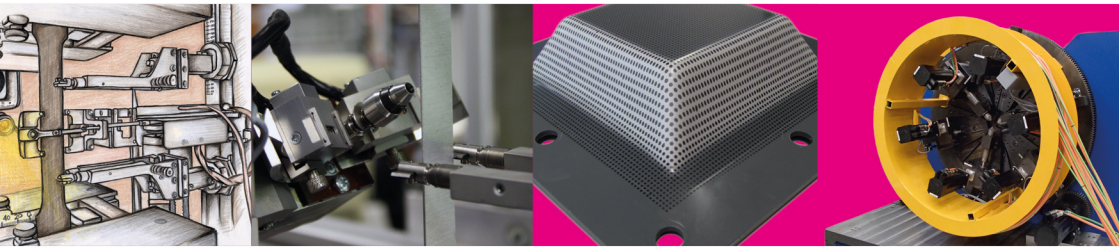
Institute of
Forming Technology and
Lightweight Construction

Activity Report

13



technische universität
dortmund

Institut für
Umformtechnik
und Leichtbau

Activity Report

13

technische universität
dortmund

Imprint

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Editorial

Preface

Dear Readers,
Dear Friends of the IUL,

Beginnings and endings mark our academic proceedings, and our research passes through different phases of preparation, realization, and conclusion. Thus, we welcome and say goodbye to young colleagues who start their career at the Institute of Forming Technology and Lightweight Construction and move on to research and development departments and industry. We start research projects looking for insight along the way and anticipating answers in the end. Events which we plan and participate in, cooperation we establish, and machines we newly put into operation are also parts of our scientific course of things.

Again, we look back on a dynamic and eventful year. 2013 has brought special highlights as well as continual phases of work and progress. It is great for us to see that the IUL is part of a growing circle of reliable partners and friends far beyond specific occasions. Hence, every meeting with our colleagues serving scientific exchange and dialogue is special to us:

For example, the 16th Workshop "Simulation in Forming Technology", hosted by the IUL in April offered once again the opportunity to discuss recent developments. This forum gathered contributions of sheet metal forming and bulk metal forming and its focus on simulation addressed a topic which is not only highly relevant to production engineering but even initiates interesting changes and many new opportunities.

The International Conference on Extrusion and Benchmark (ICEB) in Dortmund may count as another highlight in 2013. The conference is organized every two years alternately in Bologna and Dortmund. It aims at presenting the latest state of technology, innovation, and simulation of bar extrusion of light metal alloys, defining guidelines for process analysis and optimization of products, making accessible the potentials of recent simulation software and providing exhaustive information on simulation of bar extrusion. 105 participants from 16 nations attended the conference this year.

In preparation for the Extrusion Benchmark, the IUL conducted bar extrusion experiments under predefined conditions, employing a specially developed compression mold with extensive measuring techniques. Software developers

and users from universities and industry were invited to model and compute the forming process. The previously unpublished test results have been contrasted with the simulation results and discussed at the ICEB 2013. The Extrusion Benchmark 2013 was kindly supported by the German Academic Exchange Service (DAAD).

Our new acquisitions, too, mark the beginning of the developments of innovative processes and products adding to secure Germany's advance in production engineering research:
Our new servo press forms sheets to the desired complex shapes quickly and in large quantities. A machine for incremental tube forming (IRU), especially developed at the IUL, enriches our technical equipment and enables us to produce almost any type of bent tubes with variable cross sections made of high-strength materials. Our new machine for sheet-bulk metal forming is unique with its five controllable axes and allows innovative experiments. Another novelty is the tele-operative test cell which our students can use to conduct material characterization experiments virtually and on their own without having to be present in the testing field. They can conduct the material testing via the internet.

The tele-operative test cell celebrated its premiere in October during the lecture "Fundamentals in Forming Technology. Together with A. Erman Tekkaya the students configured a tensile test in the lecture hall. The test was started by remote-interface; four HD-cameras transferred the robot placing the material. Moreover, the measured data was provided in real-time during the test and could be assessed and analyzed subsequently. Shortly, it will be possible for students to independently plan, conduct, and analyze experiments with their tablet pc, smartphone and at home – their feedback was enthusiastic and an acknowledgement for our work.

The network GDA Lightweight Construction originates in by the Collaborative Research Center/Transregio 10 "Integration of Forming, Cutting, and Joining for the Manufacture of Lightweight Frame Structures", which is now in its third funding period. It has set its goal on gathering information on research projects which deal with the development of aluminum lightweight structures and, furthermore, on becoming an interface between aluminum industries and university research departments. Therefore, the IUL cooperates closely with the Association of the Aluminum Industry (GDA). The associated online plat-

form provides information on research activities which refer to lightweight structures made of metallic lightweight materials and have been funded by the Federal Ministry of Education and Research (BMBF), the Alliance Industrial Research (AiF), or the German Research Foundation (DFG), starting in the year 2000. Such a forum supports our conviction of how important the transfer of our results towards application and testing really is.

In a similar way, the DGM Regional Forum for Materials is an outstanding institution which opens a fruitful dialogue to our matters of research. Our participation in activities like this proves the IUL's position "in the middle of it all" and how important dynamic communication and cooperation is for science and research.

Our collaboration with the large-scale company Faurecia in France sets a good example: In 2012, we decided to establish a research center for the advancement and development of technologies for the production of vehicle components. Officially founded in January 2013, the opening of the Research Center for Industrial Metal Forming has been celebrated in April. Since then, a number of ideas have jointly been generated and specified with the Faurecia departments of Technologies for Emission Control (FECT) and Car Seats (FAS). Thus, these interesting and fascinating research topics provide for a full perspective in the coming years of our cooperation.

Our students are part of our academic circuits as well: We accompany them on their promising ways for a little while only. This year, the first students have successfully finished their Master of Manufacturing Technology (MMT), and we are overwhelmed by the positive response of the industry. In all probability, some of these highly talented graduates will stay with us and contribute to Germany staying a location for sciences and industry. Thus, together we reach our ambitious goal: The challenging studies in English language optimally prepare graduates for the integration in national and international networks and enable them to apply theoretical contents in innovative and responsible engineering contexts.

In the course of time, dolorous losses overshadow our lives. This year, we had to say goodbye to two colleagues who have contributed tremendously to forming and production engineering – nationally as well as globally.

Günter Spur, one of the most distinguished engineering scientists worldwide, died on August 20th suddenly and unexpected during the CIRP General Assembly in Copenhagen at the age of 84. He held an honorary doctor's degree of the Faculty of Mechanical Engineering at TU Dortmund University whose development he had accompanied vividly.

Günter Spur followed a holistic vision of production engineering. His innovative ideas of production engineering considered transport, resources, mobility, ecological protection, and health issues at a very early stage. It is this farsightedness and our ties of friendship which will make us remember Günter Spur as we continue the development of our research at the IUL.

Dieter Schmoeckel established the Institute of Forming Technology at TU Darmstadt University and was its director from 1976 until 1998. He promoted production engineering essentially and rendered outstanding services to the education of the scientific offspring. He was also one of our partners in the "Arbeitsgemeinschaft Umformtechnik" (AGU), a working group specialized on forming technology. Dieter Schmoeckel died on October 26th, 2013 at the age of 82.

Both colleagues will be missed by the scientific community and it is only a small comfort to know that their approved knowledge will be preserved and pave the way in new contexts.

Excitedly, we anticipate moving in into our new building which has been built just near our previous location on the South Campus. Its light and airy rooms will certainly inspire our work additionally! In the first months of 2014 we will move in - you are, of course, welcome, dear readers, to our new premises!

As glad as we were when Matthias Kleiner returned to the IUL, we now already have to prepare to doing without his continuous presence again: After the rotational resignation from his office as President of the German Research Foundation (DFG) for which he held responsible from 2007 until 2012, Matthias Kleiner has been elected to become the next President of the Leibniz Association in November – after only eleven months back with us in Dortmund. The Leibniz Association connects 89 independent research institutions and museums, covering all branches of science and employing some 17.000 staff members. We congratulate Matthias Kleiner and wish him all the best for his new office which he will assume in the summer of 2014.

Last but not least we say: Thank you! – To our staff at the IUL. Our co-workers have done wonderful work, untiringly accomplished tasks and brought in new ideas and enthusiasm. Thank you! – We say to our partners in research, industry, to our supporters and promoters, to all scientists and colleagues who have been our guests, who exchange ideas with us and contribute to our work and accompany our steps. We look forward to 2014!

Matthias Kleiner

A. Erman Tekkaya

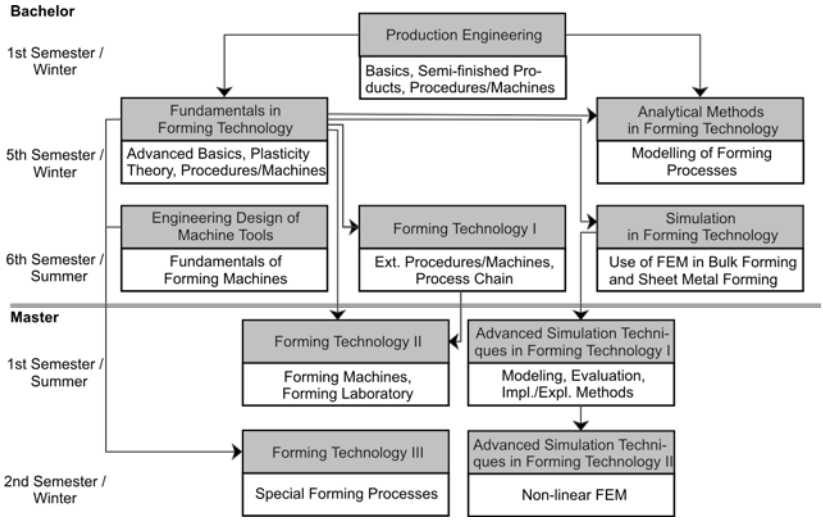
Education

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.



Structure of lectures e.g. of the study program mechanical engineering with specialization in 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
- MMT IV – From Sheet Metal to Automotive Components
- MMT V – Material Testing at Strain Rates of 10-6 s-1 to 106 s-1

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

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

As an English language, four-semester master study program in the field of manufacturing technology, the MMT aims at qualifying excellent graduates from renowned national and foreign universities to become outstanding, internationally sought-after experts in this field.
Industrial partners of TU Dortmund University support selected students by granting scholarships for the duration of their studies.

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.	

The number of excellent applicants from diverse countries is growing from year to year. In 2013 we counted 387 (compared to 280 last year, and 67 in 2011).
To create a stimulating learning atmosphere, the diversity and internationality of the student group shall be maintained. For this reason, a country quota was applied during applicant selection this year for the first time. In this way, not more than 30% of the admitted students come from the same country. Furthermore, the high quality of education is ensured through continuous evaluation and immediate implementation of the results. Keeping the learning groups small had similarly advantageous effects. Not more than 30 students are admitted to enroll in the MMT program every year.

The new MMT students are introduced to the IUL experimental field on the occasion of a Welcome Brunch.

Systematic extracurricular social activities among students contribute to the development of valuable soft skills. Joint activities, also with German students, foster mutual understanding and encourage students to reflect their own ways of acting and thinking – a relevant precondition for successfully working in international teams in future. Second-year students take responsibility in acting as official student advisors to the newcomers making it easier for them to settle in their new surroundings and become familiar with the foreign, German higher education culture.

Active relationship care, e.g. in the frame of joint activities, and mutual help foster the ability to communicate and co-operate.

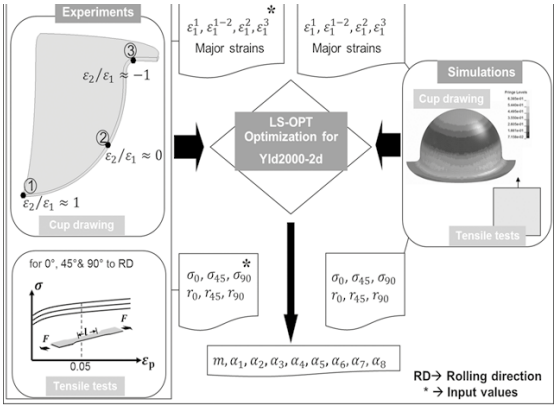
We are proud to be able to congratulate the first graduates this year. Renowned industrial companies offer MMT students the opportunity to prepare their master thesis with them. The confidence was rewarded and we appreciate the excellent work, that was accomplished. We can say that the concept of the program turned out to be a full success. Our industrial partners have expressed an increased interest in employing further master thesis students or, now also, graduates of this program. In turn, new fields for co-operation have been opened for the IUL.

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

1.3 Doctoral Theses

Aydin, Mustafa Seckin	Efficient Parameter Characterization for Hardening and Yield Locus Models for Sheet Metals
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2013
Oral exam	June 21, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing. E. h. A. E. Tekkaya Prof. Dr.-Ing. M. Liewald MBA (University of Stuttgart)
Co-examiner	Prof. Dr.-Ing. J. Mosler

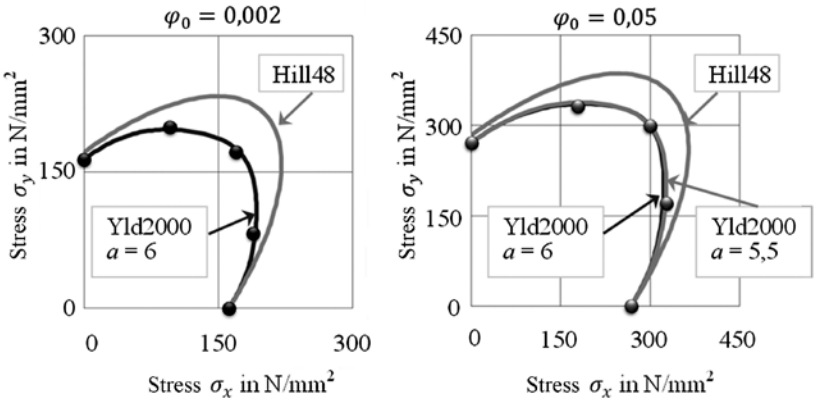
Three inverse methods based on the findings of this work with regard to strain rates, hardening and yield locus shape are proposed to determine constitutive parameters of advanced phenomenological models. The first methodology allows extrapolation of the uniaxial tensile flow curve for strains beyond the material specific uniform elongation using only uniaxial tensile test data. Strain rate modeling is an important issue when applying this technique. The second method requires cup drawing and uniaxial tensile tests to fit yield loci like Yld2000-2d including a total of nine material coefficients. Through major strains measured on a cup drawn via a hemi-spherical punch, equi-biaxial, plane strain and shear stress zones of a yield locus are optimized. The third method can also be employed for 9-parameter yield loci by exploiting uniaxial tensile and plane strain tension tests. In this case, equi-biaxial flow stress is approximated from the uniaxial tensile hardening curve in terms of the correlations accepted for low and high r-value steels.



Cup drawing test via a hemispherical punch and obtained strain modes

Canpolat, Aykut	Experimental and Numerical Evaluation of Yield Locus Determination by Means of Cruciform Tests
Original title	Experimentelle und numerische Bewertung der Fließortbestimmung mittels Kreuzzugversuch
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2013
Oral exam	June 26, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing E. h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. K. Roll (previously Daimler) Jun.-Prof. B. Kiefer, PhD

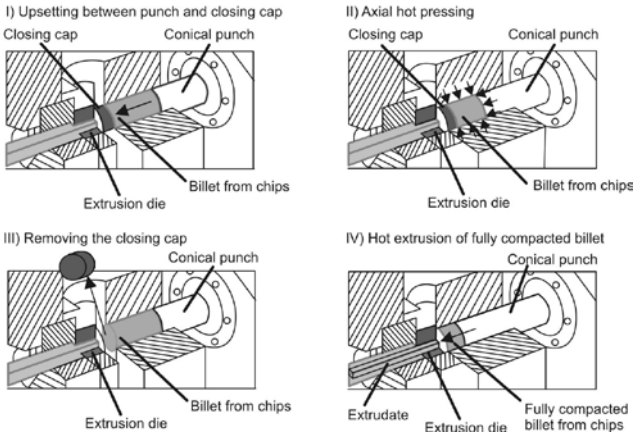
This thesis presents a fundamental investigation of the cruciform test with different sample geometries and, on the basis of this, an investigation of yield locus shapes for five deep drawing grades. Biaxial cruciform tests with different geometries are compared with the hydraulic bulge and a plane strain test. Here one design provides similar results to the reference experiments. The tested materials reveal a differential work hardening effect with ongoing straining. For all materials, except one, a saturation state is reached, whereupon the yield locus evolution is isotropic. Higher strain rates lead to yield points at higher stresses and the effect is likewise for all stresspaths. The last chapter deals with the simulation of a deepdrawn body part. The outcome of this investigation may contribute some ideas for a calibration of yield locus models to increase the accuracy of numerical simulations.



Yield locus and FOK according to Hill48 and Yld2000 for DX53D+Z

Güley, Volkan	Recycling of Aluminum Chips by Hot Extrusion
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	September 26, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
	Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr. W. Z. Misiolek (Lehigh University)
	Dr. J. M. Allwood (University of Cambridge)

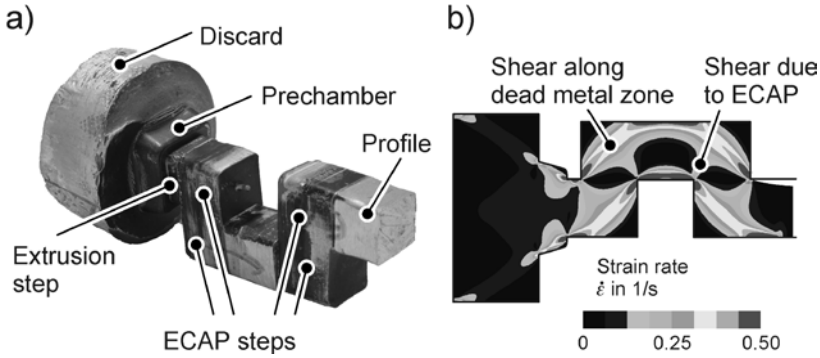
Recycling of aluminum chips by hot extrusion is a metal forming technique, which requires considerably less energy than conventional recycling by re-melting. In this thesis, first the effect of extrusion process parameters on the microstructure and mechanical properties of the profiles recycled from chips was investigated. The mechanism of chip welding during aluminum extrusion was studied based on analysis of the microstructural evolution. Based on the analytical solutions for the problem of longitudinal seam weld formation, a new approach was developed to analyze the welding of the aluminum chips. The boundary conditions for sound chip welding could be defined using the proposed analytical approach as well as with the help of simulations using the finite element method (FEM). A welding-quality-index (WQI) was introduced to define the chip welding quality under given process conditions, which can be used to quantitatively evaluate the success of recycling aluminum chips by hot extrusion. An innovative process design utilizing a closing cap and a new punch design was developed to eliminate the formation of air blisters during hot extrusion of chips.



A new extrusion process design to prevent the formation of air blisters

Haase, Matthias	Chip Extrusion with Integrated Equal Channel Angular Pressing
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	December 11, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya Prof. Dr. W. Misiolek (Lehigh University)
Co-examiner	Prof. Dr.-Ing. habil. F. Walther

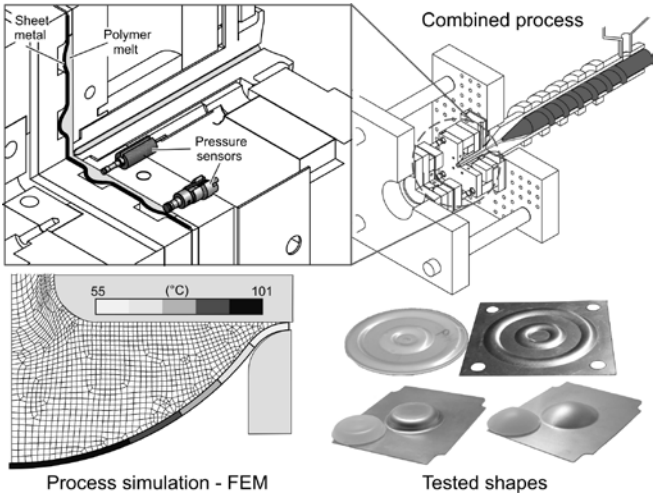
The direct conversion of aluminum alloy machining chips into finished or semi-finished products by hot extrusion is a promising approach to improve the energy balance of the aluminum recycling process, as the energy intense remelting of the material can be avoided. In this thesis, the process of hot extrusion with integrated equal channel angular pressing (iECAP) was adapted for the processing of aluminum alloy machining chips. By using the adapted iECAP die instead of conventional hot extrusion dies for the chip extrusion process, the amount of shear, strain and pressure affecting the material during extrusion was increased. This resulted in an improved chip bonding quality and, therefore, in improved mechanical properties of the chip-based aluminum extrudates.



