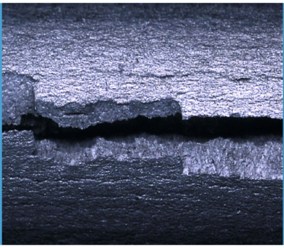
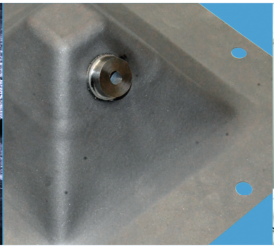





IUL Institute of Forming Technology and Lightweight Components

Activity Report 16

technische universität dortmund

Institute of
Forming Technology and
Lightweight Components

Activity Report

16

technische universität
dortmund

Imprint

Institute of Forming Technology and Lightweight Components
Technische Universität Dortmund
Baroper Str. 303
44227 Dortmund
Germany
Phone +49 (0) 231 755 2660
Fax +49 (0) 231 755 2489
www.iul.eu

Prof. Dr.-Ing. Dr. h.c. Matthias Kleiner
Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya

Editorial team
Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Nina Polak

Editing
Jeanette Brandt
Nina Polak
Beate Ulm-Brandt
Karen Wahlers

Layout
Patrick Cramer

Content

Preface

Dear Readers,

For the IUL, 2016 was mainly characterized by major projects in research and quality improvement in education: We were delighted by the decision of the German Research Foundation (DFG) to support the Collaborative Research Center SFB/Transregio 188 on “Damage-controlled forming processes” with more than 8 million Euros, which we co-applied for with RWTH Aachen University. With A. Erman Tekkaya, a head of the Institute of Forming Technology and Lightweight Components once more becomes coordinator of a SFB/Transregio, after the Transregio 10 was successfully completed in 2014. Thanks to this funding, the IUL will be able to do research on damage mechanisms acting during forming operations and their effects on the product properties with our partner institutes in Aachen and Dortmund as well as the participating institutions, Brandenburg University of Technology (BTU) and the Max-Planck-Institut für Eisenforschung GmbH (MPIE). On a long-term basis, the work of the new SFB/Transregio aims at ensuring the prediction and control of the degree of damage in components and, thus, the development of efficient lightweight products reliable during the utilization phase as well as corresponding production processes.

The investigation of the influence of production processes on the performance of components is, in turn, subject of the SFB/Transregio 73 on “Manufacturing of complex functional components with variants by using a new sheet metal forming process - Sheet-Bulk Metal Forming”. Its continuation in a third funding period was also granted by the DFG. We are looking forward to successfully continuing the projects with the coordinating University FAU (Friedrich-Alexander-Universität Erlangen-Nürnberg) as well as the Leibniz-Universität Hannover and to link to results already achieved within the scope of this Collaborative Research Center.

Another major project regarding education in engineering and its investigation started in 2016 with the ELLI 2 kick-off meeting hosted by the IUL. Thanks to the generous financial support by the Federal Ministry of Education and Research (BMBF), together with our partners of the Center for Higher Education (ZHB) of TU Dortmund University, of RWTH Aachen University, and Ruhr-Universität Bochum we purposefully work on improving engineering training by the use of remote labs and digitization of education.

In this activity report we gathered detailed reports on all current research projects and patents, information on education at the IUL as well as publications and summaries of our events in 2016 for you. The fact that the publication “60 Excellent Inventions in Metal Forming”, published and presented during a colloquium held on the occasion of Matthias Kleiner’s 60th birthday in 2015, enjoys great popularity and was already downloaded more than 70.000 times as e-book, is evidence for e.g. our events having a very positive and long-term impact.

At the IUL, we collaborate in an international team as part of an equally international community of researchers to achieve our objectives. We are thankful for the tolerant living and working conditions and the chances we experience every day – unfortunately, 2016 was not a peaceful year for all friends of the IUL across the globe.

We give our sincere thanks for the great and successful cooperation in the past research year 2016 to the numerous funding institutions collaborating with us, to the friends of the Institute of Forming Technology and Lightweight Components, to the numerous guest researchers enriching our research and everyday life at the IUL, and to the skilled and dedicated staff of the institute.

A. Erman Tekkaya

Matthias Kleiner

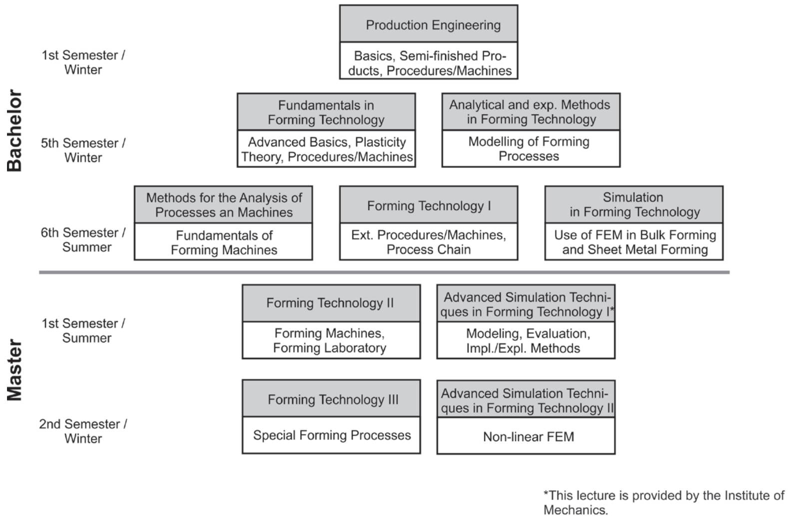
Education

01

1 Education

1.1 Offered Courses

The Institute of Forming Technology and Lightweight Components offers lectures and laboratories for 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 detail, the following lectures were offered in 2016.



Structure of lectures e.g. of the study program mechanical engineering with specialization in production engineering (all above courses are taught in German)

Further courses of the institute are:

- Lecture series in Forming Technology
- Laboratory work A for Master students of Mechanical Engineering
- Laboratory work B for Bachelor students of Industrial Engineering

Following courses are offered by the IUL for students enrolled in "Master of Science in Manufacturing Technology (MMT)". These courses are offered in English:

- MMT – Forming Technology – Bulk Forming
- MMT – Forming Technology – Sheet Metal Forming
- MMT – Advanced Simulation Techniques in Metal Forming
- MMT – Additive Manufacturing
- Lecture series in Forming Technology
- MMT Laboratory

In the year 2016 all courses offered by the IUL were integrated into the course management system moodle of TU Dortmund University. Moodle is a learning management system and offers different features. Students can download documents like lecture notes or tutorials. Starting from winter semester 2015/2016, lectures at the IUL are recorded. With this new approach students can repeat lectures to recapitulate the content or to prepare for the exam. The videos include the pictures of the projector and the voice of the teacher.

In 2016, the following guest professors and lecturers participated in the educational offers of the IUL:

- Prof. P. Haupt, Emeritus University of Kassel
- Prof. K. Roll, formerly Daimler AG Sindelfingen
- Dr. J. Sehrt, University of Duisburg-Essen

Further information at www.iul.eu/lehre

1.2 Master of Science in Manufacturing Technology (MMT)

Coordination — Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Frigga Göckede B. B. A. • Oliver Napierala M. Sc.
Dipl.-Ing. Tobias R. Ortelt • Dr.-Ing. habil. Sami Chatti

About 60 excellent students from more than 20 different countries are currently enrolled in the English-language, four-semester master study program 'Master of Science in Manufacturing Technology' (short: MMT) in the field of manufacturing technology which started in 2011. In 2016, more than 1,000 students from more than 43 different nations applied for this program.

In 2016, the MMT program was successfully reaccredited by the Accreditation Agency ASIIN.

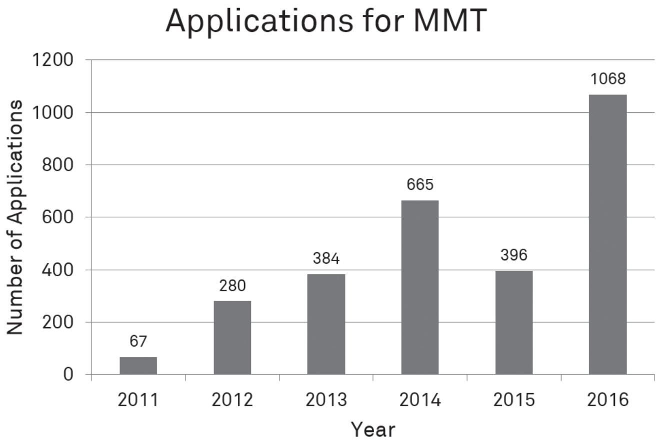
As a result, new lectures such as "Plastics Technology" or "Additive Manufacturing" were added to the module manual. The technical elective course offer could also be extended as planned, thereby taking into account new developments in research and technology.

Furthermore, the German language course offer was adapted to the students´ current needs. German language skills are not compulsory to complete the MMT program. However, for an employment in Germany they are almost indispensable. For this reason, two new German language classes, level A1 and A2, especially for MMT students have been installed in addition to the regular courses offered by TU Dortmund University to all students.

Program overview (valid from the winter semester 2016/2017)

	1st semester	2nd semester	3rd semester	4th semester
Compulsory module 1	Machining Technology			
	Machining Technology I	Machining Technology II		
Compulsory module 2	Materials Technology			
	Plastics Processing Technology	Materials Technology II		
Compulsory module 3	Forming Technology			
	Forming Technology I	Forming Technology II		
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	
Interdisciplinary qualification			Interdisciplinary Qualifications	
Master´s thesis				Master's thesis

The MMT online application portal could once more be considerably improved in cooperation with the IT & Media Center of TU Dortmund University. This step was necessary due to the steady increase in applicants and the involving amounts of data. Hence, the application procedure for the applicants as well as the processing of the applicants´ data and the subsequent selection of the students to be admitted have become even more convenient and efficient.



A total of 27 selected excellent students from 15 different countries have started their studies in the MMT program in the winter semester 2016/17. Before the start of the lecture period they were welcomed by Professor Tekkaya in his capacity as head of the MMT program within the scope of a welcome event in the lecture hall of the Mechanical Engineering Building MB III and the experimental hall of the IUL.

Further information at: www.mmt.mb.tu-dortmund.de

Welcome event for the new MMT students of the year 2016

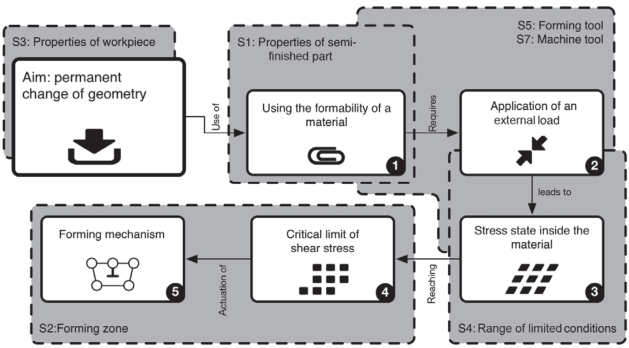
1.3 Doctoral Theses

Pleul, Christian	The Laboratory as Learning and Teaching Environment in Forming Technology - Development Strategy and Didactical Model for Higher Education
Original title	Das Labor als Lehr-Lern-Umgebung in der Umformtechnik - Entwicklungsstrategie und hochschuldidaktisches Modell
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2016, Volume 89
Oral exam	May 10, 2016
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Co-examiner	Prof. em. Dr. Dr. h. c. J. Wildt

Accomplishments and innovations in manufacturing technology, e. g., in forming technology require, to a significant amount, the experiential acquisition of knowledge. This typical engineering approach needs to be addressed in production engineering studies. This can be done using the teaching and learning format of a laboratory in an effective and requirement-oriented way.

In this work, the development and execution of a laboratory course for the forming technology is shown. By means of a systematic examination of forming itself, the course concept is based on the conceptual presentation of the analytically examined forming process. With the systematic conceptual design, a combination is done of

- an engineering-specific, structured approach covering the processing of an authentic issue through to resolving the defined problem and
- a specialized didactic design for the purpose of experiential and problem-based learning geared to a student-centered and competence-oriented environment.

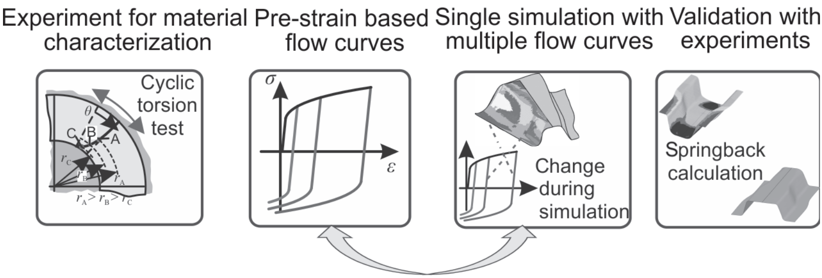


Combination of the developed conceptional representation of forming and the systemic view of the forming process

Hassan, Hamad ul	Springback in Deep Drawing – Accurate Prediction and Reduction
Series	Dortmunder Umformtechnik, Volume 90
Publisher	Shaker Verlag, Aachen, 2016
Oral exam	October 19, 2016
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. Erman Tekkaya
Co-examiner	Prof. Dr. -Ing. K. Roll

One of the major problems in the field of deep drawing is springback. After the deep drawing process, the parts are unloaded which results in a deviation of the formed part from the desired geometry due to elastic strains. Failure in predicting springback properly can lead to problems during the assembly, resulting in an unwanted increase in cost and time delays due to tool reworking.

The application of a single stress-strain curve for the springback prediction using FE simulations has shown limited potential for complex parts. In addition, the springback reduction based only on the increase of the constant blankholder force is limited. In this research work, an FE simulation-based strategy for the application of multiple stress-strain curves for an accurate springback prediction is presented, as shown in the figure. A variation of the blankholder force for the reduction of springback during the deep drawing process is carried out to reduce springback efficiently. The springback results are verified by the deep drawing experiments.



Strategy for accurate springback prediction

Education

01

Research for Engineering Education

02

2 Research for Engineering Education

Excellent education is based on excellent research and excellent research needs excellently educated engineers. Therefore, teaching must be adjusted to current topics like digitization or Industry 4.0 (German term for cyber physical systems). In January 2016, the new department of "Engineering Education and Remote Manufacturing" was established at IUL in charge of the design of several projects for a sustainable development of engineering education in interaction with research for teaching and learning. The main focus of attention of this department is the science-based investigation to improve learning in engineering laboratories. By means of laboratories or by performing experiments, students are able to combine theory and practical relevance. Results of this research were part of the acatech study „The lab in engineering education – Future-oriented approaches resulting from the IngLab project".

