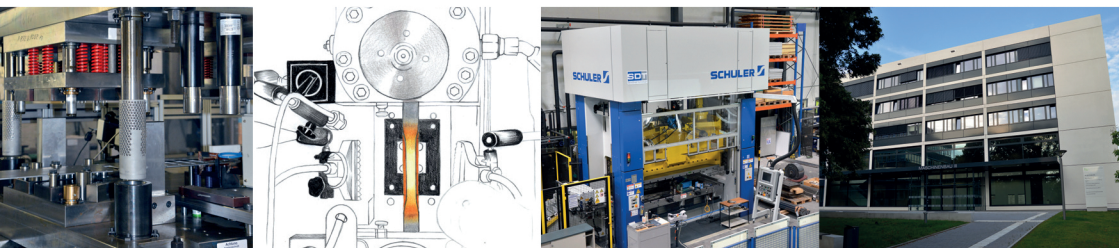


Activity Report

14





Activity Report

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Imprint

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Preface

Dear Readers,

The year 2014 was not only a great success for Germany's national soccer team at the World Cup in Brazil. Also, the Institute of Forming Technology and Lightweight Construction is again looking back on a busy and, above all, successful year.

With five terminations and six new hires, the number of staff remained almost constant in 2014. We are particularly pleased about the great interest of IUL graduates in a subsequent employment with the institute, which is the reason why the majority of new hires are students. Furthermore, the department of Applied Mechanics in Forming Technologies has finally found a new head, Mr. Till Clausmeyer, highly motivated and talented, which shall foster the initiation of more projects in this field in future. Furthermore, a total of seven doctorates were successfully completed in 2014.

In April, the IUL staff officially celebrated their removal to the new mechanical engineering building MB III. Owing to the good organization by the responsible units, work at the institute could be continued without interruption not only during the construction time but could also be taken up again right after the removal. Many thanks for this! The modern visual appearance and the very good facilities and furnishings make this new building a flagship of mechanical engineering, in particular, production engineering in Dortmund.

A multitude of national and international guests had the opportunity to enjoy the new building in 2014. Besides very enriching research stays of scientists from the United States, Italy, Korea, Portugal, and Japan, many presentations by and motivating discussions with industrial and scientific partners invariably left valuable impressions at the institute. We would like to express our sincere thanks for this excellent collaboration. We are already looking forward to further exciting co-operations to come.

In October 2014, A. Erman Tekkaya became Dean of the Faculty of Mechanical Engineering. Next year, to foster the collaboration and to initiate joint research project between TU Dortmund University and The Ohio State University, A. Erman Tekkaya will make regular visits there. This year, he was awarded the JSTP Prize for his lifetime achievement in "Process innovation, process cha-

racterization and international leadership“. As many as six prizes were awarded to employees of the institute, which we are all very proud of.

In terms of education, the response to the study program Master of Science in Manufacturing Technology (MMT) is particularly worth mentioning. The number of applicants of about 700 in 2014 had almost doubled in comparison to last year. The industry as well is very enthusiastic about the capacities of the students and is highly interested in students preparing their final theses with them and in acquiring staff from the group of graduates. Moreover, one of the female MMT students was presented with the DAAD Award for Outstanding Achievements by International Students.

As many as two outstanding events were organized by the IUL this year. The conference ManuLight took place in April and dealt with subjects concerning modern lightweight construction. 44 contributions from 11 different nations gave rise to fruitful dialogs between academia and application. In October, the fifth Dortmund conference on tube and profile bending (“5. Dortmunder Kolloquium zum Rohr- und Profilbiegen“) was held. With its presentations, this conference offered also a very interesting forum for discussion. As many as 100 participants from countries like the Netherlands, Belgium, Austria, Switzerland, Luxembourg, Denmark, and Germany came to attend the DORP 2014.

To be able to consider immediately current developments in the research landscape and impulses from industry, the IUL is continuously extending its pool of technical equipment. For example, at the end of the year, a five-axis universal milling machine, type DMU 50, of the company DMG Mori Seiki Academy GMBH was purchased. The kinematics of this milling machine shall be used in future research projects for tasks in forming technology, e.g., incremental forming.

The death of Prof. Dr.-Ing. Dr. h.c. Klaus Siegert came as sad news to us. He had been the Head of the Chair and later the Institute for Metal Forming Technology of the University of Stuttgart until his retirement in October 2004. He was involved in research in the field of bulk metal forming and set new directions in sheet metal forming. Here, he focused his research activities mainly on tool and press technology as well as on forming of metal sheets, tubes, and profiles with hydraulic and pneumatic working media.

We thank all our IUL staff members, who have contributed considerably with outstanding skills and great dedication to the success of the institute. Finally, we would like to express our sincerest thanks to the research funding institutions, industrial enterprises, and all colleagues with whom we are linked by ties of co-operation.



A. E. Tekkaya

A. Erman Tekkaya



M. Kleiner

Matthias Kleiner

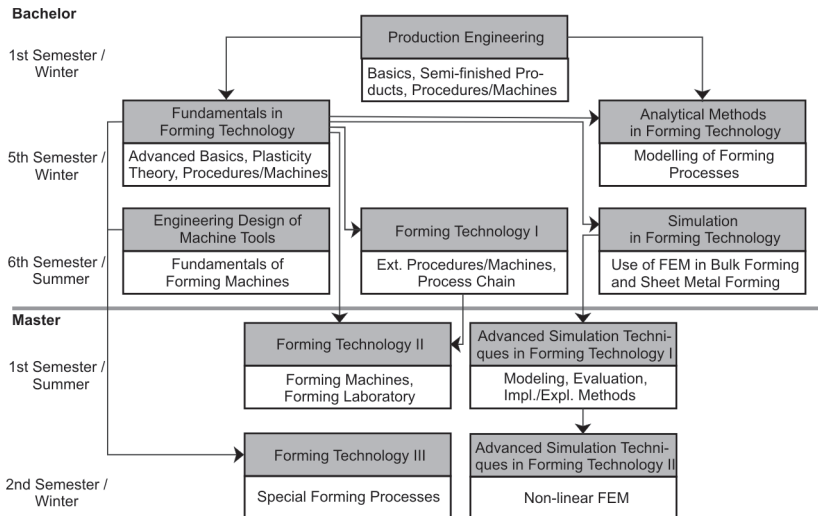
Education

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1 Education

1.1 Offered Courses

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.



Structure of lectures e.g. of the study program mechanical engineering with specialization in production engineering

Further courses of the institute are:

- MMT I – Forming Technology – Bulk Forming
- MMT II – Forming Technology – Sheet Metal Forming
- MMT III – Advanced Simulation Techniques in Metal Forming
- MMT IV – From Sheet Metal to Automotive Components
- MMT V – High dynamic Testing of Materials

- Industrial Lecture Course: Industrial Field Reports
- Laboratory work A for Students of Mechanical Engineering
- Laboratory work B for Students of Industrial Engineering
- MMT Laboratory work
- Scientific writing in engineering science
- Competence in scientific writing and text comprehension now have their own place in the course offering of the IUL: In colloquia and classes, PhD students and students train the composing and phrasing of different kinds of scientific texts and work on structural, compositional, and stylistic aspects of scientific communication. The modules also cover issues of references and the use and citation of scientific publications and pictures as well as reading comprehension and the productive correcting of drafts and papers. The participants get to know the characteristics of scientific writing and apply them in exercises and their own academic texts alone and in groups. A special focus lies on written communication in professional engineering contexts. Hence, the IUL contributes to a comprehensive education of its students by building a critical scientific awareness in addition to their technical knowledge.

In 2014, the following visiting lecturers participated in the educational offers of the IUL:

- Prof. P. Haupt, Emeritus University of Kassel
- Prof. K. Roll, formerly Daimler AG Sindelfingen
- Dr. E. Lach, ISL – French-German Research Institute of Saint-Louis, France
- Dr. H. Schafstall, Simufact Engineering GmbH, Hamburg
- Dr. J. Vochsen, SMS Meer GmbH Moenchengladbach

Further information at www.iul.eu/lehre (or using the following QR code)



1.2 Master of Science in Manufacturing Technology (MMT)

Program start October 2011
Coordination Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
 M.Sc. M.Eng. C. Pleul • Dipl.-Ing. D. Staupendahl
 M.Sc. O. Napierala • Dipl.-Fachübers. A. Hallen

The English-language, four-semester master study program in the field of manufacturing technology experienced a further, exponential rise in application numbers. As many as 671 candidates from 30 different countries had applied for the MMT for the winter semester 2014/15. After a careful selection of the candidates, finally 25 excellent graduates from renowned universities and from 17 different countries started their studies at TU Dortmund University. Some selected students were awarded a scholarship for the duration of their studies.

The country quota for the selection of the candidates, which limits the share of students from the same country in a class to a maximum of 30% and which was applied last year for the first time, guarantees a high internationality and diversity. Evaluations on a regular basis ensure a high quality of education and mentoring.

Program overview

The combination of scientific, theoretical courses and practical units qualify the graduates to become outstanding, internationally sought-after experts for solving manufacturing technology tasks.

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

The range of MMT technical elective modules, with which students shape their individual profile, always also considers new technological developments. This winter semester, a module in the field of high dynamic testing of materials was added to the existing module range. New courses covering the areas plastics technology and additive manufacturing are being planned for the year to come. On top of this, students are free to also choose manufacturing technology related courses offered by other universities.



The new class of 2014 during the official welcome at the IUL. A guided tour through the experimental hall on that occasion gave first impressions on the institute's research work.

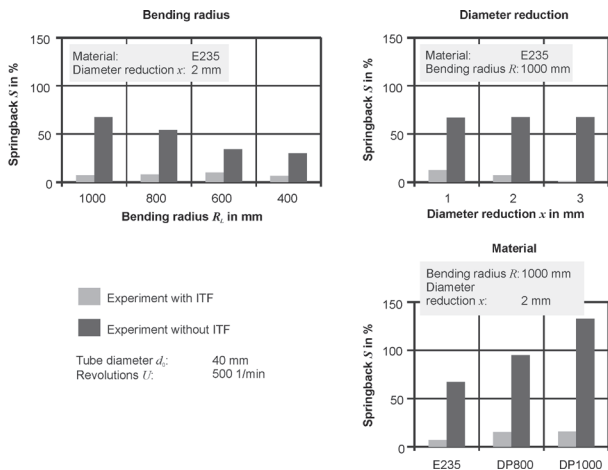
For further information, please click on www.mmt.mb.tu-dortmund.de or use the following QR code:



1.3 Doctoral Theses

Becker, Christoph	Incremental Tube Forming of High-Strength Materials
Original title	Inkrementelles Rohrumformen von hochfesten Werkstoffen
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	July 10, 2014
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. F. Klocke (RWTH Aachen University)

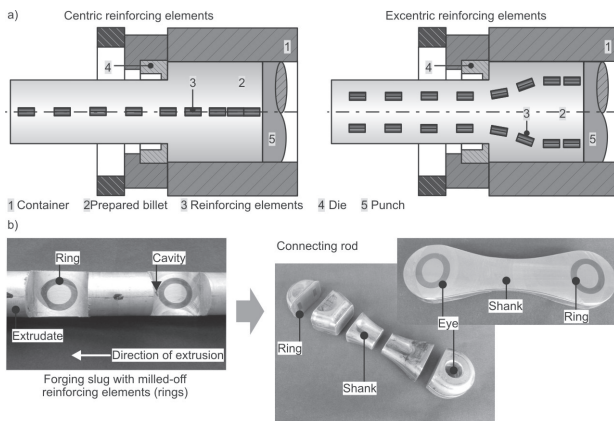
The incremental tube forming process is a forming process which combines a tube bending and a tube spinning process. This combination leads to a significant reduction of the needed bending moment. This reduction has been described theoretically and investigated by using numerical and experimental setups. By changing specific influencing parameters like the revolution speed or the diameter reduction during the spinning process, the reduction of the bending moment can directly be influenced. Furthermore, the process combination leads to a reduction of the springback which can also be described by a theoretical model. The reduction of the bending moment and the springback make the process especially suitable for the forming of high strength-steels.



Comparison of springback after bending with and without diameter reduction

Foydl, Annika	Hot Extrusion of Discontinuously Reinforced Aluminum Profiles
Original title	Strangpressen partiell verstärkter Aluminium-profile
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2015
Oral exam	December 15, 2014
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. B.-A. Behrens (Leibniz Universität Hannover)

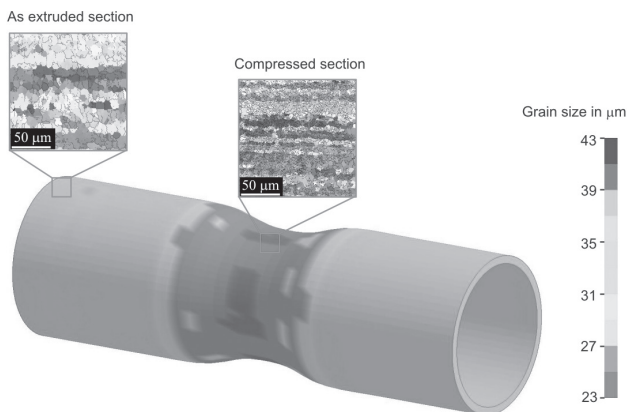
For the production of light hybrid products with high technical characteristics the novel discontinuous composite extrusion, which is developed in the present work, can be utilized. The process allows combining conventional aluminum billets with high strength materials by the usage of conventional extrusion dies. Thereby, discontinuous reinforcements are embedded in the extrudate. Aim of this work is the characterization of the novel process by identifying the process limits and determining rules in order to predict the position of the reinforcing elements in the extrudates. In order to achieve these goals, experimental, analytical, and numerical methods are utilized. In the end, it is shown that further processing of the partially reinforced profiles is possible by hybrid forging. In this case, a connecting rod is utilized as a demonstrator.



a) Process principle, b) Further processing by hybrid forging

Güzel, Ahmet	Microstructure Evolution during Thermomechanical Multi-Step Processing of Extruded Aluminum Profiles
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	July 24, 2014
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiners	Prof. Dr.-Ing. H. J. Maier (Leibniz Universität Hannover) Prof. Dr. W. Z. Misiolek (Lehigh University)

In order to meet the demands of specific mechanical properties and to introduce additional functional elements in the geometry of the extruded profiles, subsequent forming processes are required. The utilization of electromagnetic forming subsequent to hot aluminum extrusion to manufacture functionally graded extrusion profiles is an innovative forming technology. The large deformations, intermediate to very extreme strain rates and elevated temperatures, which characterize the process chain of hot extrusion, and subsequent electromagnetic compression lead to a complex development in the microstructure which is linked to the mechanical properties of the material. In this research work, the effect of thermo-mechanical processing conditions on the microstructure evolution was investigated for a wide range of plastic strain rates. Based on the proposed dynamic recrystallization model, the final microstructure of the thermo-mechanically processed material was simulated during the entire process chain.

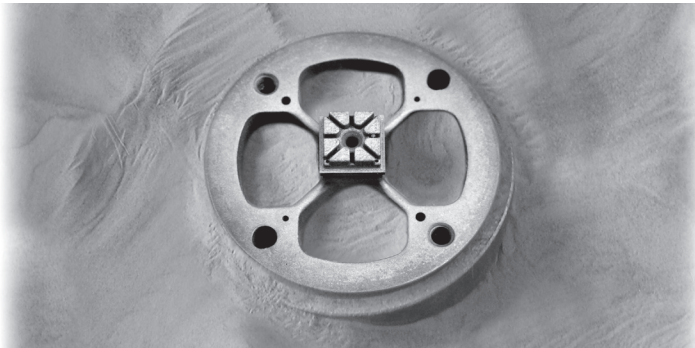


Microstructure simulation of the process chain of extrusion and electromagnetic tube compression

Hölker, Ramona	Extrusion Dies with Conformal Cooling Channels Manufactured by Additive Manufacturing Technologies for Increasing the Productivity in Hot Aluminum Extrusion
Original title	Additiv hergestellte Werkzeuge mit lokaler Innenkühlung zur Produktivitätssteigerung beim Aluminium-Strangpressen
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	September 19, 2014
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. H. Palkowski (TU Clausthal)

During hot aluminum extrusion with rising extrusion speed and, in consequence thereof, with an increased workpiece temperature surface defects like hot cracks and grain coarsening can occur. As a result of this, the working area is limited. A local inner die cooling offers a big potential in order to increase the productivity during aluminum extrusion. Inserting of conformal, near-surface cooling channels into the die is not possible by conventional manufacturing methods as for profiles and extrusion dies with complex geometries. The use of rapid tooling methods is a promising approach to overcome this problem.

In the present work the development of novel extrusion dies with near-surface cooling channels manufactured by rapid tooling methods is presented as well as the investigation of their performance, especially in regard to the increase of the extrusion speed during hot aluminum extrusion. Supported by numerical and analytical methods, dies were designed and the influencing parameters of the novel die cooling were investigated fundamentally.

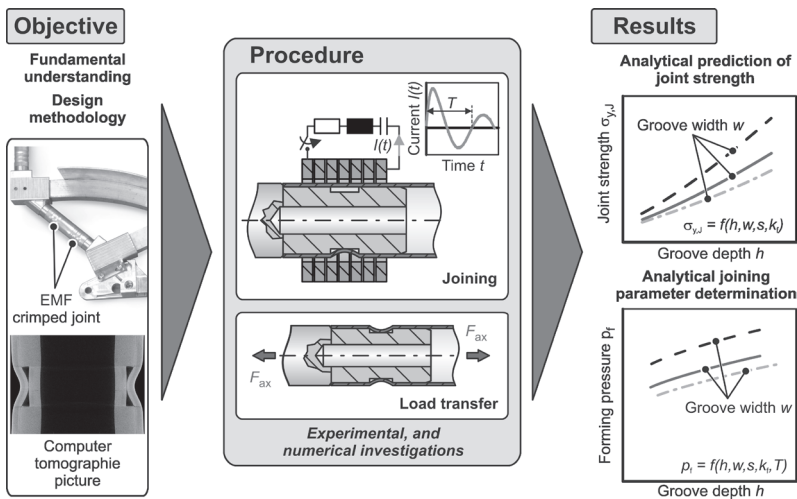


Mandrel of an extrusion die additively manufactured in the powder bed

Weddeling, Christian
Series
Publisher
Oral exam
Advisor
Co-examiner

Electromagnetic Form-Fit Joining
Dortmunder Umformtechnik
Shaker Verlag, Aachen, 2015
December 18, 2014
Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Prof. Dr. G. S. Daehn
(The Ohio State University)

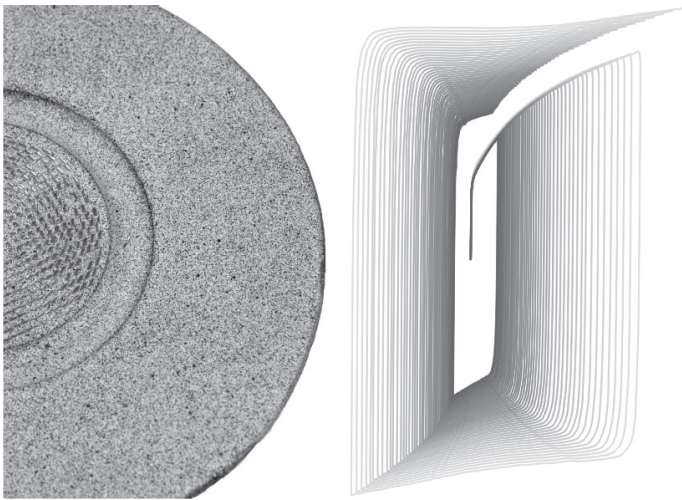
An innovative process to manufacture lightweight frame structures without heating or penetrating the profiles is joining by electromagnetic crimping. This technique is characterized by the use of pulsed magnetic fields to form a profile made of an electrically conductive material into form-fit elements, like grooves, of the other joining partner. Thereby, an interlock is generated which enables the load transfer. A fundamental process understanding of the manufacturing and the load transfer of form-fit connections manufactured by electromagnetic crimping is developed in this thesis. Based on analytical, experimental, and numerical studies, major parameters are identified and their influence on the joining process and the achievable joint strength is analyzed. For the analytical investigations a continuous approach describing the manufacturing of the connections as well as the load transfer is introduced. This model also facilitates the process and joining zone design of electromagnetically crimped connections.



Objective, procedure, and results of the thesis

Yin, Qing	Hardening and Damage Behavior of Sheet Materials Using the In-Plane Torsion Test
Original title	Verfestigungs- und Schädigungsverhaltens von Blechwerkstoffen im ebenen Torsionsversuch
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	April 28, 2014
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. W. Volk

The aim is to develop new experimental and evaluation procedures as well as new applications in order to establish the in-plane torsion test. Optical strain measurement is used to develop new evaluation procedures in order to obtain monotonic and cyclic flow curves. A modified specimen geometry with round slits is presented which allows to identify shear flow curves in a specific material orientation. For the characterization of the ideal shear fracture of sheet materials a new specimen is designed. The results provide the required fundamental knowledge for a more frequent usage of the in-plane torsion test in scientific and industrial applications. The potential of this test method offers various possibilities in the field of sheet metal characterization and numerical simulation of forming processes.



Grooved torsion specimen with pattern to evoke perfect shear fracture and multiple cyclic flow curves determined by one single in-plane torsion test

Yue, Zheming

Ductile Damage Prediction in Sheet Metal Forming Processes

Oral exam

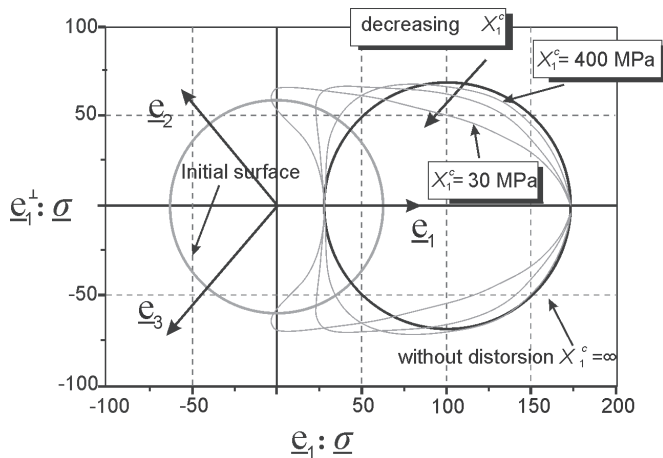
September 8, 2014

Advisors

Prof. K. Saanouni (University of Technology of Troyes)

Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

In this work, based on the thermodynamics of irreversible processes, the advanced fully coupled constitutive equations are proposed, taking into account the initial and induced anisotropic, isotropic, and kinematic hardening as well as the isotropic ductile damage. The microcrack closure, the stress triaxiality, and the lode angle effects are introduced to influence the damage rate under a wide range of triaxiality ratios. A series of experiments for three materials is conducted for the identification and validation of the proposed models. An inverse methodology combining MATLAB-based minimization with ABAQUS FE codes through a Python script is used. Forming limit diagrams and forming limit stress diagrams based on the Marciniak-Kuczynski approach are computed for comparison purposes. At last, through the comparisons between experimental and numerical results, including the ductile damage initiation and propagation, the high capability of the fully coupled continuum damage model is proved.

Effect of the distortion parameter X_{l1}^c on the yield surface in the deviatoric plane

1.4 Completed Master's Theses

Babariya, Mohit

Supervisor: Tekkaya, A. E. • ul Hassan, H. • Gröbel, C. (SONA BLW)
Design and Analysis of Lightweight Differential Housing Based on Thick Sheet Metal Forming

Braun, Alexander

Supervisor: Tekkaya, A. E. • Selvaggio, A.
Constructive Development of a Mounting Device for the Extrusion of Profiles with Variable Wall Thickness
Original title: Konstruktive Ausarbeitung einer Anbauvorrichtung zum Verstellen eines Strangpresswerkzeuges für die Fertigung von Profilen mit variablen Wandstärken

Bussmann, Dominik

Supervisor: Tekkaya, A. E. • Kloppenborg, T.
Analysis and Optimization of the Dummy Block for Extrusion Processes
Original title: Analyse und Optimierung der Pressscheibenfunktion beim Strangpressen

Hahn, Marlon

Supervisor: Tekkaya, A. E. • Weddeling, C.
Experimental and Analytical Comparison of Magnetic Pulse Welding and Vaporizing Foil Actuator Welding

Haupt, Marco

Supervisor: Tekkaya, A. E. • Mennecart, T.
The title is subject to confidentiality.