Chip extrusion with integrated equal channel angular pressing (iECAP: a) iECAP die, b) Material flow in the die

Hussain, Muhammad Masood	Polymer Injection Sheet Metal Forming-Experiments and Modeling
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2013
Oral exam	April 08, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya Prof. Dr.-Ing. Dr. h.c. M. Kleiner
Co-examiner	Prof. Dr.-Ing. B. A. Behrens (Leibniz Universität Hannover)

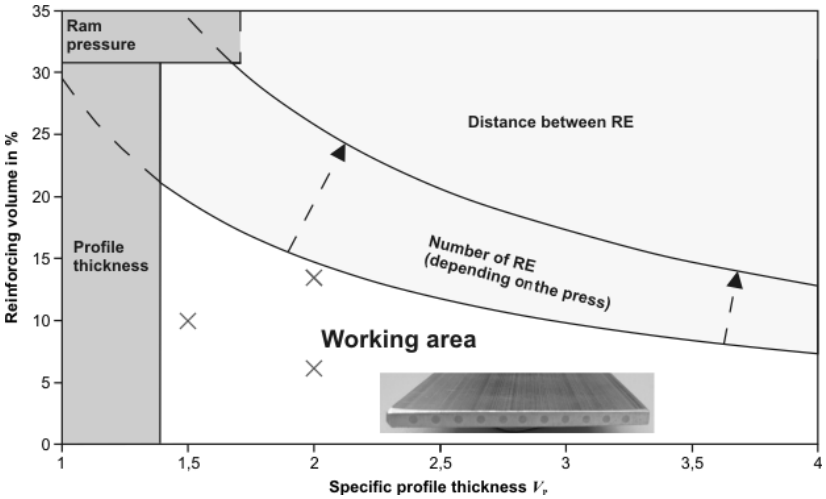
Polymer Injection Forming (PIF) is a new production technique to manufacture plastic-metal hybrid components using injected polymer melt as a pressure medium. Tests are performed for three different forming shapes. For this, injection mold has been developed and integrated with sensors. The forming results indicate the presence of the non-uniform pressure and temperature distribution. The thickness of the flow channel has a decisive influence on the forming pressure distribution. A new FEM simulation approach is proposed which offers multi-physics modeling by a single simulation code. The key is to treat the flow field of the melt as a Lagrangian field. The non-Newtonian behavior of the melt is modeled through viscoplastic relations. The simulation model is validated over the local and temporal domain. The simulation results are generally in good agreement with the experimental results.



Polymer Injection Sheet Metal Forming - Experiments and Modeling

Pietzka, Daniel	Enhancement of the Composite Extrusion Process to High Reinforcing Volume and Functional Compounds
Original title	Erweiterung des Verbundstrangpressens zu höheren Verstärkungsanteilen und funktionalen Verbunden
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2014
Oral exam	October 10, 2013
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr. P. Hora (ETH Zurich) Prof. Dr.-Ing. Dr. h.c. M. Kleiner

A promising way for the manufacture of endless reinforced aluminum profiles for lightweight applications is the composite process. The major aim of the thesis is the understanding of the extrusion process depending on the reinforcing volume. To achieve this, the effect of the reinforcements on the material flow and the occurring ram forces was analyzed. In further steps, extrusion dies to enhance the variety of producible reinforced profile cross-sections were developed. In that context, the general influence of the die design on the ram force was regarded. The process limits and a process window for the maximum reinforcing volume were determined. To enlarge the profile properties and reach a higher flexibility, investigations for the embedding of functional elements, like isolated electrical conductors, were done.



Process window for the composite extrusion with continous reinforcing elements

1.4 Completed Master's Theses

Anjami, Nassir
Supervisor: Tekkaya, A. E. • Kloppenborg, T.
Parameter-study of warm forging of bevel gears on automatic horizontal multi-station press by FEM

Bhat, Prabhat Ranjan
Supervisor: Tekkaya, A. E. • Demir, O. K.
Increasing the forming limits using the combination of deep drawing and electromagnetic forming to achieve sharp corner radius

Dahnke, Christoph
Supervisor: Tekkaya, A. E. • Selvaggio, A.
Design and experimental investigation of a hydraulic drive for the extrusion of profiles with variable wall thicknesses
Original title: Konstruktion und experimentelle Untersuchung eines hydraulischen Antriebs für das Strangpressen von Profilen mit variablen Wandstärken

Löbbe, Christian
Supervisor: Tekkaya, A. E. • Gies, S.
Investigations on the thermal loads in electromagnetic forming
Original title: Untersuchung des thermischen Belastungskollektivs bei der elektromagnetischen Umformung

Morales San Juan, Alberto
Supervisor: Tekkaya, A. E. • Sadiki, A. • Pleul, C.
Robot Simulation for Eduactional Purposes

Ni, Junyan
Supervisor:Tekkaya, A. E. • Thesing, T. (Hella) • Isik,K. • Soyarslan, C.
Implementation of forming and fracture simulation of sheet metal parts in ABAQUS

Sözumert, Emrah
Supervisor: Tekkaya, A. E. • Hackl, K. (RUB) • Hoppe, U. (RUB) • Isik, K. • Soyarslan C.
Numerical investigation of tube forming processes using damage coupled plasticity

Weiß, Simone
Supervisor: Tekkaya, A. E. • Bensing, D. (GEA) • Hermes, M.
Development of a corrosion specification for air cooled condensation units
Original title: Erstellung einer Standard-Korrosionsschutzspezifikation für luftgekühlte Kondensationsanlagen im weltweiten Anlagenbau

1.5 Completed Diploma Theses

Ansenjo, Beatriz Ania
Supervisor: Tekkaya, A. E. • Gies, S.
Effect of coil winding geometry on weld seam formation in magnetic pulse welding by tube expansion.

Dang, Thai
Supervisor: Tekkaya, A. E. • Kronholz, C. (Benteler) • Roth, I. (Benteler)
Yin, Q.
Determination of forming limit for steel tubes by using damage mechanics
Original title: Bestimmung der Umformgrenzen von Stahlrohren unter Anwendung der Schädigungsmechanik

Dogan, Murat
Supervisor: Tekkaya, A. E. • Alkas Yonan, S.
Experimental and numerical Analysis of incremental Forming of metal-thermoplastic sandwich panels
Original title: Experimentelle und numerische Analyse der inkrementellen Umformung von Metall-Thermoplast-Sandwichplatten

Hilbig, Timo
Supervisor: Tekkaya, A. E. • Pleul, C. • Ortelt, T. R.
Conception and development for the automation of a Sheet Metal Testing Machine in interaction with a robot.
Original title: Konzeptionierung und Entwicklung der Automatisierung einer Blechumformprüfmaschine in Interaktion mit einem Industrieroboter

Kadifeoglu, Gökay Ahmet
Supervisor: Tekkaya, A. E. • Fuchs, D. (GEA) • Isik, K.
The Stiffness Comparison of Finned Tube Bundle in Different Temperatures to Enhance Existing Fin Geometry using FEM
Original title: Der Steifigkeitsvergleich des Rippenrohrbündels in unterschiedlichen Temperaturen zur Weiterentwicklung der bestehenden Rippengeometrie mittels der Finite-Element-Methode

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

Levin, Eilina
Supervisor: Tekkaya, A. E. • Foydl, A.
Experimental investigation of composite extrusion of discontinuously non-centric positioned reinforcing elements by using the round bars
Original title: Experimentelle Untersuchung von exzentrisch positionierten Verstärkungselementen beim partiellen Verbundstrangpressen am Beispiel von Rundstangen

Pahl, Alexander
Supervisor: Tekkaya, A. E. • Hermes, M. • Becker, C.
Investigation of producibility of car components with Incremental Tube Forming
Original title: Untersuchung der Herstellbarkeit von Fahrzeugbauteilen mit dem Inkrementellen Rohrumformen (IRU)

1.6 Completed Bachelor Theses

Bussmann, Dominik
Supervisor: Tekkaya, A. E. • Kloppenborg, T.
Numerical analysis of the die geometry influence on the curving effect during extrusion
Original title: Numerische Analyse zum Einfluss der Werkzeuggeometrie auf den Rundungseffekt beim Strangpressen

Cakar, Sedat
Supervisor: Tekkaya, A. E. • Richter, H. (TKSE) • Rösen, H. (TKSE) • Isik, K. Soyarslan, C.
Analysis and Optimization of the Evolution Methods of Experimental Test Data for the Characterization of High-Strength Sheet Materials
Original title: Analyse und Optimierung der Auswertmethode experimenteller Prüfdaten zur Kennzeichnung von Blechkurven höchstfester Werkstoffdaten

Geuting, Sigrid
Supervisor: Tekkaya, A. E. • Chatti, S. • Weddeling, C.
Analyis of the the manufacturing of sheet to sheet joints by magnetic impulse welding
Original title: Analyse zur Herstellung von Blech–Blech-Verbindungen mittels Magnet-impulsschweißen

Nguyen, Khac Minh
Supervisor: Tekkaya, A. E. • Richter, H. (TKSE) • Rösen, H. (TKSE) • Isik, K., Soyarslan, C.
Investigation of stress-state dependency of crack initiation for sheet specimens from high strength steel using FEM
Original title: Untersuchung mittels Finite Elementverfahren zur Spannungszustand-Abhängigkeit der Rissinitiierung von Flachzugproben aus hochfesten Stahlblechen

Ossenberg, Philipp
Supervisor: Tekkaya, A. E. • Pleul, C.
The Laboratory in Engineering Education
Original title: Ingenieurausbildung im Labor

Rasel, Marco
Supervisor: Tekkaya, A. E. • Haase, M.
Cold extrusion of chip-based extrudates
Original title: Fließpressen spänebasierter Strangpressprofile

Traphöner, Heinrich
Supervisor: Tekkaya, A. E. • Graff, S.(ThyssenKrupp) • Yin, Q.
Adaption and development of a criteria to predict surface defects during hot forming of sheets with GammaProtect coating
Original title: Anpassung und Weiterentwicklung eines Kriteriums für die Prognose von Oberflächendefekten bei der Verarbeitung der GammaProtect-Beschichtung in einem Blechwarmumformprozess

Wernicke, Sebastian • Bouzkri, Yassine
Supervisor: Tekkaya, A. E. • Hermes, M.
Analysis of semi-finished product standards, bent profiles and profile bending processes for the development of an industrial standard for the bending sector
Original title: Analyse von Halbzeugnormen, gebogenen Profilen und Profilbiegeverfahren zur Entwicklung eines Industriestandards für die Profilbiegetechnik

Zikas, Panagiotis
Supervisor: Tekkaya, A. E. • Selvaggio, A.
Synchronization of a Robot System for the Extrusion of 3D-Curved Profiles
Original title: Synchronisation eines Robotersystems und einer Strangpresse zur Fertigung gerundeter Profile

1.7 Completed Student Theses

Koeppen, Daniel
Supervisor: Tekkaya, A. E. • Hiegemann, L.
Development of an ejector system for the automation of a deep drawing wear resistant test
Original title: Entwicklung eines Auswerfer-Systems zur Automatisierung eines Tiefzieh-Verschleißversuchsstands

Mustafa, Sögüt
Supervisor: Tekkaya, A. E. • Kloppenborg, T.
Manufacturing of graded aluminum parts
Original title: Herstellung gradierter Aluminiumbauteile

1.8 Completed Project Theses

Anjami, Nassir • Krankroliwala, Murtaza Moiz
Supervisor: Tekkaya, A. E. • Gies, S.
Influence of driver sheets on the efficiency of the electromagnetic sheet metal forming process

Babariya, Mohit • Parekh, Keval
Supervisor: Tekkaya, A. E. • Sieczkarek, P.
Optimization of the production of surface structures on forming tools and application during the forming process

Esch, Benedikt Wilhelm • Bauer, Maik
Supervisor: Tekkaya, A. E. • Jäger, A.
Analysis of the manufacturing and of the properties of aluminum light-weight I-beams
Original title: Untersuchung zur Herstellung und zum Verhalten von aus der Presswärme plastisch umgeformten Aluminiumprofilen als Leichtbauträger

Haupt, Marco
Supervisor: Tekkaya, A. E. • Yin, Q.
Influence of the inner clamping structure on the feasibility of large strains in the in-plane torsion test
Original title: Bestimmung des Einflusses der inneren Stempelgeometrie zum Erreichen höherer Umformgrade im ebenen Torsionsversuch

Häußler, Helge • Betz, Pascal • Söldenwagner, André
Supervisor: Tekkaya, A. E. • Foydl, A.
Development of a tool for combined composite extrusion
Original title: Entwicklung eines Werkzeuges zum kombinierten Verbundstrangpressen

Mennemann, Marleen • Skaradzinski, Christian
Supervisor: Tekkaya, A. E. • Chatti, S. • Weddeling, C.
Strength of form-fit connections at joining by electromagnetic forming
Original title: Festigkeit von Nutverbindungen bei der elektromagnetischen Umformung

Lin, Xinqi • Kondo, Sayako
Supervisor: Tekkaya, A. E. • Pietzka, D.
Effect of die pocket on material flow during extrusion of asymmetric L-shaped section bar

Research for Education

02

2 Research for Education

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

The main focus of attention inside the field of engineering education research is the scientific 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" in its different shapes 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 of the section "research for education" are clustered in the "research association of engineering education" together with our colleagues of the zhb of TU Dortmund University.
The projects are in particular:

- TeachING-LearnING.EU
- ELLI - Excellent teaching and learning in engineering education
- IngLab - The laboratory in engineering education
- KoM@ING – Modeling and development of competences according to mathematics and its substitution in engineering studies
- PBLL@EE – Problem-based Laboratory Learning in Engineering Education
- 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.

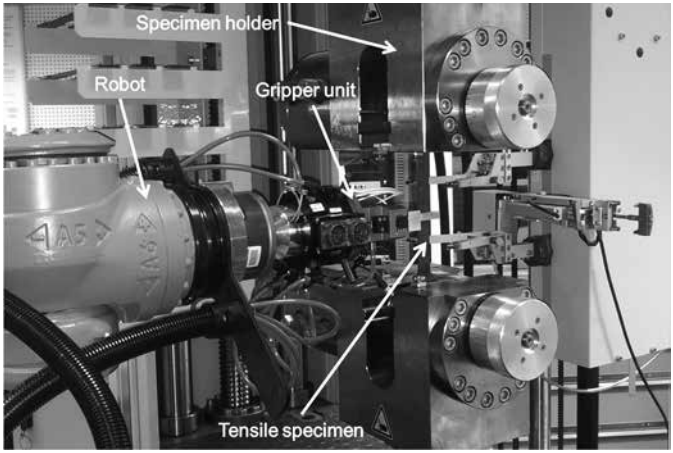
In 2013, at the location of Dortmund, TeachING-LearnING.EU had three main areas: monitoring and evaluation of the projects currently financed by the "Flexible Funds", implementation of the final conference in Dortmund and creation of an own publication.
By the Dortmund team, a total of 9 Flexible Fund projects were funded, accompanied in their implementation and scientifically examined or evaluated during the reporting period. The intensive supervision of the teachers was the main focus. From the evaluation results, general recommendations were derived, some of which have already been announced, but will be published in 2014 in a separate publication.

The TeachING-LearnING.EU final conference "movING forward – Engineering Education from Vision to Mission" took place on the 18th and 19th of June in the international meeting center of Technische Universität Dortmund. With over 130 participants from universities and universities of applied science from all over Germany, the conference showed the continued interest in the topic of engineering education and the need for more research in this field. At the end of 2013 a conference volume, which summarizes the conference and its discussion results, will be published. Further information and impressions can be found at www.teaching-learning.eu.

2.2 ELLI – Excellent Teaching and Learning in Engineering Education

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

ELLI is a supra-regional joint research project of researchers of RWTH Aachen University, Ruhr-University Bochum and TU Dortmund University with the vision of improving the German engineering studies.
In a first step, the mechanical engineering education shall become excellently prepared for the future. The aim of ELLI is the improvement of the study conditions and the development of teaching quality. ELLI is divided into four parts: "virtual learning environments", "support of mobility and internationality", "student lifecycle" and "creativity and interdisciplinarity".
The founded research group "LEED – Laboratories in Engineering Education – Manufacturing Technology" of the IUL deals with 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".



Automated inserting of a tensile specimen

The first sub-project "investigation on lab courses in engineering education" focuses on a conceptual collection of aspects, which should be considered when the integration of tele-operative experiments is planned. The sub-project consists of an investigation of existing lab concepts, which already integrate remote labs. Based on the results, concepts of labs (such as integrated tele-operative labs in normal lectures) have been identified. These concepts consist of the realization of intended learning outcomes based on fundamental components of learning objectives, e.g. the use of instruments and theoretical models.

Prof. Tekkaya during the premiere of the tele-operative testing cell

In consequence of this, the full potential of engineering lab courses could be better utilized when the limitations of the learning process, e. g. when working on engineering problems or planning experiments, are minimized.. In accordance with the current state of knowledge, if courses contain so-called fundamental experiments, they should not only focus on proper procedures but particularly on revealing the entire potential in order to contribute to a basic science education.
Future activities of the project will consist of a step-wise completion of the collection of conceptual aspects, which are relevant in terms of the integration of tele-operative experiments in engineering education.

In the spring of 2013 the tele-operative testing cell for material characterization of the second sub-project "development and integration of remote and

virtual labs" was put into operation in an official ceremony. In the future students can design, perform, modify, watch and interpret tele-operative or virtual experiments.

The testing cell allows different experiments, such as tensile test, compression test or cupping test according to Nakajima (FLC), to determine important material properties for forming technology.

For this purpose the testing cell consists of the following machines or components:

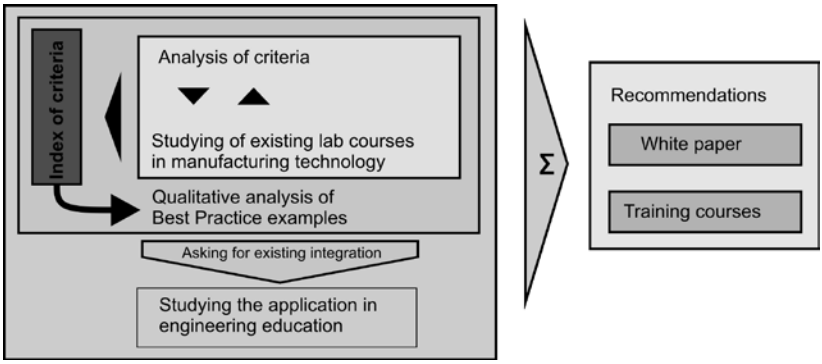
- Universal testing machine Zwick Z250
- Sheet metal testing machine Zwick BUP1000
- Industrial robot KUKA KR30-3 including different specimen grippers
- Automated specimen stack
- Optical measuring system (GOM ARAMIS 4M)
- Realtime control system
- Safety system (PLC, laser scanners, protect switches)
- Camera system

Current developments are aimed at the automation of the machines, which are partly designed only for manual mode, to allow a tele-operative, interactive us. e This also includes the validation of the experiments regarding their option of automation and interactive adjustments. The handling of the specimens is an example of this.
A flexible robot with a wide range of tools and grippers is used. With regardto the safety concept and feasibility, several simulations were performed and different possible scenarios were analyzed. Afterwards, the robot was programmed and tested. In addition to these developments, the integration of the tele-operative testing cell in E- or Mobile-Learning-Environments and the networking with the project partners in Aachen and Bochum are promoted.
In October 2013 the premiere of the tele-operative testing cell took place in the lecture "Fundamentals in Forming Technology". A tensile test was configured and controlled from the lecture hall. By transferring measurement data and camera streams, both in real time, the experiment was watched live by all the students. The students actively participated in the experiment, because they changed the experiment parameters and were involved in the discussion of the results.

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

Within the scope of engineering education, working with experiments within the setup of labs is a traditional as well as powerful element in application- and also in research-oriented study courses. The processes of examining theoretical models within an application oriented context, performing and analyzing experiments and critically judging one´s own approaches have given the laboratory a central significance.
The project "IngLab" focuses on the enhancement of hands-on laboratory training courses in engineering education. As shown in the Fig. below, firstly, the state of the art was studied. Derived from that step, a catalog was developed consisting of characterizing aspects for labs in engineering education with a focus on manufacturing technology. These aspects were made available in an online information system and structured for an interactive as well as collaborative use. After the following exchange with experts, advanced training courses on laboratory didactics will be developed. The interdisciplinary project team consists of excellent expertise in the fields of engineering from the IUL as well as didactics for higher education from the zhb of TU Dortmund University.



Schematic representation of the core objectives for IngLab

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

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

The three subprojects of KoM@ING are worked on by the project partners Leuphana University of Lüneburg, University of Paderborn, Ruhr-University Bochum, TU Dortmund University, University of Stuttgart und IPN – University of Kiel.
The overall objective of the different subprojects is the preparation of a model of competence for the required mathematic skills in engineering studies.

In the subproject B, the IUL is collaborating on an interdisciplinary basis with the colleagues of the zhb (Zentrum für HochschulBildung) of TU Dortmund University and Ruhr-University Bochum on the modeling, the ascertainment and the development of competences in mechanical engineering.

The following working packages were treated in 2013:

- WP2: Normative analysis of capturing competences
  - Interviews with experts (teaching, science and business) were conducted by zhb
- WP3: Analysis of typical exercises
  - Analysis of working processes (at Ruhr-University Bochum
  - Survey of students by question paper
  - Monitoring of students during the analysis of experiments (IUL Lab – tensile test)

All working packages refer to the use of mathematics in selected educational activities of the IUL. The main focus here is on the preparation, the performance and the analysis during the IUL Lab for material characterization.

2.5 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
Status	Completed

Considering current research questions, the project PBLL@EE made lab courses in engineering much more active and up to date. Based on the activity-oriented didactical approach of problem-based learning for an active involvement with engineering practice, students work in small teams on real problems of engineering science (Fig 1). The framework of the course combines presence and independent sessions as well as learning and assessment sessions. The planned activities which are based on the intended learning outcomes are in alignment with the requirements for the competence oriented assessments.
In the second 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 (Fig. 2). To this end, they analyze the engineering context, identify 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. During the step of test planning students have the opportunity to perform their own tele-operative experiments..
Through continuous feedback, many enhancements could already be implemented for the second pilot phase.

