Institute of
Forming Technology and
Lightweight Construction

Activity Report 12

technische universität
dortmund

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Lightweight Construction

Activity Report

12

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dortmund

Imprint

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Preface

The significance of manufacturing technology to the wealth of a nation has presumably never been brought out so clearly by a politician as was done by US President Obama in the United States in 2012. The rebuild of the American manufacturing industry was one of the three major promises made by the American President during his election campaign. He actually followed up his promise with action by allocating a special budget of 1 billion US dollars for manufacturing technology to the American research institutions in 2012. We know from our American friends that the, in the United States, so called "German research model" is very often referred to as a model by American politicians in their current efforts to foster manufacturing technology. This year we have also observed that the North American Manufacturing Research Conference (NAMRC) has managed to link up with its high period in the 1980ies through a multitude of contributions from young American researchers on manufacturing technology topics. We think that this American U-turn should be assessed very carefully in Europe, especially in those countries in which the service industry has more and more eliminated the traditional industry.

A very pleasant development for the Institute of Forming Technology and Lightweight Construction (IUL) in 2012 was the foundation of the "Research Center for Industrial Metal Processing (ReCIMP)" in the frame of a joint research project with the global concern Faurecia. Faurecia has identified the IUL as a leading research institute in the field of metal processing and, via ReCIMP, aims to foster research and development in the field of manufacturing technology for the production of automotive metal components.

An important step in the research activities was the onsite review for continuation of the Transregional Collaborative Research Center "SFB TR 73" in Dortmund in 2012. Together with the SFB TR73 spokeswoman Professor Marion Merklein – whom we heartily congratulated at the end of the year on being awarded the prestigious Leibniz Prize – and our partners from Erlangen and Hannover, we are very pleased about this successful review and the ensuing appropriation of the second phase.

In 2012 the IUL could expand its field for experimentation considerably through the acquisition of several experimental machines and facilities. The incremental tube bending machine (Co. Transfluid), which was produced from an IUL-owned patent, the specially designed incremental thick metal sheet forming machine (Co. Schnupp), the punching machine (Co. Trumpf) for the first electromagnetic punching, the 4,000 kN servo press (Co. Schuler) with a complete periphery for sheet metal processing from the coil, the automated test cell for material characterization (Co. Zwick and Co. Kuka) with a tensile testing machine, a sheet metal testing machine, a fully automated sample magazine (IUL) and a robotic gripper for telemetric experimentation will serve as the basis for several research projects in the years to come.

The number of staff members remained constant in 2012 – nine new employers joined the IUL and nine left us. Assistant Professor (Juniorprofessor) Alexander Brosius accepted the W3 professorship (chair) "Institute of Forming and Cutting Manufacturing Technology" at TU Dresden where he will continue his impressive career as a member of the forming community and esteemed colleague. We wish him great success and all the best in this new endeavor. Furthermore, with six completed doctoral theses (among these the first in industry) and 25 diploma, master´s and bachelor´s theses as well as seminar papers, we look back at a very successful academic year.

Two international conferences were organized by the IUL in 2012. The established International Conference on High Speed Forming provided a platform for leading researchers from all over the world to discuss the latest developments in the field of impulse forming. The French German Summer School on hardening and damage of materials was held for the first time and attended by numerous young European PhD students. It was an exceptional event due to the excellent lectures given by renowned researchers.

The second batch of students of the international master study program MMT (Master of Science in Manufacturing Technology) began their studies in October 2012. We were overwhelmed by the huge number of applications. More than 300 students from all over the world applied for 25 MMT university places. The MMT students of the first batch have already deeply integrated themselves into the everyday research work of the chairs and institutes and already now make important contributions to the research activities of the Faculty of Mechanical Engineering.

Also the year 2012 was coined by numerous international guests at the IUL. Renowned scientists supported us by giving lectures and several junior scientist and PhD students from the US, Japan, China, Brazil, Slovenia and Italy, who were on longterm visits at the IUL, gave important impulses to our research activities. We cordially thank our guests and international partners for this fruitful cooperation.

The success of the Institute of Forming Technology and Lightweight Construction would not have been possible without the committed engagement of all staff members and without the contributions of research supporting institutions, industrial companies and the international research community as well as of all university colleagues entertaining cooperations with us. Many thanks!

Matthias Kleiner

A. Erman Tekkaya

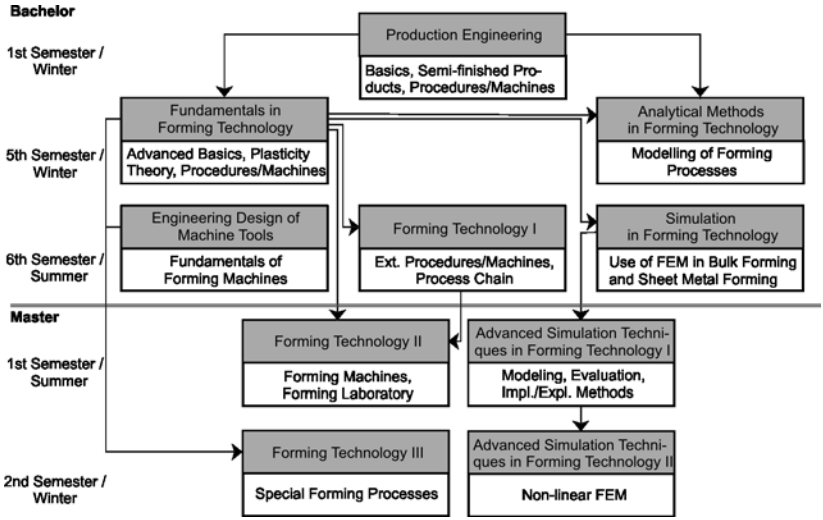
Education

01

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.



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

Further courses at the institute are:

- MMT I – Forming Technology – Bulk Forming
- MMT II – Forming Technology – Sheet Metal Forming
- MMT III – Advanced Simulation Techniques in Metal Forming
- Industrial Lecture Course: Industrial Field Reports
- Theme Laboratory A for Students of Mechanical Engineering
- Theme Laboratory B for Students of Industrial Engineering
- Seminars
- Tutorials
- Visits to industrial companies

Further information under www.iul.eu/lehre (also linked with 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 Dipl.-Fachübers. A. Hallen

Japan, China, India, Turkey, Iran, Pakistan, Columbia, Mexico – the currently 38 MMT students are from very different home countries but are in perfect agreement when it comes to their high motivation and enthusiasm about studying at TU Dortmund University. And they are not alone. „I so much enjoy working with these students!“, says program senior coordinator Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya, who gives the lectures in forming technology.
The MMT is a two-year English-language master study program in the field of manufacturing technology and is designed for committed and highly motivated students and graduates from renowned German and foreign universities. Its main emphasis is on international students.
The program was launched in the winter semester 2011/12 with 13 master students. In the winter semester 2012/13, the second batch of then 25 MMT students started their studies at TU Dortmund University.

Welcome of the second batch of MMT students in the experimental hall of the IUL in October 2012

Program structure

	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.	

Evaluation procedures conducted on a regular basis ensure continuous improvement of education. The list of elective modules is consistently reviewed and expanded to offer students an optimal range of research and practice relevant subjects.

Prof. A. E. Tekkaya and MMT students in the experimental hall of the IUL

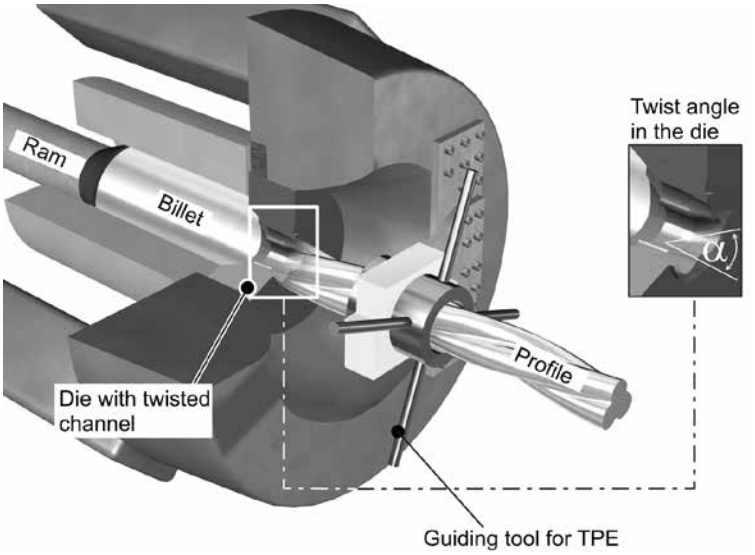
We will see the first MMT graduates in fall of next year. As a result of growing globalization, they will be specialists in high demand in an intercultural environment. The interest for this study program on the part of the industry remains correspondingly high. Renowned industrial companies offer MMT students the opportunity to do their master´s thesis with them. In addition to that, this year as well, selected MMT students are supported by scholarships from industrial partners of TU Dortmund University.

Further information can be found on the internet at www.mmt.mb.tu-dortmund.de and through the following QR code:

1.3 Doctoral Theses

Ben Khalifa, Noomane	Extrusion of Helical Profiles
Original title	Strangpressen schraubenförmiger Profile am Beispiel von Schraubenrotoren
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2012
Oral exam	March 5, 2012
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr.-Ing. H. Palkowski

The aim of this work was to develop and analyze alternative forming processes for the manufacture of profiles with helical shapes. The processes selected and investigated in this work are tube hydroforming, twisting, and extrusion. The focus of the work was on the development and investigation of two new extrusion processes, twisted profile extrusion (TPE), in which the material flow is deflected by an external guiding tool, and helical profile extrusion (HPE), in which a special die with a helical-shaped channel is used. The experimental equipment was developed and the influencing parameters on the twist angle as well as the process limits were detected.

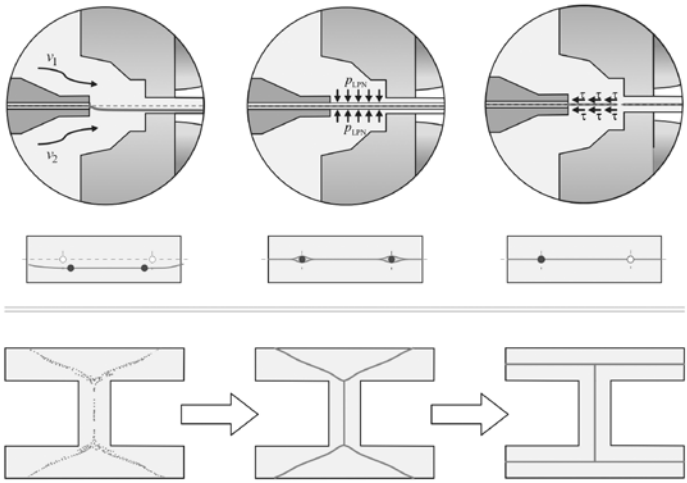


Process combination of twisted and helical profile extrusion

Kloppenborg, Thomas	Methods for the Analysis and Optimization of Composite Extrusion
Original title	Analyse- und Optimierungsmethoden für das Verbundstrangpressen
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2012
Oral exam	July 24, 2011
Advisor	Prof. Dr.-Ing. A. Brosius
Co-examiner	Prof. Dr.-Ing. habil. Dipl.-Math. B. Awiszus Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

The composite extrusion process is a production process that enables the increase of stiffness of aluminum profiles for the same profile cross section due to embedding high strength steel wires. In this research work general valid methods for the analysis and the reliable design of extrusion dies for composite extrusion processes are given. The methods are based on numerical calculations by simulations with finite element analyses. In the focus of the developments were methods for the following three quality criteria as well as the integration of them in an automatic optimization algorithm:

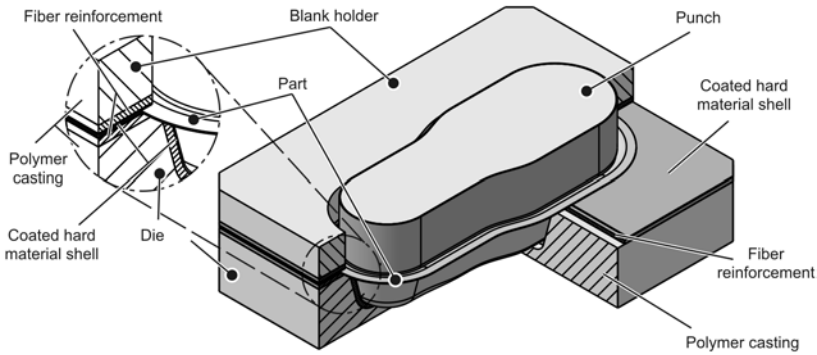
- position of the reinforcing elements
- embedding quality of the reinforcing elements
- reliability during the feeding of the reinforcing elements



Methods for the Analysis and Optimization of Composite Extrusion

Kolbe, Jörg	Thermally Sprayed, Fiber-Reinforced Polymer Tools for Forming High-Strength Sheet Materials
Original title	Thermisch beschichtete, faserverstärkte Polymerwerkzeuge für die Umformung höherfester Blechwerkstoffe
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2012
Oral exam	August 13, 2012
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr.-Ing. W. Volk

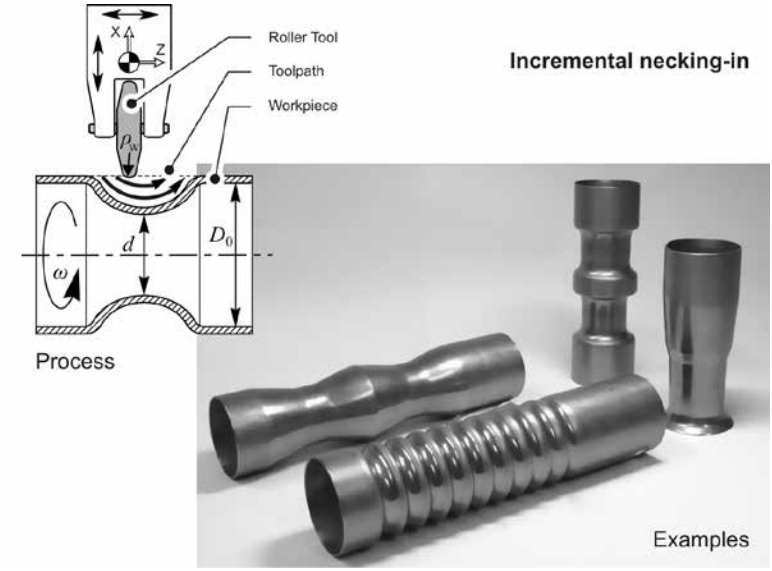
Topic of this thesis is the investigation of thermally sprayed deep drawing tools made of polymers for forming high strength steels, which are used in small to medium batch size productions. The tools are realized as hybrid structure. A body material made of polymer is wrapped with a thermally sprayed coating, which is a protection against wear. An indirect coating process is developed in order to manufacture these coatings. The coatings are adequate for a direct use in forming processes without mechanical finishing. With these coatings the wear resistance of the tools is increased significantly compared to common polymer deep drawing tools. The deep drawing tool is adequate to form mild as well as high strength steels.



Design of the developed deep drawing tool

Kwiatkowski, Lukas	Necking-In of Thin-Walled Tubes by Dieless Spinning
Original title	Engen dünnwandiger Rohre mittels dornlosen Drückens
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2012
Oral exam	August 13, 2012
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr.-Ing. W. Homberg

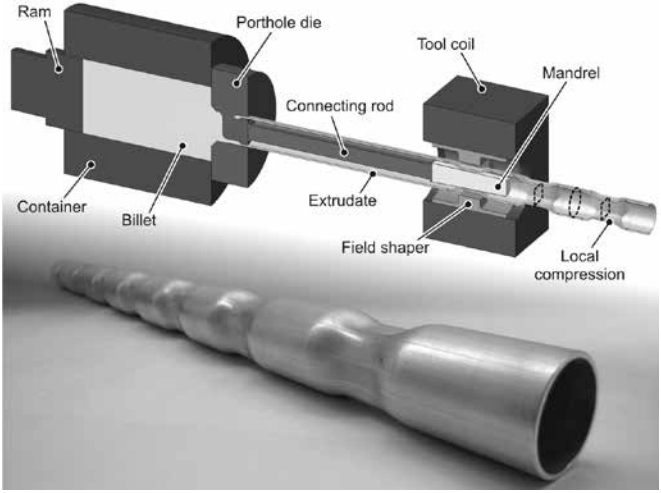
As this spinning operation is done without any mandrel, tubular parts with nearly arbitrary contours can be manufactured. However, many process parameters have to be considered. Therefore, the work focused on the identification and explanation of cause-and-effect principles of this flexible forming process. Process and part properties were analyzed by experiments and by numerical simulations. As a result, the effects of the tools and process parameters, the tool path, and different materials on several target values were presented using analytical and phenomenological models. Consequently, the results can be used as a basis to design and to optimize this process. This was finally presented by three specific case studies.



Incremental necking-in – a process to reduce tube diameter flexibly

Jäger, Andreas	Hot Extrusion of Aluminum Profiles with Process-Integrated Metal Forming Processing
Original title	Strangpressen von Aluminiumprofilen mit prozessintegrierter umformtechnischer Weiterverarbeitung
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen
Oral exam	November 5, 2012
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr.-Ing. G. Hirt

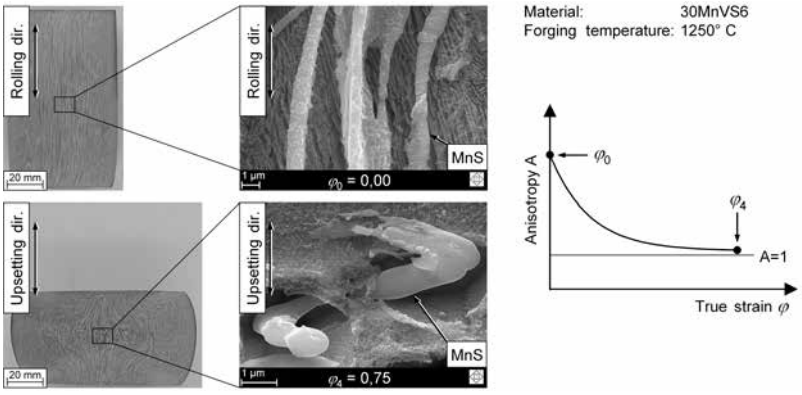
The work deals with subsequent hot forming operations integrated into the process chain of hot aluminum extrusion for the manufacturing of profiles having a non-constant cross section over the profiles' length.
For the processing of hollow profiles, the process combination of hot extrusion and electromagnetic compression was developed and analyzed. To increase the geometric complexity of locally compressed areas, tools were developed which allow the manufacturing of cross sections differing substantially from the original extruded ones.
For the processing of open sections a corrugating process, performed as a rolling process, was developed and combined with hot extrusion. The process was applied in the processing of I-beam-shaped profiles for the production of lightweight beams with a corrugated shaped web.



Hot extrusion and electromagnetic compression

Schuster, Andreas	Characterization of the Fiber Flow in Forged Steels and its Influence on Mechanical Properties
Original title	Charakterisierung des Faserverlaufs in umgeformten Stählen und dessen Auswirkungen auf mechanische Eigenschaften
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen
Oral exam	November 12, 2012
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr. rer. nat. S. Schmauder Prof. Dr.-Ing. habil. F. Walther

The fiber flow in steel plays an important role. It is experimentally shown that elongated manganese sulphides are responsible for this typical structure. A modification of the MnS geometry and the reorientation of the manganese sulphides during upsetting in rolling direction at room temperature and at 1250°C is observed. The change of the mechanical properties of the steel, e.g. notch impact energy, is also examined. Raising the true strain leads to a significant decrease of the hot rolled steel's anisotropy, especially at 1250°C due to the shape change of the MnS. The determination of the flow curves of MnS in steel allows the simulation and prediction of the MnS shape change during hot upsetting in rolling direction. A satisfying accordance between simulation and observation is observed. The examination of the stress ratios around curved MnS in steel during an appropriate load shows a potential detrimental effect of flattened MnS on the steel's strength. Some examples of components illustrate this effect additionally.