Hilbring, Joachim

Supervisor: Tekkaya, A. E. • Kloppenborg, T.
Experimental and Numerical Analysis of the Embedding of Functional Elements with Low Strength during Composite Extrusion
Original title: Experimentelle und numerische Untersuchungen zur Einbettung von Funktionselementen mit geringen Festigkeiten beim Verbundstrangpressen

Jaeger, Jan

Supervisor: Tekkaya, A. E. • Grzanic, G.
Development and Implementation of a Software System for the Machine Control of the Incremental Profile Forming

Original titel: Entwicklung und Implementierung eines Softwaresystems zur Realisierung einer Maschinensteuerung für die Inkrementelle Profilmformung

Kargupikkar, Nikhil

Supervisor: Tekkaya, A. E. • Chatti, S. • Ping Li, S. (Volkswagen AG) • Mennecart, T.

Investigation on Buckling Behaviour of Sandwich Sheets

Kondo, Sayako

Supervisor: Tekkaya, A. E. • Steinbach, F.

Investigation of Relaxation Forming of AlMgSc Aeroplane Fuselage Panel

Lin, Xinqi

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

Investigation on the Seam Weld Quality of an Industrial AA6082-Alloy Extrudate through Simulations and Experiments

Ludolfs, Johannes

Supervisor: Tekkaya, A. E. • Steinbach, F.

Forming Behavior of Steel-Plastic Hybrid Semi-Finished Parts

Original title: Umformverhalten von Stahl-Kunststoff Hybridhalbzeugen

Napierala, Oliver

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

Influence of Subsequent Manufacturing Processes on the Distorsion of Cold-Forged Shafts

Original title: Einfluss nachgelagerter Fertigungsprozesse auf den Verzug kaltumgeformter Wellen

Perekh, Keval

Supervisor: Tekkaya, A. E. • Steinbach, F.

The title is subject to confidentiality.

Schultz, Daniel

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

Development of a Measurement Device for the Contour Analysis of Three-Dimensionally Bent Profiles

Original title: Entwicklung einer Messvorrichtung für das Analysieren von Konturen dreidimensional gebogener Profile

Wernicke, Sebastian

Supervisor: Tekkaya, A. E. • Göttmann, A. (WPC GmbH) • Sieczkarek, P.
Systematic Optimization of the Tool Life in Sheet-Bulk Metal Forming of
Starter Gears

*Original title: Systematische Optimierung der Werkzeugstandzeit in der
Blechmassivumformung von Anlasserzahnkränzen*

Venkatachalam, Chockalingam

Supervisor: Tekkaya, A. E. • ul Hassan, H. • Rashidy H.

Development of Advanced Perfume Application Process for Mass Produc-
tion of Hygiene Products

1.5 Completed Diploma Theses**Kuscu, Ahmet**

Supervisor: Tekkaya, A. E. • Demir, O.

Extending Drawing Ratio at Deep-Drawing with Integrated Electromagnetic
Forming

*Original title: Erweiterung des Grenzziehverhältnisses beim Tiefziehen mit
integrierter elektromagnetischer Umformung*

Langolf, Andreas

Supervisor: Tekkaya, A. E. • Gies, S.

Development of an Automated Coil Clamping Mechanism with Integrated
Cooling Mechanism for the Electromagnetic Forming Process

*Original title: Entwicklung einer automatisierten Spulenklammerung mit
integrierter Kühlvorrichtung für die elektromagnetische Umformung*

Öztürk, Kasim

Supervisor: Tekkaya, A. E. • El Budamusi, M.

Investigation of the Damage Behavior Using High-Strength Aluminum and
Steel Material in Cyclic Bending

*Original title: Untersuchung zum Versagensverhalten hochfester Stahl- und
Aluminiumwerkstoffe beim zyklischen Biegen*

Reimer, Andreas

Supervisor: Tekkaya, A. E. • Hiegemann, L. • Alkas Yonan, S.

Development and Construction of a Tempered Deep-Drawing Tool

*Original title: Entwicklung und Konstruktion eines temperierten
Prüfwerkzeugs für den Tiefungsversuch*

1.6 Completed Bachelor Theses

Kleinekathöfer, David

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

Numerical Simulation and Validation of Induction Brazing for Tube Joining

Original title: Aufbau und Validierung eines Simulationsmodells für das induktive Löten von Rohrverbindungen

Knoblauch, Daniela

Supervisor: Tekkaya, A. E. • Yin, Q.

Start-Up of a Compression-Tension Test for Sheet Metal Materials

Original title: Inbetriebnahme eines Zug-Druck-Versuchs für Blechwerkstoffe

Komodromos, Anna Katarina

Supervisor: Tekkaya, A. E. • El Budamusi, M.

Investigation and Analysis of the Forming Behavior of a High-Strength Microalloyed Steel

Original title: Untersuchung und Analyse des Biegeumformverhaltens eines hochfesten mikrolegierten Stahlkaltbandes unter Berücksichtigung des mechanischen und mikrostrukturellen Ausgangszustandes

Maaß, Fabian

Supervisor: Tekkaya, A. E. • Gies, S.

Failure Mode and Effect Analysis (FMEA) for the Integrated Electromagnetic Sheet Metal Forming Process

Original title: Fehlermöglichkeits- und Einflussanalyse (FMEA) für die prozessintegrierte elektromagnetische Blechumformung

Moumou, El Mehdi

Supervisor: Tekkaya, A. E. • Demir, O.

Die Design and Construction for Deep-Drawing with Integrated Electromagnetic Forming

Original title: Werkzeugauslegung und Konstruktion für Tiefziehen mit integrierter elektromagnetischer Umformung

Pajonk, Daniel

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

The title is subject to confidentiality.

Schwienke, Sascha

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

Manufacturing and Geometrical Optimization of a Tractor Cabin Made from 3D-Bent Structural Elements

Original title: Herstellung und Geometrieoptimierung einer Traktorkabine aus 3D-gebogenen Einzelelementen

Thomssen, Patrick.

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

Experimental Analysis of Seam Welds at Hot Extruded Hollow Aluminum Profiles

Original title: Experimentelle Analyse von Längspressnähten bei stranggepressten Aluminium-Hohlprofilen

1.7 Completed Project Theses**Braun, Alexander**

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

Constructive Development of a Mounting Device for the Extrusion of Profiles with Variable Wall Thickness

Original title: Konstruktive Ausarbeitung einer Anbauvorrichtung zum Verstellen eines Strangpresswerkzeuges für die Fertigung von Profilen mit variablen Wandstärken

Cwiekala, Nils

Supervisor: Tekkaya, A. E. • Yin, Q.

Numerical Analyses of the Plane Torsion Test

Original title: Numerische Analysen des ebenen Torsionsversuchs

Finke, Reinhard

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

Modification of a Test Rig and Determination of Aluminum Flow Curves by means of Hot Compression Tests

Original title: Anpassung eines Prüfstandes und Ermittlung von Aluminium-fließkurven mittels Warmstauchversuchen

Keite, Matthias • Wissel, Constantin

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

Advanced Methods for the Identification of Material Parameters for 3D Profile Bending

Original title: Erweiterte Ansätze zur Bestimmung von Werkstoffparametern für das 3D-Profilbiegen

Klassen, Sergei • Szalata, Fabian

Supervisor: Tekkaya, A. E. • Ortelt, T. R.

Concept and Construction of a Test Unit for Different Load Cases of Copper Wire

*Original title: Konzeptionierung und Konstruktion einer Prüfeinheit für verschiedene Belastungszustände von Kupferdraht***Kolpak, Felix**

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

FEM Simulation and Parametric Study of a Model Experiment for the Analysis of Pressure Welding of Aluminum

*Original title: FEM-Simulation und Parameterstudie eines Modellversuchs zur Analyse des Pressschweißens von Aluminium***Nazari, Esmaeli • Anbazhagan, Vijayasathy**

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

Study on the Effect of Temperature and Feed Rates due to Induction Heating on Material Properties of Air-hardening Steel in Comparison to Mild Steel for Implementation in Induction Bending

Ozaydin, Onur • Manzoor, Anus

Supervisor: Tekkaya, A. E. • Isik, K.

Material Characterization by Tensile Test for Hole Expansion Test of AHSS

Pajonk, Daniel • Fiscoeder, Martin

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

Design Criteria for Extrusion Tools and Extruded Profiles

*Original title: Auslegungskriterien für Strangpresswerkzeuge und stranggepresste Profile***Samadi, Sina • Aragon Jimenez, Luis Alan**

Supervisor: Tekkaya, A. E. • Staupendahl, D. • Steinbach, F.

Hydroforming of Partially Cold Roll-Bonded Sheets

Tuzak, Elif • Erbas, Onur

Supervisor: Tekkaya, A. E. • Sieczkarek, P. • Isik, K.

Controlling Local Properties of Sheet Metal with Incremental Rolling Process

von der Mühlen, Jochen

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

Numerical Analysis of Impurities in Aluminum Extrusion Profiles

Original title: Grundlegende numerische Untersuchungen zur Analyse von Verunreinigungen in Aluminium Strangpressprofilen

Research for Education

02

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 on this field.

The main focus of attention in the field of engineering education research is the science based investigation on learning in engineering laboratories, which should lead to its enhancement and continuous development. In engineering education, laboratory learning is one of the core elements. The so-called „laboratory” or “laboratory practical work” with all its varied characteristics represents an important feature in engineering education, aiming at practical experience as part of experiential learning and implementing theoretical basics. On this background, the aim is to close existing knowledge gaps concerning efficient strategies to integrate modern labs. This includes the application and modification of modern didactical concepts as well as the use of innovative technologies to enhance and extend labs in a media-related and technological manner. Especially in manufacturing technology, laboratory courses are mostly based on expensive equipment, which is not easily affordable at any location.

The projects of the section “research for education” are clustered in the “research association of engineering education” together with our colleagues of the zhb at TU Dortmund University.

The projects are in particular:

- TeachING-LearnING.EU
- ELLI - Excellent teaching and learning in engineering education
- IngLab - The laboratory in engineering education
- KoM@ING – Modeling and development of competences according to mathematics and its substitution in engineering studies
- MasTech – Flexible modular master program in technology

2.1 Project TeachING-LearnING.EU

Funding	VolkswagenStiftung and Stiftung Mercator
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	Dr.-Ing. habil. S. Chatti

Since June 2010 the three North Rhine-Westphalia universities

- RWTH Aachen
- Ruhr-Universität Bochum
- Technische Universität Dortmund

have jointly constituted and operated the competence and service center TeachING-LearnING which is financed for the period of three years through the program “Bologna – The Future of Teaching”, funded by VolkswagenStiftung and Stiftung Mercator.

The TeachING-LearnING.EU project was successfully completed on schedule in 2014. In addition to the preparation of the project documentation and the organizational closure, the publication of the proceedings of the final conference in June 2013 was in focus this year. With over 130 participants from universities and universities of applied science from all over Germany, the conference showed the continuing interest in the topic of engineering education and the need for more research in this field. The proceedings “movING forward – Engineering Education from Vision to Mission” summarizes the results of the conference, reflecting the multifaceted discussion on engineering education as part of the TeachING-LearnING.EU project. In addition to providing the project results, this publication also presents to a broad public numerous projects and enterprises for the improvement and innovation of engineering education of other universities as a result of the numerous external conference participants, who also contributed to the proceedings.

Further information and impressions can be found at www.teaching-learning.eu.

2.2 ELLI – Excellent Teaching and Learning in Engineering Education

Funding	BMBF/DLR
Project-ID	01 PL 11082 C
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dipl.-Ing. T. R. Ortelt Dipl.-Inf. A. Sadiki Dr.-Ing. habil. S. Chatti

ELLI is a trans-regional, joint research project of researchers of RWTH Aachen, Ruhr-University Bochum and TU Dortmund University with the vision of improving the German engineering studies. In a first step, the mechanical engineering education shall become excellently prepared for the future. The aim of ELLI is the improvement of the study conditions and the development of the teaching quality. ELLI is divided into four parts: “virtual learning environments”, “support of mobility and internationality”, “student lifecycle”, and “creativity and interdisciplinarity”.

IUL is working on two sub-projects within the core part “virtual learning environments – resources for experiments: remote labs and virtual labs”.

- Investigation on lab courses in engineering education
- Development and integration of remote and virtual labs

In the scope of the first sub-project “investigation on lab courses in engineering education”, a phase model has been developed to integrate the procedure of a tele-operative experiment into a course in forming technology. The sub-project further involves an investigation of existing lab concepts which already apply remote labs. Based on these results, concepts of labs (like tele-operative labs integrated in lectures and as preparation for exercises in the MMT) have been identified and carried out. These concepts comprise the development of intended learning outcomes on the basis of fundamental components of learning objectives, e.g., the use of instruments and theoretical models. Here, the characteristic feature of many lab courses, i.e., a rigid structure and determination of individual work steps, becomes apparent. This is especially true for the phases of experiment preparation, planning, and execution as well as, less frequently, also for the procedures concerning the analysis of the experimental data. The resulting limitations to the learning process e.g. when working on engineering problems or planning experiments can significantly affect the use of the full potential of engineering lab courses.

Especially for courses that involve so-called fundamental experiments, the current state of knowledge suggests not only to cope with routines in the frame of a proper experimental procedure but also to make more use of the potential with regard to a fundamental scientific education. Future activities of the project shall consist in the transfer of the gained experience to our project partners to foster the network of tele-operative experiments and to intensify the cooperation among partners.

The second sub-project “development and integration of remote and virtual labs” involves the development of a tele-operative testing cell for material characterization. Students can use it over the internet to design, perform, modify, watch, and interpret tele-operative or virtual experiments. The testing cell allows different experiments, such as tensile test, compression test, or deep drawing test according to Nakajima (FLC) or Swift, to determine material properties relevant for forming technology.

Already last year, the tele-operative testing cell was used for the first time in the lecture “Umformende Fertigungstechnologien” (Fundamentals in Forming Technology). The experiment was controlled from the lecture hall in interaction with the students. The control was limited to the teacher. To guarantee a location and time-independent access, the tele-operative testing cell i.e. the tensile test was integrated into the iLab platform. This platform is a software framework which was developed by the MIT (Massachusetts Institute of Technology) and is used worldwide as an open source solution for the access to remote labs. iLab allows the management of the experiments. Students can book timeslots for their experiments, execute the experiments, watch them, and download the measured data via iLab.

After the successful integration of the tensile test into the iLab platform, a test run was done with students of the master study course MMT. The students had to determine material properties employing tensile tests in the frame of an exercise. 25 students joined this test run and everyone executed at least one tensile test, thereby confirming the reliability of the system. With the help of the experience as well as the feedback of the students, some improvements were implemented. Later in 2014, the tele-operative testing cell was used by future MMT students in the context of a preparatory course. The students performed the experiments in their respective homelands before going to Dortmund for the first time.

In August the development of the tele-operative testing cell especially in the field of controlling processes and machines via the internet was presented at the event “nrw.units meets production”, which took place at the IUL.

Tensile Test

Back to ServiceBroker ↩

Settings

Specification: Strainrate: Parametrized Strainrate Specimen type: DC04, Rolling direction: 0°, Length: 120, Width: 20, Thickness: 1, Magazine: Static, Count: 3
 Experiment Id on iLab: -1

Parameter:
 Strainrate (1/s): 0.0025, minimum value: 0.0025 and maximum value: 0.08
 LO (mm): 80, minimum value: 80 and maximum value: 80
 ClampForce (Bar): 50, minimum value: 30 and maximum value: 200
 Save parameters

5_Initialized: The Tensile controller is initialized and ready for Experiment

Experiment control

Prepare Start Pause Resume Cancel

Data and Streams

Displacement: -- [mm], Force -- [N], Time: -- [s], Specimen Width variation: -- mm, Temperature: -- °C

Force-Displacement Strain-Stress Raw-Data

Force-Displacement diagram

Force in N

Displacement in mm

Camera control:

Left Up Down Right Zoom In Zoom Out Snapshot

iLab-Client-Interface for the tele-operative tensile test

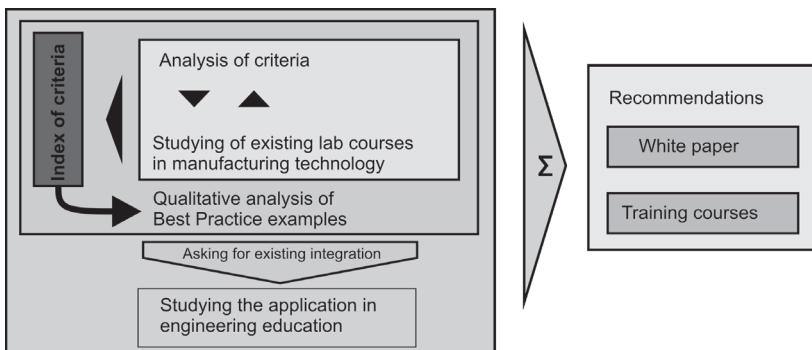
In November the tele-operative testing cell was used again in the scope of the lecture “Umformende Fertigungstechnologien” (Fundamentals in Forming Technology). For the first time, the cameras were able to turn, pan, or zoom during the experiment. After the lecture, the access to the tele-operative testing cell was given to all 250 students of this course. Students are now able to use the tele-operative testing cell autonomously and independently of location and time to combine their theoretical knowledge with practical experiences.

2.3 IngLab – The Laboratory in Engineering Science Education

Funding	acatech - NATIONAL ACADEMY OF SCIENCE AND ENGINEERING
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dr.-Ing. F. Maevus

Teaching and learning using experiments in laboratory is a common method in engineering education. Laboratories take a central role by providing the opportunity to students to cope with theoretical interrelations in an application oriented context, carry out and analyze experiments as well as critically evaluate their own approaches.

On the basis of the experiences gained during the analysis of laboratory criteria (see figure below), a catalog was developed consisting of characterizing aspects for labs in engineering education with a focus on manufacturing technology. These aspects were provided in an online information system and structured for an interactive as well as collaborative use. The project team intends to develop laboratory design guidelines. Therefore, national and international experts were asked to evaluate the importance of the lab as part of engineering studies. The recommendations will be gathered in a white paper and an advanced training course offer on laboratory didactics will be developed. The interdisciplinary project team comprises excellent expertise in the fields of engineering from IUL as well as didactics for higher education from the zhb of TU Dortmund University.



Schematic representation of the core objectives for IngLab

2.4 KoM@ING – Modeling and Development of Competences according to Mathematics and its Substitution in Engineering Studies

Funding	BMBF/DLR
Project	01PK11021A
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dipl.-Ing. T. R. Ortelt

The three subprojects of KoM@ING are processed by the project partners Leuphana University of Lüneburg, University of Paderborn, Humboldt-Universität zu Berlin, TU Dortmund University, University of Stuttgart und IPN – University of Kiel. The main topic of the different subprojects is combined in the preparation of a competences model for the required mathematic skills in engineering studies.

In the subproject B, the IUL is collaborating on an interdisciplinary basis with the colleagues of the zhb (Center of Higher Education) of TU Dortmund University and the Humboldt-Universität zu Berlin on the development of a competences model for mathematical competences in context of laboratory learning for engineering studies.

The following working packages were treated under the leadership of the zhb in 2014:

- WP3: Analysis of typical exercises:
Students' way of working on the tasks in a tensile test lab was observed.
- WP4: Modeling of competences:
On the basis of the observed way of working on tasks, the relevant mathematical competences were determined.
- WP5: Creation of item formats and instruments:
Formats for the determination of competences were developed to create a wide range of competence-orientated exercises and systematic competence detection instruments.

In February 2014 a two-day project meeting took place in Stuttgart. The different subprojects presented their results and concepts for the next steps were declared.

2.5 MasTech – Flexible Modular Master Program in Technology

Funding	EU, TEMPUS
Project	511277-TEMPUS-1-2010-1-DE-TEMPUS-JPCR
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	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 MasTech program consists of basic and speciality modules. The modular structure of this master program (different educational modules independent from each other) gives not only consistency and flexibility to education in manufacturing but also allows an easy implementation in training programs for vocational education of manufacturing engineers to support the lifelong learning process and to easily introduce a certification process for engineers. The idea is to have a joint basic structure with 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, which will lead to a greater 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 will be facilitated for the graduates by focusing the education in manufacturing fields specifically on PC industries and fortifying the university-enterprises relationship. The Royal Institute of Technology (KTH), Stockholm, Sweden, and the “Ecole Nationale Supérieure d’Arts et Métiers (ENSAM), ParisTech, Metz, France are the European partners of the project. The Master program started in November 2013 in three universities in Tunisia and Algeria. In 2014, the master program was also accredited in Morocco at two universities and is offered, as in Tunisia and Algeria, as a special international master program. The project was successfully completed in 2014. The cooperation between the nine project partners will persist.

Research

03

3 Research

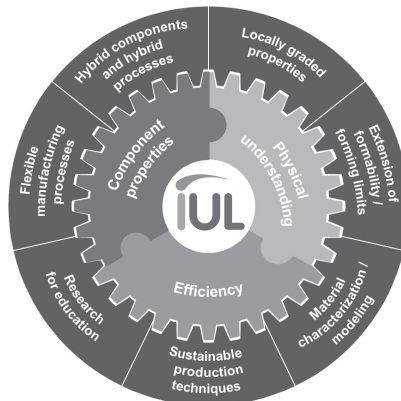
The research activities of the Institute of Forming Technology and Lightweight Construction pursue three main objectives. The setting and improvement of component properties, the acquirement of physical understanding of forming processes, and a holistic view on efficiency are the aims of the five departments Sheet Metal Forming, Bending, Bulk Metal Forming, Non-Conventional Processes, and Applied Mechanics in Forming Technologies as well as of the cross-departmental working group “Project Planning”.

The main objectives are divided into the following research topics:

- Flexible manufacturing processes
- Hybrid components and hybrid processes
- Locally graded properties
- Extension of formability / forming limits
- Material characterization / modeling
- Research for education
- Sustainable production techniques (Recycling)

The project work is done in thematic teams within the departments as well as across departments depending on the required expertise.

2 chief engineers, 39 scientists, 14 technicians and administrative staff members, and approximately 50 student assistants ensured a sustainable success in 2014.



Research objectives of the Institute of Forming Technology and Lightweight Construction

3.1 Coordinated Research Programs

3.1.1 ReCIMP – Research Center for Industrial Metal Processing

Head Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Manager Dipl.-Ing. D. Staupendahl

The “Research Center for Industrial Metal Processing“ (ReCIMP) was founded in the beginning of 2013. It is supported by Faurecia, an international company specialized on automotive products, the IUL and TU Dortmund University. The ReCIMP aims at advancing and deepening of scientific knowledge on innovative metal production processes, process chains and hybrid processes, the analysis of new scientific trends in metal processing, and networking with leading research institutes and companies. To reach these aims, the ReCIMP is set up as a central organizational entity which can benefit from the competences of all departments of the IUL. This structure works in close cooperation with Faurecia – especially with the divisions seating and emission control technologies – to ensure the fulfillment of project requirements.

After an initial phase of project specification and identification in which research activities were set up in the fields of

- extension of forming limits,
- advanced high-strength steels,
- alternative production methods,
- flexible production,
- hybrid structures,
- and standards for processing of metal,

several projects are currently in the research phase. As a result, the number of researchers and student assistants involved in the ReCIMP has steadily increased to 10 since the beginning of 2013. Additionally, twelve students were involved in running projects in 2014 by performing student research projects and working on thesis projects.

The figure shows the research projects that are currently carried out as part of ReCIMP. Furthermore, their integration in different research fields is presented. The projects marked in light grey are funded by third-party funds and are described in the chapter Research. Roll forming and air bending with elastomer tools is worked on in the context of the research project Forming limit extension of high-strength steels in bending processes by using innova-

Extension of forming limits	Roll forming and air bending with elastomer tools
	Local induction heating in forming processes
	Extension of the formability by the use of heat
Advanced high strength steels	Bending and induction heating of air hardening tubes
	Characterization of DP and HSLA materials
Alternative production methods	Influence of the cutting edge on formability
	Dry blanking of metallic and polymer materials
	Combination of cold roll bonding and hydroforming
Standards for processing of material	Design guide for 3D bending
	Development of a design strategy for hydroforming
	Analysis of induction heating for tube joining

Current ReCIMP research projects

tive process management and tools. The projects Bending and induction heating of air hardening tubular material and Design guide 3D bending focus on investigations of cold and warm bending of tubes and profiles and the development of analytic approaches for the reduction of manufacturing tolerances. The first phase of the projects was worked on in the project Development of a bending machine for the production of three-dimensionally shaped complex parts made of profile material, which was completed in 2014. Additionally to the mentioned third-party funded projects, the chapter Research includes the descriptions of the projects Extension of the formability by the use of heat within the process chain, Characterization of DP and HSLA Materials for Bending Applications, and Analysis of induction heating for tube joining and approaches for optimization.