Fig. 1 Students working on conceptual solutions in teams

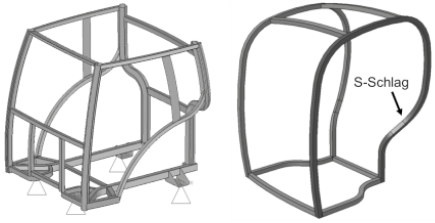


Fig. 2 Tractor space frame conventional (left) and re-designed (right)

2.6 MasTech – Flexible Modular Master Program in Technology

Funding	EU, TEMPUS
Project	511277-TEMPUS-1-2010-1-DE-TEMPUS-JPCR
Project leader	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Contact	Dr.-Ing. habil. S. Chatti

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

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

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

The Royal Institute of Technology (KTH), Stockholm, Sweden, and the “Ecole Nationale Supérieure d‘Arts et Métiers (ENSAM), ParisTech, Metz, France are the European partners of the project. The Master program started in November 2013 in three universities in Tunisia and Algeria as new and international Study program. In 2014 Morocco will also follow.

2.7 miniLABS

Funding	TU Dortmund University, 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 the capacity for teamwork 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
- Metallography
- 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.

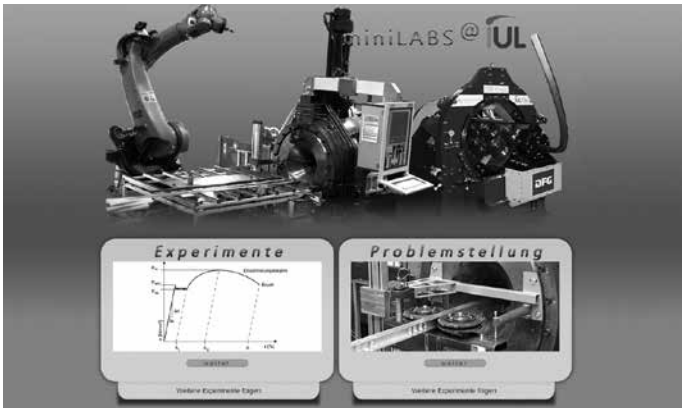


Illustration of the current miniLabs website

Research

03

3 Research

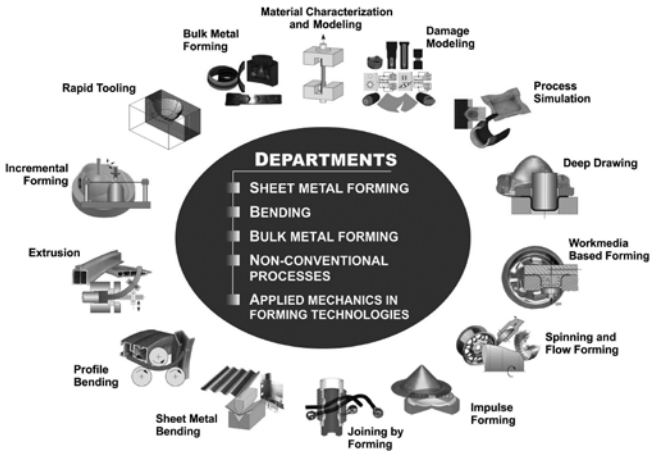
The IUL staff includes 2 chief engineers and 42 scientists, research assistants, PhD-students as well as 13 technicians and administrative staff members and 52 student assistants.

The IUL is divided into five departments:

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

The working group “Project planning” has been established to support the departments.

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

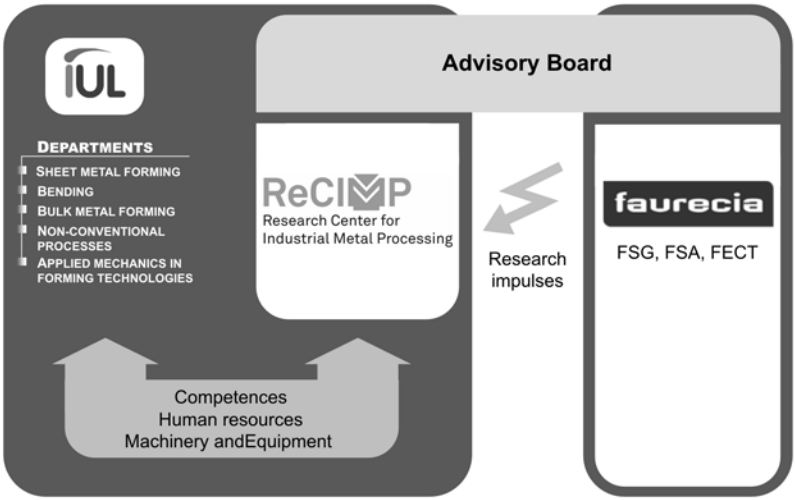
3.1.1 ReCIMP – Research Center for Industrial Metal Processing

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

Faurecia, an international company specialized on automotive products, the Institute of Forming Technology and Lightweight Construction (IUL), and TU Dortmund University support a new research center. The establishment, newly founded in the beginning of 2013, 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
- Characterization and modelling of new materials
- Analysis of new technological and scientific trends in metal processing
- Networking with leading research institutes and companies

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



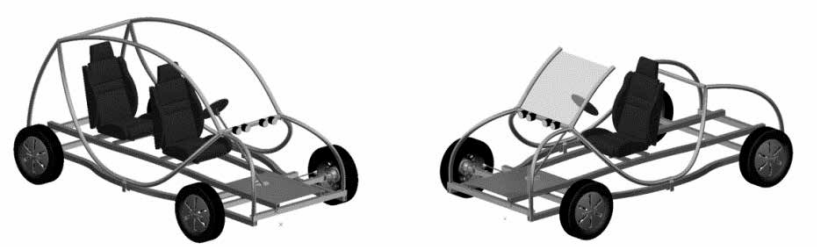
Incorporation of the ReCIMP into the organizational structure of the IUL

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

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

The development of scientific fundamentals and methods for the design of integrated process chains for an automated product-flexible batch production of lightweight frame structures is the major target of the collaborative research center. Therefore, an exemplary model for the combination of forming, cutting, and joining by implementing an idealized process chain for the flexible production of lightweight structures was developed. The main focus of the current funding period aims at increasing the flexibility of the processes and the whole process chain. To illustrate the achieved flexibility, a demonstrator will be fabricated in the form of a buggy by using the processes investigated in the collaborative research center.
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



Current demonstrators of the Transregio 10

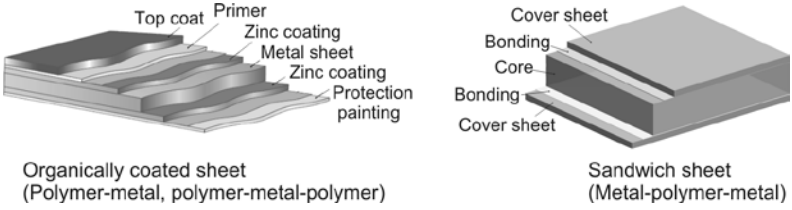
3.1.3 Dry Shear Cutting of Metal Laminated Composite Material

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

Objective of the AiF/DFG-cluster is the development of a processing technology to shear hybrid laminated composite material without additional lubricants to ensure the application of such materials in lightweight construction. Within two DFG projects, the basic scientific knowledge about the process will be explored. Three additional AiF projects are going to deal with the further development for serial application of shearing processes for different material specifications. The starting point for the study is the scientific analysis of the fundamental mechanisms and their influences on dry shearing in terms of tribology, process control, tool load, and tool wear. Based on the results of these pre-studies, the shearing process will be further developed and optimized to allow shearing of different laminated composite materials without additional lubrication by maintaining the part quality and by ensuring a capable process. Furthermore, the process has been well mastered for economical production without increasing tool wear.

Participating research institutes are:

- IUL, Institute of Forming Technology and Lightweight construction, TU Dortmund
- PtU, Institute for Production Engineering and Forming Machines, TU Darmstadt
- utg, Institute of Metal Forming and Casting, TU München

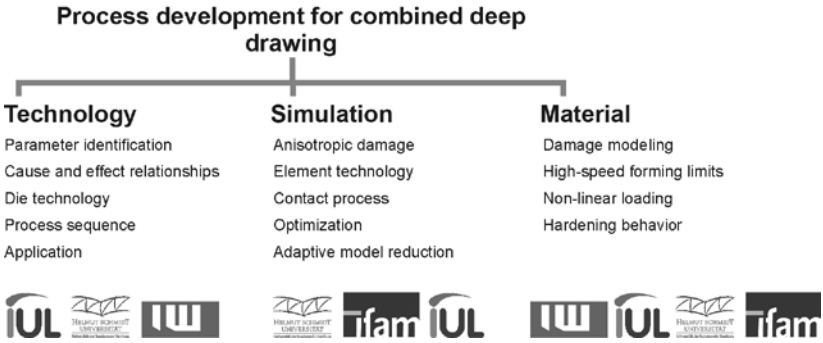


Hybrid laminated composite materials in the cluster

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 collaborative research project, the process combination composed of deep drawing and electromagnetic forming is analyzed. As a result of this combination, rapid changes in strain path and strain rate occur during the process. The objective of this project is to utilize these extensive changes to extend previous forming limits and to develop a fundamental process understanding.
In the first funding period deep drawing followed by electromagnetic calibration was used to decrease the achievable edge radii. To realize higher drawing ratios, deep drawing continuously assisted by electromagnetic forming is investigated in the on-going second funding period.
The research is being carried out in 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).

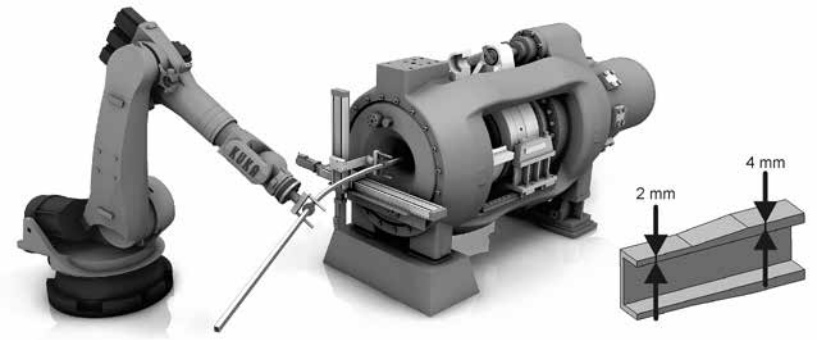


Collaboration of project partners

3.2 Department of Bulk Metal Forming

Head Dipl.-Wirt.-Ing. Matthias Haase

The department of bulk metal forming focuses on research and development of processes for the production of functional by graded and locally property-adapted structural components, mainly based on lightweight materials. In the area of producing composite components, the process of infeeding high-strength reinforcement elements into the matrix material during hot extrusion aims at improving the mechanical properties of the fabricated profiles. Furthermore, the infeeding of functional elements is investigated. The process of multi-axis curved profile extrusion is used for altering the shape and geometry of hot extruded profiles. This allows the production of 3D-curved profiles by deflecting the material flow. Simultaneously, the wall thickness of the extruded profiles can be altered over the profile length by a moveable tool system integrated into the hot extrusion die. The combination of hot extrusion with electromagnetic tube compression is used for the production of profiles with locally compressed and functionally adapted cross section geometries. Hot extrusion with integrated equal channel angular pressing is utilized for the direct conversion of aluminum alloy machining chips into semi-finished products. The integration of cooling channels into hot extrusion dies is realized by additive manufacturing methods. In cold forging, the influence of the forming process with subsequent heat treatment on the distortion of fabricated parts is investigated. Numerical methods are used in all projects for the design, analysis, and enhancement of the developed processes.



Multi-axis curved profile extrusion with variable wall thicknesses

3.2.1 Multi-Axis Curved Profile Extrusion

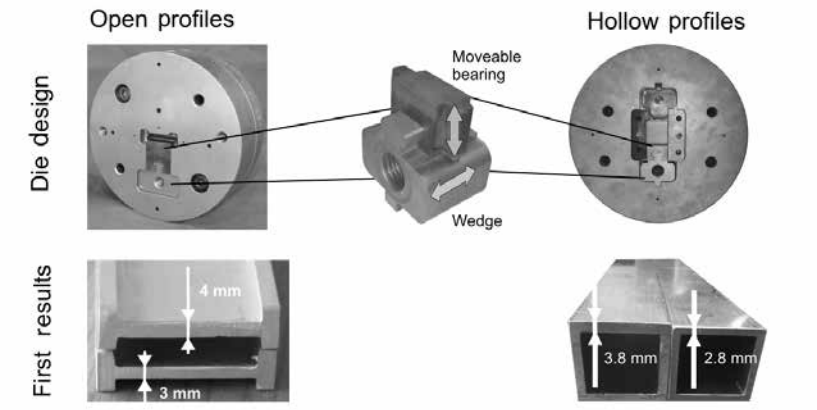
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A1
Contact	Dipl.-Inform. A. Selvaggio

Project Description

This project deals with the further development of the "Multi-Axis Curved Profile Extrusion" and represents the beginning of the process chain, which is examined in the collaborative research center SFB 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". The wall thickness of the extrudates can be modified by moveable tool elements which are used to alter the position of the die bearing.

Current Results

With a new tool design the extrusion of open profiles and rectangular hollow profiles with varied wall thicknesses is possible. In experimental tryouts the wall thickness could be varied by 33 %. Currently, the main factors having an impact on the force necessary for the variation of the wall thickness are identified.



Profile cross sections with variable wall thicknesses fabricated by hot extrusion

3.2.2 Composite Extrusion

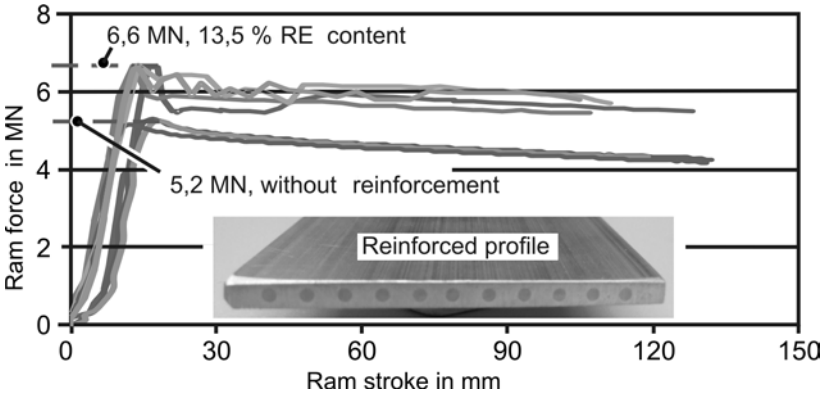
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A2
Contact	M.Sc. C. Dahnke

Project Description

The aim of the project is to identify and expand the process limits of embedding reinforcing and functional elements in structural components made of aluminum alloys by extrusion.

Current Results

In the previous phases of the project the general understanding of the process was investigated. Based on the gained experience, a technological process window for the composite extrusion of profiles with continuous reinforcing elements (RE) is developed in the current phase. Theoretical process limits, like ram force, thickness of the profile, RE content, and the distance between the individual reinforcing elements, will be investigated. Regarding the increase of the weight-specific strength of endless reinforced aluminum profiles, the determination of the maximum possible RE-content is a main aspect of the research. Up to now, a maximum content of 13.5% was realized in thin-walled rectangular solid sections. To extend the flexibility of the process, the embedding of ceramic fibers and functional elements is aspired.



Influence of the reinforcing elements on the required ram force

3.2.3 Integral Design, Simulation, and Optimization of Extrusion Dies

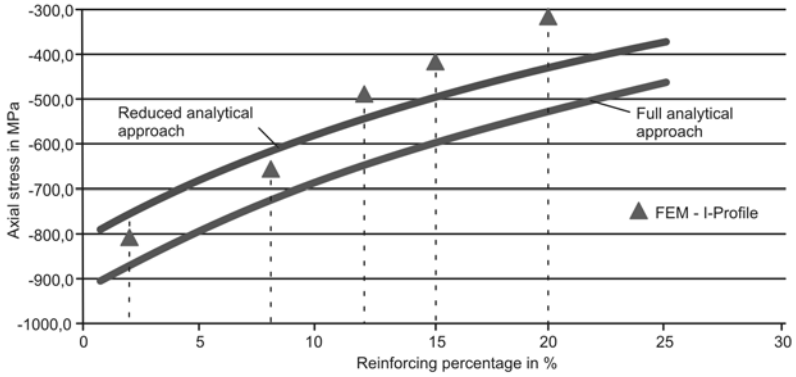
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject B1
Contact	Dipl.-Ing. M. Schwane

Project Description

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

Current Results

The RS in composite profiles occur during cooling due to different thermal expansion coefficients of the aluminum and of the material of the reinforcing elements. For the analytical calculation of the RS, an approach assuming elastic material behavior for double symmetric profiles was developed. A good agreement of the analytical approach with elastoplastic FEM simulation is found at low reinforcing percentage. The increasing difference between numerical and analytical results at high reinforcing fractions results from the growing influence of the plastification in the aluminum.



Residual stresses in reinforcing elements

3.2.4 Thermomechanical Processing of Aluminum Alloys Subsequent to Extrusion

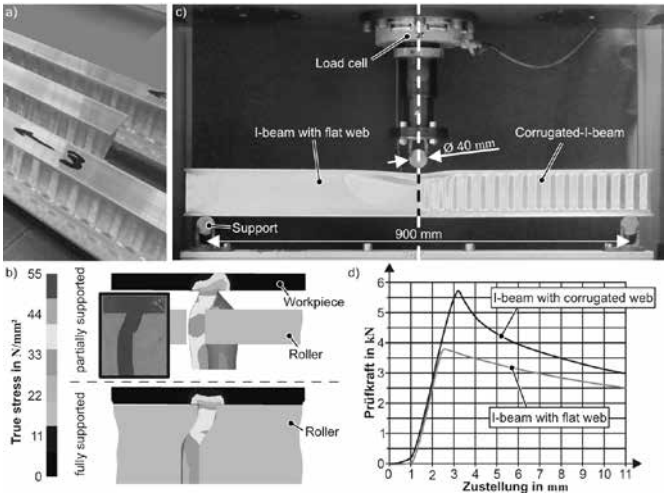
Funding	German Research Foundation (DFG)
Project	SFB/TR 30 • Subproject A2
Contact	Dr.-Ing. A. Jäger

Project Description

This project deals with the manufacturing of products with locally adapted properties by integrating the thermo-mechanical forming and heat treatment operations into the process chain of extrusion. Therefore, 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

For the developed process combination of hot extrusion and corrugation new profile geometries were designed and experimentally tested. The re-dimensioned and manufactured corrugated-I-beams are able to carry much higher loads than beams with a simple flat web (figure). In combined hot extrusion and electromagnetic compression, which is also under development in the project, modified field shapers were designed to extend the geometrical complexity of the products.



Combined hot extrusion and corrugating: a) corrugated-I-beams, b) optimization of the geometry of the rollers by FEM c) three-point bending test, d) load-displacment curve of I-beams

3.2.5 Chip Extrusion with Integrated Equal Channel Angular Pressing

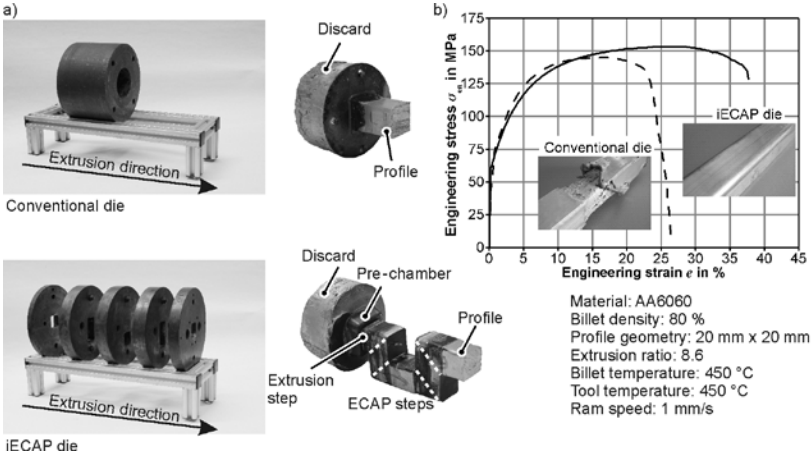
Funding	Graduate School of Energy Efficient Production and Logistics
Contact	Dipl.-Wirt.-Ing. M. Haase
Status	Completed

Project Description

In this project, the process of extrusion with integrated equal channel angular pressing (iECAP) was adapted for the direct recycling of aluminum alloy machining chips. By integrating ECAP steps into a hot extrusion die, an increase of the amount of strain and pressure affecting the chips during hot extrusion is aspired.