New concepts of education complement new scenarios resulting from digitization and prepare students for daily professional life in the context of Industry 4.0. This connection can be achieved by different approaches. On the one hand, the ELLI tele-operative testing cell for material characterization provides a location and time-independent access to experiments via the internet. On the other hand, live experiments are integrated into lectures and students can use their own mobile devices to answer polls during the lectures live and anonymously. This way, didactical concepts are combined with new technologies.

The projects in detail are:

- ELLI – Excellent Teaching and Learning in Engineering Science
- MINTReLab – International Manufacturing Remote Lab (project of the faculty of Mechanical Engineering)

2.1 ELLI/ELLI2 – Excellent Teaching and Learning in Engineering Science

Funding	BMBF/DLR
Project-ID	01 PL 11082 C (until September 2016 - ELLI) 01 PL 16082 C (since October 2016 - ELLI 2)
Head	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Contact	Dipl.-Ing. Tobias R. Ortelt • Dipl.-Inf. Alessandro Selvaggio Rickmer Meya M. Sc. • Joshua V. Grodotzki M. Sc. Dr.-Ing. habil. Sami Chatti

The second funding period of the transregional joint research project of RWTH Aachen University, Ruhr-University Bochum, and TU Dortmund University started in October 2016. The project will run until the end of 2020. Since 2011, this project has been funded by the Federal Ministry of Education and Research.

ELLI 2 is divided into four different fields:

- Remote lab and virtual learning environments
- Support of mobility and internationality
- Student lifecycle
- Entrepreneurship

At TU Dortmund University, ELLI 2 is still processed by the IUL in collaboration with the Center for Higher Education (zhb).

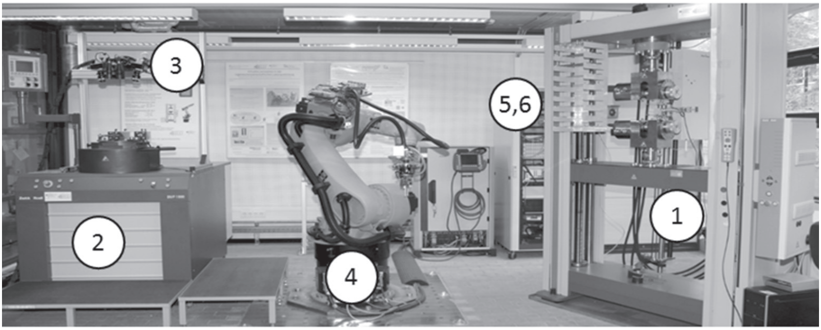
During the first funding period until September 2016 the IUL principally worked on two sub-projects of the first field "virtual learning environments":

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

Major parts of the first sub-project "Investigation on lab courses in engineering education" were already finished in 2015. In 2016, an evaluation of the developed remote lab was performed in cooperation with the zhb and focused on two different levels, i.e., technology and teaching or learning. The results of this evaluation lead to a continuous improvement of the experiments.

The second measure "Development and integration of remote and virtual labs" dealt with the development of the tele-operative testing cell at the IUL. The following picture shows the tele-operative testing cell and its individual components:

1. Universal testing machine Zwick Z 250
2. Sheet metal testing machine Zwick BUP 1000
3. Optical measuring system GOM ARAMIS 4M
4. Industrial robot KUKA KR30-3
5. Realtime control system from National Instruments
6. Safety system SICK + Camera system



Tele-operative testing cell at IUL

In January 2016, the premiere of the tele-operative cupping test took place in the lecture ‘Fundamentals in Forming Technology’. This new experiment was performed in the lecture hall and the automated BUP 1000 was used. Students were able to identify the influence of the chain power on the deep drawing process. Various mistakes such as wrinkling were observed and theory and practice were linked.

Students were able to identify the effect of tension superposition as a machine for incremental forming (IRU) was automated within ELLI.
Through this innovative process a reduction of the bending power and the springback is achieved. Students can define and adapt tube geometry under load through the establishment of a tele-operative interface in LabVIEW. They are able to view the axis movement in the program in advance. Afterwards, the experiment can be watched through a live webcast by a HD camera.

Diagrams of bending moment and feed rate can be generated using measured data such as the power on the bending head. An adaption of parameters and switching the tension superposition on and off shows the benefits of this procedure.

The tele-operative testing cell was repeatedly used during an online course for new international students of the master study program Master of Science in Manufacturing Technology (MMT). These students conducted an experiment via internet from their home country (such as India, Iran, Nepal, or Mexico) before they have ever been to Dortmund.

Results of the ELLI project were presented at national and international conferences, for instance the dghd's annual meeting in Bochum, the REV 2016, and the EDUCON 2016. At the REV 2016, the experiments in the tele-operative testing cell received the "Best Demonstration (Best Experiment) Award".

In ELLI 2 the IUL pursues two measures in the field "Remote lab and virtual learning environments":

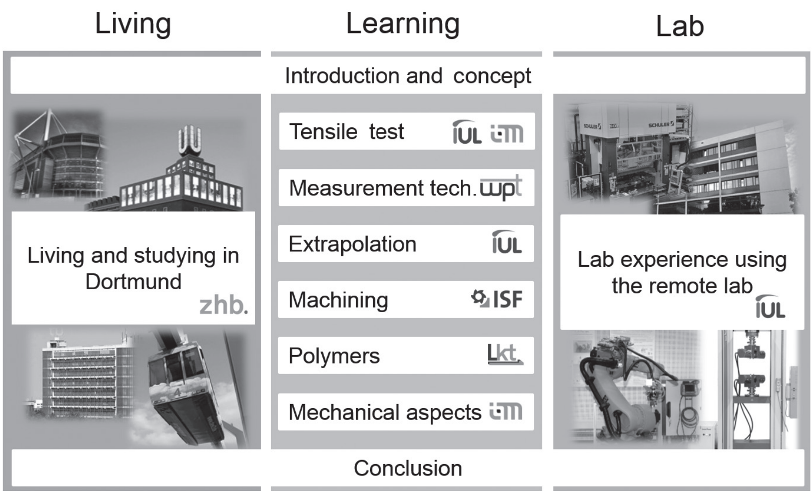
- Development of the tele-operative testing cell and integration of new experiments
- Virtual forming lab

This will include the automation of two additional machines, an additive manufacturing machine and a tube bending machine, including the corresponding experiments and their integration into the tele-operative testing cell. Experiments in the fields of machining technologies and materials test engineering will be developed in cooperation with the Institute of Machining Technology and the Department of Materials Test Engineering. Furthermore, new technological possibilities of digitization, such as virtual and augmented reality, will be integrated into engineering training in forming technology.

2.2 MINTReLab – International Manufacturing Remote Lab (Project of the Faculty of Mechanical Engineering)

Duration	October 2015 - May 2017
Funding	Stifterverband
Head	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya (as the Dean of the Faculty of Mechanical Engineering)
Contact	Dipl.-Ing. Tobias R. Ortelt

In the project “MINTReLab – International Manufacturing Remote Lab” five different partners of the Faculty of Mechanical Engineering (Department of Materials Test Engineering (wpt), Institute of Mechanics (im), Institute of Machining Technology (ISF), Institute of Forming Technology and Lightweight Components (IUL), Chair of Polymer Technology (LKT)), and experts of the Center for Higher Education (zhb) have developed a MOOC (Massive Open Online Course). The course will deal with the unidimensional tensile test from different subject-specific perspectives. The different chapters are batched and the tele-operative testing cell of the IUL is used for experiments. The remote lab should combine theory with practical relevance. In addition to this, the MOOC should also advertise studies in Germany, and especially at TU Dortmund University, by showing social aspects of the life in the Ruhr District. Therefore, the MOOC is divided into three parts (Living, Learning, Lab).



Concept of the MINTReLab MOOC

Research

03

3 Research

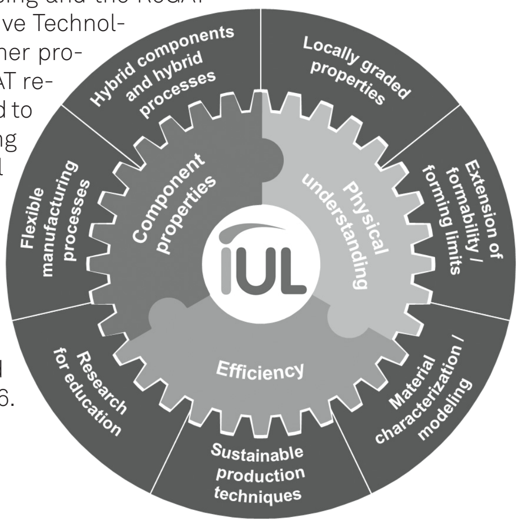
The research activities of the Institute of Forming Technology and Lightweight Components pursue three main objectives. The setting and improvement of component properties, the acquirement of physical understanding of forming processes, and a holistic view on efficiency are the aims of the departments Sheet Metal and Bending Technology, Bulk Metal Forming, Non-Conventional Processes, Applied Mechanics in Forming Technologies as well as Research for Engineering Education.

The main objectives are divided into the following research topics:

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

The IUL departments are complemented by the ReCIMP - Research Center for Industrial Metal Processing and the ReGAT – Research Group on Additive Technology. As with basically all other projects, the ReCIMP and ReGAT research projects are assigned to issue-specific teams working both at an intradepartmental and interdepartmental level.

2 chief engineers, 44 scientists, 11 technicians and administrative staff members, and approximately 50 student assistants ensured a sustainable success in 2016.



Research objectives of the Institute of Forming Technology and Lightweight Components

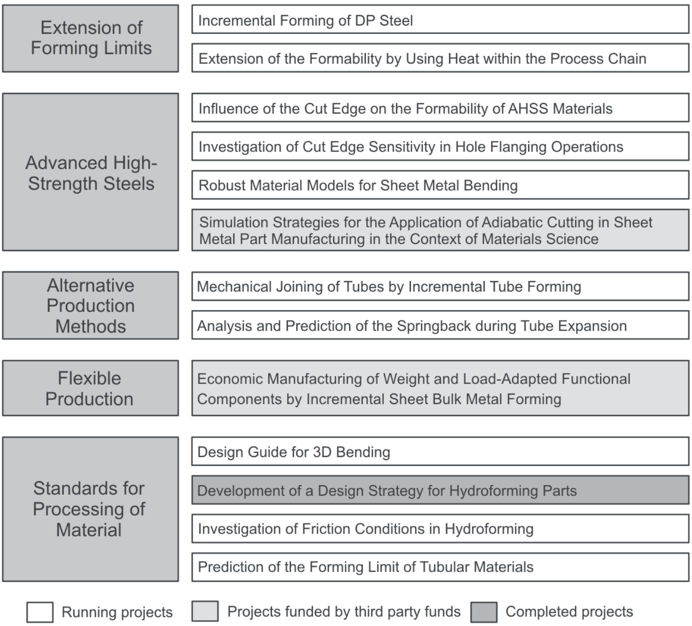
3.1 Research Groups and Centers

3.1.1 ReCIMP – Research Center for Industrial Metal Processing

Head Dipl.-Ing. Daniel Staupendahl

The „Research Center for Industrial Metal Processing" (ReCIMP) was founded at the IUL in 2013 in cooperation with Faurecia and aims at extending and deepening basic knowledge about innovative metal production processes, process chains and hybrid processes, the investigation of new scientific trends in manufacturing technology, and at networking with further companies and leading research institutions. Faurecia is one of the leading automotive suppliers in these three fields: Automotive Seating, Clean Mobility (formerly known as Emissions Control Technologies), and Interior Systems.

Together with the Faurecia groups "Automotive Seating" and "Clean Mobility", high-priority research topics were defined, which were further divided into specific research projects.



ReCIMP research projects worked on in 2016

13 research projects in total were performed in 2016, of which one was successfully completed in that year. Relevant achievements were the design and setup of a modular hydroforming tool, which increases the cost efficiency of hydroforming parts when producing a large number of variants. Additionally, a tool for incremental thickening of tube ends was developed and produced using the institute's new additive manufacturing Laser powder deposition machine. Furthermore, one invention was produced and a corresponding patent was filed. Two of the projects are third-party funded by the AiF/FOSTA: Economic manufacturing of weight- and load adapted functional components by incremental sheet bulk metal forming and Development of Simulation Strategies for the Application of Adiabatic Cutting in Sheet Metal Part Manufacturing in the Context of Material Science, both of which are described later in this chapter.

8 researchers and 6 student researchers were involved in ReCIMP projects in 2016. Furthermore, 3 master theses, 1 bachelor thesis and 4 student research projects were completed and 3 master theses and 5 student research projects are still running. A large part of these works was performed by students of the international Master study program “Master of Manufacturing Technology” (MMT).

Thanks to the great performance of everybody involved, after now 4 years of successful cooperation the extension of the ReCIMP beyond the first funding period, lasting until the end of 2017, is planned. Ideas are already filling the roadmap 2018-2022. In this second funding period, the field of hybrid technologies will be addressed. Hybrid structures are, besides the application of high strength steel, one of the building blocks essential for the realization of lightweight design and the resulting reduction of CO_2 emissions of motor vehicles.

An important topic when using high strength steels is a thorough material examination, comprised of experimental material characterization, robust material modelling (described later in this chapter), and the analysis of their behavior in forming processes and in later application. For example the cut edge sensitivity of sheet metal is investigated, a major topic and great challenge in sheet metal forming. The choice of material, coupled with the need for cost reduction and saving of valuable resources also affect two other fields of competence: process and production. On the one hand this means mastering processes by setting up standards and extending forming limits. On the other hand this means developing alternative production methods and flexible processes. The increased complexity of forming conditions and the reduced forming limits of modern high strength materials can be addressed by target-oriented and precise predictions of exactly this forming behavior. One example is the generation of forming limit diagrams especially setup for the forming of tubes. Once the predictions produce stable results they are implemented in standards. Expert workshops are used for knowledge transfer. Early in 2016, for instance, a workshop on the finite element analysis and optimization of induction coils used for brazing operations and hot forming was performed.

When talking about hot forming, the extension of process limits is in focus. Under investigation is the hot forming of tubes as well as the influence of additional heat treatment steps between forming operations (detailed description later in this chapter). The competence in the field of hot forming also generates cross-project impacts: by partial induction heating and thus, the local extension of forming limits, the manufacturing of an industrial sheet-bulk metal forming part was optimized. As an additional approach in the extension of forming limits, incremental sheet metal forming is analyzed. The target of current investigations is the forming of dual phase steel and the reduction of process time.