Change of the fiber flow and stretched MnS in hot rolled steel to a sidled geometry in the core area after hot upsetting in rolling direction and the associated decrease of the notch impact anisotropy in this area with raising true strain

1.4 Completed Master's Theses

Azamar, Eviel Castro
Supervisor: Tekkaya, A. E. • Demir, O. K.
Inverse material characterization at high strain rates using drop-weight tensile testing

Backs, Dominik
Supervisor: Tekkaya, A. E. • Pietzka, D. • Hoch, E. (Brökelmann)
Soldan, K. (Brökelmann)
Original title: Ermittlung und Bewertung der Einflussgrößen bei der Herstellung von Aluminium-Strangpressprofilen für Karosseriebauteile
Determination and evaluation of the influencing factors for the manufacture of extruded aluminum profiles for car body parts

Geese, Jan
Supervisor: Kobelev, V. (Mubea) • Tekkaya, A. E. • Mennecart, T.
Original title: Einfluss des Warmstrahlens auf Spannungszustand und Lebensdauer von Tellerfedern
Influence of hot shot peening on the residual stress and lifetime of disk springs

Torres Navas, Rodrigo Ernesto
Supervisor: Zillekens, N. • Tekkaya, A. E. • Chatti, S. • Becker, Ch.
Material tracking system of a copper plant

1.5 Completed Diploma Theses

Gütschow, Ulf
Supervisor: Tekkaya, A. E. • Pietzka, D.
Original title: Numerische und experimentelle Untersuchungen zur Fertigung von asymmetrischen Verbundstrangprofilen
Numerical and experimental investigations for the manufacture of asymmetrical composite extruded profiles

Jörden, Nils
Supervisor: Klein, K. (Audi AG) • Tekkaya, A. E. • Chatti, S.
Original title: Untersuchung der Einflussgrößen beim Kragenziehen und der Direktverschraubung in Blechdurchzüge in der Automobilendmontage
Investigation of the influencing factors in flange forming and the direct screw coupling in sheet metals in automotive final assembly

Kzzo, Abdullah
Supervisor: Tekkaya, A. E. • Pietzka, D. • Foydl, A.
Ben Tahar, M. (Constellium)
Experimental and numerical analysis of the process limits for hot extrusion of thin-walled hollow profiles

Langhans, Catiuscia
Supervisor: Tekkaya, A. E. • Hermes, M. • Becker, C.
Original title: Betrachtung innovativer Werkzeugkonzepte für das „Inkrementelle Rohrumformen"
Innovative tool concepts for „Incremental Tube Forming"

Mahendrarajah, Srikanthan
Supervisor: Tekkaya, A. E. • Steinbach, F.
Original title: Prozesskettenplanung und Wirtschaftlichkeitsbetrachtung bei der Fertigung von Solarabsorbern
Process chain planning and economic feasibility of the manufacturing of solar absorbers

Sadiki, Abdelhakim
Supervisor: Müller, H. • Tekkaya, A. E. • Selvaggio, A.
Original title: Bahndatengenerierung für das mehrachsige Runden beim Strangpressen mit variablen Querschnitten
Path data generation for the extrusion of multi-axis curved profiles with variable cross sections

Yuan, Xun
Supervisor: Tekkaya, A. E. • Jäger, A.
Original title: Weiterentwicklung der integrierten elektromagnetischen Umformung beim Aluminium-Strangpressen
Further development of electromagnetic forming applied subsequent to hot extrusion

1.6 Completed Bachelor Theses

Bayraktar, Ahmet
Supervisor: Tekkaya, A. E. • Becker, C. • Isik, K.
Original title: FEM-basierte Modellierung und Simulation des inkrementellen Rohrumformens zur Untersuchung der Umformzonen und der Rückfederung
FE modeling and simulation of incremental tube forming process for the investigation of the deformation zones and springback behavior

Btibet-Majorek, Zakaria
Supervisor: Abel, H.-J. (FH Dortmund) • Steinbach, F.
Original title: Konstruktion eines Werkzeuges und einer Vorrichtung zur Aufnahme der FLC nach ISO 12004 für eine Umformpresse
Design of a tool and a device to determine the FLC according ISO 12004 for a forming press

Dagdeviren, Tayfun
Supervisor: Tekkaya, A. E. • Schwane, M. • Tezsoy, C. (Schmiedag)
Original title: Experimentelle Untersuchung und Ermittlung von Prozessparametern im Gesenkschmiedeprozess zur Anwendung und Optimierung von Umformsimulationen
Experimental investigation and determination of process parameters in die forging for application and optimization of forming simulations

Dahnke, Christoph
Supervisor: Tekkaya, A. E. • Pietzka, D.
Original title: Experimentelle Untersuchungen zur Variation der Elementgeometrie beim Verbundstrangpressen
Experimental investigations for the variation of the element geometry for composite extrusion

Eickelkamp, Tim
Supervisor: Tekkaya, A. E. • Pleul, C.
Original title: Entwicklung einer integrierten Steuerungseinheit für den automatisierten Spannprozess eines teleoperativen Zugversuchs
Development of an integrated control unit for the automated clamping process as part of a tele-operated tensile test

Gerke, Stephanie
Supervisor: Tekkaya, A. E. • Pietzka, D.
Original title: Simulation und experimentelle Untersuchung des Verbundstrangpressens mit hohem Verstärkungsanteil
Simulation and experimental analysis of the composite extrusion process involving a high reinforcing volume

Hosseini, Mohamad Schamseddin
Supervisor: Tekkaya, A. E. • Demir, O. K.
Prediction of wrinkle formation during free electromagnetic tube compression

Jäger, Daniel
Supervisor: Brosius, A. • Chatti, S. • Weddeling, C.
Original title: Experimentelle Untersuchung zum formschlüssigen Fügen mittels Innenhochdruck
Experimental study on joining by hydroforming of form-fit connections

Mrosek, Matthias
Supervisor: Tekkaya, A. E. • Selvaggio, A.
Original title: Experimentelle Arbeit zur Fertigung von Profilen mit variablen Wandstärken
Experimental investigations for the extrusion of profiles with variable wall thicknesses

Napierala, Oliver
Supervisor: Tekkaya, A. E. • Hänisch, S.
Original title: Herstellung und Analyse von Verbundbauteilen durch das neuartige Tiefzieh-Späne-Verbundfließpressen
Manufacturing and analysis of hybrid components by the innovative combined deep drawing and cold forging with chips

Özkan, Ferat
Supervisor: Elkenkamp, D. (Rothe Erde) • Osen; W. (Schuler SMG)
Tekkaya, A. E. • Chatti, S.
Original title: Untersuchung des Kraftbedarfs beim Warmstauchen von Rundblöcken zur Vorformgebung bei der Ringproduktion
Investigation of the force requirement during hot upsetting of round blocks for preforming in ring production

Pinar, Turan
Supervisor: Tekkaya, A. E. • Mennecart, T.
Original title: Materialcharakterisierung von Tailor Welded Blanks aus hochfesten Mehrphasenstählen
Material chraracterisation of Tailor Welded Blanks made of high strength multiphase steels

Schyma, Frank
Supervisor: Stolp, W. (FH Südwestfalen) • Staupendahl, D.
Original title: Konstruktion einer Drehmoment-Messvorrichtung für das Tordieren von asymmetrischen Profilen während des TSS-Profilbiege-prozesses
Design of a torque measurement device for the twisting of asymmetric profiles during the TSS bending process

1.7 Completed Student Theses

Bielinski, Dennis
Supervisor: Manger, T. (ZF Sachs) • Chatti, S. • Kwiatkowski, L.
Original title: Vergleich und Bewertung von externen Ventilen für Verstelldämpfer in Kraftfahrzeugen hinsichtlich ausgewählter Konzeptparameter
Assesment of external values for vehicle dampers regarding selected concept parameters

Cakar, Sedat
Supervisor: Tekkaya, A. E. • Yin, Q.
Original title: FEM-unterstützte Versagensanalyse durch die Parametervariation beim Tiefziehen
Formability analysis of of a deep drawing part by variation of parameters using the finite element method

Hosseini, Mohamad
Supervisor: Tekkaya, A. E. • Güzel, A.
Original title: Experimentelle Bestimmung und Charakterisierung der Mikrostrukturänderung von Aluminiumlegierungen bei hohen Temperaturen und hohen Dehnraten
Experimental determination and characterization of microstructural evolution of aluminum alloys at high temperatures and high strain rates

Kersting, Jan
Supervisor: Tekkaya, A. E. • Staupendahl, D.
Original title: Entwicklung eines Prozesssimulationsmodells für das TSS-Biegen
Development of a process simulation tool for the TSS bending process

Nguyen, Minh Khac
Supervisor: Richter, H. • Rösen, H. (ThyssenKrupp Steel Europe)
Soyarslan, C. • Isik, K.
Original title: FEM-basierte Analyse und Abgleich von experimentellen Prüfdaten zum Erstellen von Bruchkurven für hochfeste Werkstoffsorten
FE analysis of experimental investigations to identify the fracture locus of advanced high-strength steels.

Savrin, Önder
Supervisor: Tekkaya, A. E. • Steinbach, F.
Original title: Konstruktion eines HBU-Werkezuges zur Umformung von partiell plattierten Blechen am Beispiel des FracTherm® Solarabsorbers
Design of a high pressure sheet metal forming tool for forming of partial roll bonded blanks using the example of the FracTherm® solar absorber

1.8 Completed Project Theses

Bhat, Prabhatranjan • Broujerdi, Pooria • Morales, Alberto • Nagendra, Vikram • Ponnambalam, Vinod • Rodríguez, César
Supervisor: Tekkaya, A. E. • Pleul, C.
Development and simulation of a work cell for a tele-operative experiment using an industrial robot

Frauenhoffer, Sigrun • Hetheier, Tobias • Kahlke, Michel
Supervisor: Tekkaya, A. E. • Pietzka, D.
Original title: Machbarkeitsstudie zur Einbettung von Funktionselementen beim Verbundstrangpressen
Feasibility study for the embedding of functional elements during composite extrusion

Glasmacher, Ron
Supervisor: Tekkaya, A. E. • Pleul, C.
Original title: Erstellung einer Adroid-App als Clientsoftware für die tele-operative Materialcharakterisierung
Development of a client software for tele-operative material testing

Goebels, Dario • Linnepe, Lasse
Supervisor: Tekkaya, A. E. • Alkas Yonan, S.
Original title: Parameterstudie zur inkrementellen Kaltumformung von thermoplastischen Polymeren
Parameter study for incremental cold forming of thermoplastic polymers

Höper, Pascal • Napierala, Oliver • Otto, Michael
Supervisor: Tekkaya, A. E. • Becker, C. • Staupendahl, D.
Original title: Entwicklung eines Konzeps zur Entscheidungsfindung und Markteinordnung von Biegemaschinen durch Nutzwertanalyse am Beispiel der innovativen Biegeverfahren des inkrementellen Rohrumformens (IRU) und des Torque Superposed Spatial- (TSS-) Biegens
Development of a concept for decision-making and market placement of bending machines by utility analysis examplarily using the innovative bending processes incremental tube forming (ITF) and torque superposed spatial (TSS) bending

Langhorst, Jens • Seif, Eugen • Spieß Sergej
Supervisor: Tekkaya, A. E. • Pleul, C.
Original title: Wirtschaftlichkeitsbetrachtung des ingenieurwissenschaftlichen Fachlabors
Estimation of the operating efficiency of an engineering lab course

Research for Education

02

2 Research for Education

Knowing that excellent education is based on excellent research and excellent research 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 the sustainable improvement of engineering education by active research in this field.

The main focus of attention inside the field of engineering education research is the scientific based investigation on learning within the engineering laboratories, which should lead to its enhancement and continuous development.

Within 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. Starting with that 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 are in particular:

- TeachING-LearnING.EU
- ELLI - Excellent teaching and learning in engineering education
- IngLab - The laboratory in engineering education
- ProLab@Ing - Laboratories in Engineering Education with Problem- and Project-Based Learning (PBL) in Forming Technology
- KoM@ING – Modeling and development of competences according to mathematics and its substitution in engineering studies
- PBLL@EE – Problem-based Laboratory Learning in Engineering Education
- Full Automation of Telemetric Compression Test Procedure
- Integrated and research-oriented laboratory
- MasTech – Flexible modular master programme in technology
- miniLABS

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 University
- 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. By combining the scientific potential of all three locations and through an interdisciplinary cooperation of general university didactics and engineering sciences, the universities see the chance to rethink and reorganize engineering sciences education and training and to give important new impetus to the formation of engineering scientific programs across Europe by a close cooperation and interaction with international partners. Further information under www.teaching-learning.eu.

In 2012 the following activities were conducted, among others:

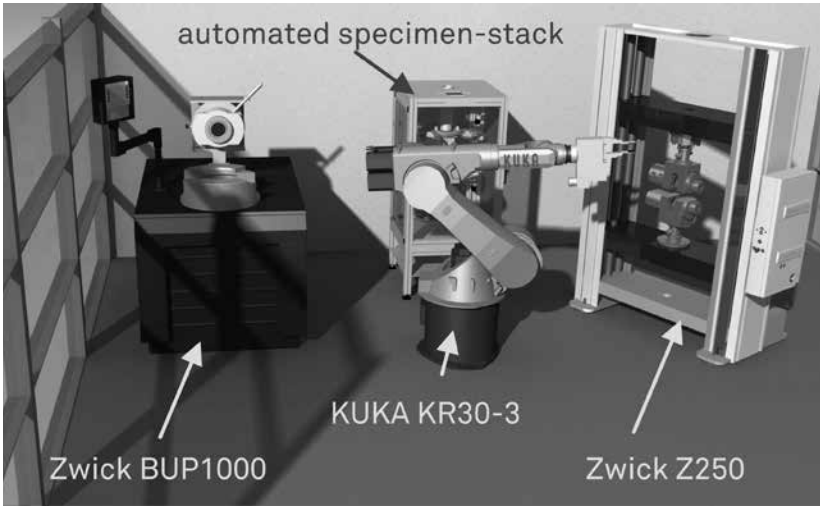
- At the meeting on the 23rd of March, members of the Community of Practice met with teachers at the Ruhr-Universität Bochum.
- In April, at the Ruhr-Universität Bochum, on top of the LehrLounge-Shortcuts, a conference of the same name took place.
- On the 19th of June the second annual meeting of TeachING-LearnING.EU was held at the Ruhr-Universität Bochum with about 100 participants.
- From 26th to 28th of September TeachING-LearnING.EU was presented in Mainz on the 41st dghd annual conference "Forschung im Fokus – Hochschullehre und Studium".
- On the 1st of October the participants of the ten Flexible Fonds projects funded in Bochum and Dortmund met.

2.2 ELLI – Excellent Teaching and Learning in Engineering Education

Funding	BMBF/DLR
Project-ID	0710511198
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dr.-Ing. M. Hermes, Dipl.-Ing. T. R. Ortelt, Dipl.-Inf. A. Sadiki, Dr.-Ing. habil. S. Chatti C. Soyarslan, PhD

ELLI is a joint research project of RWTH Aachen University, Ruhr-University Bochum and TU Dortmund University with the vision of the improvement of the German engineering studies.
In a first step the mechanical engineering education should become excellent prepared for the future. The aim of ELLI is the improvement of the study conditions and the development of teaching quality. ELLI is divided into four parts: “virtual learning environments“, “support of mobility and internationality“, “student lifecycle“ and “creativity and interdisciplinary“.
The newly founded research group “LEED – Laboratories in Engineering Education“ of the IUL is concerning the topic „virtual learning environments“.
For this purpose, the task “resources of experiments: remote and virtual labs“ is further divided into the sub-projects „ investigation on lab courses in engineering education” and “development and integration of remote and virtual labs”.
With the first sub-project “investigation on lab courses in engineering education“ documented lab courses, which use tele-operative experimental set-ups will be investigated. At the first step, the investigation aims at the identification of existing lab concepts, the characteristics of structures of learning objectives as well as the intended learning outcomes of labs in engineering education. However, it seems to be characteristic of a significant number of labs that separate steps are tightly pre-structured. This applies mainly to the lab stages of test planning and preparation, experimentation and, in some cases, also to the stage of data analysis. In consequence of this, the limitations to the learning process when working on engineering problems or planning experiments could cause a significant reduction when trying to tap the full potential of engineering lab courses. In accordance with the current state of knowledge, if courses consist of experimental aspects or provide entire fundamental experiments, they should not only focus on proper experimental procedures but particularly on revealing the entire potential in order to contribute to a foundational science education.

Continuing activities of the project will consist of further investigation on the concepts and arrangement of engineering lab courses as well as its potential for the integration of tele-operative experimental set-ups.
The second sub-project “development and integration of remote and virtual labs” deals with tele-operative and virtual labs for experimentation. Students can plan, execute, modify, observe and evaluate the experiment over the internet. For this purpose,, the IUL is developing and constructing a tele-operative testing cell for material characterization in forming technology. The testing cell is able to execute several experiments like tensile, upsetting or bulge tests.



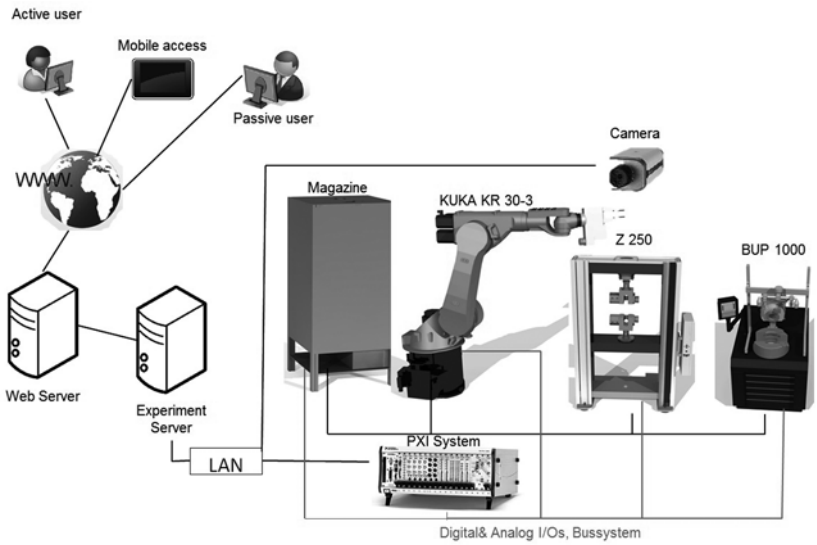
Tele-operative testing-cell of the IUL

The following testing machines are integrated into the testing cell:

- Universal Testing machine Zwick Z250
- Sheet metal testing machine Zwick BUP1000
- Industrial robot KUKA KR30-3
- Integration of an automated specimen stack

In addition to the presented equipment, an optical 3D deformation analysis system “GOM ARAMIS 4M”will be integrated into the tele-operative testing cell. The development of the testing cell puts high demands on automation, IT infrastructure and safety. This is especially important for the testing machines, because these machines are considered for the manual use. In this

case, constructive arrangements are necessary in order to extend the machines for the automated mode. Therefore, to handle a wide range of specimens that can be used in the different experiments, a flexible industrial robot of KUKA was used. In relation to the safety concept and feasibility, several simulations were performed and different possible scenarios were analyzed. In order to control and monitor the tele-operative testing cell, a real time server will be installed and programmed. This server will also stream all the measurement data as well as the live video stream to the webserver. Students can log on into the webserver and interact with the tele-operative testing cell. An important feature is the mobile access, students could then use their mobile devices to enter to the virtual environment.
Afterwards, laboratories at the three sites will be built up in an iterative process and integrated in an e-Learning environment for area-wide use.

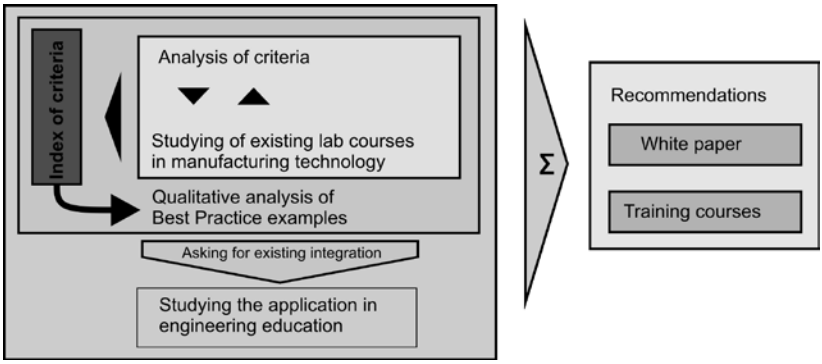


Schematic representation of the tele-operative testing cell infrastructure

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. M. Hermes

Hands-on laboratory training courses in engineering education are traditional as well as powerful elements in application- and also in research-oriented study courses. By the practical application of theoretical models in the meaning of self-dependent engineering action by performing and analyzing hands-on experiments and the critical judgment of one´s own approaches, lab courses have a central significance.
IngLab focuses on the enhancement of hands-on laboratory training courses in engineering education. As shown in the figure below, firstly, the state of the art is studied. Together with the derived recommendations about structuring hands-on laboratory training courses in engineering education a white paper will be prepared. Additionally, advanced training courses on laboratory didactics will be developed. The interdisciplinary project team commands excellent expertise in the fields of engineering as well as didactics for higher education at TU Dortmund University.



Schematic representation of the core objectives for IngLab

2.4 ProLab@Ing – Laboratories in Engineering Education with Problem- and Project-Based Learning (PBL) in Forming Technology

Funding	TeachING-LearnING.EU
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dr.-Ing. M. Hermes
Status	Completed

In the project ProLab@Ing we remodeled the master course of "Forming Technology II" into a problem-based project lab course. The aim was to bring the learning activities of the students to the center in order to achieve a shift from teaching to active learning. To this end, we structured the entire course competence oriented, from the conceptualization to the learning activities and the final assessment.
The whole course consists of four phases: the investigation of students' competencies, the processing of certain core aspects by student teams (cp. Fig. 1), working on the problems by project teams (cp. Fig. 2) and finally the scientific presentation of the results and a critical discussion with the entire class. According to the students´ own opinion, subject related and interdisciplinary relationships of different aspects are much clearer and they find it easier to develop a conceptual understanding of the engineering problem they dealt with. It is planned to carry out the "Forming Technology II" course with this concept also in the future.

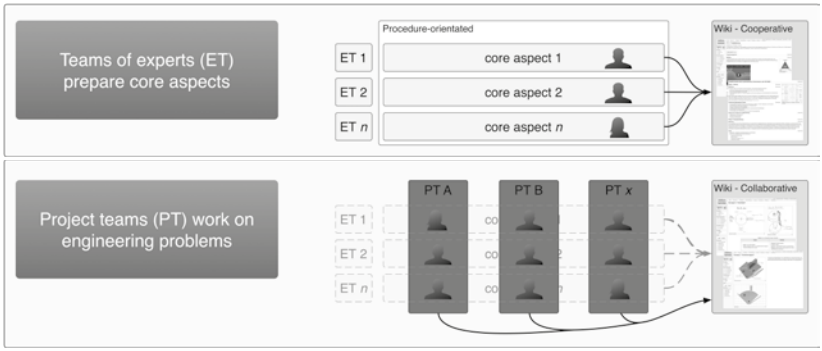


Illustration of the teamwork within expert and project groups

2.5 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

KoM@ING is a joint research project of Leuphana University of Lüneburg, University of Paderborn, Ruhr-University Bochum, TU Dortmund University, University of Stuttgart und IPN – University of Kiel.
The main topic of this project is the modeling and development of competence according to mathematics for engineering sciences like electrical engineering and mechanical engineering.
Both a quantitative IRT-based as well as a primarily qualitative verification are combined for consideration in the three subprojects. Subsequently, the results are connected.
The subproject B is carried out by the IUL and the zhb (Zentrum für HochschulBildung) of TU Dortmund University and Ruhr-University Bochum. This subproject deals with the modeling, the capturing as well as the development of competences in mechanical engineering.

