







# Activity Report

10

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# Content

## Preface

<b>1</b>	<b>Education</b>	<b>1</b>
1.1	Lectures	1
1.2	Offered Courses - Content	3
1.3	The New International Master's Program Master of Science in Manufacturing Technology (MMT)	12
1.4	Doctoral Theses	15
1.5	Completed Master Theses	17
1.6	Completed Bachelor Theses	17
1.7	Completed Diploma Theses	19
1.8	Completed Student Theses	21
1.9	Project Theses	23
2	Research for Education	24
2.1	Project TeachING-LearnING.EU	25
2.2	PeTEX – Platform for e-Learning and Telemetric Experimentation	28
2.3	Full Automation of Telemetric Compression Test Procedure	30
2.4	Integrated and Research-Oriented Laboratory	31
2.5	A New Modular Educational Program in Production Engineering	32
2.6	MasTech – Flexible Modular Master Program in Technology	33

<b>3</b>	<b>Research</b>	<b>34</b>
<b>3.1</b>	<b>Coordinated Research Programs</b>	<b>35</b>
3.1.1	Collaborative Research Center SFB Transregio 10	35
3.1.2	DFG PAK 250 Identification and Modeling of Material Behavior for the Finite-Element Analysis of Sheet Metal Forming Processes	36
3.1.3	DFG PAK 343 Development of a Methodology Regarding Combined Quasistatic and Dynamic Forming Processes	37
<b>3.2</b>	<b>Department of Bulk Metal Forming</b>	<b>38</b>
3.2.1	Multi-Axis Curved Profile Extrusion	39
3.2.2	Composite Extrusion	40
3.2.3	Simulation of Composite Extrusion Processes	41
3.2.4	Efficient Extrusion Simulation for Industrial Applications	42
3.2.5	Thermomechanical Processing of Aluminum Alloys after Extrusion	43
3.2.6	Alternative Paths for the Manufacture of Screw Rotors by Forming	44
3.2.7	Recycling of Aluminum Chips by Metal Forming	45
3.2.8	Enhancement of the Extrusion of Aluminum Chips by an ECAP Process	46
3.2.9	Microstructure Evolution during Extrusion	47
3.2.10	Development of a Hybrid Forging Process for Highly Stressed Vehicle Components in Lightweight Construction	48
3.2.11	Component Optimization by Forging of Composite Aluminum Extrusions	49
3.2.12	Basic Investigations on Hollow Lateral Extrusion of Additional Shape Elements	50
3.2.13	Analysis of the Active Correlation between Heat Treatment and Distortion of Cold Forging Workpieces	51

3.2.14	Investigation and Improvement of a Manufacturing Process Chain Covering Cold Drawing Processes through to Induction Hardening	52
<b>3.3</b>	<b>Department of Sheet Metal Forming</b>	<b>53</b>
3.3.1	Process Design of Hot Sheet Metal Forming	54
3.3.2	Hot Forming of Tubes and Profiles by Shapeless Solids	55
3.3.3	Process Design for the Forming of Organically Coated Sheet Metal	56
3.3.4	Processing of New Solar Absorbers in Steel Design Based on Partial Cold Roll-Bonded Hybrid Semi-Finished Parts	57
3.3.5	Manufacturing of Positively Locked Polymer-Metal-Hybrid Parts by Combining Injection Molding and Sheet Metal Forming	58
3.3.6	A Fundamental Investigation on the Combined Injection Molding – Sheet Metal Forming Process	59
3.3.7	Development of Concrete Dies for Sheet Metal Hydroforming	60
3.3.8	Development of a Hybrid Deep Drawing Tool Using Locally Structured Surfaces	61
3.3.9	Strategies for Springback Compensation	62
3.3.10	Identification of Material and Friction Models as well as Corresponding Parameters by Means of the Inverse Method	63
3.3.11	Analysis of Strain-Path Dependent Damage and Microstructure Development for the Numerical Design of Sheet-Bulk Metal Forming Processes	64
3.3.12	Development of an Industry-Oriented Failure Model for Sheet Metal Forming Simulations of Advanced High Strength Steels (AHSS)	65
3.3.13	Time Efficient Modeling and Calculation of Process Chains in Sheet Metal Forming and Processing	66

<b>3.4</b>	<b>Department of Bending Technology</b>	<b>67</b>
3.4.1	3D Bending of Profiles Using Stress Superposition	68
3.4.2	ProTuBend - Flexible and Cost-Effective Innovative Manufacturing of Complex 3D-Bent Tubes and Profiles Made of High-Strength Steels for Automotive Lightweight Structures	69
3.4.3	Investigation and Development of a Process and a Machine Technology for Incremental Tube Forming	70
3.4.4	Investigation of Springback Compensation in Sheet Metal Bending Processes by Incremental Compressive Stress Superposition	71
3.4.5	Development of Basics for the Selection and Process-Reliable Design of Bending Procedures to Manufacture Profiles Made of Innovative Steel Materials	72
3.4.6	Defect Analysis and Prediction in Bending Processes	73
<b>3.5</b>	<b>Department of Non-Conventional Processes</b>	<b>74</b>
3.5.1	Process Development for Combined Conventional and Electromagnetic Forming Operations	75
3.5.2	Investigation of the Complex Interdependencies in Electromagnetic Tube Forming	76
3.5.3	Joining by Forming	77
3.5.4	Surface Treatment of Thermally Sprayed Hard Material Coatings for the Application in Forming Tools	78
3.5.5	Application of Statistical Methods for Process Design and Optimization in Necking-In Processes	79
3.5.6	Process Development for Manufacturing of Load-Optimized Parts by Incremental Forming of Thick Metal Sheets	80
3.5.7	Characterization of the Dynamical Process of Incremental Sheet Metal Forming	81
3.5.8	Investigation of the Deformation Behavior of Thermoplastics during Incremental Cold Forming	82
3.5.9	Creation of a Material Model for Numerical Investigations on Forming of Laminar Thermoplastic Polymers	83



3.6	Patents	84
3.6.1	Process and Apparatus for Incremental Forming of Profiles, in Particular of Profiles with Varying Cross Sections (RoProFlex)	84
3.6.2	Process for the Manufacturing of Compound Workpieces with Reinforcing Structures as well as Accordingly Manufactured Workpieces (CompForm)	85
3.6.3	Expansion and Joining Apparatus Operating by Means of Hydroforming	86
3.7	Cooperations	87
<b>4</b>	<b>Further Activities</b>	<b>93</b>
4.1	Conferences and Meetings	93
4.2	Equal Opportunities Activities: Holiday Care for School Children at the IUL	104
4.3	Awards	105
4.4	Further Education	107
4.5	Participation in National and International Organizations: Prof. Dr.-Ing. A. Erman Tekkaya	111
4.6	Participation in National and International Organizations: Prof. Dr.-Ing. Matthias Kleiner	114
<b>5</b>	<b>International scientists at IUL</b>	<b>116</b>
<b>6</b>	<b>Technical Equipment</b>	<b>120</b>
6.1	Experimental Area	120
6.2	Hardware Equipment	123
<b>7</b>	<b>Publications and Lectures</b>	<b>Middle Part</b>
<b>8</b>	<b>Staff</b>	<b>Middle Part</b>

## Preface

Dear reader,

Having faced six on-site project reviews, the year 2010 has been a demanding but very successful year for all IUL staff members. The IUL mastered all reviews with success and we are proud of the excellent outcome of this memorable year. That is why we would like to start by thanking the magnificent IUL team and our faithful partners.

The present activity report comprises the IUL's diverse activities in education and research, in the transfer of knowledge and services to economy and society as well as in our intensive inter-national cooperation. This year the report's structure has been slightly changed. The research projects are no longer listed by project type, meaning in chronological order, but according to the four main research areas of the IUL. This new structure is supposed to give readers a better overview of the research projects pertaining to the institute's main areas.

The introduction of the chapter „Research for Education“ is another innovation of this activity report. Taking the view that “excellent education is based on excellent research and excellent research requires excellent education”, the IUL has been increasingly involved in education in recent years - motivated by the changes in global industrial activities, demographic changes, and rapid technological developments. Here, one essential concern is the topic of diversity. In this context, the international master's program “Master in Manufacturing Technology” (MMT) has been accredited in the period under report, which has been developed for the last three years with the IUL in charge. This new master's program will educate outstanding students from Germany and abroad in the field of production engineering.

Dr.-Ing. Alexander Brosius was offered a junior professorship for modeling and simulation in forming technology and lightweight construction – this was very pleasant news for the institute. Professor Brosius works at the IUL since 2002 and obtained his doctorate in 2005 on the subject of modeling of electromagnetic forming. Since 2006 he was head of the high speed forming department and since 2007 research associate and senior engineer responsible for research. Apart from being spokesman of the DFG research proposal PAK 250 “Identification and Modeling of Material Characteristics for the Finite Element Analysis of Sheet Metal Forming Processes”, funded by the German Research Foundation, Professor Brosius is in charge of several research projects. In 2009 he became Research Affiliate of CIRP. The institute considers itself fortunate that such an excellent and talented young scientist is among its staff members.

In order to improve the scientific guidance of staff members the IUL management was restructured in 2009. Dr. Michael Trompeter became second senior engineer responsible for research. The high speed forming department was converted into the new department for special processes. This year brought changes as to the direction of the department for special processes and the department for sheet metal forming as well as to the management of the Collaborative Research Center SFB/TR10.

In 2010 the IUL established an Industrial Advisory Board which held its constitutive session in September. The advisory board aims at advising the institute with regard to new research topics and intends to transfer IUL research results directly to industrial application. We would like to take the opportunity to thank these highly esteemed representatives from industry for their support.

Finally, we would like thank all those institutions promoting our research, the numerous industrial enterprises as well as university colleagues cooperating with our institute.



*M. Kleiner*

Matthias Kleiner



*A. E. Tekkaya*

A. Erman Tekkaya

Prof. em. Dr.-Ing. Eberhard Graf Finck v. Finckenstein  
\* 9. Dezember 1932 † 19. Dezember 2010

Wir trauern um den großen Wissenschaftler, renommierten akademischen Lehrer, steten Mentor und geschätzten Kollegen, der uns ein Vorbild bleibt.

Eberhard v. Finckenstein absolvierte eine technische Ausbildung und ein ingenieurwissenschaftliches Studium mit anschließender Promotion und Habilitation an der Universität Hannover. Als junger Hochschullehrer gründete er den Lehrstuhl für Umformende Fertigungsverfahren an der Universität Dortmund, aus dem das heutige Institut für Umformtechnik und Leichtbau hervorgegangen ist.

Eberhard v. Finckenstein etablierte sich in Wissenschaft und Forschung auf nationaler und internationaler Ebene mit viel beachteten Arbeiten der Produktionstechnik in einer großen Bandbreite von Grundlagenforschung und deren Anwendungspraxis. Er vermittelte seinen Studierenden, Doktoranden und Mitarbeitern das Bewusstsein für Qualität, Solidität und Bescheidenheit und lehrte alle, Neugier, Erkenntnis und das kritische Hinterfragen in den Mittelpunkt zu stellen. Das hat uns geprägt und dafür sind wir dankbar.

*Prof. Dr.-Ing. Matthias Kleiner                      Prof. Dr.-Ing. A. Erman Tekkaya*  
*Für das Team*  
*des Instituts für Umformtechnik und Leichtbau*



# 1 Education

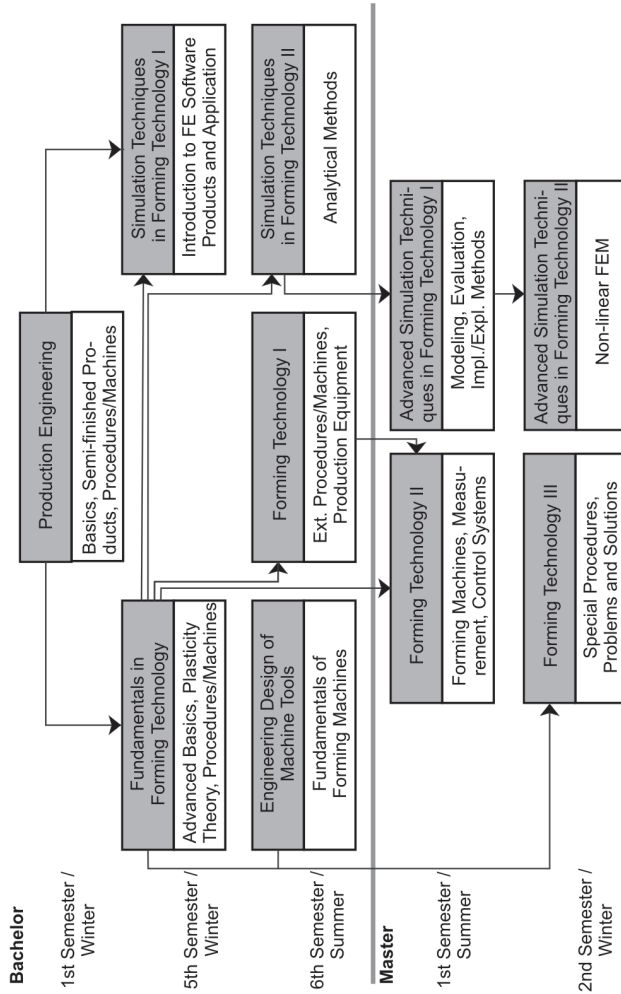
## 1.1 Lectures

The new bachelor courses Mechanical Engineering, Industrial Engineering and Management, and Logistics have started successfully in winter semester 2008. The necessary revision of courses and lectures has largely been finished (see figure on the right: mechanical engineering, focus on production engineering). The master courses started in summer semester 2010.

The lecture "Production Engineering" is provided in cooperation with the Institute of Machining Technology (ISF) and scheduled for all courses of studies stated above. The part of the IUL imparts basic knowledge in forming technology with main focus on manufacturing of semi-finished products and important procedures in massive forming and sheet metal forming. The subsequent lectures "Fundamentals in Forming Technology" and „Forming Technology I and III“ deepen this technological basic knowledge with a detailed presentation of advanced theoretical basics, relevant forming procedures, and necessary process chains.

Knowledge about forming machines and the according competences with respect to instrumentation, control, and automation is presented in the lectures „Engineering Design of Machine Tools“ and "Forming Technology II". Furthermore, the compulsory modules "Virtual Production Techniques I-II" and "Advanced Simulation Techniques I-II" offer the necessary basics on numerical simulation of forming processes.

Restructured lectures illustrated by the example of mechanical engineering, focus on production engineering





## 1.2 Offered Courses - Content

The Institute of Forming Technology and Lightweight Construction teaches mainly bachelor and master students majoring in logistics, industrial engineering, and mechanical engineering. In addition, the lectures are attended by students of education, computer science, and physics in their minor subject. In this way, the students gain the knowledge and skills which are necessary for a successful career entry in industry or research. In the following, the individual lectures are presented.

### Production Engineering – Subject “Forming Production”

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. habil. S. Chatti  
Dipl.-Ing. C. Becker

In cooperation with the Institute of Machining Technology

Scope 2 L  
Date winter semester

#### Content IUL

The lecture „Production Engineering“ gives students a general view of the processes and machines used in production technology. The lecture is held in cooperation with the Institute of Machining Technology (ISF). The ISF starts with an introduction to machining technology and the IUL subsequently schedules a presentation of primary shaping and forming within six sessions.

- Product examples, forming production, process overview
- Relevant basics
- Overview of primary shaping processes
- Bulk forming processes: rolling, compression/forging, and extrusion

- Sheet metal forming processes: die bending/swivel bending, stretch drawing, and deep drawing
- Lightweight construction and outlook on advanced lectures in forming

## Fundamentals in Forming Technology

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. habil. S. Chatti • Dipl.-Ing. Q. Yin  
Dipl.-Wirt.-Ing. D. Pietzka • Dipl.-Ing. A. Jäger

Scope 2 L + 1 T

Date winter semester

The lecture „Fundamentals in Forming Technology“ gives a detailed introduction to forming technology and extensively discusses the theoretical basics.

- Metallurgical fundamentals in forming technology
- Flow curve, theory of plasticity, and friction model
- Strip, disc, and tube model
- Material characterization
- Membrane theory
- Analytical methods, computing methods (load bounding method)
- Forming limit curves (FLC)
- Bulk forming processes (rolling, profile rolling, compression, forging, extrusion, wire drawing)
- Sheet metal forming processes (die bending, swivel bending, stretch drawing, deep drawing)
- Cutting and joining
- Overview of forming machines
- Laboratory lecture with guided tour illustrating the individual forming processes

## Forming Technology I / Forming Technology in Industrial Engineering and Management

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. habil. S. Chatti  
Dr.-Ing. Dipl.-Wirt.-Ing. M. Marré

Scope 2 L + 1 T  
Date summer semester

The lecture „Forming Technology I“ is based on the lecture „Fundamentals in Forming Technology“. Important forming processes, process chains as well as tools and materials which have not yet been discussed are explained in detail.

- Extrusion I – Basics and standard methods
- Extrusion II – Process chain, failure, and economic efficiency
- Manufacturing of profiles by roll forming
- Reducing, ironing, and drawing
- Metal spinning processes
- Profile bending and tube bending
- High pressure forming
- Working media-based sheet metal forming
- Materials in forming technology
- Seminar lectures

### Aspects concerning all forming processes

- Process principle and variations
- Analytical modeling (state of stress, state of strain)
- Force path during the forming process
- Failure examples
- Technological information (machinery, tools)

## Engineering Design of Machine Tools

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. M. Trompeter • M.Sc. V. Franzen

In cooperation with the Institute of Machining Technology (ISF)

Scope 2 L + 2 T

Date summer semester

### Content IUL

The lecture „Engineering Design of Machine Tools“ introduces the relevant fundamentals with regard to the design of production engineering machine tools. The lecture is held in cooperation with the Institute of Machining Technology and is structured as follows:

- Introduction
- Frames/guidings
- Gears/engines
- Control and sensors
- Work-linked presses
- Stroke-linked presses
- Force-linked presses
- Press design
- Bending and rolling machines
- Servo presses and special purpose machines

## Simulation Methods in Forming Technology I/ Methods of Virtual Production II

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. habil. S. Chatti  
Dipl.-Ing. F. Steinbach

Scope 2 L + 1 T  
Date winter semester

The lecture „Simulation Methods in Forming Technology I/ Methods of Virtual Production II“ provides a detailed introduction to FEM which is illustrated by various examples from the field of forming technology. Apart from different means of time integration and essential element types students become acquainted with diverse simulation software within the scope of the lecture as well as the tutorial. Furthermore, different means of optimization by using FEM simulations are being discussed.

- Introduction
- Introduction to FEM basics
- Solutions strategies by means of examples
- Introduction to ABAQUS
- Modeling and simulation with ABAQUS
- ABAQUS: Model and simulation optimization
- Introduction to LS-DYNA
- Modeling and simulation with LS-DYNA
- LS-DYNA: Model and simulation optimization
- Presentation of further FE programs
- Examples from practical experience

## Simulation Methods in Forming Technology II/ Methods of Virtual Production I

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. A. Brosius  
Dipl.-Ing. J. Witulski • M.Sc. A. Güzel • M.Sc. A. Güner

Scope 2 L + 1 T  
Date summer semester

The lecture "Simulation Methods in Forming Technology II/ Methods of Virtual Production I" presents forming technology methods used for modeling of forming operations.

- Application examples (process simulation, component layout etc.)
- State of deformation & state of stress (basics, special cases, von Mises criterion / Tresca criterion, introduction to anisotropy)
- Flow criteria, flow curve, flow rule, parameter identification
- Specification of analytical, semi-analytical, and numerical approaches
- Slip-line theory, upper-bound method, and membrane theory
- Thermodynamics in forming technology
- Introduction to tribology
- Introduction to the Finite-Element-Method (FEM) and Finite-Volume-Method (FVM) including interpretation and application

## Forming Technology II

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. M. Trompeter  
Dipl.-Ing. M. Hermes

Scope 2 L + 1 T  
Date summer semester

The lecture „Forming Technology II“ gives an even more detailed overview of forming machinery. Complex machinery as well as machine tools are explained, knowledge about sensors and control systems of forming machinery is broadened. The theoretical background is deepened by means of seminars and practical examples.

- Machinery and tools
- Sensors and control systems
- Automation
- Modern drive technology, hydraulics

## Forming Technology III

Prof. Dr.-Ing. A. E. Tekkaya • Dr.-Ing. V. Psyk • Dr.-Ing. habil. S. Chatti  
Dr.-Ing. M. Trompeter • Dipl.-Ing. T. Kloppenborg

Scope 2 L + 1 T / field trip  
Date winter semester

The lecture „Forming Technology III“ deals with special procedures of forming technology.

- Superplastic forming
- High-speed forming processes
- Incremental forming
- Thixoforming
- Special extrusion procedures

- Micro forming procedures
- Hot sheet metal forming
- Project work and field trip

## **Industrial Lecture Course**

Industrial Field Reports  
Prof. Dr.-Ing. A. E. Tekkaya et al.

Scope 2 L  
Date winter semester, summer semester

In this lecture course, different guest speakers from industry provide first-hand insight into practical applications. To ensure a broad professional exchange this lecture course addresses students of different majors as well as university research and industrial staff. The course covers the subjects of sheet metal forming and bulk forming.

## **Specialist Laboratory A for Students of Mechanical Engineering**

Within the scope of the specialist laboratory the students of mechanical engineering carry out one of the following tests, depending on winter or summer semester:

- Hydraulic deep drawing test and tensile test
- Material characterization by a tensile and compression test

After teaching the theoretical aspects and testing the knowledge of the students, experimental tests are carried out and the required data is acquired. Afterwards, the tests are simulated in order to e.g. find out the friction coefficient in compression tests. The evaluation of the results is carried out by means of a scientific report which has to be prepared by student groups of up to four students.



## Specialist Laboratory B for Students of Industrial Engineering

Within the scope of this specialist laboratory the students carry out a uniaxial flat tensile test on the universal testing machine ZWICK Z250 in the winter semester. The material specific data is recorded during the test and evaluated concerning its suitability for forming processes. The tests and the results achieved are then summarized in a scientific laboratory report.

### Seminars

The following seminar topics were offered in the summer semester 2010 within the scope of the lectures „Forming Technology I“ and „Forming Technology in Industrial Engineering and Management“:

- Manufacturing of extruded profiles by chip recycling
- Manufacturing of profiles
- Manufacturing of tubes
- Bending of tailored semi-finished parts
- Extrusion and drawing of semi-finished parts
- High pressure forming of tubes and profiles
- Working media-based sheet metal forming

Furthermore, a continuum mechanics seminar was held by Prof. Dr.-Ing. Peter Haupt.

### Additional Seminars

- CAD with Catia-V5 for beginners
- CAD with Catia-V5 for advanced students
- Basics und application of GOM measuring systems for 3D digitalization and deformation measurement
- Introduction to the simulation of bulk forming procedures with Deform
- Introduction to metrology with GOM systems

### 1.3 The New International Master's Program Master of Science in Manufacturing Technology (MMT)

Program starts	as of October 2011
Coordination	Prof. Dr.-Ing. A. E. Tekkaya M.Sc. M.Eng. C. Pleul Dipl.-Ing. D. Staupendahl

A new international Master's program focusing on production engineering has been developed in the last three years under the direction of the IUL and was accredited by the accreditation agency ASIIN on October 1, 2010. The program was drawn up in cooperation with the Institute of Machining Technology, the Institute of Mechanics, the Institute of Materials Engineering, the Chair of Industrial Engineering, the Chair of Industrial Robotics and Production Automation, and the Chair of Measurement and Test Engineering.

The „Master of Science in Manufacturing Technology“ (MMT) is an English-language four-semester Master's program which will be offered for the first time in the winter semester 2011. The Master's Program is geared towards dedicated and highly motivated students and graduates of renowned German and foreign universities with main emphasis on international students. Chosen students will be able to study on a scholarship for the duration of the program.

#### Program contents and profile

Mechanical engineers are significant pioneers for progress and development in the field of industrial production. Germany as a location for business is characterized by excellent industrial production and scientific research at international level. Due to the increasing complexity of mechanical engineering developments a comprehensive understanding of the coherences within and between the individual fields of mechanical engineering is essential. Owing to an increasing globalization in the production sector cross-cultural communication has become a decisive criterion for success. English being the language of instruction, students become prepared for the integration in international networks. The Master's program „Master of Science in Manufacturing Technology“ equips students with detailed

knowledge, skills, and competences in the field of interdisciplinary production engineering. Researching learning represents a key component in this context. For this purpose, students are offered lectures and courses at different chairs and institutes of the Faculty of Mechanical Engineering. Thanks to the program's language being English and its international structure as well as due to the close co-operation with renowned industrial companies students receive the best possible preparation for a professional career in the production sector.

## Program structure

During the first two semesters students will gain profound knowledge in machining technology, materials science, and forming technology. In addition, students chose three elective modules according to their personal interests.

The third semester is characterized by project and laboratory work, teaching students the competence of applying theoretical knowledge in practical applications. The module „Interdisciplinary qualification“ is geared to impart soft skills as well as language skills in order to prepare students for their later profession.

The master's thesis is scheduled for the fourth semester.

	1st semester	2nd semester	3rd semester	4th semester
<b>Comp. module 1</b>	Machining technology			
<b>Comp. module 2</b>	Materials technology			
<b>Comp. module 3</b>	Forming technology			
<b>Elective module 1</b>	Elective 1 - Part 1	Elective 1 - Part 2		
<b>Elective module 2</b>	Elective 2 - Part 1	Elective 2 - Part 2		
<b>Elective module 3</b>	Elective 3 - Part 1	Elective 3 - Part 2		
<b>Laboratory work</b>			Laboratory work	
<b>Project work</b>			Project work	
<b>Interdiscipl. qual.</b>			Interdiscipl. qual.	
<b>Master's thesis</b>				Master's thesis

Overview of the MMT master's program curriculum

The following elective modules are offered:

- Automation and robotics
- Simulation methods in solid mechanics
- Work system and process design
- Advanced processes and methods in manufacturing technology
- Metrology, digital processing, and dynamic feedback control

### **Learning and researching in international teams**

Extensive laboratory work comprises practical investigations on chosen production engineering contents, leading students to solve problems independently. The laboratory work being organized as group work encourages the students' ability to work in a team.