Incremental forming processes are also used in the development of new production methods. Here, sheet metal forming is addressed as well as sheet-bulk metal forming, the latter being used not only to locally thicken the material but also to increase the material strength of selected materials by using their strain hardening effects. Furthermore, mechanical joining of tubes by spinning as an alternative to brazing or welding is investigated. An important aspect here is that the joined tubes must withstand high temperatures during applications (a detailed description of the project is given later in this chapter). Additionally to all of the described research topics, new project ideas that focus on current scientific trends in manufacturing technology are continuously generated and set in motion.

3.1.2 ReGAT – Research Group on Additive Technology

Head Dr.-Ing. Dipl.-Wirt.-Ing. Ramona Hölker-Jäger

The working group ReGAT, newly founded in August 2015, explores the potential of combining additive and formative manufacturing technologies. Besides additively manufactured extrusion dies with inner cooling channels and channels for the integration of measurement technique also additively manufactured tool coils and windings for electromagnetic forming consisting of two materials in order to ensure a high mechanical stability as well as a good electrical conductivity are investigated, respectively. Moreover, a proposal for a collaborative research project with the Institute for Product Engineering (IPE) at the University of Duisburg-Essen was granted by the German Research Foundation (DFG). In this project, additively manufactured sandwich sheets featuring a core geometry adapted to a downstream forming processing and the subsequent component function will be manufactured, tested, and investigated.

Besides these projects dealing with powder bed processes, a combination machine for laser deposition of metallic powder in a 5 axis-machining center, founded by the German Research Foundation (DFG) and the state of North

Additively manufactured (hybrid) parts

Rhine-Westphalia (NRW), was put into operation in March 2016. This machine offers the IUL the chance to develop a sustainable hybrid technology by integrating additive manufacturing into metal forming to combine the advantages of both technologies as e.g. the suitability for mass production, from a forming technology perspective, and the geometrical freedom, from an additive manufacturing perspective. In this novel combination machine sheets can be formed incrementally and geometrically complex form and functional elements can be added by laser powder deposition, also on already curved surfaces. The formation of steps in build-up direction resulting from the additive manufacturing process and the powder material being processed lead to a rough surface which can, if required, be mechanically refinished by roller burnishing and/or deep rolling as well as drilling and milling.
The process and the machine are based on a 5-axis machining center which can automatically pick up different tools at the tool holder/spindle:

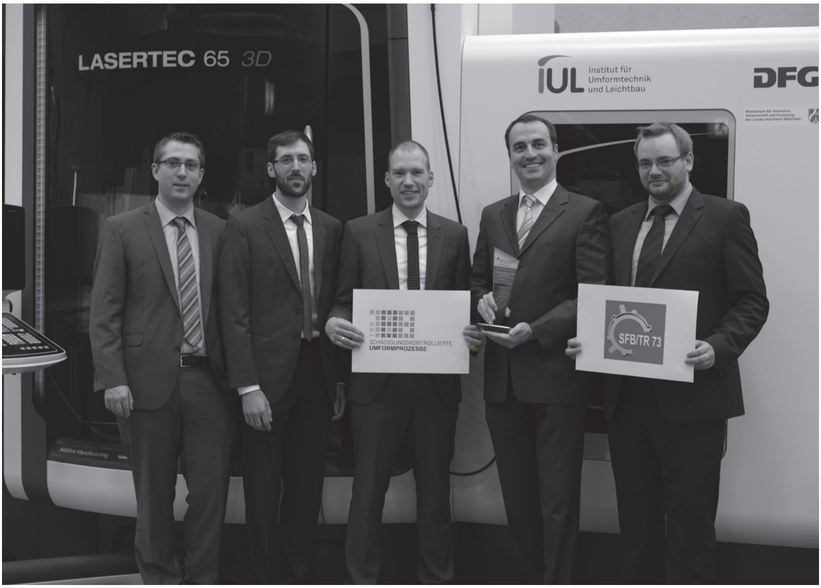
- a forming tool for incremental sheet metal forming,
- a rolling tool,
- a nozzle for laser powder deposition,
- and a die for drilling and milling.

With this machine it will be possible for the first time to integrate three manufacturing processes (formative, additive, and subtractive) in one machine.

3.2 Department of Applied Mechanics in Forming Technologies

Head Dr.-Ing. Till Clausmeyer

The department of applied mechanics in forming technologies has grown further in 2016. The research on material characterization and the processing of industry orders are coordinated in the department since the beginning of the year. New team members Dipl.-Ing. Thorben Bender, who joined the institute in January, and M. Sc. Heinrich Traphöner, who had worked in the department of sheet metal forming before, boosted the departments capacity.
The research focus is on the development and application of new material models in forming simulations with the help of the finite-element-method. In particular, the influence of hardening, damage, and failure is investigated in forming processes such as sheet forming, shear cutting, and sheet-bulk metal forming. The members of the department contributed successfully to the proposals of the collaborative research centers SFB/TR 73 and SFB/TR 188. The team members enjoy the collaboration with the Japanese visiting scientist Satoshi Sumikawa from JFE Steel Corporation.

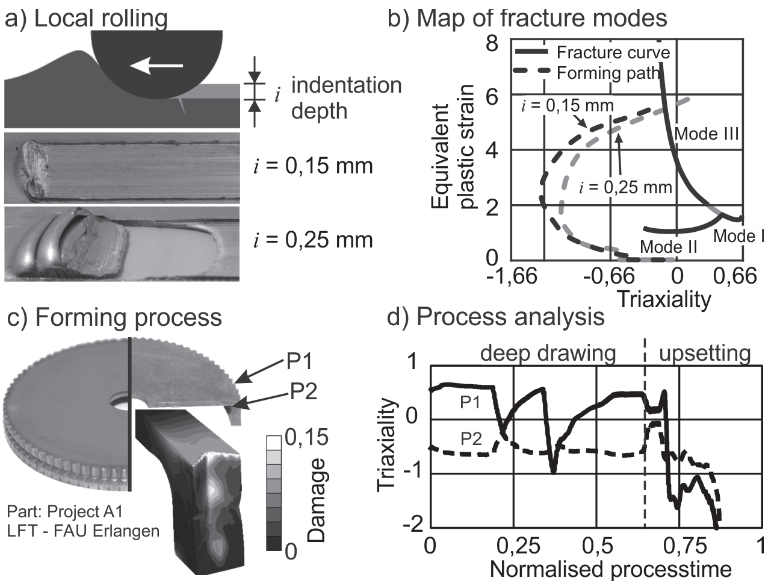


Members of the department with a scientific award and logos of the collaborative research centers

3.2.1 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/TR73 • Project C4
Contact Kerim Isik M. Sc. • Florian Gutknecht M. Sc.

The material behavior in the context of sheet-bulk metal forming (SBMF) processes is analyzed and adapted material models are qualified in collaboration with the "Institut für Werkstoffkunde" (IW) at Leibniz Universität Hannover. A controlled material flow in the direction of the sheet thickness to improve the mechanical component properties is characteristic for this novel type of manufacturing process. This approach results in significantly more complex loading paths on the material level and can even lead to Mode III failure. With the help of local rolling (see figure a) it was possible to validate analytically determined fracture curves for Mode III (see figure b). The dashed lines show the forming path for different indentation depths.
Figure c shows an exemplary part manufactured by sheet-bulk metal forming. Simulation results with a damage model are shown on an enlarged and rotated contour plot. The analysis of material points (P1, P2) reveals the forming path of a manufactured part (see figure d).

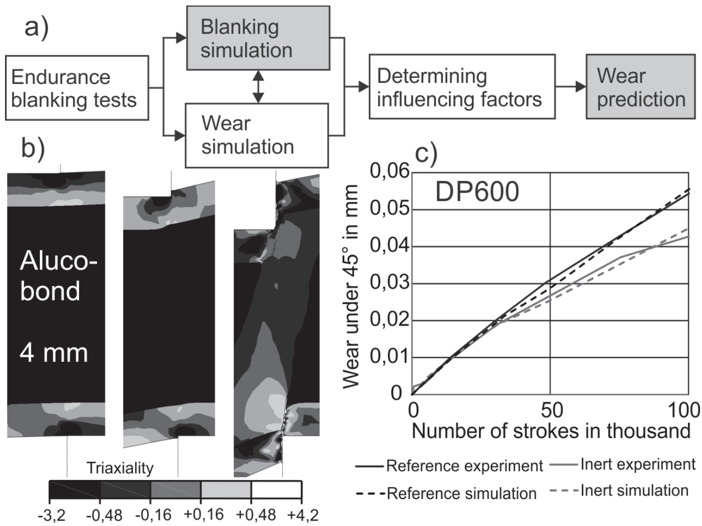


a) Experiments for the validation of Mode III failure in sheets, b) Combined fracture curves, c) Simulation of a manufactured part, d) Analysis of the loading path

3.2.2 Software Tool for Robust Design of the Blanking Process of Metal Laminated Composite Material without Lubricants

Funding	German Research Foundation (DFG)
Project	TE 508/37-1
Contact	Florian Gutknecht M. Sc.
Status	Completed

In cooperation with the Chair of Metal Forming and Casting (utg) at TU München a software tool for the prediction of wear during blanking processes has been developed within the scope of the AiF/DFG-Cluster PAK 678/0 “Dry Shear Cutting of Metal Laminated Composite Materials”. The developed method (see figure a) is based on an iterative calculation of the amount of wear. At the IUL the process has been simulated for monolithic sheets and - for the first time in literature - for sandwich panels. With the help of these simulations it was shown that the examined sandwich panels – in contrast to monolithic sheets – undergo distinct bending strains in the cover sheet (see figure b). Jointly, the institutes involved were able to predict the wear of the blanking tools for steel DP600. Figure c) exemplarily shows the progression of wear at an angle of 45° between front and lateral side at the upper blade with an increasing number of strokes. The wear progression calculated by simulation and measured in experiments for environmental atmosphere and inert atmosphere are in good agreement.

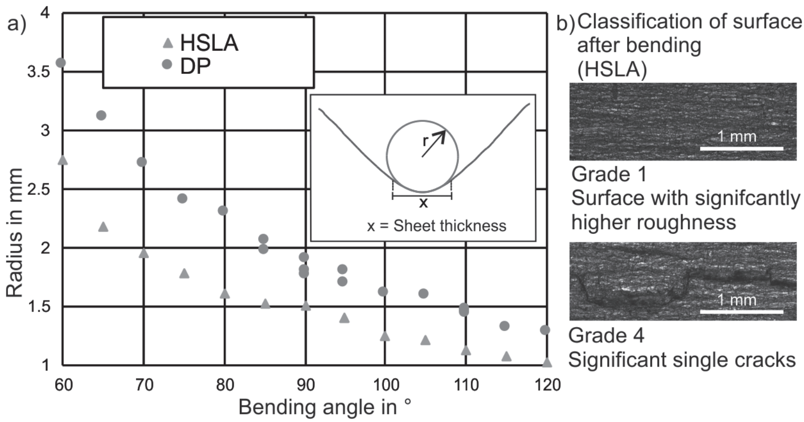


a) Method for wear prediction in blanking tools, b) Stress states for Alucobond, c) Wear progression at the upper blade

3.2.3 Robust Material Models for Sheet Metal Bending

Funding ReCIMP
Contact Dipl.-Ing. Torben Bender

The application of advanced high-strength steels (AHSS) in cars is of particular interest for the automobile industry. Steel is still a low-priced material and with the relatively new AHS steels the industry is able to develop thinner and lighter components for more fuel-efficient vehicles. The focus is on the prediction of the material behavior of these materials, in particular during bending and unbending.
A testing device was developed for the determination of the influence of kinematic hardening and damage during bending and unbending.
Different material models were applied to reproduce the experimentally determined force vs. bending angle curves. An additional testing device, which allows producing bending specimen with defined bending angles and radii, is currently being designed. A method based on light-optical measurements was developed for the exact determination of bending radii. This was a requirement to compare different steel grades with respect to their failure grade (see figure b).



c)

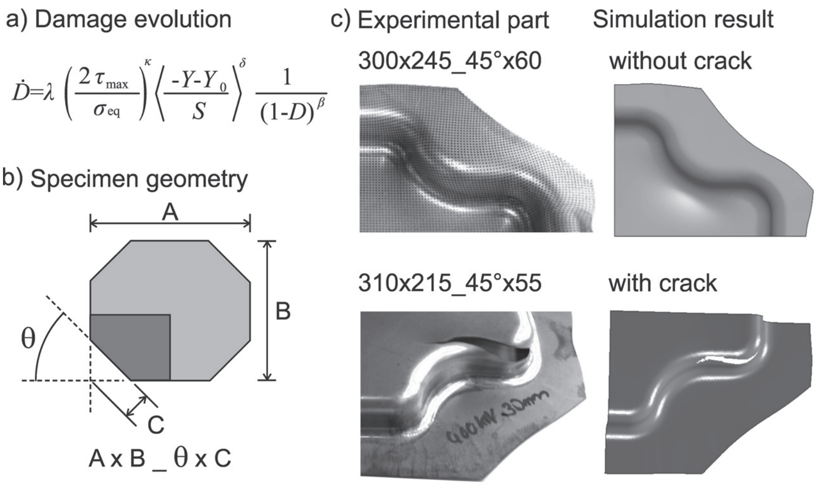
Material	Radius in mm	Bending angle in °	Classification
DP	1.45	110	1.5
HSLA	1.5	90	1

a) Radius over bending angle, b) Failure grade, c) Comparison between bending angle and failure grade

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

Funding	AiF/FOSTA
Project	P 1039
Contact	Kerim Isik M. Sc. • Dr.-Ing. Till Clausmeyer
Status	Completed

A damage model which considers the effect of different stress states was developed to predict the failure by fracture for advanced high- strength steels in deep drawing. To predict the shear-dominated fracture behavior, the damage evolution relation of the damage model was modified by considering the maximum shear stress. In a cooperation with the company inpro, the characterization tests (such as a tensile test with a notch, a Nakajima test with a round (biaxial) specimen, and an in-plane torsion test with a grooved specimen) were used to identify the material parameters for the model implemented in commercial software within the scope of the project. For the determination of the fracture behavior under shear, in-plane torsion tests with a grooved specimen and further sample geometries were evaluated with respect to their applicability. The simulations with the identified parameters could successfully predict the failure due to fracture in the industry-oriented deep drawing tests (see figure). The project is supported by automotive manufacturers, software houses and steelmakers.