Current Results

By using the iECAP die for hot extrusion of the machining chips instead of conventional hot extrusion dies, the bonding quality between the individual chips has been improved. This resulted in superior mechanical properties of the chip-based extrudates fabricated with the iECAP die compared to those of chip-based extrudates fabricated with state-of-the-art extrusion dies.



a) Conventional and iECAP die, b) mechanical properties of chip-based extrudates

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

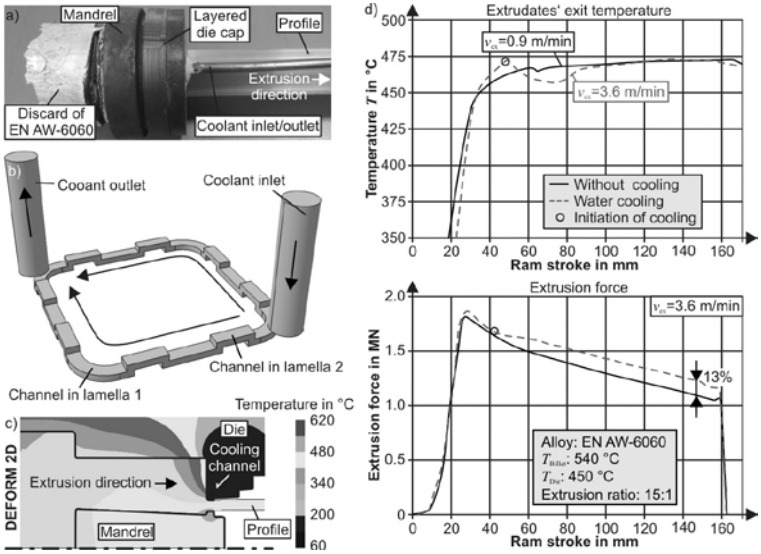
Funding	Funding German Research Foundation (DFG)
Project	TE 508/27-1
Contact	Dipl.-Wirt.-Ing. R. Hölker
Status	First Phase Completed

Project Description

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

Current Results

The interactions in the workpiece, in the die and in the process control were analyzed by experimental and numerical investigations. By cooling an increase of the productivity is possible without raising the profile´s exit temperature. At the same time the extrusion force increases less than in comparison to reference trials without die cooling and lower preheated billets.



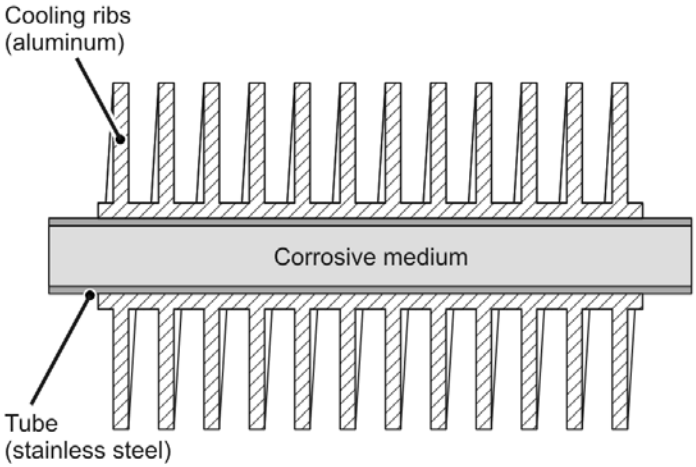
a) Layered die, b) geometry of cooling channel, c) FE simulation of the temperature distribution with cooling, d) experimental results

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

Funding	Zentrales Innovationsprogramm Mittelstand (ZIM)
Project	KF2198117RU2
Contact	Dipl.-Ing. S. Ossenkemper

Project Description

In order to increase the thermal conductivity of tubes, the application of cooling ribs is well established. However, conventional materials have an insufficient corrosion resistance, especially if highly corrosive media flow through these tubes. In this case, a combination of different materials is necessary. The company Georg Frank & Co. GmbH and the IUL develop a new process, which allows the cost-efficient manufacturing of ribbed tubes with a corrosion resistant core tube. The cooling ribs are fabricated with a different material, having a high thermal conductivity.
The process variant enables the mass production and reduces the costs of coolable tubes.



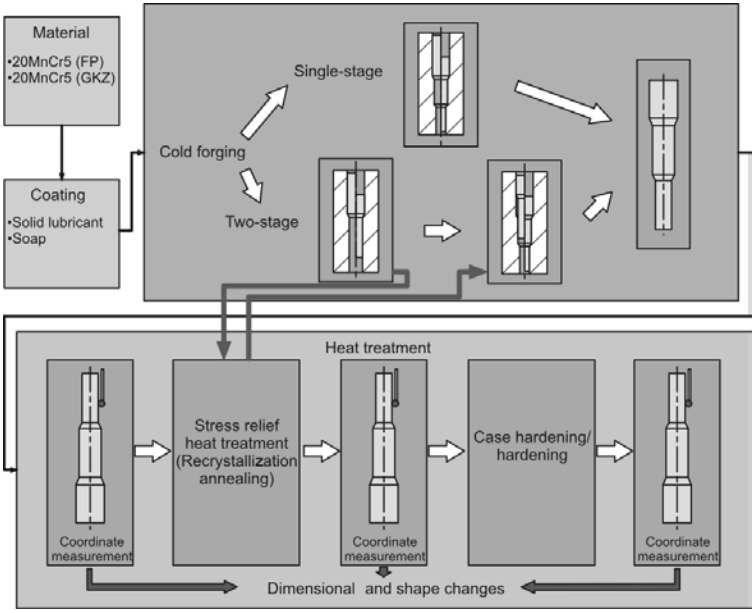
Ribbed tube for corrosive media

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

Funding	AiF ZUTECH
Project	478 ZN
Contact	Dipl.-Ing. S. Ossenkemper

Project Description

In the previous project „Analysis of the Active Correlation between Heat Treatment and Distortion of Cold Forging Workpieces" the correlation between cold forging with subsequent heat treatment and distortion was experimentally determined. In the current research project, the influence of further factors on the distortion mechanisms, like the hardening behavior of the material or the anisotropy due to perlite banding, are investigated. Furthermore, a coupled simulation of the process steps cold forging and heat treatment is performed in order to detect potential influencing factors of distortion in advance. Based on these results, process parameters can be changed to finally reduce the distortion.
This research project is performed in cooperation with IWT Bremen.



Process chain for the investigation of distortion of coldforged and heattreated components

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

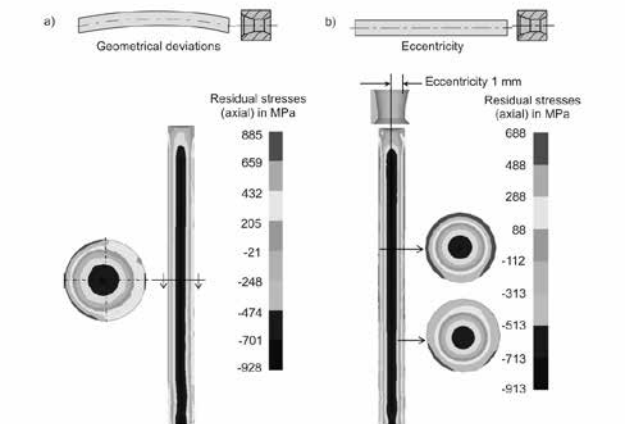
Funding	German Research Foundation (DFG)
Project	TE 508/18-2
Contact	Dipl.-Ing. S. Ossenkemper

Project Description

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

Current Results

In the process chain of cold drawing faults like geometrical deviations or an eccentricity of the initial wire can occur. This results in an asymmetric distribution of the residual stresses in the drawn semi-finished products. As residual stresses are considered to be a potential factor of distortion, the distribution of the residual stresses should be as homogenous as possible. Geometrical deviations of the initial wire can be reduced by using a pre-straightening process in order to minimize the distortion.

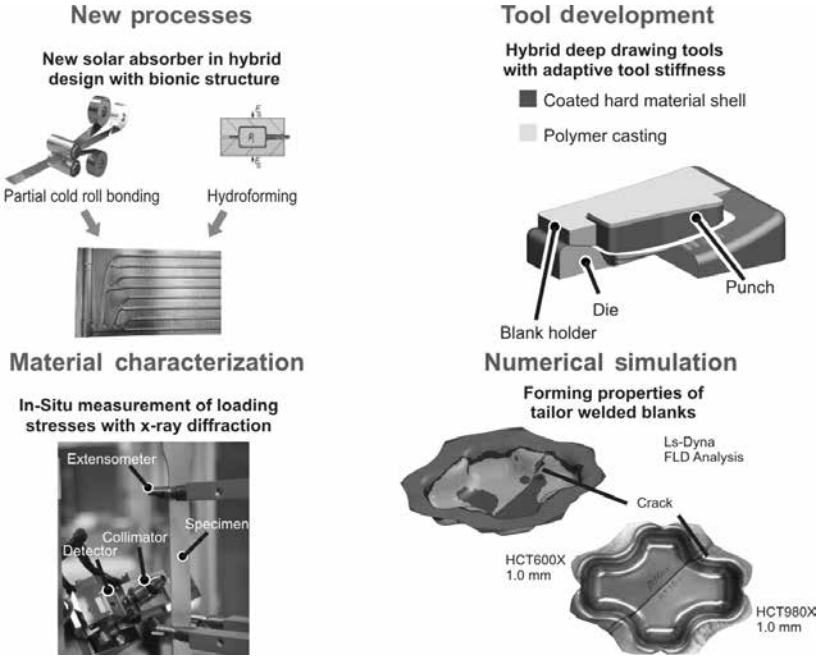


Residual stresses in the drawn wire in case of process faults, a) geometrical deviations, b) eccentricity

3.3 Department of Sheet Metal Forming

Head M.Sc. Alper Güner

The main aims of the department of sheet metal forming are the development of new sheet metal forming processes and tool technologies, analysis of these processes, and the accurate characterization of sheet metals. Here, the reliable manufacturing of sheet metal parts from high strength materials and the realization of hybrid workpieces and tools are the main focuses. Active tool systems with temporally changing stiffness, dry shear cutting, utilization of formless materials for press hardening of closed profiles, and identification of plastic properties of tailor-welded blanks are just some examples for the focus mentioned. The purpose of a new project that started in 2013 is the identification of the kinematic hardening parameters of sheet metals under cyclic loading, with the expert knowledge of the department being further deepened in the field of material characterization.



Overview of the department

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

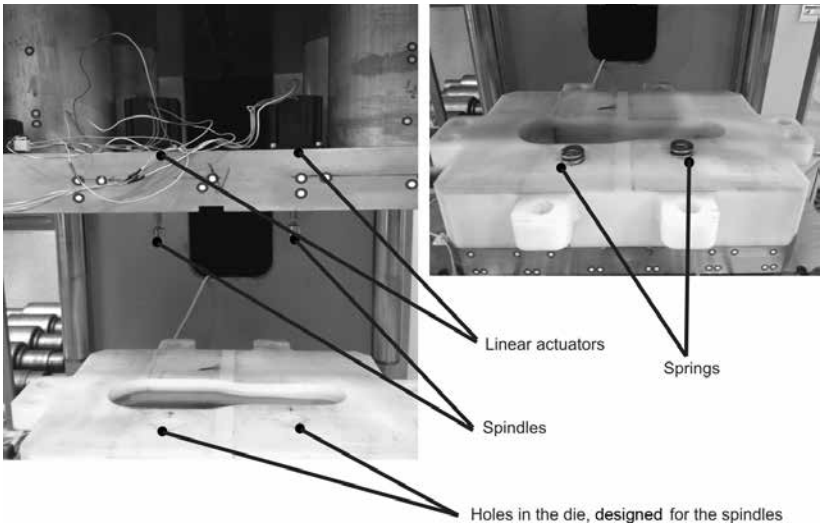
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject C1
Contact	Dipl.-Ing. T. Mennecart

Project Description

In subproject C1 of the SFB 708 hybrid deep drawing tools, which are made of polymers with a wear-resistant hard metal coating, are optimized with respect to optimization in springback behavior of the formed parts.

Current Results

The stiffness can be varied locally and temporally. This can be achieved by the use of springs with a maximum force of 1000N and linear actuators with a maximum force of 820N. With the linear actuators it is possible to vary the stiffness temporally by the use of profiles for the movement of the spindle. These profiles are optimized within subproject C3 of the SFB 708. With these variations the springback behavior of deep drawn DP600 sheets of 1.0 mm can be reduced successfully.



Elements for the stiffness variation in hybrid tools

3.3.2 Strategies for Springback Compensation

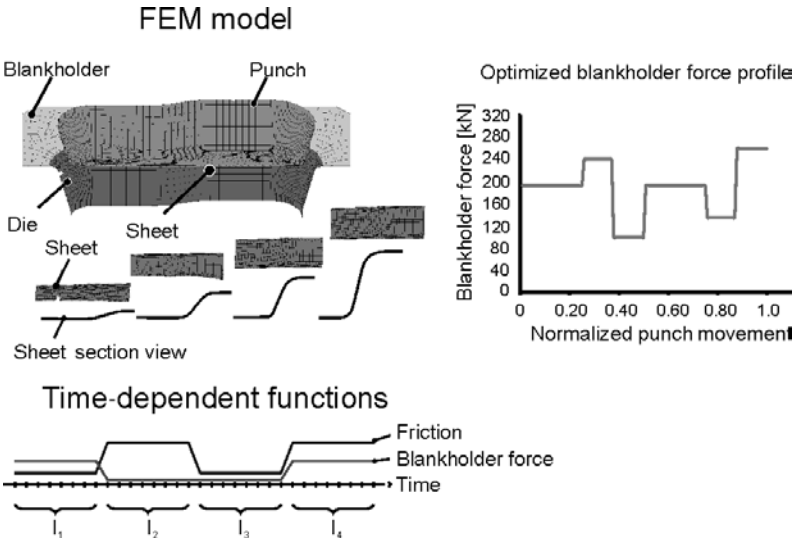
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject C3
Contact	M.Sc. H. ul Hassan

Project Description

In subproject C3 of the SFB 708 the minimization of springback of formed parts is achieved by the temporal variation of process parameters like blankholder force and friction coefficient. Deep drawing simulations based on statistical methods have been performed and their effect on springback has been analyzed.

Current Results

Springback has been minimized in the formed part by the application of optimized blankholder force trajectory. This can be achieved by the sequential analysis of the blankholder force based on a regression model over the time of the punch movement. It has been found that setting the blankholder force to the maximum value in the last 16% of punch movement leads to a substantial decrease in springback. By the application of statistical techniques developed in this subproject, the springback behavior of deep drawn DP600 sheets of 1.0 mm can be reduced successfully.



Springback reduction by time-dependent variation of process parameters

3.3.3 Forming Properties of Tailor-Welded Blanks made of High Strength Multi-Phase Steels: Characterization, Modeling, Verification

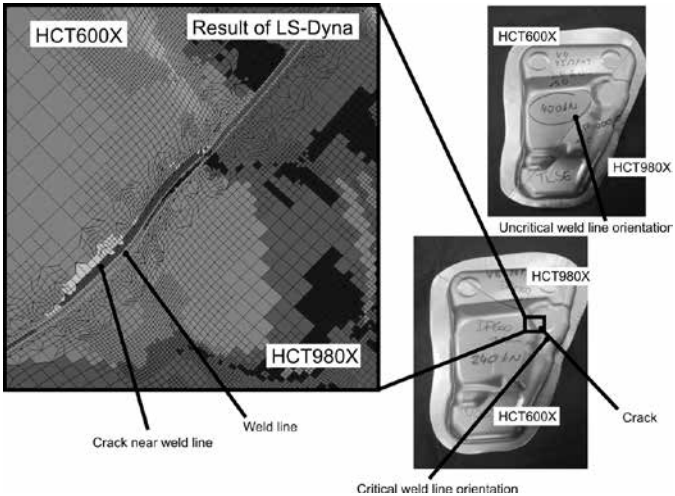
Funding	FOSTA
Project	P 890
Contact	Dipl.-Ing. T. Mennecart
Status	Completed

Project Description

In project FOSTA P 890 the formability of Tailor Welded Blanks (TWB) made of multi-phase high strength steels (HCT980X, HCT600X, HX300LAD) was investigated.

Current Results

First, the materials and the weld line were characterized. These results were used for the modeling of TWB for numerical simulation. Different strategies for modeling the blank were compared. To verify the simulations, two parts with two different weld line orientations were formed. It could be recognized that cracks occur beside the weld line. With the knowledge that TWB made of high strength multi-phase steels can be formed without failure in dependence of the load applied on the weld line, this project could be finished successfully.



Forming results of TWB made of HCT980X and HCT600X

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

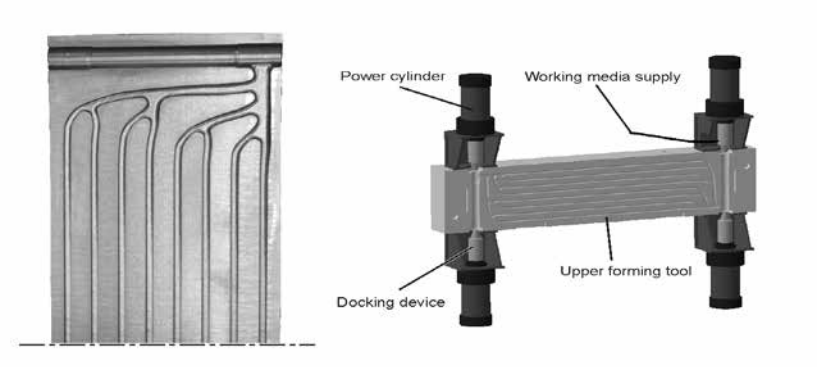
Funding	AiF ZUTECH/FOSTA
Project	339 ZN/P 820
Contact	Dipl.-Ing. F. Steinbach
Status	Completed

Project Description

By the use of partial cold roll bonding, followed by tube hydroforming, a solar absorber was developed and manufactured. With the aid of this process chain water channels shaped as quasi fractal structure (FracTherm®, in collaboration with Fraunhofer ISE) could be embedded in a hybrid material compound.

Current Results

The solar absorber could be produced with channel cross sections of different sizes. New sealing concepts for applying the inner pressure were developed. The new absorber possesses a good uniform flow with a considerably minor pressure drop compared to a conventional harp absorber of the same size.



Left: completed solar absorber (detail), right: performed tooling concept

3.3.5 Dry Shearing of Metal Materials and Polymers

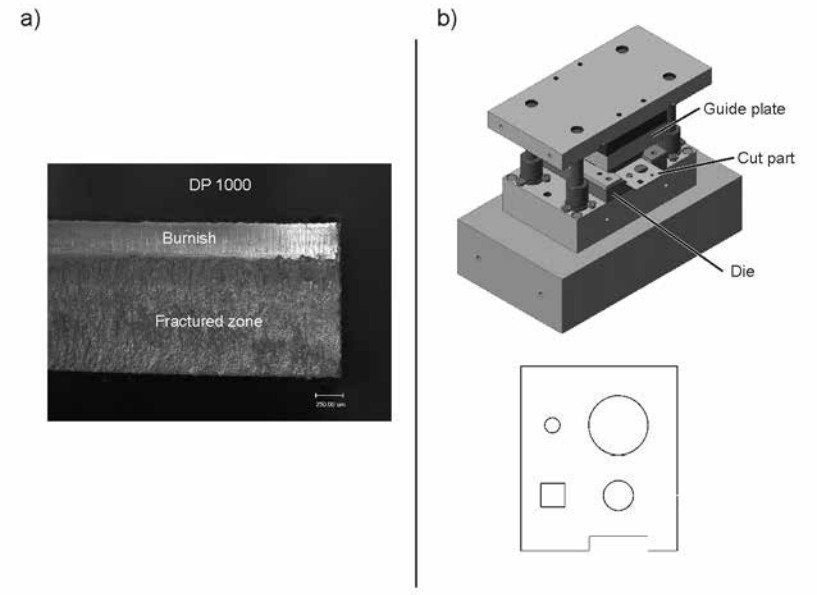
Funding	AiF/FOSTA
Project	17791 N/P 885
Contact	Dipl.-Ing. F. Steinbach

Project Description

Lubricant free shearing is paid more and more attention to due to monetary and environmental reasons. The project is part of the AiF/DFG-cluster 678/0 “Dry Shear Cutting of Metal Laminated Composite Material” and follows an approach for reaching better cut surface quality of the shearing without lubricants. With a cutting tool built in a servo press the cut surface quality as well as the wear of the active tool elements will be determined.

Current Results

At the beginning, three different tool materials will be used (1.2379, 1.2358, S390). Later on, coated tools can be used (DLC-coating, diamond-like carbon). First preliminary investigations show a very small burnish zone for the sheet material DP 1000.



a) Cutting face, DP 1000, clearance 8%, dry
b) Cutting tool and corresponding cut part

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

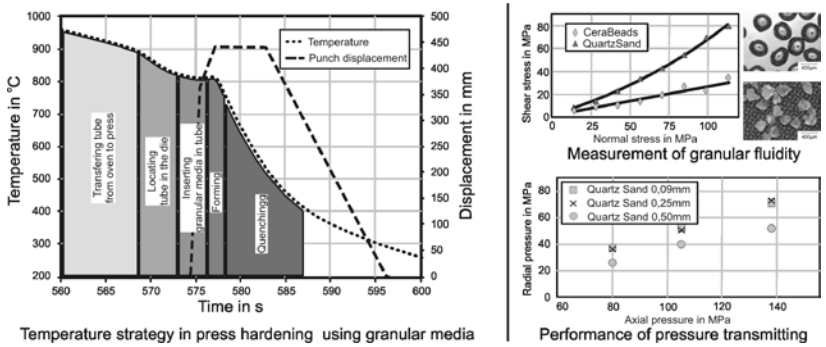
Funding Graduate School of Energy Efficient Production and Logistics
Contact M.Sc. H. Chen

Project Description

The formability of 22MnB5 tube in this granular media-based press hardening process needs to be improved due to the uncertain principle of pressure transmitting effect of granular media and heat transfer. A process window related to the coordination of internal pressure and forming temperature must be determined.