Scientific project work which shall be carried out in close cooperation with leading industrial enterprises includes a seminar paper to be issued as group work. Students will be qualified for a critical classification of scientific findings and will be able to apply theoretical knowledge. By working in an intercultural team and finally presenting the results the students' social and presentation skills are trained.

### **Graduates' career outlook**

The demand for engineers is still high. As the economic crisis has been overcome, orders in the production sector increase and, thus, the need for highly qualified engineers. Therefore, professional prospects for graduates are excellent. Engineers from the field of production engineering are ready to meet interesting challenges, their earnings and employment prospects are promising. They have a wide range of professional activities to choose from, starting from the development of new processing techniques through to the planning of complex production lines.

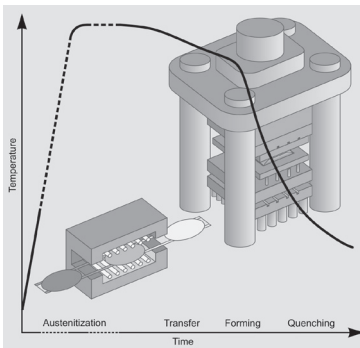
Finally, the degree „Master of Science in Manufacturing Technology“ not only qualifies graduates for a profession, but also to do their doctorate.

## 1.4 Doctoral Theses

Karbasian, Hossein	Shape Accuracy and Mechanical Properties of Hot Stamped Parts
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2010
Oral Examination	June 7 <sup>th</sup> , 2010
Primary advisor	Prof. Dr.-Ing. M. Kleiner
Co-advisor	Prof. Dr.-Ing. A. E. Tekkaya Prof. Dr.-Ing. M. Merklein

The production of high strength steel components with desired properties by hot stamping requires a profound knowledge and control of the forming procedures. In this way, the final part properties become predictable and adjustable on the basis of the different process parameters and their interaction. In addition to parameters of conventional cold forming, thermal and microstructural parameters complicate the description of mechanical phenomena during hot stamping, which are essential for the explanation of all physical phenomena of this forming method.

In this work, geometrical and mechanical properties of hot stamped parts with different process strategies are analyzed, which are essential for an optimal process design on the basis of the interaction between the process parameters. The relevance of major influencing variables could be investigated by means of the physical backgrounds, the FE simulation and the experimentally determined reference values. The Investigation of physical procedures could be summarized as guidelines for the process control of hot stamping, which are necessary for tool design and process control.



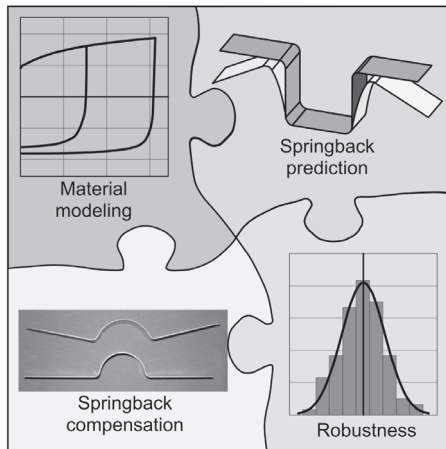
Process Chain: Hot Stamping

Gösling, Marco      Meta-Model Supported Simulation  
and Compensation of Springback  
in Sheet Metal Forming Processes

Series                  Dortmund Umformtechnik  
Publisher              Shaker Verlag, Aachen, 2009  
Oral Examination    June 7<sup>th</sup>, 2010  
Primary advisor      Prof. Dr.-Ing. M. Kleiner  
Co-advisors          Prof. Dr.-Ing. A. E. Tekkaya  
                                Prof. Dr.-Ing. K. Roll

Topic of this thesis is the simulation and compensation of springback in sheet metal forming processes. Springback after forming operations results in a deviation from the desired shape which needs to be compensated. The prediction of springback by Finite Element Analysis (FEA) is analyzed with special focus on material modeling and material characterization. Thereby, springback behavior for the hat shape drawing test was found to be predictable with relative deviations smaller than 5%.

Further emphasis is put on springback compensation with regard to process robustness. Robustness is evaluated using a Monte Carlo approach in combination with a meta-model. Here, the overall numerical costs could be reduced by about 70% in comparison to a quasi Monte Carlo approach.



Aspects of Springback Compensation

## 1.5 Completed Master Theses

### **Gangaputra, Rajan**

Supervisor: Tekkaya, A.E. • Pleul, C.

Automated Material Characterization Using A Remotely Controlled Robot

### **Isik, Kerim**

Supervisor: Tekkaya, A. E. • Soyarslan, C.

Predictive Performances of Various Failure Criteria in Formability of Sheets

### **Rudner, Thomas**

Supervisor: Remmel, J. (TFH Bochum) •

Jäger, A.

Investigations on the Material Flow in Co-Extrusion of Wrought Aluminum Alloys

## 1.6 Completed Bachelor Theses

### **Bouallegue, Houcem**

Supervisor: Tekkaya, A. E. • M. Gharbi, M.

Abel, H.-J. (FH Dortmund)

Finite Element Modeling and Simulation of Air Bending Process with FE-code LS-DYNA

### **Elhelou, Adnan**

Supervisor: Tekkaya, A. E. • M. Gharbi, M.

Abel, H.-J. (FH Dortmund)

Finite Element Modeling and Simulation of Roll Forming Process with FE-code LS-DYNA

**Elkhatibi, Marouane • Jebali, Hamdi**

Supervisor: Abel, H.-J. (FH Dortmund) • Tekkaya, A. E.  
Weinrich, A.

Springback Compensation in Sheet Metal Bending by Means  
of Incremental Stress Superposition

**Keskin, Aynur**

Supervisor: Tekkaya, A. E. • M. Gharbi, M. • Weinrich, A.  
Becker, C. • Abel, H.-J. (FH Dortmund)

Literature Research on Analytical Considerations of Bending  
Processes

**Laakel, Omar**

Supervisor: Tekkaya, A. E. • Abel, H.-J. (FH Dortmund)  
Becker, C.

Development of a Flexible Frame for a Tube Forming Machine

**Mardhiono, Hendy**

Supervisor: Abel, H.-J. (FH Dortmund) • Tekkaya, A.E.  
Rauscher, B.

Analysis of Process Parameters when forming Innovative  
Semi-Finished Sheet Metal Products by the Melt Pressure of  
an Injection Molding Machine

**Szymanski, Michael**

Supervisor: Abel, H.-J. (FH Dortmund) • Tekkaya, A. E.  
Ben Khalifa, N.

Development and Construction of a Device for the Investigati-  
on of Flow Curves by Means of Hot Torsion Tests



## 1.7 Completed Diploma Theses

### **Andreas, Robert**

Supervisor: Tekkaya, A. E. • Rauscher, B.

Manufacturing of Cylindrical, Positively Joined Plastic-Metal-Hybrid Structures by an Integrated Forming and Injection Molding Process

### **Atak, Mustafa**

Supervisor: Tekkaya, A. E. • Pleul, C.

Design and Kinematic Simulation of a Flexible Robot Workstation for the Automation of a Materials Testing Machine

### **Bartels, Matthias**

Supervisor: Weber, H.(WILO SE) • Tekkaya, A. E. • Rauscher, B.

Manufacturing of Permanent Magnets for Highly Efficient Pumps

### **Bozkurt, Mustafa:**

Supervisor: Tekkaya, A. E. • Hermes, M.

Production Chain of an Electronic Box – Analysis and Improvement

### **Chaker, Wassim**

Supervisor: Tekkaya, A. E. • M. Gharbi, M.

Lueg, J. (FH Dortmund)

Roll Design and FE Simulation of Roll Forming Processes Using COPRA

### **Enders, Michael**

Supervisor: Tekkaya, A. E. • Yin Q.

Construction and Design of a Torsion Test Setup for Sheet Materials Using CAD and FEM

### **Fischer, Bernhard**

Supervisor: Tekkaya, A. E. • Franzen, V.

Development of a Multi-Axes Force Transducer for the Application in Incremental Sheet Metal Forming

**Myslicki, Sebastian**

Supervisor: Tekkaya, A.E. • Hänisch, S.

Influence of Heat Treatment on the Residual Stresses of Cold Formed Components

**Plugge, Björn**

Supervisor: Tekkaya, A.E. • Chatti, S. • M. Gharbi, M.

Investigations on Roll Forming of Ultra High-Strength Steels

**Rödding, Daniel**

Supervisor: Tekkaya, A.E. • Graff, S. (TKS) • Karbasian, H.

Investigation on the Significance of DIN Standard Draft ISO/DIS 12004-2 for the Manufacturing of Forming Limit Curves of Experimental and Simulated Nakajima Tests for the Use in Cold and Warm Forming Processes

**Sieczkarek, Peter**

Supervisor: Tekkaya, A.E. • Becker, D. • Selvaggio, A.

Engineering and Simulation of a Die for the Extrusion of Profiles with Variable Cross Sections

**Zhang, Lijin**

Supervisor: Tekkaya, A.E. • Jäger, A.

Development of a Process and the Equipment for the Integrated Forming of Aluminum Profiles Subsequent to Hot Extrusion

**Zumsande, Kathrin**

Supervisor: Tekkaya, A.E. • Karbasian, H. • Kuhn, Patrick (Dortmunder OberflächenCentrum, ThyssenKrupp Steel Europe AG)

Influence of Aluminum on the Crack Formation of Zinc-Based Coatings in Direct Hot Forming Processes

## 1.8 Completed Student Theses

### **Althoff, Jörn**

Supervisor: Tekkaya, A. E. • Pleul, C.

Literature Research on the Topic: Tribological Aspects of Forming Procedures

### **Assraoui, Hicham**

Supervisor: Tekkaya, A. E. • Gharbi, M. M.

Investigation of Strain Distribution During Roll Forming Processes Using COPRA

### **Braun, Alexander**

Supervisor: Tekkaya, A. E. • Güley, V.

Construction of a Chip Compaction Device, a Chip Breaker, and a Chip Cleaning Facility

### **Bruns, Milena**

Supervisor: Tekkaya, A. E. • Gösling, M. • Karbasian, H.

Investigation of Sheet Metal Materials Made of Steel by Means of Tensile and Hydraulic Cupping Tests as well as Their Combination

### **Duve, Julia**

Supervisor: Tekkaya, A. E. • Witulski, J.

Characterization of Thermosetting Polymers for the Use as Deep Drawing Tools

### **Gies, Soeren • Jörden, Nils**

Supervisor: Tekkaya, A. E. • Marré, M.

Experimental und Analytical Approaches for the Design of Multiple Joints by Die-Less Hydroforming

**Gapp, Alexander • Jahnke, Matthias**

Supervisor: Tekkaya, A. E. • Sebastiani, G.

Process Layout for AISF by Virtual Surface Reconstruction

**Husemeier, Florian • Niemann, Michael**

Supervisor: Tekkaya, A. E. • Güley, V.

Production of Particle-Reinforced Composites Using AA6060 Chips as Matrix Material

**Langhans, Catiuscia**

Supervisor: Tekkaya, A. E. • Becker, C.

Experimental Investigation of the Incremental Tube Forming Process

**Marcin, Janysssek**

Supervisor: Tekkaya, A. E. • Weinrich, A.

Air Bending Improvement by Means of Incremental Stress Superposition Using FEM

**Nait Mbark, Zohair**

Supervisor: Tekkaya, A. E. • Gharbi, M. M.

Development of a Layer Compression and Shear Test Device

**Penning, Bastian • Funk, Jan**

Supervisor: Tekkaya, A. E. • Pietzka, D.

Construction and Initial Operation of a Quenching Machine for Extrusion of Hardenable Aluminum Alloys

**Peuker, Tobias**

Supervisor: Tekkaya, A. E. • Kloppenborg, T.

Quantification of the Process-Defining Parameters in Composite Extrusion processes

**Schulz, Phillip**

Supervisor: Tekkaya, A.E. • Kwiatkowski, L.

Development of a Holding Fixture for Roller Tools

**Unlen, Erol • Kadifeoglu, Gökay**

Supervisor: Tekkaya, A. E. • Rauscher, B.

Technological Potential of Hump Sheets and Lightweight Hump Plates Formed by Melt Pressure of an Injection Molding Machine

**1.9 Project Theses****Abrahams, Hendrik • Kirschner, Marko**

Supervisor: Pantke, K. • (ISF); Güley, V. (IUL)

Recycling of AA7000 Series Aluminum Chips by Forming

**Backs, Dominik • Coerschulte, Tobias**

Supervisor: Tekkaya, A. E. • Witulski, J.

Efficiency of Deep Drawing Tools Made of Polymers

**Christof, Victoria • Fohrmann, Angela • Weber, Stefanie; Wiezorrek, Anke**

Supervisor: Tekkaya, A. E. • Güley, V.

A Cost and Energy Analysis of Recycling of Chips by Forming Compared to Conventional Recycling by Remelting

**Grieb, Manuel • Pielken, Sebastian • Schmelter, Tina**

Supervisor: Tillmann, W. • Kleiner, M. • Tekkaya, A. E.

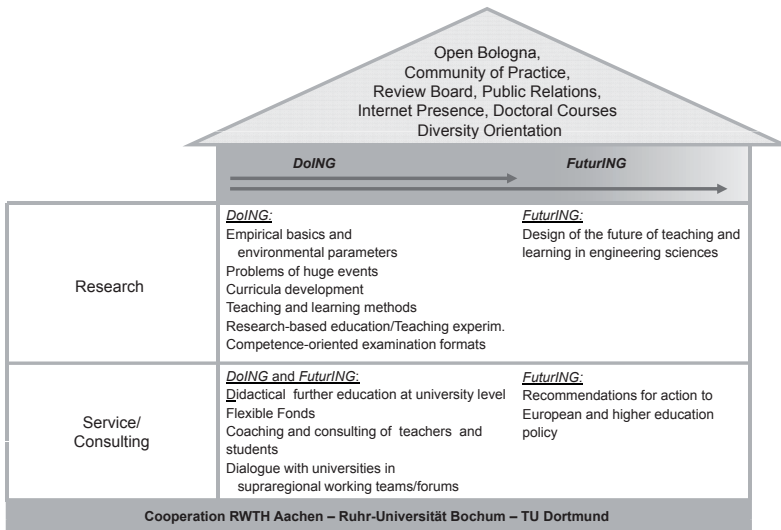
Biermann, D. • Krebs, B. • Witulski, J • Peuker, A.

Manufacture and Optimization of Coating Systems Containing Hard Materials Applied by Atmospheric Plasma and Arc Spraying for the Implementation as Wear Protection Layers in Deep Drawing Tools

## 2 Research for Education

Knowing that excellent education is based on excellent research and excellent research always requires excellent education, the IUL is always anxious to continuously advance engineering science education and has, therefore, initiated a number of projects. Their contents and ambition support and further the sustainable improvement of engineering education by active research for education. The projects are in particular:

- TeachING-LearnING.EU
- PeTEX – Platform for e-Learning and telemetric experimentation
- Full automation of telemetric compression test procedure
- Integrated and research-oriented laboratory
- MEDPRO – A new modular educational program in production engineering
- MasTech – A flexible modular master’s program in manufacturing technology



## 2.1 Project TeachING-Learning.EU

Funding VolkswagenStiftung and Stiftung Mercator  
 Project leader Prof. A. E. Tekkaya

### Motivation

To a large extent, social progress is determined by engineering developments. In order to fulfill this responsibility engineers do not only require an excellent professional education oriented towards state-of-the-art research, but increasingly need interdisciplinary competences such as creative thinking in a complex, interdisciplinary context, handling of diversity, and adequate communication skills. This – in combination with an ever growing demand for highly qualified engineers – issues a special challenge to European universities as to the impartation of contents and competences and the recruitment of Europe's best students for engineering training. These requirements necessitate a further professionalization of education as well as an increase in quality of engineering science studies.

### Goal and Structure of the Competence and Service Center

In the three years ahead, the three North Rhine-Westphalia Universities

- RWTH Aachen University  
 Responsible department: Center for Learning and Knowledge Management/Department of Information Management in Mechanical Engineering (ZLW/IMA)  
 Board member: Prof. Dr. Sabina Jeschke (ZLW/IMA)
- Ruhr-Universität Bochum  
 Responsible department: Rectorate for Internal Further Education and Consulting (IFB)  
 Board member: Prof. Dr.-Ing. Marcus Petermann (Chair of Solids Process Engineering)

- Technische Universität Dortmund  
Responsible department: Center for Research on Higher Education and Faculty Development (HDZ), Prof. Dr. Dr. h.c. Johannes Wildt (Head of HDZ), Thorsten Jungmann (Manager TeachING-LearnING.EU)  
Board member: Prof. Dr.-Ing. A. Erman Tekkaya (Institute of Forming Technology and Lightweight Construction)

will jointly constitute and operate the competence and service center TeachING-LearnING which is financed by means of the program „Bologna – The Future of Teaching“, funded by VolkswagenStiftung and Stiftung Mercator. By summarizing the scientific potential of all three locations and by an interdisciplinary cooperation of general university didactics and engineering sciences the universities see the chance to rethink and reorganize engineering sciences education and training and to give important new impetus to the formation of engineering scientific programs across Europe by a close cooperation and interaction with international partners.

The competence and service center aims at promoting the engineering education's increase in quality first at national level and to create a platform for the exchange of experiences with new teaching and learning concepts. At the same time, the German and European development shall be linked and the transferability of models shall be reviewed. In detail, the following goals shall be accomplished:

- Concentration on competences as learning outcomes
- Consideration of increasing diversity among students
- Assuring the programs' scientific quality
- Shift from teaching to learning
- Improvement of the „studyability“ and decrease of the drop-out rates
- Intensification of communication and interaction between teachers and students
- Facilitation of international mobility between European universities



- Recruitment of more motivated and high performance students for engineering science programs
- Increase of employability after a successful graduation

The research and development activities necessary for achieving these goals are combined in two sections with different time frames. The research section is geared to optimize engineering science training in Germany; the services section aims at transferring research results to educational practice at universities and provides for consulting services for teachers and students. DoING investigates short and medium-term measures for the improvement of engineering science training; FuturING focuses on the sustainability of engineering education in the common European region of higher education and prepares guidelines for universities, institutions of research funding, and European higher education and research policies.

### Further Information

The competence and service center has commenced operations in June 2010. The internet platform [www.teaching-learning.eu](http://www.teaching-learning.eu) provides information on the current status of projects and on engineering science topics and questions.

## 2.2 PeTEX – Platform for e-Learning and Telemetric Experimentation

Funding	EU, Leonardo da Vinci
Project	142270-LLP-1-2008-1DE-LEONARDO-LMP
Contact	M.Sc. M.Eng. C. Pleul
Status	Completed

Laboratory experiments are a core element of engineering science education. Particularly in production engineering these experiments involve costly equipment which is not available at every location.

The developments within the scope of the PeTEX project aim at making test facilities available to students – independent of location and time as well as interactively and in real time. For this purpose, three laboratory production engineering experiments (forming, joining, and cutting) have been tele-operatively integrated within a learning platform via the internet. This platform also includes theoretical basic information on the corresponding experiments. In this way, users are enabled to implement theoretical contents in practice within the scope of a remote-controlled experiment, to analyze the data, and to jointly interpret and discuss the results. This approach is – in regard to its scope and orientation – unique in the field of production engineering.

The laboratories involved in this project are located in three European countries: Germany (Institute of Forming Technology and Lightweight Construction – IUL, TU Dortmund) – development of a uniaxial tensile test, Italy (Department of Mechanical Technology, Production, and Management Engineering – DTMPiG, University of Palermo) - implementation of a friction stir welding process, and Sweden (Department of Production Engineering, Stockholm Technology University - KTH) – integration of a milling process. The Center for Research on Higher Education and Faculty Development (HDZ, TU Dortmund) was in charge of the didactical and pedagogical implementation during the project's term. Figure 1 shows the overall structure of the PeTEX project.

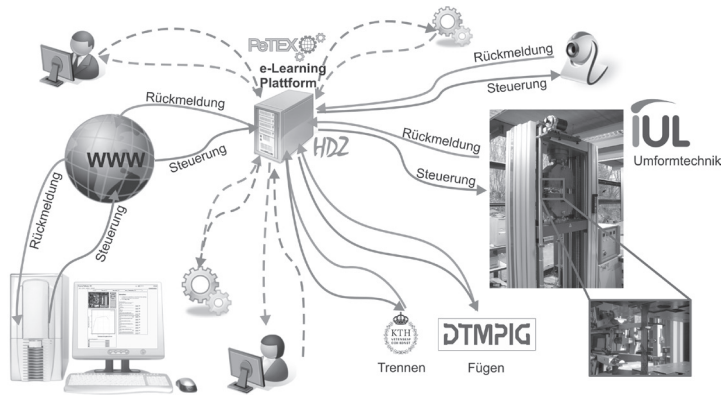


Figure 1: Overall structure of PeTEX

The target group consisting of students of technical disciplines at different levels (beginners, advanced students, experts) has access to modularized contents via the e-learning platform „Moodle“. At different points within the modules students are requested to carry out experiments. The tele-operative test facilities integrated for this purpose are being directly configured by the active user. Other students (so-called passive users) may pursue the experiment. The control and data flow structure developed for this purpose is shown in figure 2.

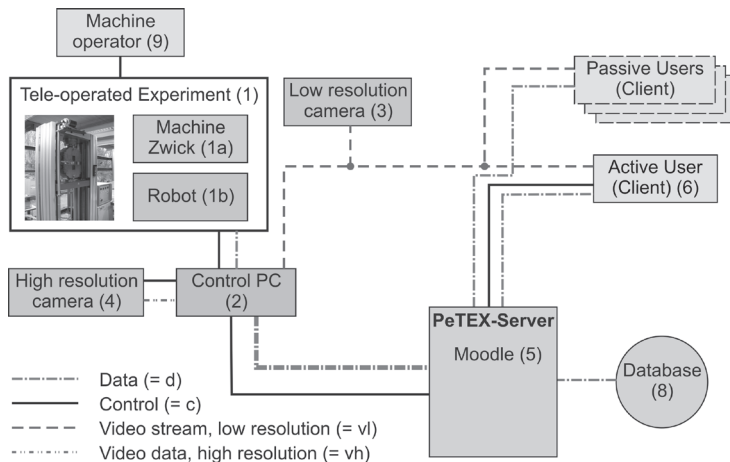


Figure 2: Control and data flow structure for a telemetric tensile test

## 2.3 Full Automation of Telemetric Compression Test Procedure

**Funding** Karl-Kolle-Stiftung  
**Contact** M.Sc. M.Eng. C. Pleul

Telemetric test facilities enable long-distance interaction with experimental units. This adds to a more effective and resource-efficient use of test facilities. Full additional benefit is achieved by using a fully automated telemetric facility. After implementing the telemetric test facilities into an e-learning environment the developed experiments and manufacturing operations can be directly used for education purposes. Here, an advantageous aspect is that a self-regulated learning process is being encouraged and that students are able to control the experiment themselves and, thus, have a much more intense learning experience. Particularly in the field of production engineering this innovative approach is a novelty.

A compression test for a distant configuration and control by transferring machine parameters has been set up within the scope of the project. For this purpose, access to the control device of the universal testing machine has been achieved by extending the experimental software testXpert (Zwick GmbH & Co. KG) with the according interface for remote access. The development of own software elements for data processing increases the flexibility of the interaction and made a two-way data exchange possible which is necessary for tele-operative use.

The six-axes robot KUKA KR 5 sixx R650 featuring a parallel gripping system was employed for automatically equipping the experimental unit. A flexible positioning of the robot is accomplished by a self-developed portable unit. Even now, a sequence program for the robot which is currently being developed enables a pick-and-place operation of the experiment.

## 2.4 Integrated and Research-Oriented Laboratory

Funding	TU Dortmund, Faculty of Mechanical Engineering
Contact	M.Sc. M.Eng. C. Pleul

The so-called „laboratory” or laboratory practical work with all its varied characteristics represents an important feature in engineering science education, aiming at practically experiencing and implementing theoretical basics. These basics are first imparted within the scope of lectures and shall then be verified in separate courses – namely the laboratory – by practical experiments.

Taking the actual situation, experiences from own teaching activities and surveys, dedicated preliminary work, and current research activities into account, the approach of researching learning within the scope of competence-oriented courses seems to be a suitable tool.

The project „Integrated and research-oriented laboratory”, which is still in its initial phase, includes the determination and handling of approaches for a sustainable improvement of engineering laboratories in the context of academic training. An analysis of the necessary requirements and the resulting basic characteristics of the „integrated laboratory” needs to be carried out in advance. At the same time the identification and qualification of possible links with other courses and the integration into the international program „Master of Science in Manufacturing Technology” (MMT) will be effected. The tele-operative test facilities necessary for this integrative strategy have been partly developed within the scope of the research project “PeTEX”, which is funded by the EU, and are being specially adapted for this purpose.

The actual engineering scientific laboratory shall not be replaced in this context. Instead, the telemetric test facility serves as a tool to integrate practical laboratory activities into other didactic formats, as e.g. lectures, and, thus, to organize future research-oriented laboratories more efficiently.

By the end of the project an engineering science laboratory shall be available facilitating the conceptual integration of competence-oriented and constructive learning.

## 2.5 A New Modular Educational Program in Production Engineering

Funding	EU, TEMPUS
Project	JEP_33157_2005
Contact	Dr.-Ing. habil. S. Chatti

Today, Tunisia looks forward to an active technology transfer. One of the national projects that have a great effect on the Tunisian national economy is the “modernization of Tunisian industry”. To achieve this program in a consistent way it is essential to prepare a new generation of engineers that can cope with the latest advances of technological, industry-related aspects.

For the development of a new modular educational program in Production Engineering (PE) for a Tunisian bachelor program and further education, which is based on the Bologna process, a new project has been initiated in 2007. It has been granted by the EU Program TEMPUS and is aimed at establishing and improving PE curricula for production engineers.

The aim of the MEDPRO project is to anticipate the needs for education of Tunisian manufacturing organizations and to provide a new generation of production engineers meeting these needs. The long term objective is to vitalize the Tunisian manufacturing industry and to strengthen its competitiveness on the global market.

Institutes from universities and the industry sector in Sweden, Germany, Poland, and Tunisia are partners of this project. The European dimension in the cooperation in PE education implies not only a guarantee for a common level of knowledge and skills for the graduates, but also assures a high quality level for teachers and the sustainability of the PE education.