The following working packages were treated in 2012:

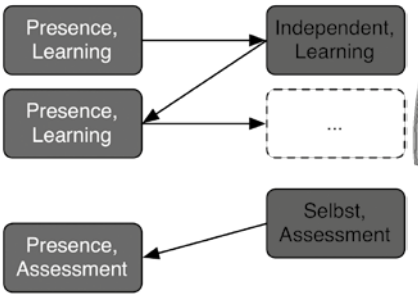
- WP1: Development of a model framework (completed)
- WP2: Normative analysis of capturing competences (completed)
- WP3: Analysis of typical exercises (started)

All working packages refer to the use of mathematics in selected educational activities of the IUL.

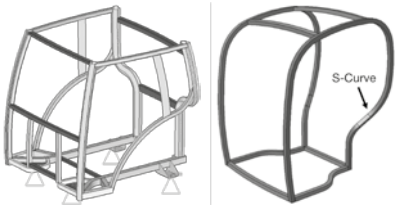
2.6 PBLL@EE – Problem-based Laboratory Learning in Engineering Education

Funding	TeachING-LearnING.EU
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul

The project PBLL@EE aims to make a lab courses in engineering much more active and up to date. Based on the activity-oriented didactical approach of problem-based learning in order to have a deep involvement with engineering practice, students work in small teams on real problems of engineering science. The framework of the course combines presence and independent sessions as well as learning and assessment sessions. Although based on the intended learning outcomes, the planned activities should be in alignment with the requirements for the assessments.
In the present pilot phase, students deal with a modern forming technique for a three-dimensional tube and profile bending process. They work on the problem of producing a lightweight component with the requested dimensions of the radii for a modern space frame of a tractor. To this end, they analyze the problem and work on possible solutions. Necessary experimental work, e.g. the identification of characteristic material values, are planned by the students and carried out on their own responsibility. By having a feedback loop after each session, an optimization of the course during the pilot phase is intended.



Structure of the PBLL@EE lecture

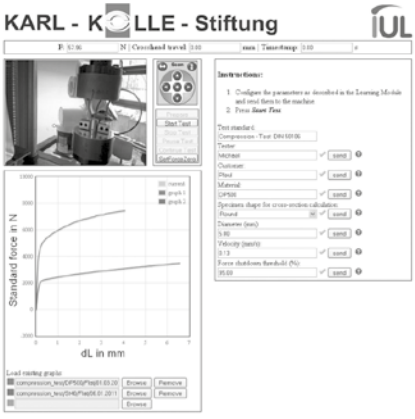


Tractor space frame conventional (left) and re designed (right)

2.7 Full Automation of Telemetric Compression Test Procedure

Funding	Karl-Kolle-Stiftung
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul
	Dr.-Ing. M. Hermes
Status	Completed

A compression test for a distant configuration and control by transferring machine parameters has been set up within the scope of the project. For this purpose, access to the control device of the universal testing machine was achieved by extending the experimental software and the interface for remote access. By using the implemented six axes robot for automatic equipment, further enhancement of flexibility is achieved. Afterwards, the development and optimization of the user interface for interactive configuration by the user was carried out. Finally, basic learning content was developed and integrated into the e-learning system Moodle. A repository for different specimens was designed and conceptually integrated in future tele-operative infrastructure. Results of the project play a crucial role for further research and development in the field of tele-operative use of experimental devices for scientific research as well as for engineering education especially in the field of technologically enhanced laboratory courses. Achievements of the projects will be incorporated in present research and development projects like ELLI and IngLab.



Representation of the user interface

Handling of the specimen

2.8 Integrated and Research-Oriented Laboratory

Funding	TU Dortmund Faculty of Mechanical Engineering
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul
Status	Completed

The project “integrated and research-oriented laboratory” included the establishment and handling of approaches for a sustainable improvement of engineering laboratories in the context of higher education.
Within the project, it was worked on a concept to integrate research-based questions with regard to present research activities into the laboratory course for engineering students. Therefore, the procedure of the problem-based approach was comprehensively adapted according to the requirements of research orientation for experiential learning. Embedded in an engineering context, the developed question serves as central starting point for further work. Students independently process this research questions during active and self-organized sections. Aspects of such section are e.g. activities for information research and first conceptions of possible solutions, amongst others by experimental investigation of a certain material behavior. Hence, the first step requires some test planning and it is intended to use the teleoperative experiment for this first trail. Students will be able to remotely control and modify the test over the Internet and manipulate parameters and finally analyze the acquired data.
After the experiments have been finished, the results should be used to develop an appropriate solution according to engineering standards. Finally, the own procedure, findings and conclusions need to be arranged in a technical report and communicated during an expert discussion section.
It is intended to use the developed concept for the format of the specialist laboratory course that is carried out by Institute of Forming Technology and Lightweight Construction.

2.9 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.

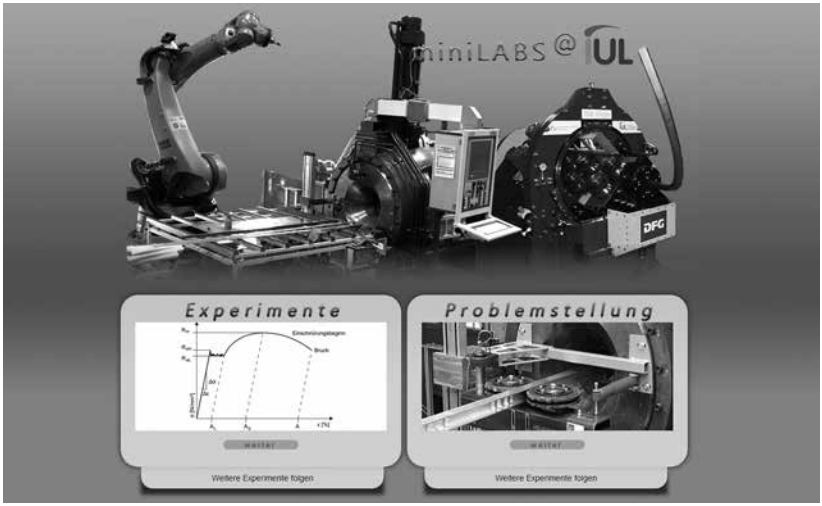
The Master program consists of basic and speciality modules. The modular structure of this master (different educational modules independent from each other) gives not only consistency and flexibility to education in manufacturing but also allows an easy implementation in training programs for vocational 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 Master basic structure having the same educational modules in the three countries and different specialization fields in each country.

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

2.10 miniLABS

Funding	TU Dortmund Faculty of Mechanical Engineering
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	M.Sc. M.Eng. C. Pleul Dipl.-Inf. A. Sadiki

Laboratory experiments are an integral part of engineering education and play a significant role in scientific and engineering work. miniLABS has the main objective to provide opportunities to engaged and interested students to get in touch with an environment of relevant technologies, machines and methods as well as to improve engineering skills like team work and how to communicate clearly in an engineering field. miniLABS includes interesting investigations in the field of material characterization and also experiments to forming processes as well as innovative manufacturing processes. Therefore, miniLABS will contain the following laboratories and experiments:
Material characterization
Investigation of material properties through hardness measurement
3D profile bending
Optical analysis for strain measurement
In addition to the already implemented labs, miniLABS will be performed by trained students who are supervised by a research assistant.



Representation of the current miniLabs website

Research

03

3 Research

The IUL staff includes 2 chief engineers and 41 scientists, research assistants, PhD-students as well as 13 technicians and administrative staff members and 55 student assistants.

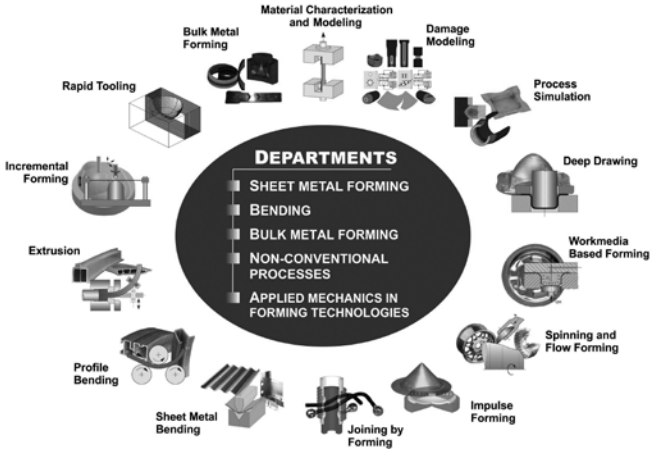
The IUL is divided into five departments:

- Sheet Metal Forming
- Bending
- Bulk Metal Forming
- Non-Conventional Processes
- Applied Mechanics in Forming Technologies

Two working groups have been established to support the departments:

- Measurement systems
- Project planning

The research projects are organized in small interdisciplinary teams. This chapter comprises an overview of research programs coordinated by the IUL. Completed and ongoing projects are presented corresponding to the five departments of the institute.



Structure of the IUL

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	Dr.-Ing. M. Hermes

Faurecia is an international company specialized on automotive products and intends to support a research center together with TU Dortmund and the Institute of Forming Technology and Lightweight Construction (IUL). The newly founded Research Center is called “Research Center for Industrial Metal Processing” (ReCIMP). It is incorporated into the IUL and aims at the following:

- to advance and deepen scientific knowledge on innovative metal production processes, process chains, and hybrid processes
- to update new technological and scientific trends in metal processing leading to innovations
- networking with leading research institutes and companies

These activities will be organized by a core team of the ReCIMP and by additional researchers who are acquired through further research projects organized by the center.

ReCIMP
Research Center for
Industrial Metal Processing

Logo of the new research center founded in 2012

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.-Wirt.-Ing. D. Pietzka

The development of scientific fundamentals and methods for the design of integrated process chains for an automated products-flexible batch production of lightweight frame structures is the major target. It is an exemplary model for the combination of forming, cutting, and joining by implementing an idealized process chain for the flexible production of lightweight structures. The third and last funding period of the research center started in 2011. The main focus of this period bases on the flexibility of the processes and the whole process chain.
Participating research institutes are:

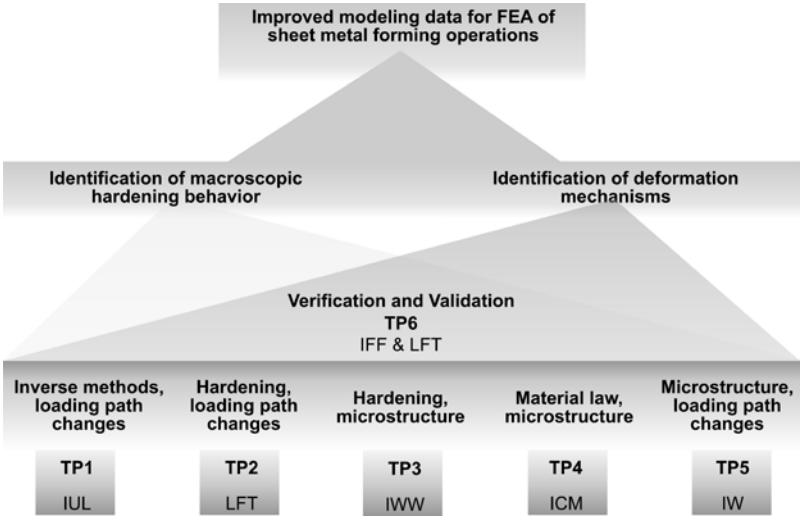
- IUL, Institute of Forming Technology and Lightweight Constructions, TU Dortmund
- ISF, Institute of Machining Technology, TU Dortmund
- wbk, Institute of Production Science, KIT – Karlsruhe Institute of Technology
- IAM-WK, Institute for Applied Materials - Materials Science and Engineering,
- KIT - Karlsruhe Institute of Technology
- iwb, Institute of Machine Tool and Industrial Management, TU München
- LLB, Institute of Lightweight Structures, TU München

Process chain SFB Transregio 10

3.1.3 Identification und Modeling of Material Characteristics for the Finite Element Analyses of Sheet Forming Processes

Funding	German Research Foundation (DFG)
Project	PAK 250
Spokesman	Prof. Dr.-Ing. A. Brosius

The purpose of the research work is the determination of the material behavior, the identification of the required material models and the corresponding parameters in order to improve the existing methods of process analysis and process planning using finite element analysis. The focus lies on the analysis of deformation mechanisms and the activated hardening processes to obtain a basic understanding of the macro and micro structural processes.
Since July 1, 2012, the spokesman, Professor Brosius, holds a professorship (Chair of Forming Technology) at the Institute of Manufacturing Technology, TU Dresden. The research project can be efficiently continued by the close cooperation between partners from Dortmund, Hannover, Chemnitz, Hamburg, Erlangen, and Dresden due to their specific and complementary knowledge in the field of sheet metal production, processing and testing as well as material modeling. The project is supported by a committee consisting of experts from the automotive industry and steel and aluminum sheet manufacturers.

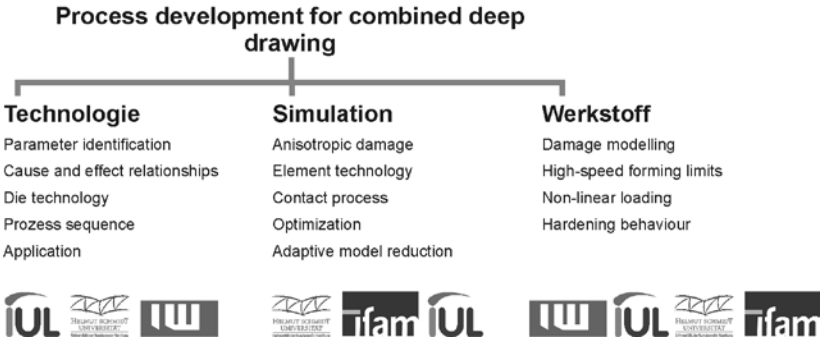


Cooperation and interaction of the subprojects within the PAK 250

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 multi-site project, the process combination consisting of deep drawing and electromagnetic forming is investigated. This combination leads to extensive strain path and strain rate changes. By means of these changes the previous forming limits can be extended. Methods to design such processes are developed.
In the first funding period the process combination was used to produce workpieces with smaller edge radii. In the on-going second funding period higher drawing ratios are supposed to be achieved by means of continuously assisting deep drawing in combination with electromagnetic forming.
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 (see figure).



Collaboration of project partners

3.2 Department of Bulk Metal Forming

Head Dr.-Ing. Andreas Jäger

The department of bulk metal forming focuses on research and development of processes for the production of lightweight components and locally property-adapted or functional adapted structural components by hot extrusion and cold forging. Besides processing of light materials, like e.g. aluminum or magnesium, the manufacturing of composite parts by innovative processes und process combinations, developed at the IUL, are under examination. For example, special dies or specially prepared billets are used to infeed reinforcing elements into the matrix material during hot extrusion continuously or partly to increase the mechanical properties. Besides improving the mechanical properties, like strength or stiffness, the embedding of functional elements is aspired. For a variation of the shape of extruded profiles four different processes are under investigation and development at the IUL. Curved profile extrusion is used to produce 3D curved profiles by deflecting the material flow in hot extrusion. By applying dies with moveable tool components the wall thickness of the profiles can be varied additionally along the profiles' length. By combination of hot extrusion and electromagnetic compression profiles with locally compressed and functionally adapted cross section geometry can be manufactured. Furthermore, aluminum chips are recycled by profile extrusion, without the need for a re-melting. By combining chip extrusion with a subsequent ECAP process (Equal Channel Angular Pressing) the mechanical properties of the product can be improved. In cold metal forming innovative processes, like the combination of deep drawing and cold forging for the manufacturing of functional graded parts, are under development.
Besides the development of new processes or process variants, processes well established in industry are under investigation. The aim is to understand the mechanisms and interdependencies for expanding the process limits or to prevent failures and scrap. Examples in the area of hot extrusion are the prediction of the material flow and the optimization of tools or the extension of process limits in hot extrusion by applying local die cooling. In the field of cold metal forming, the process chains of cold forging and wire drawing are analyzed with regard to a distortion minimization.

3.2.1 Multi-Axis Curved Profile Extrusion

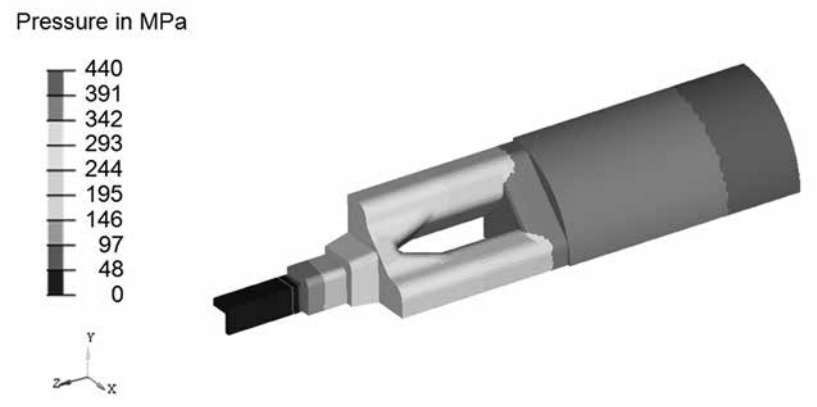
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A1
Contact	Dipl.-Inform. A. Selvaggio

Project Description

This project deals with the further development of the multi-axis curved profile extrusion process and represents the beginning of the process chain which is examined in the Collaborative Research Center Transregio 10. One main objective in the third funding period of this project 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”. Within the extrusion of profiles with variable wall thickness the wall thickness of extruded profiles can be modified during the extrusion process by making use of moveable tool elements, which are used to modify the position of the bearings.

Current Results

By the use of finite element simulation a new tool design was created to resist the high forces acting on the tool elements during the extrusion process. The tool is suitable for the extrusion of squared hollow profiles where two opposite wall thicknesses can be varied by about 20% compared to the original wall thickness.



Finite element simulation: optimization of the extrusion tool for the extrusion of profiles with variable wall thickness

3.2.2 Composite Extrusion

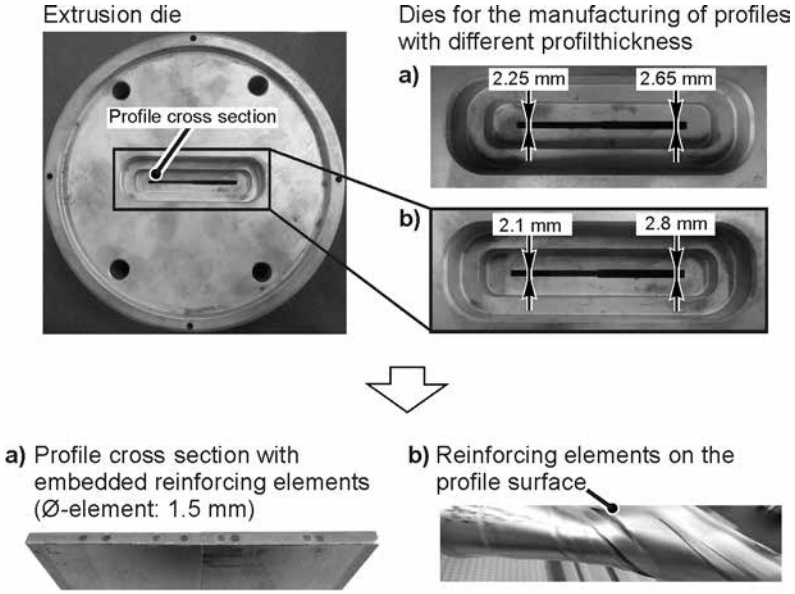
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A2
Contact	Dipl.-Wirt.-Ing. D. Pietzka

Project Description

The aim of the project is the process development for the embedding of reinforcing and functional elements in aluminum parts for lightweight applications by extrusion.

Current Results

For the embedding of high strength metallic reinforcing elements a high reinforcing volume is pursued to exhaust the potential of the forming process and to achieve a significant improvement of the specific strength of composite aluminum profiles. Attempts to increase the reinforcing volume are, for example, the reduction of the profile thickness or the reduction of the distance between two elements. In experimental investigations with a purpose-built parametrical extrusion die it was possible to manufacture profiles with a thickness of 0.375 mm between element and profile surface.