Current Results

Direct shear tests show that the fluidity of granular media is improved by better particle surface quality which indicates the higher pressure transmitting ratio. It is proved by die compaction tests that the property of granular media is nearly independent of temperature, and larger size granular media generate higher radial pressure which is applied to form the tube. A higher forming velocity improves the performance of granular media. Fast heat transfer reduces the formability, while an appropriate forming temperature window must be covered during the experiment.



Performance of granular material as forming medium

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

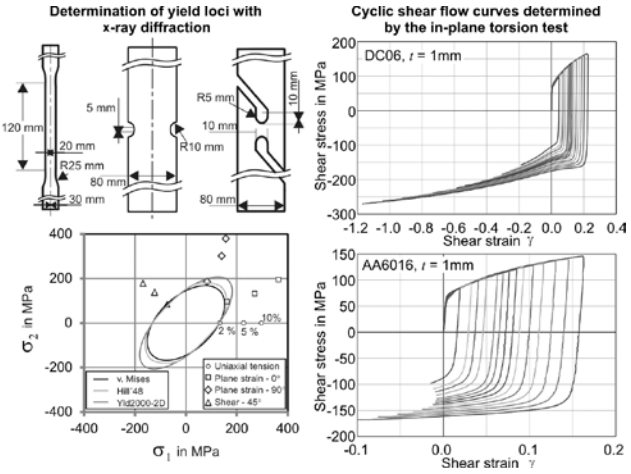
Funding	German Research Foundation
Project	PAK 250 • Subproject 1
Contact	M.Sc. A. Güner • Dipl.-Ing. Q. Yin
Status	Completed

Project Description

In this project new experimental setups were investigated and developed in order to determine subsequent yield loci. Two approaches were considered. First, the in-plane torsion test was conducted under cyclic loadings. Second, x-ray diffraction was applied on loaded tensile and shear specimen to measure local stress states directly.

Current Results

Using the in-plane torsion test, multiple cyclic shear curves can be obtained from only one single test. This set of curves can be used to identify kinematic hardening of sheet materials at different strain amplitudes. After the characterization of the elastic properties of sheet materials, the x-ray measurements were performed under uniaxial tension, plane-strain tension and shearing. This way, the yield loci of the materials DC06 and AA5182 were obtained.



Determination of yield loci with x-ray diffraction and cyclic shear flow curves determined by the in-plane torsion test

3.3.8 Identification of Stress-Dependent Bauschinger Coefficents

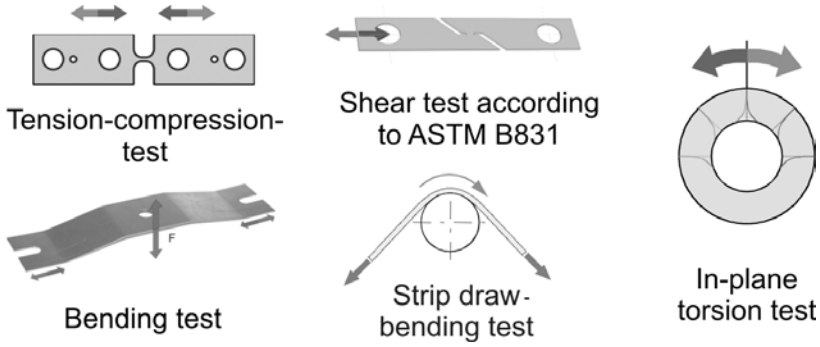
Funding	EFB/AiF
Project	17375N/1
Contact	Dipl.-Ing. Q. Yin

Project Description

This is a joint project in cooperation with the Institute of Manufacturing Technology in Erlangen. The aim is to develop evaluation methods to investigate the Bauschinger effect considering the stress state and the prestraining. Different experimental setups are involved in this research. The results are used to identify parameters for kinematic hardening models in numerical analyses of sheet metal forming processes.

Current Results

The materials DC06, HCT450X and AA5182 are selected for this project in coordination with the industrial partners. The analysis of different material classes indicates a saturation of the Bauschinger effect after a certain amount of prestrain.



Application of different experimental approaches in order to characterize kinematic hardening for sheet metals

3.4 Department of Bending Technology

Head Dipl.-Ing. Christoph Becker

The department of bending technology works in the field of tube and profile bending as well as sheet metal bending. Within these fields, several projects with focus on fundamental as well as application-based research are conducted. A main focus of the department is the development and establishment of novel innovative manufacturing processes which increase the application range of bent parts compared to the current state of the art. Concerning this, the development of the incremental profile forming process should be mentioned as an example. The design of a prototypical machine for the mentioned innovative profile forming process has been finished and the machine was put into operation (see figure). Furthermore, other projects also concentrate on the manufacture of load-optimized parts as well as on the application of high strength steels, which are more and more applied to manufacturing processes based on bending technology.

Machine prototype for the incremental profile forming process

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

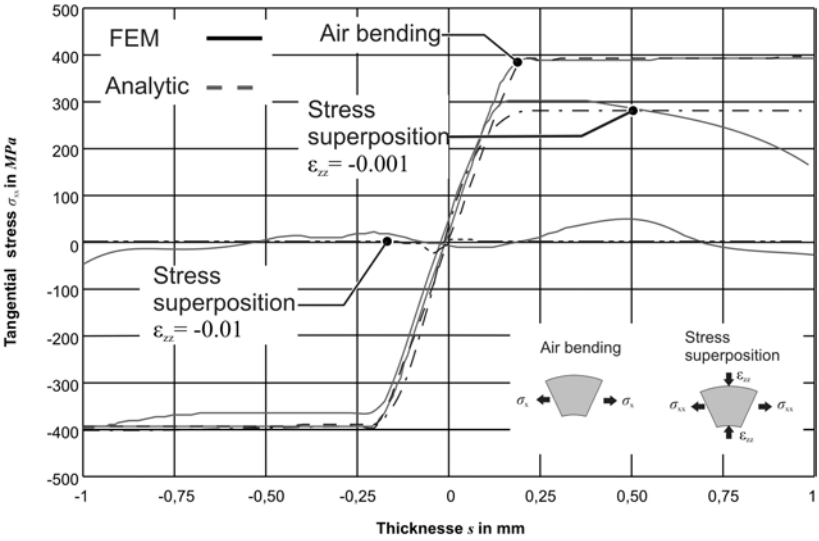
Funding	German Research Foundation (DFG)
Project	MA1883
Contact	Dipl.-Ing. A.Weinrich

Project Description

The increasing demand for lightweight structures requires the use of modern materials such as high-strength-steels. These have particularly in air bending a high springback that complicates the metal forming process.

Current Results

In the final phase of the project, among other aspects, an analytical model based on the theory of plasticity is developed. By means of this model the state of stress induced by the stress superposition can be calculated. Moreover, the process is compared with other conventional sheet bending processes. To evaluate the process, the springback and effort required has been taken into account.



Comparison of analytically and numericallyly calculated stress curves under the influence of stress superposition

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

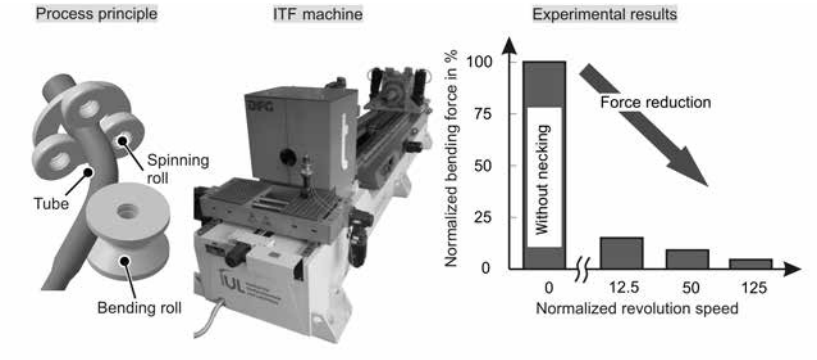
Funding	German Research Foundation (DFG)
Project	TE 508/26-1
Contact	Dipl.-Ing. C. Becker

Project Description

For the manufacture of bent, load-optimized tubes with variable diameter over the longitudinal axis the incremental tube forming process (ITF) can be used. ITF combines two tube forming processes bending and spinning. Within this project, a process model for the prediction of the reduced springback is developed. Furthermore, the incremental tube forming process will be analyzed with numerical as well as experimental approaches.

Current Results

By means of the ITF machine several influencing parameters on springback are identified as well as first approaches for the process model could be verified. The figure shows the bending force depending on the revolution speed. It is shown that the incremental tube forming process causes a bending force reduction which increases at a higher revolution speed.



Bending force reduction during the incremental tube forming process

3.4.3 Standardization of Bending Tubes and Profiles

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

Project Description

Within this joint research project, which was conducted in cooperation with Tracto-Technik GmbH & Co. KG and Universität Siegen, an industrial standard for tube and profile bending has been realized. The IUL´s participation focused on the field of bending of profiles with non-circular cross sections. Therefore, the aim of the project at the IUL was the standardization of profile bending technologies as well as the development of a process planning tool.

Current Results

The standard which has been developed in this project was finally realized both as a guideline and as a software solution. The figure shows a complexity matrix for the evaluation of a bent profile.

	Cross section	1 2D Planar radius	2 2D Tilted cross section with planar radius	3 2D S curve in one bending plane	4 3D S curve with change of bending plane	5 3D Free form bending contour	6 3D Free form bending contour with twisted cross section
A	Solid	A1	A2	A3	A4	A5	A6
B	Hollow	B1	B2	B3	B4	B5	B6
C	Open symmetrical	C1	C2	C3	C4	C5	C6
D	Closed asymmetrical	D1	D2	D3	D4	D5	D6
E	Open asymmetrical	E1	E2	E3	E4	E5	E6

Complexity matrix for the evaluation of a bent profile

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

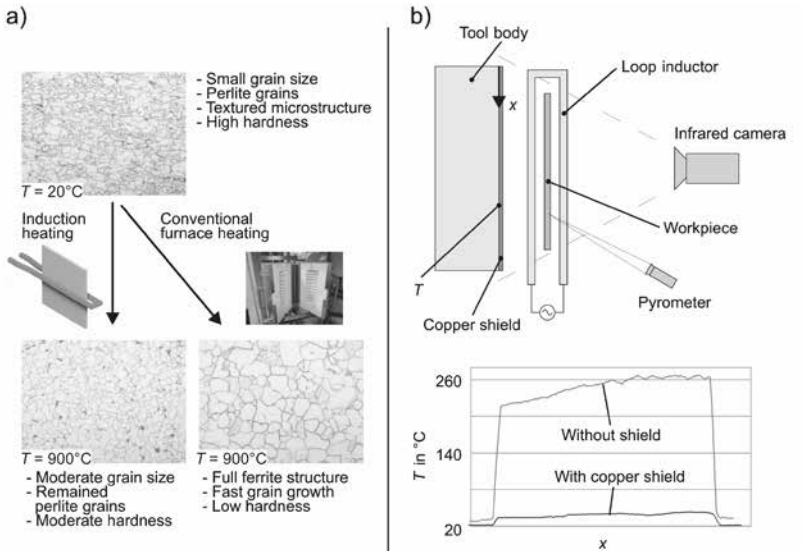
Funding	BMWi/ZIM-KF
Project	KF2198118LK2
Contact	M.Sc. C. Löbbe

Project Description

The aim of the project is the development of a technology for inductively heated bending of high-strength, conventionally cold formed steel complying with highest demands on form tolerances. In collaboration with KODA GmbH the hot bendability of the conventionally cold formed steels is proved and a bending process for complex sheet parts will be developed.

Current Results

Measured hot stress-strain curves and analytical approaches provide an ideal bending temperature with minimal springback. The induction heating is simulated in Ls-Dyna R7 to develop a homogenous and effective workpiece heating. Tests validate the electromagnetic-thermally coupled simulation and prove the shield effect of copper plates to protect bending tools against undesired heating.



a) Evolution of microstructure while heating, b) effect of copper-shield on tool body temperature

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

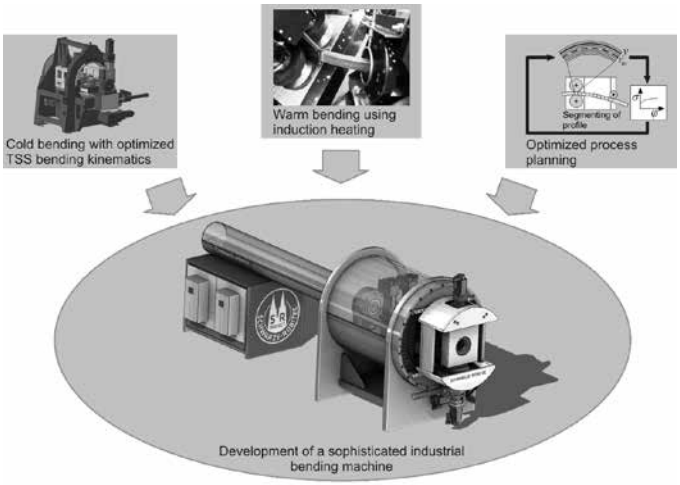
Funding	BMWi/ZIM-KF
Project	KF2198115LK1
Contact	Dipl.-Ing. D. Staupendahl

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 Schwarze Robitec GmbH. The design is based on the Torque Superposed Spatial bending process (TSS bending), which was developed at the IUL. The task of the IUL is the comprehensive investigation of the process with the aim of using the knowledge gained for the development of a process model.

Current Results

To analyze the kinematics of the bending process and the resulting process parameters, sensors for the dynamic measurement of torque and bending forces during 3D bending were developed. The knowledge gained during the 3D bending tests is used for the development of a comprehensive process model.



Merging of the knowledge gained about 3D bending into the realization of an industrial prototype

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

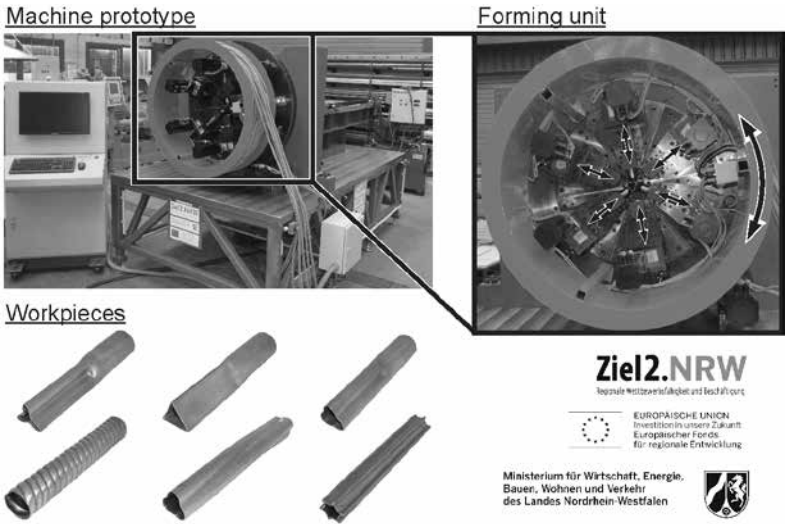
Funding	NRW.BANK
Project	300265102 • w1006sb017a
Contact	Dipl.-Ing. G. Grzancic
Status	Completed

Project Description

The RoProFlex process is an innovative forming process for the fabrication of tubes and profiles with variable cross section geometries along the center line. It was invented and developed at the IUL. For further technological development and basic research work a numerically controlled machine prototype was developed and finally realized.

Current Results

Based on the developed technological concept the design, the manufacturing of machine parts as well as the assembly of the machine prototype where carried out. Furthermore, a control system was generated and implemented in order to realize the flexible fabrication of complex profile shapes. The manufacturing of selected profiles was also archived within this research work.



Machine prototype for incremental profile forming

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

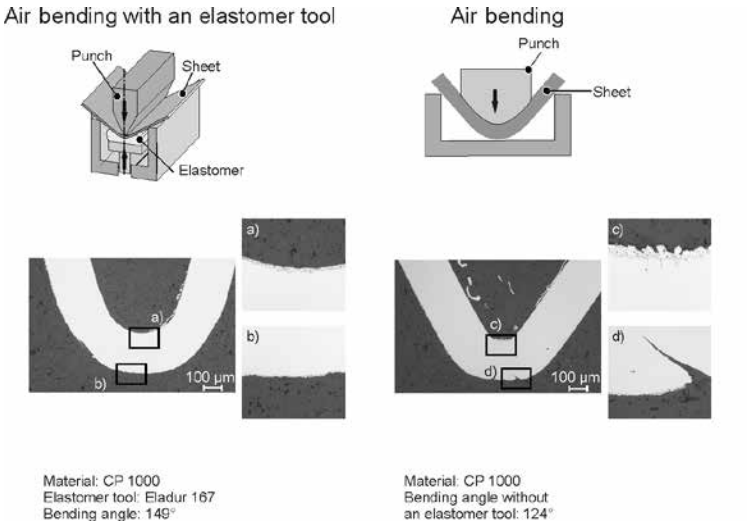
Funding	FOSTA/AiF
Project	P 930/12/2012 • IGF-No. 16585 N
Contact	Dipl.-Ing. M. El Budamusi • Dipl.-Ing. A. Weinrich

Project Description

The particular requirements occurring when bending high-strength steels lead to the need for a modification of conventional bending processes. This project focuses on the extension of current forming limits and on the compensation of springback effects during bending a high-strength steel. This is done, for example, by applying elastomer tools or by using cyclic bending.

Current Results

For the optimization of the process the bending tools are modeled using FEM and experimentally tested. The figure shows the microscopical analysis of a complex phase steel after air bending with and without an elastomer tool. The hydrostatic pressure caused by the elastomer tool leads to a decrease of springback as well as to an extension of the forming limit of the investigated steel.

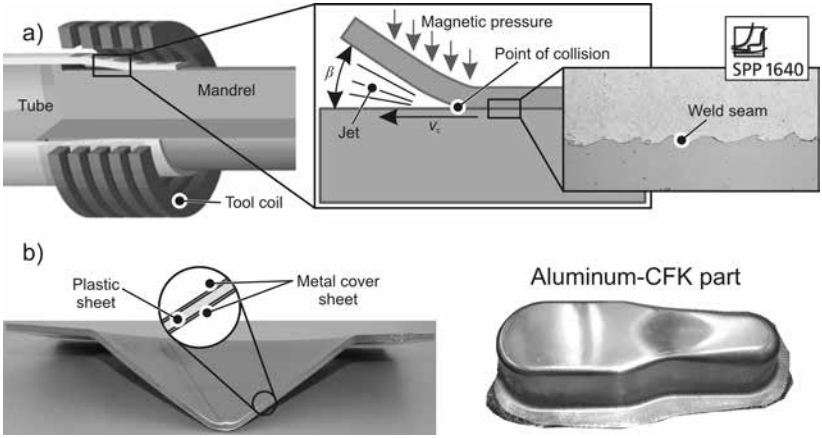


Microscopical analysis: comparison between air bending with and without an elastomer tool

3.5 Department of Non-Conventional Processes

Head Dipl.-Wirt.-Ing. Christian Weddeling

To establish alternative techniques in production engineering where conventional methods come to their limits is the main focus of the research work of this department. Especially flexible and energy-efficient processes as well as the objective to extend the forming limits known at present are topics which are currently being covered. Therefore, the major topics of research of the department are incremental forming, impulse forming, and the combination of these processes with quasi-static forming processes, respectively, as well as joining by forming. Another focus of the group is the combination of different materials in parts and structures. In this research field two new projects were started. The first one is a project regarding magnetic pulse welding which is part of the DFG-funded SPP 1640"Joining by plastic deforming". Here, among other things the joining of different metallic workpieces to each other is investigated. The second project is the BMBF-funded collaborative research project LEIKA "Efficient multi-material design for lightweight bodywork". Within in this project, the IUL is responsible for the investigation of the forming behavior of metal-plastic sandwich sheets.



a) Magnetic pulse welding of profile-profile connections, b) forming of metal-plastic hybrid structures

3.5.1 Process Development for Deep Drawing with Integrated Electromagnetic Forming

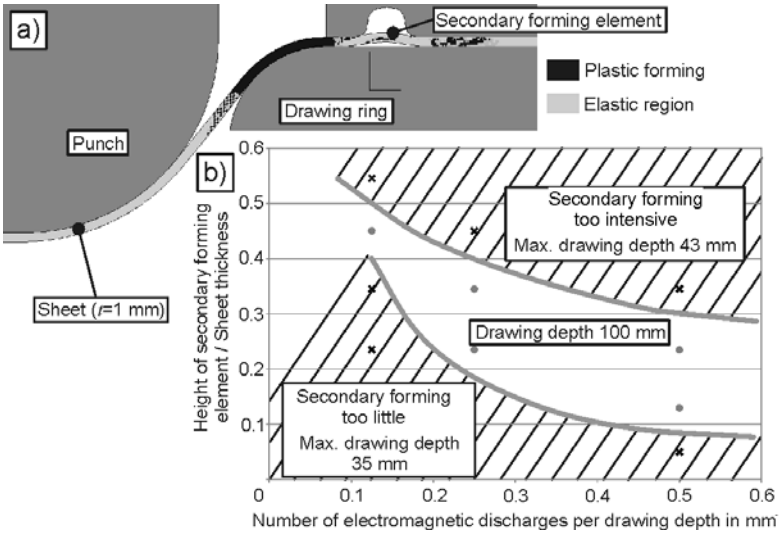
Funding	German Research Foundation (DFG)
Project	PAK 343 • Subproject 1
Contact	M.Sc. O. K. Demir

Project Description

The project focuses on extending conventional forming limits of aluminum alloys utilizing strain rate and strain path changes. The aim is the development of a new deep drawing technology in which sequential electromagnetic forming processes in the flange section are superimposed on the drawing operation. Based on experimental and numerical investigations, a fundamental understanding of the process should be acquired.