The MEDPRO project focuses on the establishment of a new modular program in PE at the Ecole Supérieure de Sciences et Techniques de Tunis (ESSTT). Due to its modular structure the program is able to train production engineers in Tunisian companies for a lifelong learning activity.

## 2.6 MasTech – Flexible Modular Master Program in Technology

<b>Funding</b>	EU, TEMPUS
<b>Project</b>	511277-TEMPUS-1-2010-1-DE-TEMPUS-JPCR
<b>Contact</b>	Dr.-Ing. habil. S. Chatti

The goal of the Flexible Modular Master in Technology (MasTech), financed by EU TEMPUS Funds, is the development and implementation of a master program encouraging the mobility of teachers as well as students between universities in the partner countries (PC) Tunisia, Algeria and Morocco. A new modular curriculum will be developed and sustainable manufacturing technology programs will be established for an innovative two-year master program of excellence in manufacturing technology reforming the higher education at six universities in these countries.

The Master program consists in basic and speciality modules. The modular structure of this master (different educational modules independent from each other) gives not only consistency and flexibility to education in manufacturing but also enables an easy implementation in training programs for vocational education of manufacturing engineers to support the lifelong learning process and to easy introduce a certification process for engineers. The idea is to have a joint Master basic structure having the same educational modules in the three countries and different specialization fields in each country.

This Master program will provide the PC with the EU state of the art education in the field of manufacturing technology, resulting in more flexibility in learning and practical qualification. The enhancement of transparency and comparability of the PC educational systems and the modernization of the manufacturing technology studies according to the latest didactical strategies will also facilitate recognition of studies abroad and make the study in PC more attractive. Also the access to the labor market of graduates will be facilitated by focusing the education in manufacturing fields specific for PC industries and fortifying the university-enterprises relationship.

The European partners of the project are the Royal Institute of Technology (KTH), Stockholm, Sweden, and the “Ecole Nationale Supérieure d’Arts et Métiers (ENSAM), ParisTech, Metz, France.

### 3 Research

The IUL staff includes 39 scientists, research assistants, PhD-students as well as 13 technicians and administrative staff members and 60 student assistants.

The IUL is divided into four departments:

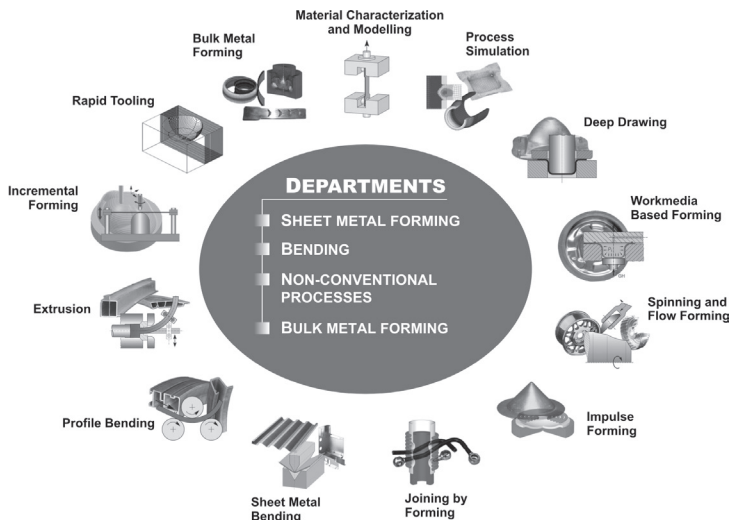
- Bulk Metal Forming
- Sheet Metal Forming
- Bending
- Non-Conventional Processes

Two working groups have been established to support the departments:

- Modeling and simulation
- Measurement systems

The research projects are organized in small interdisciplinary teams.

This chapter comprises an overview of research programs coordinated by the IUL. Completed and ongoing projects are presented corresponding to the four departments of the institute.





## 3.1 Coordinated Research Programs

### 3.1.1 Collaborative Research Center SFB Transregio 10

Spokesman     Prof. Dr.-Ing. A. E. Tekkaya  
 COO             Dr.-Ing. Dipl.-Wirt.-Ing. M. Marré | until 30 Nov. 10  
 Contact         Dipl.-Wirt.-Ing. D. Pietzka

The development of scientific fundamentals and methods for the design of integrated process chains for an automated and product-flexible batch production of light space frame structures is the major target of the Collaborative Research Center SFB/Transregio10. It is an exemplary model for the combination of forming, cutting, and joining by implementing an idealized process chain for the flexible production of lightweight structures. Here, the key aspects are in particular:

- Achieving a broad flexibility of the production technology
- Simulating the complete process chain in order to optimize the interlinking of production steps.

The year 2010 has been the year of the reviews. The green light, i.e. the pleasant news about the go-ahead for the continuation of the funding for another four years, was finally given in November. In the third funding period the focus will base on the flexibility of the processes and the whole process chain. The embedding of functional elements like electrical conductors or the manufacturing of profiles with varying cross-sections during extrusion enlarge the variety of producible parts. The requirements on the following processes and the process chain increase with the variety. The process chain is, in cooperation with the Karlsruhe Institute of Technology (KIT) and Technische Universität München (TUM), exemplarily put into practice by selected processes implying great potential for the future.

The participating institutes and chairs are:

- IUL, Institute of Forming Technology and Lightweight Construction, TU Dortmund
- ISF, Institute of Machining Technology, TU Dortmund
- wbk, Institute of Production Science, KIT – Karlsruhe Institute of Technology
- iwK I, Institute of Materials Science and Engineering I, KIT – Karlsruhe Institute of Technology
- iwB, Institute for Machine Tools and Industrial Management, TU München
- LLB, Institute of Lightweight Structures, TU München



Sonderforschungsbereich

**Transregio10**

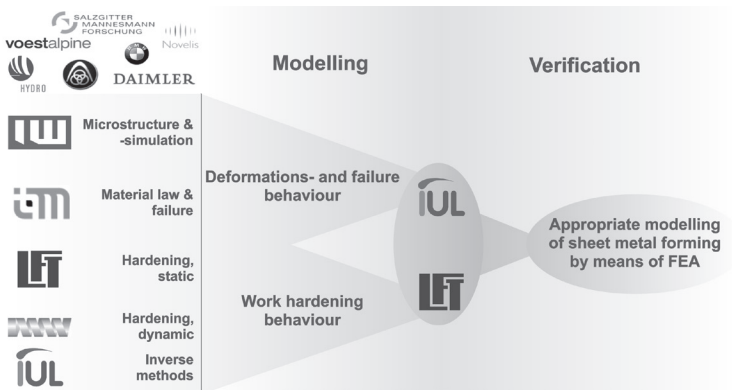
### 3.1.2 DFG PAK 250 Identification and Modeling of Material Behavior for the Finite-Element Analysis of Sheet Metal Forming Processes

Funding                    German Research Foundation  
Project                    PAK 250  
Spokesman                Dr.-Ing. A. Brosius

The purpose of this research project is the improvement of methods suitable for determining the material behavior in sheet metal forming processes as well as the identification of theoretical models used in this context and the parameters involved. The major motivation fostering the research activities is an improvement of the quality of numerical process simulations using the finite-element method as today's modern materials involve a clear deficit due to unconsidered effects in numerical modeling procedures.

Within the scope of this project researchers from Dortmund, Hanover, Erlangen, and Chemnitz cooperate in the field of manufacturing technologies, mechanics, materials engineering, and material testing. Special focus is put on an active cooperation of researchers from the industrial sector.

A central aspect of the research activities is, besides the identification of material characteristics, the development of new experimental, analytical, and numerical strategies for the evaluation and specification of the material behavior.



Cooperation, tasks, and industrial consortium

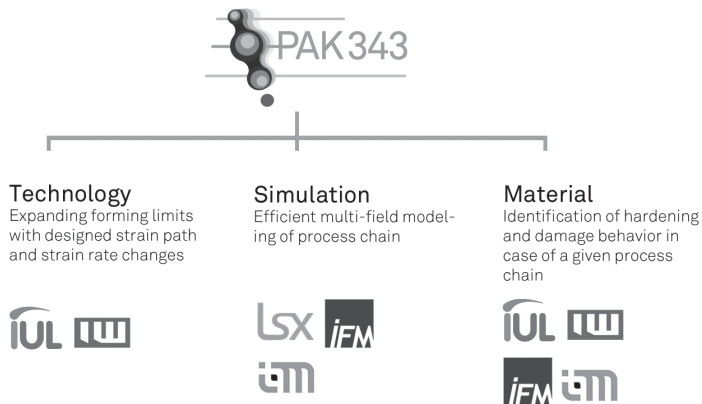
### 3.1.3 DFG PAK 343 Development of a Methodology Regarding Combined Quasistatic and Dynamic Forming Processes

Funding                      German Research Foundation  
Project                        PAK 343  
Spokesman                  Prof. Dr.-Ing. A. E. Tekkaya

The aim is the development of a suitable methodology for process chains consisting of quasi-static and dynamic forming operations. The methodology should be able to generate a suitable procedure to manufacture a desired product, which cannot be produced utilizing conventional methods.

The combination of different processes causes a variation of strain path and strain rate during forming. Experimental and numerical investigations are being performed in order to comprehend the effects of this variation upon the forming results. Using these findings, the methodology to be developed should benefit from these effects in order to extend the forming limits.

One of the examined process chains is the electromagnetic tube compression (ETC) followed by tube hydroforming (TH). ETC induces wrinkles, which must be ironed by TH. The intent is to be able to simulate the formation and straightening of the wrinkles to optimize process parameters. Results of wrinkle formation simulations are given in the figure.



Cooperation between the project partners

## 3.2 Department of Bulk Metal Forming

**Head** Dipl.-Ing. Nooman Ben Khalifa

Global warming is the top subject of today's world. To act against this phenomenon a reduction of CO<sup>2</sup> emissions not only in automobile and aerospace industries, but also in energy and resource-intensive manufacturing of metallic products has been set as a primary target of several current studies. In order to decrease the amount of energy consumption in transportation lightweight solutions must be found, for example by using lightweight materials like aluminum alloys and by the development of lightweight structures and innovative drive systems.

In the department of bulk metal forming various innovative and highly flexible solutions in the field of aluminum profile extrusion have been found to produce light complex parts featuring at the same time a higher strength. At the IUL, four different innovative profile extrusion processes have been developed in order to fulfill these commitments. One option is the Curved Profile Extrusion (CPE) of 3D profiles, deflecting the material flow directly after the profile left the die. Here, not only higher residual stresses and, thus, springback are eliminated, but also distortions in the cross section - common problems of conventional bending after extrusion. In composite profile extrusion processes the reinforcing elements are embedded into the aluminum profiles to increase the strength and stiffness of the profiles without significantly increasing the samples' weight. Twisted Profile Extrusion (TPE) involves an extruded profile being twisted directly after exiting the extrusion press by means of a guiding tool in order to manufacture helical profiles like screw rotors. Furthermore, aluminum chips are recycled in solid state by profile extrusion without the need for a re-melting operation to produce wrought material. Using this innovative recycling process, the profiles can be extruded with only a small reduction in strength compared to conventional methods.

In addition to profile extrusion, cold metal forming operations, and especially cold forging, are the second expertise field of activity of the department of bulk metal forming. Besides the development of numerous innovative processes (e.g. lateral extrusion of hollow secondary forming elements) the structural properties of extruded parts are analyzed and optimized (for example, analysis of distortion in cold forming operations).

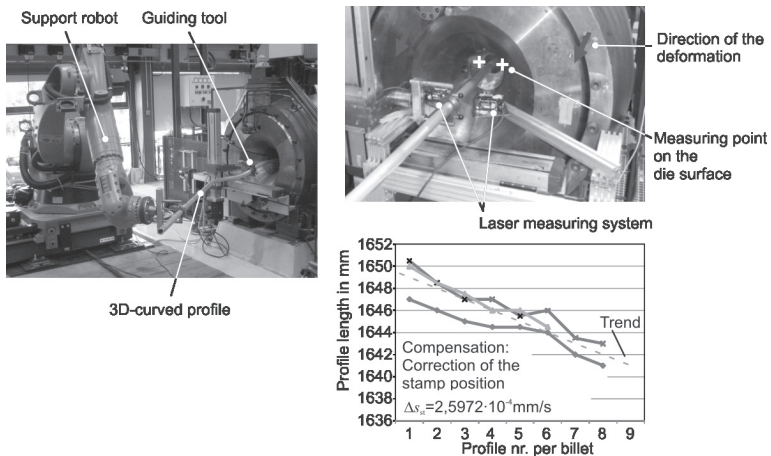
Current research activities of the department of bulk metal forming will be presented in the following.

### 3.2.1 Multi-Axis Curved Profile Extrusion

Funding	German Research Foundation
Project	SFB/TR 10 • Subproject A1
Contact	Dipl.-Inform. A. Selvaggio

The multi-axis curved profile extrusion process is being advanced and represents the beginning of the process chain which is examined within the scope of the Collaborative Research Center Transregio 10. One main objective in the second funding period was the increase of the product quality. In this context, extensive investigations have been carried out to explore the influence of the tool deformation on the product quality. In order to validate the die deformation the deflection of the die was measured in experimental investigations. As measuring device a distance sensor was used to capture the elastic deformation of the die.

The results of the investigations show that the geometry of the orifice which determines the dimension of the profile cross section is influenced by the deformation. The change of the orifice dimension causes a different extrusion ratio and, furthermore, a different profile speed. Considering the synchronization of the extrusion process with the following kinematic systems, this causes a systematic error in the process.



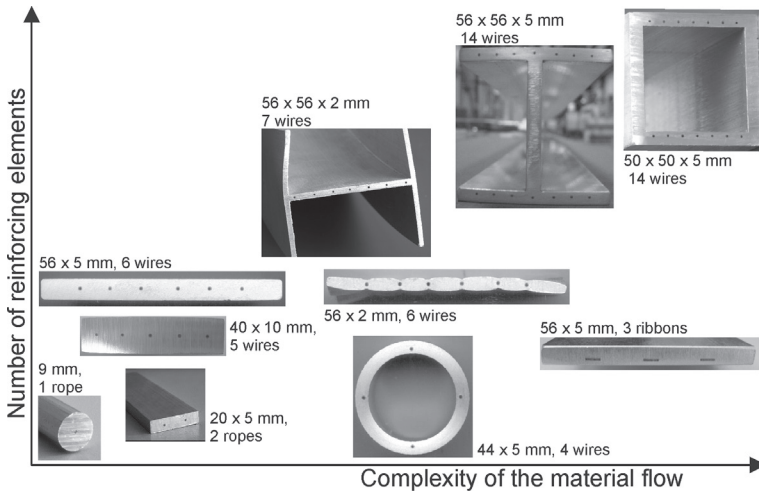
3D-curved profile extrusion and analysis of the tool deformation

### 3.2.2 Composite Extrusion

Funding German Research Foundation  
 Project SFB/TR 10 • Subproject A2  
 Contact Dipl.-Wirt.-Ing. D. Pietzka

The subproject “composite extrusion” covers the manufacturing of composite profiles using the extrusion process. The profiles are reinforced continuously, meaning that the reinforcement is realized over the entire length of the profile. The combination of the lightweight material aluminum with a second high strength component can enhance the structural behavior of profiles concerning strength and stiffness significantly.

Until now a maximum of 14 metallic reinforcing elements could be embedded. The aluminum alloys AA 6060 and 6082 have been used as matrix material. Furthermore, the magnesium alloy AZ 31 was applied for comparison purposes. To increase the reinforcing volume studies on the embedding of metallic flat ribbons have been carried out. Due to the feeding channels inside the extrusion die a very complex material flow emerges.



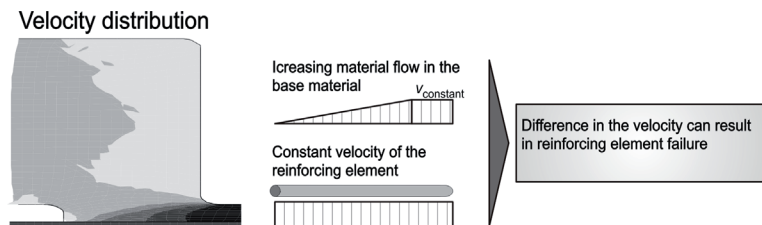
Cross-section development of composite profiles

### 3.2.3 Simulation of Composite Extrusion Processes

Funding German Research Foundation  
 Project SFB/TR 10 • Subproject B1  
 Contact Dipl.-Ing. T. Kloppenborg

The composite extrusion process is being analyzed and optimized based on the finite element method. Here, methods for the numerical analysis of complex bulk forming processes and for the process specific manufacturing limitations are developed. The methods are implemented in a fully closed optimization process to realize a secure production process.

A manufacturing criterion which is currently being analyzed is the failure of reinforcing elements. The difference in the velocity of the matrix material and the reinforcing elements results in tensile stresses in the elements which can result in failure. For the numerical calculation of the reinforcement flow line inside the welding chamber an adapted particle trace is calculated. By using interpolation, stresses and temperatures can be analyzed along this flow line. With the aid of an analytical approach and the results of the interpolation the failure can be detected. The method is fully implemented in a numerical optimization.



#### Parameters

- Material  $\alpha_{\text{Sinh}}, R, Q, A, n$
- Temperature  $\vartheta$
- Bonding length  $l_{\text{verbund}}$
- Forming velocity  $\dot{\varphi}$
- Radius of reinforcement  $r_{VE}$

#### Dependency of parameters

$$\sigma_{\text{max},VE} = \frac{2 \cdot l_{\text{Bonding}}}{\sqrt{3} \cdot \alpha_{\text{Sinh}} \cdot r_{\text{Element}}} \cdot \sinh^{-1} \left[ \left( \frac{\dot{\varphi} \cdot e^{\frac{Q}{R \cdot \vartheta}}}{A} \right)^{\frac{1}{n}} \right]$$

Failure of reinforcing elements in the steady state composite extrusion process

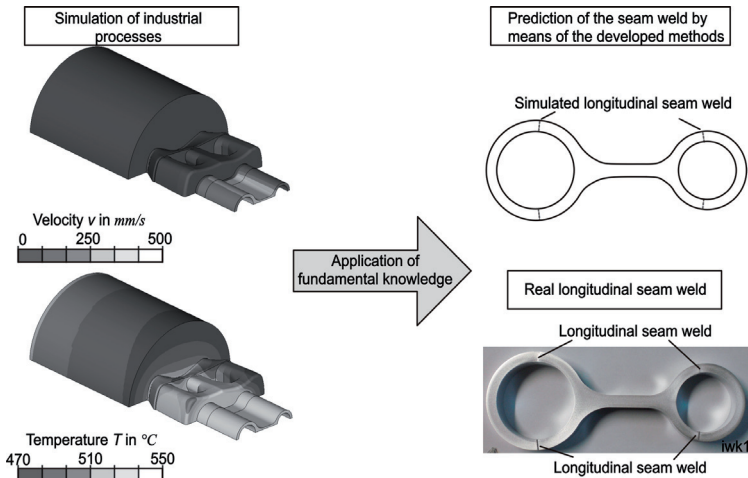
### 3.2.4 Efficient Extrusion Simulation for Industrial Applications

Funding German Research Foundation  
 Project SFB/TR 10 • Subproject T6  
 Contact Dipl.-Ing. T. Kloppenborg

Findings and simulation methods developed within the subproject on simulation of composite extrusion are being transferred to industrial applications. For example, the method for the numerical prediction of the longitudinal seam weld position is extended in terms of quality aspects. Additionally, the developed optimization procedure is used for an automated correction of the die geometry in the case of inhomogeneous material flow at the die exit, thus providing for a secure production process.

Currently, industrial experiments are in progress. Based on the results a criterion for the seam weld's quality will be determined.

Industrial participants of the project are Altair Engineering GmbH, Audi AG, F.W. Brökelmann Aluminiumwerk GmbH & Co. KG, Daimler AG, Gesamtverband der Aluminiumindustrie e.V. (GDA), Honsel AG, Kistler-IGeL GmbH, S+C ETS GmbH, and Wilke Werkzeugbau GmbH & Co. KG.



Prediction of the longitudinal seam weld for industrial profiles

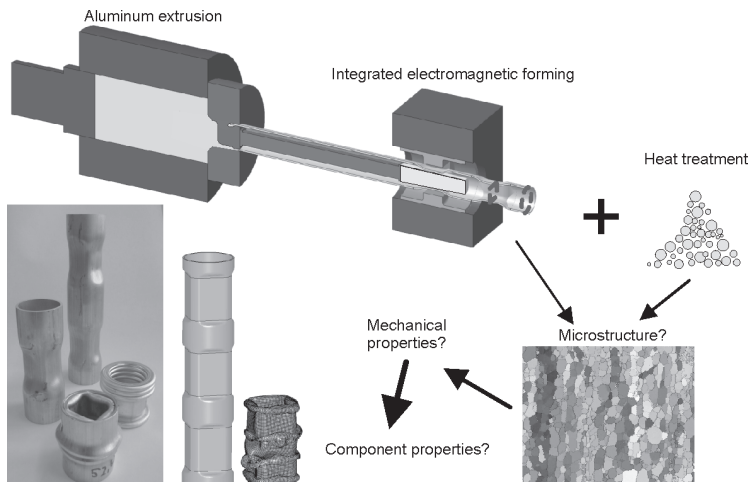


### 3.2.5 Thermomechanical Processing of Aluminum Alloys after Extrusion

Funding            German Research Foundation  
 Project            SFB/TR 30 • Subproject A2  
 Contact            Dipl.-Ing. A. Jäger • M.Sc. A. Güzel

In the first period of the project a proof of concept for the numerical prediction of the evolution of microstructure during extrusion was realized, on the one hand, and the technological realization of the process combination of extrusion - electromagnetic hot forming - heat treatment was achieved, on the other hand. By the integration of thermo-mechanical forming and heat treatment operations into the process chain of extrusion, combined with the resulting microstructure, profiles with specifically adjusted properties can be manufactured.

Based on these findings, the aim of the project's second period is to improve the selected process chain technologically and to model it numerically in order to manufacture property-optimized profiles. To manufacture profiles with purposefully adjusted geometries and mechanical properties a gradual enhancement of the profiles' complexity is intended.



Investigation and prediction of the product properties along a process chain for the production of functionally graded profiles

### 3.2.6 Alternative Paths for the Manufacture of Screw Rotors by Forming

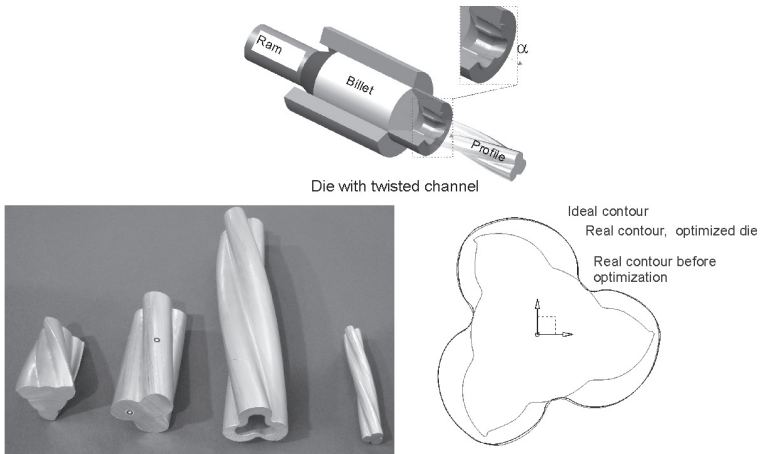
Funding	German Research Foundation
Project	TE 508/3-3
Contact	Dipl.-Ing. N. Ben Khalifa
Status	Completed

The interaction between manufacturing methods and component properties of screw rotors is investigated in cooperation with the Chair of Fluidics at TU Dortmund.

At the IUL two innovative processes have been developed: Twisted Profile Extrusion (TPE) and Helical Profile Extrusion (HPE). TPE investigations concentrated on the torque - applied to deflect the material flow - being measured. Here, the torque amounted to less than 50% during the rotation of the guiding tool and even to less than 10% in the steady state phase compared to simple twisting due to the superposition of axial and shear stresses.

In HPE operations the twist angle could be increased significantly after an optimization of the material flow and also by reducing the mass inertia. Here, the twist angle was increased from  $20^\circ/100\text{mm}$  to  $36^\circ/100\text{mm}$  and by downscaling the geometry a twist angle of  $144^\circ/100\text{mm}$  could be achieved.

#### Helical Profile Extrusion (HPE)



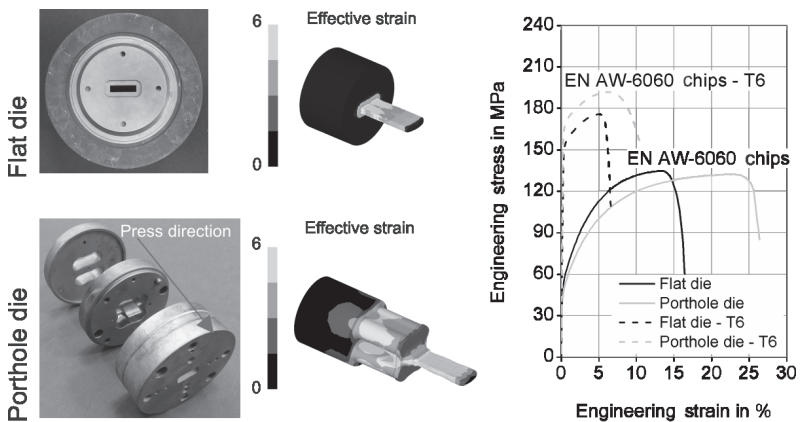
Helical Profile Extrusion (HPE): process principle, optimization of the profile geometry

### 3.2.7 Recycling of Aluminum Chips by Metal Forming

Funding German Research Foundation  
 Project TE 508/12-1  
 Contact M.Sc. V. Güley

Extrusion of aluminum chips directly to profiles can save valuable resources compared to conventional energy-intensive production processes. The aluminum chips, sorted by alloy type, were first chemically washed in a mild alkaline bath and then completely dried in an industrial oven, compacted to billets, heated up to extrusion temperature, and extruded to aluminum profiles. It was shown that the extrusion parameters like extrusion ratio, material flow, and the temperature predominantly define the properties of these profiles.