High-strength steel sheets, which allow the design of efficient lightweight applications tend to be sensitive to crack formation on cutting edges. This can actually lead to part failure during forming processes that follow upstream cutting operations. To classify materials for the use in various forming processes, the project Influence of the cutting edge on formability was established. State of the art to accomplish this task is the use of the ISO hole expansion test. In the project, additional methods for material characterization are developed in cooperation with Faurecia and compared with results of the ISO test.

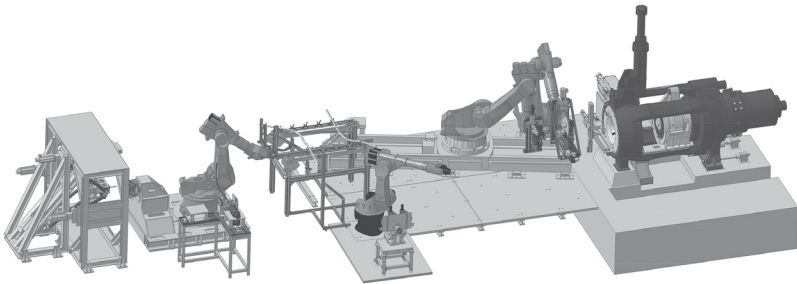
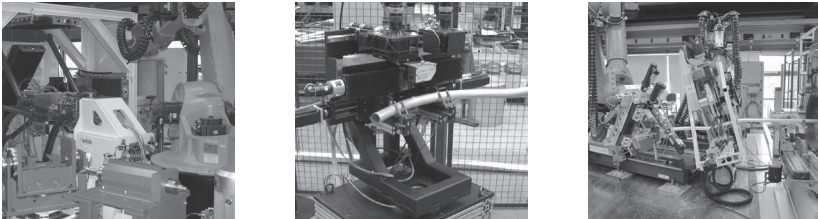
The project Combination of cold roll bonding and hydroforming aims at the development of a heat exchanger made of cold roll-bonded sheets that are subsequently shaped by hydroforming. Here, the challenge is the avoidance of using a separating layer for the exchanger contour to avoid particles that can disturb fluid flow during operation.

The project Development of a design strategy for hydroforming parts with secondary forming elements aims at the development of a guideline for designers in order to reduce design-simulation-loops and design hydroforming parts more efficiently. This is done by setting up a process simulation and varying relevant geometry, process, and material parameters and by analyzing their impact on the formability. Apart from all projects described, new projects are continuously being generated and set up. Focus is set on research fields that show current trends in manufacturing technology and present industrial relevance.

3.1.2 Integration of Forming, Cutting and Joining for the Manufacture of Lightweight Frame Structures

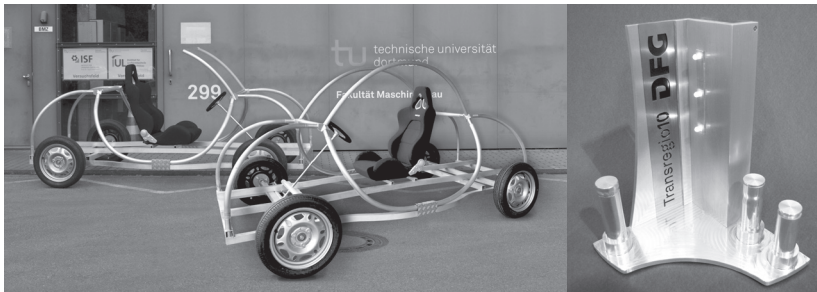
Funding	German Research Foundation (DFG)
Spokesman	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Manager	Dipl.-Inform. A. Selvaggio

The Collaborative Research Center Transregio10 (Transregio10) was successfully completed on December 31, 2014. Aim of the Transregio10 was to develop the scientific basis and methods for designing integrated process chains for the automation and product-flexible small-scale series manufacturing of lightweight frame structures. In three funding periods and at six research institutions located in Dortmund, Karlsruhe, and Munich an idealized process chain for the conjunction of forming, cutting, and joining has been engineered (see Figure). Phase I focused on the setup of virtual and physical prototypes, on verifying the simulative approaches, and on technology development as well as on construction of test components. In Phase II the simulation tools were interlinked and the different processes of Phase I were connected. A major aspect of the third and last funding period was the flexibilization of each single process as well as of the entire process chain. In order to visualize the achieved flexibility different demonstrators were built by using the developed process chain. The newly developed, innovative methods were applied successfully. Among other things, single-seaters were manufactured



Process chain of Transregio10

by solely using rounded profiles and profiles with reinforcing elements. In the process, each profile was connected by means of one of the joining methods deployed in Transregio10, such as electromagnetic forming or bifocal hybrid laser welding. Furthermore, the profiles had to undergo a quality check within the process chain by applying flexible gripping technology and metrology. Another highlight of Transregio10 was the manufacture of profiles with integrated functional elements. Here, isolated conductor paths were integrated into aluminum profiles by utilizing composite extrusion so that these resulting profiles can be used for data transport or as electric conductors. As demonstrator a bookend was designed where these conductors serve as ports for LED arrays (see figure).



Manufactured buggys (left) and bookend (right) as exemplary demonstrators of the process chain for product-flexible small-scale series manufacturing of lightweight frame structures

The achieved research results and implemented demonstrators made it possible to prove that structures for small(est)-scale series can be produced flexibly, efficiently and with high manufacturing accuracy.

Manufactured single-seaters (left) and bookend (right) as exemplary demonstrators of the process chain for product-flexible small-scale series manufacturing of lightweight frame structures

486 papers were published based on the results of the Transregio10 in three funding periods, of which about 50 % passed a peer review process and were presented to an international audience of experts.

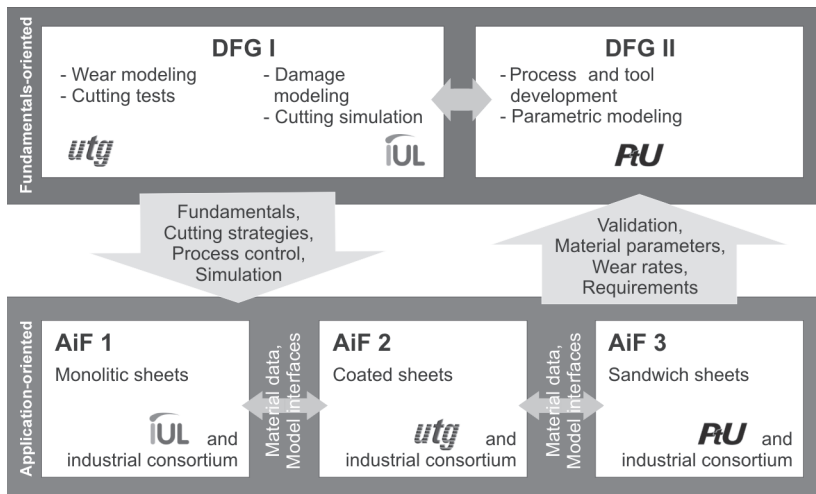
In addition, 31 doctoral theses and 5 postdoctoral theses have been successfully completed with topics of the Transregio10. In teaching, the results as well as the models and prototypes are used as practical examples in various lectures and laboratories at all locations. A total of 215 students completed their theses within the research topics of the Transregio10.

As final event of the Transregio10 the international “Conference on Manufacture of Lightweight Components” (ManuLight2014) was organized. The event took place from April 3 to 4, 2014 at the „Dortmunder U“ and represented the beginning of a series of conferences organized by the members of the Transregio10. The conference was supported by the CIRP (International Academy for Production Engineering) and offered plenty of room for discussions and opportunities for networking in the field of production of lightweight structures. Simultaneously, an exhibition presenting the results of Transregio10 by numerous exhibits and posters to a wide audience took place in the collegiate floor of the “Dortmunder U” from March 26 to April 27. Further information about the event is available on the website www.manulight.com.

3.1.3 Dry Shear Cutting of Metal Laminated Composite Material

Funding	Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V. (AiF), German Research Foundation (DFG)
Project	PAK 678/0
Spokesman	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

The AiF/DFG-Cluster develops a processing technology to shear hybrid laminated layer composites without additional lubricants. Providing constant process and part quality and reducing the tool wear should ensure the economic competitiveness of the shear cutting process. Starting point is the scientific analysis of the fundamental mechanisms and their influence on dry shearing in terms of tribology, process control, tool wear, and tool load. On this basis, the shearing process will be further developed and optimized. The work packages, which are necessary to solve the overall problem, are divided into two fundamental research DFG projects and three application-oriented AiF projects (see figure).



Cooperation and networking of the subprojects

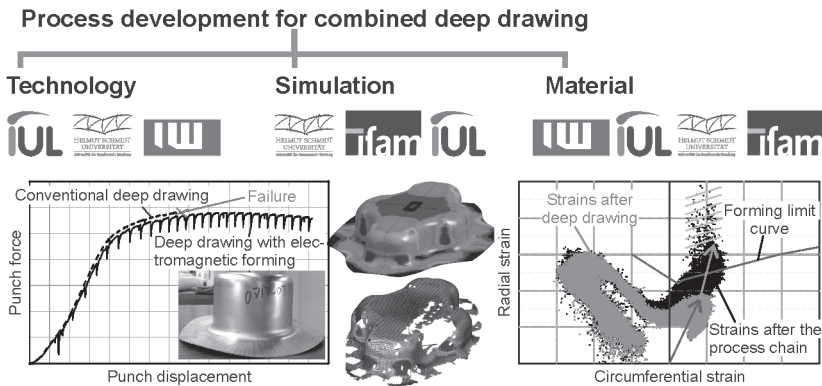
3.1.4 Development of a Methodology Regarding Combined Quasi-Static and Dynamic Forming Processes

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

In this joint project the combination of quasi-static deep drawing and dynamic electromagnetic forming is examined. Due to the strain rate and strain path changes of this process combination the forming limits shall be extended.

In the first funding period the process combination was used to produce sharper edges on deep drawn parts. In the second funding period a continuous superposition of deep drawing with the electromagnetic forming is used to increase the maximum drawing ratio.

The research is being carried out by means of cooperation with the Chair of Theory of Electrical Engineering and Computational Electromagnetics at Helmut Schmidt University Hamburg, the Institute of Applied Mechanics at RWTH Aachen, and the Institute of Materials Science at Leibniz Universität Hannover

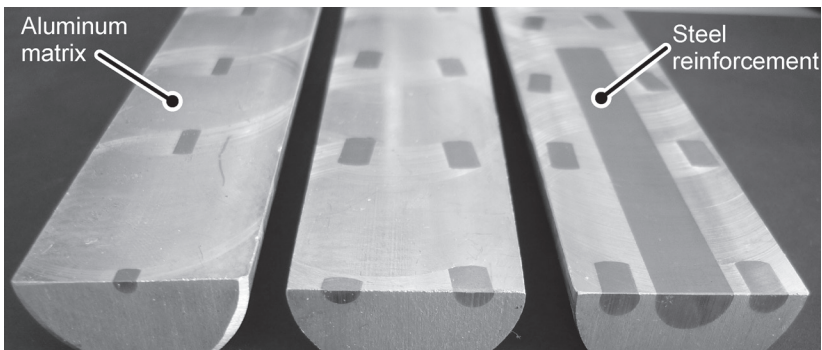


Collaboration of project partners

3.2 Department of Bulk Metal Forming

Head Dr.-Ing. Dipl.-Wirt.-Ing. Matthias Haase

The scientific assistants of the bulk metal forming group are involved in the development and adaption of innovative process variants of hot extrusion and cold extrusion. The focus of the research activities is on the production of hybrid components, the gradation of the properties of the material and on innovative approaches for scrap recycling. For the production of hybrid components the processes of composite hot and cold extrusion are currently investigated. Here, the mechanical and functional properties of the components are defined by combining lightweight materials with high strength steel elements and functional elements, like electric conductors. The gradation of the mechanical properties of a component can be achieved exemplarily by altering the wall thickness and, therefore, the stiffness of an extrusion profile over the profile length. This was realized by the application of a moveable tool system integrated into a hot extrusion die. With the innovative recycling approach of chip extrusion, aluminum alloy machining chips can be recycled directly into finished or semi-finished aluminum profiles by hot extrusion. Thus, the energy-intensive re-melting step in the conventional recycling route for machining chips can be avoided.



Steel-reinforced aluminum profiles manufactured by composite extrusion

3.2.1 Multi-Axis Curved Profile Extrusion

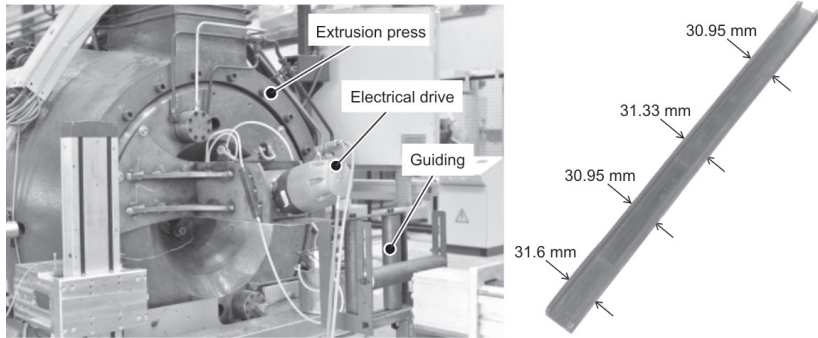
Funding	German Research Foundation (DFG)
Project	SFB/TRR 10 • Subproject A1
Contact	Dipl.-Inform. A. Selvaggio
Status	Completed

Project Description

This project deals with the further development of the “Multi-Axis Curved Profile Extrusion” and represents the beginning of the process chain which is examined in the Collaborative Research Center SFB Transregio 10. One main objective in the current funding period is the development of the process “extrusion of profiles with variable wall thickness” and the combination of this process with the “multi-axis curved profile extrusion”. In this process, the wall thickness of the extrudates can be modified by moveable tool elements which are used to alter the position of the die bearing.

Current Results

With a new tool design the extrusion of open profiles and rectangular hollow profiles with varied wall thicknesses is possible. In experimental trials the wall thickness could be varied reliably by 33 % (see Fig.). Currently, the impact of the main factors on the force necessary for the variation of the wall thickness, like the tool deformation, is quantified.



Left) Electrical drive for the extrusion of profiles with variable wall thickness; right) Extruded profile with realized variation of the wall thickness

3.2.2 Composite Extrusion

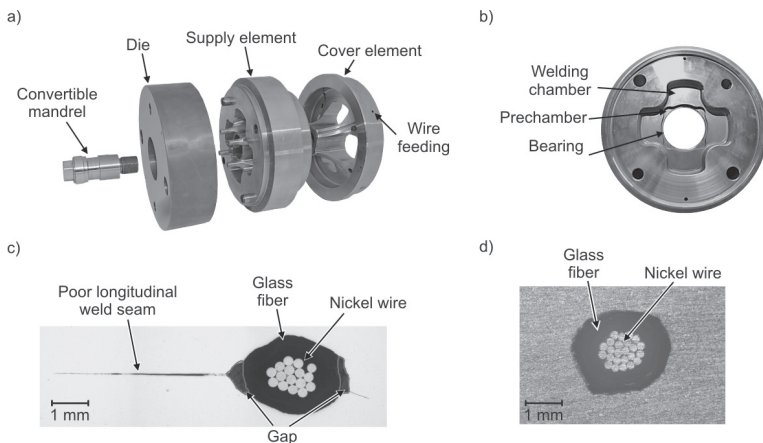
Funding	German Research Foundation (DFG)
Project	SFB/TRR 10 • Subproject A2
Contact	M.Sc. C. Dahnke
Status	Completed

Project Description

The aim of the project is to identify and extend the process limits of embedding reinforcing and functional elements in structural components made of aluminum alloys by extrusion. In the previous phases of the project the embedding of metallic reinforcement elements was primarily investigated. However, in recent studies the focus is on the integration of functional elements with low strength.

Current Results

To meet the process requirements, a die concept was developed with the help of FEM in which the feeding of the elements is positioned in an additional pre-chamber of the die. Due to the numerically aided design of the pre-chamber, the hydrostatic pressure in regions next to the feeding mandrels can be increased, resulting in an improved longitudinal weld seam quality. However, in the region of the element feeding a lowering of the pressure occurs, which leads to a reduced load acting on the functional elements. With the help of the modified die concept, profiles with embedded isolated electrical conductors could be produced in experimental studies.



a) Modular die; b) Geometry of the welding chamber; c) Embedding before modification of the die concept; d) Embedding after modification

3.2.3 Integral Design, Simulation, and Optimization of Extrusion Dies

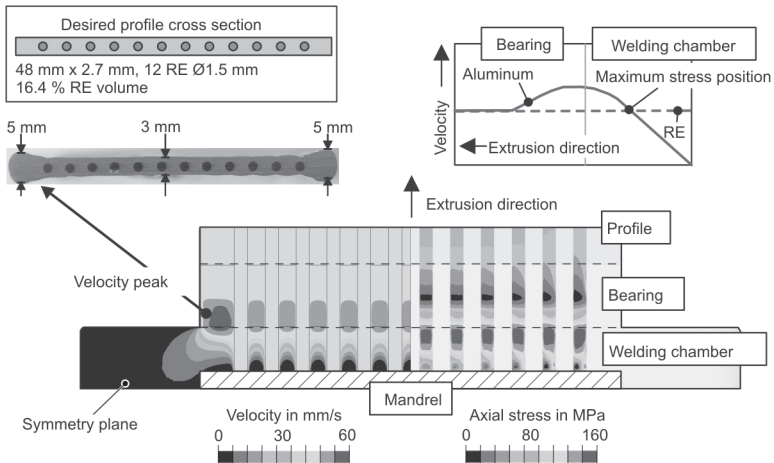
Funding	German Research Foundation (DFG)
Project	SFB/TRR 10 • Subproject B1
Contact	Dipl.-Ing. M. Schwane
Status	Completed

Project Description

A major focus of the work in subproject B1 is the analysis of (composite) extrusion processes by means of the finite element method (FEM). Furthermore, analytical approaches to identify the loads acting on the reinforcing elements during the process are developed.

Current Results

With an increasing reinforcing volume the influence of the embedded reinforcing elements (RE) on the material flow is increasingly more pronounced. Therefore, modeling approaches for steady-state simulations were investigated in order to enable the analysis of processes with high reinforcing volumes. The numerical results were validated by means of experiments. Furthermore, the computed stresses in the RE are in agreement with the analytical models.



Simulated velocities and stresses in reinforcing elements

3.2.4 Thermomechanical Processing of Aluminum Alloys Subsequent to Extrusion

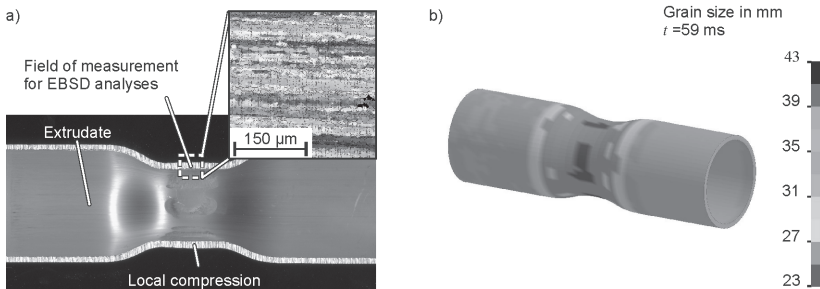
Funding	German Research Foundation (DFG)
Project	SFB/TRR 30 • Subprojekt A2
Contact	Dr.-Ing. Dipl.-Wirt.-Ing. M. Haase

Project Description

This project deals with the manufacturing of products with locally adapted properties by integrating thermo-mechanical forming and heat treatment operations into the process of direct hot extrusion. Besides the combination of hot extrusion with electromagnetic compression and local heat treatment, the process combination of hot extrusion and corrugation of hot extruded profiles is investigated.

Current Results

For the description of the developed process chains thermo-mechanically coupled numerical simulations are conducted. The results of each process are used as an input for the numerical simulation of the subsequent process. This kind of process simulation aims at the prediction of the mechanical properties and the microstructure of the fabricated parts by numerical analyses.



Combination of hot extrusion and electromagnetic compression, a) Analysis of the grain size within the profile, b) Prediction of grain size within the profile by a model implemented in a Finite-Element simulation

3.2.5 Extrusion Dies with Local Internal Cooling Channels Manufactured by Additive Manufacturing Technologies for Extending the Process Limits in Hot Extrusion

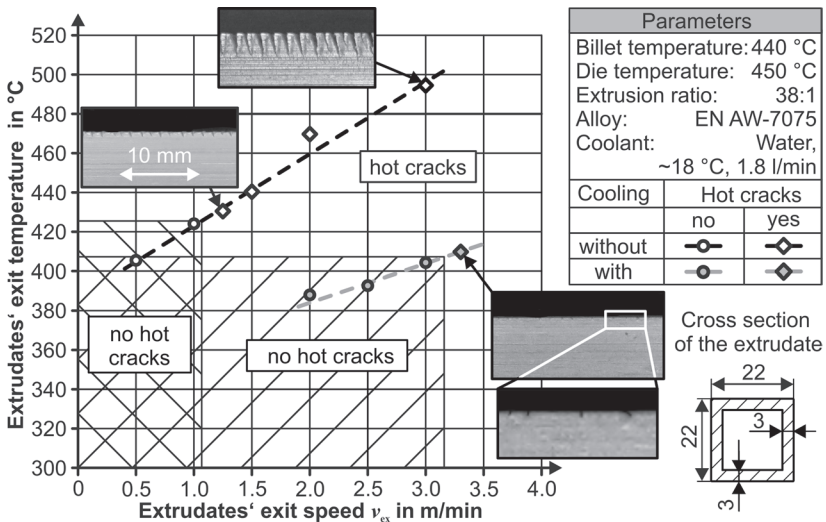
Funding German Research Foundation (DFG)
Project TE 508/27-2
Contact Dr.-Ing. Dipl.-Wirt.-Ing. R. Hölker

Project Description

In the first funding period the fundamentals of applying dies manufactured by rapid tooling with conformal cooling channels for the extension of the process limits in hot extrusion of aluminum were investigated. Tools based on the layer-laminated manufacturing method and laser melting were developed and their performance explored.

Current Results

The interactions between the workpiece, the die, and the main process parameters were analyzed by experimental, analytical, and numerical investigations. Experimentally, by applying the inner local die cooling during hot extrusion of the hard-to-extrude alloy EN AW-7075, an increase in productivity of up to 300 % could be achieved.



Extension of the process limits in hot aluminum extrusion of EN AW-7075 by using an inner die cooling

3.2.6 Development of a Process to Manufacture Ribbed Tubes by Hot Extrusion

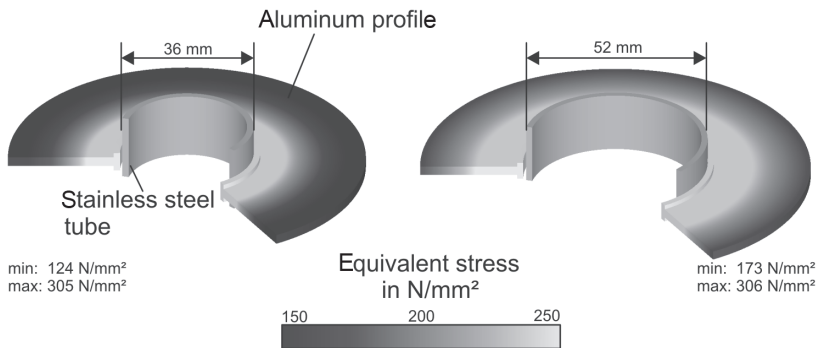
Funding ZIM
 Project KF2198117RU2
 Contact Dipl.-Ing. S. Ossenkemper

Project Description

The company Georg Frank & Co. GmbH and the IUL develop a new process which allows the cost-efficient manufacturing of ribbed tubes made of different materials. In order to increase the thermal conductivity of tubes, the application of cooling ribs is well established. The material of the tube, which contains a highly corrosive media, is in most cases a chemically resistant steel, while the material of the cooling ribs should have a high thermal conductivity.