Extrusion dies and results for the manufacture of thin-walled composite profiles

3.2.3 Integral Design, Simulation, and Optimization of Extrusion Dies

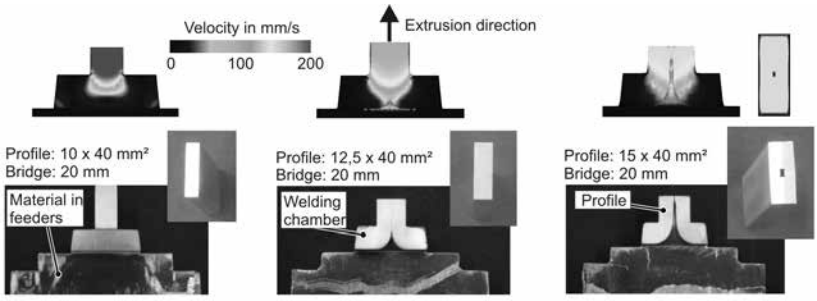
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject B1
Contact	Dipl.-Ing. M. Schwane

Project Description

An important objective of the current stage of subproject B1 is the integrated simulation of the (composite) extrusion process. So far, the steady-state stage has been modeled by means of the finite element method to analyze and optimize the process. From now on, transient sequences shall also be considered. The filling of the die during the start of the process as well as the resulting impact on the position of the reinforcing elements at composite extrusion, for example, shall be incorporated into the design of related extrusion dies.

Current Results

A novel modular die concept was developed which allows varying crucial geometrical parameters such as extrusion ratio or bridge geometry. Furthermore, visioplastic tests were conducted to analyze the material flow inside the die experimentally. Finite element results of partly unfilled die cavities could also be validated.



Influence of extrusion ratio on material flow in the welding chamber

3.2.4 Efficient Extrusion Simulation for Industrial Applications

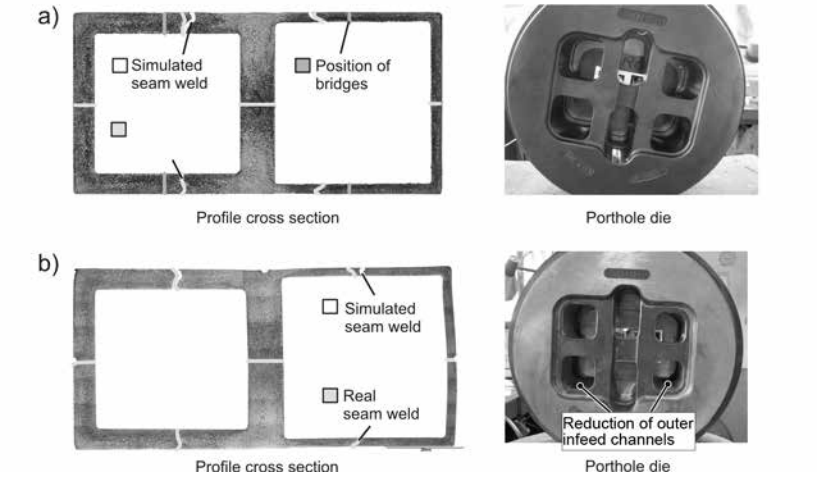
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject T6
Contact	Dipl.-Ing. M. Schwane • Dr.-Ing. T. Kloppenborg
Status	Completed

Project Description

The main objective of the project was to check whether commercial software codes, which are based on different approaches regarding continuum mechanics, are qualified to support the development of complex industrial hot extrusion dies and profile cross sections. Furthermore, it should be proved that the methods for the optimization of the material flow in extrusion processes developed in subproject B1 of Collaboration Research Center SFB / TR 10 can be applied to industrial processes.

Current Results

The optimization of a complex porthole die could be successfully realized by means of numerical methods within this project. On the basis of finite element simulations the die geometry was modified so that a significant improvement of the seam weld positions could be achieved. The numerical results were validated by extrusion tests.



Material flow in porthole die a) initial state b) optimization

3.2.5 Thermomechanical Processing of Aluminum Alloys Subsequent to Extrusion

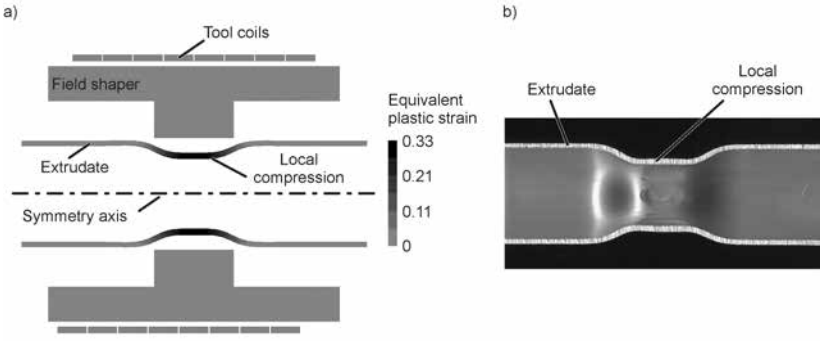
Funding	German Research Foundation (DFG)
Project	SFB/TR 30 • Subproject A2
Contact	Dr.-Ing. A. Jäger • M.Sc. A. Güzel

Project Description

This project deals with the manufacturing of products with locally adapted properties by integrating the thermomechanical forming and heat treatment operations into the process chain of extrusion. The process combination of hot aluminum extrusion, electromagnetic compression, and heat treatment must be improved technologically and modeled numerically for the production of property-optimized products.

Current Results

A novel measuring setup was developed for detecting the radial workpiece displacement in electromagnetic tube compression. The plastic flow behavior of the aluminum alloy EN AW-6082 was determined experimentally for quasistatic loading conditions as well as for very high strain rates. Based on the experimental observations, evolution of microstructure was modeled numerically.



Electromagnetic tube compression: a) FEM simulation, b) experiment

3.2.6 Enhancement of the Extrusion of Aluminum Chips by an Integrated ECAP Process

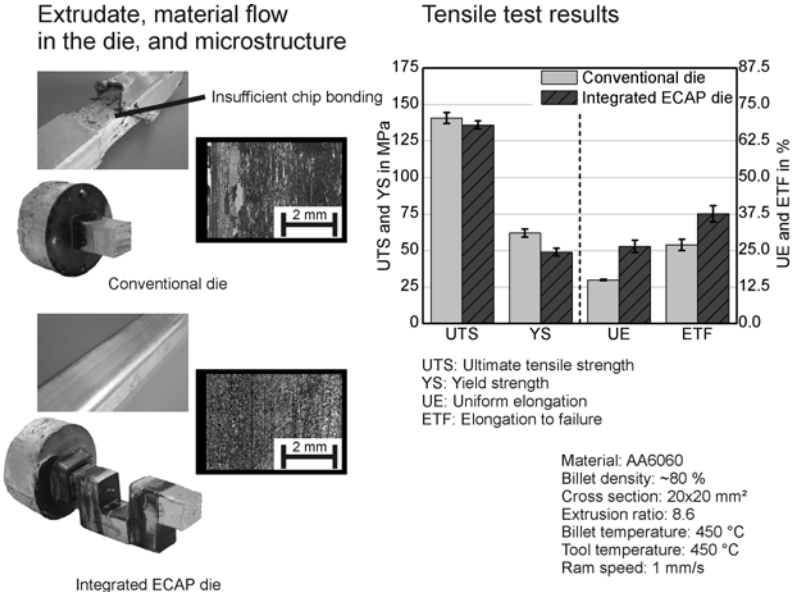
Funding	Graduate School of Energy Efficient Production and Logistics
Contact	Dipl.-Wirt.-Ing. M. Haase

Project Description

The aim of this project is the enhancement of the direct recycling of aluminum alloy machining chips by hot extrusion. By the hot extrusion of compacted aluminum alloy machining chips the energy-intense remelting of the chips as in conventional recycling can be avoided. For the enhancement of the process an equal channel angular pressing (ECAP) tool is integrated into a hot extrusion die in order to apply additional shear on the chips.

Current Results

The additional shear during the forming process results in improved bonding of the chip-based extrudates and in a modified microstructure. The ductility of chip-based extrudates is increased, without a reduction of strength, when the enhanced extrusion die is used.



Comparison between conventional extrusion die and integrated ECAP die

3.2.7 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 508/27-1
Contact	Dipl.-Wirt.-Ing. R. Hölker

Project Description

By introducing conformal cooling channels in the die close to the die bearings an extension of the process limits and the productivity is desired. For this, the interactions in the workpiece, in the die, and in the process control shall be analyzed by experimental and numerical investigations. In order to realize the surface-near cooling, the dies are manufactured by additive rapid tooling technologies.

Current Results

Cooling channels close to the die bearings could be successfully manufactured by the layer-laminated manufacturing method in the die caps and inserted by laser melting into the mandrels of extrusion dies (Fig. a). By applying compressed air and water as coolant the influence of the die cooling on the heat balance in hot extrusion and on the surface quality of the extruded profiles is investigated (Fig. b).

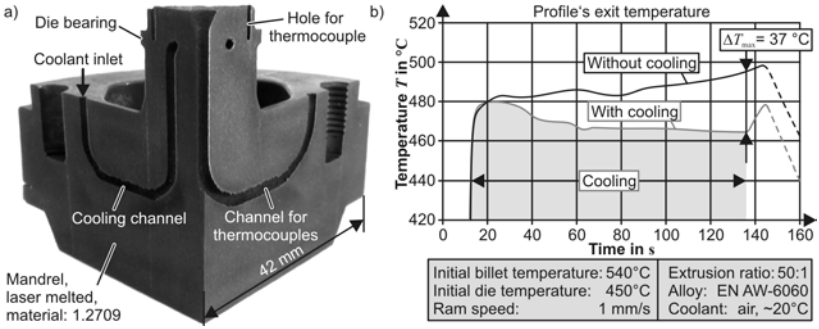


Fig.: a) Additive manufactured mandrel of an extrusion die with conformal inner die cooling, b) profile's exit temperature with and without applying cooling

3.2.8 Component Optimization by Forging of Composite Aluminum Extrudates

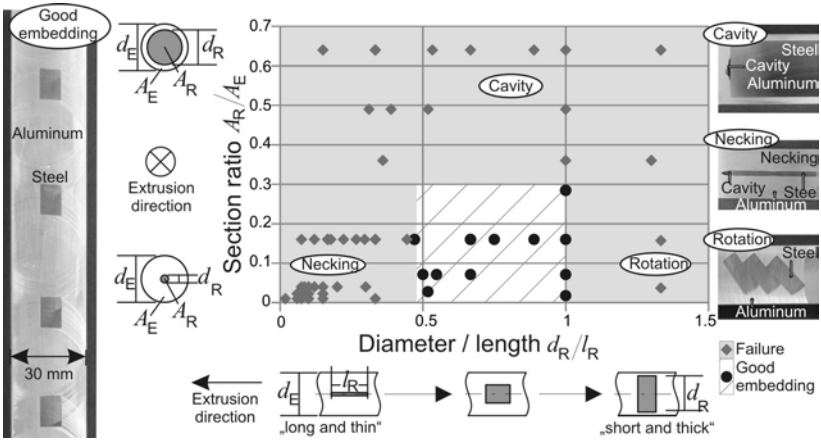
Funding	German Research Foundation (DFG)
Project	TE 508/17-1
Contact	Dipl.-Ing. A. Foydl
Status	Completed

Project Description

Within the scope of this collaborative project with the Institute of Metal Forming and Metal Forming Machines, Leipniz Universität Hannover, the manufacture and further processing of partially reinforced profiles within the process chain of extrusion and hot forging was analyzed. The reinforcing takes place by embedding steel elements during hot aluminum extrusion.

Current Results

At the IUL different process limits for the partially composite extrusion process could be found. A process window for rotationally symmetric bars with embedded cylinder was determined, different failure types (necking, cavity, rotation) were identified, and a process limit for non-centrically embedded reinforcing elements was found. Within the process chain a good embedding between the composites could be fulfilled, therefore the steel elements should be deformed plastically at a high forging temperature (550° C).



Process window for rotationally symmetric bars with cylinder embedded

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

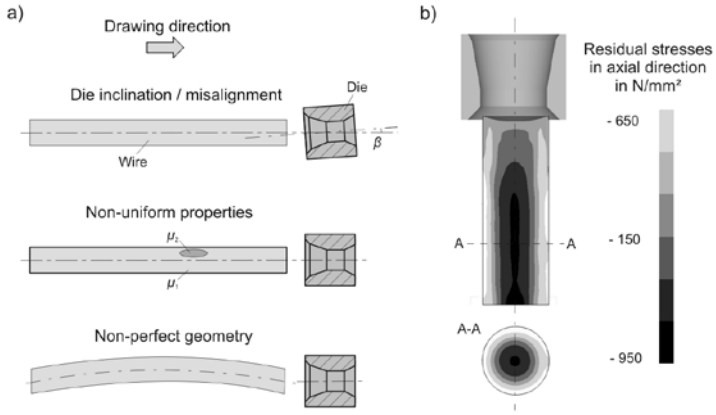
Funding	German Research Foundation (DFG)
Project	TE 508/18-2
Contact	Dipl.-Ing. S. Hänisch

Project Description

The manufacturing of components based on cold drawing may result in unwanted distortion of the workpieces. The influence of each process step on the component properties, from initial material to the straightening and cold drawing up to final heat treatment, is investigated numerically and experimentally to derive potentials for a reduction of distortion. The subtask of the IUL in this German-Brazilian joint project consists in the FEA simulation of the process step cold drawing. In real production processes there are various perturbations which can lead to an inhomogeneous stress distribution and to a deviation from the target geometry. Based on simulations with non-rotationally symmetric 3D models, the effects of possible sources of distortion are examined.

Current Results

The preliminary results of the simulation show that even small inhomogeneities have an influence on the distribution of the residual stresses. Among the cases investigated so far, the inclination between die and wire has the largest influence on distortion.



a) possible sources of distortion; b) residual stresses after cold drawing

3.3 Department of Sheet Metal Forming

Head Dr.-Ing. Jörg Kolbe

The development of new tool concepts, improved methods to characterize sheet metal materials, research on existing processes, and developments of new processes are some of the topics the department of sheet metal forming deals with. For all research activities the objectives are to extend and deepen the process knowledge in order to promote a general adaption of results. Besides the co-organization of the "Innovationsforum Verfahrensintegration", an expert forum focusing on process integration which took place in Dortmund, the installation of a blanking and forming press with a servo drive in the IUL experimental area is a highlight of the year 2012. This press features the advantages of flexible and free-defined velocity curves and will be used for the development of highly integrated forming processes.

New blanking and forming press with servo drive

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

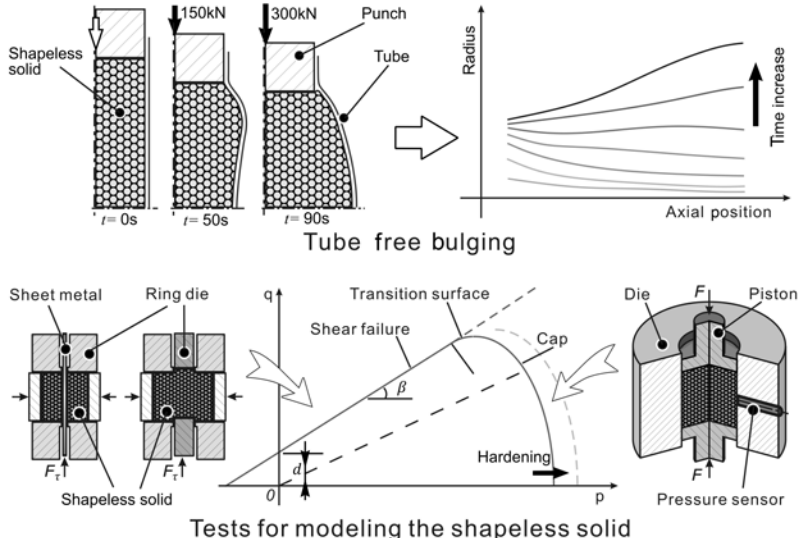
Funding Graduate School of Energy Efficient Production and Logistics
Contact M.Sc. H. Chen

Project Description

Press hardening of tubes or profiles with shapeless solid could integrate the advantages of tube hydroforming (THF) and hot forming, while it also confronts some unascertained problems regarding the complexity of the shapeless solid. This project aims at modeling the process.

Current Results

Instrumented die compression tests and shear tests are conducted for the characterization of the shapeless solid, which could be used for numerical simulation. Free bulging tests with aluminum tubes provide the pressure transition of the shapeless solid due to the inherent characteristics as well as the wall friction. The bulging radius of the tubes varies owing to the pressure gradient while the applied axial forces increase.



Characterization of shapeless solid as forming media

3.3.2 Processing of New Solar Absorbers in Steel Design Based on Partially Cold Roll-Bonded Hybrid Semi-Finished Parts

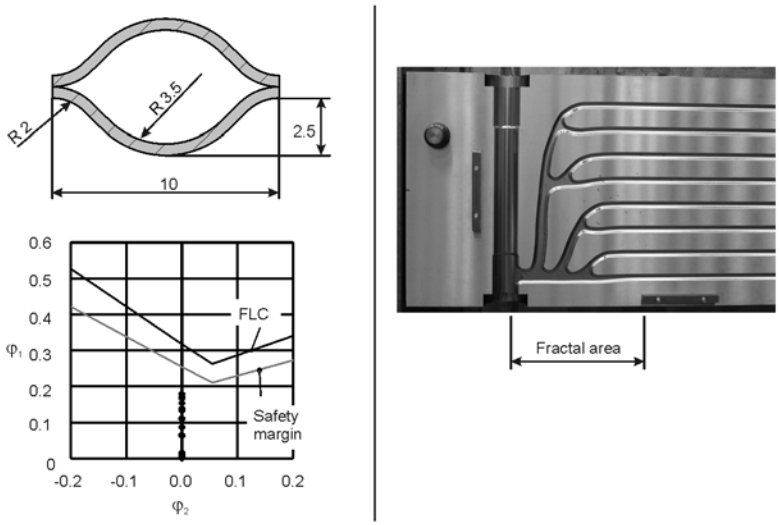
Funding	AiF ZUTECH/Fosta
Project	ZN 339/P 820
Contact	Dipl.-Ing. F. Steinbach

Project Description

Similar to symmetric hydroforming of sheet metal pairs, a solar absorber is manufactured by partial cold roll bonding, followed by a hydroforming process. Thus, a hybrid material structure emerges in which the water channels are embedded. With this process chain the channel design is additionally designed as quasi-fractal structure (FracTherm®, together with Fraunhofer ISE) for achieving a uniform flow distribution and reduction of the pressure drop.

Current Results

Particularly for the forming procedure the geometry of the channel cross section cuts is relevant, which are determined by iterative loops using FEM simulation. On the basis of this data a global geometry is designed and the forming tool for processing the absorber is manufactured.



Final channel cross section (left), forming tool (detail, right)

3.3.3 Development of Concrete Dies for Sheet Metal Hydroforming

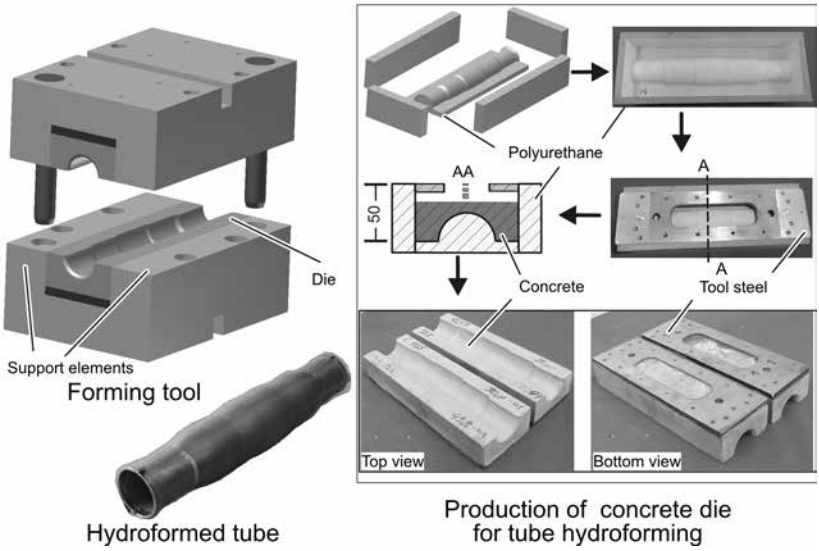
Funding	German Research Foundation (DFG)
Project	TE 508/7-2 (formerly: KL 619/28-1)
Contact	M.Sc. M. M. Hussain

Project Description

In this project, hydroforming tools made of concrete for the manufacturing of sheet metal components in prototype up to small batch size production are investigated.

Current Results

The use of concrete as tool material has been extended to hydroforming of tubes. Therefore, a tool for hydroforming of tubes has been designed which is placed in supporting elements made of steel. The supporting elements are necessary in order to compensate the low tensile strength of the concrete. The possibility to form tubes made of aluminum or steel up to a forming pressure of 60 MPa could be demonstrated by using this experimental setup.



Process chain for producing hydroformed tube profiles through die made of concrete

3.3.4 Development of Hybrid Deep Drawing Tools of High Wear Resistance with an Adaptive Tool Stiffness

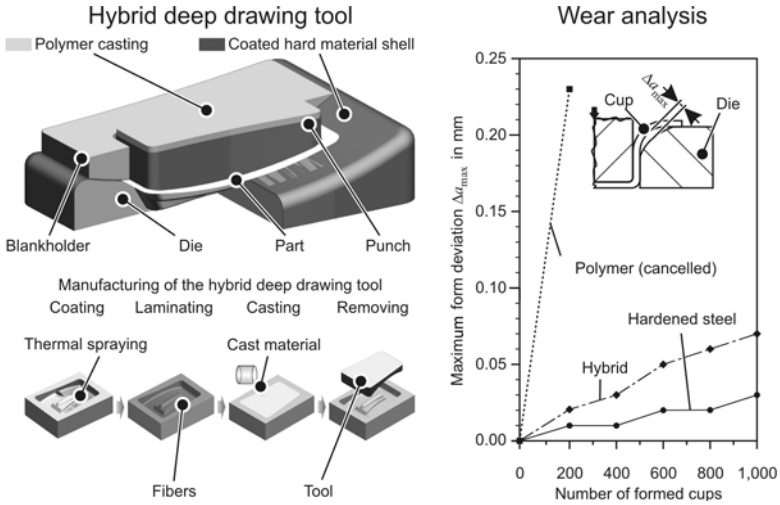
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject C1
Contact	Dr.-Ing. J. Kolbe

Project Description

Within the Collaborative Research Center Program SFB 708, this project is an efficient approach to manufacture forming tools featuring a high wear resistance for the use in small up to medium batch size production. Hard material shells are thermally sprayed on an original mold and supported by a fiber-reinforced polymer.