Besides the mechanical properties the corrosion resistance of the profiles is greatly affected by the chip characteristics. Impurities in the chips, like e.g. cooling lubricants, can decrease the strength of the profiles. The resistance of the profiles under static as well as dynamic loading conditions is comparable to conventional profiles.



Effect of the material flow on the effective strain and, thus, the ductility and strength of the profiles extruded from aluminum chips with flat and porthole dies

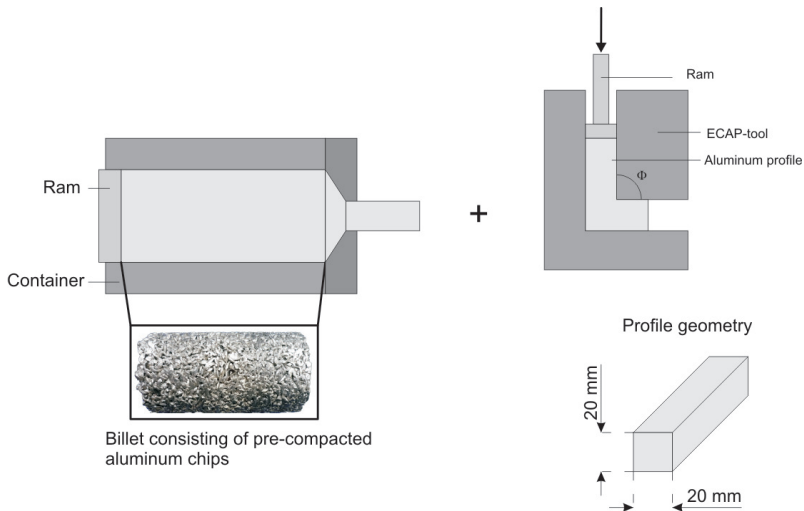
### 3.2.8 Enhancement of the Extrusion of Aluminum Chips by an ECAP Process

Funding Graduate School of Energy Efficient Production and Logistics  
 Contact Dipl.-Wirt.-Ing. M. Haase

An alternative forming process for the recycling of aluminum chips within the process chain extrusion and equal channel angular pressing (ECAP) is being investigated. Instead of the conventional re-melting process the aluminum chips are directly compacted and extruded. Different aluminum alloys and aluminum composites can be used for this process. The ECAP process influences the microstructure of the extruded profiles.

One core theme of this investigation consists in analyzing the influence of the ECAP process following the extrusion process on the mechanical properties of the profiles.

In order to analyze the mechanical properties of the profiles different methods of material testing are conducted. Microscopy is used for analyzing the microstructure. In addition, the subsequent processing of the manufactured profiles is being investigated.

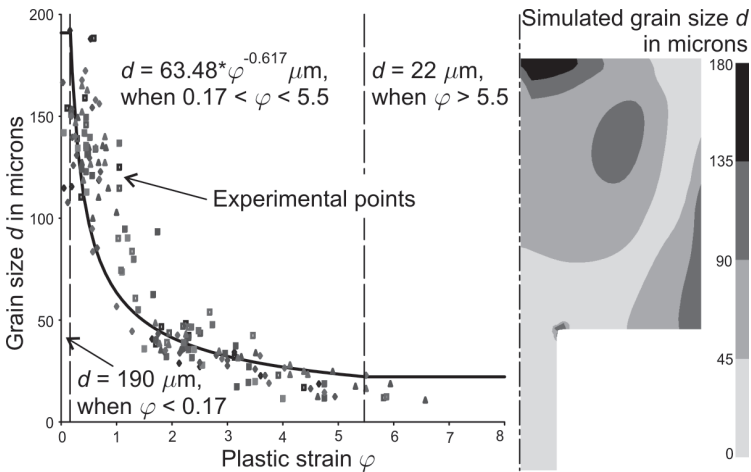


Process principle of the extrusion process with an integrated ECAP tool

### 3.2.9 Microstructure Evolution during Extrusion

Funding            German Research Foundation  
 Project            FOR 922 • Subproject 1  
 Contact            Dipl.-Ing. A. Foydl

Along with partner institutes at Leibniz Universität Hannover (IW and IFUM) and at the University of Rostock (LWT) the IUL is member of the research group “Extrusion”. This group develops of a methodology to predict the die geometry, extrusion process conditions, and heat treatment parameters based on both the mechanical properties and the geometry of a profile. The IUL works on the evolution of the grain morphology during the extrusion process, which depends on temperature, strain, and strain rates, in order to find optimized die geometries and extrusion conditions. The grain size which occurs during the extrusion process is measured by a small extrusion press and under different process conditions as the strand and the butt are quenched immediately after the interrupted process. Correlated with the simulated strain an empiric equation could be found which can be used in a finite element code by user subroutines to simulate the grain size.

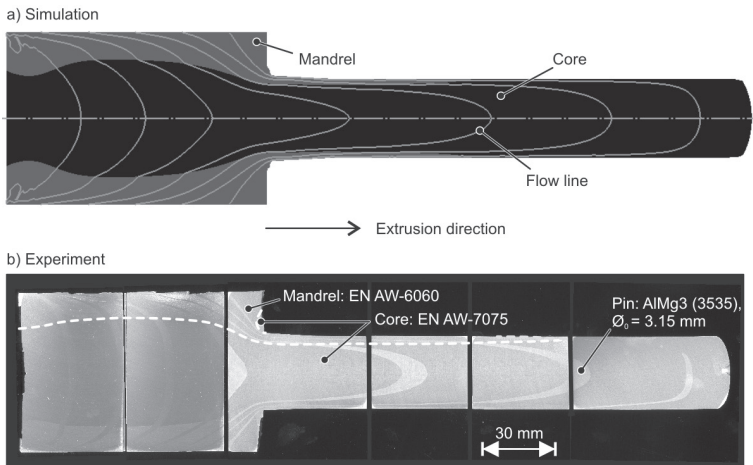


Description and calculation of the grain size depending on the strain using the example of En AW-7020

### 3.2.10 Development of a Hybrid Forging Process for Highly Stressed Vehicle Components in Lightweight Construction

Funding BMBF- ZIM  
 Project KF2198102CK9  
 Contact Dipl.-Ing. A. Jäger • M.Sc. A. Güzel

The production and subsequent treatment of composite materials is being investigated. Within the scope of this cooperative project coextrusion is used to produce compound semi-finished products for a hybrid forging process which is developed by the project partner LEIBER Group GmbH & Co. KG, Emmingen. The focus of the investigations is on the design of the material flow, the generation of optimized laminate properties as well as on the increase of the lightweight potential by high structural strength and corrosion resistance at low density. In the first half of the project a concept for the process of coextrusion of composite profiles composed of two different wrought aluminum alloys was designed. Moreover, a model for the numeric computation of the process was developed. Based on experimental work the fundamental suitability of the process for the production of compound semi-finished material was proven.



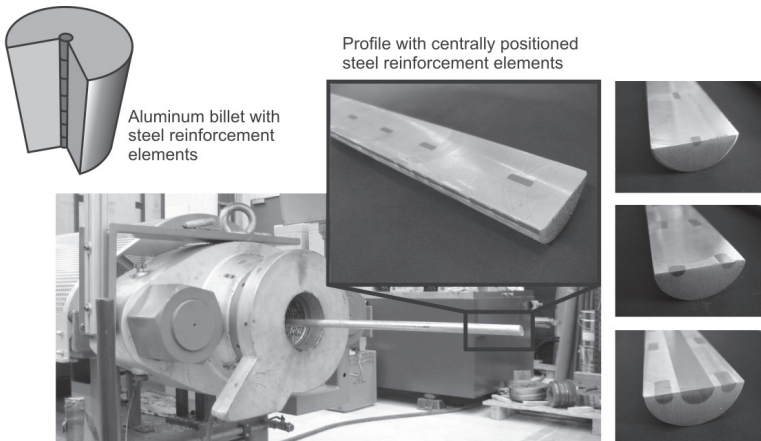
Numerical (a) and experimental (b) analysis of the position of the transverse seam weld in billet-on-billet hybrid extrusion

### 3.2.11 Component Optimization by Forging of Composite Aluminum Extrusions

Funding            German Research Foundation  
 Project            TE 508/17-1  
 Contact            Dipl.-Ing. N. Ben Khalifa • Dipl.-Ing. A. Foydl

The manufacture and further processing of partial reinforced profiles within the process chain extrusion and forging is being investigated in cooperation with the Institute of Metal Forming and Metal Forming Machines at Leibniz Universität Hannover. The reinforcement of semi-finished profiles is achieved by embedding a high-strength material into a ductile matrix during the extrusion process.

The focus of this research activity is on the design of material flow models for different profile and reinforcement geometries in order to influence the position of the reinforcement elements in the matrix as well as on the optimization of compound properties and on improving the lightweight potential of the profiles. First results show an increasing distance between the reinforcement elements along the longitudinal axis for higher extrusion ratios. The geometry of the profile cross-section influences the compound quality between matrix and reinforcement elements.



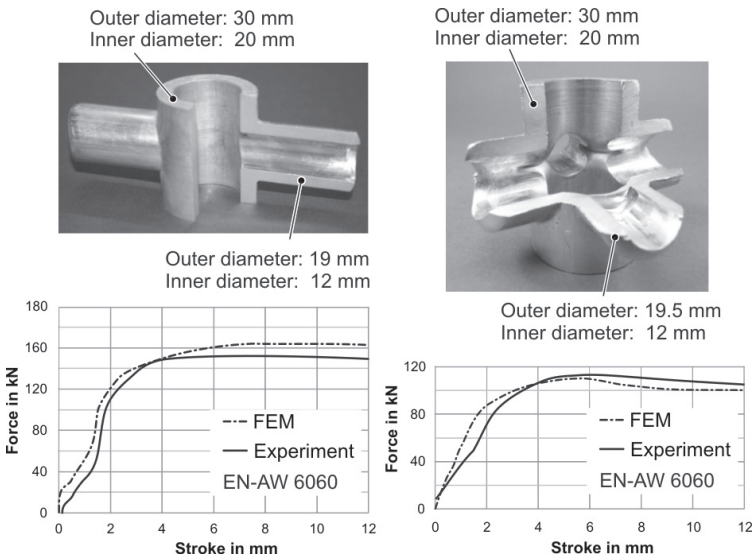
Manufacturing of partially reinforced profiles by co-extrusion of steel and aluminum

### 3.2.12 Basic Investigations on Hollow Lateral Extrusion of Additional Shape Elements

Funding German Research Foundation  
 Project TE 508/13-1  
 Contact Dipl.-Ing. M. Schwane

Basics of the hollow lateral extrusion process of hollow raw parts are developed within this joint project with the Institute for Metal Forming Technology of the University of Stuttgart. This novel process enhances the limits of cold extrusion regarding the producible components since it allows for the production of complex hollow parts.

Currently, experimental as well as numerical investigations concentrate on components having symmetrically placed, axially symmetric additional shape elements. With regard to these geometries defects like wrinkling, underfillings as well as reduction of wall thickness could be detected. Therefore, a fundamental objective is the identification of the main influencing factors that determine the process limits. Furthermore, analytical models shall be derived in order to predict the feasibility of components.



Produced components and comparison of load-stroke curves



### 3.2.13 Analysis of the Active Correlation between Heat Treatment and Distortion of Cold Forging Workpieces

Funding      AiF ZUTECH  
 Project      309 ZN  
 Contact      Dipl.-Ing. S. Hänisch

The procedure of cold forging allows an economical and true-to-form manufacture of complicated workpieces in large quantities. However, during the heat treatment often following the cold forging process the component can be distorted for reasons not yet clearly resolved. Within the scope of a joint project between IUL and IWT the relations between cold forging, heat treatment, and distortion are examined.

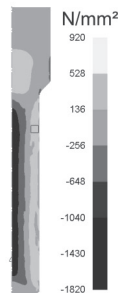
In extensive series of experiments with increasingly complicated components different process parameters like material, degree of deformation, or lubricant are varied and the component properties are analyzed. Besides experimental investigations, corresponding FEA simulations are carried out to determine residual stresses.

In addition, components from industrial manufacturing are examined in more detail. Initial evaluations indicate a lower distortion with increasing deformation and friction. Finally, recommendations and general optimization attempts will be derived from the results.

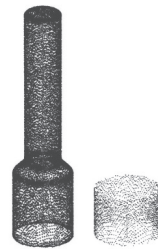
Spectrum of Components



Axial Stress



Geometric Analysis

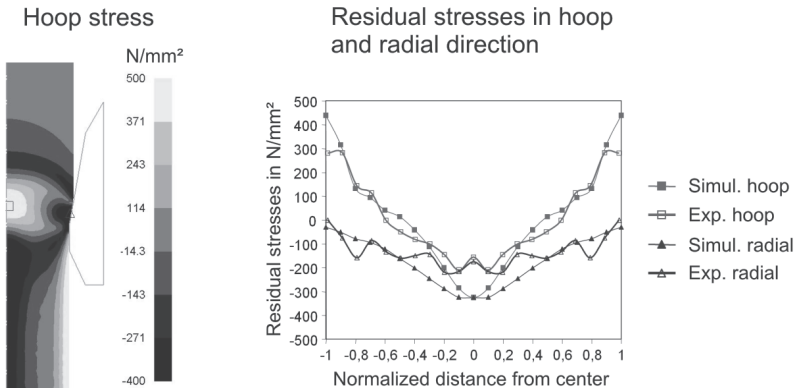


Investigated spectrum of components, FEA simulation for the determination of residual stresses, and analysis of the geometry based on the optical component measurement

### 3.2.14 Investigation and Improvement of a Manufacturing Process Chain Covering Cold Drawing Processes through to Induction Hardening

Funding            German Research Foundation  
 Project            TE 508/18-1  
 Contact            Dipl.-Ing. S. Hänisch

The manufacturing of machine components consists in general of several consecutive process steps. The improvement of one step can lead to difficulties in subsequent process steps. For example, an increase in production speed in cold drawing operations can change the material properties. This can lead to increased distortion and associated extensive rework operations such as straightening. Within the scope of the German-Brazilian joint project each step of the cold drawing process starting from raw material through to induction hardening is investigated experimentally and numerically and options for minimizing the resulting distortion are evaluated. At this Institute FEA simulations of the cold drawing process take place, taking the influence of temperature and different material behavior into account. The aim is to determine the relations between residual stresses and distortion and to deduce potentials an improvement of the process chain.



On the left: FEA simulation of cold drawing, on the right: comparison of experimentally and numerically determined residual stresses

### 3.3 Department of Sheet Metal Forming

Head Dipl.-Ing. Jörg Witulski

Objectives of the department are the development of new sheet metal forming processes, the improvement of existing processes, and the analysis and characterization of these processes as well as of the sheet material used. In particular, the manufacturing of sheet metal parts made of high-strength steels and the realization of hybrid parts made of different materials are of special interest. The research activities are based on the requirements of lightweight construction in relation to weight reduction with a simultaneous functional compliance, on one hand, and, on the other hand, on the ongoing increase of strength of safety-relevant parts.

Hence, one major subject is the analysis of the properties of hot-stamped parts. A new project will transfer this hot stamping process to high-pressure hydroforming using shapeless solids. Hydroforming of organically coated sheet metal is being investigated in order to analyze the influence of the process parameters.

Furthermore, hydroforming in combination with cold roll bonding is also used for a new approach to manufacture solar absorbers. In order to realize metal-plastic composite parts a combination of injection molding and hydroforming is applied. For this process models for the process simulation are developed and the manufacturing concept is analyzed. Further projects deal with the substitution of conventional tool materials by concrete or by hard material coated polymers which are designed for the economical forming of high-strength steels in medium batch sizes production. In order to improve the process simulation of these high strength steels the modeling of springback effects is analyzed as well as material and friction models are identified by inverse methods. Furthermore, forming simulations will be extended by implementing damage models based on experimental and numerical investigations. The computation time of simulations will be increased by using fast algorithms for realizing an online process control.

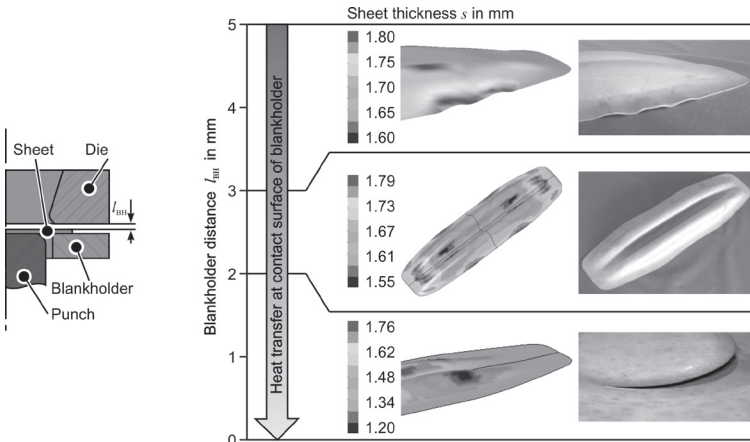
### 3.3.1 Process Design of Hot Sheet Metal Forming

Funding German Research Foundation  
 Project FOR 552 • Subproject 3  
 Contact Dr.-Ing. H. Karbasian

The properties of hot stamped parts based on thermo-mechanical and microstructural conditions have been analyzed. The investigations dealt with the influence of process and tool design on the geometrical and mechanical properties of hot stamped parts.

The knowledge of the impact of process parameters is essential for an optimized process design. Therefore, FE simulations based on a FE model have been carried out. The model took thermo-mechanical and microstructural evolution into account. Accordingly, a realistic modeling of hot forming could be realized. Based on these investigations, a guideline for process design could be developed which can be used for dimensioning process parameters and tool design.

In addition, a special process strategy was recommended in order to realize a definite adjustment of the strength of parts.



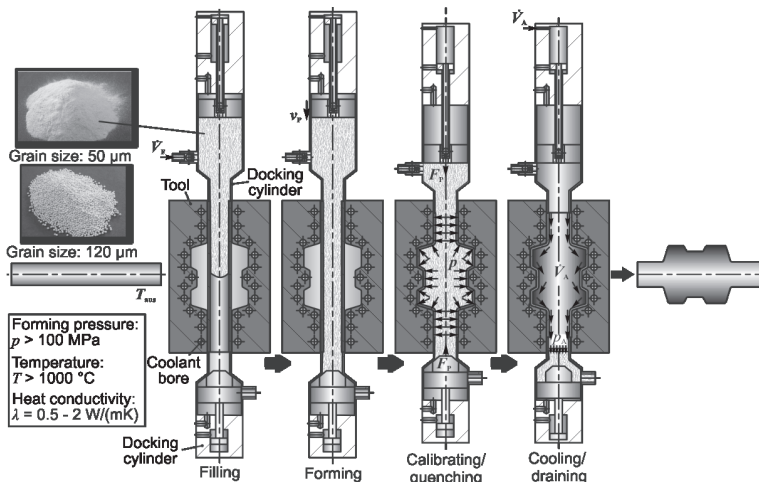
Influence of blankholder distance on forming results

### 3.3.2 Hot Forming of Tubes and Profiles by Shapeless Solids

Funding FOSTA  
 Project P 902  
 Contact Dr.-Ing. M. Trompeter

A hot forming process for tubes or profiles in which temperature and pressure resistant shapeless solids are used as pressure media is being developed. In the hot forming process boron micro-alloyed steel tubes or profiles (22MnB5) shall be formed and further processed to ultra-high-strength parts which fulfill high standards as regards crashworthiness and lightweight design due to quenching of the workpiece material in the forming tool. Quenching can only be ensured when the workpiece remains in contact with the cooled forming tool in spite of thermal shrinkage.

Therefore, high internal pressures are necessary. Compared to gases (blow forming), heat-resistant shapeless solids (e.g. ceramic powders, siliceous sands) are able to transfer high pressures with short pressure build-up times and without operational risks. In the research work the fundamentals of the new forming process will be provided particularly with regard to the influence of process parameters on the part properties.



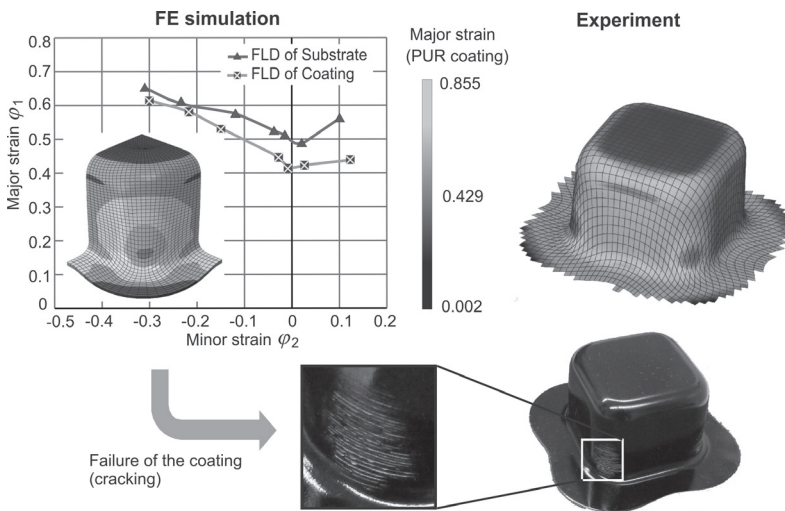
Hot forming of tubes and profiles using shapeless solids

### 3.3.3 Process Design for the Forming of Organically Coated Sheet Metal

Funding            Deutscher Akademischer Austauschdienst - DAAD  
 Contact            M.Sc. H.-D. Pham

The forming behavior and prediction of product and surface properties as e.g. gloss level and roughness of organically coated sheet metals (OCSM) is being investigated. The achieved results have shown that an increasing strain principally causes a decrease of gloss. In this case, the gloss reduction depends on both deformation and strain path. The resulting roughness is pronouncedly increased with increasing deformation.

In order to predict the change of surface properties and to investigate the influence of process parameters on the hydromechanical forming process of OCSM a FE modeling strategy and a first analytical model have been developed. The computational results prove a good applicability of the predicted model. Furthermore, the comparisons between the analytical and numerical results indicate that the analytical model can be used for process design of OCSM.



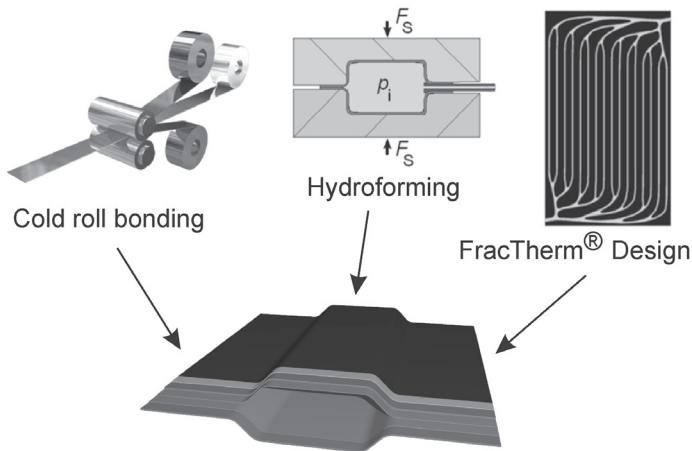
Process design for the forming of organically coated sheet metals

### 3.3.4 Processing of New Solar Absorbers in Steel Design Based on Partial Cold Roll-Bonded Hybrid Semi-Finished Parts

Funding      AiF ZUTECH / FOSTA  
 Project      ZN 339 / P 820  
 Contact      Dipl.-Ing. F. Steinbach

This new approach presents considerable advantages in contrast to conventional copper sheet metal-copper tube design as here absorbers are manufactured by a fast, nearly continuous production process which consists of cold roll bonding and subsequent hydroforming, similar to symmetric hydroforming of sheet metal pairs. Due to the higher strength of steel materials it is possible to design the channel geometry as a quasi-fractal structure (FracTherm®, developed by the Fraunhofer Institute for Solar Energy Systems) which reduces the pressure drop and the required energy for the pump.

The forming characteristics of the material (steel/copper composite) are dominated by the basic material. Various channel geometries within the hybrid sheet metal can be well applied using a suitable release agent. For a crack-free forming operation the choice of the die radius and corner radius is decisive as they are within the same range.



New absorber by combination of three innovative processes

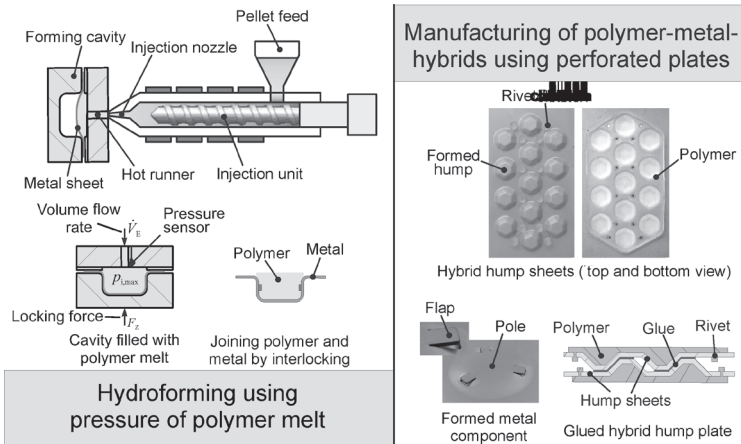
### 3.3.5 Manufacturing of Positively Locked Polymer-Metal-Hybrid Parts by Combining Injection Molding and Sheet Metal Forming

Funding German Research Foundation  
 Project GRK 1378/1 • Subproject 9-2  
 Contact Dipl.-Ing. B. Rauscher

The process combination of injection molding and hydroforming is applied in order to produce lightweight, functional metal-plastic composite parts. A key function of this manufacturing concept is the plastic component of the hybrid part which acts as working medium during the forming process plus, in solid state, provides a stiffening structural as well as functional component of the hybrid part. By using positive locking to join the components hybrid plastic-metal-structures with high mechanical load capacity are producible.

Recent process investigations include positive locking variants like cuttings in the sheet metal aiming at the production of cylindrical hybrid parts as well as lightweight hybrid plates.

Within the scope of the experimental investigations a forming tool has been developed which enables the forming of steel sheets and molding of interlocking rivets at the same time.