Current Results

Numerical simulations showed that the secondary forming element causes the plastic deformation to be concentrated between itself and the cup wall (see figure). This reduces the drawing force, thus increases the maximum drawing depth. The position and the geometry of the secondary forming element and the frequency of its insertion could be identified as the most important process parameters (see figure).



a) The process, b) numerically obtained process window in case of no friction and strain hardening

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

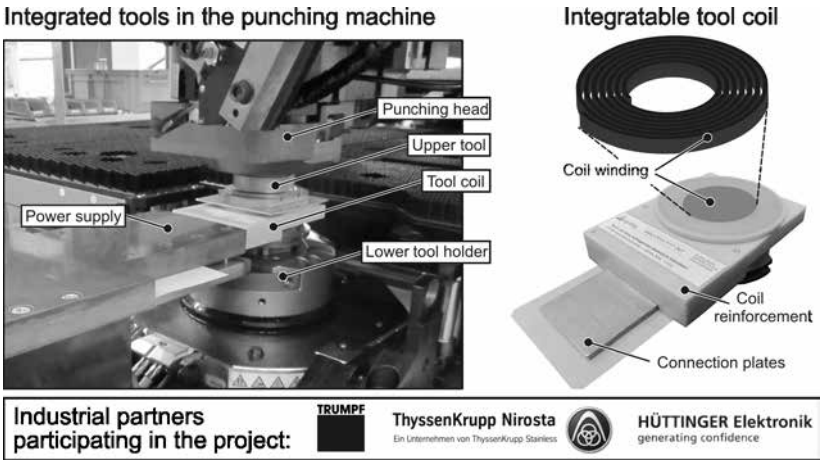
Funding	German Research Foundation (DFG)
Project	TE 508/34-1
Contact	Dipl.-Wirt.-Ing. S. Gies

Project Description

The project aims at a prototypical integration of an electromagnetic sheet metal forming process into the processing head of a punching machine, enabling the combination of quasi-static and dynamic forming operations. In this way, processes with entirely different strain rates can be combined, leading to an increase of the maximum strain before failure. This, in turn, allows an expansion of the producible parts and geometries on suchlike machines.

Current Results

The tool coil and the power supply were successfully integrated into the punching machine. Thermal loads of the tool coil were determined in long-term discharge sequences. Coil winding temperatures of up to 180°C proved that concepts for a decreased heat generation or an improved heat dissipation are required. Otherwise thermal overstressing of insulation or reinforcement might occur wich decrease the coil lifetime.



Current status of integration: a) integrated tools in the punching machine, b) dismounted tool coil

3.5.3 Joining by Forming

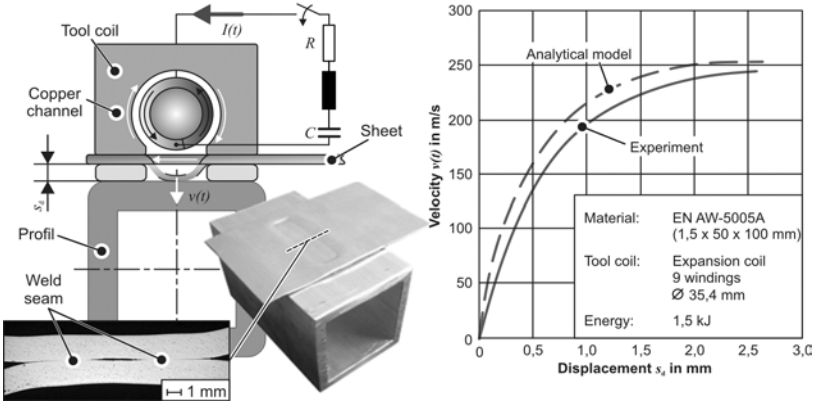
Funding	German Research Foundation (DFG)
Project	SFB/TR 10 • Subproject A10
Contact	Dipl.-Wirt.-Ing. C. Weddeling

Project Description

The focus of the project is on joining by forming of lightweight frame structures. The objective is the development of guidelines and analytical calculation models for a process and load-appropriate joining zone design. Therefore, experimental and numerical investigations of form and interference-fit joining of profile- to-profile connections by electromagnetic joining (EMJ) and joining by hydroforming are performed. Additionally, within subproject A10 the manufacturing of sheet metal to profile joints by magnetic impulse welding (MIW) is investigated.

Current Results

Within the scope of the project mathematical models for the analytical determination of the process parameters for form-fit joining by hydroforming and electromagnetic compression were developed. A similar model was also created for MIW (see figure). Based on numerical and experimental analyses, the models were validated.



Process principle of magnetic pulse welding of sheet metal to profile connections (left) selected result of the analytical determination of the collision speed at MIW (right)

3.5.4 Magnetic Pulse Welding: Targeted Manipulation of Weld Seam Formation

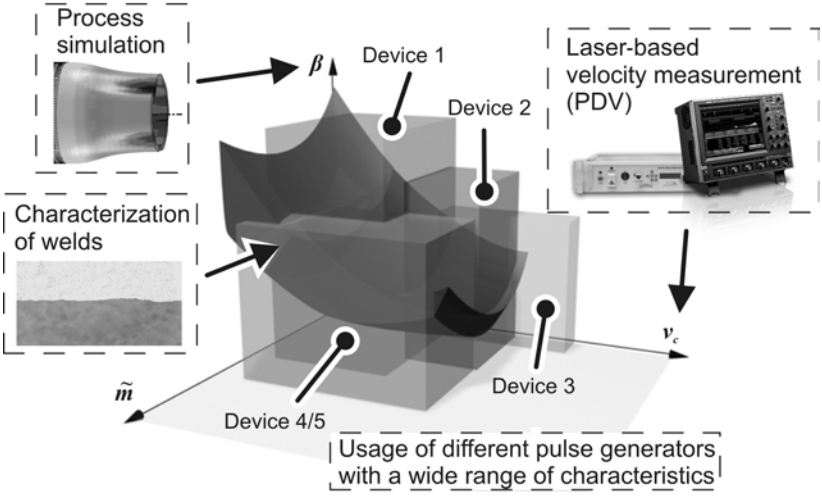
Funding	German Research Foundation (DFG)
Project	SPP 1640 • Subproject A1 (in collaboration with IF, TU Dresden)
Contact	Dipl.-Wirt.-Ing. J. Lueg-Althoff

Project Description

Magnetic pulse welding (MPW) is a solid-state shock welding process. At least one of the two joining partners is accelerated rapidly by magnetic forces and collides with the other joining partner at a collision velocity v_c and at an angle β. If the collision conditions lie in a specific parameter window, metallic bonds are created. The aim of the project is to develop applicable models for a material and system-independent prediction of the required collision conditions and the resulting weld seam formation during joining of tubes. The values of the process parameters are determined by experimental, numerical, and analytical methods and are correlated with the resulting weld seams.

Current Results

The integration of the PDV measurement into the experimental setup was realized (feeding of the laser beam through the field shaper). Furthermore, an FE model of the setup was created in order to identify those process parameters which cannot be detected by measuring techniques.



Approach for determining the values of of the joining parameters

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

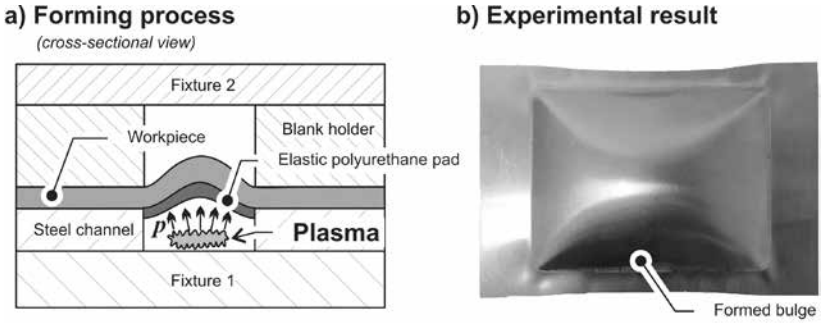
Funding	German Academic Exchange Service (DAAD)
Contact	M.Sc. S. Cai

Project Description

During this process metallic foils or wires are rapidly vaporized by high pulsed electrical currents in order to form a fast expanding plasma which generates an intensive mechanical pressure pulse. By an elastic polyurethane pad this pulse is transferred to the workpiece and leads to its plastic deformation. The aim of this project is to obtain a fundamental understanding of the process by experimental and numerical investigations. Based on this knowledge, approaches for a tailored pressure distribution shall be derived to form complex parts dieless and to avoid typical problems in impulse forming, like the rebound effect.

Current Results

Currently, an analytical approach to predict the shock wave pressure during the process is being developed. In addition, significant process parameters influencing the forming pressure like the charging energy of the capacitor, the thickness of the intermediate polymer plate, and the geometry of the foils were identified.



Sheet metal forming by vaporizing foils

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

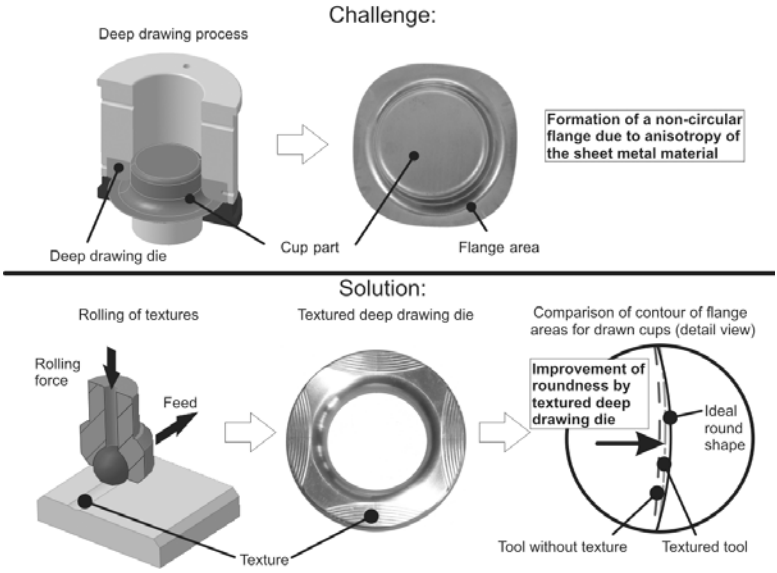
Funding	German Research Foundation (DFG)
Project	SFB 708 • Subproject A3
Contact	M.Sc. L. Hiegemann

Project Description

Within this research project, ball burnishing of thermally coated deep drawing tool surfaces is investigated. The target is to change the surface topography of the forming tools in order to influence the deep drawing process positively. This includes the smoothing of the surfaces as well as the rolling of textures.

Current Results

In forming processes like deep drawing it can be necessary to influence the material flow selectively. Therefore, the potential of rolled textures was analyzed. It could be shown that the friction coefficient can be influenced by the use of rolled textures and, consequently, the shape of the drawn parts (e. g. for compensation of the anisotropy effects) can be improved.



Influencing the material flow in deep drawing by rolled textures

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

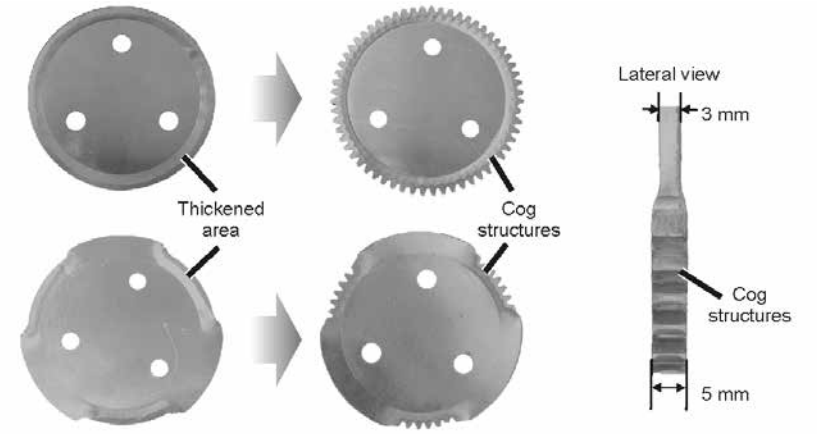
Funding	German Research Foundation (DFG)
Project	SFB/TR 73 • Subproject A4
Contact	Dipl.-Ing. P. Sieczkarek

Project Description

Incremental and localized bulk forming operations are applied to sheet metals with initial thicknesses of 2 – 3 mm. The possibility of a local setting of the workpiece contour, the sheet thickness, and the strain hardening on the basis of individual requirements are the advantages provided by this technology. The aim is the flexible manufacture of geometrically complex and load-adapted components with functional and secondary design elements made from thin sheets by metal forming.

Current Results

The investigations currently deal with a combined thickening of the plate boundary and a subsequent embossing of cog structures. The principle was confirmed experimentally by samples (figure) for components with varying thicknesses and functional elements made with a novel five-axis forming press. Furthermore, the focus lies on the analytical and numerical description of the prevailing three-dimensional material flow.



Samples of a combined thickening of the plate boundary and a subsequent embossing of cog structures

3.5.8 Characterization of the Dynamic Process Behavior during Incremental Sheet Forming

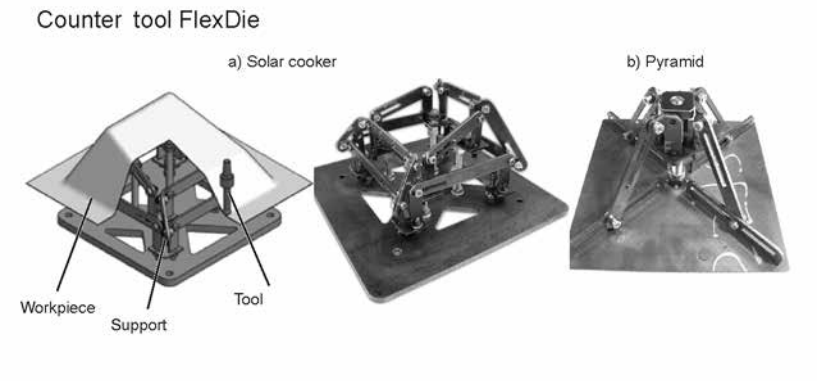
Funding	German Research Foundation (DFG)
Project	SFB 823 • Subproject B2
Contact	Dipl.-Ing. F. Steinbach
Status	Completed

Project Description

The incremental sheet forming process (ISF) is well suited for very high forming limits. In this project the cause-and-effect-principles of the influencing parameters on the process results have been investigated. The project was conducted in collaboration with the Chair for Mathematical Statistics and Applications in Sciences, TU Dortmund.

Current Results

At first, a data base by means of statistically planned experiments was created to identify potential influencing parameters. It was shown that a location-dependent process parameter adjustment is necessary. In the past, the achievement of high forming limits was assumed to be due to through-thickness shear. This theory was refuted by the experiments. Concluding, process optimizations for improving the product quality led to the development of the FlexDie concept.



Flexible counter tool FlexDie

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

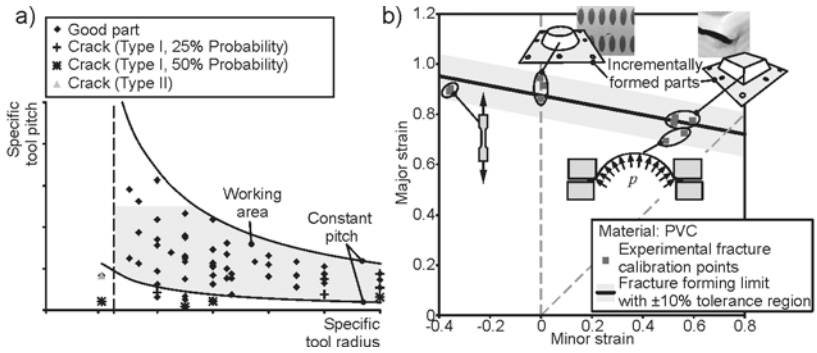
Funding	German Research Foundation (DFG)
Project	TE 508/20-1
Contact	Dipl.-Ing. S. Alkas Yonan
Status	Completed

Project Description

Due to minimal tool-dependence and low forming forces, incremental cold forming of thermoplastic plates is characterized by high flexibility and economic efficiency. The aim of the project was to work out a fundamental understanding of the incremental cold forming process of thermoplastics.

Current Results

Within the scope of this project, states of strain, forces, and process limits were experimentally determined and analyzed. Numerical investigations with 3D models revealed the states of stress depending on process parameters. The obtained knowledge was used for the creation of a process window. In addition, a method for the determination of fracture forming limit lines by means of incremental forming was developed. The determined line corresponds to the fracture forming limit line determined by conventional characterization tests. Thus, the conventional characterization tests for the description of the cold forming of thermoplastics become superfluous.



a) Process window for incremental cold forming of PVC, b) determination of fracture forming limit line for thermoplastics by incremental forming

3.5.10 Development of Efficient Integral Manufacturing Processes to Form Metal-FKV Semi-Finished Parts

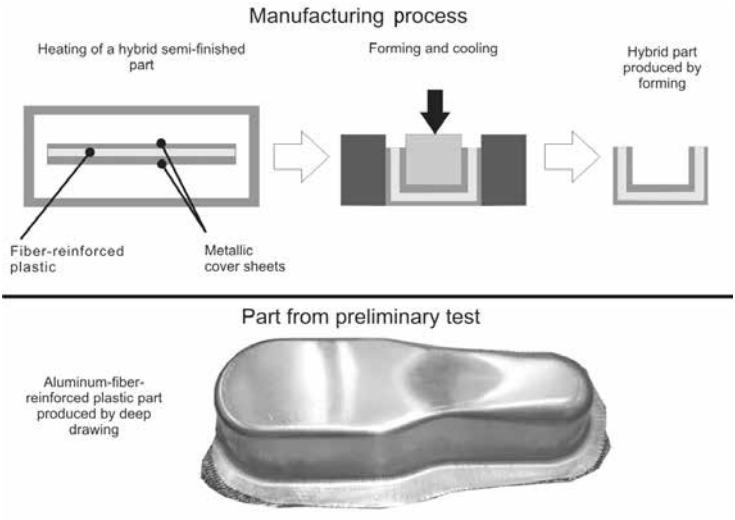
Funding	BMBF / PTKA
Project	02PJ2772 (Collaborative project LEIKA)
Contact	M.Sc. L. Hiegemann

Project Description

The aim of this collaborative project, which started in 2013, is to improve lightweight constructions in the range of electric vehicles by employing hybrid lightweight materials. For this purpose, forming processes have to be developed for hybrid metal-fiber reinforced plastic parts for mass production. This should be done by forming a hybrid semi-finished part, developed and produced by the corresponding project partners. By the use of fiber-reinforced plastics with thermoplastic matrix material, forming of the semi-finished parts at elevated temperature is possible.

Current Results

In previous studies it could be shown that a combined forming of metal and fiber-reinforced plastic composites is possible. However, due to the different material properties, several challenges (e. g. draping effects) occur during the forming process.



Production of hybrid metal-fiber-reinforced plastic parts

3.6 Department of Applied Mechanics in Forming Technologies

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

Simulation and analysis of metal forming processes by means of analytical and numerical models constitute the major part of research in this department. Besides the utilization of Finite Element Modeling programs and the implementation of further constitutive models into these programs, material characterization for the applied models and the design of the required numerical model represent the key competences of the group. In this sense, investigations on several material classes such as metals, polymers and composites give a scope for a collection of numerical models and subroutines that can be employed to a wide variety of forming processes. Thus, the group has been actively interacting with other departments and industrial partners of IUL. As a result, it has achieved a commendable status in industrial consulting, especially in the areas of material characterization, forming simulations, and formability and fracture analysis among our partners.
In this relatively small research group the investigations mainly concentrate on the modeling and prediction of the deformation and damage behavior of the materials during sheet and bulk forming processes. The experience gained is also applied to more complicated cases such as bulk forming of relatively thick sheet materials and forming of composite materials, which consist of metal and polymer layers.
Beside our national project groups, our international partners strengthen our research through close collaborations. In this sense, we have a proven track record in long-term research with our partners from Brazil, China, France, Portugal, USA, and Japan.