Current Results

Numerical simulations were conducted in order to analyze the stresses in the cooling ribs after shrinking on the tube. Before cooling, the temperature of the hot extruded profile is 500 °C. The effective stresses in the shrunk-on ribs are shown in the following figure for different diameters of the tube. The simulation of the shrinking is used to investigate the resulting press-fit.



Effective stresses in shrunk-on ribs for different diameters of the tube

3.2.7 Systematic Process Control in Cold Forging and Heat Treatment for Minimizing Distortion

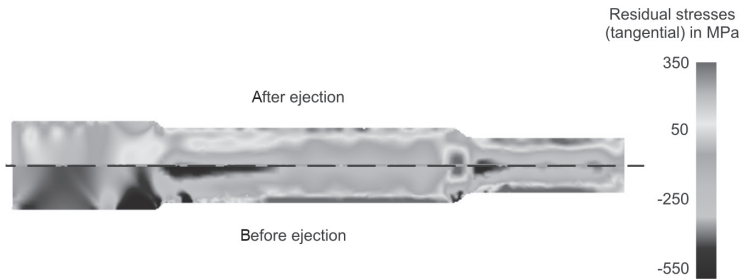
Funding	AiF ZUTECH
Project	478 ZN
Contact	Dr.-Ing. Dipl.-Wirt.-Ing. M. Haase

Project Description

The aim of this research project, which is performed in cooperation with the IWT Materials Science, Bremen, is the specific adjustment of process parameters in cold forging and subsequent heat treatment in order to reduce the distortion of the formed components. On the basis of experimentally conducted results in the previous project "Analysis of the Active Correlation between Heat Treatment and Distortion of Cold Forging Workpieces", the influence of further factors on the distortion mechanisms, like the hardening behavior of the material or the anisotropy due to perlite banding, are investigated.

Current Results

A coupled simulation of the process steps cold forging, ejection, and heat treatment is performed in order to detect potential influencing factors of distortion in advance. Based on these results, process parameters can be changed to finally reduce the distortion. The change of residual stresses in circumferential direction in the formed shaft before and after ejection is exemplarily shown below. The analysis of the residual stresses is highly relevant because their release during the heat treatment can cause distortion.



Residual stresses in tangential direction in the formed shaft before and after ejection

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

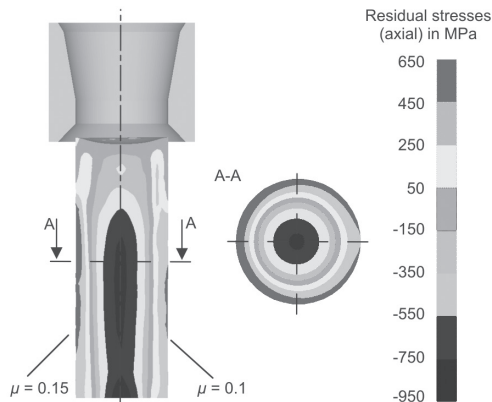
Funding	German Research Foundation (DFG)
Project	TE 508/18-2
Contact	Dr.-Ing. N. Ben Khalifa
Status	Completed

Project Description

The process chain of the cold drawing process was investigated experimentally and numerically within the scope of this German-Brazilian collaborative project. The main aim was the detection of potentials for reducing the distortion in cold drawn semi-finished products. The project is part of the BRAGECRIM framework (Brazilian-German Collaborative Research Initiative on Manufacturing Technology), which started at the end of 2005 and now connects more than 30 Brazilian and German universities, research institutes, and industrial partners.

Current Results

Due to an unequal application of lubricant in the coating process of the wire, slightly different friction values can occur during the drawing process. This results in an asymmetric distribution of the residual stresses in the drawn semi-finished products. As residual stresses are considered to be a potential factor of distortion, the distribution of the residual stresses should be as homogenous as possible.



Residual stresses in the drawn wire in case of inhomogeneous application of lubricant

3.2.9 Manufacture by Forming and Characterization of Actuator Profiles Based on Shape-Memory-Alloys

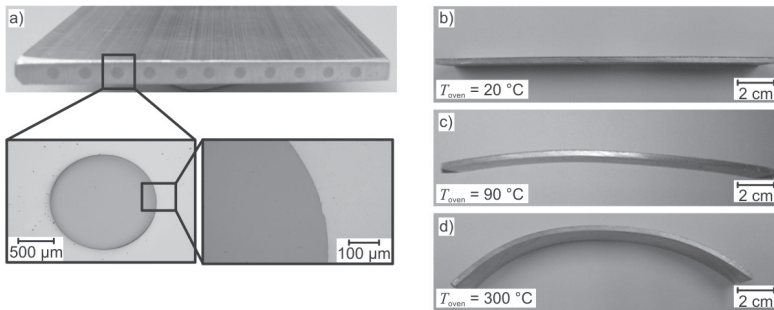
Funding	German Research Foundation (DFG)
Project	TE 508/45-1
Contact	M.Sc. C. Dahnke

Project Description

The aim of the research project is to manufacture structural components made of shape-memory metal matrix composites (SM-MMC) with an actuator function by composite extrusion and further forming processes. The mechanical and technological fundamentals of this approach are analyzed. Furthermore, the process limits of SM-MMCs are investigated.

Current Results

By using composite extrusion a thin-walled aluminum composite profile with embedded NiTi wires was produced. Microscopic studies show a gapless interface between the two materials. Specimens with a NiTi wire proportion of 15.15% by volume were taken out of the composite profile and heat-treated at different temperatures. Based on the heat treatment condition, a significant deformation of the profile could already be observed at a temperature of 90 °C, due to the contractions of the NiTi wires and the shape memory effect.



a) Embedding of NiTi elements in an aluminum matrix (EN AW-6060), b) Initial state of specimen, c) Specimen after heat treatment $T = 90\text{ °C}$, d) Specimen after heat treatment $T = 300\text{ °C}$

3.2.10 Basic Investigations on Hollow Lateral Extrusion of Additional Shape Elements

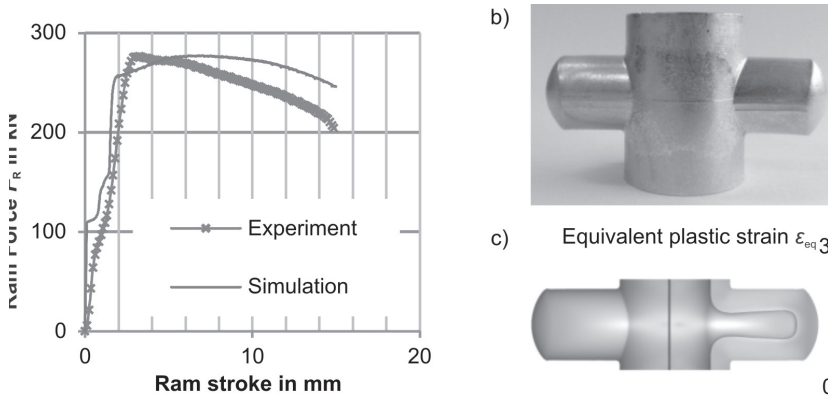
Funding	German Research Foundation (DFG)
Project	TE 508/13-3
Contact	M.Sc. O. Napierala

Project Description

The aim of this joint project between the IUL and the Institute for Metal Forming Technology at the University of Stuttgart is to investigate the basics of the manufacturing process “Hollow Lateral Extrusion” without a lateral mandrel. The identification and analysis of the interaction of geometry and process parameters by numerical simulations and experiments are two of the main aspects of this project.

Current Results

In initial studies the influence of the main process parameters, like number and position of the lateral shape elements, on the dimensional accuracy of the lateral shape elements was investigated. Based on these results, new tool concepts that can directly influence the material flow and improve the dimensional accuracy will be developed and tested.



a) Extrusion force vs. ram stroke curve, b) Produced part, c) Numerical analysis of the lateral shape elements

3.2.11 Optimization of Workpieces by Forging of Composite Aluminum Extrudates

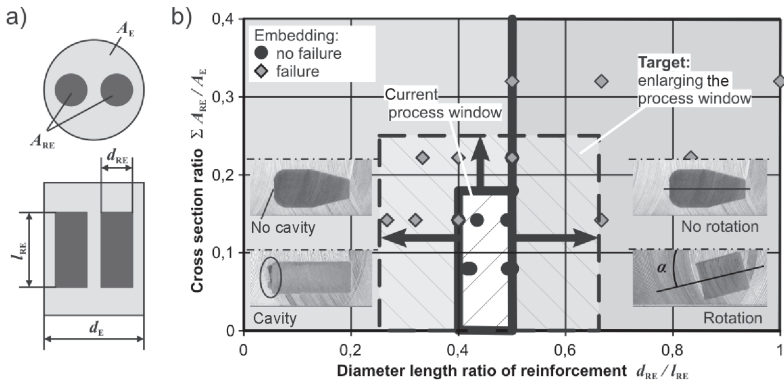
Funding	German Research Foundation (DFG)
Project	TE 508/17-2
Contact	Dipl.-Ing. E. Levin

Project Description

In the second phase of the project the specific strength of aluminum extrudates is further improved by a combination of composite extrusion with discontinuous reinforcement elements (RE) for local reinforcement and composite extrusion with continuous RE (high-strength steel wires). The produced semi-finished products are forged in this cooperative research project to reinforced finished parts at the Institute of Forming Technology and Machines of the Leibniz University Hannover.

Current Results

To enlarge the process window for the eccentrically placed reinforcing elements, the shape of the RE was optimized. This method influences the material flow during the extrusion process, which leads to an improved embedding quality of the RE and prohibits RE rotation.

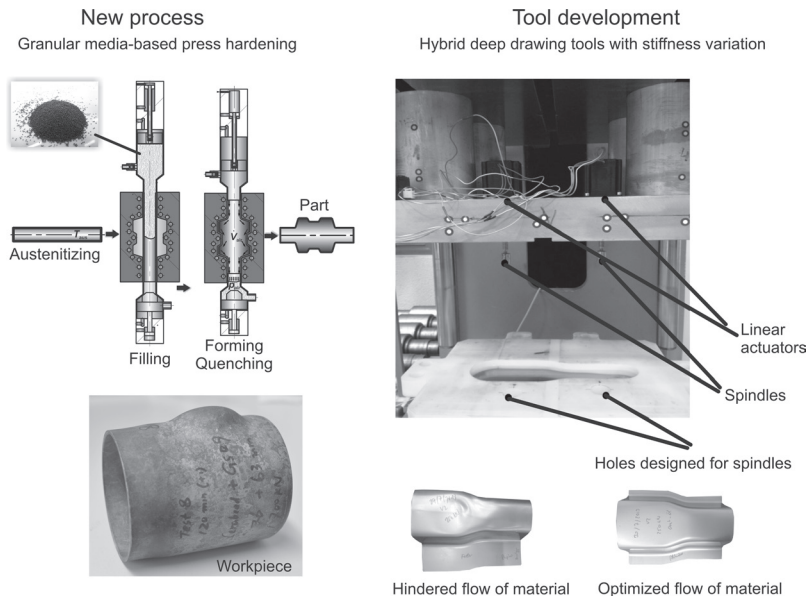


a) Extrudate with two reinforcement elements, b) Process window for eccentrically placed RE

3.3 Department of Sheet Metal Forming

Head Dr.-Ing. Alper Güner

The department of sheet metal forming is primarily concerned with the analysis and development of both known and new sheet metal forming processes and characterization of utilized sheet materials. The primary goal is to enhance the understanding of physical relations, so as to develop sustainable technologies and to end up with efficient process designs. A new project approved in 2014 represents a good example for this goal. Here, a process understanding for an integrated one-step process for the production of plastic-metal hybrid components is developed. In this context, the production of structural components by stamping and injection molding directly in an injection mold should be realized. Two concepts developed at the IUL, namely granular media-based press hardening of tubes and hybrid deep drawing tools with varying stiffness, are at the forefront of research activities.



Left: Granular media-based press hardening of tubes, Right: Hybrid deep drawing tools with varying stiffness

3.3.1 Design of Wear Resistant Hybrid Deep Drawing Tools with the Capability of Stiffness Variation

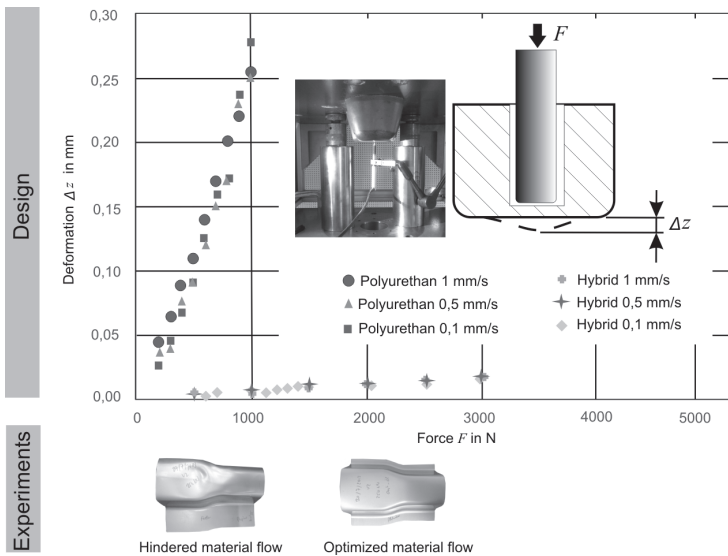
Funding German Research Foundation (DFG)
 Project SFB 708 • Subproject C1
 Contact Dipl.-Ing. T. Mennecart

Project Description

In subproject C1 of the SFB708 experiments regarding the adjustment of the tool elasticity were carried out. The adjustments are necessary for the design of the elements, like springs or actuators, to control the springback and material flow in the forming process.

Current Results

For the adjustment of springback by the use of stiffer elements, the design of the tool with these elements is necessary for an accurate control of the material flow. After the numerical and experimental design of the hybrid tool itself, the required deformations of hybrid tools could be investigated in dependency of the elements used. As shown in the figure below, for two different polymer tools the required forces are plotted over the achieved deformation. With higher deformation of the tool the material flow is hindered and springback can be reduced.



Control of tool deformation for adjustment of geometry accuracy

3.3.2 Strategies for Springback Compensation

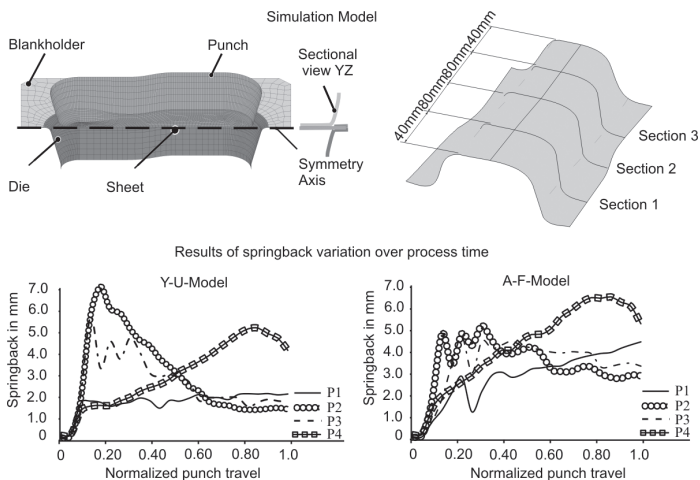
Funding German Research Foundation (DFG)
 Project SFB 708 • Subproject C3
 Contact M.Sc. H. ul Hassan

Project Description

The aim of this project is to allow for an optimal and robust layout of deep drawing and stretch drawing processes with respect to dimensional accuracy and part failures. A finite element model is generated which offers the possibility to vary process parameters such as a variation of the coefficient of friction and blankholder force. This implementation has made it possible to analyze the effects of functional input on springback in deep drawing process.

Current Results

A comparison of the effect of different material models, namely Yoshida-Uemori (YU) model and Armstrong-Frederick (AF) model, along with different tension profiles on springback have been investigated. It is shown that the variable tension gives a smaller springback as compared to the traditionally used constant blank holder force. It is also found that the YU model gives smaller springback than the AF model, regardless of the investigated geometry, which is primarily due to its ability to model non-linear kinematic hardening properly.



Simulation model and results of springback over punch travel

3.3.3 Dry Shearing of Metal Material and Polymers

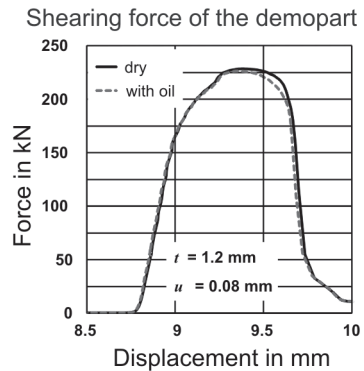
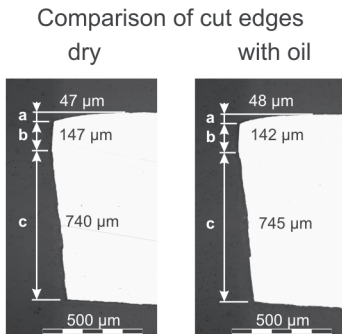
Funding AiF/FOSTA
 Project 17791 N/P 890
 Contact Dipl.-Ing. F. Steinbach

Project Description

With the absence of lubricants in the manufacturing of sheet metal parts it is possible to save considerable costs. This means, however, that in the shearing process without using lubricants the same quality of the cut edges has to be guaranteed. In addition, new tool concepts have to be used for the improvement of the wear behavior of the active tool elements.

Current Results

With shearing tools made of common material grades and slow cutting speed no significant difference between dry and lubricant-applied cuts could be seen. Nevertheless, the wear behavior of the active tool elements is considerably affected as expected. Therefore, new tool coatings are tried and tested.



Comparison of cuts with and without lubricants

3.3.4 Modeling of Press Hardening of Lightweight Structures Using Shapeless Solids as Forming Media

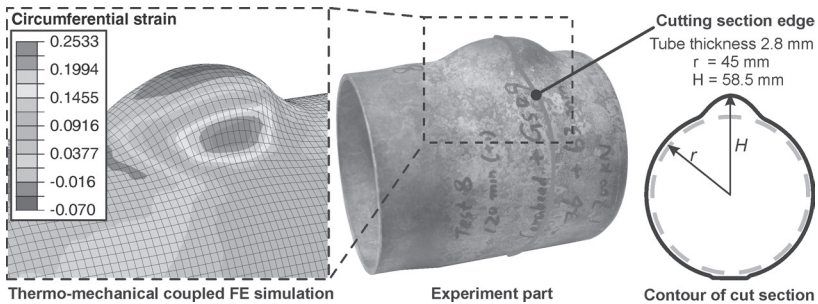
Funding Graduate School of Energy Efficient Production and Logistics
 Contact M.Sc. H. Chen

Project Description

Using granular material as forming media achieved the press hardening purpose for tube hydroforming. The frictional properties of granular media, which differ from conventional fluid working media, give the need for numerical and experimental investigations on process parameters from both the process aspect and media aspect.

Current Results

Coarse granular material such as quartz sand presents a better radial-axial pressure transmitting ratio, but higher interfacial friction, which reduces the axial pressure transfer effect. Granular material with higher roundness presents an opposite behavior. Reducing the interfacial friction coefficient, decreasing the granular media charging volume, or using tailored granular media improves the formability of the process. Unlike conventional tube hydroforming, a maximum thickness reduction appears at the corner rather than the peak point of the nose in a granular media-based T-shape tube press hardening experiment because of the feeding effect of interfacial friction.



Experimental and numerical simulation results of granular media-based tube press hardening

3.3.5 Identification of Stress-Dependent Bauschinger Coefficients

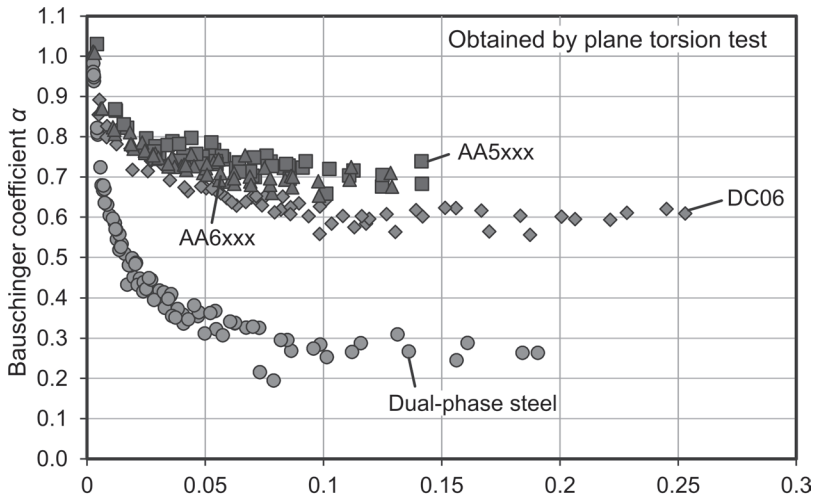
Funding EFB / AiF
 Project 17375N/1
 Contact Dr.-Ing. A. Güner

Project Description

This project is carried out in cooperation with the Institute of Manufacturing Technology in Erlangen. The main objective is to investigate the Bauschinger effect as a function of different stress states and prestraining. For this purpose, cyclic shear tests and tension-compression tests are performed. Experimentally obtained cyclic curves are used to identify parameters of different kinematic hardening models.

Current Results

The Bauschinger coefficients obtained by the plane torsion test at different hardening levels show that all of the analyzed materials show a saturation of the Bauschinger effect after a certain amount of prestrain. It was found that the Bauschinger effect is more dominant for the dual phase steels. These results were also verified by uniaxial tension-compression tests.



Bauschinger coefficient for different materials at different prestrains

3.3.6 Production of Structural Elements by means of Deep Drawing and Back Injection in the Injection Mold

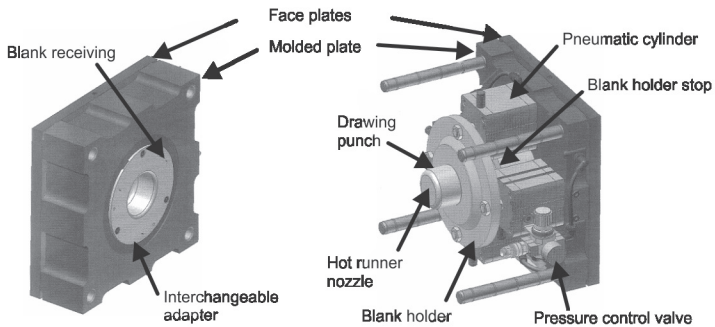
Funding	AiF
Project	18075 N
Contact	M.Sc. S. Hess

Project Description

The project aims are process development and generation of process understanding of an integrated single-stage process for the production of plastic-metal-hybrid components consisting of a formed sheet metal and a functional structure of thermoplastics. Therefore, the drawing components die, drawing punch, and blank holder are to be integrated into the injection mould. The project runs in cooperation with the Institute of Plastics Processing at RWTH Aachen University.

Current Results

For the design and production of an integrated deep drawing and injection molding tool results of preliminary studies regarding material selection, bonding agents, and lubricants are obtained. The function of the blank holder should be controlled separately from the kinematics of the injection moulding machine. Effects of deep drawing and injection parameters on forming quality and properties of the plastic-metal compound are investigated.



Concept of a combined deep drawing and injection mould tool using a pneumatic blank holder

3.3.7 Extension of the Formability by the Use of Heat within the Process Chain

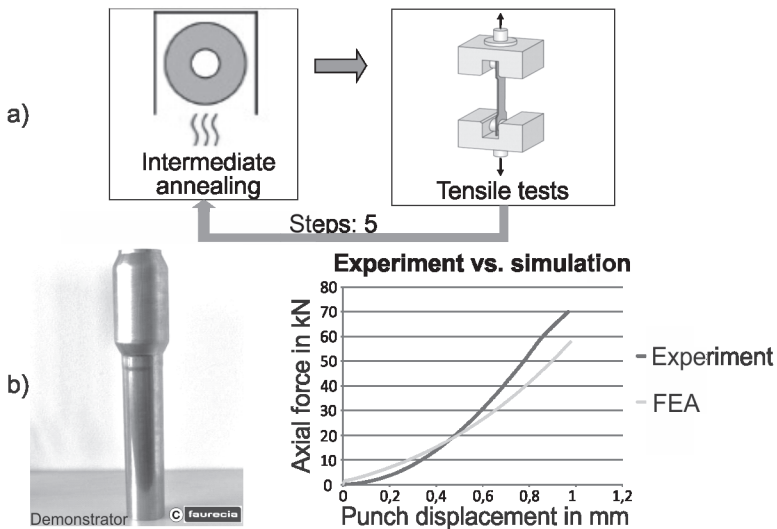
Funding ReCimp
Contact M.Sc. S. Hess

Project Description

Focus of the project is increasing the formability of hydroformed parts by using heat. There are two strategies: first, the heat is inserted into the process chain in such a way that intermediate annealing is used between the forming steps. Further, the heat is used directly during the forming procedure. Here, shapeless solids are used as an alternative to the fluidic forming medium of hydroforming.