Process principle and produced parts using an integrated manufacturing process of forming and injection molding

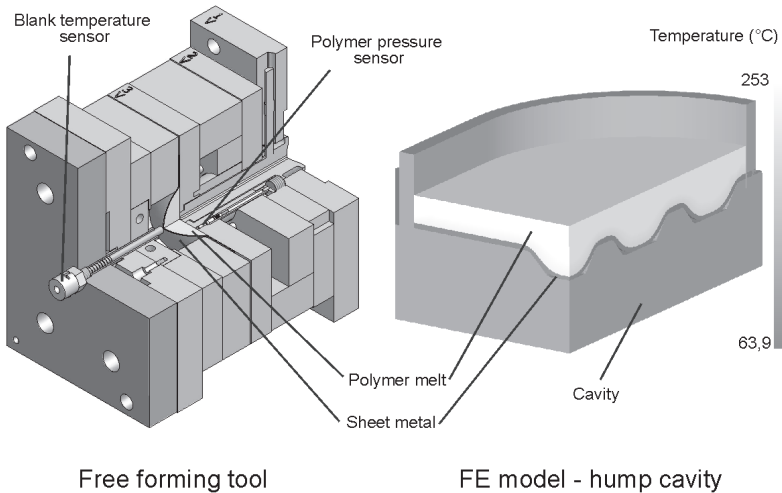


### 3.3.6 A Fundamental Investigation on the Combined Injection Molding – Sheet Metal Forming Process

Funding German Research Foundation  
 Project GRK 1378 • Subproject 9/1  
 Contact M.Sc. M.M. Hussain

A basic understanding of the role of polymer melt as a pressure medium in sheet metal forming shall be developed. For this purpose, experimental as well as numerical approaches have been adopted. An experimental tool with the necessary integrated sensors has been developed for a simultaneous injection molding and sheet metal forming process. The development of process parameters as a result of varying process conditions has been analyzed and compared with standard hydroforming processes.

The focus remained on identifying the factors influencing the formability in free forming as well as cup forming processes. Moreover, a thermo-mechanical FE model for combined processes has been proposed. A lagrangian approach has been taken as a basis for the complete modeling. The Newtonian behavior of the melt is described by constitutive viscoplastic formulations. The proposed model has been validated by the experimental findings.



Experimental and numerical investigations of the combined process

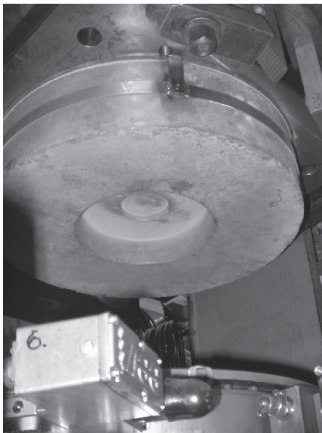
### 3.3.7 Development of Concrete Dies for Sheet Metal Hydroforming

Funding	German Research Foundation
Project	TE 508/7-2 (formerly: KL 619/28-1)
Contact	Dr.-Ing. M. Trompeter

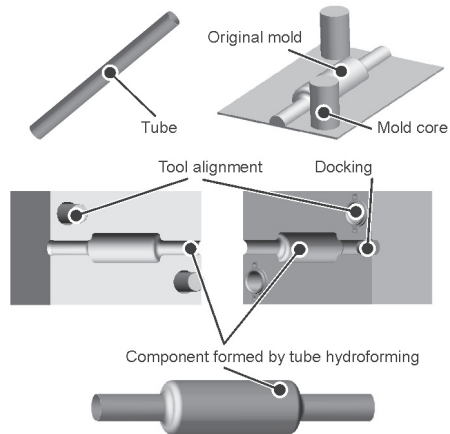
Forming tools made of concrete for the manufacturing of sheet metal parts by hydroforming in prototype and small batch size production are being developed. In the first funding period a fine grain concrete matrix reinforces by steel fibers could be developed which is adequate to be used for hydroforming of simple geometries. For the second funding period this technology will be advanced to complex part geometries as well as to hydroforming of tubes. The loading capacity of the tool material is to be determined by investigating the stress-strain behavior of concrete under combined tensile and compressive stress state conditions.

For reasons of functional integration the key advantages of the process are to be used, e.g. the implementation of a multi-point drawing technique.

Concrete forming tool



Tube hydroforming with concrete forming tool

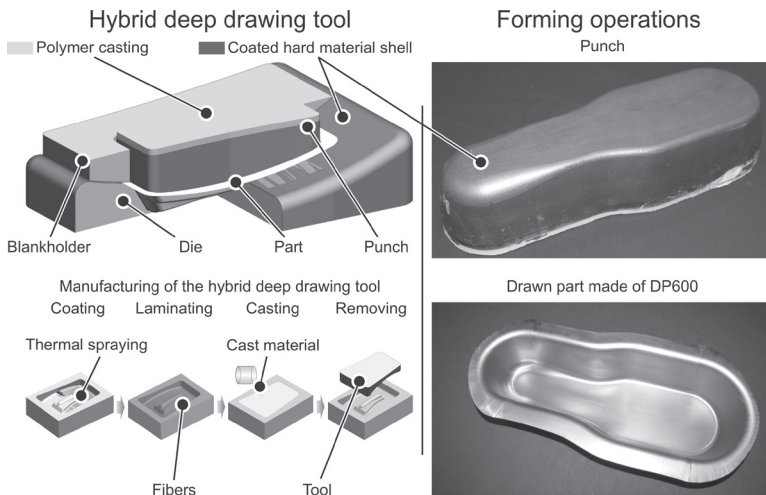


Produced forming tool made of concrete (1. funding period) and process extension to tube hydroforming (2. funding period)

### 3.3.8 Development of a Hybrid Deep Drawing Tool Using Locally Structured Surfaces

Funding German Research Foundation  
 Project SFB 708 • Subproject C1  
 Contact Dipl.-Ing. J. Witulski

A rapidly producible and cost-effective hybrid deep drawing tool featuring high wear resistance to form sheet metal parts with free formed surfaces in particular made of high-strength steels for the small to medium batch size production is being developed. For this purpose, hard material shells are thermally sprayed on a negative mould, if necessary reinforced with fibers, and backfilled with a polymer. The bonded hard material shell is removed from the negative mould and acts as the surface of the forming tool. Within the Collaborative Research Centre Program SFB 708 this is an alternative approach to manufacture forming tools of a high wear resistance. The investigations demonstrate that the use of this manufacturing technique is not limited to simple geometries, but is also suited for complex deep drawing tools with an adequate accuracy. These tools can be used to form sheet metal parts made of mild as well as high-strength steels.

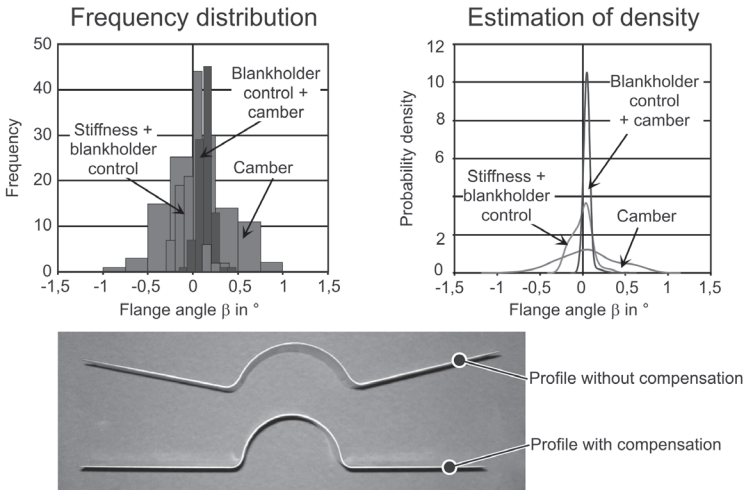


Process chain for the manufacturing of the hybrid deep drawing tool and forming results

### 3.3.9 Strategies for Springback Compensation

Funding German Research Foundation  
 Project SFB 708 • Subproject C3  
 Contact Dr.-Ing. M. Gössling

Strategies for compensating dimensional variations caused by springback are vital for coated tools within the Collaborative Research Center SFB 708 as the potential of manual rectification work is limited. Therefore, this research work covers the correct numerical prediction of deep drawing tools, followed by a springback compensation. In order to describe the amount of springback statistic quality characteristics are defined and analyzed by experimental as well as numerical investigations. It could be shown that adequate simulations can be achieved by using a cinematic-isotropic material hardening model. These models are used for an offline compensation of springback. Here, a robust process design is suggested which, on one hand, compensates deviations caused by springback and, on the other hand, allows small variations of the springback values. This approach leads to a decrease of the deviation between the set and actual geometry.



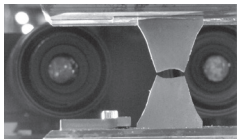
Robustness of different compensating strategies

### 3.3.10 Identification of Material and Friction Models as well as Corresponding Parameters by Means of the Inverse Method

Funding German Research Foundation  
 Project PAK 250 • Subproject 1  
 Contact M.Sc. A. Güner • Dipl.-Ing. Q. Yin

Material parameters have been identified by inverse parameter identification and new experimental setups have been implemented. In 2010, various steel and aluminum alloys were characterized by the help of notched specimen geometry. For this purpose, the algorithm developed for the inverse analysis has been adjusted and coupled with the flexible flow criterion YLD2000-2D. By using notched specimen geometries inhomogeneous strain distributions are obtained and exploited for an efficient characterization of the initial anisotropy of the sheet materials. The obtained material parameters have been verified by means of realistic workpieces.

In the context of this project a plane-torsion-testing device has been developed, manufactured, and put into operation which is able to carry out plane torsion tests. An evaluation strategy was developed to obtain flow curves using optical strain measurement. By this, very high plastic strains of up to 0.8 have been reached.

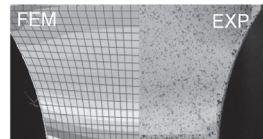


Experiments with notched specimens and optical measurement systems

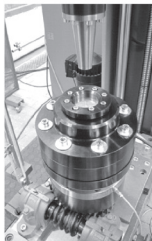
Objective function

- Principal strain distribution
- Forces
- Biaxial point

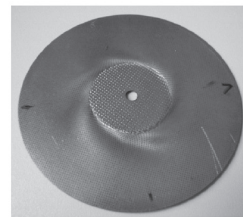
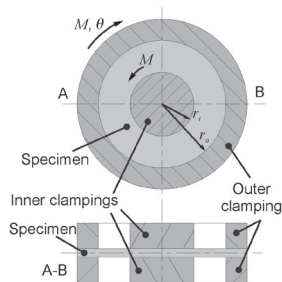
$$\Phi = \sum (\Delta \epsilon)^2 + \sum (\Delta F)^2 + \Delta \sigma_b$$



Measured and inverse obtained deformations fields with Yld2000-2d



Experimental setup for plane torsion test



Deformed specimen

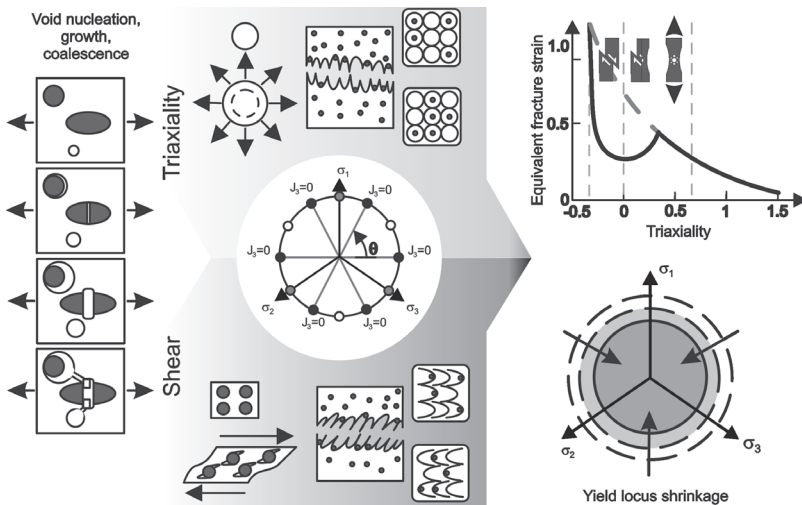
Material characterization by means of inverse finite element analysis and plane torsion test

### 3.3.11 Analysis of Strain-Path Dependent Damage and Microstructure Development for the Numerical Design of Sheet-Bulk Metal Forming Processes

Funding German Research Foundation  
 Project SFB/TR 73 • Subproject C4  
 Contact PhD. C. Soyarslan

Combined experimental and numerical investigations of the microstructure development within the context of damage prediction during sheet-bulk metal forming are aimed at. Experimental studies cover mechanical material characterization and validation as well as subsequent surface inspections where the void-related destabilizing mechanisms leading to material failure are being investigated. Numerical studies involve the improvement and implementation of existing physically-based damage models which take account of normal as well as shear stress state dominated material damages into nonlinear finite element models.

A database including the quantitative forming limits in sheet-bulk metal forming processes is being developed in order to assist the choice of materials in current applications.



Mechanisms and effects of ductile damage

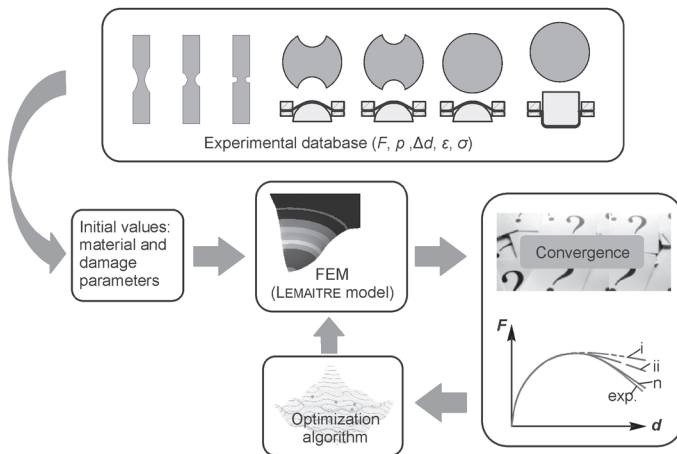
### 3.3.12 Development of an Industry-Oriented Failure Model for Sheet Metal Forming Simulations of Advanced High Strength Steels (AHSS)

Funding FOSTA  
 Project P 853  
 Contact M.Sc. K. Isik

An industrial-suited failure prediction model for sheet metal forming simulations shall be provided. Here, optimized software tools requiring minimal experimental data need to be developed.

Depending on the theory of the failure model, various damage parameters are required for failure prediction. The identification of damage parameters requires both costly equipment and considerable effort. In order to further its applicability in the industry an optimized procedure shall be provided.

Within the scope of the failure prediction a micromechanical-based Lemaitre model is chosen as a coupled failure model. The implementation of the failure model into software tools widely used in the industry will provide a practical opportunity for the usage of this failure model. The identification and prediction of the parameters for the model will be done by means of standard test methods for material characterization in order to obtain a solution responding to the industry's demands.



Inverse method for the determination of damage model parameters

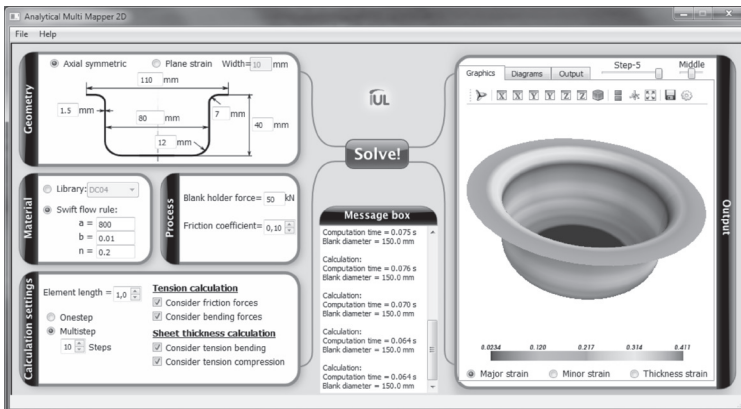
### 3.3.13 Time Efficient Modeling and Calculation of Process Chains in Sheet Metal Forming and Processing

Funding        German Research Foundation  
 Project        SPP1204 • Te 508/11-2  
 Contact        Dipl.-Ing. T. Cwiekala

Manufacturing processes of sheet metal parts need to be calculated as fast as possible. In this context, computation times are aspired which allow an online closed loop control of the process chain deep drawing – cutting – heat treatment – welding.

Within the scope of this project the IUL developed a simulation method for deep drawing processes by combining multiple analytical approaches which enables a very fast calculation and yet considers material behavior and deformation history.

The calculation of strains and stresses in complex part geometries is carried out along radial section lines positioned by means of a velocity field. Depending on the number of section lines the computation time takes up to 0.2 s. By adaption of an artificial neuronal network the computation time of axisymmetric parts was reduced to less than  $1 \times 10^{-4}$  s.



2D simulation software (Download:  
[http://www.iul.eu/de/index.php?option=com\\_content&task=view&id=69&Itemid=90](http://www.iul.eu/de/index.php?option=com_content&task=view&id=69&Itemid=90))



## 3.4 Department of Bending Technology

Head Dipl.-Ing. Matthias Hermes

In recent years lightweight construction has been increasingly implemented by using structures made of profiles with complex cross sections and high-strength materials. Those structures offer the advantage of high safety and good stiffness at the same time. This is an important aspect for transport systems and also involves a lower energy consumption by the weight reduction achieved. To realize esthetical and aerodynamic structures there is a strong demand in industry for 3D bend contours made of such profiles. The integration of functions and the high level of ergonomic use demands innovative solutions for the production technology.

The department of bending technology provides a broad range of solutions for these special properties by process developments, process optimization, and basic research in the field of bending and forming of sheets and tubes. This is achieved by combining basic research and innovative ideas.

One example is the internationally patented process “TSS Bending” (torque – superposed – spatial) for 3D freeform bending of profiles with arbitrary cross sections. The department has developed a machine prototype and a special process planning tool based on analytical insights. By this work the technology has reached a high industrial standard and the according patent has been transferred to a company from North Rhine-Westphalia. Another example is “Incremental Tube Forming” (ITF). At the moment, a machine prototype is being developed in cooperation with another partner company. This company also a license for the according patent.

Furthermore, the department focuses on sheet metal as semi-finished product and the production of sheet metal based profiles. Particularly roll forming and free bending of high-strength materials is under investigation. An important aim is the investigation and prevention of crack failure to allow wider process windows for the production of thin-walled lightweight profiles. For example, the patented process “free bending with incremental stress superposition” tries to extend these limits by the superposition of hydrostatic pressure in the bending area of the sheet metal bending process.

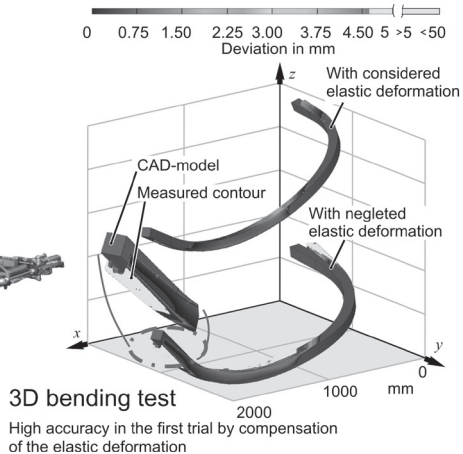
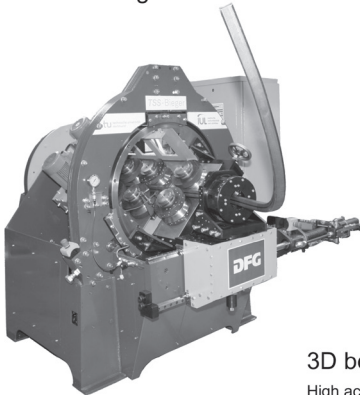
### 3.4.1 3D Bending of Profiles Using Stress Superposition

Funding	German Research Foundation
Project	Te 508/15-2
Contact	Dipl.-Ing. M. Hermes

An innovative process for 3D bending of profiles is being theoretically and experimentally investigated. Compared to conventional processes like stretch bending the advantage of Torque Superposed Spatial (TSS) bending is a kinematic definition of the bending contour leading to more flexibility and cost efficiency. In the first research period the focus was placed on the design of a special machine which was built and developed at the IUL.

Current work includes the development of a process planning tool to calculate a NC code for applied workpieces. The process planning tool uses the semi-analytical calculation to design a springback-compensated bending part. The compensation also includes the stiffness of the machine and of the workpiece in the tool set in the elastic areas. By this, it is possible to bend with high accuracy in the first trial (see figure).

Prototype of the TSS-bending machine



Left: The developed prototype of the TSS bending machine, right: a bending experiment – high accuracy in the first trial without trial and error tests

### 3.4.2 ProTuBend - Flexible and Cost-Effective Innovative Manufacturing of Complex 3D-Bent Tubes and Profiles Made of High-Strength Steels for Automotive Lightweight Structures

Funding EU, RFCS  
 Project RFSR-CT-2009-00017  
 Contact Dipl.-Ing. D. Staupendahl • Dipl.-Ing. C. Becker

Current demands on complex structures and individual lightweight design make the flexible bending of high-strength steel tubes and profiles a necessity in the modern production technology sector. As an alternative to form-bound and inflexible processes and process chains, two new bending methods were developed at the IUL: Torque Superposed Spatial (TSS) bending and Incremental Tube Forming (ITF). The aim of the ProTuBend project is to advance these two processes for industrial use capable of forming and bending load-optimized 3D tubes and profiles made of high and ultrahigh-strength steel.

In the initial project period demonstrators and materials were chosen. A structural member of a tractor cabin was chosen for the TSS bending process, while an automotive back rest frame was chosen for the ITF process. Current experimental investigations examine the springback behavior of the test specimens at different parameter setups as well as the process limits and possible process extensions.

#### Applications and demonstrators

##### TSS bending



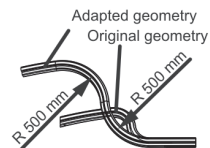
Cabin of the APL tractor of CNH



Current cabin design



Possible optimization by process extension

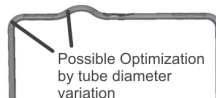


Demonstrator

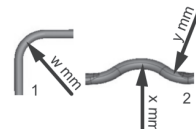
##### Incremental Tube Forming



Automotive back seat rest



Current back seat rest frame



Demonstrator parts

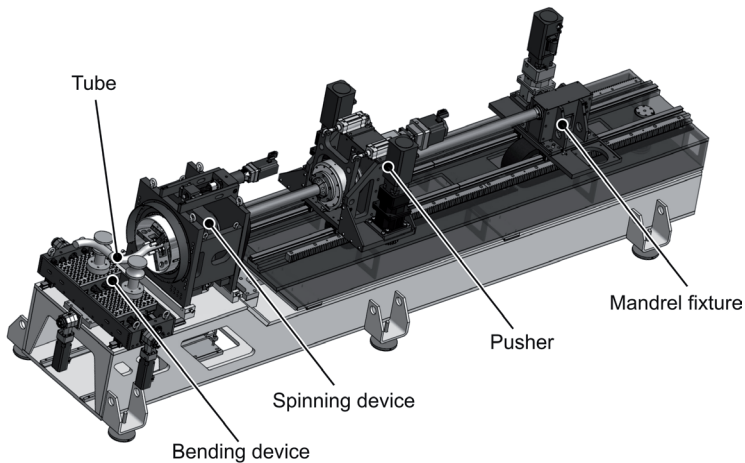
Applications and demonstrators for TSS bending and ITF

### 3.4.3 Investigation and Development of a Process and a Machine Technology for Incremental Tube Forming

Funding BMWi / ZIM-KF  
 Project KF2198101LK9  
 Contact Dipl.-Ing. C. Becker

The incremental tube forming process, which was patented by the IUL, is a combination of a tube spinning process and a free-form bending process. The process enables the manufacture of bent tubes with varying cross sections along the longitudinal axis. The tube is pushed by a pusher device through a rotating tool, which shrinks the diameter of the tube. After that the free-form bending process is superposed. This combination provides a reduction of the needed bending forces and a reduction of the springback effect, especially for high strength materials.

As part of this project, which is carried out in cooperation with our partner transfluid Maschinenbau GmbH, the IUL develops a new process and machine technology for incremental tube forming. After having designed and accomplished a prototype serving to define process limitations and dependencies the process and machine technology will be optimized and set up for industrial use.



Machine technology for incremental tube forming

### 3.4.4 Investigation of Springback Compensation in Sheet Metal Bending Processes by Incremental Compressive Stress Superposition

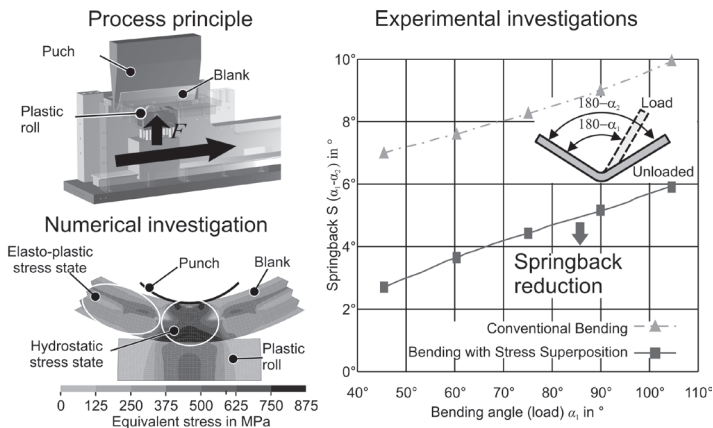
Funding German Research Foundation  
 Project MA1883/3-1  
 Contact Dipl.-Ing. Andres Weinrich

Bending high strength steels by air bending is a great challenge as they feature very high springback and low ductility. Therefore, a new process variant has been developed at the IUL. This variant is based on the incremental stress superposition in air bending procedures.

The aim of the project was to investigate the potential of the new process with regard to springback reduction, on the one hand, and, on the other hand, the origin of the springback reduction.

Within the experimental investigations a springback reduction of up to 60% could be achieved. The reason for the springback reduction is the hydrostatic stress state caused by the roll in the forming zone. Despite of this stress state a residual springback could be observed. The residual springback is determined by the elasto-plastic state in the areas where the roll does not have any contact.