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

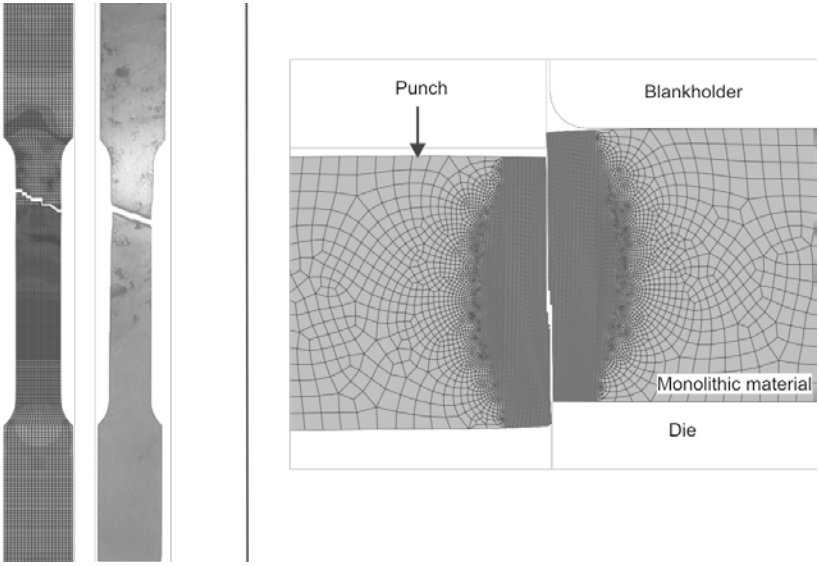
Funding	German Research Foundation (DFG)
Project	TE 805/37-1
Contact	Dipl.-Ing. T. Dang

Project Description

This sub-project of the AiF/DFG cluster "Dry-shear cutting" analyzes layered composites and the phenomena of tool wearing and shear failure of materials in cooperation with the Institute of Metal Forming and Casting at TU München. The IUL focuses on material characterization and simulation of shear-cutting process by using continuum damage models.

Current Results

The tensile and shear stress are performed on different geometrical specimens for material characterization and related damage parameters of the constitutive failure model are identified. The fracture behavior of monolithic material during shear processes can be simulated by the Finite Element Method.



Material characterization (left), shear simulation (right)

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

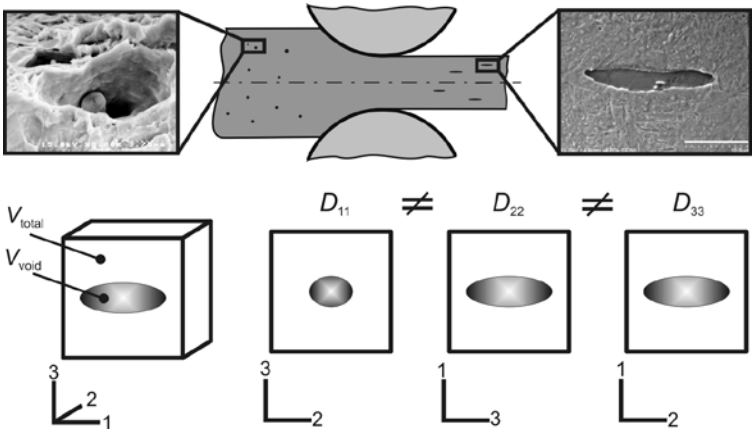
Funding	German Research Foundation (DFG)
Project	SFB/TR 73 • Subproject C4
Contact	M.Sc. K. Isik

Project Description

The application of bulk forming processes on sheet blanks in combination with conventional sheet forming operations enables the realization of complex near-net-shape parts. The objective of this project is the experimental and numerical investigation of microstructure and damage behavior of the material during this new class of sheet bulk metal forming processes.

Current Results

Similar to plasticity, anisotropy of the sheet results in an anisotropic damage evolution under loading. Therefore, the investigated damage models are extended to anisotropic ones. In the phenomenological (Lemaitre) model the material deterioration is formulated by a second order tensor instead of a scalar variable. In the micromechanical (Gurson) model an additional shape factor gives account for anisotropic voidage. Micromechanical damage behavior is investigated in collaboration with the Institute of Materials Science in Hannover. Preliminary investigations show the improvement of damage prediction for the applied forming processes.



Anisotropic damage behavior

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

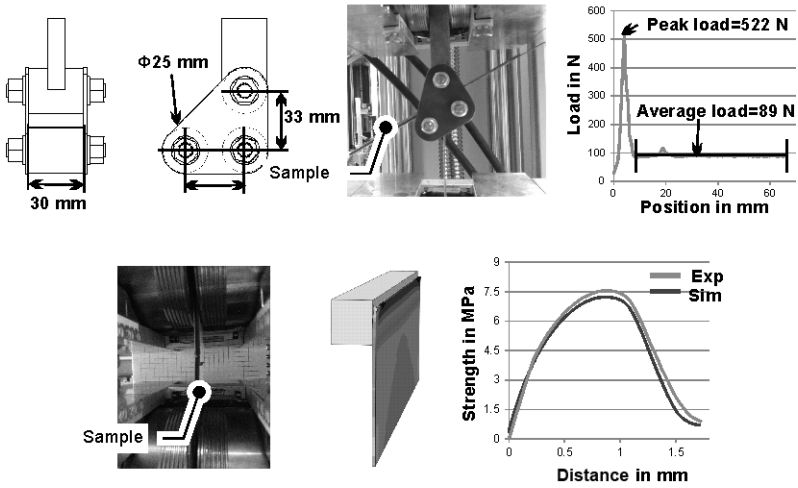
Funding	German Academic Exchange Service (DAAD)
Contact	M.Sc. L. Chen

Project Description

In this project, the focus is on investigations of failure mechanisms in forming of monolithic metallic and metal/polymer/metal sandwich plates. At this stage, main concentration is devoted to the investigation of the mechanical behavior of the interface between metal and polymer layer. Within this scope, the interface behavior of aluminum/polyethylene/aluminum was studied in the framework of classical fracture mechanics and characterized by series of delamination tests under different failure modes. The finite element analysis of interface behavior was conducted by means of an ABAQUS built-in cohesive zone model.

Current Results

Preliminary results show that the typical delamination properties are demonstrated by floating roller tests, shear tests, and so on. Simulation results with the parameters obtained by these tests match well with the experimental results.



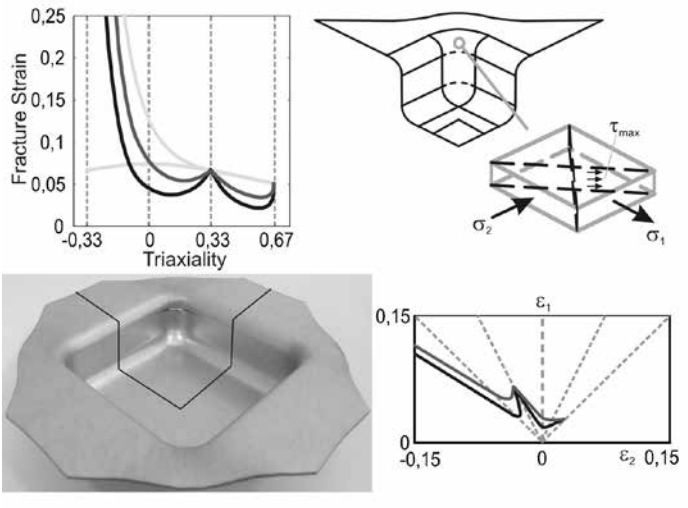
Test results of floating roller test and modeling of shear test

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

Funding	FOSTA
Project	P 1039
Contact	M.Sc. K. Isik

Project Description

For formability analyses, continuum mechanics based models appear to be a strong alternative to the forming limit curve (FLC) in the deep drawing of advanced high strength steels. The Lemaitre model was further improved in the preceding project (P853) to give account for a realistic failure prediction. Recent studies reveal that the fracture strain of modern advanced high strength steels shows a complex damage behavior which cannot only be explained by triaxiality dependence. Especially for low triaxiality, e.g. pure shear ($\eta \approx 0$) and plane strain ($\eta \approx 1/\sqrt{3}$) stress states, a more flexible mathematical model answer is required. The main aim of the planned project is the enhancement of the developed model by considering a maximum shear stress effect. To characterize damage at low stress triaxialities, the IUL in-plane-torsion test and existing shear tests will be analyzed.



Modeling ductile shear fracture observed in square cup drawing

3.7 Patents

3.7.1 Published Patents

Title Process and Apparatus for the Incremental Bending of Profile Tubes, in Particular of Profile Tubes Having Cross Sections which Vary over the Longitudinal Axis

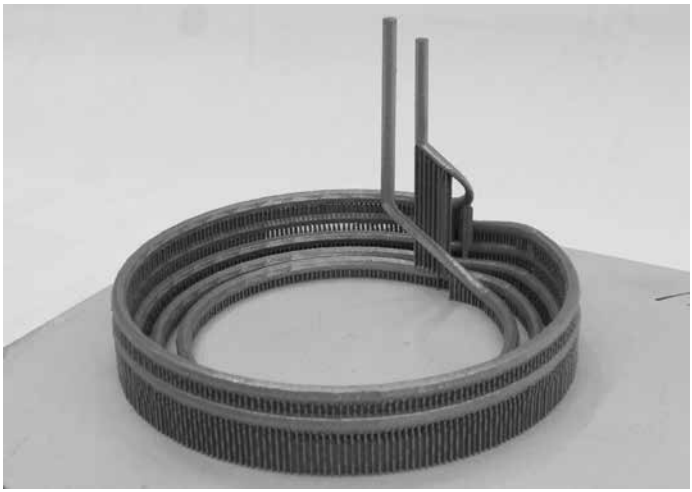
Application Number	WO 2013/143512 A1
Patentholder	TU Dortmund University
Status	Published October 3, 2013
Inventors	M. Hermes • C. Becker • A. E. Tekkaya

3.7.2 Filed Patents

Process for the Manufacturing of Tool Coils and/or Tools for the Electromagnetic Forming of Thin Walled Electrically Conductive Workpieces as well as Tool Coils Based on This Strategy

Application number	DE 10 2013 013 335.1
Patent applicant	TU Dortmund University
Status	Filed
Inventors	A. Jäger • R. Hölker, • J. Lueg-Althoff L. Kwiatkowski • O. K. Demir • A. E. Tekkaya

The invention is dealing with tool coils for electromagnetic forming and a process for their manufacture. The conductive winding is produced by additive manufacturing (figure). By making use of additive manufacturing, the geometry of the tool coil as well as the magnetic field can be individually and free designed and adapted to the metal forming operation. Supported by coupled electromagnetic and mechanical simulation, an optimized geometry of a tool coil can be determined. By manufacturing the tool coil using additive production processes, the design of the tool is almost unlimited. Thus, a free design of the path of the current, of the electromagnetic field, and of the resulting electromagnetic pressure on the workpiece is possible.



Winding of a tool coil manufactured by selective laser melting based on a building platform with support structure

Further Activities

04

4 Further Activities

4.1 Conferences and Meetings

In 2013 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.

- Children's University Day: How did the hole get in the pipe? From aluminum block to soccer goal! • venue: Dortmund, Germany • January 11
- Inauguration of new machines at the IUL • venue: Dortmund, Germany • February 5
- IUL-GDA-Workshop • in cooperation with the "Gesamtverband der Aluminiumindustrie e. V." • venue: Dortmund and Düsseldorf, Germany • March 20 and October 15
- Expert Forum Faurecia: presentation of ReCIMP • in cooperation with Faurecia • venue: Nantes, France • April 10
- Workshop "Simulation in Forming Technology" • in cooperation with the Institute for Metal Forming Technology, University of Stuttgart• venue: Dortmund, Germany • April 12
- Opening Ceremony of the ReCIMP (Research Center for Industrial Metal Processing) • in cooperation with Faurecia • venue: Dortmund, Germany • April 22
- Alumni Reunion • venue: Dortmund, Germany • June 7
- TeachIng-LearnING.EU closing conference "movING forward – Engineering Education from Vision to Mission" • venue: Dortmund, Germany • June 18 – 19
- Meeting of the IUL Industrial Advisory Council • venue: Dortmund, Germany • September 3
- IUL-Excursion • venue: Erlangen and Munich, Germany • September 11 – 13
- International Conference on Extrusion and Benchmark (ICEB) • in cooperation with the German Academic Exchange Service (DAAD) • venue: Dortmund, Germany • October 7 – 9

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 25
- Stahl fliegt (Flying steel) • July 3 – 4
- SchnupperUni • August 29
- KinderUni • January 11 and April 19
- Open Day of TU Dortmund University • November 9

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

Children’s University Day: How did the hole get in the pipe? From aluminum block to soccer goal!

In the frame of the Children’s University Day at TU Dortmund University, interested children aged eight to twelve years had the opportunity to attend a lecture on metal forming.
Here, the basics of metal forming were brought closer to the approximately 80 participant, by means of examples appropriate for children. The children had the opportunity to conduct simple experiments on their own. Using a play dough press, the principle of a bar extrusion process was explained and, in this way, the answer to the question how a soccer goal can be produced from an aluminum block could be given.

Prof. Tekkaya illustrates the principle of extrusion using a play dough press to the participants of the KinderUni

IUL/GDA-Workshop

In this workshop, a lightweight network is established, which collects and prepares information on completed and ongoing research projects related to the development of lightweight aluminum structures. This lightweight network symbolizes the close cooperation between the Institute of Forming Technology and Lightweight Construction (IUL) and the general association of the aluminum industry (Gesamtverband der Aluminiumindustrie - GDA) and acts as an interface between industrial companies and research institutions.
As a result of this cooperation, a web portal, which can be reached under the following link, has been established:
www.alu-leichtbau.de.
On this portal, research activities associated with lightweight aluminum structures and funded by the BMBF, DFG or AIF are documented beginning in the year 2000. To the individual projects, the cooperating institutes are named as contacts for future projects, allowing a quick response of interested industrial companies.

Simulation in Forming Technology

The 16th workshop on "Simulation in Forming Technology", organized in collaboration between the Institute of Forming Technology and Lightweight construction (IUL) and the Institute for Metal Forming Technology of the University of Stuttgart, took place at TU Dortmund University on April 12th, 2013. This year's event focused on "Process Control and Workpiece Properties in Forming Technology". As the lectures came from research institutes as well as from industrial companies, the topic was discussed from various perspectives. Here, both current works related to basic problems as well as insights into industrial practice of forming simulation were presented. In accordance with the workshop's goals, the professional exchange between the participants was deepened during intense discussions on the contributions.

Opening Ceremony of the ReCIMP – Research Center for Industrial Metal Processing

In the beginning of 2013, the Institute of Forming Technology and Lightweight Construction and Faurecia, the sixth largest automotive supplier worldwide, founded a collaborative research center for applied research in the field of metal processing.
The research aims are the optimization and deepening of basic knowledge about innovative metal forming processes, process chains, hybrid processes,

and the investigation of new scientific trends for the application in innovative manufacturing processes. Also the topics lightweight design by application of thin-walled hollow structures made of AHSS (Advanced High Strength Steel), methods for flexible manufacturing, and manufacturing of metal-polymer hybrid products are part of the first research works. The center is also open to interdisciplinary cooperations with further partners from an industrial and research context.
On April 22nd, the center named ReCIMP – Research Center for Industrial Metal Processing – was ceremonially opened by Dr.-Ing. Matthias Hermes (Manager of ReCIMP from January until August 2013, in the beginning of September the management responsibility was given to Daniel Staupendahl), Christophe Aufrère (Vice President Group Technology Strategy, Faurecia), Dr.-Ing. Hosen Sulaiman (Manager Metal Forming, Faurecia), Prof. A. Erman Tekkaya (Head of the IUL), Prof. Andreas Menzel (Dean of the Faculty of Mechanical Engineering of TU Dortmund University), and Dr. Claudia Keidies (City of Dortmund Economic Development Agency).
At the ceremony, the aims of the center and first planned research projects were presented.

Photo taken in front of the Schuler press, from left to right: Prof. Andreas Menzel (Dean), Christoph Aufrère (Faurecia), Prof. A. Erman Tekkaya, Dr.-Ing. Hosen Sulaiman (Faurecia), Dr. Claudia Keidies (City of Dortmund Economic Development Agency), Dr.-Ing. Matthias Hermes

Alumni Reunion

After the successful launch of the Alumni Reunion in 2011, on June 7, 2013, the 2nd Alumni Reunion took place in the IUL experimental hall. All former employees had been invited to be presented the recent developments of their former place of activity. Both Prof. Kleiner and Prof. Tekkaya welcomed their guests and informed about the current topics of research of the IUL. Everybody was invited to take a guided tour or move freely through the experimental hall to inspect the IUL equipment and machines. There was a vivid exchange of knowledge, experience and, of course, memories between the alumni and also with present IUL staff members. The event was organized by Christoph Becker and Goran Grzancic.

Alumni Reunion 2013

TeachING-LearnING.EU closing conference “movING forward - Engineering Education from vision to mission”

On the 18th and 19th of June, the competence and service center for teaching and learning in engineering science TeachING-LearnING.EU held its third symposium – this year at the IBZ and zhb of TU Dortmund University. More than 130 attendees discussed various subjects related to engineering education during the two days. All in all 50 contributions from nearly 20 universities in Germany made a very interesting and exciting conference. This clearly shows that concerns related to the enhancement of engineering education not only unbowed but also the scientific community is continuously growing in this interdisciplinary field of activity.
During the keynotes, the conference topic was viewed and discussed from different perspectives. For example, a historic review was given of the devel-

opment of engineering didactics and the highly innovative subject of remote labs and virtual learning environments was discussed. In addition to that, the IUL presented its international master study program in manufacturing technology "MMT".

6th Meeting of the IUL Industrial Advisory Council

On September 3rd, 2013, the sixth meeting of the IUL industrial advisory council took place. This advisory council was established in 2010 and has the aim to assist the IUL by giving advice on the direction of the institute´s application oriented basic research, e.g. in the planning of collaborative research projects. Furthermore, advisory council assists in the transfer of results from university to industrial application. The IUL receives valuable suggestions and ideas regarding technological demands and needs for research work directly from industrial practice. The IUL returns detailed results of basic research and innovation to industry. The focus of the discussion in 2013 included the topics lightweight construction, the use of new, high-strength steels and the use of magnesium in forming technology. Members of the IUL industrial advisory council are:

- Dr. Gerhard Brüninghaus, Brüninghaus & Drissner GmbH
- Adolf Edler von Graeve, KIST Kompetenz- und Innovationszentrum für die StanzTechnologie Dortmund e.V.
- Marius Fedler, Kunststoff-Institut für die mittelständische Wirtschaft NRW GmbH
- Dr. Frank O. R. Fischer, Deutsche Gesellschaft für Materialkunde e.V.
- Wolfgang Heidrich, GDA - Gesamtverband der Aluminiumindustrie e.V.
- Dr. Stefan Keller, Hydro Aluminium Rolled Products GmbH
- Dr. Lutz Keßler, ThyssenKrupp Steel AG
- Dr. Hansjörg Kurz, Volkswagen Aktiengesellschaft
- Nico Langerak, Tata Steel Research & Development
- Prof. Gideon Levy, TTA – Technology Turn Around
- Franz-Bernd Pauli, Franz Pauli GmbH & Co. KG
- Dr. Heinz-Jürgen Prokop, TRUMPF Werkzeugmaschinen GmbH & Co. KG
- Dr. Hendrik Schafstall, simufact engineering GmbH
- Dr. Joachim Schondelmaier, Schondelmaier GmbH
- Dr. Hosen Sulaiman, Faurecia Autositze GmbH
- Prof. Karl Schweizerhof, DYNAmore GmbH

- Sabine Widdermann, German Cold Forging Group (GCFG)
- Dr. Hans-Joachim Wieland, Stahlinstitut VDEh

IUL-Excursion

A close contact to partner institutes and industry is the basis for innovations made at IUL. Only in this way e.g. integrative lightweight concepts can be fully conceived and implemented. With this in mind, 43 IUL staff members set out on a three-day excursion to the experience and knowledge exchange to the south of Germany from 11th to 13th of September. First, the friendly chair of Prof. Merklein (LFT, FAU Erlangen-Nürnberg) was visited, where a lively exchange about current research topics took place. On the second day the excursion was continued to Munich. For a detection of lightweight potentials in large vehicles a tour at MAN Truck & Bus AG was performed in the impressive truck assembly. In the afternoon a tour took place in the plant and tool shop of the BMW Group, followed by a discussion. Especially the aspect of the Simulations was highlighted. The evening was rounded off with a social gathering at the famous "Hofbräuhaus". The excursion ended on the third day with a visit of the "Deutsches Museum". Here guided tours were offered, e.g. in the field of aerospace. Here the focus was on the metal forming aspect in this industry.

International Conference on Extrusion and Benchmark – ICEB 2013

From October, 8 to 9, 2013, the „International Conference on Extrusion and Benchmark" (ICEB) was held in Dortmund. The conference, taking place every second year alternately in Bologna and Dortmund covers the latest advances in extrusion technology of light metal alloys and the simulation of the processes. The conference was attended by 105 participants from 16 countries. For the Extrusion Benchmark experimental extrusion trials under defined conditions were realized at the IUL with a specially designed extrusion die and extensive measurement technique. Software houses, users from universities as well as industry were invited to simulate the extrusion process. The results from experiments and simulations, wich had been undisclosed until the conference, were presented and published to the audience. The Extrusion Benchmark 2013 has been realized with financial support of the The German Academic Exchange Service (Deutscher Akademischer Austauschdienst, DAAD).

4.2 Awards

6th JSTP International Seminar on Precision Forging

This year the head of the institute, Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya, and two research assistants, Mrs. Ramona Hölker and Mrs. Annika Foydl, were invited to the "6th JSTP International Seminar on Precision Forging" to Kyoto/ Japan to present their research results. Prof. Tekkaya gave a keynote lecture about "Geometric Gradation of Profiles for Lightweight Applications", Mrs. Hölker presented her works on additive manufactured extrusion dies with conformal cooling channels and Mrs. Foydl presented her results on partially reinforced aluminum profiles to international experts. Besides scientific presentations during the five-day seminar (March, 10th-15th, 2013), the Japanese companies „Kotani Corporation" (Forging, warm and cold rolling), „Kurimoto, Ltd." (forming presses) und „Nichidai Corporation" (forging dies) were visited. The seminar was organized by the „Japan Society for Technology of Plasticity".