Current Results

For the investigation of using intermediate annealing, forming limit curves of five-stage tensile tests are examined. The main interest lies on the effect of annealing time and temperature on the forming limit. For annealing during forming the application of different shapeless solids is investigated. For the setup of comprehensive FE-models these shapeless solids and the tube material are being characterized experimentally and a material model was chosen.



a) Use of intermediate annealing, b) Application of shapeless solids

3.4 Department of Bending Technology

Head Dr.-Ing. Christoph Becker

In the department of bending technology several bending processes for sheet metal as well as tubes and profiles are investigated. The work concentrates on basic research of the processes as well as on the development of innovative bending processes. Here, one focus is on the extension of process limits. This extension can be reached by using process combinations or by using warm forming steps in addition to the bending step.

In the year 2014, the work and results of the department were, for example, presented on an exhibition stand at the TUBE fair in Düsseldorf. Furthermore, the conference on tube and profile bending (DORP2014) has been organized, which led to interesting and inspiring discussions among experts in the field of bending technology and similar fields.



Exhibition stand at the TUBE 2014 fair

3.4.1 Investigation of Springback Compensation in Sheet Metal Bending Process by Incremental Compressive Stress Superposition

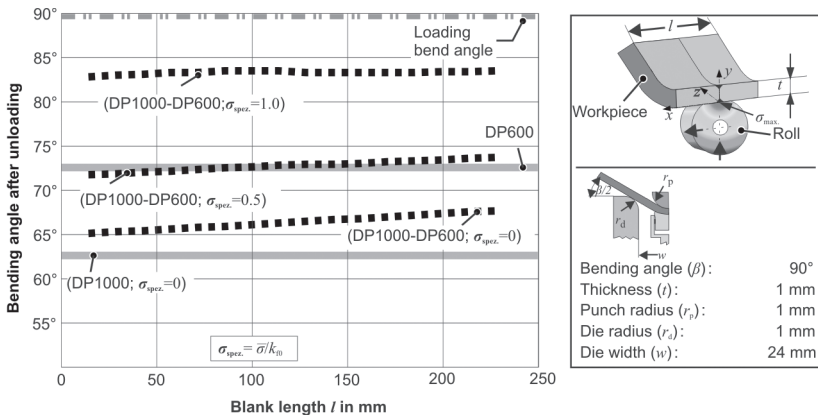
Funding German Research Foundation (DFG)
 Project MA1883
 Contact Dr.-Ing. F. Maevus
 Status Completed

Project Description

During bending of high-strength sheet metals and tailored blanks the high and also varying springback leads to significant shape deviations. Within this project possible strategies for minimizing the springback by using a local pressure in the forming zone have been investigated.

Current Results

It has been shown that additional pressure leads to a stress superposition in the forming zone which causes a significant reduction of the springback. Furthermore, a defined pressure application according to graded sheet metal properties is possible. This leads to a compensation of local inhomogeneities and, therefore, an almost constant bending angle along the whole bending length can be reached.



Weinrich et al. (2014)
 (DOI: 10.4028/www.scientific.net/AMR.1018.301)

Influence of pressure superposition during bending of tailor-welded blanks

3.4.2 Investigation of Incremental Tube Forming to Establish a Process Model in Order to Predict Springback

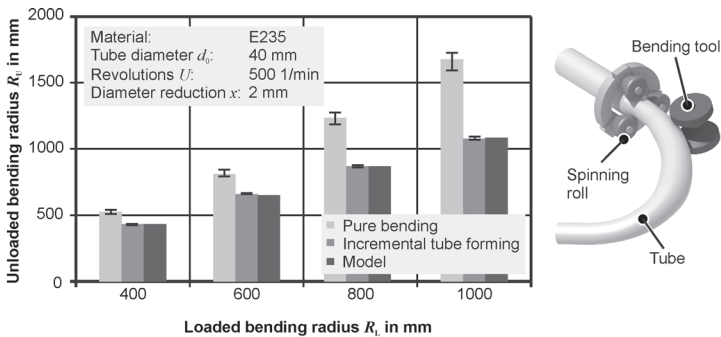
Funding German Research Foundation (DFG)
 Project TE 508/26-1
 Contact Dr.-Ing. C. Becker

Project Description

The incremental tube forming process (ITF) is a process combination of tube bending and spinning. The result of this combination is a reduced bending force as well as a reduced springback compared to conventional tube bending processes. Within this project, the springback should be described by establishing a process model.

Current Results

In the first project phase a process model was developed which is able to predict the springback. The springback depends, for example, on the revolutions, the diameter reduction, and the bending radius. The figure shows the loaded and unloaded bending radius. It can be seen that the incremental tube forming process leads to a springback reduction compared to a conventional pure bending process. On the other hand, it is shown that the process model can describe the springback quite accurately.



Figures according to Becker (2014) (ISBN 3-8440-2947-5)

Springback for different bending radii

3.4.3 Indubend – Technology for Inductive In-Situ-Heating in Stamp and Bend Forming with Progressive-Press-Tools

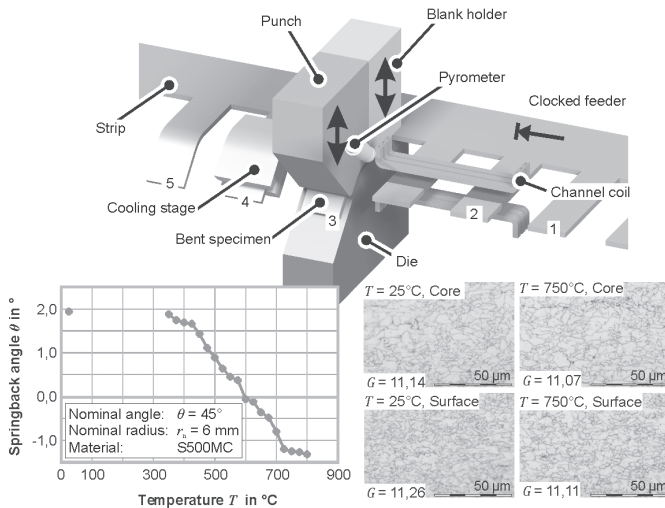
Funding BMWi / ZIM-KF
 Project KF2198118LK2
 Contact M.Sc. C. Löbbbe

Project Description

In the project Indubend a technology for warm bending in progressive dies is being developed in cooperation with KODA GmbH in order to reduce springback of high-strength steels. The project covers the design process of the induction heating as well as an investigation of formability of micro-alloyed steels at elevated temperatures.

Current Results

The result is a flexible prototype tool with an inline induction heating in the form of a channel coil applied directly before bending. Through the modular design the effect of different arc geometries and heating strategies can be investigated. Experiments show a huge reduction of springback in consequence of higher temperatures, which is in accordance with the calculation based on hot tensile tests. Despite high temperatures up to 750°C, an alternation of microstructure is avoided due to the short dwell times.



Process principle, springback angle, and microstructure pictures at elevated temperatures

3.4.4 Development of a Bending Machine for the Production of Three-Dimensionally Shaped Complex Parts made of Profile Material

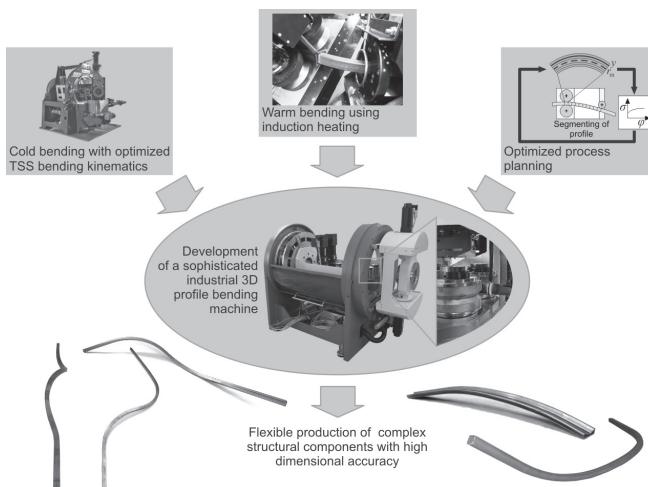
Funding	BMWi/ZIM-KF
Project	KF2198115LK1
Contact	Dipl.-Ing. D. Staupendahl
Status	Completed

Project Description

In the course of the project a new machine technology for the flexible cold and warm bending of profiles with complex cross sections to three-dimensional structures has been developed in cooperation with Schwarze-Robitec GmbH. The design is based on the Torque Superposed Spatial bending process (TSS bending), which was developed and patented by the IUL. Comprehensive investigations of the bending process and the bending kinematics were carried out and a process model of the TSS bending process has been designed.

Current Results

The two- and three-dimensional cold and warm bending process as well as the influence of torsion on the produced bending contour was investigated. Additionally, sensors for the dynamic measurement of torque and bending forces were developed in order to support the investigations.



Realization of an industrial prototype of the bending machine in cooperation with Schwarze-Robitec GmbH

3.4.5 Forming Limit Extension of High-Strength Steels in Bending Processes by Using Innovative Process Management and Tools

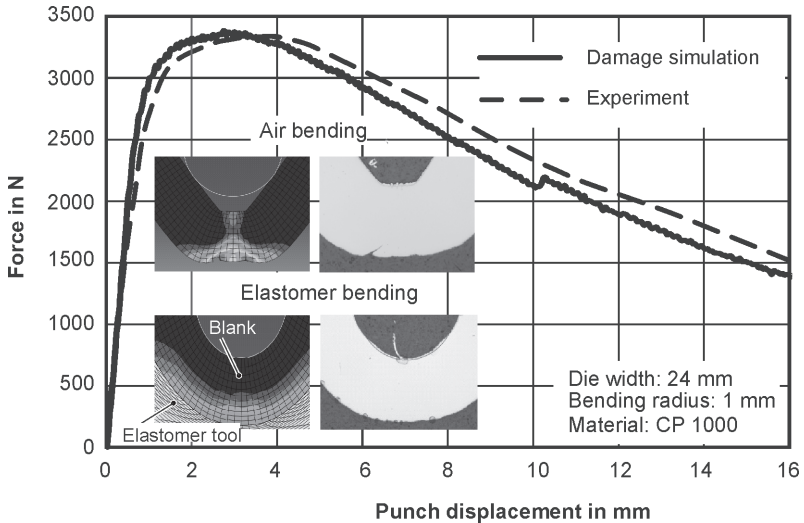
Funding AiF/FOSTA
 Project P 930 • IGF-No. 16585 N
 Contact Dipl.-Ing. M. El Budamusi

Project Description

The aim of the project is the extension of forming limits in bending processes using high strength-steels. Here, conventional sheet metal bending processes are extended by process modifications, for example by using additional stresses on the workpiece during the forming process for an extension of the forming limits.

Current Results

In addition to experimental investigations in air and elastomer bending, numerical studies have been used in order to optimize the bending processes. After validation of the numerical model the position of the elastomer tool was optimized with regard to extending the forming limits by reducing process forces and tool wear.



Numerical and experimental study on the influence of stress superposition on the damage evolution in bending processes

3.4.6 Analysis of Induction Heating for Tube Joining and Approaches for Optimization

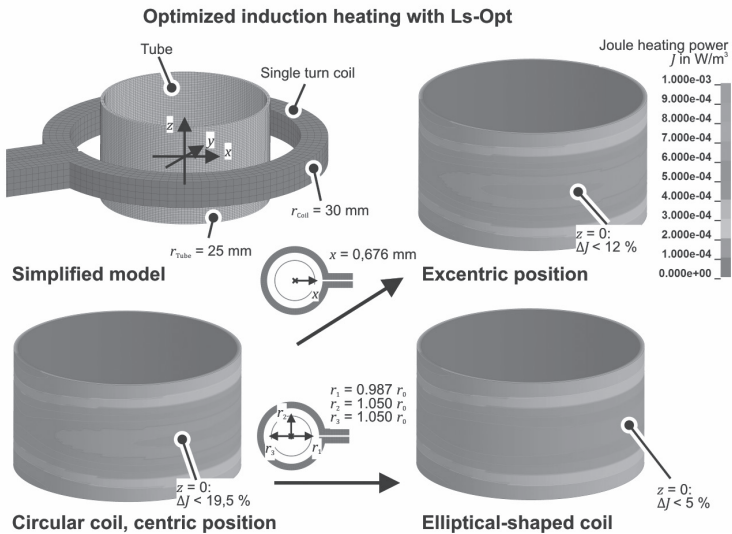
Funding ReCIMP
Contact M.Sc. C. Löbbe

Project Description

In cooperation with Faurecia Emission Control Technologies GmbH a brazing process for tube joining through induction heating is analyzed and optimized. The target is a homogenous eddy current heating of the joining area in order to enable high quality joints despite temperature-sensitive solder and large manufacturing tolerances.

Current Results

In the material characterization stage fundamental parameters as the electrical conductivity and the emission factor were determined for elevated temperatures with regard to a numerical simulation and validation. To analyze the process and disclose the detailed mechanisms, a model was implemented in Abaqus and compared with experimental results. Recent work covers a design optimization of the induction coil based on a metamodel, whereby a more homogenous Joule heating power is reached.

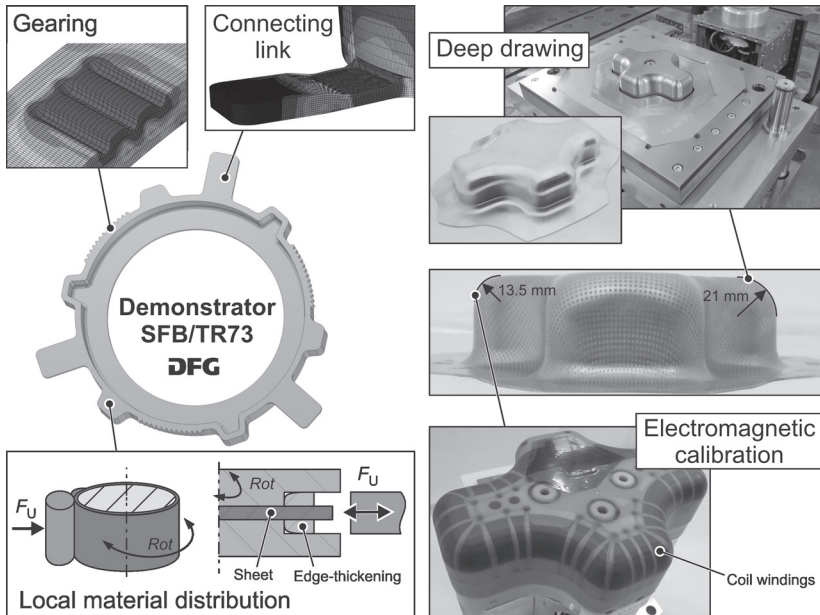


Simplified numerical model to determine the Joule heating power and optimize the heating pattern through position and shape adaption

3.5 Department of Non-Conventional Processes

Head Dr.-Ing. Dipl.-Wirt.-Ing. Christian Weddeling

The objective of the research work of this department is to establish alternative technologies in production engineering where conventional methods come to their limits. Current topics are flexible and energy-efficient processes as well as the extension of forming limits known at present. Therefore, the research of the department focuses on incremental forming and impulse forming or rather the combination of the corresponding processes with quasi-static forming methods. Techniques covered are, for instance, incremental sheet-bulge metal forming, which allows the flexible manufacturing of complex functional parts, and the combination of deep drawing and electromagnetic forming. By combining these processes an enhancement of the quasi-static process limits is achieved (see figure). Joining by forming is another focus of the department. A major advantage of this group of processes is the possibility to connect dissimilar materials.



Left: Manufacturing of secondary design elements by incremental sheet-bulge metal forming. Right: Process combination of deep drawing and electromagnetic forming

3.5.1 Process Development for Deep Drawing with Integrated Electromagnetic Forming

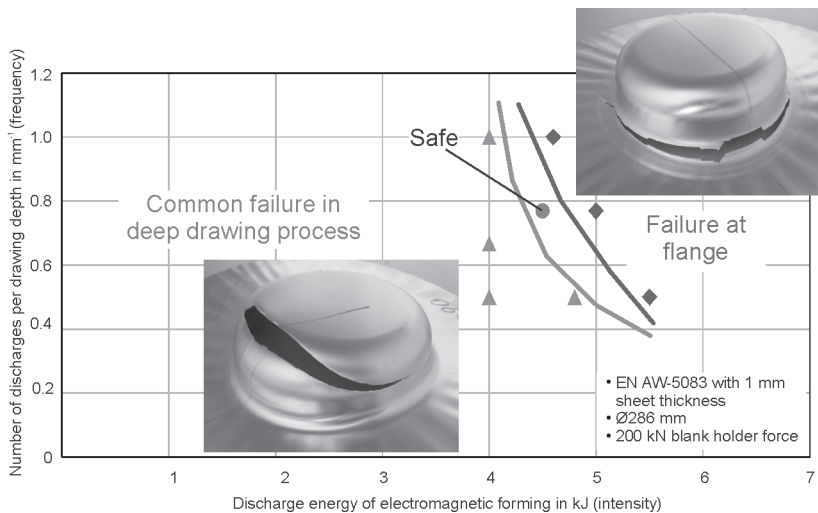
Funding German Research Foundation (DFG)
 Project PAK 343 • Subproject 1
 Contact M.Sc. O. K. Demir

Project Description

In this project, a new deep drawing technology is examined in which the drawing is superimposed by sequential electromagnetic forming in the flange. By means of this process combination the drawing limits of aluminum alloys existing so far should be extended. For this purpose, a fundamental understanding of the process should be acquired based on experimental and numerical investigations.

Current Results

Experimental investigations showed that an increase in the maximum drawing ratio can be achieved by such a process combination (see figure). In addition to the drawing ratio, the blank holder forces, and the lubrication, the repetition rate and the intensity of the electromagnetic discharges were identified as parameters with a significant influence on the formability of the material.



Experimentally obtained process window for deep drawing with integrated electromagnetic forming; the achieved drawing ratio is 2.2 compared to a maximum ratio of 2.0 in conventional deep drawing processes

3.5.2 Integration of Electromagnetic Sheet Metal Forming into the Processing Head of a Punching Machine

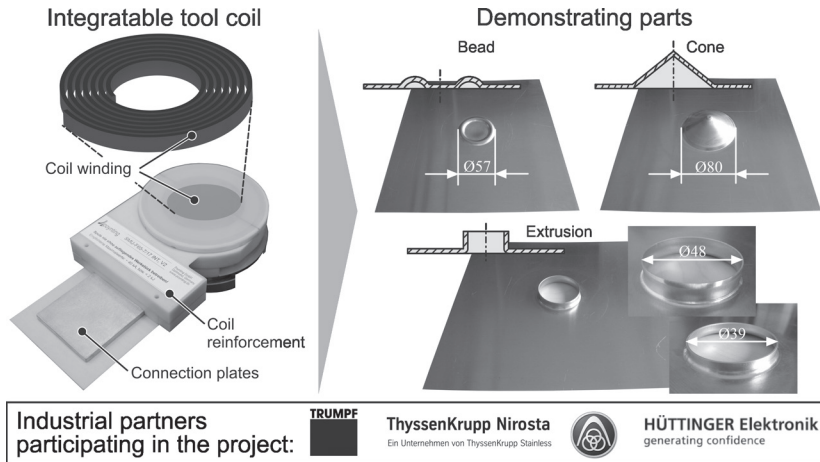
Funding	German Research Foundation (DFG)
Project	TE 508/34-1
Contact	Dipl.-Wirt.-Ing. S. Gies
Status	Completed

Project Description

The project aims at a prototypical integration of an electromagnetic sheet metal forming process into the processing head of a punching machine. This way, a sequential combination of conventional quasi-static processes with an electromagnetic forming operation using one machine tool was enabled.

Current Results

By integration of an automatic coil clamping mechanism and by means of a tool coil which can be stored in the tool magazine (see figure) all basic requirements for an automated setup of the tool coil during the production process were fulfilled. Based on a process FMEA, suitable measures for an increased process reliability under close-to-production conditions were derived. The final proof of functional capability and flexibility of the prototypical integration was provided by the production of the demonstrating parts depicted in the figure below.



Integratable tool coil and electromagnetically formed demonstrating parts

3.5.3 Joining by Forming

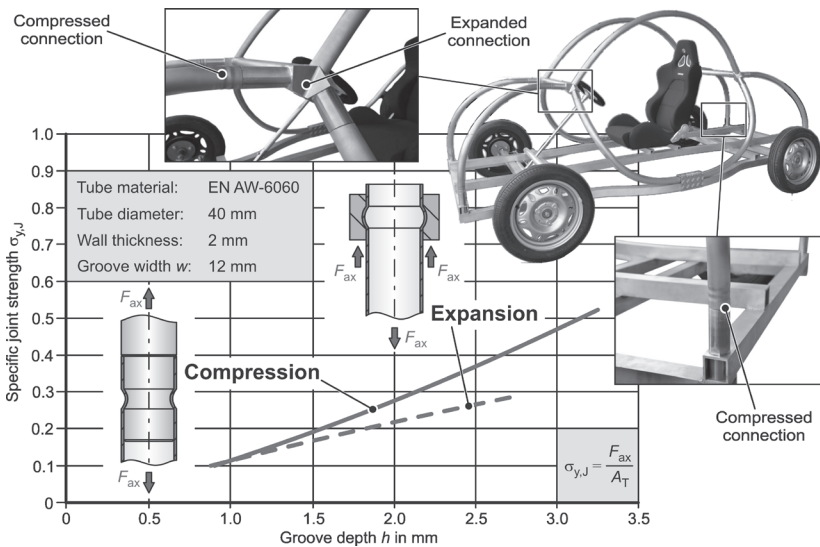
Funding	German Research Foundation (DFG)
Project	SFB/TRR 10 • Subproject A10
Contact	Dr.-Ing. Dipl.-Wirt.-Ing. C. Weddeling
Status	Completed

Project Description

The objective of the project was the development of a fundamental process understanding of the joining of lightweight frame structures and the load transfer of the corresponding connections. This knowledge was obtained by analytical, experimental, and numerical investigations on form- and interference-fit joining by electromagnetic forming and hydroforming. Additionally, joining by magnetic pulse welding was analyzed. Based on the acquired process understanding, guidelines for a process- and load-appropriate joining zone design were developed.

Current Results

An analytical model for the prediction of the strength of form-fit joints was developed on the basis of experimental and numerical studies (see figure). In addition to the connection design, the model allows a process-independent identification of important joining zone parameters.



Analytical joint strength comparison of compressed and expanded connections

3.5.4 Magnetic Pulse Welding: Targeted Manipulation of Weld Seam Formation

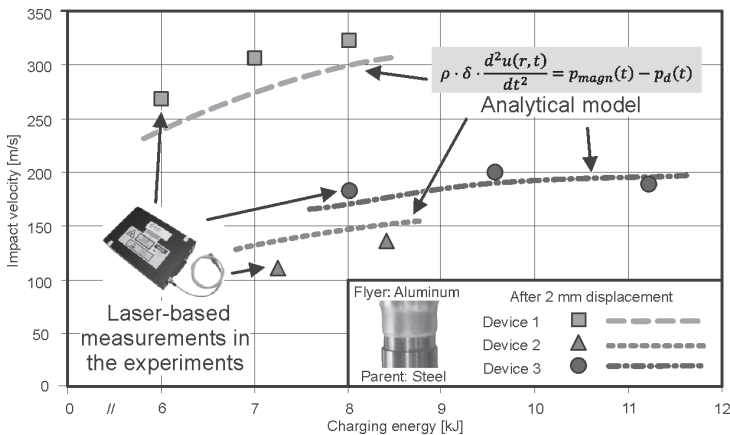
Funding	German Research Foundation (DFG)
Project	SPP 1640 • Subproject A1 (in collaboration with IF, TU Dresden)
Contact	Dipl.-Wirt.-Ing. J. Lueg-Althoff

Project Description

Magnetic Pulse Welding (MPW) is an appropriate process for the formation of adhesive bonds between dissimilar materials. The project aims at the development of applicable models for a system- and material-independent prediction of the required collision conditions. These conditions are primarily determined by the impact velocity and the collision angle between the flyer and the parent joining partner. In this project, the MPW of tubular parts by electromagnetic compression is investigated by experimental, numerical, and analytical methods.