Within the scope of the next application period the main focus will lie on low ductile materials. The new method will be used to investigate how the process limits can be extended.



Principle of the process; experimental and numerical investigations of the incremental stress superposition in air bending

### 3.4.5 Development of Basics for the Selection and Process-Reliable Design of Bending Procedures to Manufacture Profiles Made of Innovative Steel Materials

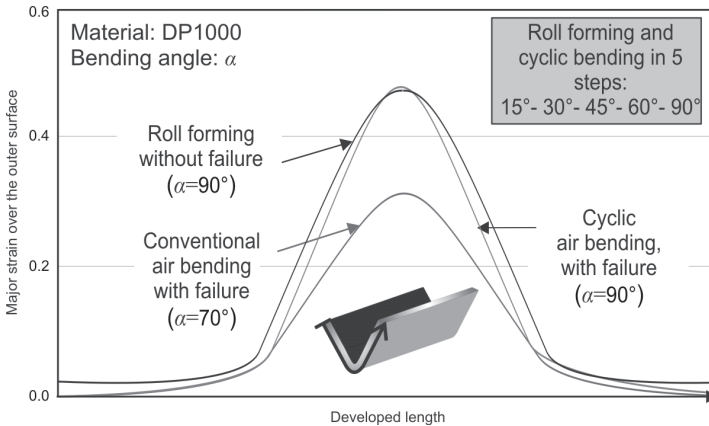
Funding	FOSTA
Project	P 789
Contact	M. Sc. M. M. Gharbi • Dipl.-Ing. A. Weinrich
Status	Completed

The use of profile components made of high-strength steels in light-weight structures in small and large batch production is constantly increasing. However, the formability of these materials is severely restricted because of their low ductility.

The applicability of these materials in air bending and roll forming processes is being investigated. Here, focus is put on the determination of process limits to achieve the maximum use of the materials and process potential.

It has been shown that the failure (crack formation) in air bending occurs earlier in comparison to roll forming. Furthermore, it could be observed that not only the stress states are the cause of this earlier failure, but also the stress history of the component.

Consequently, the advantages of the roll forming process have been transferred to air bending where a so-called cyclic bending is utilized instead of a one-step bending method. It was shown that the formability of the material is increased by cyclic bending.



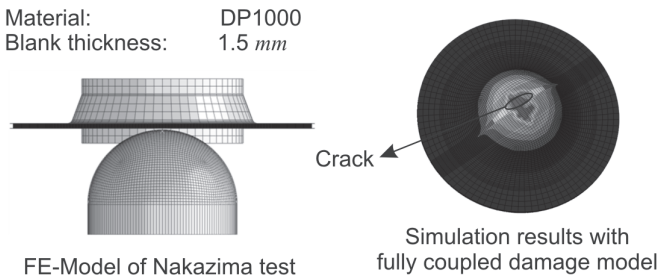
Comparison of the strain distribution over the outer surface in different processes

### 3.4.6 Defect Analysis and Prediction in Bending Processes

Funding            German Research Foundation  
 Project            TE 508/21-1  
 Contact            M. Sc. M. M. Gharbi

Nowadays, material formability is usually assessed by means of strain-based or stress-based forming limit diagrams. These failure criteria are not reliable for sheet metal bending processes where the strain path is non-linear and material hardening strongly depends on the shape of the loading path.

To overcome this shortcoming an advanced material model on the basis of phenomenological-experimental investigations considering fully coupled constitutive equations and including the isotropic and anisotropic behavior of the material, mixed non-linear hardening, and the non-local character of the isotropic and anisotropic ductile damage is needed. In order to identify the material and failure parameters preliminary phenomenological-experimental investigations have been carried out. A free bending process with this fully coupled damage model is being simulated. The ability of this model to predict location and time of inelastic flow occurrences due to the earliest stage of ductile damage initiation without reference to any initial imperfection has been illustrated.



	Punch displacement* in mm	Major strain* in %
Experiment	15 - 16 mm	37.1
Simulation	15.3 mm	36.2

\* Evaluated data just before the crack appearance

Simulation results and comparison with experimental investigation

## 3.5 Department of Non-Conventional Processes

Head Dipl.-Ing. Lukas Kwiatkowski

Innovative technologies and complex forming processes – the recently founded department of non-conventional processes introduces itself:

The purpose of the department is to boost the application of emerging forming processes and to combine atypical with conventional manufacturing techniques, for example with the objective of extending current forming limits. The aim is to provide attractive alternatives to already established systems or to develop specialized techniques for niches within the production technology sector. At present the department's research focuses on incremental forming and forming based on electromagnetic fields. Main objective is to deliver fundamental knowledge based on a robust process control. In the long run this will allow a systematic transfer of the gathered knowledge to industrial applications.

As a contribution to the understanding of the complex forming mechanisms of incremental forming extensive parameter studies are conducted in close collaboration with the faculty of statistics. This is done for sheet metals and tubular semi-finished products made of steel and aluminum. Here, the full use of the processes' potential is aimed at, combined with an adaptation of the process parameters to the specific production task. Even thermoplastics and hybrid materials have shown their feasibility to be treated by incremental forming. The deformations obtained are comparable to those obtained with metals. Another issue apart from the manufacturing of hollow bodies is the application of bulk metal forming processes to sheet metal. The research subjects concerning incremental forming are completed by the development of processes for the post treatment of coated tools for deep drawing operations by roller burnishing. In regard to electromagnetic forming, one research topic is the development of methods for an efficient combination of these processes with conventional ones. The main motivation is to meet complex geometric requirements and to shift current forming limits. Focus of the work is the development of contact-free joining processes based on electromagnetic forming and their application to lightweight structures.

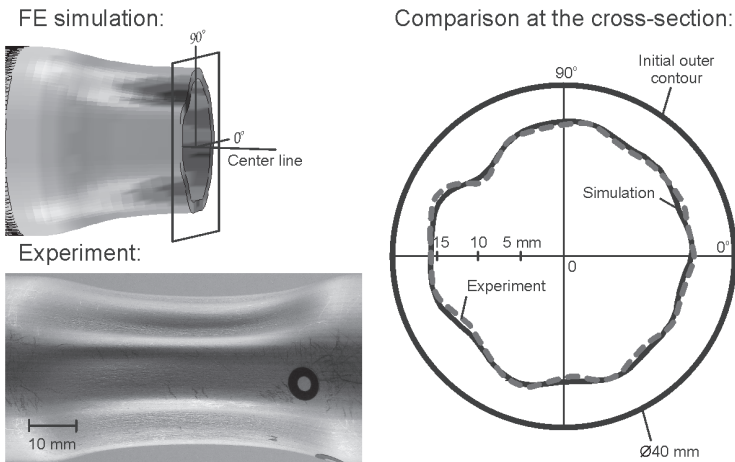


### 3.5.1 Process Development for Combined Conventional and Electromagnetic Forming Operations

Funding            German Research Foundation  
 Project            PAK343 • Subproject 1  
 Contact            M.Sc. O. K. Demir

The forming limits of quasi-static forming methods can be extended by means of a combination with an electromagnetic forming process. Given the final product, the project aims at developing a suitable methodology to design such process chains. Two selected process chains are investigated.

The combination of electromagnetic tube compression (ETC) with tube hydroforming (TH) is used to form cylindrical parts. To form sheet metal deep drawing is combined with electromagnetic sheet metal forming. The intent is to manufacture a desired geometry which cannot be produced with conventional forming processes. Experimental and numerical investigations are being performed in order to comprehend the effects of strain path and strain rate variations upon the forming results. The research is being carried out in collaboration with the Institute of Applied Mathematics at TU Dortmund, the Institute of Applied Mechanics at RWTH Aachen, and the Institute of Materials Science at Leibniz Universität Hannover.



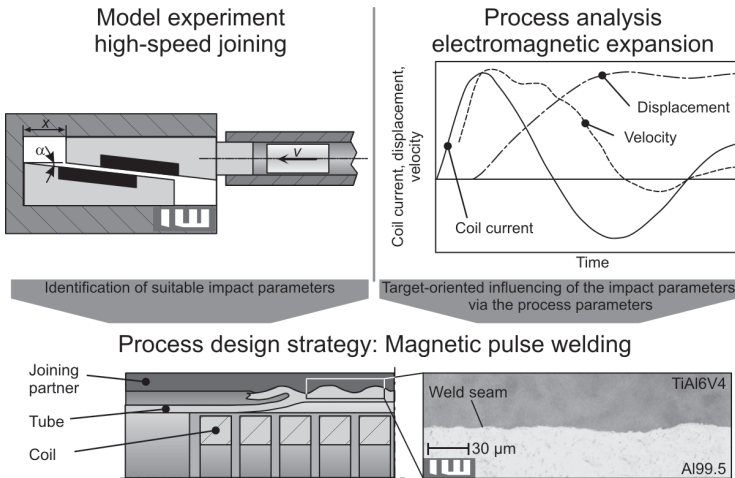
Simulation of wrinkle formation in electromagnetic compression

### 3.5.2 Investigation of the Complex Interdependencies in Electromagnetic Tube Forming

Funding German Research Foundation  
 Project TE 508/19-1  
 Contact Dr.-Ing. V. Psyk

In cooperation with the Institute of Materials Sciences (IW) of the Leibniz Universität Hannover firmly bonded joints manufactured by electromagnetic forming (EMF), are dimensioned. Within the scope of the process the joint is significantly influenced by the impact angle and velocity so that these parameters have to be adapted to the forming task. This can only be implemented indirectly via tool coil and machine parameters and the charging energy.

Therefore, the two research institutes pursue two subgoals: at the IW beneficial impact conditions are identified using a model experiment while the dependencies of the impact conditions on the adjustable parameters during EMF are determined at the IUL. In a synthesis step the results are combined in order to dimension the joining process in a target-oriented way. First investigations show that, compared to thermal joining technologies, less intermetallic phases occur in joining by EMF on the basis of intermetallic bonding.



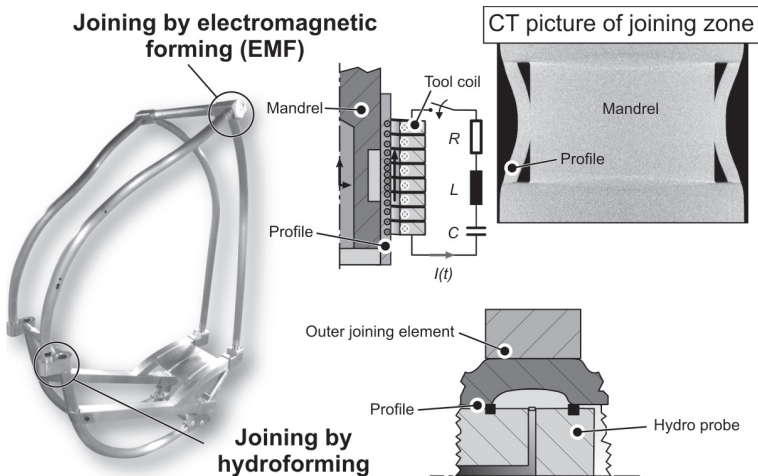
Strategy for the process design for joining by EMF on the basis of intermetallic bonding

### 3.5.3 Joining by Forming

Funding German Research Foundation  
 Project SFB/TR 10 • Subproject A10  
 Contact Dipl.-Wirt.-Ing. C. Weddeling

Based on fundamental technological investigations alternative joining strategies for joining by forming are developed within subproject A10 of the Collaborative Research Center SFB/TR10. The interference-fit and form-fit connections which are treated within the scope of the project are joined either by electromagnetic forming or by hydroforming. A station for joining by EMF and by hydroforming was developed and integrated in the flexible process chain of the SFB/TR10. The influence of different process parameters (e.g. forming pressure) and joining zone characteristics (e.g. joining zone design) on the achievable joint strength was investigated.

Based on the results of these investigations a variety of general principles for the process design and joining zone design was developed. In the upcoming third period of the SFB/TR10, which will start in 2011, welded sheet-to-profile connections will be investigated as well. To manufacture these joints magnetic pulse welding will be used.



Joining by electromagnetic forming and hydroforming

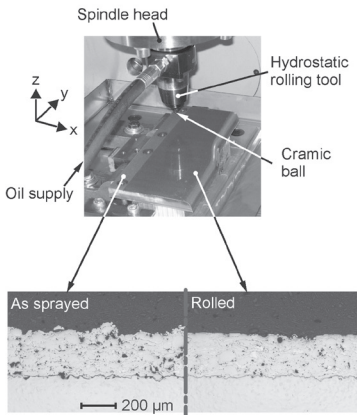
### 3.5.4 Surface Treatment of Thermally Sprayed Hard Material Coatings for the Application in Forming Tools

Funding German Research Foundation  
 Project SFB 708 • Subproject A3  
 Contact M.Sc. V. Franzen

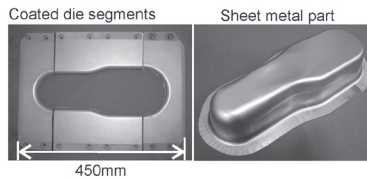
Thermally sprayed hard material coatings for the application in sheet metal forming tools are mechanically refined. The hard material coatings need to meet the high tribological requirements during forming of high strength sheet materials. The sprayed coatings show high roughness after spraying and are not suitable for the use in forming tools in their initial state. The coatings are smoothed in a subsequent incremental roller burnishing process which is analyzed in this research project.

In addition, residual compressive stresses are generated by the rolling process which compensate the residual tensile stresses after coating. The CNC-based incremental rolling process allows the manufacturing of textured effective tool surfaces which make the local adjustment of the frictional properties in the deep drawing process possible. By the end of the first funding period a coated deep drawing tool was successfully tested (see Fig.).

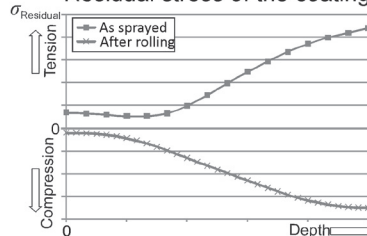
#### Rolling process



#### Coated deep drawing tool



#### Residual stress of the coating



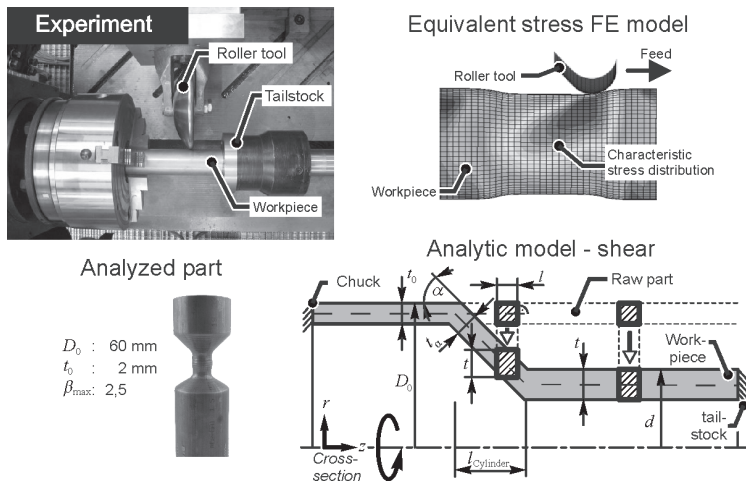
Incremental roller burnishing of coated surfaces

### 3.5.5 Application of Statistical Methods for Process Design and Optimization in Necking-In Processes

Funding	German Research Foundation
Project	SFB 475 • Subproject T2
Contact	Dipl.-Ing. L. Kwiatkowski
Status	Completed

In collaboration with the faculty of statistics the cause-and-effect-principles of incremental necking-in have been analyzed. Main objective was the development of methods which allow a systematic and reproducible design strategy of this complex forming operation. Based on a combination of simplifying analytic techniques and design of experiments, process windows and forming limits could be established for a variety of steel and aluminum materials.

Furthermore, the efficiency of a methodology developed for the optimization of various target parameters could be demonstrated. The workpieces could be optimized taking into account their specific case of application by the introduction of desirabilities. Main focus of the work was to meet the geometric requirements. The investigations were carried out in collaboration with the industry partners Volkswagen, Mannesmann Präzisionsrohr, Benteler, WF Maschinenbau, and Winkelmann Dynaform.



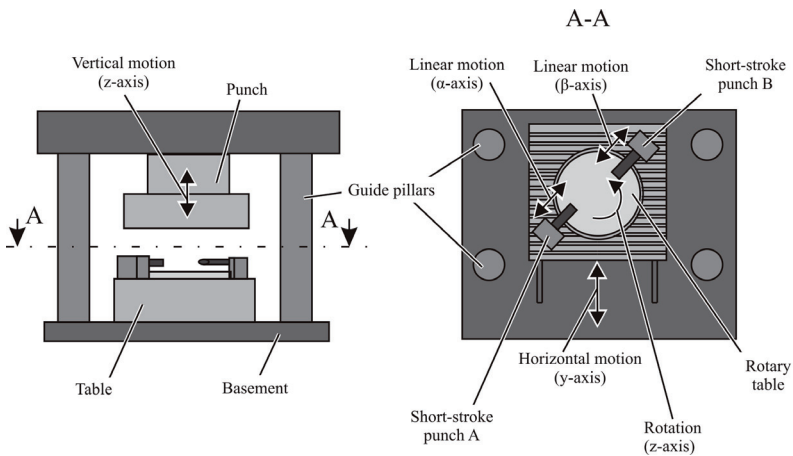
Experimental investigations and used models for incremental necking-in

### 3.5.6 Process Development for Manufacturing of Load-Optimized Parts by Incremental Forming of Thick Metal Sheets

Funding German Research Foundation  
 Project SFB/TR 73 • Subproject A4  
 Contact Dipl.-Ing. B. Plugge

A process to manufacture near net shape and load-optimized parts of blank sheets by the application of bulk metal forming operations to sheets is being developed. The characteristic feature is the application of different forming processes in locally restricted sections, e.g. rolling, stretch forming, coining, compression, and embossing. These processes distribute the material first. Afterwards a final geometry is being formed.

The distribution of the material leads to a modification of the local thickness as well as of the surface hardening. This is advantageous for the application of the finished product. Current investigations focus on the development of appropriate strategies for the individual and combined processes. Here, experimental work and numerical methods are used. Based on the results a new machine concept has been developed. This machine allows the further investigation of sequential forming operations in the next period of the project.



Layout of a machine concept for incremental sheet bulk metal forming

### 3.5.7 Characterization of the Dynamical Process of Incremental Sheet Metal Forming

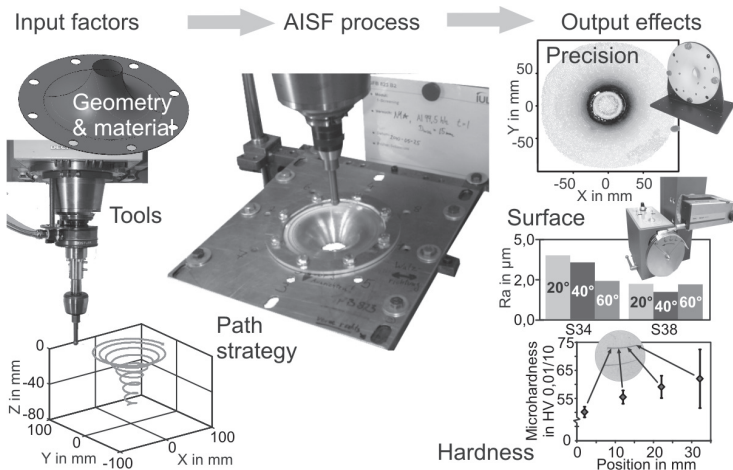
Funding German Research Foundation  
 Project SFB 823 • Subproject B2  
 Contact Dipl.-Ing. (FH) G. Sebastiani M.Sc.

Combining the fields of engineering and statistics, the project deals with an AISF process model based on transferable physical relations. The present project period focuses on developing an investigation environment to identify the fundamental cause-and-effect interrelations.

Using a fractional factorial experimental design, the main factors material, part geometry, tools, and path strategy are being investigated. As quality objectives, geometry, thinning, roughness at the processing surface as well as microhardness are considered.

Based on the investigation environment, all experimental and measurement tasks could be realized as small batch series and qualitatively assessed, thus providing engineering students a hands-on-experience.

Within the SFB 823, B2 as technological subproject is embedded into basic statistical research. Consequently, all projects profit from synergies regarding statistical methods, process knowledge, and test data for the mentioned methods.



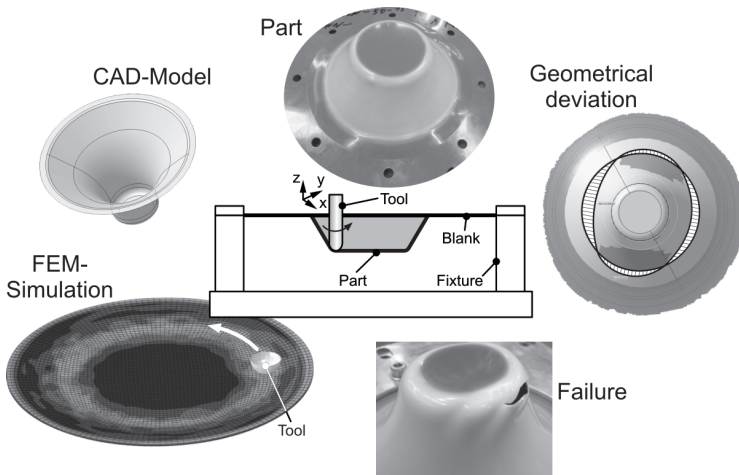
Factors and effects investigated in incremental sheet forming

### 3.5.8 Investigation of the Deformation Behavior of Thermoplastics during Incremental Cold Forming

Funding	German Research Foundation
Project	TE 508/20-1
Contact	Dipl.-Ing. S. Schunck

Current methods for the production of thermoplastic parts, such as injection moulding, are not economical for prototyping and small patch production due to the part-dependent tooling and accordingly high investments in equipment. In contrast, preliminary tests have shown that thermoplastic sheets can be formed by a flexible incremental sheet forming process. The aim of this project is the fundamental research-based development of an incremental forming process of thermoplastics so that forming potentials can be exploited to the greatest possible extent by an adequate process design. For this purpose, experimental work and numerical simulations are carried out.

In the experimental work three thermoplastics (PVC, PC, and HDPE) are formed incrementally. Here, the influence of the process parameters is being investigated by applying statistical design of experiments methods. The experimental studies are simultaneously complemented by numerical simulations.



Work stages necessary for determining the deformation behavior of thermoplastics during incremental forming

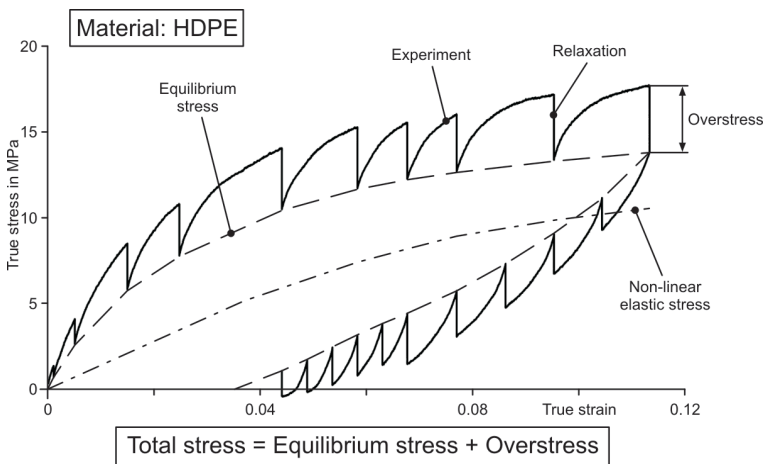


### 3.5.9 Creation of a Material Model for Numerical Investigations on Forming of Laminar Thermoplastic Polymers

Funding Graduate School of Energy Efficient Production and Logistics  
 Contact Dipl.-Ing. S. Alkas Yonan

Thermoplastic polymers can be formed at room temperature, as earlier incremental sheet forming tests have shown. The aim of this project is to characterize the deformation behavior of thermoplastics at room temperature and to analyze the mechanical properties of cold-formed parts. Different sheet forming processes will be investigated numerically and experimentally.

Within this project material characterization tests on three different thermoplastics are carried out in order to determine the stress-strain behavior at room temperature. The tests show the expected non-linear strain rate dependency and prove the existence of an equilibrium hysteresis, which is a criterion of the permanent strain. Based on the behavior of thermoplastics during loading and unloading as well as on the relaxation behavior a viscoplastic material model is being formulated, which is required for the subsequent numerical studies.



Material modeling of thermoplastics

## 3.6 Patents

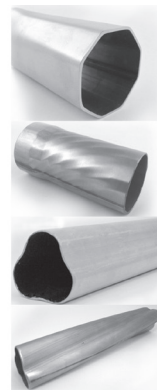
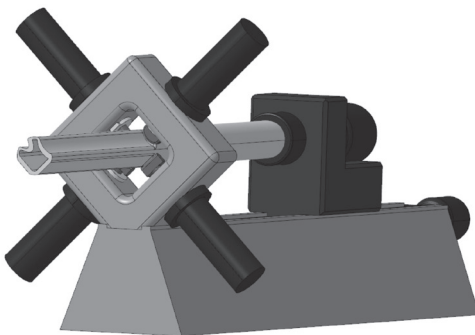
### 3.6.1 Process and Apparatus for Incremental Forming of Profiles, in Particular of Profiles with Varying Cross Sections (RoProFlex)

Patentnumber	10 2010 025 593.9
Patentholder	Technische Universität Dortmund
Status	Filed
Inventors	Dipl.-Ing. C. Becker Dipl.-Ing. M. Hermes R. Wagner Prof. Dr.-Ing. A. E. Tekkaya

To produce asymmetric profiles with bent and straight areas different process chains are currently applied.

At the Institute of Forming Technology and Lightweight Construction (IUL) a new flexible manufacturing process for tubes and profiles called RoProFlex was invented and patented. With the RoProFlex process the cross section of tubes and profiles can be formed CNC-controlled along the longitudinal axis to almost any desired workpiece shape.

Because of the large variety of possible geometries the process offers a wide field of application. From lightweight parts for cars and utility vehicles to ultra light precision parts like gears or screw rotors to e.g. medical implants - a manufacturing is theoretically possible at yet considerably lower tooling costs.

