develop process combinations or substitute operations, and developing specialized machining tools and engineering technology.

Our approaches to improving energy and resource efficiency involve switching to minimum quantity lubrication or dry machining, and using near-net-shape processes in conjunction with precision machining methods.

The components used in aviation, automobile manufacturing as well as energy and medical technology sectors are becoming increasingly complex and sophisticated. They also need to be lighter, often thinner, yet at the same time more resistant. We need materials and processes which can meet these new requirements. Fraunhofer IWU is developing efficient machining solutions for high-strength materials, material composites and composite materials.

We apply our precision and micro manufacturing techniques to powertrain components as well as components for medical and optical applications. Demand is high for the processes, technologies and equipment required for high-precision manufacturing of components and structures in a stable process, some of which are extremely small. The increasing focus on resource efficiency has shone the spotlight on micro manufacturing technologies, as they can be used to optimize the tribological properties of components to reduce friction and wear.

Numerical simulation plays an important role in improving machining processes. Simulation methods like the Finite Element Method (FEM) allow us to delve deeply into the complex interactions involved in machining. Hardware and software advances allow us to create increasingly detailed models of chip and burr formation, tool designs, tool and workpiece machining techniques, and coating-substrate systems and determine how process forces and temperatures influence component behavior. Our simulations are closely linked to actual experiments so that our findings are as realistic as possible.

Integrating milling into turning machines reduces lead times and costs significantly.

Imprint

Fraunhofer Institute for Machine Tools
and Forming Technology IWU
Reichenhainer Strasse 88
09126 Chemnitz, Germany

Phone +49 371 5397-0
Fax +49 371 5397-1404
info@iwu.fraunhofer.de
www.iwu.fraunhofer.de

Directors

Executive Director
Prof. Dr.-Ing. Welf-Guntram Drossel
welf-guntram.drossel@iwu.fraunhofer.de

Director
Prof. Dr.-Ing. Martin Dix
martin.dix@iwu.fraunhofer.de

Director
Prof. Dr.-Ing. Reinhard Mauermann
reinhard.mauermann@iwu.fraunhofer.de

Public Relations

Jan Müller
jan.mueller@iwu.fraunhofer.de

Photo acknowledgments