Current Results

An analytical approach for the approximation of the impact velocity by use of measured current curves was developed. This model allows gaining better insight into the process details and helps to simplify the process design, making complex simulations and elaborate experiments redundant. The integration of the collision angle into the model and the consideration of system parameters as well as a welding criterion are key aspects of the further project work.



Flyer part velocity as a function of charging energy

3.5.5 Sheet Metal Forming by Means of Tailored Pressure Distribution of Vaporizing Foils

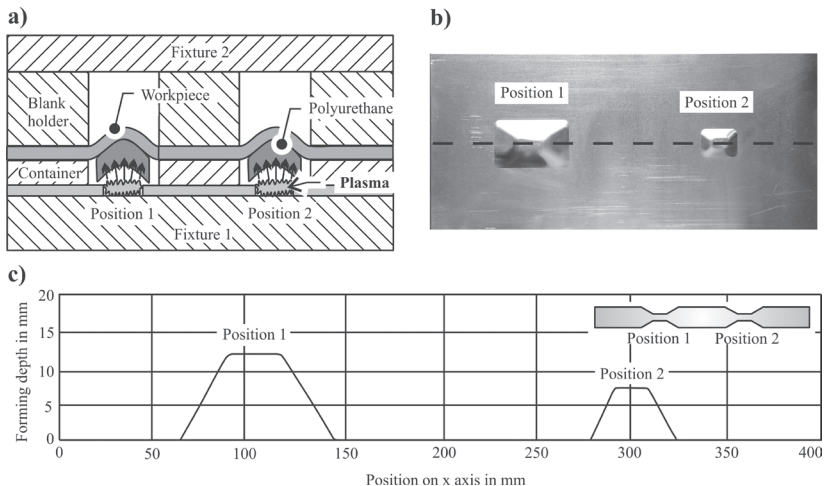
Funding German Academic Exchange Service (DAAD)
 Contact M.Sc. S. Cai

Project Description

In this process metallic foils or wires are rapidly vaporized by high pulsed electrical currents. Hence, a fast expanding plasma which generates an intensive mechanical pressure pulse is formed. The aim of the project is to realize tailored pressure distribution with respect to the desired part shape. The part accuracy can be improved due to a reduced rebound effect.

Current Results

An analytical model for the prediction of the acting pressure amplitude was developed. Additionally, a tailored pressure distribution was realized based on experimental investigations regarding general process parameters. A part with different forming depths was then successfully manufactured by the tailored pressure distribution (see figure).



Metal forming by vaporizing foils. a) Tailored pressure distribution; b) Sheet metal forming; c) Profile of formed part

3.5.6 Optimization and Texturing of Coated Tool Surfaces by Local Plastic Deformation

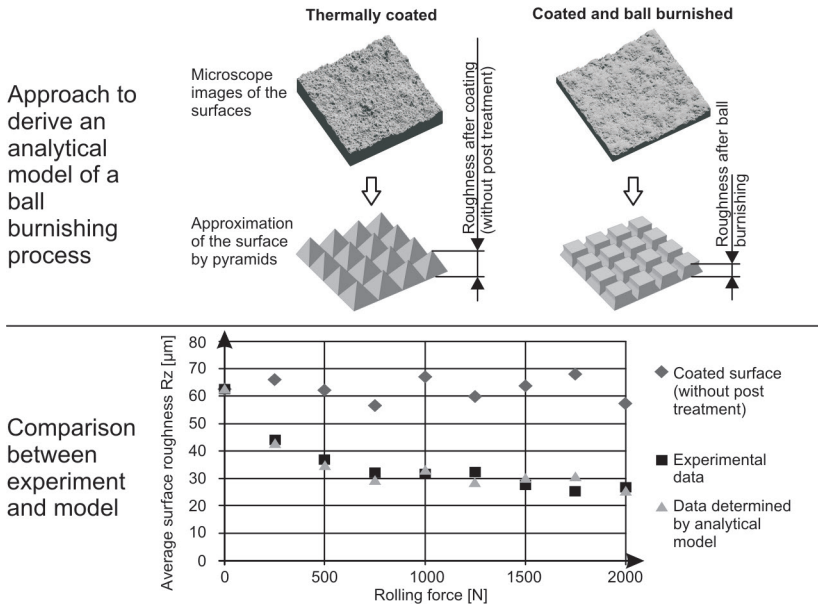
Funding German Research Foundation (DFG)
 Project SFB 708 • Subproject A3
 Contact M.Sc. L. Hiegemann

Project Description

The roughness of the surface of thermally coated deep drawing tools can be smoothed by a ball burnishing process. By this, the material flow in deep drawing can be improved and the process window can be increased.

Current Results

In order to obtain a desired surface roughness by a ball burnishing process, corresponding rolling parameters have to be set. For this purpose, an analytical model is developed that approximates the surface based on pyramids. By analysis of the deformation of one roughness peak it becomes possible to predict the roughness after rolling or the required rolling forces. Comparisons between model and experiments demonstrated a good general validity of the model.



Derivation and verification of an analytical model to determine the roughness after a ball burnishing process

3.5.7 Fundamental Research and Process Development for the Manufacturing of Load-Optimized Parts by Incremental Forming of Metal Sheets – Sheet-Bulk Metal Forming (SBMF)

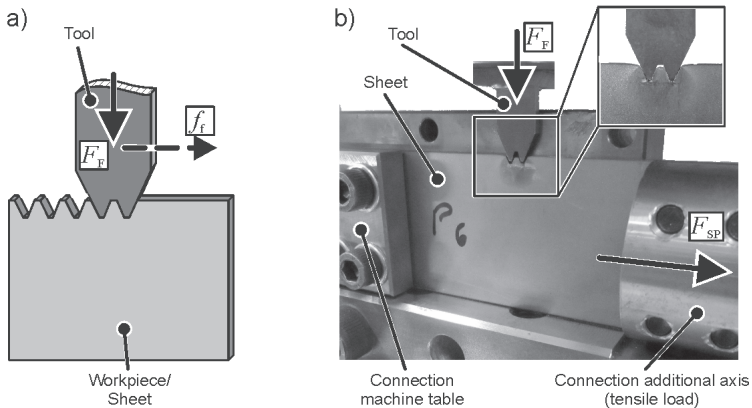
Funding German Research Foundation (DFG)
 Project SFB/TR 73 • Subproject A4
 Contact Dipl.-Ing. P. Sieczkarek

Project Description

The objective of this project is the manufacturing of geometrically complex components with integrated functional and secondary design elements only by forming operations. These parts are realized near-net-shaped and load-adapted by an incremental application of bulk forming operations to thin sheets (2 – 3 mm). A special feature is the possibility of a very flexible sequence of different localized forming operations on a novel multi-axis press.

Current Results

For the determination of the required forming forces during the edge-thickening of sheets an analytical model was developed and verified. The incremental embossing of teeth elements into sheets creates new challenges for the small forming tools. Despite the incremental procedure these tools are constantly exposed to high loads. One possibility to reduce the forming forces and, thus, the tool load is provided by the principle of a superposition of tensions. The feasibility of this approach is currently investigated and first results show a significant force reduction.



a) Incremental gearing process on the sheet edge b) Force reduction by superposition of tensions (experimental setup)

3.5.8 Development of Efficient Integral Manufacturing Processes to Form Metal-FRC Semi-Finished Sheet Products

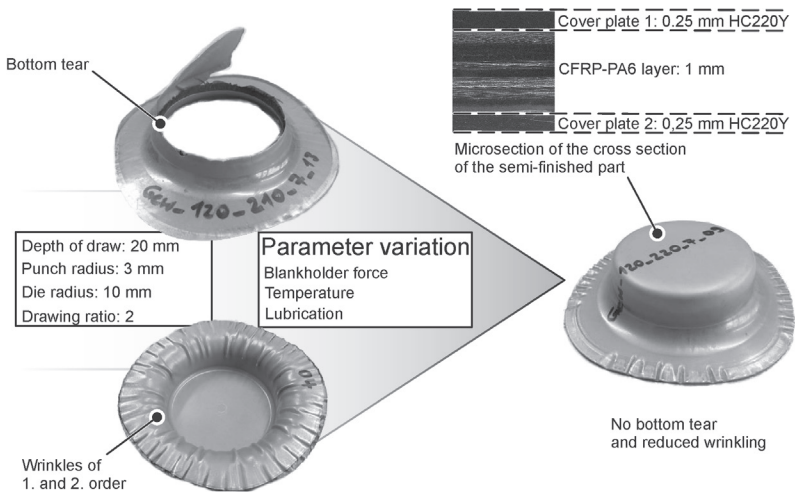
Funding BMBF/PTKA, Promotion Platform FOREL
 Project 02PJ2772 (Collaborative project LEIKA)
 Contact M.Sc. M. Hahn

Project Description

The goal of this project is to make better use of the lightweight potential of electric vehicles. For this purpose, the applicability of mass-production-suitable forming processes for sandwich semi-finished products developed by project partners should be investigated. These products consist of a carbon fiber-reinforced thermoplastic matrix (CFRP) sheet covered with metal sheets (steel alloys and Mg-alloys).

Current Results

The project focus is on forming characteristics of the semi-finished parts. When deep drawing cups, it is found that the desired flow behavior of the matrix only occurs in a very small temperature range. The wrinkle formation in the metal cover plates, which is advantaged by the matrix, can be reduced distinctly by increasing the blankholder force. For reasons of comparison with FEM simulations, a heatable tool was developed for a hydraulic sheet metal testing machine that allows optical in-situ failure detection.



Extract of test series of CFRP metal hybrid semi-finished parts deep drawn on an eccentric press

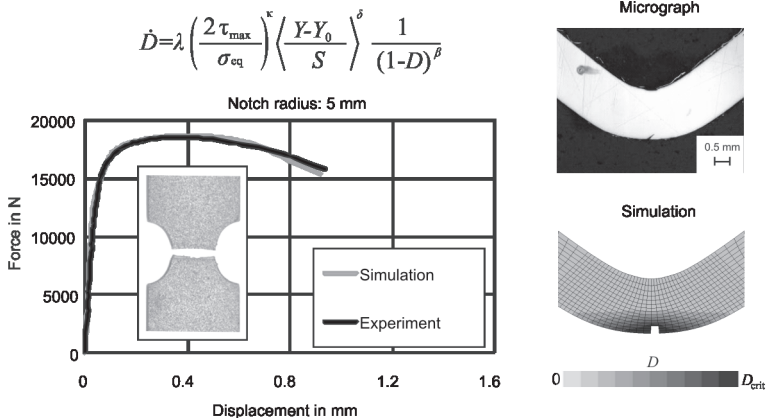
3.6 Department of Applied Mechanics in Forming Technologies

Head Dipl.-Ing. Till Clausmeyer

A new head and an additional scientist joined the department in July 2014 and October 2014, respectively. The analysis of forming processes with analytical and numerical models constitutes the main field of activity. The aim is to transfer new scientific findings from the field of mechanics to forming simulation. In the research projects material models for ductile damage and elasto-plasticity are developed and implemented into finite-element programs. Simultaneously, researchers improve methods for material characterization. Experiments for material characterization are a requirement for the successful identification of parameters for the developed models.

Currently, the blanking process of monolithic sheets and composite sheets is investigated. Moreover, damage models which consider the complex dependency of damage on the stress state are developed. These material models are applied to sheet metal forming. In a further project the influence of damage on novel sheet bulk forming processes is analyzed. The department collaborates with the bending department on the extension of forming limits in bending.

Alexander von Humboldt fellow Dr. Yanshan Lou supports the research on fracture criteria since September 2014. Within the context of other projects the department cooperated with international scientists from Japan and Portugal.



Fields of activity: modeling, characterization, process simulation

3.6.1 Development of a Software Tool for Robust Design of the Shear Cutting Process of Metal Laminated Composite Material without Lubricants

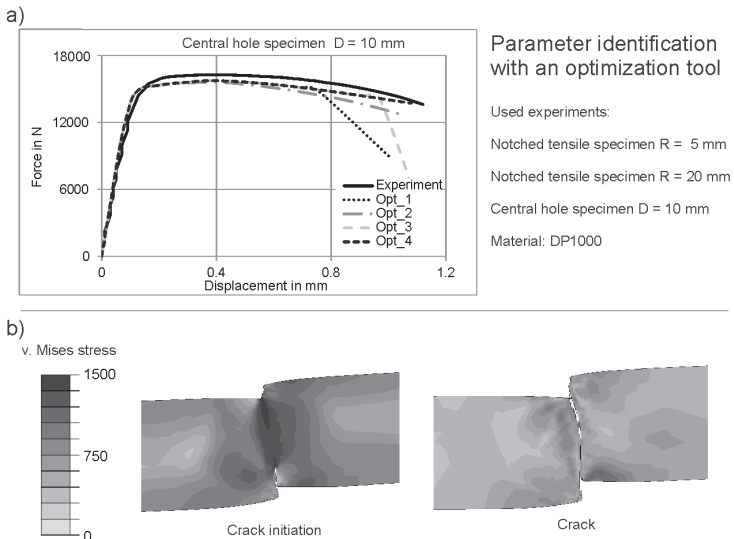
Funding German Research Foundation (DFG)
 Project TE 805/37-1
 Contact Dipl.-Ing. T. Dang

Project Description

The fracture behavior of monolithic and laminated composite materials in dry shear cutting process is investigated numerically in cooperation with the Institute of Metal Forming and Casting (utg) at TU München within the framework of a DFG/AiF Cluster. The aim of this project is the development of a simulation tool. The research in the field of simulation was supported by a related DAAD project.

Current Results

Currently, the focus is on the identification of the damage parameters and the modeling of the shear process. An optimization tool was developed to determine the material parameters. The simulation results are verified with the experimental data of notched tensile tests.



a) Optimization tool, b) Crack evolution in shear cutting process

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

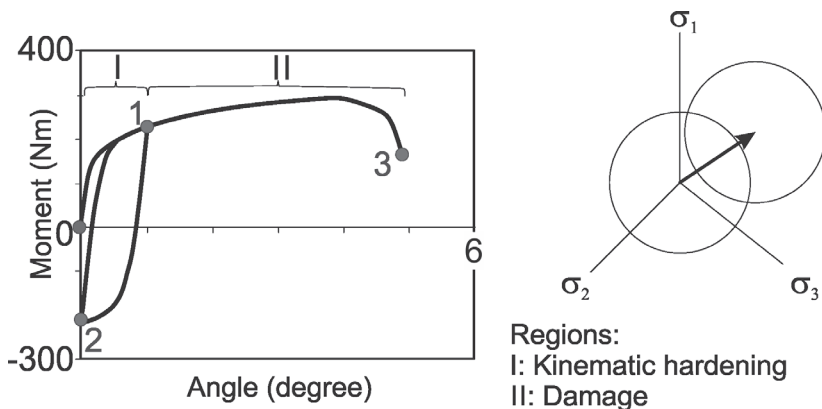
Funding German Research Foundation (DFG)
 Project SFB/TR 73 • Subproject C4
 Contact M.Sc. K. Isik

Project Description

The application of the combination of conventional sheet forming operations with bulk forming enables the realization of complex near-net- shape parts. The objective of this project is the experimental and numerical investigation of the microstructure and the corresponding damage behavior of the material for this novel type of sheet bulk metal forming processes. The project work is performed in collaboration with Institute of Materials Science of Leibniz Universität Hannover.

Current Results

In order to model complex loading cases including load reversals, which occur during sheet-bulk forming, the elasto-plastic damage material model was extended for kinematic hardening. The cyclic in-plane torsion test was applied to identify the kinematic hardening parameters. The anisotropic damage models were integrated in this material model.



Moment-angle-diagram for the identification of kinematic hardening and damage behavior

3.6.3 An Investigation of Failure Mechanisms in Forming of Monolithic and Composite Plates

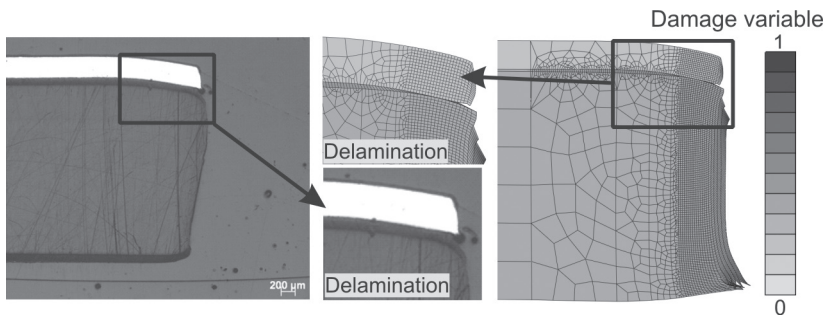
Funding German Academic Exchange Service (DAAD)
 Contact M.Sc. L. Chen

Project Description

In this DAAD-funded doctoral program the focus is on the investigation of failure mechanisms in forming of monolithic metallic and metal/polymer/metal sandwich plates. At this stage, main concentration is devoted to the investigation of the mechanical behavior of the aluminum surface layer and polymer layer. The mechanical behavior of an aluminum layer is studied with the Lemaitre damage model. The pressure-sensitive plastic behavior of the polymer layer is characterized by the Drucker-Prager model. After the successful parameter identification the material models are used in the simulation of a shear-cutting process. The research in this project was conducted in collaboration with the AiF/DFG cluster “Dry shear-cutting”.

Current Results

First results show a good agreement between the predicted cutting edge and the experimental one with regard to the rollover of the aluminum layer, the partial delamination of the interface close to the cutting edge, and the upper part of the polymer layer.



Blanked cutting edge and simulation results of the shear cutting of Al/LDPE structure

3.6.4 Enhanced Continuum Damage Mechanics Model for Low Triaxialities for the Deep Drawing Simulation of Advanced High Strength Steels

Funding FOSTA
 Project P 1039
 Contact Dipl.-Ing. T. Clausmeyer

Project Description

Continuum damage models represent a strong alternative to the classical method of forming limit curves (FLC) for the prediction of failure in deep drawing of advanced high-strength steels. The aim of this project is to extend the existing model for the description of complex fracture strain-triaxiality curves.

Current Results

The dependence of the fracture strains on the maximum shear stress was considered in an extension of the existing model. The enhanced model can account for the highly non-linear fracture strain-triaxiality curves. The process simulation of a deep drawn cup shows physically reasonable results for the location and the punch displacement at failure.

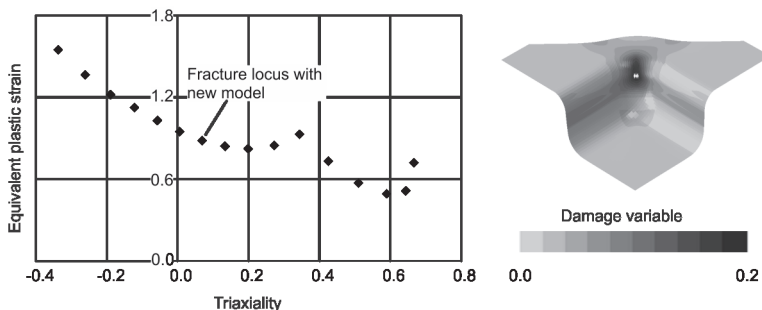
Damage evolution

$$\dot{D} = \lambda \left(\frac{2\tau_{\max}}{\sigma_{\text{eq}}} \right)^k \left(\frac{-Y - Y_0}{S} \right)^\delta \frac{1}{(1-D)^\beta}$$

Square cup

Drawing depth: 23 mm

Material: HCT600XD



Predicted fracture strain-triaxiality curve and result of forming simulation

3.6.5 Characterization of DP and HSLA Materials for Bending Applications

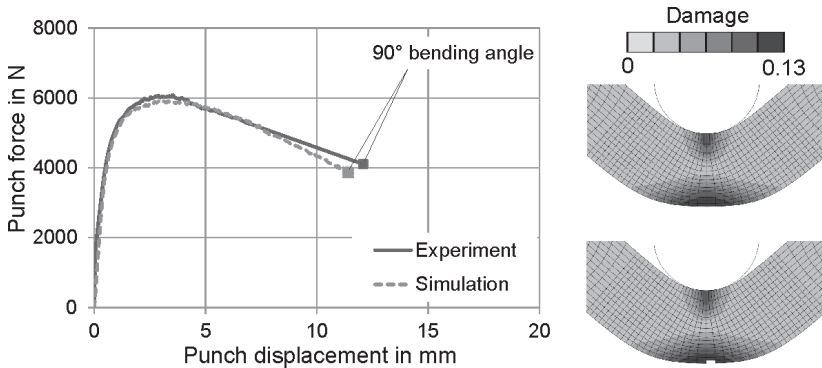
Funding ReCIMP
Contact Dipl.-Ing. T. Dang

Project Description

Within the scope of the ReCIMP and in cooperation with Bilstein GmbH the forming limits of dual phase steel and micro-alloyed steel is investigated experimentally and numerically. The objective is the prediction of damage evolution in air bending by using a damage model. Suitable materials for bending applications can be derived from the research results.

Current Results

In this subproject it has been shown that the material damage behavior of metallic material can be represented in air bending by using FE models. Extensive series of tension tests have been carried out in order to characterize the mechanical properties and parameters.



Comparison of the experimental and numerical force curves

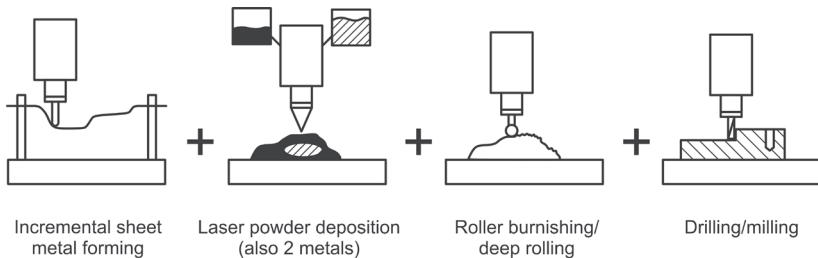
3.7 Filed Patents

Process and Apparatus for the Combined Manufacturing of Workpieces by Incremental Sheet Metal Forming and Additive Manufacturing Methods in one Setup

Application number	DE 10 2014 014 202.7
Patent applicant	TU Dortmund University
Status	Filed
Inventors	R. Hölker • N. Ben Khalifa • A. E. Tekkaya

The invention deals with a process and an apparatus that forms workpieces in one step or in one machine incrementally and is able to add extra geometrically complex form elements by laser powder deposition - simultaneously, afterwards, or even in between - without reclamping. It can also be applied to curved surfaces.

Furthermore, a surface finishing by roller burnishing and deep rolling or drilling/milling can be carried out, if needed. Thus, the rough surfaces resulting from the additive manufacturing process can be burnished. The process and the machine are based on a 5-axis machining center which can automatically pick up different tools: a forming tool for incremental sheet metal forming, a nozzle for laser powder deposition, a die for drilling/milling, and a rolling tool. With a second spindle or a second (portal-) arm the dies can also be used simultaneously.



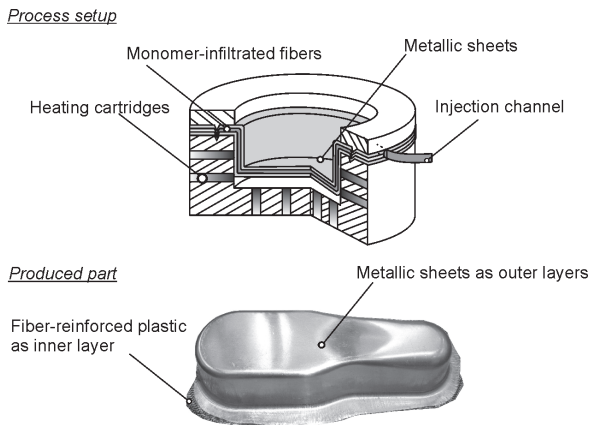
Four manufacturing methods integrated in one machine

Process for the Production of Fiber-Metal-Laminate Parts Based on Thermoplastics by Forming as well as Hereby Produced Fiber-Metal-Laminate Parts

Application number	DE 10 2014 001 132.1
Patent applicant	TU Dortmund University, Karlsruhe Institute of Technology
Status	Filed
Inventors	A. E. Tekkaya • F. Henning • N. Ben Khalifa K. A. Weidenmann • A. Güner • T. Mennecart • A. Rösner

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Production of hybrid parts

Further Activities

04

4 Further Activities

4.1 Conferences and Meetings

In 2014 diverse 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. In the following, you will find more information on selected events.