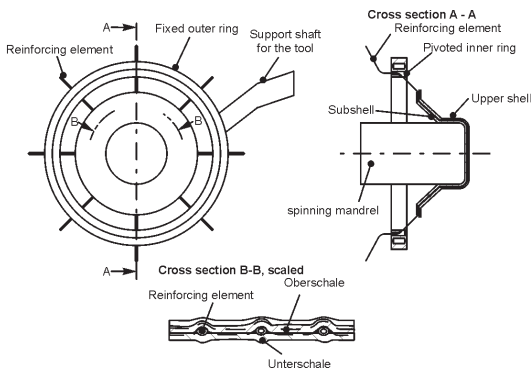


Machine layout and several samples producible by RoProFlex

### 3.6.2 Process for the Manufacturing of Compound Workpieces with Reinforcing Structures as well as Accordingly Manufactured Workpieces (CompForm )

Application number	PCT/DE2010/000619
Patentholder	Technische Universität Dortmund
Status	Filed
Inventors	Dipl.-Ing. G. Sebastiani Dipl.-Ing. P. Schmelzer Dr.-Ing. M. Marré Dr.-Ing. M. Trompeter Dr.-Ing. A. Brosius Prof. Dr.-Ing. A.E. Tekkaya

The patent application comprises forming procedures producing compound workpieces made of sheet metal with local reinforcing structures or functional elements. While semi-finished parts made of sheet metal are processed to hollow or flat sheet metal components reinforcing or functional elements are being embedded into the sheet metal base material or into a double blank compound structure; in this way, forming and reinforcement or embedding are made possible within one manufacturing step. Thus, reinforced or multifunctional sheet metal formed parts can be manufactured by means of a short, efficient process chain. Apart from reinforcements by high-strength wires or meshes the embedding of electric conductors or pipes is conceivable. This compound generation is also applicable to tube and profile components.



Manufacturing of compound workpieces with reinforcing structures by spinning

### 3.6.3 Expansion and Joining Apparatus Operating by Means of Hydroforming

Patent number 10 2010 012 452.4  
 Patent holder Technische Universität Dortmund  
 Status Filed  
 Inventors R. Andreas  
 R. Hense  
 Dr.-Ing. Dipl.-Wirt.-Ing. M. Marré  
 Prof. Dr.-Ing. A. E. Tekkaya

Joining by hydroforming can be used to manufacture interference-fit and form-fit joints for lightweight frame structures. Therefore, the profile has to be positioned in a connection element. Afterwards the profile is expanded by hydraulic pressure against the outer connection element. To manufacture an interference-fit connection the two joining partners are deformed elastic-plastically. For the generation of a form-fit joint the profile is formed into a groove which was machined in the outer joining partner before. The required hydraulic pressure is applied through a joining probe. Current probes only allow joining of profiles with a round cross section. To enhance the field of application of the process a new joining probe concept was developed at the IUL. This new tool concept also allows the manufacturing of connections with rectangular cross sections. It was already successfully used for the joining of a SFB/TR10 demonstrator.

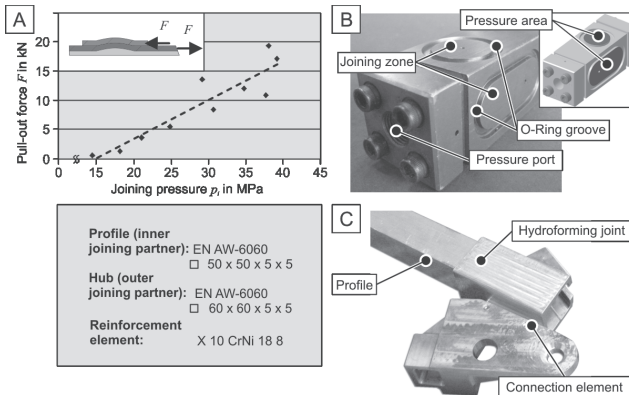


Figure: A) Pull-out force with respect to the joining pressure, B) Joining probe for rectangular profiles, C) Form-fit joint of a rectangular profile of the SFB/TR10 demonstrator

## 3.7 Cooperations

At this point we would like to express our gratitude to the large number of various cooperation partners in 2010 which have added to our joint success.

### University cooperations

#### University cooperations at national level

- Fachgebiet Fluidtechnik, Technische Universität Dortmund
- Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg
- Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, Technische Universität Chemnitz
- Lehrstuhl für Wissenschaftliches Rechnen, Technische Universität Dortmund
- Lehrstuhl für Werkstoffkunde, Universität Paderborn
- Lehrstuhl für Werkstofftechnik, Universität Rostock
- Lehrstuhl für Werkstofftechnologie, Technische Universität Dortmund
- Materialprüfungsanstalt, Universität Stuttgart
- Professur Werkstoffe des Maschinenbaus, Technische Universität Chemnitz
- Hochschuldidaktisches Zentrum, Technische Universität Dortmund
- Institut für Bildsame Formgebung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Fertigungstechnik und Werkzeugmaschinen, Leibniz Universität Hannover
- Institut für Angewandte Mechanik, RWTH Aachen
- Institut für Massivbau, Technische Universität Dresden
- Institut für Mechanik, Technische Universität Dortmund
- Institut für Metallurgie, Technische Universität Clausthal
- Institut für Produktionstechnik und Umformmaschinen, Technische Universität Darmstadt

- Institut für Spanende Fertigung, Technische Universität Dortmund
- Institut für Umformtechnik, Universität Stuttgart
- Institut für Umformtechnik und Umformmaschinen, Leibniz Universität Hannover
- Institut für Werkstoffkunde, Leibniz Universität Hannover
- Laboratory for Chassis Suspension Technology, FH Osnabrück
- Lehrstuhl für Fertigungstechnik und Werkzeugmaschinen, Universität Siegen
- Lehrstuhl für Fertigungstechnologie, Friedrich-Alexander-Universität Erlangen-Nürnberg
- Lehrstuhl für Leichtbau, Technische Universität München
- Lehrstuhl für mathematische Statistik und naturwissenschaftliche Anwendungen, TU Dortmund
- Lehrstuhl für Umformende und Spanende Fertigungstechnik, Universität Paderborn
- Institut für Werkzeugmaschinen und Betriebswissenschaften, Technische Universität München
- Lehrstuhl für Umformtechnik und Gießereiwesen, Technische Universität München
- Institut für Werkstoffkunde I, Karlsruher Institut für Technologie (KIT)
- wbk Institut für Produktionstechnik, Karlsruher Institut für Technologie (KIT)

### University cooperations at international level

- Center of Manufacturing and Industrial Management (CMIM), Universidade Técnica de Lisboa, Portugal
- Construerende Technische Wetenschappen, Technische Mechanica, Universiteit Twente, Niederlande
- Department of Industrial Engineering, University of Palermo, Italy
- Department of Materials Science and Engineering, The Ohio State University, Ohio, USA
- DIEM-Tech Manufacturing Technology Group of the University of Bologna, Italien

- Institut Charles Delaunay, Laboratoire des Systèmes Mécaniques et d'ingénierie Simultanée (LASMIS), Université de Technologie de Troyes, Frankreich
- Institute for Manufacturing, Department of Engineering, University of Cambridge, Großbritannien
- Loewy Chair in Materials Forming and Processing, Institute for Metal Forming, Lehigh University, Bethlehem, Pennsylvania, USA
- Metal Forming Center of Excellence, Atilim Universität, Ankara, Türkei
- Royal Institute of Technology KTH, Department of Production Engineering, Stockholm, Schweden
- School of Materials Science & Engineering and the Department of Plasticity Forming Engineering at Shanghai Jiao Tong University, China
- School of Engineering, Swansea University, Wales, Großbritannien
- Technische Universität Cluj-Napoca, Klausenburg, Rumänien
- University of Milano Bicocca, Mailand, Italien
- Warsaw University of Technology, Warschau, Polen

### **Industrial cooperations at national and international level**

- Airbus S. A. S.
- Alcan CRV (Centre de Recherches de Voreppe)
- Aleris Aluminum Duffel BVBA
- Alu Menziken AG, Schweiz
- ALUTEC Leichtmetallfelgen GmbH
- ARBURG GmbH + Co KG
- ASCAMM Technology Centre
- ASERM – Asociación Española de Rapid Manufacturing
- Auerhammer Metallwerk GmbH
- AUDI AG
- Benteler AG
- BMW AG
- borit Leichtbau - Technik GmbH
- BRUDERER AG

- Corus Strip Products, England
- CRF – Centro Ricerche Fiat S.C.p.A.
- Daimler AG
- Data M Sheet Metal Solutions GmbH
- DYNAmore GmbH
- Erbslöh Aktiengesellschaft
- EvoBus GmbH
- Faurecia Autositze GmbH
- Forschungsvereinigung Stahlanwendung e. V.
- Franz Pauli GmbH & Co. KG
- F.W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Hirschvogel Umformtechnik GmbH
- Honsel AG
- Hydro Aluminium Deutschland GmbH
- imk automotive GmbH
- Inspire AG - IRPD
- JFE Steel Corporation, Japan
- Johnson Controls Hilchenbach GmbH
- Kirchhoff Automotive GmbH
- Kistler-Igel GmbH
- Koda Stanz- und Biegetechnik GmbH
- Kunze GmbH
- LEIBER Group GmbH & Co. KG
- Novelis Technology AG
- Otto Fuchs KG
- Poynting GmbH
- Physica Ltd.
- Rehau AG + Co
- Repkon, Istanbul, Türkei
- Robert Bosch GmbH
- S+C Extrusion Tooling Solutions GmbH
- Salzgitter Mannesmann Forschung GmbH
- Salzgitter Mannesmann Präzisrohr GmbH



- Schnupp GmbH & Co. KG
- Schondelmaier GmbH
- Schuler AG
- Schwarze-Robitec GmbH
- Siemens Aktiengesellschaft
- Simufact Engineering GmbH
- SMS Meer GmbH
- SSAB Swedish Steel GmbH
- SSAB Tunnplåt AB, Schweden
- Tata Steel (ehem. Corus Technology BV)
- TECOS – Slovenian Tool and Die Development Centre
- ThyssenKrupp Presta AG
- ThyssenKrupp Steel Europe AG
- TRACTO-TECHNIK GmbH & Co. KG Spezialmaschinen
- Transfluid Maschinenbau GmbH
- TRUMPF Werkzeugmaschinen GmbH + Co. KG
- Viessmann Werke GmbH & Co KG
- Voestalpine AG
- VOLKSWAGEN AG
- Welser Profile GmbH
- WF Maschinenbau und Blechformtechnik GmbH & Co. KG
- Wilke Werkzeugbau GmbH & Co KG
- WILO SE
- Winkelmann Dynaform Technik GmbH & Co. KG
- ZWEZ-Chemie GmbH

## Associations

- acatech - Deutsche Akademie der Technikwissenschaften
- AGU - Arbeitsgemeinschaft Umformtechnik
- AIST - Association for Iron and Steel Technology
- ASM International N.V.
- CIRP - The International Academy for Production Engineering
- DGM - Deutsche Gesellschaft für Materialkunde e.V.
- Kunststoff-Institut Lüdenscheid
- Esaform European Scientific Association For Material Forming
- Europäische Forschungsgesellschaft für Blechverarbeitung e.V.
- FOSTA - Forschungsvereinigung Stahlanwendung e.V.
- GCFG - German Cold Forging Group
- ICFG - International Cold Forging Group
- IDDRG - International Deep Drawing Research Group
- I<sup>2</sup>FG - International Impulse Forming Group
- Industrieverband Blechumformung
- Industrieverband Massivumformung
- GDA - Gesamtverband der Aluminiumindustrie e.V.
- German Cold Forging Group
- KIST - Kompetenz- und Innovationszentrum für die StanzTechnologie e. V.
- Stahlinstitut VDEh
- Leichtbacluster
- TMS The Minerals, Metals & Materials Society Inc.
- VDI - Verein Deutscher Ingenieure e.V.
- VDW Verein Deutscher Werkzeugmaschinenfabriken e.V.
- Wirtschaftsverband Stahl- und Metallverarbeitung e.V.
- WGP - Wissenschaftliche Gesellschaft für Produktionstechnik

## Foundations

- Karl-Kolle-Stiftung
- VolkswagenStiftung

## 4 Further Activities

### 4.1 Conferences and Meetings

In 2010 the following conferences and workshops were hosted or co-organized by the Institute of Forming Technology and Lightweight Construction to present research results and to meet researchers from industry and universities.

- ICHSF10/4<sup>th</sup> International Conference on High Speed Forming • in cooperation with Prof. Glenn S. Daehn, Department of Materials Science and Engineering, The Ohio State University • venue: Ohio, USA • March 9 - 10
- 13<sup>th</sup> Workshop „Simulation in der Umformtechnik“ (Simulation in Forming Technology) • in cooperation with Prof. Mathias Liewald, Institut für Umformtechnik, Universität Stuttgart • venue: Stuttgart • March 29
- International Conference on Product Property Prediction – P<sup>3</sup> • in cooperation with ISF and LWT, TU Dortmund • April 12 - 13
- 2<sup>nd</sup> Workshop „Scientific Publishing“ • April 22
- Journal of Materials Processing Technology - Editorial Meeting • June 14
- Constitutive Session of the Industrial Advisory Board of the IUL • September 27
- Workshop „Biegen in Siegen“ (Workshop on Bending) • in cooperation with Prof. Bernd Engel, Lehrstuhl für Umformtechnik, Universität Siegen • venue: Dortmund • October 7
- DGM Workshop „Einführung in die Grundlagen des Tiefziehens“ (Introduction to Deep Drawing Fundamentals) • November 18 – 19 (hosted by IUL, organized by DGM - German Society for Materials Science)
- HDZ Workshop „Wissenschaftliches Schreiben in der Lehre“ (Scientific Writing for Didactic Purposes) • in cooperation with HDZ (Center for Research on Higher Education and Faculty Development), TU Dortmund • November 29 – 30

Furthermore, the IUL participated in the following events, some of which were also open to a non-scientific audience of different target groups:

- Stahl fliegt (Flying Steel) • April to July
- Girls' Day • April 22
- Campus Open Day • June 19
- SchnupperUni • August 26
- KinderUni (Childrens' University) in Werne • December 10

In the following, you will find more information on selected events.

### **International Conference on High Speed Forming ICHSF 2010**

On March 9 and 10, 2010, the International Conference on High Speed Forming was held in Columbus, Ohio, USA. The conference was organized as joint event of the Department of Materials Science and Engineering of the Ohio State University and the IUL. More than 60 participants from 11 nations from industry and academics attended the conference. In addition to the presentation of new research results regarding high speed forming, the conference provided a forum for the exchange of experiences and the discussion between industrial operators and researchers on an international stage.

The conference covered, among other things, the topics of industrial applications for high speed forming processes, electro-hydraulic forming, joining by electromagnetic forming as well as modeling and simulation of these processes..



Participants of the ICHSF2010

## 13<sup>th</sup> Workshop on „Simulation in Metal Forming“

The thirteenth workshop on “Simulation in Metal Forming” was held on March 19, 2010, at the University of Stuttgart. The workshop was organized as a collaboration between the Institute for Metal Forming Technology (IFU) in Stuttgart and the IUL. The main topic of this year’s workshop was the modeling of hardening mechanisms in sheet metal forming. Selected works from the universities and industry were presented during the workshop. The presentations from the universities showed recent theoretical developments of micro-mechanical material models that are used to obtain the macro hardening behavior of metallic materials. The software vendors of the leading finite element simulation software presented the newly implemented models and application examples. The required material parameters and characterization tests were also discussed in this session. The industrial aspects of the topic were also considered on the basis of real industrial problems and solution strategies presented by the participants from industry. The authors had the opportunity to discuss the topics with more than 80 workshop participants.



Impression of the workshop hosted in Stuttgart

## Cluster of Excellence Product Property Prediction – P<sup>3</sup>

The manufacturing technology encounters fundamental challenges due to changing economic and ecological conditions. The Cluster of Excellence Product Property Prediction – P<sup>3</sup> aims at developing visionary approaches for resource and energy efficient manufacturing technologies of the future. The vision of the Cluster of Excellence is to predict and adjust the final mechanical properties of a product. Thereby, not only time, but also material and energy can be saved during the product development process. Such an academic research program requires the cooperation of multiple disciplines as engineering, physics, mathematics, and statistics.

At the 1st International Conference on Product Property Prediction – P<sup>3</sup>, held on April 12 and 13 at TU Dortmund, new approaches initiating the next generation of production technology were presented. The highlights of this conference were the presentations of Nobel Prize winners Peter Grünberg from Forschungszentrum Jülich and Ernst Worrell from Utrecht University. The conference was organized by three manufacturing technology institutes of the Faculty of Mechanical Engineering of TU Dortmund: Institute of Machining Technology (ISF), Institute of Forming Technology and Lightweight Construction (IUL), and the Institute of Materials Engineering (LWT). In addition to oral presentations, discussions between the speakers and the conference organizers as well as the highly reputable international participants were central to the conference.



From left to right: Prof. A. Erman Tekkaya (IUL), Prof. Dirk Biermann (ISF), Prof. Ernst Worrell (Utrecht University), Prof. Wolfgang Tillmann (LWT), Prof. Peter Grünberg (Forschungszentrum Jülich), Prof. Ursula Gather (Rector of TU Dortmund)

## 2<sup>nd</sup> Workshop „Scientific Publishing“

On April 22, 2010, the second Workshop “Scientific Publishing” took place in Hannover within the scope of the SFB/TR73.

Prof. Dr.-Ing. A. Erman Tekkaya, Editor-in-Chief of the Journal of Materials Processing Technology (Elsevier), and Mrs. Rebecca Wilson and Mr. Christopher Greenwell, both Publisher at Elsevier, imparted fundamentals for the procedure of writing of scientific publications. In lectures like „Research Process“, “How to Get Published in Scientific Journals”, and “Author’s Rights and Responsibilities” the co-workers of the institutes involved in the SFB/TR73 could obtain important information and advice for the publication of research results in peer-reviewed journals.

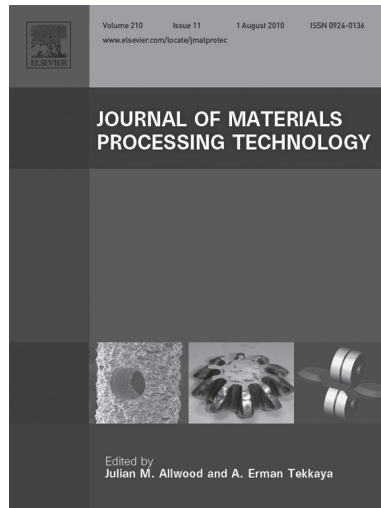


Impressions of the workshop on „Scientific Publishing“

## Journal of Materials Processing Technology - Editorial Meeting

The Editorial Meeting of the “Journal of Materials Processing Technology” (JMPT), Elsevier, was held on June 14, 2010 at the Institute of Forming Technology and Lightweight Construction (IUL) in Dortmund. In addition to the editors-in-chief, Dr. Julian Allwood, University of Cambridge, UK, and Prof. Dr.-Ing. A. Erman Tekkaya, IUL, TU Dortmund, and the technical assistant of the JMPT, Mrs. Ramona Hölker, also the subject editors, Dr. Carlos H. Caceres, University of Queensland, Brisbane, QLD, Australia, responsible for casting, heat treatment, welding, and surface treatment, and Prof. Thomas H. C. Childs of the University of Leeds, Leeds, England, UK, responsible for machining, participated.

The journal covers the processing techniques used for the manufacturing of components made of metals and non-metallic materials. Mrs. Rebecca Wilson, Elsevier publisher responsible for the “Industrial & Manufacturing Engineering” division, reported on good news: with almost 2 million downloaded papers from the JMPT website on Science Direct in the past year, more than 2.000 submitted publications, and an impact factor of 1,420 JMPT belongs to one of the most important and most read journals in the field of manufacturing engineering.



Cover of the Journal JMPT



## Constitutive Session of the Industrial Advisory Board IUL

On September 27, 2010, the constitutive session of the Industrial Advisory Board of the IUL was held. The Industrial Advisory Board will support the IUL in its applied research policies. Besides advising the institute on the development of collaborative research projects, the Industrial Advisory Board shall promote the dissemination of fundamental research results to pave the way for their industrial application. Members are:

- Dr. W. Volk, BMW AG
- Prof. K. Roll, Daimler AG
- Dr. F. O. R. Fischer, Deutsche Gesellschaft für Materialkunde e.V.
- Prof. K. Schweizerhof, DYNAmore GmbH
- F.-B. Pauli, Franz Pauli GmbH & Co. KG
- W. Heidrich, Gesamtverband der Aluminiumindustrie e.V. (GDA)
- S. Widdermann, German Cold Forging Group (GCFG)
- Dr. S. Keller, Hydro Aluminium Deutschland GmbH
- Prof. G. N. Levy, Inspire AG - IRPD
- A. Edler von Graeve, Kompetenz- und Innovationszentrum für die StanzTechnologie e. V. (KIST)
- Dr. M. Herrmann, Kistler-Igel GmbH
- M. Fedler, Kunststoffinstitut Lüdenscheid
- Dr. J. Schondelmaier, Schondelmaier GmbH
- Dr. H. Schafstall, Simufact Engineering GmbH
- Dr. H.-J. Wieland, Stahlinstitut VDEh
- N. Langerak, Tata Steel Europe
- Dr. L. Keßler, ThyssenKrupp Steel Europe AG
- F. Kilian, Trumpf GmbH & Co. Maschinenfabrik



Participants of the constitutive session of the Industrial Advisory Board at the IUL

**Workshop “Introduction to Deep Drawing Fundamentals”  
organized by the German Society for Materials Science  
(DGM), November 18 – 19, 2010**

Deep drawing and stretch drawing are the most important sheet metal forming processes used to form sheet metal parts for car body, utility vehicle, and aircraft construction, but also for many products in consumer goods industries. Facing ever growing demands on the quality of sheet metal formed parts, on the one hand, and an enormous cost pressure, on the other hand, a profound technological understanding represents an essential condition for the design of robust and economic sheet metal forming processes.

The advanced training course imparted basic knowledge about deep drawing and stretch drawing processes, their modeling by analytical and numerical approaches as well as the necessary identification of material parameters. Furthermore, different types of sheet metal forming processes and their range of application were outlined, complemented by design examples of modern deep drawing tools.

Additionally, the category of working media-based sheet metal forming processes was introduced which, particularly in the context of complex part geometries and small quantities, represent an interesting alternative to conventional deep drawing and stretch drawing processes. In addition to conveying theoretical basics, the forming processes and parameter identification could be practically applied in the IUL experimental area. For this purpose, efficient forming machines, practice-oriented tool systems, and modern metrology devices were provided for the participants. The advanced training course particularly referred to engineers and technicians working in the field of industrial production engineering.

## Workshop on “Scientific Writing for Didactic Purposes” Organized by the Center for Research on Higher Education and Faculty Development (HDZ)

On November 29 – 30, 2010, a workshop on “Scientific Writing for Didactic Purposes” was organized by the Center for Research on Higher Education and Faculty Development under the direction of Dr. Hartwig Junge. The workshop aimed at enabling the participants to review students’ papers as well as own scientific publications.

At the beginning of the workshop the basic structure and the formal standards of scientific texts were discussed. Here, special focus was put on the outline of a text, the correct quotation of sources as well as the set-up of a time schedule. The next step covered the development of the actual written work, from conceptual notes through to a completely elaborate text. Finally, the participants were asked to assess a scientific text and to give constructive feedback.

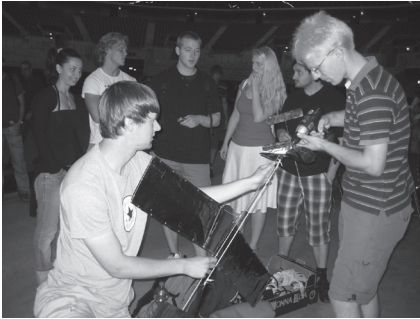
The 15 participants from the Institute of Forming Technology and Lightweight Construction and the Institute of Machining Technology acquired basic competences in the field of scientific writing. The participants’ achievements could be directly applied and practiced by a variety of exercises.



Participants of the HDZ-Workshop

## Stahl fliegt – Flying Steel

„Stahl fliegt“ (Flying steel) is an interdisciplinary ideas competition for creatively thinking students which is supported by FOSTA (The German Research Association for Steel Application). The aim of this innovative steel-lightweight competition is to design and build an aircraft consisting completely of steel or other metals having an iron percentage of at least 70%. Students from RWTH Aachen University, Technische Universität Darmstadt, the University of Kassel, Technische Universität Dortmund, Saarland University, and the University of Bremen have been taking part in the competition.



Activities during the „Stahl fliegt“ students competition

## Girls' Day

The IUL listed the Girls' Day 2010 under the motto: „How is sheet metal turned into a car?“. 14 girls at the age of 10 to 15 took the opportunity to gain insight into the metal forming technology. A presentation explained what forming technology actually is and where it is met in everyday life. By visiting the experimental area of the IUL the girls could experience forming technology manufacturing processes live. Particularly deep-drawing of cups and hoods was shown. At a hand-operated screw press they could have a try in coining. The group was supervised by Annika Foydl and Andreas Jäger.



Participants of the Girls' Day 2010

## SchnupperUni

SchnupperUni („Get to know your university!“) is a one-week event organized by TU Dortmund for secondary school senior class students. At the end of the summer break more than ten faculties of TU Dortmund opened their lecture halls and invited interested senior class students to take part in SchnupperUni 2010. SchnupperUni gives senior class students the opportunity to get to know the university and, in particular, scientific-engineering subjects by attending lectures, experiments, and tutorials and by meeting students, professors, lecturers, and people having extensive practical experience. 28 senior class students attended the IUL seminar dealing with the topic: “How to form cars/airplanes made of metal!”. The following questions could be resolved:

- 1) Where is forming technology implemented?
- 2) What is forming technology?
- 3) What fields of activity are covered by forming engineers?

## KinderUni (Childrens' University)

As in recent years, the IUL engaged in this year's KinderUni - a program seeking to promote tomorrow's scientists by giving children (and their accompanying persons) the opportunity to hear lectures on different subjects, just like at real universities.