Current Results

In order to evaluate the performance of the tool under long-term loading, cups made of high strength steels are deep drawn. Therefore, the tool wear is determined. The results show a significant increase of the wear resistance when using hard material shells compared to pure polymer tools. In conclusion, this tool is adequate for achieving the intended batch size of formed parts.



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

3.3.5 Strategies for Springback Compensation

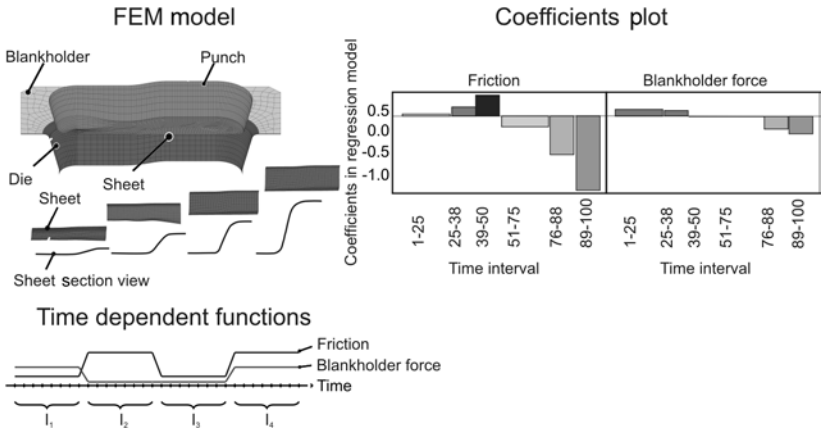
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject C3
Contact	M.Sc. H. ul Hassan

Project Description

The aim of this project is to develop an optimal and robust method for deep drawing processes in order to minimize springback effects. Therefore, process parameters are varied in deep drawing simulations during the process time based on statistical methods and their effect on springback is analyzed.

Current Results

Deep drawing simulation has been divided into several time periods. Within these periods the blankholder force and the friction coefficient have been varied in two levels based on a statistical design. Using statistical methods, a regression model has been developed. It is shown that the values of the investigated parameters have the largest influence on springback at the end of the deep drawing process.



Effects of temporal variation of blankholder force and friction on springback

3.3.6 Identification of Material Models as well as Corresponding Parameters by Means of the Inverse Method and Novel Experimental Setups

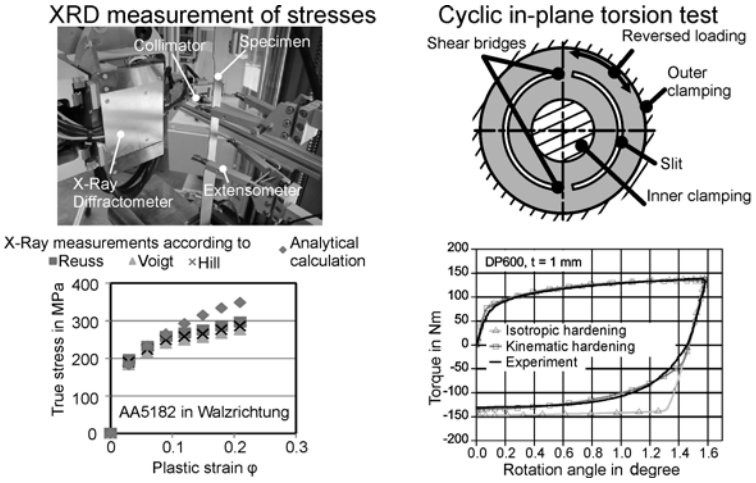
Funding	German Research Foundation (DFG)
Project	PAK 250 • Subproject 1
Contact	M.Sc. A. Güner • Dipl.-Ing. Q. Yin

Project Description

The aim of the project is to investigate and develop new experimental setups to determine subsequent yield loci of sheet metal materials. Two approaches are analyzed in this subproject. The plane torsion test with cyclic loading is the first focus. The second field of research involves the application of X-Ray Diffractometers (XRD) for the direct measurement of loading stresses on specimens.

Current Results

For both, the full planar torsion specimen and the twin bridge specimen, cyclic shear curves are obtained for the determination of kinematic hardening. In this respect, inverse and analytical evaluation methods have been devised. To accurately measure the loading stresses, tensile tests are performed. Here, the analytically calculated stresses are compared with X-ray measurements.



Measurement of loading stresses in tensile test and cyclic twin bridge torsion test

3.3.7 Forming Properties of Laser-Welded Tailor-Welded Blanks Made of High-Strength Multi-Phase Steels – Characterization, Modeling, Verification

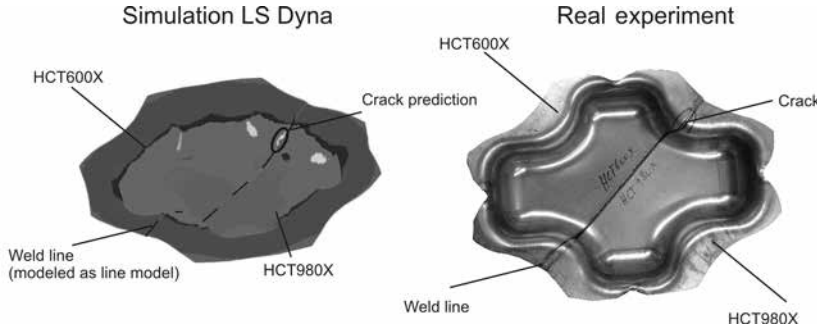
Funding	FOSTA
Project	P 890
Contact	Dipl.-Ing. T. Mennecart

Project Description

The use of tailor-welded blanks made of high-strength steel is currently rare in the automotive industry due to the fact that the weld line modeling is not precise in forming simulations. The aim of this project is the characterization of the weld line concerning its forming properties, the modeling of the weld line in different ways, and the verification by real forming experiments. This project is done in cooperation with ThyssenKrupp Steel Europe.

Current Results

Tailor-welded blanks made of three common steel grades are characterized. Due to these characterizations a flow behavior of the weld line can be evaluated. First approaches of modeling of the weld line as a line model are verified by means of real forming experiments.



Verification of modeling of the weld line by means of real experiments

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

Funding	German Research Foundation (DFG)
Project	SPP 1204 • TE 508/11-2

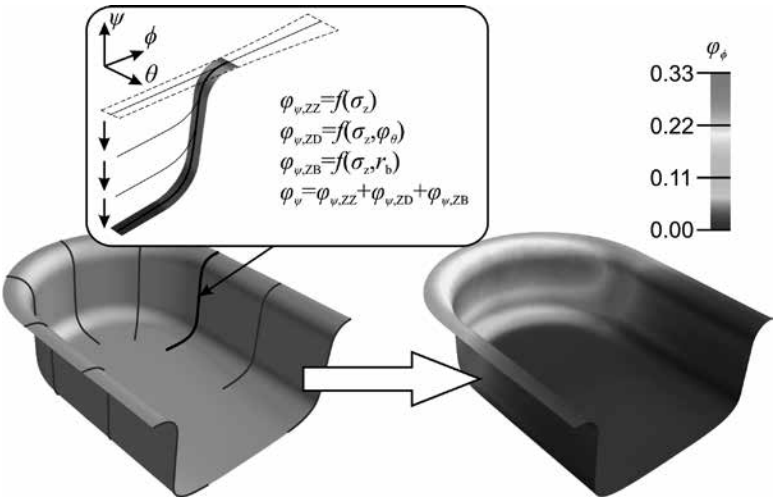
Project Description

Finite element simulations of deep drawing processes are time-consuming due to non-linearities. The aim of this project is the time-efficient calculation of the process chain deep drawing – cutting – heat treatment – welding.

Current Results

For the calculation of deep drawing processes an analytically based method was developed within this project, which allows the prediction of strains in the deep drawn parts. To predict the part properties after heat treatment as well, this method was extended to enable the calculation of microstructural properties and material strength depending on previous deformation and heat treatment.

As Prof. Dr.-Ing. A. Brosius holds a professorship at the Institute of Forming and Cutting Technology since July 2012, this project will be continued at TU Dresden.



Process chain for the manufacturing of a hybrid deep drawing tool and results of the wear analysis

3.4 Department of Bending Technology

Head Dr.-Ing. Matthias Hermes

The department of bending technology works on both fundamental and application-oriented research projects.
Based on this work, innovative processes and patents are being developed year by year. These results often enhance the process limits of the state of the art and allow more possibilities for the production of new workpiece generations for lightweight applications. Load-optimized and graded structures coupled with new advanced high-strength metal alloys are in the focus of the department's successful work. Some highlights of the department in 2012 were the second rank at this year's "Stahlinnovationspreis" (Steel Innovation Award) in the category research and development, a successful presentation at the international fair "TUBE" in Düsseldorf, and the new research machine for incremental tube forming with interesting results.

Stand of the IUL department of bending technology at the TUBE 2012 fair

3.4.1 Standardization of Bending Tubes and Profiles

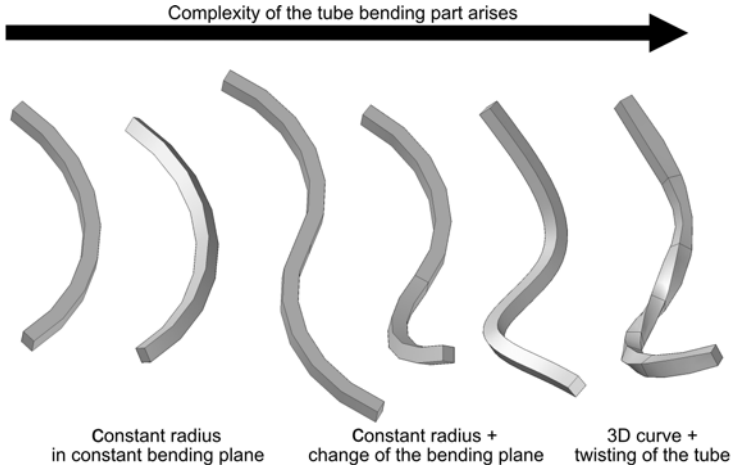
Funding	Federal Ministry of Economics and Technology
Project	01FS11019
Contact	Dr.-Ing. M. Hermes

Project Description

Within this joint research project Tracto-Technik GmbH & Co. KG, Universität Siegen, and Technische Universität Dortmund will realize for the first time an industrial standard for profile and tube bending. Focus at the IUL ist the field of bending of profiles with non-circular cross sections.

Current Results

In the first phase of the project standards for tubes, profiles, and bending processes were investigated, focusing on the process limits in bending. Current work is the analysis of a range of industrial bending workpieces and their producibility applying different bending processes. For this purpose, bending workpieces are categorized into different values of complexity.



Bending complexity of different workpieces

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

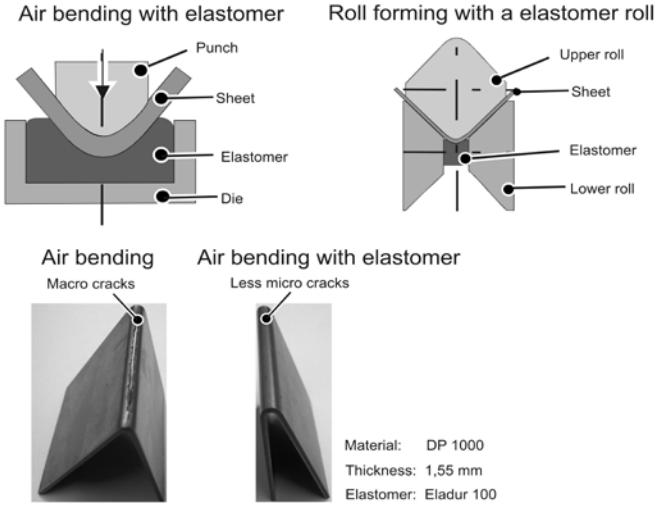
Funding	FOSTA / AIF
Project	P 930/12/2012 / IGF-No. 16585 N
Contact	Dipl.-Ing. M. El Budamusi • Dipl.-Ing. A. Weinrich

Project Description

Low ductility of advanced high-strength steels leads to an increase of requirements on manufacturing technologies. This results directly in the need to adapt or modify conventional technologies in order to provide the ability to process these new materials. An extension of forming limits will be realized by applying hydrostatic pressure in air bending and roll forming processes in the bending zone. The tests will be made experimentally and numerically.

Current Results

The project has started recently. The emphasis is on a detailed material characterization. Furthermore, the materials will be investigated in depth in terms of their damage mechanisms. In addition, extensive studies with respect to their forming limits will be performed. After this, tools for the extension of the forming limits will be constructed.



Preliminary tests: Bending with elastomer tools

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

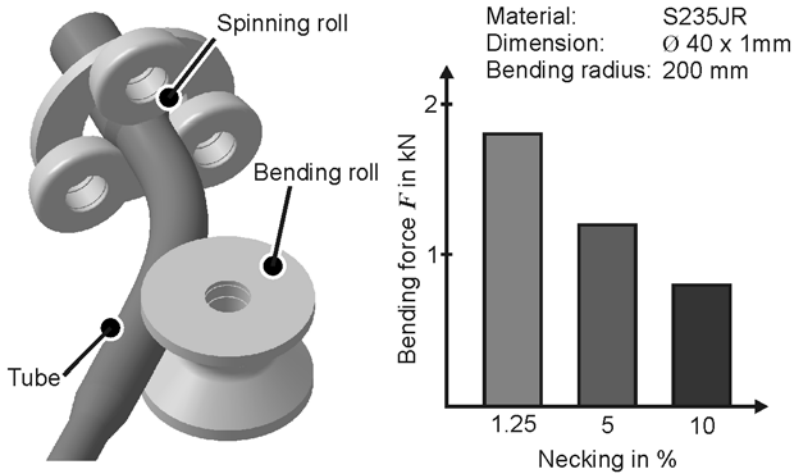
Funding	German Research Foundation (DFG)
Project	TE 508/26-1
Contact	Dipl.-Ing. C. Becker

Project Description

The incremental tube forming process is a process combination of tube spinning and free form bending. Within this project a process model to predict springback will be developed in order to gain deeper process knowledge of incremental tube forming. In several work packages the realized process model as well as the entire process will also be numerically and experimentally examined and validated.

Current Results

To observe possible process-influencing parameters as well as to validate the process model later on, the ITF process has been modeled using FEM. The figure shows the influence of the diameter reduction of the tube on the bending force. A decrease of the bending force takes place with a simultaneous increase of the diameter reduction.



FEM model and numerical results concerning necking-in

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

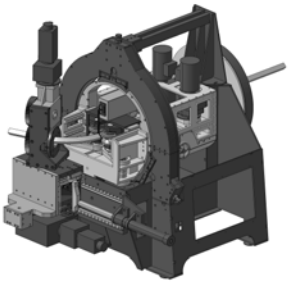
Funding	BMWi / ZIM-KF
Project	KF2198115LK1
Contact	Dipl.-Ing. D. Staupendahl

Project Description

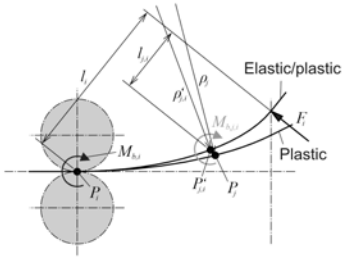
A new manufacturing and machine technology for the flexible cold and warm bending of profiles with complex cross sections to three-dimensional structures is currently being developed in cooperation with the Schwarze-Robitec GmbH. The design is based on the Torque Superposed Spatial bending process (TSS bending), which was developed at the IUL.

Current Results

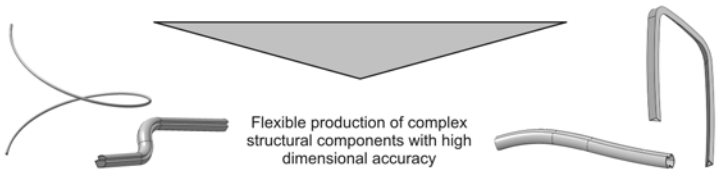
After specifying all necessary machine parameters in cooperation with Schwarze-Robitec GmbH, the layout of the machine was started. The design of the machine is done by Schwarze-Robitec GmbH. Currently, the design is soon to be finished and first machine parts are going into production. The IUL works mainly on the development of a stable process control, which takes the high standards needed for the processing of profiles into account, especially concerning the dimensional accuracy and shape tolerance.



Extended TSS bending kinematics



Development of the process control



Development and implementation of the process control

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

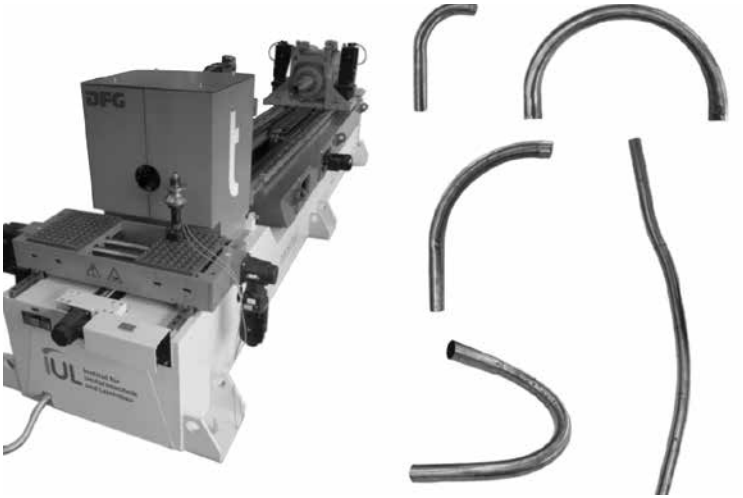
Funding	BMWi / ZIM-KF
Project	KF2198101LK9
Contact	Dipl.-Ing. C. Becker
Status	Completed

Project Description

Within this project the process characteristics of the incremental tube forming process were examined. Based on this, a prototype machine was developed which is oriented to industrial needs in order to cover a wide range of workpiece geometries. The prototype machine, which remains for further research activities at the IUL, has eight numerically controlled axes as well as a range of tubes varying from 25 mm to 90 mm in diameter.

Current Results

In this project the potentials of incremental tube forming concerning producible tube geometries have been shown. Bending radii of 4xD have been realized. Furthermore, a prototype machine was developed which is able to produce industry-related products as well as a basis for further research work was established.



Machine system for incremental tube forming and produced workpieces

3.4.6 ProTuBend – Flexible and Cost-Effective Innovative Manufacturing of Complex 3D-bent Tubes and Profiles Made of High-Strength Steels for Automotive Lightweight Structures

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

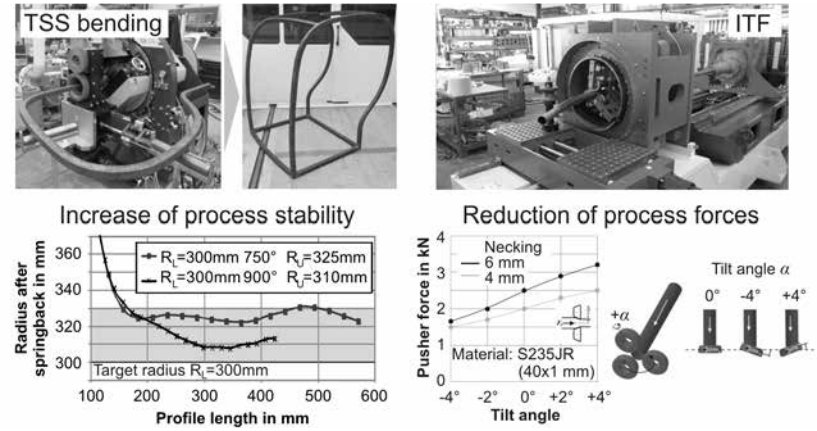
Project Description

The aim of the ProTuBend project was to advance the Torque Superposed Spatial (TSS) bending process and Incremental Tube Forming (ITF) for the industrial use capable of forming and bending load-optimized 3D tubes and profiles made of high and ultrahigh-strength steel.

Current Results

In the project the process limits and possible process extensions of the two processes were analyzed using high strength air hardening steel and dual phase steel.

Through the extension of the TSS bending kinematics by additional servo axes higher process stability could be reached and, in addition, the possibility of preventing the self-torsion of unsymmetrical profiles was explored. The use of induction heating during bending resulted in a significant bending radius and springback reduction. In incremental tube forming the use of optimized tooling resulted in a significant reduction of process forces.