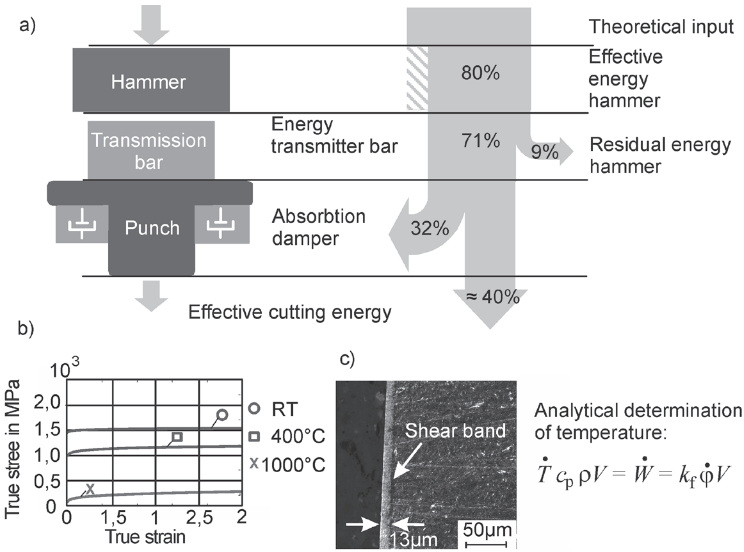


a) Evolution relation for damage, b) Blank geometry, c) Comparison of the simulation with the enhanced model and the experiment

3.2.5 Development of Simulation Strategies for the Application of Adiabatic Cutting in Sheet Metal Part Manufacturing in the Context of Materials Science

Funding	AiF/FOSTA
Project	18865 BG – P 1127
Contact	Fabian Schmitz M. Sc.

Adiabatic blanking is characterized by a high cutting quality in comparison to conventional blanking methods for high-strength and advanced high-strength steels. A temperature-induced softening occurs due to the high local rate of deformation ($\dot{\varepsilon} > 10^3\ s^{-1}$) and the short process time ($t < 2$ ms). A number of different analytical approaches was developed to compute the temperature in the shear band. Upper bounds for the necessary separation energy as well as temperatures reported in the literature could be determined with these methods. The correct prediction of the temperature field is necessary for the validation of the process simulation. Adiabatic blanking is investigated experimentally and with the help of finite element simulations. Geometries ranging from simple shapes to industrially relevant finished parts are analyzed. The project is conducted in cooperation with the Institute of Materials Science and Engineering (LWW) in Chemnitz. The LWW team focuses on the materials science-based phenomena.

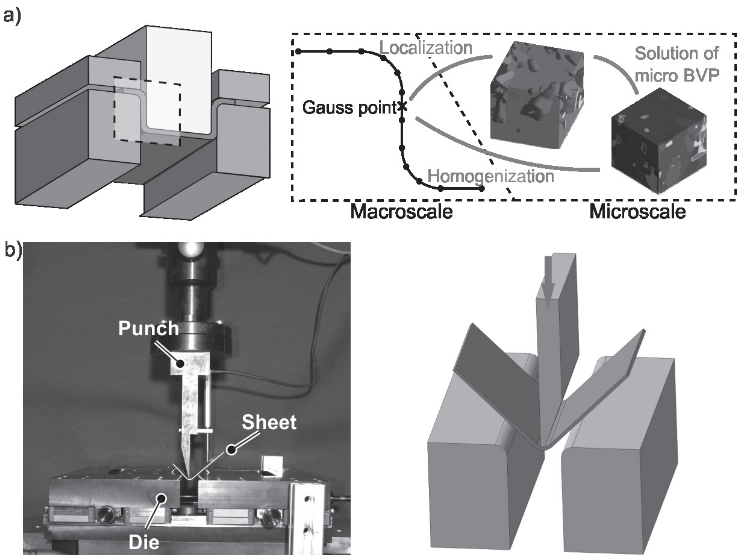


a) Energy loss in adiabatic blanking process, b) Temperature-dependent flow stress, c) Adiabatic shear band in C75S

3.2.6 Micromechanical Modeling of Material Forming for the Prediction of Anisotropic Hardening

Funding	Mercator Research Center Ruhr
Project	Pr-2015-0049
Contact	Dr.-Ing. Till Clausmeyer

New micromechanical multiscale material models are developed to predict the influence of microstructural parameters on the forming behavior. The focus of the project is the description and microstructure specific prediction of anisotropic hardening during forming. Two different approaches are investigated and evaluated. In the first approach the elementary deformation and hardening mechanisms are modeled in representative volume elements (RVE) based on a detailed representation of the actual microstructure. In the second approach a direct coupling of microstructure models with macroscopic simulations within the scope of the FE2 method is accomplished. For this method beam elements are used.
The project is conducted in cooperation with Professor Hartmeier at the Interdisciplinary Centre for Advanced Materials Simulation (ICAMS) in Bochum and Professor Schröder at the Institute of Mechanics of the Universität Duisburg-Essen. Two graduate students are supervised by the three principal investigators (Prof. Hartmaier, Prof. Schröder, Prof. Tekkaya).

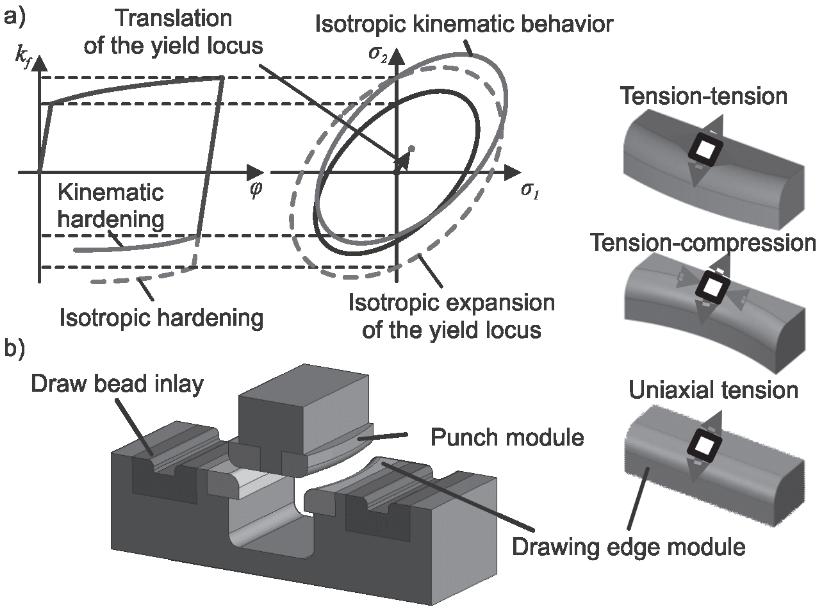


a) Deep drawing and two-scale calculation approach (Courtesy of Jörg Schröder), b) Air bending

3.2.7 Analysis of Material-Specific and Geometric Influences on the Numerical Springback Prediction

Funding AiF/EFB
Project 17613N
Contact Heinrich Traphöner M. Sc.

This project is being carried out in cooperation with the Institute of Manufacturing Technology in Erlangen. The focus is on the evaluation of springback behavior for sheet metal materials. On the one hand, this will be achieved by the analysis of material properties, such as planar anisotropy and Bauschinger effect. On the other hand, models and indicators are developed that improve the numerical prediction and allow to estimate the characterization effort. This serves the purpose to reduce the characterization effort. With the model being developed, it will be possible to use different sets of material parameters in a simulation that is applied based on the load path. On the basis of a modular deep drawing tool, different defined stress states can be generated in a deep drawing component and used to evaluate the numerical models determined. As shown in the figure, various inlays for stamps, dies, and draw beads can be combined to create a desired condition.

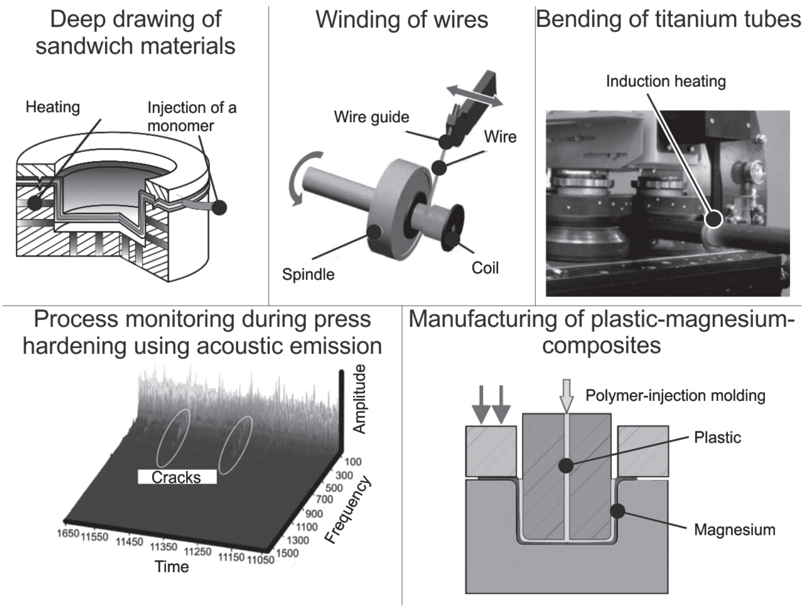


a) Yield locus and flow curve for isotropic and kinematic hardening, b) Modular deep drawing tool for the analysis of defined stress conditions

3.3 Department of Sheet Metal and Bending Technology

Head Lars Hiegemann M. Sc.

At the beginning of 2016, the department of sheet metal forming was combined with the department of bending technology. Due to this fusion, the department now includes the research areas of sheet metal forming, profile forming as well as profile and wire bending. The resulting closer cooperation between the individual projects allows the best possible use of synergies. For example, strategies for temperature control are important in profile bending as well as in sheet metal forming. Research assignments of the department are the development of new and the expansion of existing forming processes. This is carried out to comply with the aims of lightweight construction as well as resource efficiency. In this context, the focus is on an extended understanding of each forming process in order to comprehend and describe the acting physical effects. In the course of the year five new research projects could be initiated (Figure). These projects deal with deep drawing of sandwich materials, wire bending, bending of titanium tubes, process monitoring during press hardening, and manufacturing of hybrid plastic-magnesium composite parts.

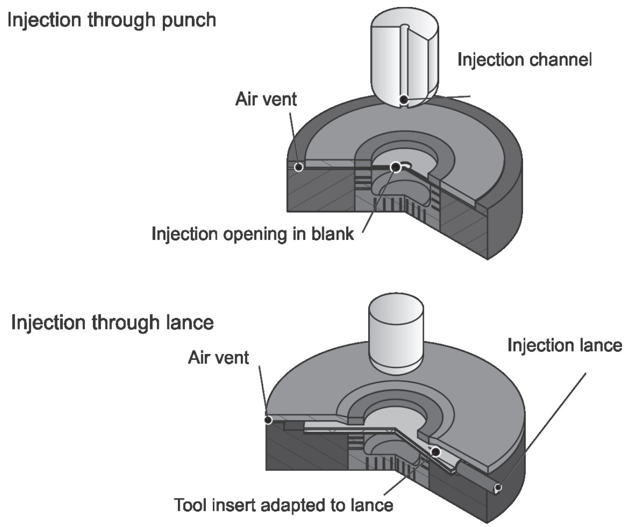


Research projects initiated in 2016 by the Department of Sheet Metal and Bending Technology

3.3.1 In-Situ Hybridization in Deep Drawing Processes – Thermoplastic Fiber-Metal Sandwich Parts Based on Cast Polyamide 6

Funding	German Research Foundation (DFG)
Project	BE 5196/4-1
Contact	Dipl.-Ing. Thomas Mennecart

Deep drawn parts made out of fiber-metal sandwich material are produced in a one-step process in this cooperative research project with Karlsruhe Institute of Technology (KIT). This method prevents a further step before the production of the semi-finished product. For this, the thermoplastic components can be injected by a resin transfer molding process between the sheets at any given moment of the deep drawing process. A combined deep drawing and resin transfer molding forming tool is being developed. Different injection methods, as shown in the figure, are combined in this tool by its modular design. With these modules the injection of the polymer can be realized before, during, and after forming of the stacked sheets to realize different viscosities. First forming experiments of cylindrical cups with metal sheets made of DC04 and AA5182 and a thickness of 1.0 mm showed differences in their forming behavior with when using different viscosities between the sheets. Due to the flow of the fluid medium, generated by pressure during forming, zones with different fluid quantities are created.

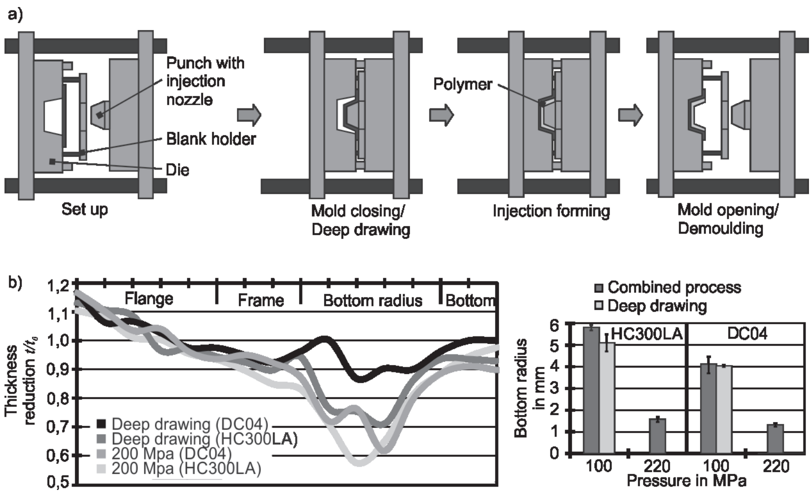


Combined forming and resin transfer molding tool with different injection strategies

3.3.2 Production of Structural Elements by Deep Drawing and Back Injection in Injection Molds

Funding	AiF/FOSTA
Project	18075 N
Contact	Sigrid Hess M. Sc.
Status	Completed

In cooperation with the Institute of Plastics Processing (IKV) in Industry and the Skilled Crafts at RWTH Aachen University, a combined process consisting of deep drawing and injection molding was developed. This process enables the production of hybrid plastic/metal structural components in one process step. Therefore, the deep drawing tools punch, die, and blank holder have been integrated into the injection mold. By closing the tool, the sheet is deep drawn so that this additional forming step does not increase the cycle time of the injection process. The subsequent injection of the plastic is analogous to high-pressure sheet metal forming. Using a cup-shaped test specimen, it has been shown that the pressure induced by the injection process has the greatest influence on the shape quality and that it is a useful calibration parameter. At higher pressures smaller radii can be formed at the bottom of the cup, but this is accompanied by a thinning of the steel sheet (see figure).