Lectures at Gifu University in Nagoya, Japan

For several years now, the Institute of Forming Technology and Lightweight Construction of TU Dortmund University has been in a constant contact with the Department of Mechanical Engineering of Gifu University in Nagoya, Japan. In the beginning of this year an official cooperation agreement has been signed by both faculties of mechanical engineering. As part of this partnership, Prof. Tekkaya held a series of lectures at Gifu University from March 1 to March 6, 2014. On March 3, 2014, Prof. Tekkaya presented the lectures “Basics of Extrusion and Composite Extrusion” and “Collaboration with Industry and Research Funding in Germany” to students, scientists, and young engineers from Japanese industry at the G-Cadet and attracted wide interest among the audience. On March 5, 2014, two more lectures entitled “Research Process” and “Scientific Publishing - An Editor’s Perspective” followed. The talks were primarily aimed at students and staff members of the entire Department of Mechanical Engineering of Gifu University and also generated great interest. At the time of the lectures Ms. Esmeray Üstünyagiz from the Master’s program MMT of TU Dortmund University was a visiting student at the Gifu University within the context of the G-Cadet program. In future, the connection to the Gifu University, currently consisting of the exchange of students, should be expanded and strengthened by joint research projects. On June 20, 2014, a return visit by Dr. Yoshida and a Japanese delegation in Dortmund took place to discuss further cooperation opportunities.

IUL/GDA Workshop “Aluminum Lightweight Network”

This year the workshops organized by the Institute of Forming Technology and Lightweight Construction (IUL) and the Gesamtverband der Aluminiumindustrie (GDA) were realized on January 30 at IUL and on November 6 at GDA. These meetings symbolize the close cooperation between the IUL, the Collaborative

Research Center Transregio 10 and the GDA and act as an interface between industrial companies and research institutions. In the workshops the next steps of establishing a lightweight network were discussed. Additionally, scientific lectures about the manufacturing of aluminum components by new developments were presented and ideas of new research projects were found in the discussions with industrial companies.

ManuLight2014

The first International Conference on Manufacture of Lightweight Components – ManuLight2014 – took place from April 3 to 4, 2014, at the „Dortmunder U“, Dortmund’s art and event center collaborating closely with TU Dortmund University. This CIRP-sponsored conference was organized by the DFG-promoted Collaborative Research Center Transregio10 (Transregio10), which aims at the integration of forming, cutting, and joining for the flexible production of lightweight structures in a process chain and in which engineers of TU Dortmund University, the Karlsruhe Institute of Technology, and Technische Universität München (TUM) are engaged. ManuLight2014 served as an event for presenting improvements of existing technologies as well as new processes, equipment, and applications. The authors who had contributed 44 presentations and the numerous participants from 11 nations and three continents used the conference for a fruitful dialog between fundamental research and industrial applications and needs. The program covered all major areas of metal lightweight construction, for example: forming, cutting and joining of high-strength and multi materials, products with graded properties, integration of functions, assembly, and joining. Simultaneously, an exhibition presenting the results of Transregio10 by numerous exhibits and posters took place on the collegiate floor of the Dortmunder U, from March 26 to April 27, 2014.



Exhibits of Transregio10 presented during the ManuLight2014 conference at the Dortmunder U

Inauguration of the New Mechanical Engineering Building MB III

On September 17, 2014, the new mechanical engineering building MB III on the University's south campus was inaugurated. After a construction period of about two years from March 2012 to April 2014 the new building was handed over to the Institute of Forming Technology and Lightweight Construction, the Institute of Machining Technology, the Department of Materials Test Engineering, the central training workshop, and parts of the central workshop. The construction costs amounted to around 18 million euros. The placement of the staff at south campus is optimal, because of the short distance to the



Inauguration of the new mechanical engineering building MB III , Photo: Roland Baege/TU Dortmund

experimental hall. On an area of about 4000 m², the new building offers superbly equipped office space, several conference rooms, seminar rooms, laboratories, and one auditorium as well as staff rooms with kitchenettes. The modern look and good quality of the building promote the international visibility of production engineering at TU Dortmund University, which currently ranks on position three in Germany in this category. During the construction period, the organizational units were housed in comfortable replacement buildings consisting of container segments, which ensured the work capacity completely by its good infrastructure. After speeches by the Rector Ursula Gather and the Professors A. Erman Tekkaya, Andreas Menzel, and Frank Walther, an opening ceremony with the participation of all employees followed.



The new mechanical engineering building MB III

5th Tube and Profile Bending Conference – DORP 2014

This year, the 5th Tube and Bending Conference - DORP 2014 - took place on October 1, giving scientists, machine manufacturers, and industrial users a platform for exchanging know-how and experiences. With a total number of about 100 participants from the Netherlands, Belgium, Austria, Switzerland, Luxembourg, Denmark, and Germany, the event was attended by an international audience. After being welcomed by Prof. Tekkaya, interesting industrial and scientific lectures were given regarding current projects and developments



Participants of the DORP 2014

in the field of tube and profile forming. The main topics were tube and profile manufacture, tube and profile bending as well as innovative tube forming methods. Besides the series of lectures, the industrial partners exhibited demonstrators, posters etc., offering additional space for further conversations and discussions before, between, and after the individual lecture sessions. These were intensified during lunch, which took place in the experimental area of the IUL. Furthermore, the machinery of the IUL has been visited by the participants. The newly constructed building Maschinenbau III of the TU Dortmund University with its inviting design served as conference venue and contributed to the big success of the entire event.

Meetings of the IUL Industrial Advisory Council

Since 2010, the Industrial Advisory Council supports the IUL in its strategic aligning of application-oriented basic research and advises the institute on the implementation of collaborative research projects and the transfer of research results into industrial applications. The council meets twice a year and gives valuable input regarding industrial technologies and research needs and, in return, receives detailed results of basic research and innovation. The first meeting took place on April 11, 2014. The topics of its discussion were methods of surface finishing, wear protective coatings for tools, and process combinations during aluminum extrusion. The second meeting followed on October 10, 2014. The presentation of the institute's objectives and the presentation of the roadmaps of the institute's departments were the basis for a constructive discussion. Both meetings were enriched by valuable presentations held by members of the industry advisory council.

Lecture by Em. Prof. Dr. Ir. Paul Van Houtte

On October 14 2014, Emeritus Professor Paul Van Houtte visited the IUL and held a lecture entitled "A hierarchical multi-scale model for metal forming bridging the grain scale with the engineering scale". Prof. Van Houtte comes from the Department of Metallurgy and Materials Engineering (MTM) of the KU Leuven in Belgium. He is known as an experienced expert in the field of deformation processing and mechanical behavior of metals. Focusing on the understanding and modeling of microstructural developments, crystallographic texture evolution, and mechanical behavior of metallic materials during and after plastic deformation, he has made an outstanding contribution to the field of metal forming. His presentation showed results of a long-term project. The original project aim was to perform FE simulations of metal forming processes while taking the anisotropy of the material, resulting



Em. Prof. Dr. Ir. Paul Van Houtte

from a crystallographic texture, into account. At the same time, excessive computational demands should be avoided. So far, results have been achieved for single-phase materials (or materials in which one of the phases dominates the plastic anisotropy). The developed measurement techniques for the orientation distribution function of the crystallographic deformation texture were described. Numerical models and analytical methods used for the prediction of the deformation texture and plastic anisotropy were also presented. Results with a focus on the validation by quantitative methods to compare the measured and predicted plastic anisotropy and deformation textures were shown.

Project Meeting „ELLI – Excellent Teaching and Learning in Engineering Education” at the IUL



Participants of the project meeting

On December 10 and 11, 2014, a project meeting for the project “ELLI – Excellent Teaching and Learning in Engineering Education” took place at the IUL. The entire ELLI teams with ?? researchers of the three project partners RWTH Aachen University, Ruhr University Bochum, and TU Dortmund University participated as well as the responsible professors Prof. Dr. rer. nat. Sabina Jeschke (Head of the Institute Cluster IMA/ZLW & IfU of RWTH Aachen University), Prof. Dr.-Ing. Marcus Petermann (Head of the Chair of Particle Tech-

nology of Ruhr University Bochum), and Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya took part in the meeting.

The first day was divided into two sessions. On the one hand, the status quo was summarized and presentations for the next day were prepared. On the other hand, ideas and concepts for the ongoing project were developed. The focus was on the networking between the project partners and the connection to other partners outside this consortium. Concepts for the connection of the different remote labs were developed. At the end of the first day, the community visited Dortmund's Christmas market. On the second day, the prepared presentations were shown to the community and were discussed extensively. Additionally, precise aims for the next steps were declared.

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

- Girls' Day • March 27
- Stahl fliegt (Flying steel) • July 2 - 3
- SchnupperUni • August 13
- Open Day of TU Dortmund • October 25

4.2 Awards

Professor A. Erman Tekkaya awarded with JSTP Prize 2014

On October 20th, 2014, A. Erman Tekkaya, Professor and Head of the Institute of Forming Technology and Lightweight Construction, was awarded the “2014 JSTP International Prize for Research & Development in Precision Forging” in the presence of 650 congress participants during the 11th International Conference on Technology of Plasticity in Nagoya, Japan. The most important international prize in metal forming is awarded every three years by the “Japan Society for Technology of Plasticity” (JSTP). In previous years, 12 international scientists received the JSTP Prize: Prof. H. Kudo (Japan), Prof. T. Altan (USA), Dr. HLD Pugh (UK), Prof. K. Kondo (Japan), Prof. K. Osakada (Japan), Prof. N. Bay (Denmark), Prof. T. Dean (UK), Prof. JL Chenot (France), and Prof. T. Nakamura (Japan). Previous recipients from Germany are: Prof. K. Lange (Stuttgart), Prof. R. Kopp (Aachen), and Prof. M. Geiger (Erlangen).

For the designation of the prize winner a selection committee consisting of international consultants is convened. The jury honored A. Erman Tekkaya for his life’s work on “Process innovation, process characterization, and international leadership” and handed over the JSTP price in the form of a gold medal, a glass certificate, and prize money.

ICTP Best Paper Award

The paper „Cold Extrusion of Hot Extruded Aluminum Chips“ by Dr. Matthias Haase and Professor A. Erman Tekkaya, which was presented at the 11th International Conference on Technology of Plasticity (ICTP), was selected by an international committee from more than 400 papers and awarded with the

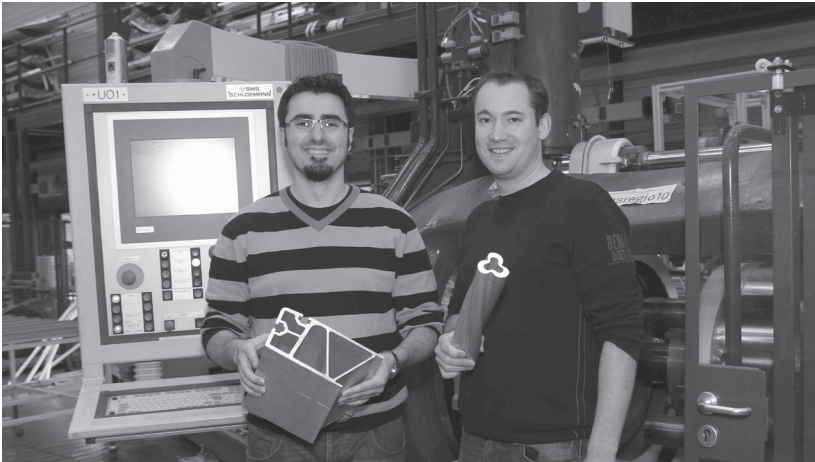


Award ceremony during the gala dinner

„Best Paper Award“. An alternative recycling route to the conventional remelting of aluminum alloy machining chips by a combination of hot extrusion with subsequent cold extrusion is presented in the paper. The ICTP is regarded as the “Olympic games of forming technology” and takes place every three years. This year, hundreds of scientists from all over the world met in Nagoya (Japan) in order to present their research results.

Incorporators team ISPT GmbH & Co. KG awarded with tu>startup AWARD

On Thursday, January 9th, the incorporators team of ISPT GmbH & Co. KG, consisting of Mr. Alessandro Selvaggio and Dr. Thomas Kloppenborg, both of them scientific employee of the Institute of Forming Technology and Lightweight Construction (IUL) at TU Dortmund University, has been awarded with the tu>startup AWARD as part of a New Year reception that took place at the Rudolf-Chaudoire-pavilion of TU Dortmund University. On the basis of their research work, they founded the ISPT, a business company acting as service provider for simulation and optimization of forming technology, especially extrusion processes.



Mr. Alessandro Selvaggio and Dr. Thomas Kloppenborg

The tu>startup AWARD is an award bestowed by the TU Dortmund University. Until November 13th 2013, students, alumni, and employees who had founded a scientific or research-based company within the last five years, were allowed to apply. After narrowing down the choice, the six most promising

companies were invited to a presentation in front of the jury, where the expert jury finalized the three winning teams. For the decision not only scientific demand, but also the potential for growth and employment as well as the quality of offering a unique selling point and social relevance were taken into account. The jury honored the incorporators team of ISPT with the 2nd prize.

Collegiate Competition „ZukunftErfindenNRW“

During the award presentation ceremony of the collegiate competition „ZukunftErfindenNRW“ („Inventing the Future NRW“) on May 22, 2014, North Rhine-Westphalian Science Minister Svenja Schulze nominated Prof. A. Erman Tekkaya, Dr. Nooman Ben Khalifa, and Alessandro Selvaggio for their invention entitled „Continuous extrusion press for aluminum profiles“, which was patented in cooperation with the company SMS Meer GmbH, in the category „Progress by transfer“ and awarded them as laureates in the category „Engineering and applied natural sciences“.

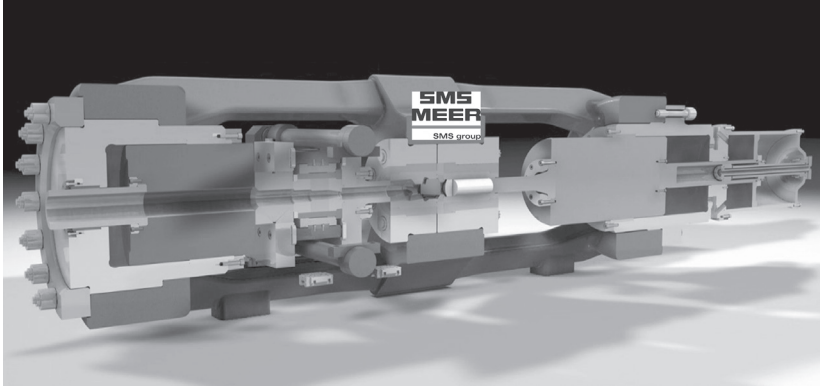
Extrusion molding is a technique well established for decades for the manufacturing of aluminum profiles and it is applied in large-scale productions as well as in small-scale series for special products. Conventional extruders



Presentation of the award certificate (from left to right: Rector Prof. Dr. Ursula Gather, Alessandro Selvaggio, Dr. Nooman Ben Khalifa, Prof. A. Erman Tekkaya, Science Minister NRW Svenja Schulze) Photo: PROvendis

experience about 20 percent construction-induced production downtime. By contrast, this new „Kontipress“ automatically reloads stored material, resulting in a continuous and efficient production method.

The award presentation of the collegiate competition „ZukunftErfindenNRW“, which is advertised annually by the patent-marketing company PROvendis and supported by the Ministry for Innovation, Science, and Research of North



Patented plant for the continuous extrusion of profiles

Rhine-Westphalia (MIWF), had been issued under the motto „Mastering challenges – motivation and safety for collegiate inventions“. All in all, 155 teams of North Rhine-Westphalian scientists applied for an award within the three categories of the contest.

DAAD Award for Outstanding Achievements by International Students



Esmeray Üstünyagız with Rector Professor Ursula Gather, Thomas Westphal, General Manager Wirtschaftsförderung Dortmund, Mayor Manfred Sauer, and Dr. Barbara Schneider, Director of the International Office at TU Dortmund University (from left) Photo: Oliver Schaper

During the 12th annual International Reception by TU Dortmund University, Mrs. Esmeray Üstünyagiz was presented with this year's DAAD Award for Outstanding Achievements by International Students. TU Dortmund University had selected Mrs. Üstünyagiz for this DAAD prize, for her outstanding academic performance and her, at the same time, remarkable social engagement. Mrs. Üstünyagiz is a student of the international master study program Manufacturing Technology (MMT) of TU Dortmund University and will graduate soon most probably top of her class.

Christian Löbbe awarded with Hans-Uhde-Prize 2014

Christian Löbbe, research assistant at the Institute of Forming Technology and Lightweight Construction, was awarded with the Hans-Uhde-Prize of the Hans-Uhde-Foundation for his excellent master thesis along with eight other laureates on March 11th, 2014. In the master thesis the thermal loads of coils for electromagnetic forming were investigated by experiments and numerical simulations. Finally, different approaches emerged from the thesis to enhance the coil lifetime.

Hans Uhde, son of the company founder of Uhde GmbH (today ThyssenKrupp Industrial Solutions AG) launched the Hans-Uhde-Foundation in 1986. Purpose of the foundation is to promote science, education, and culture. Every year, excellent study and academic achievements are awarded with a prize consisting of a gold medal, a prize money, and a certificate.



Hans-Theo Kühr (General Manager of ThyssenKrupp Industrial Solutions GmbH), Prof. Dr. Gisela Schäfer-Richter (Prorector Research and Transfer Dortmund University of Applied Sciences and Arts), Detlef Sassenberg (ThyssenKrupp Industrial Solutions GmbH), the laureates 2014, Prof. Bodo Weidlich (Chairman Gesellschaft der Freunde der TU Dortmund e. V.), and Rector Prof. Dr. Ursula Gather (from left) Photo: ThyssenKrupp Industrial Solutions AG, Process Technologies, Dortmund

Dr. Matthias Haase awarded with the Dissertation Award of TU Dortmund University

The rectorate of TU Dortmund University awards the authors of excellent dissertations with the Dissertation Award of TU Dortmund University. This year, Dr. Matthias Haase, head of the Department of Bulk Metal Forming, received this award in the Faculty of Mechanical Engineering for his dissertation „Mechanical Properties Improvement in Chip Extrusion with Integrated Equal Channel Angular Pressing“. The award ceremony was part of the University's annual celebration, which was organized by the rectorate and “Gesellschaft der Freunde der TU Dortmund“.



The Prorector Research Prof. Dr.-Ing. Dirk Biermann awarded Dr. Matthias Haase (2nd from right) with the Dissertation Award of TU Dortmund University. Photo: Oliver Schaper

4.3 Participation in National and International Organizations: Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya

Memberships of Research Boards

- acatech – Member of the “German Academy of Science and Engineering” (“Deutsche Akademie der Technikwissenschaften”); acatech ambassador at TU Dortmund
- AGU – Member of “Wissenschaftliche Arbeitsgemeinschaft Umformtechnik“
- CIRP - Fellow of the “The International Academy for Production Engineering”
- Curatorship member of “Karl-Kolle Stiftung“, Dortmund, Germany
- DGM – Member of “Deutsche Gesellschaft für Materialkunde“
- ESAFORM – Member of the Scientific Committee of the “European Association for Material Forming”
- GCFG – Member of the “German Cold Forging Group”
- Honorary member of the “TechNet Alliance”
- ICFG – Member of the “International Cold Forging Group“
- ICTP – Member of the Standing Advisory Board of the “International Conference on Technology of Plasticity” (until October 2014), currently Advisor
- I²FG – Member of the “International Impulse Forming Group”
- JSTP – Member of “The Japan Society for Technology of Plasticity”
- Member of “DGM Regionalforum Rhein-Ruhr“
- Member of the “German Academic Society for Production Engineering” (WGP: „Wissenschaftliche Gesellschaft für Produktionstechnik“)
- Member of the Scientific Advisory Board of “Exzellenzcluster Integrative Produktionstechnik für Hochlohnländer“, RWTH Aachen University, Germany
- Vice president of the consortium of “Deutsch-Türkische Universität” (German-Turkish University)

Journals/Editorship

- Editor-in-Chief, “Journal of Materials Processing Technology” (Elsevier)
- Member of the Editorial Board, “CIRP Journal of Manufacturing Science and Technology“(Elsevier)

- Member of the International Advisory Committee, “International Journal of Material Forming” (Springer)
- Member of the International Advisory Committee, “Romanian Journal of Technical Sciences - Applied Mechanics”
- Member of the International Editorial Board, Journal “Computer Methods in Materials Science”
- Member of the Scientific Editorial Board, “International Journal of Precision Engineering and Manufacturing” (Springer)

Further Memberships

- DAAD Scholar Committee, Ankara, Turkey
- IUTAM – “Turkish Branch of the International Union of Theoretical and Applied Mechanics”, Turkey
- Member of the Advisory board and of the International Program Committee, “The 16th International Conference on machine design and production” (UMTIK 2014), Ankara, Turkey
- Member of Scientific Committee, “International Conference on high speed forming” (ICHSF 2014), Daejeon, Korea
- Member of Scientific Committee, “4th International Conference on steels in cars and trucks” (SCT 2014), Braunschweig, Deutschland
- Member of the Scientific Committee, “21st International Forging Congress” (IFC 2014), Berlin, Germany
- Member of the Scientific Committee, “The 9th International Conference on Industrial Tools and Material Processing Technologies” (ICIT & MPT 2014), Ljubljana, Slovenia
- Member of the Scientific Committee, “The 9th International Conference and Workshop on Numerical Simulation of 3D Sheet Metal Forming Processes” (NUMISHEET 2014), Melbourne, Australia
- Member of the Scientific Committee, “The 15th International Conference on metalforming” (Metalforming 2014), Palermo, Italy
- Member of the Scientific Committee, “The 16th International Conference on Sheet Metal” (SheMet 2015), Erlangen, Deutschland
- Turkish-German Cultural Association, Ankara, Turkey

Activities as Reviewer

In Scientific Committees

- acatech – Deutsche Akademie der Technikwissenschaften
- AiF – Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V. (AiF)
- Alexander von Humboldt Foundation
- CIRP - International Academy for Production Engineering
- DFG – German Research Foundation, Member of Fachkollegium 401 (Review Board on Production Engineering)
- École polytechnique fédérale de Lausanne, Switzerland
- Evaluation Committee of Mechanical Engineering, TU Eindhoven und TU Twente, The Netherlands
- External Advisory Committee, Department of Mechanical Engineering, KAIST, Korea
- Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany
- Koc University, Istanbul, Turkey
- The Research Council of Norway
- University of Michigan, USA

For Journals

- ASME - Journal of Manufacturing Science and Engineering
- International Journal of Solids and Structures, Elsevier
- Journal of Materials Processing Technology
- Journal of Mechanical Engineering, Strojniski vestnik
- Journal of Production Engineering, Research and Development, Springer
- Manufacturing Letters, Elsevier
- Procedia Engineering, ICTP 2014 – International Conference on Technology of Plasticity
- The International Journal of Advanced Manufacturing Technology, Springer

4.4 Participation in National and International Organizations: Prof. Dr.-Ing. Dr. h.c. Matthias Kleiner

Scientific Academies

- Academia Europaea
- acatech – Council of technical Sciences of the German Academy of Science and Engineering
- Berlin-Brandenburg Academy of Science and Humanity
- CIRP – The International Academy for Production Engineering
- German Academy of Natural Scientists Leopoldina
- European Academy of Sciences and Arts
- Indian National Science Academy
- Russian Academy of Engineering
- Swiss Academy of Engineering Sciences

Advisory Boards

- Global Learning Council
- Scientific Council of the European Research Council (ERC)
- STS Council – Science and Technology in Society Forum, Japan
- Member of the Supervisory Board „Haus der Zukunft e. V.“
- Advisory Committee Japan Science and technology Agency (JST) Tokyo
- Program Advisory Board, Research Funding Program LOEWE, Federal Stat of Hesse
- Board of Trustees, Max Planck-Institute of Molecular Cell Biology and Genetics, Dresden

University Advisory Boards

- Member of the University Council, Johann Wolfgang Goethe-University, Frankfurt
- Member of the University Council, TU Dresden
- Member of the University Council, Bremen University
- Board of Trustees, TU Berlin

Foundation Advisory Boards

- Board of Trustees, Deutsche Telekom Foundation
- Board of Trustees, Daimler und Benz Foundation
- Scientific Advisory Board, Fritz Thyssen Foundation
- Scientific Advisory Board of the Excellence Initiative Johanna Quandt – Charité Foundation
- Advisory Board, Werner Siemens-Stiftung

Professional Chairs

- AGU – Working Group on Forming Technology
- WGP – German Academic Society for Production Engineering
- Board of Trustees, FOSTA Research Association for Steel Application

Consultant and Advisory Board

- Tang Prize International Advisory Board, Taipei
- „Zwanzig20 – Partnerschaft für Innovation“, Funding Program of the Federal Ministry of Education and Research (BMBF), Chairman of the Jury/Expert Group
- Chairman of the Jury of MINternational, Stifterverband für die Deutsche Wissenschaft e. V.
- Member of the Jury of the Holtzbrinck Publishing Group for the “Deutscher Innovationspreis”
- Member of the Jury of the Georg von Holtzbrinck Prize for Science Journalism
- Board of Trustees of the “Zukunftspreis” of the Federal President

Cooperation Advisory Boards

- Advisory Board, ALHO Holding
- Advisory Board, Siepmann Werke
- Advisory Board, Winkelmann Group

Senat Memberships

- MPG – Max-Planck-Gesellschaft
- HGF – Helmholtz-Gemeinschaft
- DFG – Deutsche Forschungsgemeinschaft (Guest)

International Exchange

05

5 International Exchange

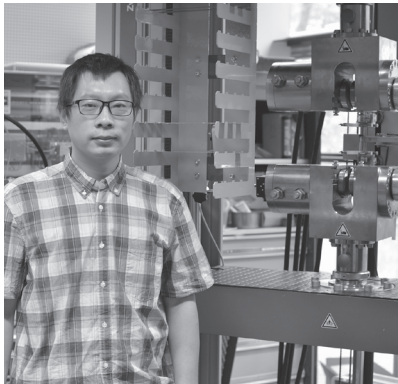
Prof. Wojciech Z. Misiolek

Professor Wojciech Z. Misiolek of the Institute for Metal Forming (IMF) at the Lehigh University (PA, USA) supported the IUL as a Mercator visiting professor, funded by the German Research Foundation, with his knowledge in the area of microstructure development of aluminum and magnesium alloys. From May 19 to August 19, 2014, he collaborated with different colleagues of the bulk metal forming group. The intense collaboration will be extended in the summer of next year, with the aim of publishing new research results at international conferences and in international research journals.