As part of this year's lecture course “KinderUni in the Unna region” the IUL visited the Anne-Frank-Gymnasium in Werne. The lecture “Churning out” automobiles – How car bodies are made! was greatly to the children's liking, particularly the hands-on experiments attracted the participants' attention.



Impressions of the Childrens' University

## 4.2 Equal Opportunities Activities: Holiday Care for School Children at the IUL

For the second time, a holiday care took place as part of the Collaborative Research Center Transregio 73. The premises of the Institute of Forming Technology and Lightweight Construction could be used again this year for the care of 6 school children aged 8 to 14 and a small child at the age of 3. The IUL organized the infrastructure of the project and supported the care management team in its planning.

The care and the organization prior to the project were taken over by three students of the TU Dortmund. Owing to the increased number of child carers per child it was possible to offer and choose the proposed services and activities more sophisticatedly and according to age. In particular the young child could benefit from newly acquired and developmental toys and creative materials. The trips offered also became a good and worth-while experience all children (“Zoom” Erlebniswelt in Gelsenkirchen, “Phänomena” in Lüdenscheid, indoor playground “Monkey Town”). Furthermore, the departments of sport and textile design cooperated by providing their facilities.



Impressions of this year's holiday care group

## 4.3 Awards

### Federal Cross of Merit for Professor Matthias Kleiner

Professor Matthias Kleiner has been honored with the Officer's Cross of the Order of Merit of the Federal Republic of Germany. The awarding ceremony took place at the Max-Liebermann-Haus in Berlin and was held by the Federal Minister of Education and Research, Professor Annette Schavan. Professor Kleiner receives this honor for his great commitment for German research.



Prof. Matthias Kleiner was decorated with the Federal Cross of Merit by Prof. Annette Schavan, Federal Minister for Education and Research

## Outstanding Paper Award 2010

In May, Prof. Dr.-Ing. A. Erman Tekkaya, head of the Institute of Forming Technology and Lightweight Construction (IUL), Technische Universität Dortmund, and Prof. Paulo Martins, head of the Center of Manufacturing and Industrial Management (CMIM) of the Instituto Superior Técnico, Lisbon, Portugal, were awarded the “Outstanding Paper Award 2010” the of the „Emerald Literati Network Awards for Excellence“ for their joint publication entitled „Accuracy, reliability, and validity of finite element analysis in metal forming: A user’s perspective“. The article was published in the journal “Engineering Computations”, Vol. 26 (2009) 7-8, pp. 1026-1055. The jury of the Literati Network Awards for Excellence chose the contribution as one of the best articles in this journal in 2009. The prize is being awarded annually since 2007.

In this paper, Professor Tekkaya and Professor Martins outline the capability and limitations of numerical methods in the field of forming technology for users in industry, education, and research. Besides suggestions for the analysis of the results, methods to validate finite elements simulations are given.

## Most Downloaded Paper 2010

With its review paper entitled “The technology of Incremental Sheet Forming - A brief review of the history”, the IUL scores among the 10 most downloaded papers of the Journal of Materials Processing Technology of Elsevier in the year 2010 (JMPT, Vol. 210, Iss. 8, pp. 981-997). The paper originates from the collaboration of Mr. G. Sebastiani (IUL) and Mr. W. C. Emmens from CORUS RD&T and Mr. A.H. van den Boogaard of the University of Twente/The Netherlands.

The authors give an historical overview of the technological development of asymmetrical incremental sheet forming. Special attention is given to the large number of patents focusing on the method’s technological implementation. The article comprises a large pool of ideas for the implementation and - regarding the economic significance of the patent rights - represents an industrially relevant contribution.



## 4.4 Further Education

Further education is a matter of course for IUL staff members. In the following, a choice of the major professional training measures is listed, including courses to enhance technical, educational, and soft skills of the staff members.

### Further Education Science and Theory

- WGP Summer School 2010 • Topic: Sustainable Manufacturing July 21 – 28, 2010 • Institut für Werkzeugmaschinen und Fabrikbetrieb in cooperation with Fraunhofer-Institute for Production Systems and Design Technology • Berlin
- Workshop „Statistische Versuchsplanung zur Qualitätsoptimierung“ • March 1 – 5, 2010 • SFB 823 „Statistical modeling of nonlinear dynamic processes“, NRW Graduate School of Energy Efficient Production and Logistics - Forschungsschule für energieeffiziente Produktion und Logistik • Dortmund
- Workshop Scientific Publishing • April 22, 2010 • SFB Transregio 73 • Hanover
- Damage Mechanics and Local Approach to Fracture • May 25 – 28, 2010 • Professor Jacques Besson, Materials Ageing Institute (MAI), EDF R&D • Moret-sur-Loing, France
- „Academic Writing“ • September 27 – October 1, 2010 • NRW Graduate School of Energy Efficient Production and Logistics - Forschungsschule für energieeffiziente Produktion und Logistik • Dortmund
- Seminar for Doctoral Students, winter semester 2010/11 October 8, 2010 • Scholarship students of NRW Graduate School of Energy Efficient Production and Logistics - Forschungsschule für energieeffiziente Produktion und Logistik (TU Dortmund) and Research School (Ruhr-Universität Bochum), Dortmund
- Workshop “The 7<sup>th</sup> European Research Framework Programme (FP7) and the European Research Council (ERC)” • October 14, 2010 • EU Bureau of the Federal German Ministry of Education and Research (BMBF), Deutsches Zentrum für Luft- und Raumfahrt • Bonn
- HY-LIGHT – Winter School on Hybrid Lightweight Joining Technologies for Naval Applications • October 31 – November 5, 2010 University of Palermo (Prof. Fratini and Prof. Valenza) • Erice, Sicily, Italy

- Workshop for applicants of IGF research proposals (Industrielle Gemeinschaftsförderung) • November 18, 2010 • Europäische Forschungsgesellschaft für Blechverarbeitung e.V. (EFB) • Hanover
- Workshop „Das Rahmenprogramm für Antragstellende“ • December 14 – 15, 2010 • EU Bureau of the Federal German Ministry of Education and Research (BMBF), Deutsches Zentrum für Luft- und Raumfahrt • Bonn

### Further Education Software

- Modelling Metals with MF GenYld + CrachFEM - Basic Course March 9, 2010 • Matfem • Munich
- DEFORMTM Anwendertreffen und Gefügeworkshop 2010 November 16 – 17, 2010 • Munich

### Further Education Didactics

- Workshop „Forschendes Lernen als didaktisches Prinzip kompetenzorientierter Lehr-Lern-Veranstaltungen“ • September 1 and 10, 2010 • organized within the project USuS & TeachING-Learning.EU • Center for Research on Higher Education and Faculty Development - Hochschuldidaktisches Zentrum (HDZ) • TU Dortmund
- Workshop „Wissenschaftliches Schreiben in der Lehre für Lehrende der Fakultät Maschinenbau“ (Scientific Writing for Didactic Purposes) • November 29 - 30, 2010 • Center for Research on Higher Education and Faculty Development - Hochschuldidaktisches Zentrum (HDZ) • TU Dortmund

### Soft Skills and Social Competences

- Zwischen Chaos und Perfektion - Dissertation als Projekt managen (Between chaos and perfection – How to manage your dissertation as a project) • January 18, 2010 • SFB 823 Akademie • Ruhr-Universität Bochum
- Hochschulpatente in den Ingenieurwissenschaften (Engineering patents in higher education) • March 4, 2010 • Transferstelle (TU Dortmund and Provendis)
- Seminar Patentrecht (Patent law) - Graduiertenkolleg 1378 March 2- 23, 2010 (once a week) • LWT, TU Dortmund

- Besprechungen moderieren (How to moderate meetings)  
November 15 – 16, 2010 • Zentrum für Weiterbildung, class for employees of TU Dortmund  
Projektmanagement (Project management) • February 3 and March 1, 2010 • Zentrum für Weiterbildung, class for employees of TU Dortmund
- Medien und Öffentlichkeitsarbeit (Media and public relations)  
June 27 – 29, 2010 • Zentrum für Wissenschaftsmanagement e.V.(ZWM) • Kassel
- Professionelle Pressearbeit, Crash-Kurs für die kleine Pressestelle (Professional public relations) • August 30 – September 1, 2010  
Fortbildungsakademie des Innenministeriums des Lands NRW • Herne
- Workshop „Stimm- und Sprechtraining“ (Vocal and speech training) • SFB 823 Akademie • September 19, 2010 • Ruhr-Universität Bochum
- Selbstmarketing und Auftrittspräsenz - Imagearbeit für den Beruf (Self marketing and appearance – professional image training) • September 20 – 21, 2010 • Zentrum für Weiterbildung • TU Dortmund
- Erfolgswirksame Kommunikation (Efficient communication) • September 28 – 29, 2010 • Zentrum für Weiterbildung, class for employees of TU Dortmund

## Operational and Occupational Safety

Workshop „Gefährdungsbeurteilung“ (Risk assessment) • May 19, 2010  
• Zentrum für Weiterbildung • TU Dortmund

Furthermore, numerous staff members attended first-aid seminars, fire control trainings as well as courses to acquire a crane driver's license.

## WGP Summer School 2010 – Sustainable Manufacturing

This year's WGP – Summer School was organized by the Institut für Werkzeugmaschinen und Fabrikbetrieb, Berlin, in cooperation with the Fraunhofer-Institute for Production Systems and Design Technology.

Mr. Matthias Haase participated as a member of the Institute of Forming Technology and Lightweight Construction. From July 21 until July 28 over 30 postgraduates from WGP institutes discussed various topics, listened to reports, and worked on problems in the field of “Sustainable Manufacturing”. Different groups worked on the following topics:

- Production with renewable energies
- Production technology for renewable energies
- Virtual product design in a sustainable chain of economic value added
- Human-oriented automation
- Sustainable joining and coating technology

In addition to the group work, different companies were visited. At the Federal Institute for Materials Research and Testing the participants were able to gain insights in upcoming problems in the fields of joining technology, tribology, and materials science. At Siemens Power Generation, the production of gas turbines was shown. Finally, at the Jonas & Redmann Cooperation the production of standardized solutions for automated handling, transport, and assembly were presented. As social program, a team challenge at a high ropes course, a dinner with the professors, and a visit to a theater were offered.

Due to the interesting topics, company visits, and social program this year’s Summer School led to an interdisciplinary knowledge exchange of young scientists from all over Germany.



Participants of the WGP Summer School 2010

## 4.5 Participation in National and International Organizations: Prof. Dr.-Ing. A. Erman Tekkaya

### Memberships of Research Boards

- CIRP - Fellow of the International Academy for Production Engineering
- acatech – Member of the German Academy of Science and Engineering (Deutsche Akademie der Technikwissenschaften)
- AGU – Member of „Wissenschaftlichen Arbeitsgemeinschaft Umformtechnik“
- GCFG – Member of the German Cold Forging Group
- ICFG – Chairman of the International Cold Forging Group
- ICTP – Member of the Standing Advisory Board of the International Conference on Technology of Plasticity and co-organizer of ICTP 2011
- I2FG –Vice chairman and founding chairman of the International Impulse Forming Group
- DGM – Member of „Deutsche Gesellschaft für Materialkunde“
- ICEB – Chairman of the International Conference on Extrusion and Benchmark
- Member of the International Scientific Advisory Council of the Institute of Mechanical Engineering (IDMEC) and Associated Laboratory for Energy, Transports, and Aeronautics (LAETA), Lisbon, Portugal
- ESAFORM – Member of the Scientific Committee of the European Association for Material Forming
- Honorary member of the TechNet Alliance
- Guest professor at Shanghai Jiao Tong University, Shanghai, China
- Curatorship member of „Karl-Kolle Stiftung“, Dortmund
- Founding director of the Center of Excellence for Metal Forming, Atilim University, Ankara, Turkey
- Member of the Scientific Advisory Board of „Exzellenzcluster Integrative Produktionstechnik für Hochlohnländer“ of RWTH Aachen University
- International reviewer, Romanian Research Assessment Exercise

- Vice president of the consortium of “Deutsch-Türkische Universität” (German-Turkish University)
- Reviewer, Doctorate in University of Excellence – Research Assessment and Support for Scientific Publishing, Romania

### **Journals Editorship**

- Editor-in-Chief of the „Journal of Materials Processing Technology” (Elsevier)
- Member of the Editorial Board of the „Journal of Manufacturing Science and Technology” (Elsevier)
- Member of the International Editorial Board of the „Journal of Computer Methods in Materials Science”
- Member of the Scientific Circle of the Journal “Steel Grips” - Journal of Steel and Related Materials
- Member of the International Advisory Committee of the “International Journal of Material Forming” (Springer)
- Member of the Scientific Editorial Board of the “International Journal of Precision Engineering and Manufacturing” (Springer)

### **Further Memberships**

- Turkish-German Cultural Association, Ankara, Turkey
- Advisory Board of the congress trade fair „Proform“ 2010, Dortmund
- DAAD Scholar Committee, Ankara, Turkey
- IUTAM - Turkish Branch of the International Union of Theoretical and Applied Mechanics, Turkey
- Member of the Scientific Committee, 10th International Conference on Numerical Methods in Industrial Forming Processes (NUMIFORM 2010), Pohang, Korea
- Member of the International Program Committee, International Conference on Machine Design and Production 2010 (14th UMTIK), Güzelyurt, Northern Cyprus, Turkey
- Member of the Scientific Committee, 50th IDRRG Conference 2010, Graz, Austria

- Member of the International Program Committee, 5th International Conference and Exhibition on Design and Production of Machines and Dies/Molds 2011, Ankara, Turkey
- Member of the Scientific Committee of the 12th International Cold Forging Congress (ICFC 2011), Stuttgart
- Member of the International Committee of the 3rd International Conference on Distortion and Engineering (IDE 2011), Bremen
- Member of the Technical Working Group “Internetbasierte Simulationsanwendungen für KMU – simKMU” (Internet-based simulation applications for SME), Federal Ministry of Economics and Technology, Berlin
- Member of the International Scientific Committee of the 14th International Conference on Sheet Metal (SheMet 2011), Leuven, Belgium
- Member of the International Scientific Committee of the 8th International Conference and Workshop on Numerical Simulation of Sheet Metal Forming Processes (Numisheet 2011), Seoul, Korea
- Member of the eLEARNING-TUDo2011 Program committee, Dortmund
- Member of the Scientific Committee of the International Deep Drawing Research Group (IDDRG 2011), Bilbao, Spain

## Activities as Reviewer

### In Scientific Committees

- DFG – German Research Foundation
- Bayerische Forschungsstiftung
- University of Cambridge
- German Academic Exchange Service - Deutscher Akademischer Austausch Dienst (DAAD)
- Anhalt University of Applied Sciences - Hochschule Anhalt (FH)
- Helmut Schmidt University, University of the Federal Armed Forces, Hamburg
- Royal Institute of Technology (KTH), Stockholm, Sweden

### **For Journals**

- International Journal of Advanced Manufacturing Technology
- Journal of Computational Materials Science
- International Journal of Precision Engineering and Manufacturing
- CIRP Journal of Manufacturing Science and Technology
- International Journal for Numerical Methods in Engineering
- Journal of Materials Processing Technology
- Precision Engineering
- Technologies, Ljubljana, Slovenia, 2009 - ICIT & MPT 2009

## **4.6 Participation in National and International Organizations: Prof. Dr.-Ing. Matthias Kleiner**

### **Memberships and Further Memberships and Cooperation etc.**

- Academia Europaea
- acatech – German Academy of Science and Engineering
- AGU – Wissenschaftliche Arbeitsgemeinschaft Umformtechnik
- AiF - German Federation of Industrial Research Associations (Curatorship Member)
- Berlin-Brandenburgische Akademie der Wissenschaften
- Adviser of Siepmann-Werke GmbH & Co.KG
- Adviser of SimuForm GmbH
- Adviser of Winkelmann Group GmbH & Co. KG
- CIRP – The International Academy for Production Engineering
- German Academy of Sciences Leopoldina
- European Academy of Sciences and Arts (Member)



- FOSTA - Research Association for Steel Application (Curatorship Member)
- LOEWE Program (Member of the Advisory Board)
- SATW – Swiss Academy of Engineering Sciences (Member)
- Steel Institute VDEh
- VDI – The Association of German Engineers
- WGP – German Academic Society for Production Engineering

## 5 International scientists at IUL

Professor Dong-Yol Yang, head of the Laboratory for Computer-Aided Net Shape Manufacturing of the Department of Mechanical Engineering of the Korea Advanced Institute of Science and Technology (KAIST) in South Korea und Vice-President of KAIST in charge of R&D was a guest of the IUL in August 2010 within the scope of the Research Training Group GRK 1378. In addition to discussions of analytic and numerical considerations of sheet metal and bulk metal forming processes Prof. Yang communicated different techniques of creativity and methods in furtherance of innovations.

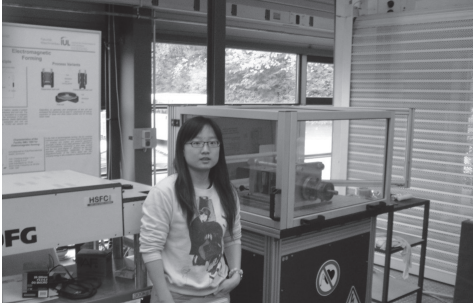


Professor Tekkaya and Professor Yang with IUL scientists attending a guest lecture

Miss Yu-Yi Chu, scientific coworker at the Metal Forming Laboratory, National Cheng Kung University, visited the IUL from May 2010 until February 2011 within the scope of a 10 months scholarship, financed by the Deutscher Akademischer Austausch Dienstes (DAAD) and the National Science Council in Taiwan (NSC).

She has done research on high-speed forming under the guidance of Dr. Psyk. Miss Chu's work concentrated on forming of sheet metal during the impact with different conical dies.

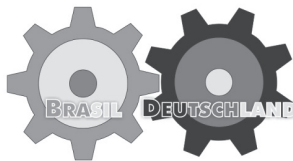
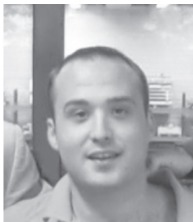
The acceleration of the sheets results from Lorentz forces which are exerted on highly conductive workpieces by pulsed electromagnetic fields. The aim of the investigations is the determination of material parameters for forming with very high strain rates, on the one hand. On the other hand, Miss Chu has analyzed the influence of the frequency of the discharging current that induces the magnetic fields on the workpiece velocity and on the deformation.



Yu-Yi Chu performing experiments in the IUL experimental hall

## Guests at IUL

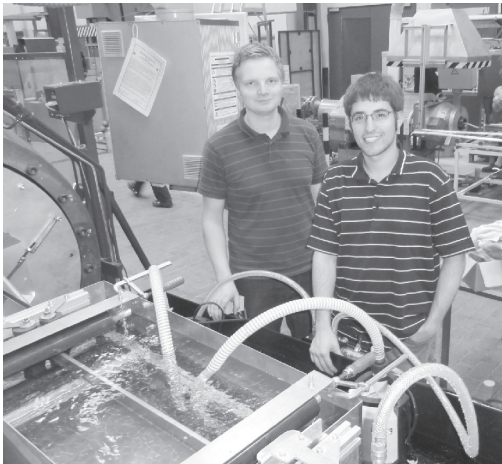
From January to July, two students, Tomaz Fantin de Souza (on the left) and Tiago Brun Coser, of the UFRGS in Porto Alegre, Brazil, visited our institute. Within the scope of the German-Brazilian research project („Cold Drawing“, German Research Foundation TE 508/18-01, BRAGE-CRIM, Investigation and Improvement of a Manufacturing Process Chain Covering Cold Drawing Processes through to Induction Hardening) on cold drawing they conducted, among other things, FEA simulations for the determination of residual stresses.



Tomaz Fantin de Souza and Tiago Brun Cose from Brazil

## RISE (Research Internships in Science and Engineering) July to August 2010

RISE is a summer internship program provided by the German Academic Exchange Service (DAAD) for undergraduate students from the United States, Canada, and the UK studying natural, engineering, or life sciences. It offers undergraduate students the unique opportunity to work within research groups at universities and research institutions across Germany for a period of 2 to 3 months during the summer. RISE interns are matched with doctoral students whom they assist and who serve as their mentors. Within this program Anthony P. Ventura, a student from the Lehigh University, Bethlehem, PA, USA, had the opportunity to work on a research project at the IUL, supervised by Andreas Jäger, dealing with the quantitative analysis of time-temperature-dependencies of the microstructure development in the process chain of hot extrusion of heat-treatable aluminum alloys. To help covering his living expense Mr. Ventura was financially supported by a grant partly covered by the DAAD and the Integrated Graduate School (MGK) of the DFG Collaborative Research Center SFB/TR30.



Guest student A. P. Ventura (right) and his mentor A. Jäger

## Further Guest Scientist at the IUL

- **Mamadou Ndong**  
Structural Engineer  
ICD/LASMIS  
University of Technology of Troyes

## Scientist Exchange to France

From February 1st until April 30, 2010, the IUL research associate M.Sc. Mohammad Malekipour Gharbi had the opportunity to stay as a visiting scientist at the University of Technology of Troyes, Charles Delaunay Institute, Laboratory of Mechanical Systems and Concurrent Engineering in the group of virtual manufacturing within the scope of the DFG project „Defect analysis and prediction in bending“ (TE 508-21-01). Director of the institute is the renowned Professor Khemais Saanouni. It already was Mr. Gharbi's 2nd stay in France during this project.

## 6 Technical Equipment

### 6.1 Experimental Area

#### Presses

- Hydraulic drawing press, 2600 kN, triple action, SMG HZPUI 260/160-1000/1000
- Extrusion press 250t, Collin, PLA250t
- 10 MN (direct) extrusion press, suitable for curved profile extrusion, SMS Meer
- Screw press, 3150 kN, Weingarten PS 180, 3150kN
- C-frame-eccentric press, 630 kN, Schuler PDR 63/250
- Hydraulic drawing press, 1000kN, HYDRAP HPSZK 100-1000/650
- Hydraulic drawing press, 10MN triple action, M+W BZE 1000-30.1.1
- Press for working media based sheet metal forming, 100 MN, SPS

#### Further Forming Machines

- Swivel bending machine, FASTI 2095
- Press brake, 110 kN, HERA COP 110/3100
- Three-roller bending machine, FASTI RZM 108-10/5.5
- Three-roll bending machine, Irle B70 MM
- Three-roll bending machine, Roundo R-2-S Special
- Profile bending machine TSS-3D
- Mandrel bending machine, Schwarze-Wirtz CNC 60
- Profiling machine RAS 24.10, Reinhardt Maschinenbau GmbH, Sindelfingen
- Roller spinning machine, Bohner & Köhle BD 40
- Spinning machine, Leifeld APED 350NC, CNC Siemens 840 D
- Machine for electromagnetic forming, 1,5 kJ, PPT SMU 1500

- Machine for electromagnetic forming, 32 kJ, Maxwell Magneform 7000
- Workshop press with chips compaction device

## Material Testing Machines

- Bulge-testing machine, 200 kN, Erichsen 142/20
- Universal testing machine, Zwick 1475 100KN
- Universal testing machine, Zwick SMZ250/SN5A
- Vertical testing machine, Zwick FR250SN.A4K, Allround Line
- Compression test machine, IUL 1000 kN

## Measurement Technique and Electronics

- Large volume SEM, Mira XI by Visitec
- 3D-coordinate measurement machine, Zeiss PRISMO VAST 5 HTG
- Residual stress measurement devices using borehole method
  - - High-speed procedure
  - - Air-abrasive procedure
- Hardness testing device, Wolpert Diatestor 2 RC/S
- Thickness measuring device, Krautkrämer CL 304
- 4-channel-digital-oscilloscope, Tektronix TDS 420A
- 3D-video measuring system, Optomess A250
- Infrared measuring device, PYROSKOP 273 C
- GOM: Argus, Atos, Tritop, Aramis - optical measuring systems for geometry and strains
- High-speed camera, HSFC pro of the company PCO Computer Optics GmbH
- Light optical microscope AxioImager.M1m adapted for polarization, Zeiss AG
- Laser Surface Velocimeter (LSV): non-contact velocity measurement
- Temperature measurements by means of pyrometer or thermo-sensors
- Keyence Laser: non-contact distance measurement

## Miscellaneous

- Roll seam welding machine, Elektro-Schweißtechnik Dresden UN 63 pn
- Turning machine, Weiler Condor VS2
- CNC universal milling machine, Deckel Maho DMU 50
- Low-pressure beam system , PIT
- Column drilling machine, Alzmetall AB 4/SV
- Plate shear, Durmazlar RGM 2004
- Circular shear, Fasti 501 KS
- Vacuum dryer, Leybold VT5042
- Electric frame saw, Kläger & Müller 4B-200
- High-performance metal circular saw, Häberle AL 380
- Belt grinding machine, Baier PB-1200-100S
- Borehole device, Milling Guide RS 200
- Etching and polishing station - LectoPol-5, Struers GmbH
- 6-axes robot, KUKA-Industrieroboter KR 5 sixx R650
- Pressure intensifier, 2000 bar
- Pressure intensifier, 4000 bar
- Hydraulic power unit, Bosch 250 L
- Hydraulic power unit, Röco
- Hydraulic power unit, Ecoroll, HGP 4.0
- Hydrostatic roller burnishing tool, Ecoroll, HG13 und HG6
- Measuring rack, Boxdorf HP-4-2082



## 6.2 Hardware Equipment

### General Equipment

- Different Servers and approx. 220 networked workstation PCs with an extensive periphery

### Hardware for Simulation Technology in the Field of FEM and Software Development

- Linux Cluster with 4 nodes with altogether 12 processing units

### Operating Systems and Software Applications

- Windows 7 Professional
- Office 2007 Professional
- Diverse Adobe products, as for example Photoshop, Freehand, Acrobat, InDesign, Illustrator11, Premiere Pro1.5
- Corel Designer X4

### CAD

- Unigraphics
- Catia
- AutoCad
- Mechanical Desktop

### FEM Special Purpose

- Pam Stamp
- Autoform
- Hyperworks/HyperXtrude
- Deform
- QForm
- Superform

### **FEM General Purpose**

- MARC
- Ansys
- Abaqus
- LS-Dyna

### **Mathematical-Technical Calculation Programs**

- Maple
- Mathcad
- Matlab