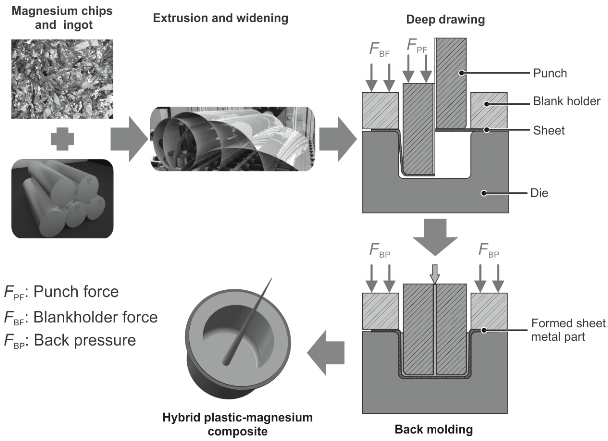


a) Process scheme, b) Influence of forming pressure on part quality

3.3.3 Development of Hybrid Plastic-Magnesium Composites for Ultra-Lightweight Design Applications

Funding European Fund for Regional Development (EFRD)
Project EFRE-0800113
Contact Hamed Dardaei M. Sc.

Combining magnesium and plastic leads to a new hybrid material with favorable material properties. New composite materials offer the opportunity to reduce the necessary process steps for innovative lightweight design in different sectors considerably. A hybrid material produced by deep drawing of a magnesium alloy and back injection molding of plastic, as it is shown in figure, enables an economic production of light but high-strength structures featuring a high level of functionality.
The aim of this project is to develop an integrated deep drawing and back injection molding process. To this end, a suitable bonding method (nano ceramic layers) for plastic-magnesium composites based on surface modifications of magnesium parts needs to be applied. Moreover, new tool concepts not only for the provision of the magnesium alloy, but also for the integation of the forming and shaping steps of the new hybrid material need to be considered. Finally, a prototype of the hybrid part and an analysis of the complete process will be available. This project will be performed in cooperation with the Institute of Plastics Processing (IKV) in Industry and the Skilled Crafts at RWTH Aachen University, TWI GmbH, KODA Stanz- und Biegetechnik GmbH, and JUBO Technologies GmbH.

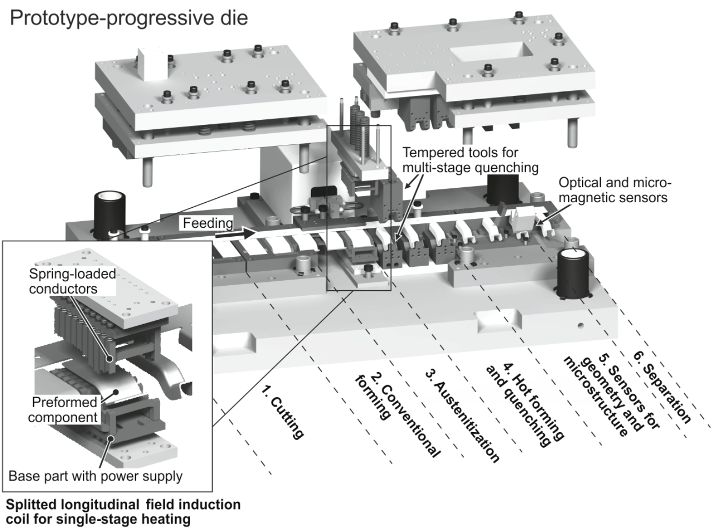


Production process of hybrid plastic-magnesium composite parts

3.3.4 ConProBend – Closed Loop Control of Product Properties in Progressive Dies

Funding	BMWi/ZIM-KF
Project	LF2198138LP4
Contact	Christian Löbbe M. Sc.

In cooperation with the company KODA a technology for the heat-assisted forming in progressive dies is developed in order to manufacture lightweight and tailor-made steel products. The approach is based on a closed loop control of flexible process parameters so that a compensation of geometrical parameters and microstructure target values is feasible.
The picture shows the prototype tool which is designed for the manufacturing of demonstrator components out of boron-manganese steel sheets with a thickness of 2.5 mm at a stroke rate of 20 min^{-1}. After shear cutting and conventional cold forming in the original condition, the rapid heating through a splitted longitudinal field inductor is used for the short-term austenitization in a subsequent step. Afterwards, the forming operations with a high amount of strain are performed in the ductile state before quenching is conducted in multiple stages. In the last step before separation the feedback for the process controller is obtained using various optical and micro-magnetical sensors. Thus, the new technology provides a solution to transfer the advantages of the established press hardening in terms of lightweight formability aspects to the fast-clocked manufacturing of sheet components in progressive dies.

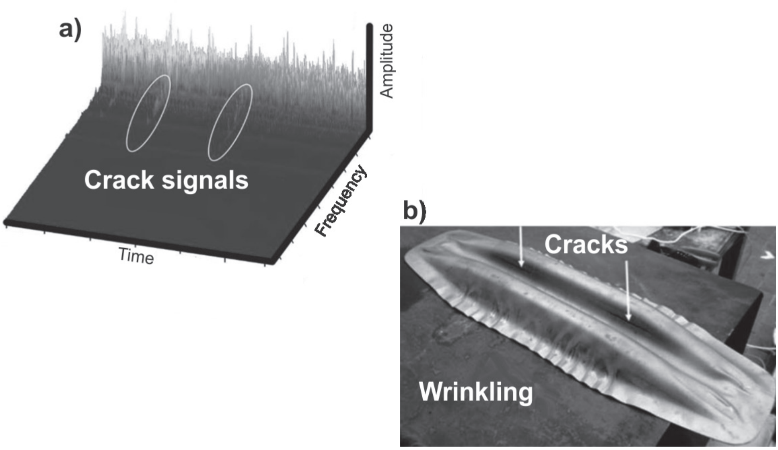


Progressive die tool for setting geometrical and microstructure target values

3.3.5 Optiform – Optimized Online Process Monitoring to Improve the Deep Drawing Properties of High-Strength Steel During Hot Forming

Funding European Fund for Regional Development (EFRD)
Project EFRE-0800265
Contact Mike Kamaliev M. Sc.

In cooperation with the Qass GmbH statements about the forming and material behavior in hot stamping processes are made. Structure-borne noises measured during the process serve as a basis. The input parameters of this project are acoustic emission waves which are absorbed in the form of solid state sound waves by piezo ceramic sensors directly at the tool. This specific procedure is known as high-frequency-impulse-measurement (HFIM) and is based on the mathematical principles of envelope analysis. Spectra of individual frequencies are created by means of an FFT of time-amplitude signals, resulting in a three-dimensional measurement output. Based on temperature-controlled tensile tests as well as pressing of demonstrators, statistical elaborations of the measured signals are carried out. In some cases, errors are introduced deliberately in the parts to see how they affect the measured signals (see figure 1). In this way, it is possible to give statements about the process.

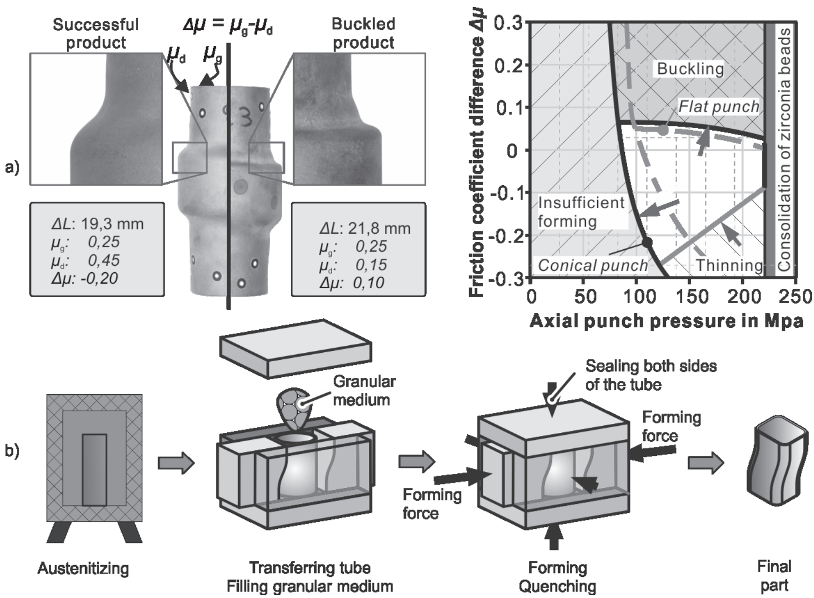


Defective part b) with corresponding time-amplitude signal in its frequency spectra a)

3.3.6 Granular Media-Based Tube Press Hardening

Funding German Research Foundation (DFG)
Project TE 508/52-1
Contact Sigrid Hess M. Sc.

Press hardening enables the production of high-strength components with strengths of more than 1500 MPa. It combines hot forming with a controlled cooling process and is state of the art in sheet metal forming. For the production of press-hardened tube components, granular media is used as forming media alternatively to gaseous media. It can be used at temperatures of up to 1000 °C and pressures of up to 100 MPa. The process window is limited by the friction ratios between tube wall and die as well as between tube wall and granular media. It was found that the use of granular media with lower internal friction and less compressibility can significantly improve the forming process. In addition, the force transmission from axial to radial direction can be optimized using a conically shaped punch. Thus, the required external energy is minimized, too. Besides the active use of granular forming media, the idea of a passive application has been developed (as shown in the figure). The project is carried out in collaboration with the German Aerospace Center (DLR) in Cologne.

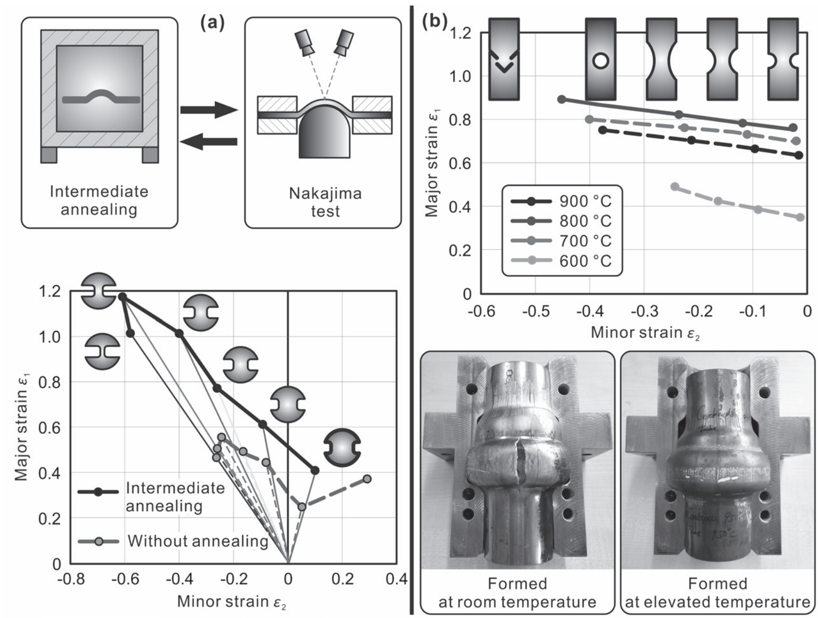


a) Active and b) passive granular media-based tube press hardening

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

Funding ReCIMP
Contact Hui Chen M. Sc.

The potential application of ferritic stainless steel as a substitute for austenitic stainless steel is limited by the relatively low formability. To extend the forming capacity of ferritic stainless steel in a tube hydroforming process, two approaches are proposed. The first approach is to include intermediate annealing steps between the forming steps. The FLC is elevated significantly through intermediate annealing according to Nakajima tests. Thus, tubular parts with complex shapes can be produced by multiple hydroforming steps. The second approach is to directly form the material at elevated temperatures. A granular forming medium is used to realize the forming temperature of up to 900 °C. The formability, especially on the left side of the FLC, is improved at elevated temperatures. Hot forming of ferritic stainless steel tubes at high temperatures can reach high expansion ratios at which specimen formed at room temperature show fracture.

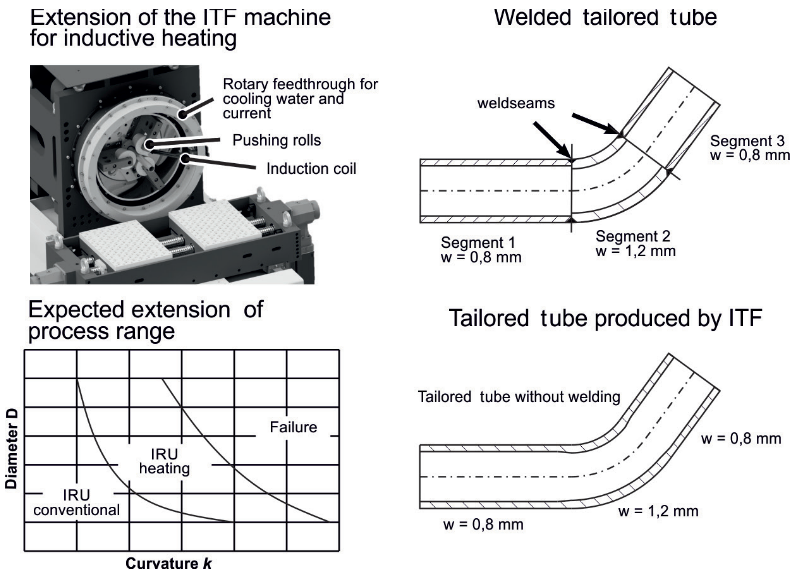


a) Extend the forming capacity by Intermediate annealing, b) Granular medium-based tube hot forming

3.3.8 Freeform Bending of Aviation-Relevant Tubular Parts

Funding	BMWi/DLR
Project	20W1514B
Contact	Lars Hiegemann M. Sc. • Rickmer Meya M. Sc.

Titanium (Ti-2) and titanium alloys (Ti3Al2.5V) have a manifold range of application in the aerospace sector. However, their high strength and low ductility impede the tube forming process. The rotary draw bending process is established in aviation companies, but it has various limitations as e.g. a long tooling time and a limited complexity in the part geometry. Therefore, in this project the Incremental Tube Forming (ITF) as a freeform bending process will be qualified for producing aviation-relevant parts. The project partner PFW Aerospace GmbH produces load-adapted tubes by welding of tubes with different properties. By using ITF with a mandrel the tube diameter and wall thickness can be systematically adjusted. Therefore, load-adapted tubes can be produced without welding and without associated costly quality checks of the welded area (see figure). Due to the high demands of titanium and the aim of extending the process range, the machine will be extended by inductive heating (see figure). The effects of the heating on the process range have to be analyzed.