Potentials of the enhanced process concepts

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

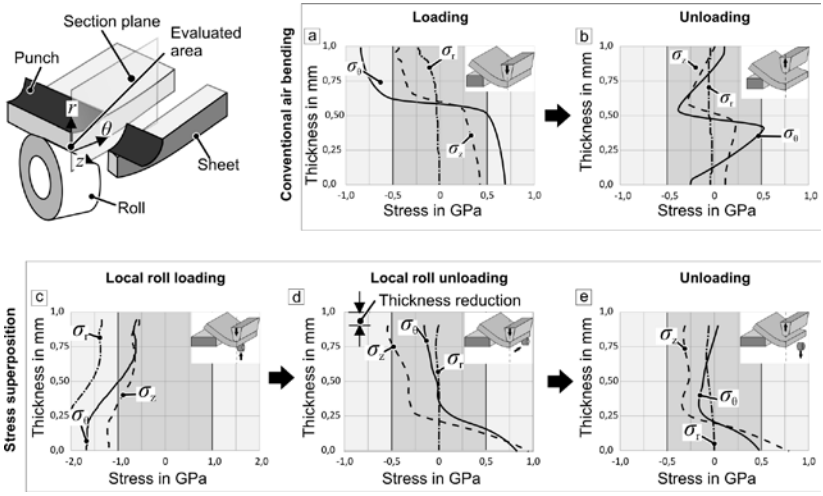
Funding	German Research Foundation (DFG)
Project	MA1883
Contact	Dipl.-Ing. A. Weinrich

Project Description

The increasing demand for lightweight structures requires the use of modern materials. These have particularly in air bending a high springback. This can be reduced by using stress superposition.

Current Results

A high springback compensation and a homogenization of the bending angle on so-called tailored blanks has already been demonstrated experimentally in the past.
Because of the horizontal movement of the roll the workpiece undergoes a three-dimensional load. To look closely to these effects a 3D FE model was created and then a profound analysis has been realized. In the analysis a significant effect on the residual stresses has been detected.



Analysis of stress states over the sheet thickness (a and b) in the conventional air bending (c, d, and e) at various stages during the incremental stress superposition

3.4.8 Flexible Production of Lightweight Structures by Innovative Forming Technologies – RoProFlex Process

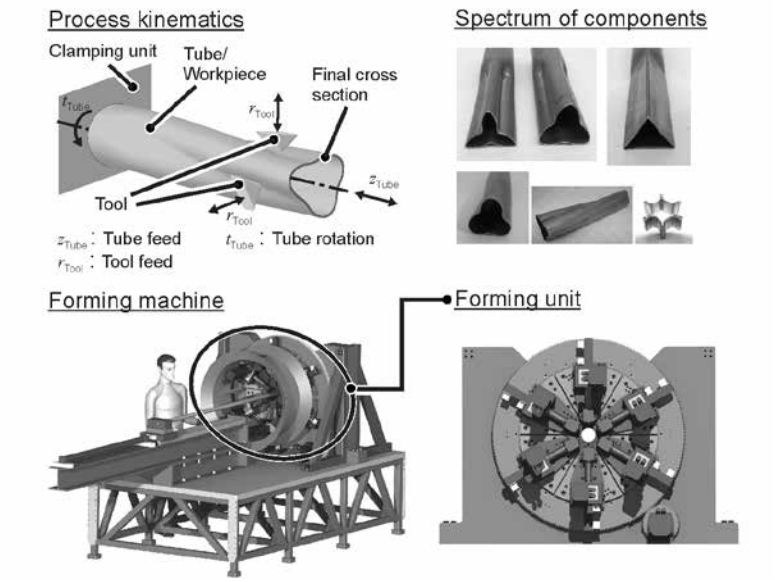
Funding	NRW.BANK
Project	w1006sb017a
Contact	Dipl.-Ing. G. Grzancic

Project Description

The RoProFlex process, which was developed at the IUL, is an incremental forming process for the flexible manufacturing of tubes and profiles with variable cross-section geometries along the center line. Within this research project, a numerically controlled forming machine is being built, in order to lift the forming process to a higher technological level and to enable further process investigations. In the final stages of the project the process potentials will be explored fundamentally.

Current Results

Based on the developed technological concept, the machine design was completed and the manufacturing of the first machine parts has begun. Furthermore, the planning and the assembling of the necessary control systems take place.



Process kinematics, spectrum of workpieces, and developed machine design

3.5 Department of Non-Conventional Processes

Head Dr.-Ing. Lukas Kwiatkowski

The purpose of the research work in this department is to establish alternative techniques in production engineering where conventional methods come to their limits. Special topics are flexible and energy- efficient processes as well as the objective to extend the forming limits known at present. Therefore, the major focus of the department is currently on incremental forming and burnishing, impulse forming, and joining by forming.
Here, our equipment was extended to include a new punching machine provided by the company TRUMPF. Additionally, future work of the department is supported by a new multi-axis press, which was developed by the IUL in collaboration with the company Schnupp Hydraulik. The machine allows adapting local bulk forming processes to metal sheets. In this context, the Collaborative Research Center (SFB) Transregio 73, concentrating on sheet-bulk metal forming, was successfully assessed in Dortmund. The activities in this field of research can now be continued for four more years, funded by the German Research Foundation.

Experimental investigations using the purpose-built multi-axis press of the SFB/TR 73

3.5.1 Process Development for Deep Drawing with Integrated Electromagnetic Forming

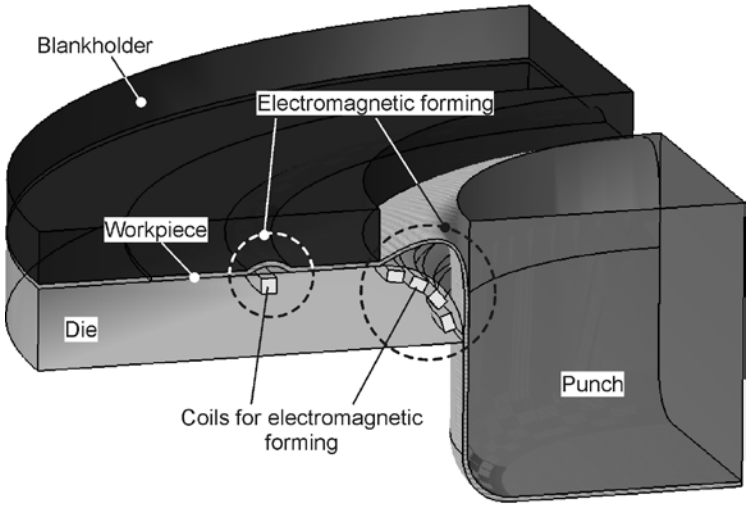
Funding	German Research Foundation (DFG)
Project	PAK 343 • Subproject 1
Contact	M.Sc. O. K. Demir

Project Description

The process chain consisting of deep drawing followed by electromagnetic forming is investigated. The transition from one process to the other leads to a major change in strain rate and strain path. As a result of this change, the previous forming limits can be exceeded.
Electromagnetic forming is conducted in different parts of the workpiece (see figure). Drawing is continually assisted by electromagnetic forming during the process.

Current Results

Numerical simulation showed that, depending on the geometry and position of the electromagnetically formed shape, it can reduce the drawing force. This reduction should assure that the drawing force does not reach the yield strength in the cup wall. In this case, plastic forming, and thus the failure in the cup wall, is prevented.



Deep drawing with integrated electromagnetic forming

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

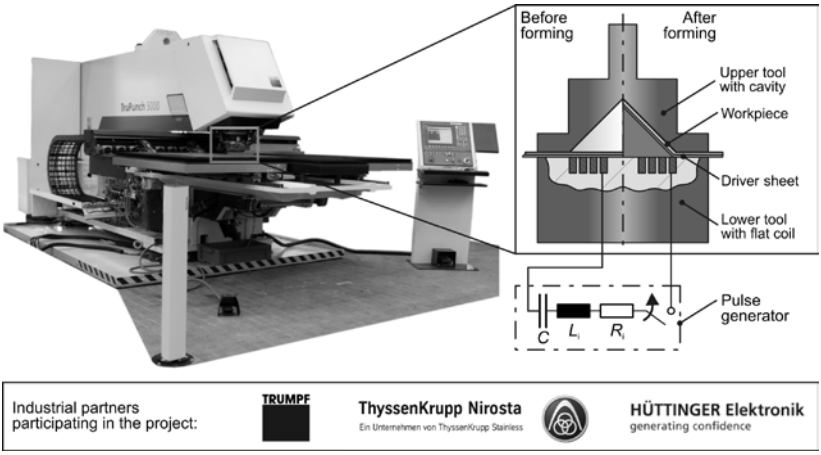
Funding	German Research Foundation (DFG)
Project	TE 508/34-1
Contact	Dipl.-Wirt.-Ing. S. Gies

Project Description

The project aims at the combination of quasi-static and dynamic forming processes by integrating a tool coil for the electromagnetic sheet metal forming process into the processing head of a punching machine. This combination of two processes with entirely different strain rates increases the maximum strain before failure and, thus, allows exceeding the conventional forming limits. In addition to aluminum also steel and stainless steel are used as workpiece materials and are analyzed regarding their suitability for this combined forming process.

Current Results

Analytical results proved that an optimum value for the thickness of the driver foils exists. The driver is needed for workpiece materials with a low electrical conductivity. This optimum thickness depends on the geometrical, mechanical, and physical properties of the workpiece material.



Punching machine TruPunch 5000 used within the project and tool concept with integrated flat coil in the lower tool part

3.5.3 Investigation of the Complex Interdependencies in Electromagnetic Tube Forming

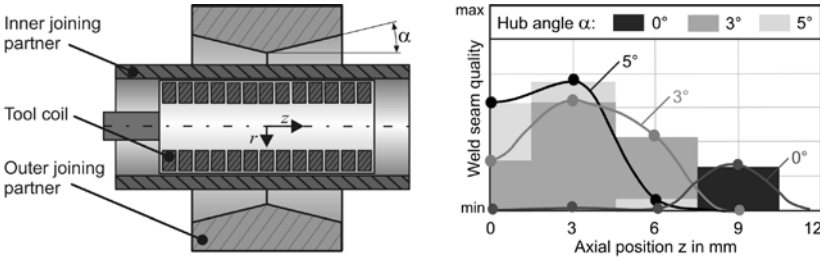
Funding	German Research Foundation (DFG)
Project	TE 508/19-1
Contact	Dipl.-Wirt.-Ing. S. Gies

Project Description

Magnetic pulse welding (MPW) is a joining technique which is based on the electromagnetic forming process to manufacture connections based on metallurgical bonding. However, a weld seam formation requires a proper adjustment of the impact parameters between the workpieces to be joined. In collaboration with the Institute of Materials Science of the Leibniz Universität Hannover the best impact parameters are identified using a model experiment. In a subsequent step the effect of different process parameters is analyzed at the IUL so that the impact parameters during the joining process match with the optimum values identified in the model experiment.

Current Results

Experimental investigations proved that geometrical shaping of the outer joining partner is a suitable method to adjust the impact parameters, which leads to an increased weld seam quality.



Tool coil		Tube (Inner joining partner)		Process parameters	
Length:	36 mm	Material:	EN AW-1050A	Pulse generator	SMU 1500
Outer diameter:	27 mm	Outer diameter:	40 mm	Charging energy	1.500 J
Turns:	13	Wall thickness:	2 mm	Impact velocity	~ 180 ms^{-1}

Experimental setup with v-shaped outer joining partner (left) and results of weld seam quality investigations (right)

3.5.4 Joining by Forming

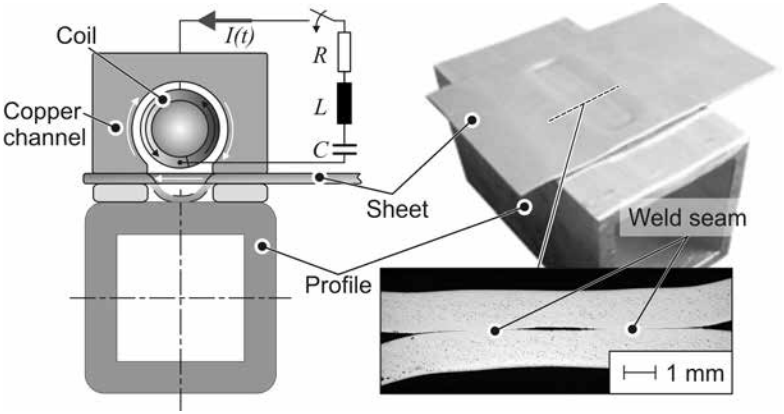
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A10
Contact	Dipl.-Wirt.-Ing. C. Weddeling

Project Description

The objective of the project is the development of guidelines for a process and load-optimized joining zone design for joining by forming of lightweight frame structures. Therefore, experimental investigations of form and interference-fit joining of profiles to profile connections by electromagnetic joining (EMJ) and joining by hydroforming are performed. Additionally, the manufacturing of sheet metal to profile joints by magnetic impulse welding (MIW) is investigated within this project.

Current Results

For MIW a new tool coil concept was developed. Compared to conventional designs, this concept shows an increased efficiency. Based on fundamental investigations, analytical models for a process design of MIW as well as joining by hydroforming and EMJ were developed.



Developed tool concept for magnetic pulse welding of sheet metal to profile connections

3.5.5 Investigation of Dieless Sheet Metal Forming by Foil Explosion

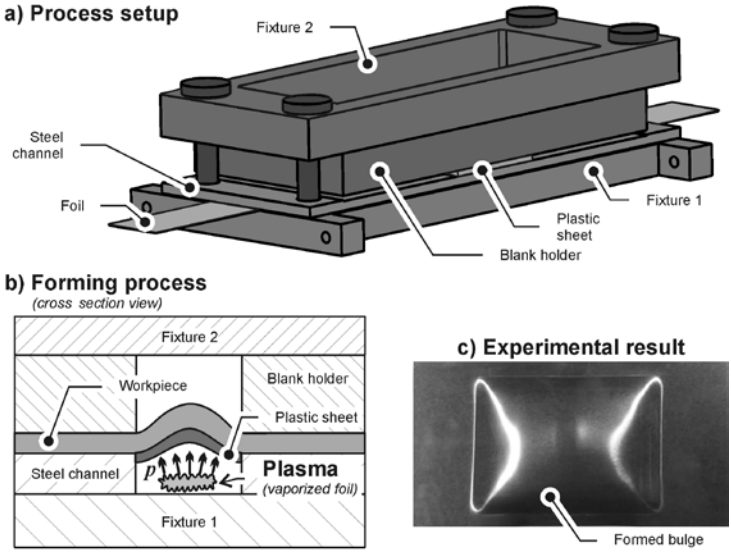
Funding	German Academic Exchange Service (DAAD)
Contact	M.Sc. S. Cai

Project Description

Through high speed forming processes the forming limits can be exceeded compared to conventional quasi-static processes like deep drawing. Using vaporizing foils, forming speeds of up to 500m/s can be realized. The vaporizing effect is initiated by a very short current impulse with high amplitude. The project is organized as collaboration with the Ohio State University (USA), supervised by Prof. Daehn.

Current Results

A first experimental setup was realized. The results showed that the charging energy, foil material, and geometry have an effect on the pressure amplitude and its distribution as well as on the forming velocity.



Sheet metal forming by vaporizing foils

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

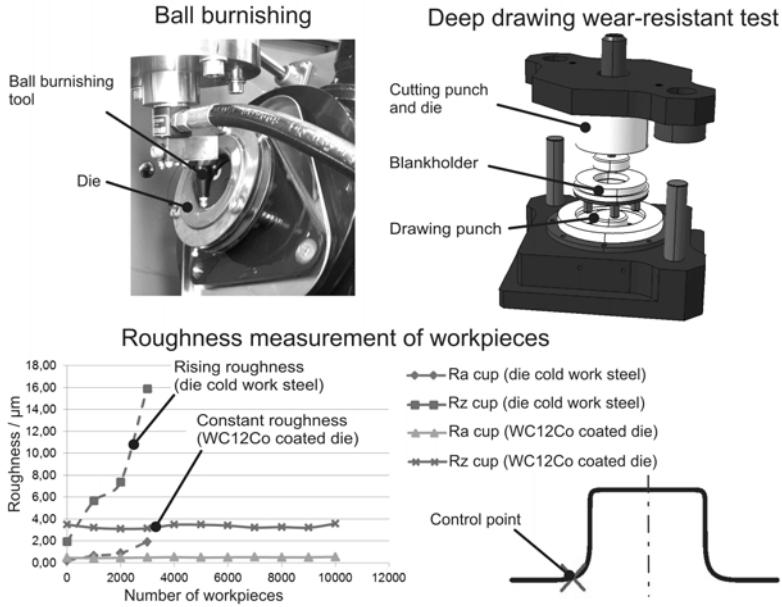
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject A3
Contact	M.Sc. L. Hiegemann

Project Description

The aim of this project is to smooth thermally sprayed tool surfaces by ball burnishing and to investigate the performance of the coatings in sheet metal forming.

Current Results

Using a deep drawing wear-resistant test, the wear behavior of a thermally sprayed ball burnished tool was compared to the behavior of a conventional reference tool. Due to the coating the service time of the tool and the quality of the workpieces can be improved. It is shown that ball burnishing can successfully be used to smooth thermally sprayed tool surfaces.



Wear tests of thermally sprayed ball burnished tool surfaces

3.5.7 Process Development for the Manufacturing of Load-Optimized Parts by Incremental Forming of Thick Metal Sheets

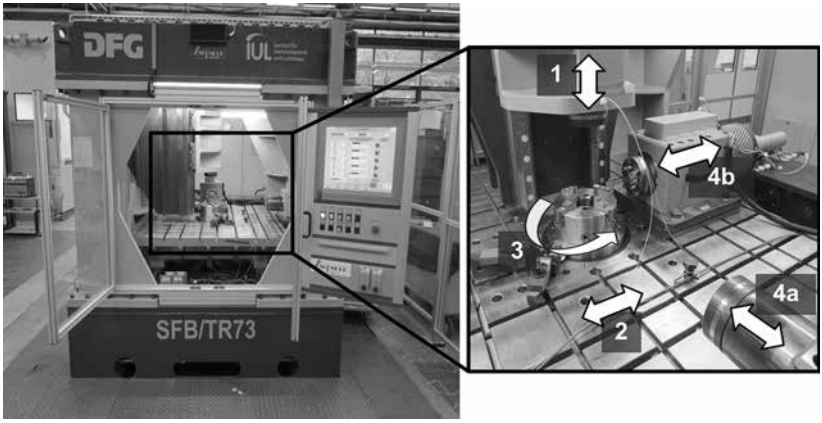
Funding	German Research Foundation (DFG)
Project	SFB/TR 73 • Subproject A4
Contact	Dipl.-Ing. P. Sieczkarek

Project Description

The objective of this project is the production of geometrically complex functional parts with secondary design elements made of sheet metal. Therefore, bulk forming operations are applied to sheet metals. With the incremental approach the workpiece is processed by a sequential series of locally restricted forming operations, such as rolling or embossing. Here, the material is distributed first and then calibrated in a final forming step.

Current Results

Currently the focus is on a locally defined thickening of the sheet metals. First studies deal with analytical predictions for the thickening of the material with the slip line theory. These are only partly transferable to sheet-bulk metal forming.
For a flexible incremental approach a novel forming press with five axes of motion was designed and realized.



Multi-axis press TR 73 with its five axes of motion
(1. Ram, 2. Machine table, 3. Turntable, 4.a + 4.b Additional axes)

3.5.8 Characterization of the Dynamic Process Behavior during Incremental Sheet Forming

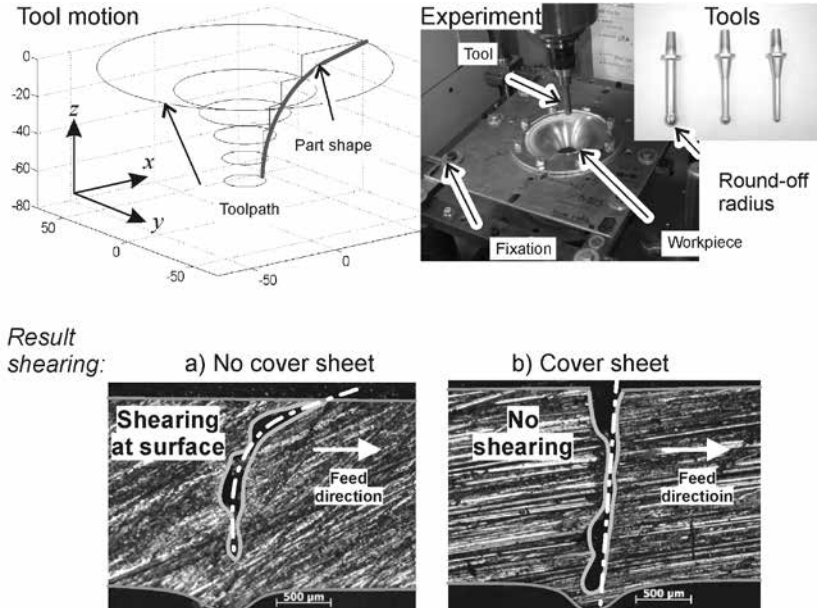
Funding	German Research Foundation (DFG)
Project	SFB 823 • Subproject B2
Contact	Dipl.-Ing. F. Steinbach

Project Description

Using the incremental sheet forming process (ISF) very high forming limits can be achieved. To detect the major forming mechanism, cause-and-effect-principles are investigated in collaboration with the Chair of Mathematical Statistics and Applications in Sciences, TU Dortmund.

Current Results

The through-thickness shear was assumed to be the major aspect to reach high forming limits during ISF for a long time. Using the hole drilling method, this theory was disproved by comparing the strains of forming experiments with and without cover sheets. In both experiments the same strains were reached.