Prof. Wojciech Z. Misiolek

Alexander von Humboldt Scholar Dr. Yanshan Lou



Dr. Yanshan Lou

Dr. Yanshan Lou will collaborate with the department of applied mechanics in forming technologies from September 2014 until August 2015 during his stay at the IUL. He is an expert in the field of fracture mechanics. He developed novel fracture criteria for metals in his dissertation at the Korean Advanced Institute of Science and Technology and later during his time as post-doc with Prof. Jeong Whan Yoon at the Swinburne University of Technology, Australia. These fracture criteria were successfully used to compute forming limit curves (FLC). In further research, he investigated the correlation between the evolution of the microstructure at the fracture surface and the stress state, in particular for shear-dominated stress states. He will collaborate with project TR73 C4 and the DAAD project on shear cutting. He is accompanied by his wife and two daughters during his stay.

Dr. Beatriz Silva

Dr. Beatriz Silva, Assistant Professor of Manufacturing from the Instituto Superior Técnico (IST), Lisbon, Portugal visited the IUL for two short stays (September 10-14 and December 10-20). The collaboration was funded and organized within the context of the Collaborative Research Center Transregio 73 funded by the German Research Foundation, DFG. She conducted experiments concerning the fracture behavior of metals under mode I and mode II loading. The results of the collaborative work with Kerim Isik contribute to the studies of the fracture modes during sheet-bulk forming processes in subproject C4 of the Transregio 73.



Dr. Beatriz Silva

Teresa Citrea

Ms. Teresa Citrea, PhD student at the University of Calabria (Italy), visited the IUL during a research stay from October 2013 until July 2014. In this period she was involved in the investigation of the composite hot extrusion process, which was conducted in subprojects A2 and B1 of the SFB TR10. A major focus of her work was the numerical process simulation. In particular, computations for the design of composite extrusion dies for asymmetric profile cross sections were carried out and modeling approaches for the simulations of processes with high reinforcing volumes were developed. In order to validate the simulation results, experiments using the 10 MN extrusion press were conducted in the IUL laboratory. Results gained during her research stay were published internationally.



Besuch des Bergbau-Museums in Bochum



G-CADET International Exchange Program (Gifu University, Japan) – Ryoma Adachi

A cooperation agreement to further the studies of students and faculty through exchange programs between Gifu University, Japan, and Technische Universität Dortmund opened the opportunity to exchange excellent master students of the Faculty of Engineering (Gifu University) and the Faculty of Mechanical Engineering (Technische Universität Dortmund). Within this scope, Mr. Ryoma Adachi of Gifu University was selected for a research stay at the IUL from 15 October to 30 November 2014. In the department of Applied Mechanics in Forming Technologies and supervised by the department head Mr. Till Clausmeyer, he conducted plane torsion tests for advanced high strength steels. He used the experimental results to identify material parameters for a kinematic hardening model.

RISE (Research Internships in Science and Engineering) – Kevin Chan

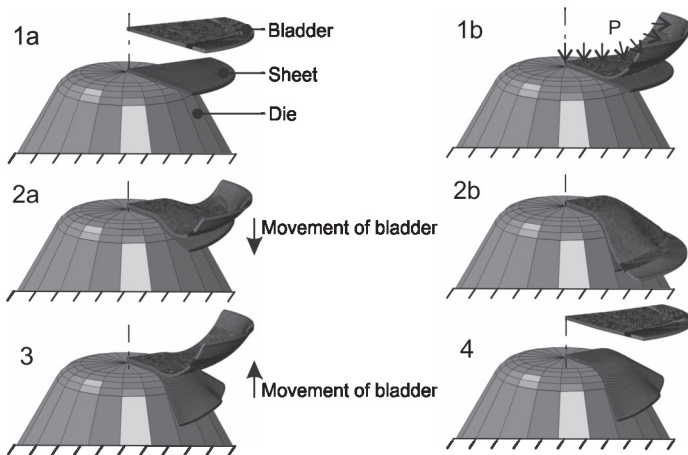
From May until August 2014, Kevin Chan from Cornell University, Ithaca, New York (USA), was at the IUL within the framework of the RISE program of the German Academic Exchange Service (DAAD). The program gives Bachelor students from North America and the UK the opportunity to do internships at German research institutions. The stay of Mr. Chan was financed by a grant collectively funded by the DAAD and the DFG Collaborative Research Center Transregio 10. Under the supervision of Mr. Lueg-Althoff and Mr. Weddeling, Mr. Chan was engaged in experimental investigations regarding adhesive bonding of tubes and profiles. Among other things, he developed a device for the testing of the weld seam quality of joints made by magnetic pulse welding.

In 2014, we welcomed the following international students at the IUL:

- Kevin Larkin, Princeton University, Reach Internship
- John Webster, Tufts University, International Summer Program 2014

International Master Thesis in Cambridge

In winter term 2013/14 the Institute of Forming Technology and Lightweight Construction (IUL) cooperated with the English Department of Engineering at the University of Cambridge. Supervised by Professor Julian Allwood and Professor Tekkaya, Ms. Sigrid Hess, research assistant at the IUL division for sheet metal forming, worked on her master thesis „Modelling Bladder Forming with FEM” in Cambridge. Focus was on the numerical investigation of a new hydroforming process for forming rotationally symmetric sheets into hollow parts. A stiff bladder was assumed as forming tool which was filled and pressurized by a fluid. The bladder was moved upon the sheet lying on a die so that the sheet was formed into its desired shape.



Process procedure of bladderforming

Technical Equipment

06

6 Technical Equipment

6.1 Experimental Area

Presses

- Hydraulic drawing press, 2600 kN, triple action, SMG HZPUI 260/160-1000/1000
- Extrusion press 2,5 MN, Collin, PLA250t
- 10 MN (direct) extrusion press, suitable for curved profile extrusion, SMS Meer
- C-frame-eccentric press, 630 kN, Schuler PDR 63/250
- Hydraulic drawing press, 1000 kN, HYDRAP HPSZK 100-1000/650
- Hydraulic drawing press, 10 MN triple action, M+W BZE 1000-30.1.1
- Press for working media based sheet metal forming, 100 MN, SPS
- Blanking- and forming press with servo drive, 4000 kN, Schuler MSD2-400

Further Forming Machines

- Swivel bending machine, FASTI 2095
- Press brake, 110 kN, HERA COP 110/3100
- Press brake, 1300 kN, TrumaBend V 1300X
- 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
- 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, 6 kJ, Poynting SMU 0612 FS
- Machine for electromagnetic forming, 32 kJ, Maxwell Magneform 7000

- Multi-axes forming press TR 73, 100 kN, prototype with five axes of motion (Schnupp Hydraulik)
- Hydraulic punching machine TruPunch 5000, 220 kN, RUMPF Werkzeugmaschinen GmbH & Co. KG
- Machine for Incremental Tube Forming, IRU2590, transfluid Maschinenbau GmbH
- Machine for Incremental Profile Forming
- DMU 50 – 5-Axis-millingmaschine, DMG Mori Seiki Academy GMBH

Material Testing Machines

- Bulge-testing machine, 200 kN, Erichsen 142/20
- four Universal testing machines, Zwick 1475 100 kN, Zwick SMZ250/SN5A, Zwick FR250SN.A4K, Allround Line, Zwick Z250
- Sheet metal testing machine Zwick BUP1000
- Plastometer, IUL 1 MN

Measurement Technique and Electronics

- Laser based Photon-Doppler Velocimeter for the measurement of high workpiece velocities
- Optical frequency domain reflectometer ODiSI-B10 from Luna Technologies. System for the space- and time-resolved measurement of temperature and strain
- Large volume SEM, Mira XI by Visitec (in cooperation with the “Institut für Spanende Fertigung” and “Lehrstuhl für Werkstofftechnologie, TU Dortmund University)
- 3D-coordinate measurement machine, Zeiss PRISMO VAST 5 HTG (in cooperation with the “Institut für Spanende Fertigung”, TU Dortmund University)
- 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, 3 x Aramis – optical measuring systems for geometry and strains
- High-speed camera, HSFC pro of the company PCO Computer Optics GmbH
- Light optical microscope Axiomager.M1m adapted for polarization, Zeiss AG
- Laser Surface Velocimeter (LSV): non-contact velocity measurement
- Multi-wavelength pyrometer, Williamson pro 100 series
- Keyence Laser: non-contact distance measurement
- X-ray diffractometer for measuring residual stresses – StressTech Xstress 3000
- Pontos 4M, GOM, dynamic 3D analysis, resolution 2358 x 1728 pixel
- ARAMIS 4M, GOM, optical 3D-deforming analysis
- Infrared Camera, Infratec VarioCam HD head 680 S / 30 mm, Resolution 1280 x 960 Pixel

Miscellaneous

- Laser processing center, Trumpf LASERCELL TLC 1005
- Plastic injection molding machine, Arburg Allrounder 270 C 400-100
- Roll seam welding machine, Elektro-Schweißtechnik Dresden UN 63 pn
- Turning machine, Weiler Condor VS2
- different machines for machining purposes
- 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
- Industrial robot KUKA-KR 5 sixx R650, 6-axes robot
- Industrial robot KUKA KR 30-3
- Three hydraulic power units and pressure intensifiers up to 4000 bar
- Hydrostatic roller burnishing tool, Ecoroll, HG13 and HG6
- Measuring rack, Boxdorf HP-4-2082

6.2 Hardware and Software Equipment

General Equipment

- different Servers and approx. 220 networked workstation PCs with an extensive periphery
- Linux Cluster with 4 nodes with altogether 12 processing units
- diverse Microsoft Software (Windows 7/8 Professional, Office 2010 Professional etc.)
- diverse graphics software (such as Adobe-products like Photoshop, Acrobat, InDesign, Illustrator and Corel Designer X4)
- diverse High-End simulation PCs for CAD and FEM simulations

CAD

- Unigraphics
- Catia
- AutoCad
- Mechanical Desktop

Mathematical Calculation Programs

- Maple
- Mathcad
- Matlab

FEM

- Pam Stamp
- Autoform
- Hyperworks/HyperXtrude
- Deform
- Simufact
- MSC MARC
- ANsys
- Abaqus
- LS-Dyna

Kooperationen | Cooperations

07

Kooperationen | Cooperations

Auf diesem Wege möchten wir uns für die vielfältige Zusammenarbeit im Jahr 2014 bedanken, ohne die unser gemeinsamer Erfolg nicht möglich wäre.

At this point we would like to express our gratitude to the large number of various cooperation partners in 2014 which have added to our joint success.

Universitäre Kooperationen auf nationaler Ebene | University cooperations at national level

- Fachgebiet Maschinenelemente, Technische Universität Dortmund
- Fachgebiet Werkstoffprüfung, Technische Universität Dortmund
- FH Südwestfalen
- Institut für Mechanik, Technische Universität Dortmund
- Institut für Spanende Fertigung, Technische Universität Dortmund
- Lehrstuhl für mathematische Statistik und naturwissenschaftliche Anwendungen, Technische Universität Dortmund
- Lehrstuhl für Werkstofftechnologie, Technische Universität Dortmund
- Lehrstuhl für Wissenschaftliches Rechnen, Technische Universität Dortmund
- Zentrum für Hochschulbildung, zhb, Technische Universität Dortmund

- Fachbereich Produktionstechnik, Universität Bremen
- fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen, RWTH Aachen
- Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg
- Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS, Dresden
- Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, IWU, Technische Universität Chemnitz
- Fraunhofer-Projektgruppe im Dortmunder Oberflächen-Centrum (DOC) der TKSE AG, Dortmund
- Gemeinschaftslabor für Elektronenmikroskopie, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Angewandte Mechanik, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Bildsame Formgebung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Fertigungstechnik und Werkzeugmaschinen, Leibniz Universität Hannover
- Institut für Formgebende Fertigungstechnik, Technische Universität Dresden
- Institut für Kunststoffverarbeitung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Leichtbau und Kunststofftechnik, Technische Universität Dresden
- Institut für Massivbau, Technische Universität Dresden

- Institut für Metallformung, Technische Universität Bergakademie Freiberg
- Institut für Metallurgie, Abteilung Werkstoffumformung, Technische Universität Clausthal-Zellerfeld
- Institut für Produktionstechnik und Logistik, Universität Kassel
- Institut für Produktionstechnik und Umformmaschinen, Technische Universität Darmstadt
- Institut für Umformtechnik und Umformmaschinen, Leibniz Universität Hannover
- Institut für Werkstoffkunde I, Karlsruher Institut für Technologie (KIT)
- Institut für Werkstoffkunde, Leibniz Universität Hannover
- Institut für Werkzeugmaschinen und Betriebswissenschaftlichen, Technische Universität München
- Labor für Fahrwerktechnik, Hochschule Osnabrück
- Laboratorium für Werkstoff- und Füge-technik, Universität Paderborn
- Lehrstuhl für Fertigungstechnologie, Friedrich-Alexander-Universität Erlangen-Nürnberg
- Lehrstuhl für Konstruktion und Fertigung, Brandenburgische Technische Universität Cottbus
- Lehrstuhl für Leichtbau, Technische Universität München
- Lehrstuhl für Umformende und Spanende Fertigungstechnik, Universität Paderborn
- Lehrstuhl für Umformtechnik und Gießereiwesen, Technische Universität München

- Lehrstuhl für Umformtechnik, Universität Siegen
- Lehrstuhl für Umformtechnik, Universität Stuttgart
- Lehrstuhl für Werkstoffkunde, Universität Paderborn
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- Professur Theoretische Elektrotechnik und Numerische Feldberechnung, Helmut-Schmidt-Universität, Universität der Bundeswehr Hamburg
- Professur Virtuelle Fertigungstechnik, Technische Universität Chemnitz
- wbk Institut für Produktionstechnik, Karlsruher Institut für Technologie (KIT)
- Werkzeugmaschinenlabor, Rheinisch-Westfälische Technische Hochschule Aachen

Universitäre Kooperationen auf internationaler Ebene | University cooperations at international level

- Abdelmalek Essaâdi University (UAE), Martil, Morocco
- Charles Delaunay Institute, Laboratoire des Systèmes Mécaniques d'ingénierie Simultanée (LASMIS), Université de Technologie de Troyes, France
- Department of Mechanical and Systems Engineering, Gifu University, Yanagido, Japan
- Department of Materials Science and Engineering, The Ohio State University, Ohio, USA
- Department of Mechanical Engineering, Instituto Superior Técnico, University of Lisbon, Portugal

- Department of Mechanical Engineering, Università della Calabria, Rende (CS), Italy
- DIEM-Tech Manufacturing Technology Group, Università di Bologna, Italy
- Ecole nationale Supérieure d'Arts et Métiers (ENSAM), ParisTech, Paris, France
- Forming Laboratory, Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia
- Institute for Manufacturing, Department of Engineering, University of Cambridge, Great Britain
- Laboratory of Physics and Mechanics of Materials, Arts et Métiers ParisTech (Metz Campus), France
- Loewy Chair in Materials Forming and Processing, Institute for Metal Forming, Lehigh University, Bethlehem, Pennsylvania, USA
- Nagoya University, Nagoya, Japan
- Universitatea Babeş-Bolyai, Cluj-Napoca, Romania
- Université Hassan II Mohammedia (UH2M), Casablanca, Morocco
- University of Badji Mokhtar Annaba (UBMA), Annaba, Algeria
- University of Monastir, National Engineering School of Monastir (ENIM), Monastir, Tunisia
- University of Sciences and Technology Houari Boumediene (USTHB), Algiers, Algeria
- University of Sousse, National School of Engineers (ENISo), Sousse, Tunisia

Nationale und internationale Kooperationen im industriellen Umfeld | Industrial cooperations at national and international level

- Aleris Aluminum Duffel BVBA
- alutec Metallwaren GmbH & Co. KG
- ASCAMM Technology Centre
- ASERM – Asociación Española de Rapid Manufacturing
- AUDI AG
- Auerhammer Metallwerk GmbH
- Autoform Engineering GmbH
- Becker Apparatebau
- Benteler AG
- Bilstein GmbH & Co. KG
- BMW AG
- borit Leichtbau-Technik GmbH
- Böhler-Uddeholm Deutschland GmbH
- Carl Bechem GmbH
- Constellium CRV (Centre de Recherches de Voreppe)
- CRF – Centro Ricerche Fiat S.C.p.A.
- Daimler AG
- Data M Sheet Metal Solutions GmbH
- Deutsche Edelstahlwerke GmbH
- DYNAMORE GmbH

- EADS Deutschland GmbH
- ESI GmbH
- F.W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Faurecia Group
- Forschungsvereinigung Stahlanwendung e. V.
- Franz Pauli GmbH & Co. KG
- FRIMO Group GmbH Composites & Tooling Technologies
- Grundfos GmbH
- GSU-Schulungsgesellschaft für Stanz- und Umform-
technik mbH
- HELLA KGaA Hueck & Co.
- Hirschvogel Umformtechnik GmbH
- Hüttinger Elektronik GmbH & Co. KG
- Hydro Aluminium Deutschland GmbH
- inpro Innovationsgesellschaft für fortgeschrittene Produk-
tionssysteme in der Fahrzeugindustrie mbH
- Inspire AG - IRPD
- JRC-ITU Institute for Transuranium Elements, Karlsruhe
- JFE Steel Corporation, Japan
- Johnson Controls Hilchenbach GmbH
- Josef Fröhling GmbH & Co. KG
- Kirchhoff Automotive GmbH
- Kistler-IGeL GmbH
- Koda Stanz- und Biegetechnik GmbH
- KraussMaffei Group GmbH
- Kunststoff-Institut Lüdenscheid GmbH
- LG Corporation
- LEIBER Group GmbH & Co. KG
- MatFEM
- MUBEA Unternehmensgruppe
- Otto Fuchs KG
- Poynting GmbH
- Premium AEROTEC GmbH
- Rehau AG + Co
- 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
- Simufact Engineering GmbH
- SimuForm GmbH
- SMS Meer GmbH
- Société Tunisienne des filtres (MISFAT), Jedeida, Tunisia
- Sparkasse Dortmund
- SSAB Swedish Steel GmbH
- SSAB Tuniplåt AB, Schweden
- Tata Steel (former Corus Technology BV)

- Tata Steel Strip Products UK
- TECOS – Slovenian Tool and Die Development Centre
- ThyssenKrupp Nirosta GmbH
- ThyssenKrupp Steel Europe AG
- ThyssenKrupp VDM GmbH
- TRACTO-TECHNIK GmbH & Co. KG Spezialmaschinen
- Transfluid Maschinenbau GmbH
- TRUMPF Werkzeugmaschinen GmbH + Co. KG
- Viessmann Werke GmbH & Co. KG
- voestalpine AG
- VOLKSWAGEN AG
- Vorrichtungsbau Giggel GmbH
- Vossloh AG
- Welser Profile GmbH
- Westfalia Presstechnik GmbH & Co. KG
- Wilke Werkzeugbau GmbH & Co. KG
- WILO SE
- Zentrum für BrennstoffzellenTechnik GmbH

Industriebeirat des IUL | IUL Industrial Advisory Board

- Adolf Edler von Graeve, KIST Kompetenz- und Innovationszentrum für die Stanztechnologie Dortmund e. V.
- Marius Fedler, Kunststoff-Institut für die mittelständische Wirtschaft NRW GmbH

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- Jörg Ihne, Otto Fuchs KG
- Franz Jurt, Feintool Technologie AG
- Dr. Stefan Keller, Hydro Aluminium Rolled Products GmbH
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- Dr. Joachim Schondelmaier, Schondelmaier GmbH
- Prof. Karl Schweizerhof, DYNAmore GmbH
- Dr. Hosen Sulaiman, Faurecia Autositze GmbH
- Sabine Widdermann, German Cold Forging Group (GCFG)
- Dr. Hans-Joachim Wieland, Stahlinstitut VDEh

Verbände | Associations

- acatech – Deutsche Akademie der Technikwissenschaften
- AGU – Arbeitsgemeinschaft Umformtechnik

- AiF – Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V.
- ASM International
- CAE – Chinese Academy of Engineering
- CIRP – The International Academy for Production Engineering
- DAAD – Deutscher Akademischer Austauschdienst
- DFG – Deutsche Forschungsgemeinschaft
- DGM – Deutsche Gesellschaft für Materialkunde e. V.
- EFB – Europäische Forschungsgesellschaft für Blechverarbeitung e. V.
- FOSTA – Forschungsvereinigung Stahlanwendung e. V.
- GCFG – German Cold Forging Group
- GDA – Gesamtverband der Aluminiumindustrie e. V.
- I²FG – International Impulse Forming Group e. V.
- IBU – Industrieverband Blechumformung
- ICFG – International Cold Forging Group
- IDDRG – International Deep Drawing Research Group
- IMU – Industrieverband Massivumformung
- ITA – International Tube Association
- JSTP – The Japan Society for Technology of Plasticity
- KIST – Kompetenz- und Innovationszentrum für die Stanztechnologie e. V.
- Stahlinstitut VDEh
- VDI – Verein Deutscher Ingenieure e. V.

- WGP – Wissenschaftliche Gesellschaft für Produktionstechnik

Stiftungen | Foundations

- Caspar Ludwig Opländer Stiftung
- Karl-Kolle-Stiftung
- VolkswagenStiftung
- Werner Richard – Dr. Carl Dörken Stiftung

Ausgewählte Veröffentlichungen und Vorträge |
Selected Publications and Lectures

08

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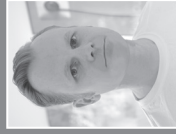
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