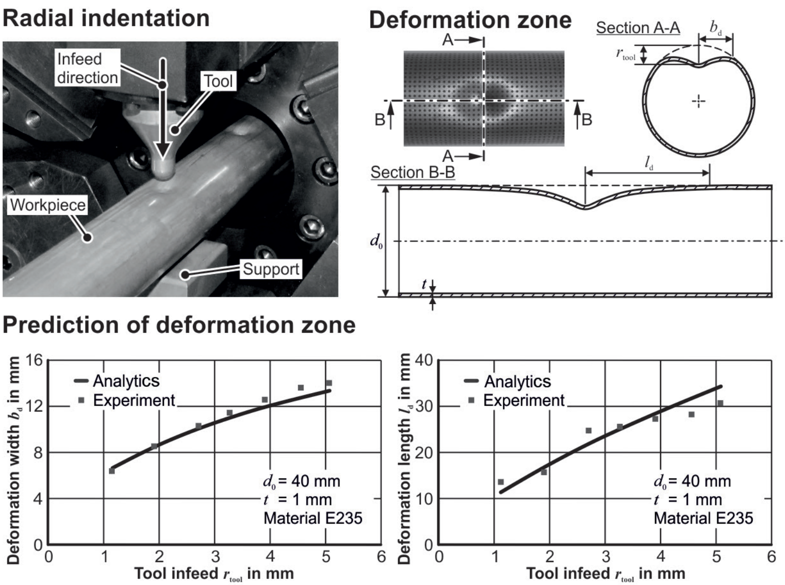


Extension of the process range of ITF and its usage for aviation-relevant tubular parts

3.3.9 Fundamentals of Incremental Profile Forming

Funding German Research Foundation (DFG)
Project BE 5196/3-1
Contact Dipl.-Ing. Goran Grzancic

Incremental Profile Forming (IPF) allows the step-by-step forming of tubes and profiles by one or more locally acting tools. Since the unexplained forming behavior in IPF depends on a variety of process parameters, a systematic and fundamental process analysis is required. For this reason, experimental and numerical studies are carried out and analytical process models are developed. An important part of the process studies is the investigation of component properties. In particular, local tube forming operations lead to undesired part deformations in the vicinity of the tool contact area. In order to control this behavior with regard to higher part accuracy, corresponding process know-how is built up. Deformations occurring in unilateral forming operations as well as results of their prediction are provided in the figure.

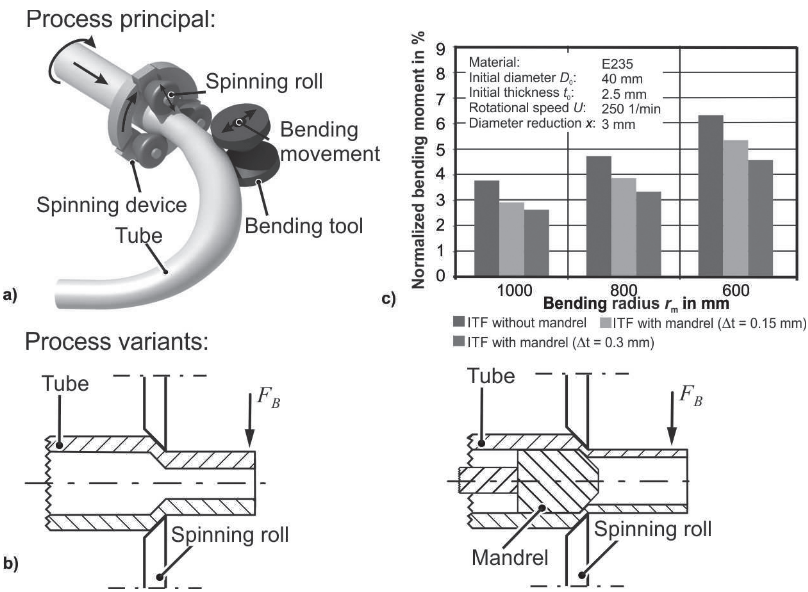


Investigation and modeling of workpiece deformations in Incremental Profile Forming (IPF)

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

Funding	German Research Foundation (DFG)
Project	TE 508/26-2
Contact	Esmaeil Nazari M. Sc.

Incremental Tube Forming (ITF) is a process to manufacture bent, load-optimized tubes with variable diameters and thickness over the longitudinal axis by a combination of a bending and a spinning processes, as shown in figure a. A reduction of the bending moment and springback is the result of this process combination. The process can be used with and without internal tool (see figure b). In the first phase of the project, an approach without mandrel has been investigated and a process model has been developed to predict the bending moment and springback. In the second phase of the project, the main aim is to control the thickness by using a mandrel. The material is compressed between the spinning rolls and the mandrel. First experimental results showed that the bending moment is reduced even more when using a mandrel. It can also be seen that a stronger decrease in thickness leads to a further reduction of the bending moment, as shown in figure c. In the next step a process model considering internal tools will be developed to predict the bending moment and springback.

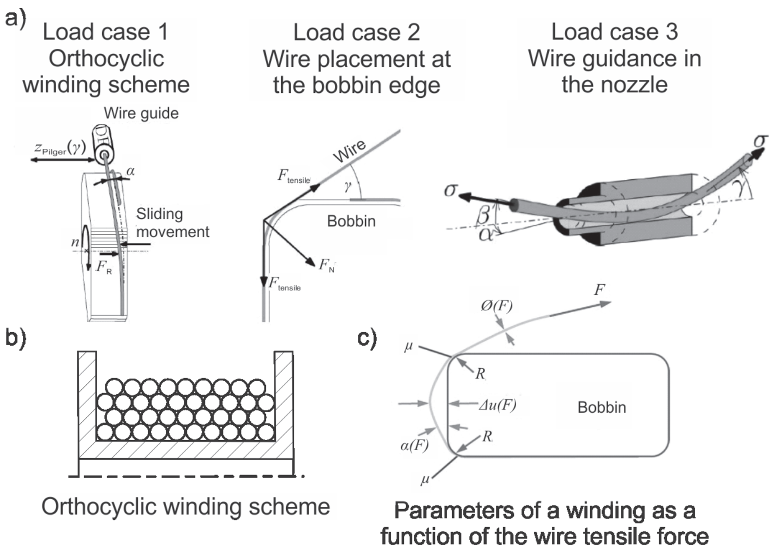


Process principle of Incremental Tube Forming (ITF)

3.3.11 Forming-Based Process Modeling of the Linear Winding Method

Funding	German Research Foundation (DFG)
Project	TE 508/56-1
Contact	Anna Komodromos M. Sc.

The linear winding method allows the winding of non-circular bobbins for the use in concentrated stator-windings of electric motors. By using the linear winding method an orthocyclic winding scheme (see figure b) and, thus, the highest copper fill factor can be generated. In cooperation with the Institute of Production Science (wbk) at the KIT a process model for the description of the linear winding method is being developed. It focuses on the defect-free winding of rectangular bobbins with copper wire up to a diameter of 3.55 mm. The IUL concentrates on characterizing the material behavior by experimental and numerical investigations. In this context, a material characterization and an analysis of the different load cases in the winding process is being carried out (see figure a). In load case 1 the influencing variables regarding the generation of an orthocyclic winding scheme are analyzed. Concerning the wire placement at the bobbin edge a reduction of the clearance (see figure c) shall be reached. An analysis of the wire behavior is carried out in load case 3.

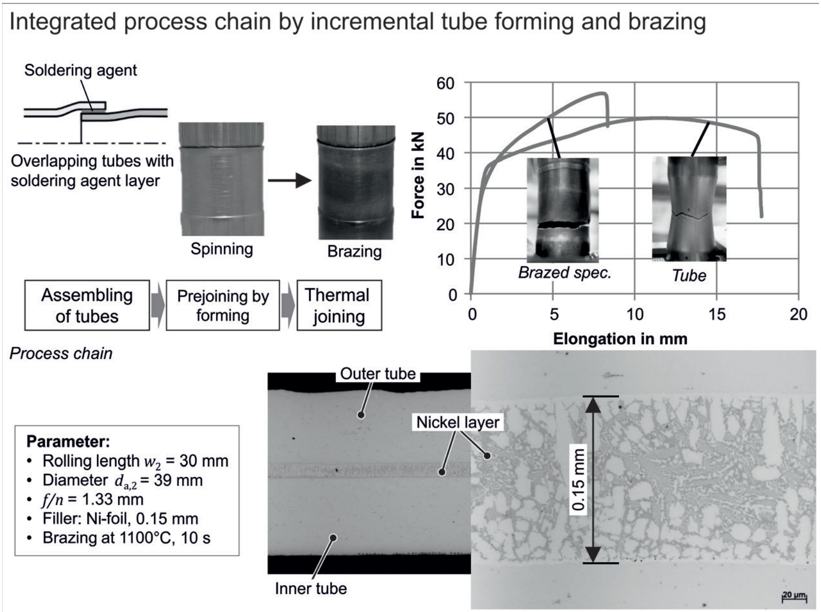


a) Investigated load cases, b) Target-winding scheme for the bobbin, c) Forming parameters on the bobbin

3.3.12 Mechanical Joining of Tubes by Incremental Tube Forming

Funding ReCIMP
Contact Christian Löbbe M. Sc.

Joining of exhaust systems by brazing with nickel and copper agents becomes of increasing importance for reducing the wall thickness and weight. A common challenge is the high sensitivity of the product quality against the process fluctuations and the tolerance influence of the raw material. A promising approach is the application of crimping or spinning processes to calibrate the tube ends and prejoin the partners so that process errors are neglected.
In the current project in cooperation with the company Faurecia integrated process chains are investigated in which optimized tube end designs are shaped by incremental forming processes for the subsequent brazing by induction heating. The picture shows the integrated process chain to calibrate and prejoin the workpieces consisting of the concentrical tubes and the soldering agent layer. The results show that an adaption of the process steps leads to both a reduced impact of the disturbing geometry influences and a reduced sensitivity of the inductive soldering process against the alternating contact conditions between the soldering agent and the base material.

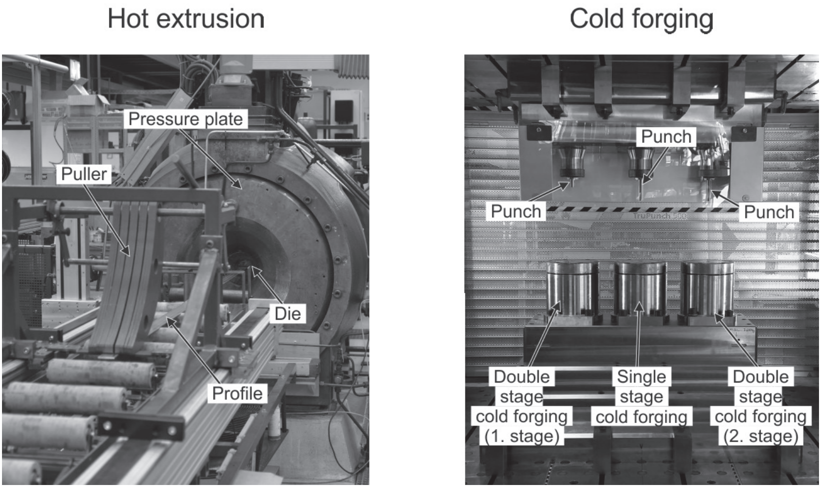


Integrated process chain for the joining of tube ends by incremental tube forming and brazing

3.4 Department of Bulk Metal Forming

Head Christoph Dahnke M. Sc.

The research of the bulk metal forming department focuses in particular on the development of innovative processes in the area of hot extrusion and cold forging. With regard to the concepts of lightweight construction, the specific improvement of local component properties as well as the production of composite components are central points in the process development. Even ecological aspects are taken into account, for example by the direct recycling of aluminum chips by means of chip extrusion. With regard to the production of hybrid components, different types of composite extrusion and cold forging processes are investigated. These allow both a combination of lightweight materials with high-strength steels to improve mechanical properties as well as the integration of functional elements such as electrical conductors or shape memory elements. An improvement of the local component properties in the case of e.g. cold forging can be achieved by adapting the die geometry or changing the process route (single or multi-stage).

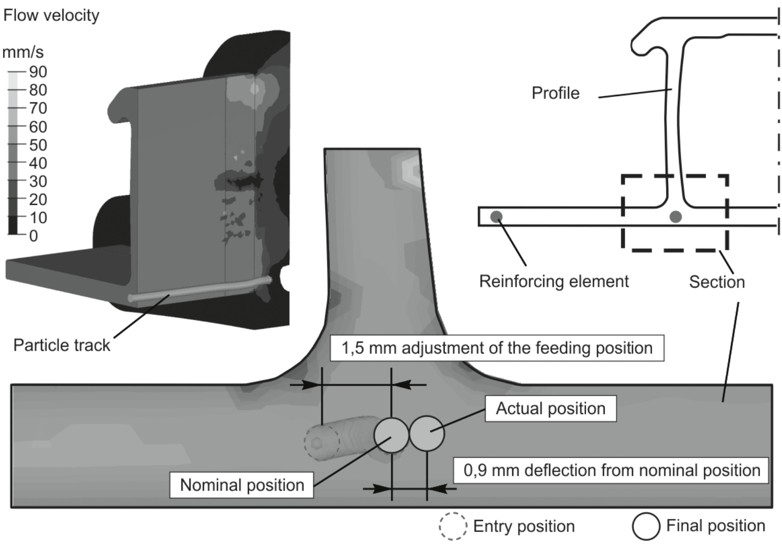


Central research areas of the Bulk Metal Forming Department

3.4.1 Production of Aluminum Profiles with Continuous Reinforcement

Funding	AiF/Stifterverband Metalle
Project	18959 N/1
Contact	André Schulze M. Sc.

The aim of this project is the further development of the composite extrusion process for an industrial application. The process is to be optimized with regard to more complex profiles which are used for structure parts in car bodies. The challenges concerning the tool design that have to be faced are thinner profile geometries, lower diameters of the reinforcing wires as well as the limited assembly space and the poor accessibility of the extrusion presses and dies. In addition, economical aspects such as productivity and efficiency in terms of high extrusion speeds and the simultaneous extrusion of several profile strips have to be taken into account. For the investigations a side impact beam with four reinforcing elements has been chosen as a demonstrator. Corresponding to the mentioned requirements, the development of a die concept is carried out by means of FEM. In the simulations the final position of the reinforcing elements in the profile is investigated and the resulting stresses affecting the wires during the embedding process can be determined.