Shearing during incremental sheet forming using direct tool contact or a protecting cover sheet

3.5.9 Investigation of the Deformation Behaviour of Thermoplastics during Incremental Cold Forming

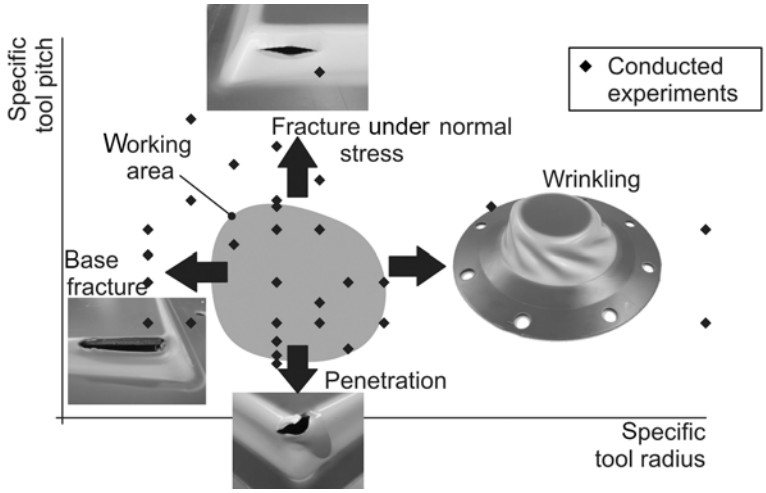
Funding	German Research Foundation (DFG)
Project	TE 508/20-1
Contact	Dipl.-Ing. S. Alkas Yonan

Project Description

The incremental forming process features a particularly flexible and economic alternative for small batch production. The aim of this project is the fundamental-based development of incremental forming of thermoplastics so that forming potentials can be utilized as far as possible by an adequate process design.

Current Results

The evaluation of experimental tests results in an empirical process window, which localizes a certain working area for incremental forming of parts with critical wall angles (>60°). Furthermore, different failure modes are detected when leaving this area. Identified process limits are to be analyzed using analytical approaches.



Empirical process window for incremental forming of thermoplastic parts

3.5.10 Numerical Investigation of Cold Forming of Laminar Thermoplastic Polymers

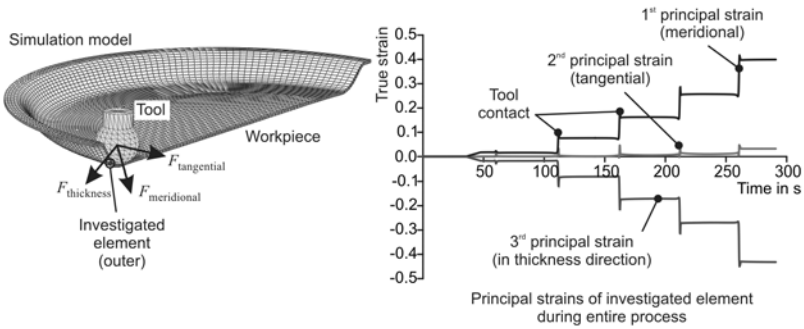
Funding	Graduate School of Energy Efficient Production and Logistics
Contact	Dipl.-Ing. S. Alkas Yonan
Status	Completed

Project Description

The aim of this project was to characterize the deformation behaviour of thermoplastics at room temperature by means of numerical investigations and to analyze the properties of cold-formed parts. Different sheet forming processes were investigated numerically and experimentally.

Current Results

For numerical investigations, a material model was specifically developed. Using the example of incremental forming, the states of stress and strain in the forming zone on tool-facing and tool-averted sides were investigated. The investigation resulted in a state of stress which is characterized by bending with superimposed tension. The resulting strain comes mainly from the meridional and thickness direction, which was also experimentally proven. The identified principal strains account amongst others for the appearance of fractures under normal stress, which proceed in tangential direction.



State of strain during incremental forming of thermoplastics

3.6 Department of Applied Mechanics in Forming Technologies

Head Celal Soyarslan, PhD

This department aims at a thorough understanding of the underlying physical mechanisms in forming processes and at using this know-how for technological enhancements in this field of research. While doing so, the department adopts state-of-the-art approaches in mechanistic and phenomenological constitutive modeling for metals, thermoplastics, and their composites, including material damage and fracture, formability analysis, material characterization and forming simulation and develops various (semi-)analytical and numerical tools which represent one of the key competences of the department. These include e.g. an extensive and ever-enlarging subroutine library with numerous ductile damage and fracture models implemented for ABAQUS and SIMUFACT and complementary fracture locus plotters for stress, strain, and triaxiality spaces, and completely parallelized robust inverse material parameter identification programs. A boost in using these tools and simulation power is expected thanks to the new high end work station for high performance parallel computing. Its deployment will be realized by the end of 2012. Although being the youngest department at the IUL, this department maintains many national and international scientific collaborations including Brazil, France, Italy, China, and Japan, especially in the fields of experimental and numerical investigations of ductile damage in metallic materials. In one of these international collaborations with France the department organized a successful Summer School on “Hardening and Damage of Materials under Finite Deformations: Constitutive Modeling and Numerical Implementation”, which took place in Dortmund from September 3 to 7, 2012.
With three additional scientific researchers joining the department in 2013, this department will increase its strength further to work intensively in close collaboration with the other IUL departments of sheet forming, bulk forming, bending, and unconventional forming.

Snapshot taken at the Summer School organized by the Department of Applied Mechanics in Forming Technologies

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

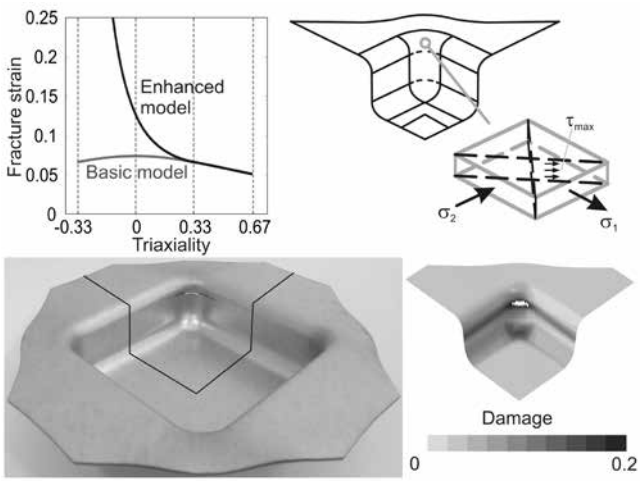
Funding	FOSTA
Project	P 853
Contact	M.Sc. K. Isik • C. Soyarslan, PhD
Status	Completed

Project Description

This study aims at proposing an affordable methodology for industrial failure prediction using continuum damage mechanics (CDM). For this purpose, an enhanced Lemaitre damage model with quasi-unilateral damage evolution which is strongly coupled with plasticity is used. Material characterization involves experiments with a range of stress triaxiality ratios, i.e. tensile tests, in-plane shear, and Nakajima tests. For validation, deep drawing tests with round, square and, cross die geometries are conducted.

Current Results

Damage model parameters obtained by inverse parameter identification provide promising results for failure prediction in the forming processes. Further improvements of the damage model are done for shear fracture cases in which the maximum shear stress is taken into consideration.



Modeling ductile shear fracture observed in square cup drawing

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

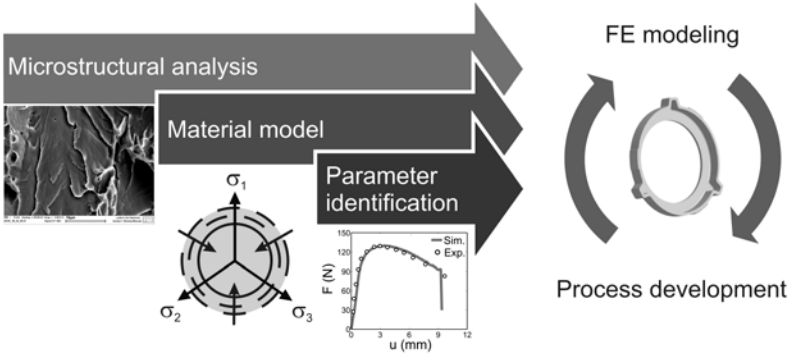
Funding	German Research Foundation (DFG)
Project	SFB/TR 73 • Subproject C4
Contact	M.Sc. K. Isik • C. Soyarslan, PhD

Project Description

This study aims at combined experimental and numerical investigations of microstructure development in the context of voidage during sheet bulk metal forming. Experimental studies include mechanical material characterization and validation as well as subsequent surface inspections where the void-driven destabilizing mechanisms leading to material fracture are being investigated. Numerical studies involve the implementation and improvement of existing physically-based advanced damage theories, which give account for normal as well as shear stress state-dominated material deterioration, and the implementation into a finite element framework.

Current Results

Regarding material characterization, the micromechanical investigations provide the void-related model behavior for the Gurson Model, although for the Lemaitre Model inverse parameter optimization is required. Under observed monotonic loading paths, phenomenological (Lemaitre) and micromechanical (Gurson) damage models result in similar failure predictions in terms of failure time and failure zone for the modeled sheet bulk forming processes, which are in correlation with the experimental investigations.



Numerical design of sheet bulk metal forming processes

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

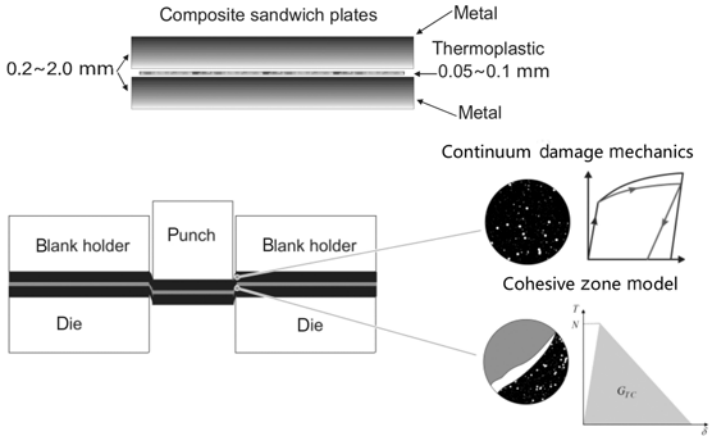
Funding	German Academic Exchange Service (DAAD)
Contact	M.Sc. L. Chen • C. Soyarslan, PhD

Project Description

In this project the focus is on investigations of failure mechanisms in forming of monolithic metallic and metal/polymer/metal sandwich plates. In the first phase, main concentration is devoted to the modeling of various processes using finite element analysis. The mechanical behavior of the metallic layers is characterized by finite strain rate-independent elasto-plasticity in which progressive material deterioration and ductile fracture are modeled using continuum damage mechanics (CDM). This material model is made accessible via implementations as VUMAT subroutines for ABAQUS/Explicit. Possible failure of the thermoplastic polymer which may lead to delamination of the metallic layers is modeled using ABAQUS built-in cohesive zone elements.

Current Results

Preliminary results show that the developed modeling approach can sufficiently model unintended failure modes, i.e. adhesive bond failure and failure of polymer layer under shear and tension.



Associated material models for forming of sandwich plates

3.7 Patents

3.7.1 Published Patents

Title **Method and Device for Incrementally Shaping Profiled Pipes, in Particular Profiled Pipes having Cross-Sections that vary over the Longitudinal Axis and Profiled Pipe of This Type**

Application Number	DE 10 2010 025 593 A1
Patentholder	TU Dortmund
Status	Published November 29, 2011
Inventors	C. Becker, M. Hermes, R. Wagner, A. E. Tekkaya

Title **Device and Process Principle for the Bending of Closed Tubes**

Application Number	DE 10 2011 118 763.8
Patentholder	TU Dortmund
Status	Priority Period ended on November 17, 2012
Inventors	A. Selvaggio, M. Hermes, A. E. Tekkaya

Title **Method for Producing Composite Parts by Means of a Combination of Deep Drawing and Impact Extrusion**

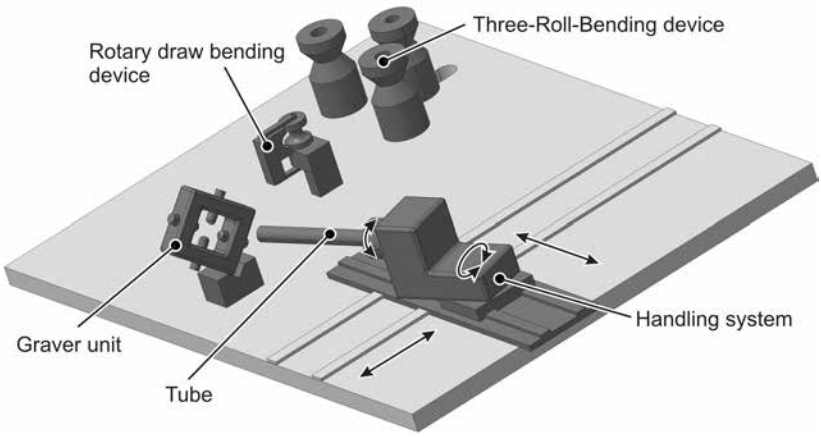
Application Number	PCT/DE2011/00001053
Patentholder	TU Dortmund
Status	Published November 15, 2012
Inventors	A. Jäger, S. Hänisch, S. Bröckerhoff, A. E. Tekkaya

3.7.2 Filed Patents

Process and Apparatus for Incremental Bending and Forming of Profiles, in Particular of Profiles with Varying Cross Sections along the Longitudinal Axis

Application number	PCT/DE2012/000327
Patent applicant	Technische Universität Dortmund
Status	Filed
Inventors	Dipl.-Ing. C. Becker
	Dr.-Ing. M. Hermes
	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

The patent application contains a process as well as an apparatus for the manufacture of bent structures with varying cross sections along the longitudinal axis. For these structures several processes and process chains exist at present. These process chains show a restricted flexibility during the manufacturing of the mentioned structures. Therefore, the described patent application enables the production of these structures within a single machine and production system.
An example of such a manufacturing device is shown in the figure below where several forming stations and processes are combined within one manufacturing system.

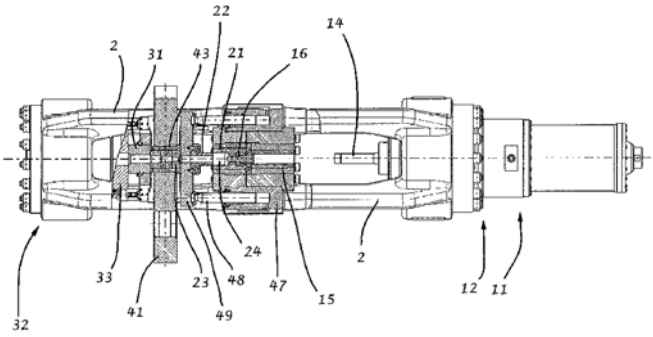


Manufacturing system for bent structures with varying cross sections

Extrusion Press and Method for Continuously Pressing Metal

Application number	PCT/DE2011/001698
Patent applicant	SMS Meer GmbH
Status	Filed
Inventors	Dipl.-Ing. U. Muschalik Dr.-Ing. N. Ben Khalifa Dipl.-Inf. A. Selvaggio Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

The invention relates to a continuously operating extrusion press for the extrusion of metals. In this context, the patent enables the manufacture of metallic profiles without dead times occuring during extrusion owing to the loading of the machine with new billets. Moreover, the patented extrusion press can be used for direct as well as for indirect extrusion of profiles. A schematic view of the extrusion press is shown in the following picture.

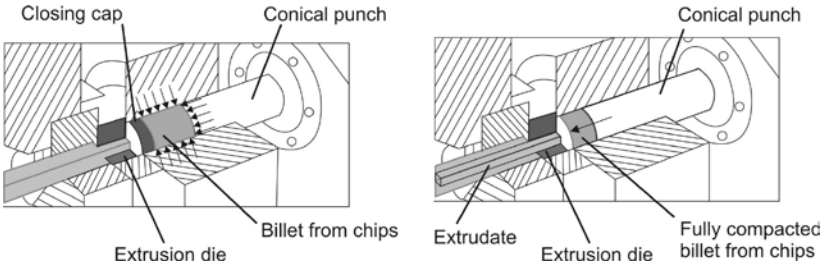


Schematic view of the extrusion press for continuously pressing metal

Set-up and Process for the Production of Non-Porous Profiles Made of Chips by Hot Extrusion

Application number	PCT/DE2012/000948
Patent applicant	Technische Universität Dortmund
Status	Filed
Inventors	M.Sc. V. Güley
	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya

The invention provides a new set-up with a new process design for the production of non-porous profiles hot extruded from chips. Previous to hot extrusion a closing cap is placed between the extrusion die and the container. In combination with a conical dummy block the chips billet is compacted to a dense billet. The conical shape of the dummy block leads to a different pressure distribution within the porous billet which provokes a release of the entrapped air from the core to the surface. Thus, almost fully compacted billets made of chips can be produced which can be extruded to profiles without air blisters.



Hot isostatic pressing of chips previous to hot extrusion and extrusion of fully compacted billet to profiles without air blisters

Further Activities

04

4 Further Activities

4.1 Conferences and Meetings

In 2012 the following conferences and workshops were hosted or co-organized by the Institute of Forming Technology and Lightweight Construction to present research results and to meet researchers from industry and universities.

- 15th Workshop “Simulation in Forming Technology“ • in cooperation with the Institute of Forming Technology, University of Stuttgart • venue: Vaihingen, Germany • February 23
- Conference „Energie- und Ressourceneffizienz in der Fertigungstechnik“ (conference on energy and resource efficiency in production engineering) • in cooperation with “DER INNOVATIONSSTANDORT“ and “In|Die Region Ruhr“ • venue: Dortmund, Germany • March 20
- 5th International Conference on High Speed Forming (ICHSF) • in cooperation with the Ohio State University • venue: Dortmund, Germany • April 24–26
- Meeting of WGP secretaries • in cooperation with the German Academic Society for Production Engineering (WGP) and the Institute of Machining Technology, TU Dortmund • venue: Dortmund, Germany • May 10–11
- “Innovationsforum Verfahrensintegration“ (expert forum on process integration) • in cooperation with the “Kunststoffinstitut Lüdenscheid“, City of Dortmund Economic Development Agency, and “Westfalenhallen Dortmund“ • venue: Dortmund, Germany • July 4–5
- German French Summer School • in cooperation with Dr. Tudor Balan, LEM 3, ENSAM Metz and Université franco-allemande • venue: Dortmund, Germany • September 3–7
- VDI-Fachforum „Kaltfließpressen” (expert forum on cold forging) • in cooperation with the The Association of German Engineers (VDI) • venue: Bad Vilbel, Germany • November 15–16
- IUL-GDA-Workshop • in cooperation with the “Gesamtverband der Aluminiumindustrie e. V.“ • venue: Düsseldorf, Germany • November 19

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 • April 26
- do-camp-ing 2012 • July 8–13
- Stahl fliegt (Flying steel) • July 11–12
- SchnupperUni • August 15
- IdeenPark 2012 • August 11–23
- Open Day of TU Dortmund • October 27

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

5th International Conference on High Speed Forming – ICHSF2012

From April 24–26, 2012, the 5th International Conference on High Speed Forming – ICHSF2012 was held at Dortmund U-Tower. The event was organized and hosted in cooperation with the Department of Materials Science and Engineering of the Ohio State University. More than 80 participants from 13 nations from industry and academics attended the event. In addition to the presentation of new research results regarding impulse forming, the event provided a forum for the exchange of experience and the discussion between industrial users and researchers on an international stage. Within the scope the conference an exhibition took place as well. This allowed the vendors of machines and measurement techniques for high speed forming processes the presentation of their latest products. The conference covered the process analysis of high speed forming and joining operations, the material characterization under high strain rates, the tool and machine development, the industrial applications for high speed forming processes as well as modeling and simulation of these processes.

Participants of the ICHSF2012

German French Summer School 2012

Hardening and Damage of Materials under Finite Deformation: Constitutive Modeling and Numerical Implementation

Each year many new alloys are introduced in metal working processes applied in the automotive and aerospace manufacturing industries. These alloys aim at combining conflicting properties such as lightness, strength, and hardness. An assessment of the formability, crashworthiness, and service life cannot be accomplished without a fundamental understanding of the complicated phenomena taking place in the underlying physics. Encouraged by this motivation, with the support of German French University, the German French Summer School on "Hardening and Damage of Materials under Finite Deformations: Constitutive Modeling and Numerical Implementation" took place in Dortmund from September 3 to 7, 2012, jointly organized by Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya of TU Dortmund and Dr. Tudor Balan of LEM3, ENSAM Metz. The speakers included Jacques Besson of Mines ParisTech, France, Rodrigue Desmorat of LMT Cachan, France, Anne-Marie Habraken of Université de Liège, Belgium, Dirk Helm of Fraunhofer IWM, Germany, Xavier Lemoine of ArcelorMittal Research, France, Andreas Menzel of TU Dortmund, Germany, Dirk Mohr of LMS, Ecole Polytechnique, France, Karl Roll of Daimler AG, Germany, Siegfried Schmauder of University of Stuttgart, Germany, and finally Fusahito Yoshida of Hiroshima University, Japan.

The Summer School was addressed to an international audience of doctoral students, postdoctoral researchers, and engineers from academia and industry with a background in mechanical engineering, civil engineering, or material sciences and with an interest in current state-of-the-art behavior of metallic materials under finite strains during forming as well as their experimental and computational applications. With more than 70 participants

Snapshot taken at the Summer School showing the female participants with Prof. Habraken

from nearly 20 countries all over the world, the summer school was a great success and received positive feedback from the participants.

IUL-GDA-Workshop

On November 19, a workshop was held in Düsseldorf in co-operation with the "Gesamtverband der Aluminiumindustrie e. V." (GDA). The participants of the workshop, i.e. representatives from the aluminum industry and their major customers, discussed pre-competitive main research regarding aluminum as material, its processing and application. 25 people in all from different companies took part. Before the discussion several OEMs from the automobile and rail vehicle industry held key-note presentations. Furthermore, one presentation about the challenges of corrosion during the application of aluminum parts was held by GDA. One result of the workshop is the creation of an overview comprising information on the topic of aluminum, making research activities in this field much more transparent.