Best Paper Award für miniLABs auf der IEEE EDUCON 2013 in Berlin

With the contribution "miniLABs: Drop in and become fascinated by engineering experiments - Focused experiments in manufacturing technology related to forming processes (a work in progress)" the authors Pleul, C., Hermes, M., Chatti, S. and Tekkaya, A. E. have been awarded with the Best Paper Award in the in the category "Best innovative paper".
The paper describes the status quo of the initiative "miniLABs". With these "small labs" students will have the opportunity to attend real experiments at the testing field at IUL. During these sessions, students get to know not only machines and instruments but also appropriate procedures when carrying out scientific experiments. During the first miniLABs, attendees came from different courses, years and nationalities and have been happy about such an opportunity of looking behind the scenes.
The initiative have been supported by the Faculty of Mechanical Engineering at TU Dortmund. More information can be found in the project description "miniLABs".

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 “Arbeitsgemeinschaft Umformtechnik“
- CIRP - Fellow of the “The International Academy for Production Engineering”
- Curatorship member of “Karl-Kolle Stiftung“, Dortmund, Germany
- DGM – Member of ”Deutsche Gesellschaft für Materialkunde“
- ESAFORM – Member of the Scientific Committee of the “European Association for Material Forming”
- Founding director of the “Center of Excellence for Metal Forming”, Atilim University, Ankara, Turkey
- GCFG – Member of the ”German Cold Forging Group”
- Guest professor at Shanghai Jiao Tong University, Shanghai, China
- Honorary member of the “TechNet Alliance”
- ICEB – Chairman of the “International Conference on Extrusion and Benchmark”
- ICFG – vice president of the “International Cold Forging Group” (until August 2013)
- 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”
- Member of the “German Academic Society for Production Engineering” (WGP: „Wissenschaftliche Gesellschaft für Produktionstechnik“)
- 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 "Türkisch-Deutsche Universität" (Turkish-German 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 Editorial Committee, CIRP
- 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) (until August 2013)

Further Memberships

- DAAD Scholar Committee, Ankara, Turkey
- IUTAM – "Turkish Branch of the International Union of Theoretical and Applied Mechanics", Turkey
- Member of the Advisory board, "The 16th International Conference on machine design and production" (UMTIK 2014), Ankara, Turkey
- Member of the International Program Committee, "International Conference on Machine Design and Production 2014" (16th UMTIK), Antalya, Turkey
- Member of Scientific Committee, "International Conference on high speed forming" (ICHSF 2014), Daejeon, Republic of Korea
- Member of Scientific Committee, "4th International Conference on steels in cars and trucks" (SCT 2014), Braunschweig, Germany
- Member of the Scientific Committee, "21st International Forging Congress" (IFC 2014), Berlin, Germany

- Member of the Scientific Committee, "The 9th International Conference on Industrial Tools and Material Processing Technologies" (ICIT & MPT 2014), Ljubljana, Slovenia
- Member of the Scientific Committee, "The IDDRG 2013 Conference", Zürich, Switzerland
- Member of the Scientific Committee, "The 11th International Conference on Numerical Methods in Industrial Forming Processes" (NUMIFORM 2013), Shanghai, China
- Member of the Scientific Committee, "The 9th International Conference and Workshop on Numerical Simulation of 3D Sheet Metal Forming Processes" (NUMISHEET 2014), Melbourne, Australia
- Member of the Scientific Committee, "The 15th International Conference on metalforming" (Metalforming 2014), Palermo, Italy
- Member of the Scientific Committee, "The 15th International Conference on Sheet Metal" (SheMet 2013), Belfast, United Kingdom
- 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
- CIRP - International Academy for Production Engineering
- DFG – German Research Foundation, Member of "Fachkollegium 401" (Review Board on Production Engineering)
- DLR - Deutsches Zentrum für Luft- und Raumfahrt e. V.
- ELSEVIER
- Frederick University Cyprus, Nicosia, Cyprus
- Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), Erlangen, Germany
- "German Academic Society for Production Engineering" (WGP: "Wissenschaftliche Gesellschaft für Produktionstechnik")
- Industrieverband Massivumformung (IMU), Hagen, Germany

- Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany
- Koc University, Istanbul, Turkey
- Middle East Technical University Northern Cyprus Campus (METU NCC), Ankara, Turkey
- Ministry of Science, Research and Arts, Baden-Württemberg, Germany
- PAZI, The IAEC-UPBC Joint Research Foundation, Israel
- RWTH Aachen University, Aachen, Germany
- Springer UK
- Technical University of Chemnitz, Germany
- Technical University of Denmark (DTU), Lyngby, Denmark
- Technical University of Eindhoven, the Netherlands, Research assessments
- TÜBITAK, Ankara, Turkey
- University of Nagoya, Japan

For Journals

- ASME - Journal of Manufacturing Science and Engineering
- International Journal 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 Applied Mathematic Methods
- 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 (Selection)

Memberships and Distinctions

- Academia Europaea
- acatech – Council of Technical Sciences of the German Academy of Science and Engineering Berlin-Brandenburg Academy of Sciences and Humanities
- Advisory Board, ALHO Holding
- Advisory Board, Siepmann Werke
- Advisory Board, Werner Siemens Foundation
- Advisory Board, Winkelmann Group
- AGU – Working Group on Forming Technology (Arbeitsgemeinschaft Umformtechnik)
- Berlin-Brandenburg Academy of Sciences and Humanities
- Board of Trustees, Daimler and Benz Foundation
- Board of Trustees, Deutsche Telekom Foundation
- Board of Trustees, FOSTA Research Association for Steel Application
- CIRP - The International Academy for Production Engineering
- European Academy of Sciences and Arts
- German Academy of Natural Scientists Leopoldina
- Indian National Science Academy
- Member of the University Council, Goethe University, Frankfurt
- Member of the University Council, TU Dresden
- Program Advisory Board, Research Funding Program LOEWE, Federal State of Hesse
- Scientific Advisory Board, Fritz Thyssen Foundation
- Scientific Council of the European Research Council (ERC)
- STS Council - Science and Technology in Society Forum, Japan
- Swiss Academy of Engineering Sciences
- WGP – German Academic Society for Production Engineering (Wissenschaftliche Gesellschaft für Produktionstechnik)

Activities as Reviewer and in Committees (Selection)

- Indo-German Science and Technology Center (IGSTC), Member of the evaluation committee
- Open Topic Tenure Track Professorships, future concept of a synergetic university, TU Dresden, Chairman of the finding commission
- “Zwanzig20 – Partnerschaft für Innovation”, funding program of the Federal Ministry of Education and Research (BMBF), Chairman of the jury

Visiting Researchers

05

5 Visiting Researchers at the IUL

Visitors from UK: Delegation led by Dr. Julian M. Allwood, University of Cambridge

On September 24th, 2013 a delegation led by Dr. Julian M. Allwood from the Department of Engineering of the University of Cambridge did an excursion to German research institutes including the Institute of Forming Technology and Lightweight Construction. In addition to research assistants from the Department of Engineering and the Department of Applied Mathematics of the University of Cambridge, there were guests from the University of Oxford and also guests from the industry i.e. from Jaguar Land Rover Company. The twelve-member team was made up of: Dr. Julian M. Allwood, Mr. Chris Cleaver, Mr. James Polyblank, Dr. Evros Loukaidis, Dr. Ed Bambley, Dr. Chris Cawthorn, Mr. Jeremy Minton, Prof . Stephen Duncan, Dr. Matt Arthington, Prof. Roger C. Reed, Dr. Roger Darlington and Mr. Mark Clifton. In addition to getting on insight into German research institutes in the field of manufacturing technology, the main part of the visit was dedicated to the exchange between the German and British scientists regarding the topics “Closed-loop Control” and “Flexible Forming”. This exchange was marked by presentations and inspiring discussions making the visit for all parties a successful event of high value. On their tour through Germany, the British scientists also visited the Institute of Metal Forming of RWTH Aachen and the Institute for Production Engineering and Forming Machines at TU Darmstadt. After the excursion Dr. Allwood attended Mr. Volkan Güley´s PhD defense as a member of the examination committee.

Prof. Paulo António Firme Martins

Prof. Paulo Martins from the Technical University of Lisbon, Portugal, was working as a guest scientist with the IUL from September 1st until November 29th, 2013.
As one of the leading researchers in the field of incremental sheet forming, his work focused on the support of the subprojects A4 and C4 of the Collaborative Research Center / Transregio 73 (DFG - German Research Foundation). With the aim of producing load adapted functional components by sheet-bulk metal forming, the focus of the investigations lay on the analytically, numerically, and experimentally verified description of the novel, three-dimensional material flow and crack modeling. In addition, he worked on studies to determine the formability of sheet metals by means of fracture curves. As a result, an alternative method for the determination of forming limit diagrams

and complicated fracture criteria is available. Further collaborations are planned in the frame of this study. He also supported the DFG project 508/TE20-1, in which previously unknown relationships between material flow and fracture of thermoplastics during cold single point incremental forming (SPIF) were studied. Furthermore, Prof. Martins held lectures on "Incremental forming" and "Innovative joining of tubes" to further educate the IUL staff in this field.

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 fruitful 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 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 were reached. It is desirable to continue this fruitful scientific collaboration and knowledge exchange between the institutes in the following years.

Teresa Citrea

Ms. Teresa Citrea, scientific assistant at of the University of Calabria, Italy, is has been working from October 14th 2013 until March 31st 2014 as a visiting researcher at with the IUL from October 14th 2013 until March 31st 2014. The focus of her research lies on the analysis of the influence of process parameters on the material flow in the composite extrusion process. She will conducts numerical analyseis regarding the material flow of profiles with asymmetrical cross-sections. Especially the effect of the reinforcing elements on the material flow and the extrusion speed will beare analyzed. Subsequent experimental investigations are performed to validate the numerical results. The work will beis conducted in close cooperation with the subprojects A2 and B1 of the SFB TR 10.

RISE (Research Internships in Science and Engineering)
Benjamin Tarloff

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. Students from natural science, engineering and social science are given the opportunity to work in an academic or an industrial research group by the program. From May to August 2013 Benjamin Tarloff from the Rochester Institute of Technology, Rochester, New York, USA, was at the IUL as a RISE scholar. Under the supervision of Christian Weddeling, he was engaged in experimental investigation regarding form-fit joining of lightweight frame structures by electromagnetic forming. The stay of Benjamin Tarloff was financed by a stipend collectively funded by the DAAD and the DFG collaborative research center Transregio 10.

Technical Equipment

06

6 Technical Equipment

6.1 Experimental Area

Presses

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

Further Forming Machines

- Swivel bending machine, FASTI 2095
- Press brake, 110 kN, HERA COP 110/3100
- Press brake, 1300 kN, TrumaBend V 1300X
- Three-roller bending machine, FASTI RZM 108-10/5.5
- Three-roll bending machine, Irle B70 MM
- Three-roll bending machine, Roundo R-2-S Special
- Profile bending machine TSS-3D
- Profiling machine RAS 24.10, Reinhardt Maschinenbau GmbH, Sindelfingen
- Roller spinning machine, Bohner & Köhle BD 40
- Spinning machine, Leifeld APED 350NC, CNC Siemens 840 D
- Machine for electromagnetic forming, 1,5 kJ, PPT SMU 1500
- Machine for electromagnetic forming, 6 kJ, Poynting SMU 0612 FS
- Machine for electromagnetic forming, 32 kJ, Maxwell Magneform 7000

- Multi-axes forming press TR 73, 100 kN,
  prototype with five axes of motion (Schnupp Hydraulik)
- Hydraulic punching machine TruPunch 5000, 220 kN,
  RUMPF Werkzeugmaschinen GmbH & Co. KG
- Machine for Incremental Tube Forming, IRU2590,
  transfluid Maschinenbau GmbH
- Machine for Incremental Profile Forming

Material Testing Machines

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

Measurement Technique and Electronics

- Laser based Photon-Doppler Velocimeter for the measurement of high
  workpiece velocities
- Optical frequency domain reflectometer ODiSI-B10 from Luna Technologies. System for the space- and time-resolved measurement of temperature and strain
- Large volume SEM, Mira XI by Visitec (in cooperation with the “Institut
  für Spanende Fertigung” and “Lehrstuhl für Werkstofftechnologie,
  TU Dortmund University)
- 3D-coordinate measurement machine, Zeiss PRISMO VAST 5 HTG (in
  cooperation with the “Institut für Spanende Fertigung”,
  TU Dortmund University)
- Residual stress measurement devices using borehole method
  - High-speed procedure
  - Air-abrasive procedure
- Hardness testing device, Wolpert Diatestor 2 RC/S
- Thickness measuring device, Krautkrämer CL 304
- 4-channel-digital-oscilloscope, Tektronix TDS 420A
- 3D-video measuring system, Optomess A250
- Infrared measuring device, PYROSKOP 273 C
- GOM: Argus, Atos, Tritop, 3 x Aramis – optical measuring systems for
  geometry and strains

- High-speed camera, HSFC pro of the company PCO Computer Optics GmbH
- Light optical microscope 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 2013 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 2013 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
- fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen, RWTH Aachen
- Fraunhofer-Institut für Solare Energiesysteme ISE, Freiburg
- Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS, Dresden
- Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik, IWU, Technische Universität Chemnitz
- Fraunhofer-Projektgruppe im Dortmunder Oberflächen-Centrum (DOC) der TKSE AG, Dortmund
- Gemeinschaftslabor für Elektronenmikroskopie, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Angewandte Mechanik, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Bildsame Formgebung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Fertigungstechnik und Werkzeugmaschinen, Leibniz Universität Hannover
- Institut für Formgebende Fertigungstechnik, Technische Universität Dresden
- Institut für Kunststoffverarbeitung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Leichtbau und Kunststofftechnik, Technische Universität Dresden

- Institut für Massivbau, Technische Universität Dresden
- Institut für Metallformung, Technische Universität Bergakademie Freiberg
- Institut für Metallurgie, Abteilung Werkstoffumformung, Technische Universität Clausthal-Zellerfeld
- Institut für Produktionstechnik und Logistik, Universität Kassel
- Institut für Produktionstechnik und Umformmaschinen, Technische Universität Darmstadt
- Institut für Umformtechnik und Umformmaschinen, Leibniz Universität Hannover
- Institut für Werkstoffkunde I, Karlsruher Institut für Technologie (KIT)
- Institut für Werkstoffkunde, Leibniz Universität Hannover
- Institut für Werkzeugmaschinen und Betriebswissenschaften, Technische Universität München
- Labor für Fahrwerktechnik, Hochschule Osnabrück
- Laboratorium für Werkstoff- und Fügetechnik, Universität Paderborn
- Lehrstuhl für Fertigungstechnologie, Friedrich-Alexander-Universität Erlangen-Nürnberg
- Lehrstuhl für Konstruktion und Fertigung, Brandenburgische Technische Universität Cottbus
- Lehrstuhl für Leichtbau, Technische Universität München
- Lehrstuhl für Umformende und Spanende Fertigungstechnik, Universität Paderborn
- Lehrstuhl für Umformtechnik und Gießereiwesen, Technische Universität München
- Lehrstuhl für Umformtechnik, Universität Siegen
- Lehrstuhl für Umformtechnik, Universität Stuttgart
- Lehrstuhl für Werkstoffkunde, Universität Paderborn
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- Professur Theoretische Elektrotechnik und Numerische Feldberechnung, Helmut-Schmidt-Universität, Universität der Bundeswehr Hamburg
- Professur Virtuelle Fertigungstechnik, Technische Universität Chemnitz
- wbk Institut für Produktionstechnik, Karlsruher Institut für Technologie (KIT)
- Werkzeugmaschinenlabor, Rheinisch-Westfälische Technische Hochschule Aachen

Kooperationen auf internationaler Ebene | University cooperations at international level

- Abdelmalek Essaâdi University (UAE), Martil, 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, Instituto Superior Técnico, University of Lisbon, Portugal
- Department of Mechanical Engineering, Università della Calabria, Rende (CS), Italy
- DIEM-Tech Manufacturing Technology Group, Università di Bologna, Italy
- Ecole nationale Supérieure d'Arts et Métiers (ENSAM), ParisTech, Paris, France
- Forming Laboratory, Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia
- Institute for Manufacturing, Department of Engineering, University of Cambridge, Great Britain
- 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
- Böhler-Uddeholm Deutschland GmbH
- Carl Bechem GmbH
- Constellium CRV (Centre de Recherches de Voreppe)
- CRF – Centro Ricerche Fiat S.C.p.A.
- Daimler AG
- Data M Sheet Metal Solutions GmbH
- Deutsche Edelstahlwerke GmbH
- DYNAmore GmbH
- EADS Deutschland GmbH
- ESI GmbH
- F.W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Faurecia Group
- Forschungsvereinigung Stahlanwendung e. V.
- Franz Pauli GmbH & Co. KG
- FRIMO Group GmbH Composites & Tooling Technologies
- Grundfos GmbH
- GSU-Schulungsgesellschaft für Stanz- und Umformtechnik mbH
- HELLA KGaA Hueck & Co.
- Hirschvogel Umformtechnik GmbH
- Hüttinger Elektronik GmbH & Co. KG
- Hydro Aluminium Deutschland GmbH
- inpro Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH
- Inspire AG - IRPD
- JRC-ITU Institute for Transuranium Elements, Karlsruhe
- JFE Steel Corporation, Japan
- Johnson Controls Hilchenbach GmbH
- Josef Fröhling GmbH & Co. KG
- Kirchhoff Automotive GmbH
- Kistler-IGeL GmbH
- Koda Stanz- und Biegetechnik GmbH
- KraussMaffei Group GmbH
- Kunststoff-Institut Lüdenscheid GmbH
- LG Corporation
- LEIBER Group GmbH & Co. KG
- MatFEM
- MUBEA Unternehmensgruppe
- Otto Fuchs KG
- Poynting GmbH
- Premium AEROTEC GmbH
- Rehau AG + Co
- S+C Extrusion Tooling Solutions GmbH
- Salzgitter Mannesmann Forschung GmbH
- Salzgitter Mannesmann Präzisrohr GmbH
- Schnupp GmbH & Co. KG

- Schondelmaier GmbH
- Schuler AG
- Schwarze-Robitec GmbH
- Simufact Engineering GmbH
- SimuForm GmbH
- SMS Meer GmbH
- Société 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
- Westfalia Presstechnik GmbH & Co. KG
- 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.
- EFB – Europäische Forschungsgesellschaft für Blechverarbeitung e. V.
- FOSTA – Forschungsvereinigung Stahlanwendung e. V.
- GCFG – German Cold Forging Group
- GDA – Gesamtverband der Aluminiumindustrie e. V.
- I2FG – International Impulse Forming Group e. V.
- IBU – Industrieverband Blechumformung
- ICFG – International Cold Forging Group
- IDDRG – International Deep Drawing Research Group
- IMU – Industrieverband Massivumformung
- ITA – International Tube Association
- JSTP – The Japan Society for Technology of Plasticity
- KIST – Kompetenz- und Innovationszentrum für die StanzTechnologie e. V.
- Stahlinstitut VDEh
- VDI – Verein Deutscher Ingenieure e. V.
- WGP – Wissenschaftliche Gesellschaft für Produktionstechnik

Stiftungen | Foundations

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

Ausgewählte Veröffentlichungen und Vorträge |
Selected Publications and Lectures

08

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Ossenkemper, S., Haase, M., Soyarslan, C., Jäger, A., Tekkaya, A. E., 2013. Tool design induced anisotropic flow behavior of hot extruded aluminum profiles. In: Advances in Hot Metal Extrusion and Simulation of Light Alloys, Proceedings of ICEB 2013, Dortmund, Germany.

Pietzka, D., Ben Khalifa, N., Gerke, S., Tekkaya, A. E., 2013. Composite extrusion of thin aluminum profiles with high reinforcing volume. In: Key Engineering Materials 554-557, Esaform 2013, Aveiro, Portugal.

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Schwane, M., Kloppenborg, T., Ben Khalifa, N., Jäger, A., Tekkaya, A. E., 2013. Finite element based determination and optimization of seam weld positions in porthole die extrusion of double hollow profile with asymmetric cross section. In: Advances in Hot Metal Extrusion and Simulation of Light Alloys, Proceedings of ICEB 2013, Dortmund, Germany.

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Sieczkarek, P., Kwiatkowski, L., Tekkaya, A. E., Krebs, E., Kersting, P., Tillmann, W., Herper, J., 2013. Innovative tools to improve incremental bulk forming processes. In: Key Engineering Materials 554-557, Esaform 2013, Aveiro, Portugal.

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Foydl, A., 2013. Extrusion of Discontinuously Steel-Reinforced Aluminum Profiles. 6th JSTP, International Seminar of Precision Forging (ISPF) 2013, 12.03.2013, Kyoto, Japan.

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1 Nur der/die Vortragende/die Vortragenden werden genannt.
2 Only the lecturer/the lecturers are stated.

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Schwane, M., 2013. Strangpresssimulation mit dem Lagrange- und Euleransatz. DEFORM-Anwendertreffen, 28. – 29.01.2013, Munich, Germany.

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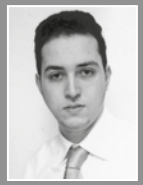

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