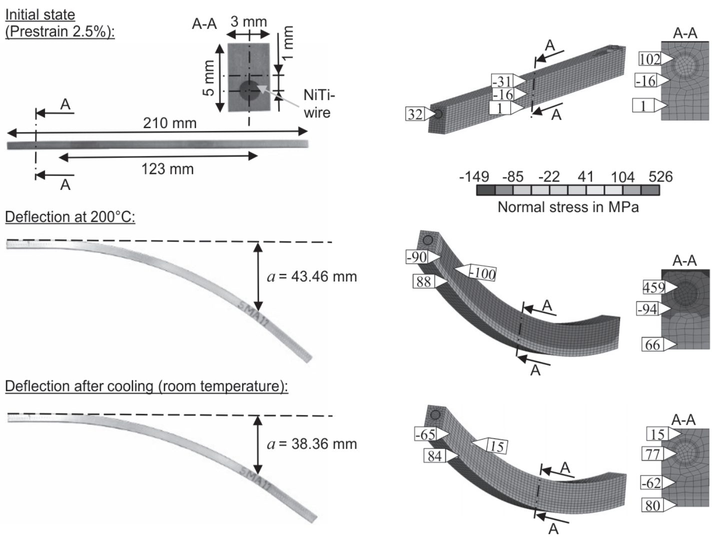


Particle tracking for the prediction of the positioning of the reinforcing elements in the profile

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

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

The shape memory effect and super-elasticity make shape memory alloys interesting for a wide range of applications. Even in combination with lightweight materials, such as aluminum or magnesium, shape memory alloys show high potential. The composite components are characterized by improved mechanical properties and are also suitable for sensor or actuator applications. In this project, shape memory alloy wires are embedded in an aluminum matrix by means of continuous composite extrusion and investigated in cooperation with the IAM-WK of Karlsruhe Institute of Technology (KIT). Due to a subsequent thermomechanical treatment of the composites after the extrusion process, an actuator function can be generated. The contraction of the prestrained wires as well as the eccentric positioning enables a deformation of the component. Thus, the produced profiles have the ability of achieving different deflections depending on the temperature in repeatable cycles. The design of the composite components as well as the specific use of the shape memory effect is supported by numerical analyses using FEM (see picture).



Experimentally achieved deflection of specimens and numerical analysis of the stress state

3.4.3 Experimental and Numerical Investigation of Complex Industrial Extrusion Dies with an Integrated Die Cooling

Funding	BMWi/ZIM-KF
Project	KF2198142KO4
Contact	Dr.-Ing. Dipl.-Wirt.-Ing. Ramona Hölker-Jäger Oliver Hering M. Sc.

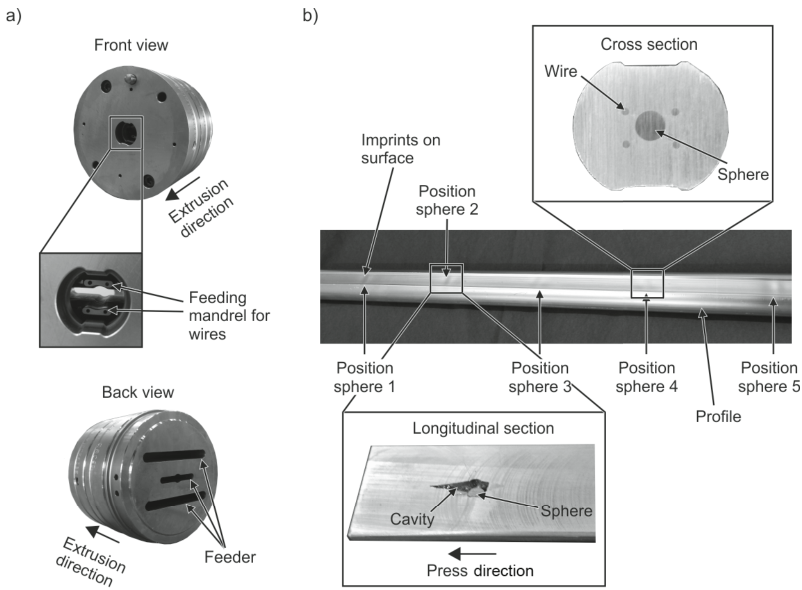
The cooling of extrusion dies allows an increase of the extrusion speed and, thus, productivity. An effective heat dissipation without an excessive increase of the extrusion forces requires a concentrated cooling of the dies. Therefore, the aim of the project is to design, analyze, and test industrial die concepts of additively manufactured extrusion dies with conformal cooling channels in cooperation with the project partner WEFA Inotec GmbH.
For the tool manufacturing, materials which satisfy the requirements for thermomechanically highly loaded extrusion dies and suitable for powder-based manufacturing are selected and characterized by hot tensile tests (see figure). Different tools were manufactured both conventionally, provided with subtractive inserted cooling channels, and additively with integrated conformal cooling channels. Subsequently, the different dies are evaluated, based on experimental and numerical investigations, with regard to the achievable cooling capacity.

a) Additively built cylinder for powder-based tensile specimens, b) Additively manufactured tensile specimens

3.4.4 Optimization of Workpieces by Forging of Composite Aluminum Extrudates

Funding	German Research Foundation (DFG)
Project	TE 508/17-2
Contact	Dipl.-Ing. Martin Schwane • Christoph Dahnke M. Sc.
Status	Completed

In cooperation with the IFUM at Leibniz Universität Hannover, the overall objective was the production of complex composite components with application-adapted properties by means of composite extrusion and subsequent forging. The focus was on the development of the individual processes as well as on the consideration of possible interactions along the process chain. In this regard, a subordinated objective was the combination of the partial and continuous composite extrusion process. To determine the process limits, a die for the continuous feeding of 4 wires as well as a partial, centric reinforcement was developed (see figure a). Experimental investigations showed that the process combination can be realized. However, process limits occur in particular with sinking profile dimensions. Decreasing distances between the continuous and partial reinforcements restrict the possibilities of the die design. These restrictions result in a non-optimal material flow, which can lead to cavities in the area of the partial reinforcement as well as imprints on the profile surface (see figure b).

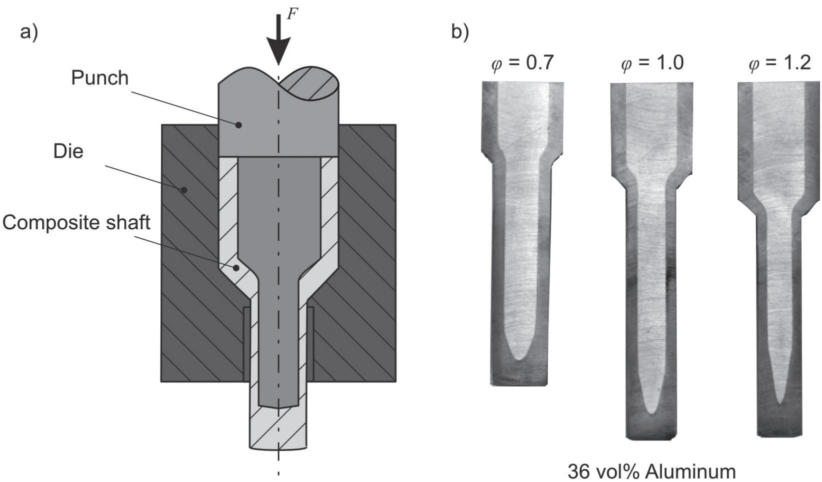


a) Die design for the combined partial and continuous composite extrusion process, b) Results of the experimental investigations

3.4.5 Composite Cold Forging of Cold Forged Semi-Finished Parts

Funding German Research Foundation (DFG)
Project TE 508/54-1
Contact Dipl.-Ing. Stefan Ossenkemper

Composite cold forging means simultaneous cold forging of several semi-finished parts to one single composite part. The individual semi-finished parts made of different materials are placed into or onto one another and subsequently cold forged together through a shaping die orifice. Due to the cold forging, the semi-finished parts can be joined by form-fit, force-fit or even by adhesive bond.
Within the project composite gear shafts are manufactured and investigated. In the first step of the process chain, cups made of steel are backward cup extruded. In the second step, a core made of a light metal, e. g. aluminum, is inserted. Subsequently, this semi-finished multi-component is further processed by single-stage or multi-stage forward rod extrusion (see figure a). The final gear shaft consists of a light core and a wear-resistant sleeve made of steel. Currently, the main focus of this work is on the analysis of the bond quality as well as on the material distribution within the shaft (see figure b).

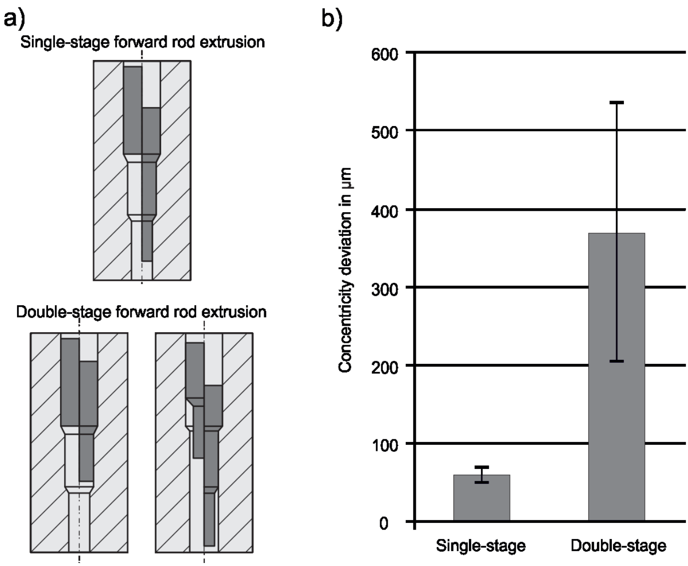


a) Composite forward rod extrusion (schematic), b) Cold forged steel-aluminum shafts

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

Funding	AiF/FSV
Project	478 ZN
Contact	Oliver Hering M. Sc.

To minimize distortion during cold forging with subsequent heat treatment, the specific adjustment of various process parameters is investigated in cooperation with the Foundation Institute of Materials Science (IWT) in Bremen. The manufacturing deviations (before heat treatment) are influenced by the manufacturing route and the sequence of stages (see figure a), respectively. Single-stage forward rod extrusion, for example, leads to lower concentricity deviations than double-stage forward rod extrusion (see figure b). These differences are caused by the reinsertion into the next stage as well as the second ejection.
A subsequent heat treatment at temperatures below the phase transition (<Ac1) leads to plastic degradation of manufacturing-induced residual stresses when exceeding the temperature-depended yield strength of the material. Therefore, single-stage cold forged shafts show minor dimensional changes after the heat treatment due to lower residual stresses compared to double-stage cold forged parts.

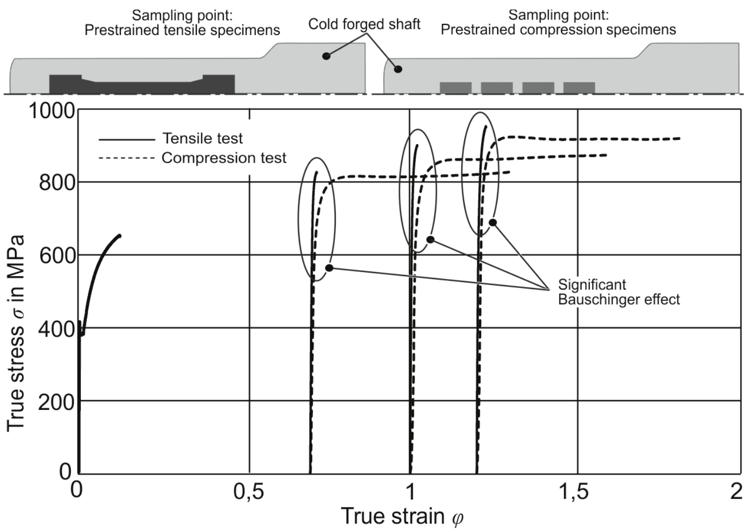


a) Single-stage and double stage forward rod extrusion, b) Concentricity deviation after forward rod extrusion

3.4.7 Prediction of Local Product Properties in FEM Forming Simulations

Funding AiF/FOSTA
Project 18225 N/P1057
Contact Felix Kolpak M. Sc.

The objective of this subproject as part of the project "Massive Lightweight Construction" is the improvement of the prediction of local component properties in forming simulations. The subproject is a collaboration between the IUL and the ISF at TU Dortmund University as well as the IFU at the University of Stuttgart. With regard to cold forging processes, mixed isotropic-kinematic hardening models are currently being investigated. These models allow an illustration of the Bauschinger effect and, thus, point to an anisotropy of the local component strengths.
To characterize the effect, experimental methods such as tensile and compressive tests of cold forged parts are being investigated (see picture). The extracted data is then used for the parameter determination of the investigated material models. It can be shown that the enhanced material models lead to a remarkable improvement of the local property prediction in forward rod extrusion compared to standard isotropic models. Regarding the component design, it has to be taken into account that the forming-induced anisotropy can have a strong influence on the local component strength.

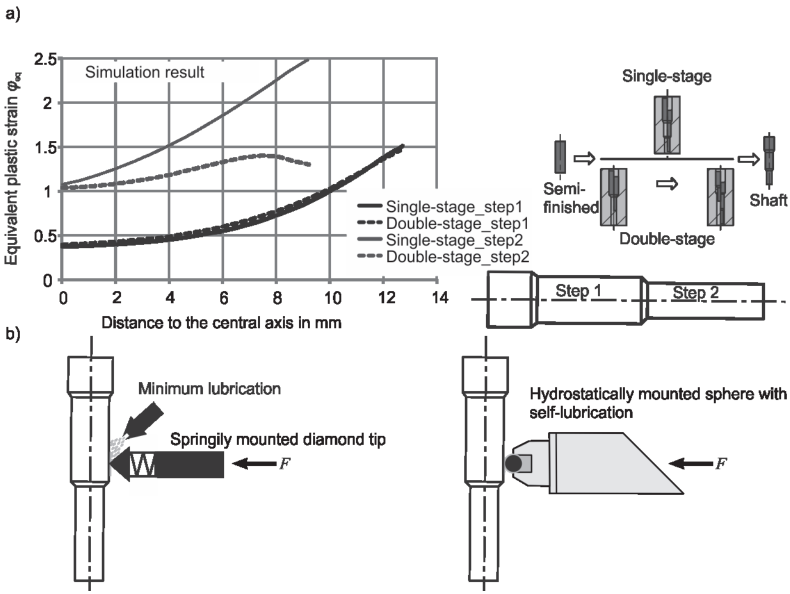


Flow curves of prestrained specimens illustrating the Bauschinger effect in forward rod extrusion

3.4.8 Extended Technological Limits of Bulk Forming Processes in Different Temperature Ranges

Funding AiF/FOSTA
Project 18229 N/P1058
Contact Oliver Napierala M. Sc.