4.2 Awards

Honorary Degree Awarded to Prof. Dr.-Ing. A. Erman Tekkaya

Prof. Dr.-Ing. A. Erman Tekkaya was awarded the honorary degree Doktor-Ingenieur Ehren halber (Dr.-Ing. E.h.) by the Faculty of Engineering of Friedrich-Alexander-Universität Erlangen-Nürnberg on Friday, October 19, 2012. Professor Tekkaya was presented with this honorary degree for his pioneer work in the field of numerical modeling of forming processes.
The award ceremony took place within the scope of a ceremonial act on the occasion of the 30th anniversary of the Department of Mechanical Engineering of Friedrich-Alexander-Universität Erlangen-Nürnberg.

Photo: Prof. Dr.-Ing. A. Erman Tekkaya is awarded the honorary degree Doktor-Ingenieur Ehren halber (Dr.-Ing. E.h.) of the Faculty of Engineering of Friedrich-Alexander-Universität Erlangen-Nürnberg by Prof. Dr.-Ing. habil. Marion Merklein, Dean of the Faculty of Engineering

Prof. Dr.-Ing. Dr. h.c. Kleiner nominated into INSA

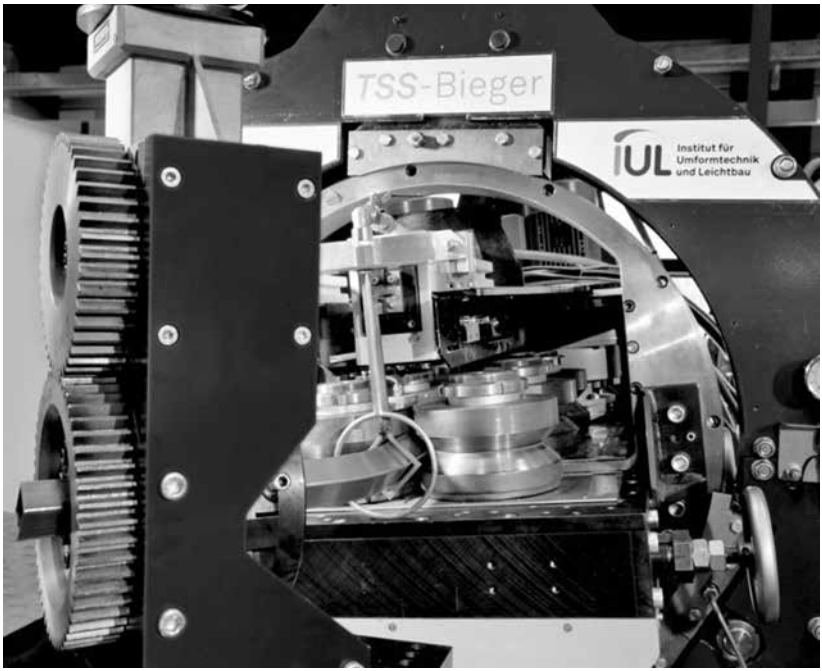
Prof. Kleiner has been admitted into Foreign Fellow of the National Science Academy (INSA) as Foreign Fellow. The Indian National Science Academy (founded in 1935 as "National Institute of Sciences of India") promotes science and its use in India. Since 1945 INSA is the major scientific institution of the country, representing all sciences of India in the world with the aim to support international cooperation between different national scientific representatives. Another main purpose is the promotion and award of excellent academic and technological performances.
INSA awards a large number of of academic prizes, publishes various journals, series (of papers) and monographs and organizes scientific symposia.

IUL receives "Stahl-Innovationspreis" 2012 (Steel Innovation Award) for project on three-dimensional profile bending with induction heating

The Steel Innovation Award was presented on June 27, 2012. 13 awardees, selected from a total of 658 applicants, received their awards from the event's patron Prof. Dr.-Ing. Wolfgang Reitzle, Chief Executive Officer of Linde AG, and Dr. Jost A. Massenberg, a member of the Executive Board of ThyssenKrupp Steel Europe AG and Chairman of the Steel Information Center. Daniel Staupendahl and Dr.-Ing. Matthias Hermes, both staff members of the Institute of Forming Technology and Lightweight Construction, received the second place in the category "Steel in research and development / Processes" for the new process combination three-dimensional bending and integrated hardening. This excellently rated project uses the high innovative potential of steel in an exemplary manner.

Daniel Staupendahl (second from left) and Dr.-Ing. Matthias Hermes at the Steel Innovation Award 2012 between patron, Prof. Dr.-Ing. Wolfgang Reitzle (left), and the Chairman of the Steel Information Center, Dr. Jost A. Massenberg

Due to increasing demands for lightweight design and safety thin-walled profiles made of high-strength steel gain increasing importance. Here, the adaption of profiles to the product requirements is crucial, e.g. by adaption of the wall thickness, the profile cross-section, or the material characteristics to the specific application. Additionally, the manufacturing of profile contours with complex bending lines is necessary to be able to produce aesthetical structural elements. By means the 3D-bending process "TSS Bending", which was developed at the IUL, the flexible manufacturing of these spatial structures is possible. Through the extension of the machine by an induction heating device and a flexible cooling device the mechanical properties of, for example, air-hardening steels can be specifically defined. The lower yield strength, occurring during the heating of the profiles, additionally opens up the possibility to bend steels which are usually hard to form.
The new process combination allows a drastically increased efficiency in the manufacturing of complex, load-optimized structures, e.g. cabin frames for utility vehicles or space frame structures in the automotive sector.



Three-dimensional profile bending with induction heating was awarded with the Steel Innovation Award 2012 (source: Steel Innovation Center)

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 ambassoador at TU Dortmund
- AGU – Member of “Wissenschaftliche Arbeitsgemeinschaft Umformtechnik“
- CIRP – Fellow of the “The International Academy for Production Engineering”
- DGM – Member of ”Deutsche Gesellschaft für Materialkunde“
- Honorary member of the “TechNet Alliance”
- ESAFORM – Member of the Scientific Committee of the “European Association for Material Forming”
- Founding director of the “Center of Excellence for Metal Forming”, Atilim University, Ankara, Turkey
- Guest professor at Shanghai Jiao Tong University, Shanghai, China
- GCFG – Member of the ”German Cold Forging Group”
- ICEB – Chairman of the “International Conference on Extrusion and Benchmark”
- ICFG – vice president of the “International Cold Forging Group”
- ICHSF – Chairman of the “5th International Conference on High-Speed Forming”, April 2012 in Dortmund, Germany
- ICTP – Member of the Standing Advisory Board of the “International Conference on Technology of Plasticity”
- ICTP – Member of the “Task force for investigating future plans of SAV of ICTP“
- I2FG –Vice chairman and founding chairman of the “International Impulse Forming Group”
- JSTP – Member of “The Japan Society for Technology of Plasticity”
- Curatorship member of “Karl-Kolle Stiftung“, Dortmund, Germany
- Member of the “International Scientific Advisory Council” of the “Institute of Mechanical Engineering” (IDMEC) and “Associated Laboratory for Energy, Transports, and Aeronautics” (LAETA), Lisbon, Portugal

- 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)
- Subject Editor for Forming, CIRPedia (Springer-Verlag)

Further Memberships

- DAAD Scholar Committee, Ankara, Turkey
- IUTAM – “Turkish Branch of the International Union of Theoretical and Applied Mechanics“, Turkey
- Member of the International Program Committee, “International Conference on Machine Design and Production 2014“ (16th UMTIK), Antalya, Turkey
- Member of the Scientific Committee, „The IDDRG 2013 Conference”, Zurich, Switzerland
- Member of the Scientific Committee, „The 15th International Conference on Sheet Metal” (SheMet 2013), Belfast, United Kingdom
- Member of the Scientific Committee, „The 11th International Conference on Numerical Methods in Industrial Forming Processes” (NUMIFORM 2013), Shanghai, China
- Organisator Mini-Symposium ESAFORM 2013, Aveiro, Portugal
- 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)
- CINECA, Ministero dell’Istruzione, dell’Università e della Ricerca, Italy
- DFG – German Research Foundation, Member of Fachkollegium 401 (Review Board on Production Engineering)
- ELSEVIER
- Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany
- ICAA 13, The 13th International Conference on Aluminum Alloys, 2012
- Industrieverband Massivumformung (IMU), Hagen, Germany
- Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
- Koc University, Istanbul, Turkey
- Norwegian University of Science and Technology (NTNU), Trondheim, Norway
- Ohio State University (OSU), Columbus (OH), USA
- Research Foundation Flanders (FWO), Belgium
- RWTH Aachen University, Aachen, Germany
- Springer UK
- Technical University of Denmark (DTU), Lyngby, Dänemark
- Chemnitz University of Technology, Chemnitz, Germany

For Journals

- ASME – Journal of Manufacturing Science and Engineering
- International Journals of Damage Mechanics
- International Journal of Machine Tools and Manufacture, Elsevier
- International Journal of Mechanical Sciences
- International Journal of Precision Engineering and Manufacturing, Springer
- Journal of Computational and Applied Mathematics, Elsevier
- Journal of Materials Processing Technology
- The International Journal of Advanced Manufacturing Technology, Springer

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

- Academia Europaea
- acatech – German Academy of Science and Engineering
- AGU – Wissenschaftliche Arbeitsgemeinschaft Umformtechnik
- AiF – German Federation of Industrial Research Associations (Curatorship Member)
- Berlin-Brandenburgische Akademie der Wissenschaften
- Advisor of ALHO Group
- Adviser of Siepmann Group
- Adviser of Winkelmann Group
- CIRP – The International Academy for Production Engineering
- German Academy of Sciences Leopoldina
- European Academy of Sciences and Arts (Member)
- FOSTA - Research Association for Steel Application (Curatorship Member)
- INSA – Indian National Science Academy
- Deutsche Telekom Stiftung (Curatorship Member)
- LOEWE Program (Member of the Advisory Board)
- SATW – Swiss Academy of Engineering Sciences (Member)
- Steel Institute VDEh
- VDI – The Association of German Engineers
- Stifterverband für die Deutsche Wissenschaft (Ex Officio Member of the Executive Board)
- WGP – German Academic Society for Production Engineering

Visiting Researchers

05

5 Visiting Researchers at the IUL

Mercator Visiting Professor Wojciech Z. Misiolek

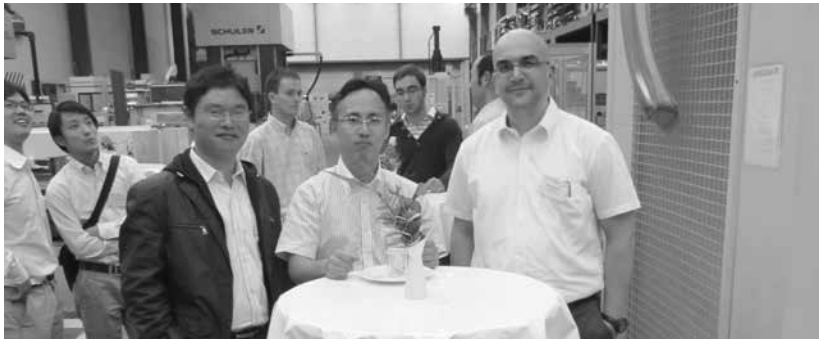
Wojciech Z. Misiolek, the Loewy Professor of Materials Forming and Processing from Lehigh University in Bethlehem, PA, USA, spent half a year at IUL (until January 2012), supported by the DFG as a Mercator Visiting Professor. He did close collaborate research work with the IUL research staff and with graduate students and advised PhD candidates.
On the teaching front he was involved in launching the international M.S. program in manufacturing technology (MMT). He helped preparing class lectures and taught selected classes in metal forming.
The Mercator professorship gave Professor Misiolek the opportunity to give presentations in Germany and other European countries about his use of numerical modeling packages and microstructure characterization to refine and control metal forming processes.
Misiolek gave the keynote address at the 10th International Conference on Technology of Plasticity (ICTP) in Aachen, Germany, in September 2011, focussed on modeling of microstructure response to deformation parameters in selected metal forming processes. In October 2011, he gave a plenary lecture at the Fourth International Conference on Extrusion and Benchmark in Bologna (ICEB), Italy, on numerical modeling of extrusion welding in magnesium alloys.
He also gave a series of research seminars to his colleagues at Technische Universität Dormund, at the AGH - University of Science and Technology in Krakow, Poland, his alma mater, and others.

Dr. Francesco Gagliardi

Dr. Francesco Gagliardi, scientist at the University of Calabria, Italy, visited the IUL from November 1, 2011 until October 31, 2012. The research stay was organized within the scope of the Collaborative Research Center SFB/TR 10. A focus of his work was on the analysis of the influence of the tool design on the state variables and process parameters during aluminum extrusion. Numerical process simulations were used to gain new information, for example with regard to the relation between the feeder geometry and the resulting stress states in the welding chamber of porthole dies. Furthermore, Dr. Gagliardi carried out experimental tests with newly developed tool components. The work was conducted in close cooperation with subproject B1 (TR 10). The professional exchange with other subprojects was stimulated by visits of research group meetings.

Dr. Xincun Zhuang

During his stay as visiting researcher at the IUL from April 15 until October 15, 2012, Dr. Xincun Zhuang of the Institute of Forming Technology & Equipment, Shanghai Jiao Tong University, China, has closely collaborated with the Department of Applied Mechanics in Forming Technologies (AMU). This collaboration focused on the topic of "damage accumulation and fracture prediction in shearing and blanking of metal sheets using shear-enhanced damage models". As an outcome of this collaboration, novel experimental techniques for the detection of low to vanishing triaxialities for steel sheets were developed. This is crucial especially for a proper simulation of blanking processes, relying on extensive simulative efforts and devising advanced material models.



Dr. Takahiro Ishiguro

During the second part of his research stay at the IUL from June 4, 2012 until March 29, 2013, Dr. Takahiro Ishiguro of Nagoya University, Japan, has closely collaborated with the Department of Applied Mechanics in Forming Technologies (AMU). This collaboration has focused on the topic of "FE analysis of single-side piercing processes for hollow forging products". In the course of his stay as visiting researcher material characterization studies are extended for Lode parameter dependent fracture criteria where a new experimental methodology, which aims at fracture development for a wide range of triaxiality ratios and Lode parameters, is developed.
Based on these experimental findings, the fracture parameters of the material are found using an inverse parameter identification framework, developed by the AMU. To this end, the outcomes are used in FE analyses of single-side piercing processes for hollow forging products and promising results are expected.

Dr. Yuji Kume

Between October 08th and December 06th, Dr. Yuji Kume was a visiting researcher at the IUL. Dr. Kume is Assistant Professor of the research group of Prof. Naoyuki Kanetake at Nagoya University (Japan). He is engaged in the development of new severe plastic deformation processes (SPD) and he is investigating metal foams and metal matrix composites. Dr. Kume exchanged experiences with researchers of the IUL, among other things on the recycling of metal chips by metal forming.
Dr. Kume used his stay to get a broader insight into the German research landscape. He attended several trade shows and traveled for short visits to manufacturing engineering research institutions at the universities of Aachen, Bremen, and Paderborn.

M.Eng. Dan Cooper

Within the scope of the cooperation with Dr. Julian M. Allwood, head of the „Low Carbon and Materials Processing Group", Department of Engineering, University of Cambridge, Mr. Dan Cooper visited the IUL in April 2012. Together with IUL staff members of the bulk forming group he investigated the production of profiles for decorative applications by hot extrusion of aluminum chips. The results are included in the project WellMet 2050, a study on novel methods of meeting global carbon emission targets for steel and aluminum processing funded by the British government.

M.Sc. Zhenming Yue

In this second visiting period of his research, joint doctoral student, Mr. Zhenming Yue, who is financed by the CSC (Chinese scholarship committee), continued his thesis studies on the topic of damage prediction in sheet metal forming. The aim at this stage was the development of a unified hybrid experimental-numerical methodology for plasticity and damage parameter identification for advanced high-strength steel as well as aluminum sheets.

Matej Hudovernik, univ.dipl.inž

Matej Hudovernik is a doctorate student of the Faculty of Mechanical Engineering, University of Ljubljana, currently working at the Slovenian Tool and Die Development Centre - TECOS in Celje, Slovenia. Following his two and a half months stay in 2011, Matej Hudovernik has spent a period of 8 months as a guest researcher at the IUL in 2012, focusing on the improvement of work regarding his research topic in the ProTuBend project and the numerical investigation of the TSS bending process. In this period he also performed experimental investigations needed for further improvement in cooperation with Daniel Staupendahl and worked on validating and optimizing his present work. He is expected to perform additional experimental work needed for the optimization and finalization of his work in the spring of 2013.

M.Sc. Anupam Vivek

Anupam Vivek, a graduate student from the Department of Materials Science and Engineering of the Ohio State University, was a visiting researcher at the IUL in May 2012 for one month. During his stay in Dortmund, Mr. Vivek worked on forming and joining by wire vaporization. In this impulse forming process, thin metal conductors are vaporized by very high electrical currents. The resulting plasma generates a shockwave, which is used for the forming operation. The stay of Anupam Vivek was financed by the DFG collaborative research center Transregio 10.

RISE (Research Internships in Science and Engineering)

Andrew Daehn

The RISE program of the German Academic Exchange Service (DAAD) offers students from North America and Great Britain the opportunity of a 2 to 3 month internship in Germany. The program gives students from natural science, engineering and social science are given the opportunity to work in an academic or an industrial research group. From June to August 2012, Andrew Daehn from the Ohio State University, Columbus, Ohio, USA, was at the IUL as a RISE scholar. Under the supervision of Christian Weddeling, he was engaged in experimental investigation regarding joining of lightweight frame structures by magnetic pulse welding. The stay of Andrew Daehn was financed by a stipend collectively funded by the DAAD and the DFG collaborative research center Transregio 10.

Richard Bowman

In the frame of the „International Summer Program“, Mr. Richard Bowman of the University of Virginia (USA) did a six-week internship at the IUL. Besides producing different kinds of tools, Mr. Bowman helped the IUL researchers in experimental investigations.

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

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

- Large volume SEM, Mira XI by Visitec (in cooperation with the “Institut für Spanende Fertigung” and “Lehrstuhl für Werkstofftechnologie, TU Dortmund)
- 3D-coordinate measurement machine, Zeiss PRISMO VAST 5 HTG (in cooperation with the “Institut für Spanende Fertigung”, TU Dortmund)
- 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, 2 x Aramis – optical measuring systems for geometry and strains
- High-speed camera, HSFC pro of the company PCO Computer Optics GmbH
- Light optical microscope AxioImager.M1m adapted for polarization, Zeiss AG
- Laser Surface Velocimeter (LSV): non-contact velocity measurement
- 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, solution 2358 x 1728 pixel
- ARAMIS 4M, GOM, optical 3D-deforming analysis

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 2012 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 2012 which have added to our joint success.

Ausgewählte Kooperationen im universitären Bereich | Selected university cooperations

Kooperationen auf nationaler Ebene | University cooperations at national level

- Fachgebiet Maschinenelemente, Technische Universität Dortmund
- Fachgebiet Werkstoffprüftechnik, Technische Universität Dortmund
- 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
- Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg
- Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, IWU, Technische Universität Chemnitz
- 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 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 Betriebswissenschaften, Technische Universität München
- Labor für Fahrwerktechnik, Hochschule Osnabrück
- 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

Kooperationen auf internationaler Ebene | University cooperations at international level

- Abdelmalek Essaâdi University (UAE), (Martil) Tetuon-Tanger, Morocco
- Charles Delaunay Institute, Labarotoire des Systèmes Mécaniqueset d'ingénierie Simultanée (LASMIS), Université de Technologie deTroyes, France
- Department of Industrial Engineering, Università degli Studi di Palermo, Italy
- 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, 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
- Jiao Tong University, Shanghai, China
- 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
- Metal Forming Center of Excellence, Atilim Universitesi, Ankara, Turkey
- Nagoya University, Nagoya, Japan
- Royal Institute of Technology KTH, Department of Production Engineering, Stockholm, Sweden
- School of Materials Science & Engineering and the Department of Plasticity Forming Engineering, Shanghai Jiao Tong University, China
- 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
- 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
- ESI GmbH
- F.W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Faurecia Group
- Forschungsvereinigung Stahlanwendung e. V.
- Franz Pauli GmbH & Co. KG
- Grundfos GmbH
- HELLA KGaA Hueck & Co.
- Hirschvogel Umformtechnik GmbH
- Hüttinger Elektronik GmbH & Co. KG
- Hydro Aluminium Deutschland GmbH
- INPRO GmbH
- 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
- 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
- SMS Meer GmbH
- Société Tuniesienne des filtres (MISFAT), Jedeida, Tunesia
- Sparkasse Dortmund
- SSAB Swedish Steel GmbH
- SSAB Tunnplåt 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
- Wilke Werkzeugbau GmbH & Co. KG
- WILO SE
- Zentrum für BrennstoffzellenTechnik GmbH

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.
- 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

Zeitschriftenbeiträge | For Journals

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2012 ausgeschieden | Staff who left in 2012

Prof. Dr.-Ing. Alexander Brosius

Dr.-Ing. Tim Cwiekala

M.Sc. Volker Franzen

M.Sc. Mohammad M. Gharbi

Roger Giertulla

M.Sc. Volkan Güley

Dr.-Ing. Jörg Kolbe
zum 31.12.2012 ausgeschieden
left as of Dec. 31st, 2012

Dipl.-Ing. Arthur Wawrosch

Ulrich Wornalkiewicz