In cooperation with IFU Stuttgart and IFUM Hannover the manufacturing of gear shafts by cold forging is investigated in this subproject of the project “Massive Lightweight Construction”. The main objective is the improvement of the strength in the peripheral zone of the component. Due to the cold hardening, the strength increases with an increasing deformation degree. The local deformation degree in the peripheral zone is investigated in numerical experiments. Thereby, the influence of friction, shoulder angle, transition radius, and the process route is analyzed. It is shown that a single-stage process route, compared to a double-stage process route, is more suitable to generate a high deformation degree in the peripheral zone of the second step (see figure a). To replace the conventional heat treatment, it will be determined in further investigations whether a deep rolling process is also able to increase the strength in the peripheral zone. Here, two different tool systems, a hydrostatically mounted sphere and a springily mounted diamond tip (see figure b), will be investigated.

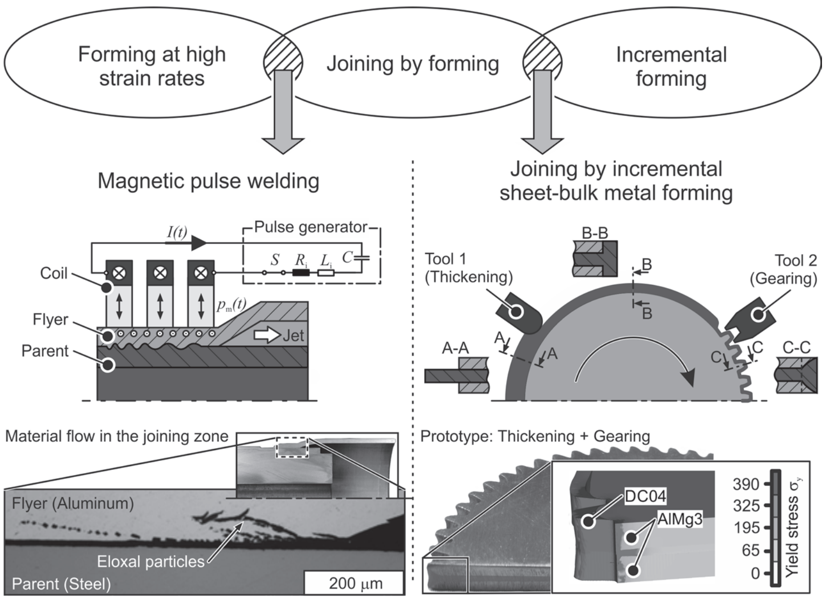


a) The Influence of the process route on the degree of deformation, b) Deep rolling tool concepts

3.5 Department of Non-Conventional Processes

Head Dipl.-Wirt.-Ing. Soeren Gies

Joining by forming, forming at high strain rates, and incremental forming are the three fields of research in the department of non-conventional processes. Especially technologies which combine the advantages of different categories show an outstanding potential in terms extended process limits.
A combination of joining by forming and forming at high strain rates is realized in the magnetic pulse welding process. This joining technique can be used to produce metallic bonds without the drawbacks of heat affected zones or intermetallic layers. Research in this field is performed in cooperation with the Institute of Manufacturing Technology at TU Dresden and focuses on the activation of the joining mechanism.
A technological innovation is realized by the combination of joining by forming and incremental sheet-bulk metal forming. This way, a stack of different metal sheets can be joined to one hybrid part. In subproject A4 of the collaborative research center SFB/TR 73 the potential of this technology in terms of weight reduction, joint strength, and increased functionality is investigated.

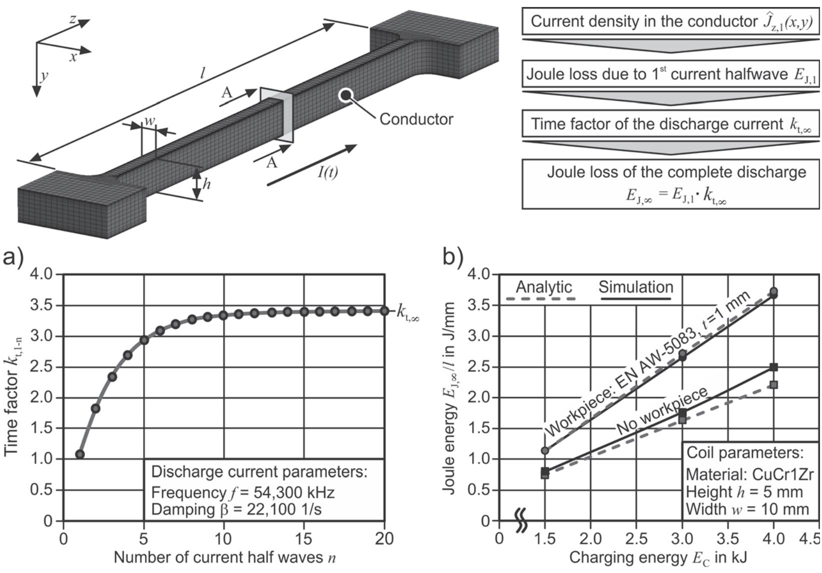


Processes combining different fields of research

3.5.1 Optimized Working Coil Windings for Electromagnetic Forming Employing Additive Manufacturing Techniques

Funding German Research Foundation (DFG)
Project TE 508/51-1
Contact Dipl.-Wirt.-Ing. Soeren Gies

An increased efficiency and lifetime of working coils can only be reached if the energy conversion sequence of the process and the loads acting on the working coil are known.
For this reason, an analytical approach for the determination of Joule heat losses in the working coil was developed within the collaborative project with the Institute of Machine Tools and Factory Management (IWF) of TU Berlin. Taking into account the discharge current as well as the geometrical and thermo-physical properties of conductor and workpiece the current density in the conductor cross section $\hat{j}_{z,1}\ (x,y)$ is determined. This current density is used to calculate the joule heat loss of the first current half wave $E_{J,1}$. In Combination with the time factor $k_{t,\infty}$ this energy parameter can be converted into the total joule heat loss $E_{J,\infty}$ of the complete current discharge. Moreover, the time factor can be used to quantify the effect of the single current half-waves on the total heat loss.

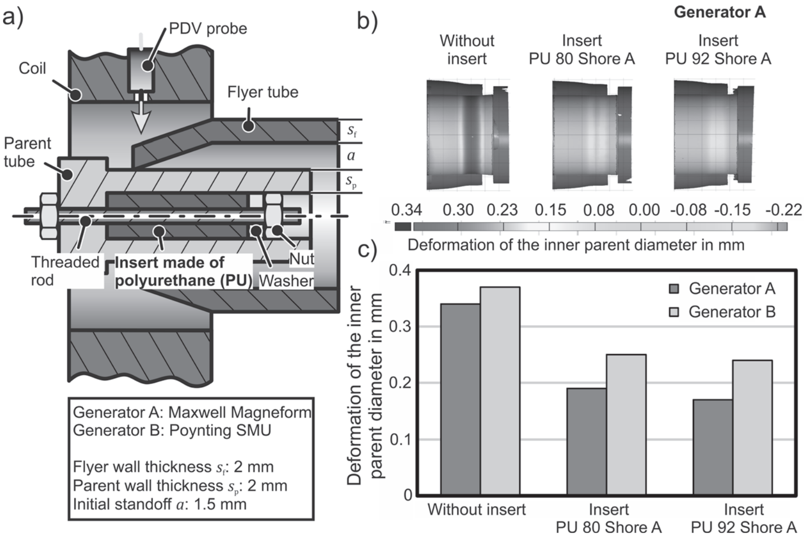


Joule heat losses: a) Effect of current half-waves, b) Comparison of analytical and numerical results

3.5.2 Magnetic Pulse Welding: Targeted Manipulation of Weld Seam Formation

Funding German Research Foundation (DFG)
Project SPP 1640 • Subproject A1
Contact Dipl.-Wirt.-Ing. Jörn Lueg-Althoff

The analysis of the mechanism of the weld seam formation in the magnetic pulse welding process is the main objective of this project, which is executed together with the Institute of Manufacturing Technology at TU Dresden. The influence of the impact pressure pulse, which is established during the collision of the flyer tube and the parent tube, is investigated. Here, the focus is on the role of the temporal course of the magnetic pressure, which is strongly dependent on the specific discharge characteristics. By means of various pulse generators at both institutes discharge current courses with different frequencies and amplitudes are compared.
A reduction of the wall thickness of the parent tube for lightweight purposes leads to an increased plastic deformation of this joining partner due to the impact of the flyer. This deformation affects the weld formation and is, in turn, also affected by the characteristics of the discharge current. Moreover, different approaches for the reduction of such undesired deformations are tested, e.g. by inserts made of polyurethane (see figure).



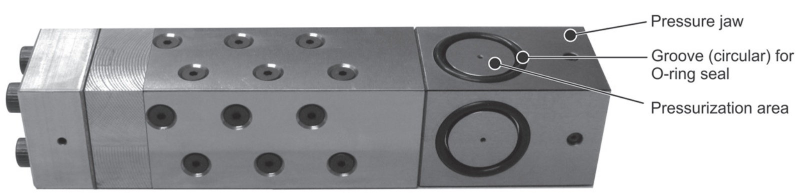
Reduction of parent deformation: a) Setup, b) 3D scans, c) Influence of the pulse generator

3.5.3 Joining by Die-Less Hydroforming of Profiles with Non-Rotationally-Symmetric Cross Section

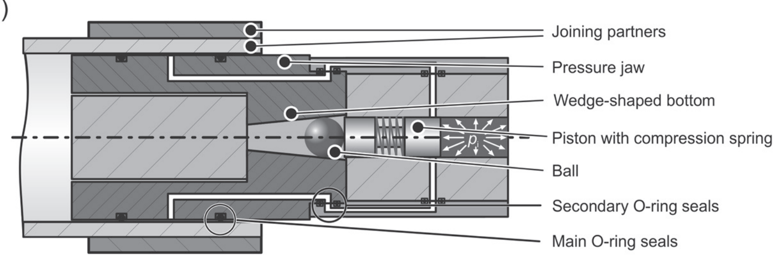
Funding	German Research Foundation (DFG)
Project	TE 508/50-1
Contact	Michael Müller M. Sc.

The aim of the project is the extension of the joining by die-less hydroforming process to enable the joining of profiles with non-rotationally-symmetric cross sections. A tool for the joining of rectangular tubes was developed and manufactured (see figure a). The sealing system allows a separate pressurization of the profile surfaces. Numerical investigations proved that the achievable interference pressures are not significantly different compared to a circumferential pressurization. For compensating tolerances of semi-finished products and due to the reduction of the sealing's preloading during expansion, the tool's pressure jaws can be adjusted by a ball-piston system (see figure b). The principle is similar to a pressure relief valve. A spring between the piston parts compresses when the preloading of the O-ring seals is reached and releases the working media channels. Currently, an analytical approach is being developed which allows the calculation of a suitable fluid pressure range for the joining process.

a)



b)

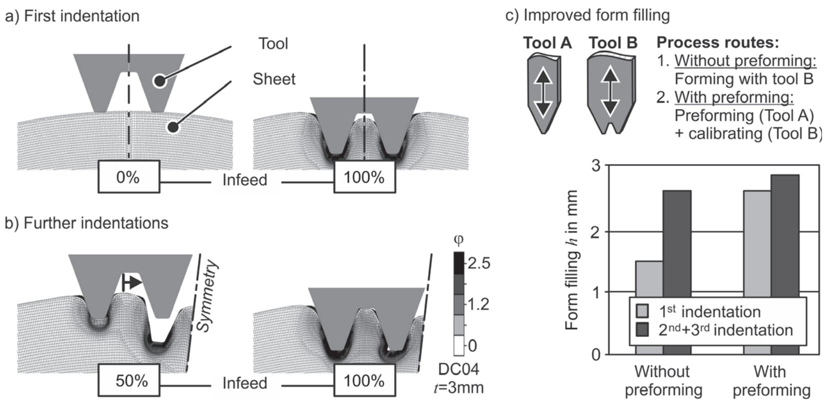


Joining probe: Prototype and schematic sectional view

3.5.4 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. Peter Sieczkarek

The objective is the manufacturing of geometrically complex components using sheets with integrated functional elements by forming operations. The three-dimensional material flow is characteristic for this technology and was fundamentally investigated for the defined process control. With the incremental procedure the sheet is processed by a flexible arrangement of localized forming operations. After a material distribution in the sheet plane or on the sheet edge, a calibration of the form elements takes place. Current investigations deal with the incremental forming of gears on the sheet edge. The form filling of the first indentation shows geometric deviations from the subsequently shaped elements. While the first indentation is formed into the solid material (a), the further forming steps are clocked by one gear (b). The different form filling of the first indentation can be explained by the limited material flow. Remedy can be achieved by an additional preforming step with a single-wedge tool (Tool A). Compared to process route 1, the form filling of the first indentation was improved by 45% (c).

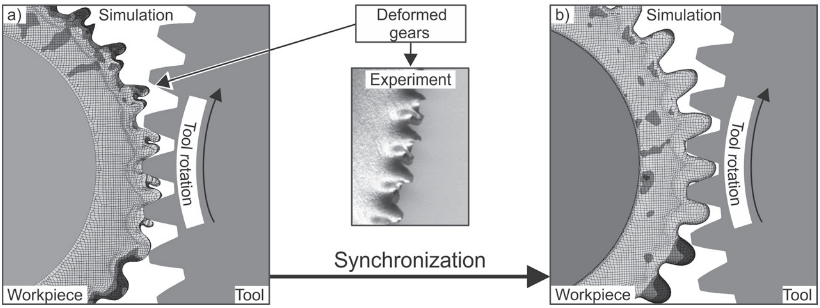


Gear forming: a) First indentation into the solid material, b) Further indentations, c) Improved form filling

3.5.5 Economic Manufacturing of Weight and Load-Adapted Functional Components by Incremental Sheet Bulk Metal Forming

Funding AiF/FOSTA
Project 18663 N/1
Contact Sebastian Wernicke M. Sc.

Aim of the project is the economic manufacturing of industrially relevant functional components. The investigations focus on a defined thickening of the sheet edge (see figure a), followed by a gear forming operation (see figure b). To reach the aim of an economic manufacturing, the process will be accelerated close to real cycle times of industrial processes. The major challenge is to investigate and control the target conflict between the increased forming heat due to process acceleration and the desired strain hardening at the gearing. Further challenges are the process-typical tool loads combined with the unknown tribological system.
The cycle times needed for an economic use of the technology have been achieved. Numerical and experimental investigations on the material flow have shown the necessity of a synchronized rotation velocity between the workpiece and the gearing tool. Without this synchronization already formed gears become deformed in subsequent calibration steps.

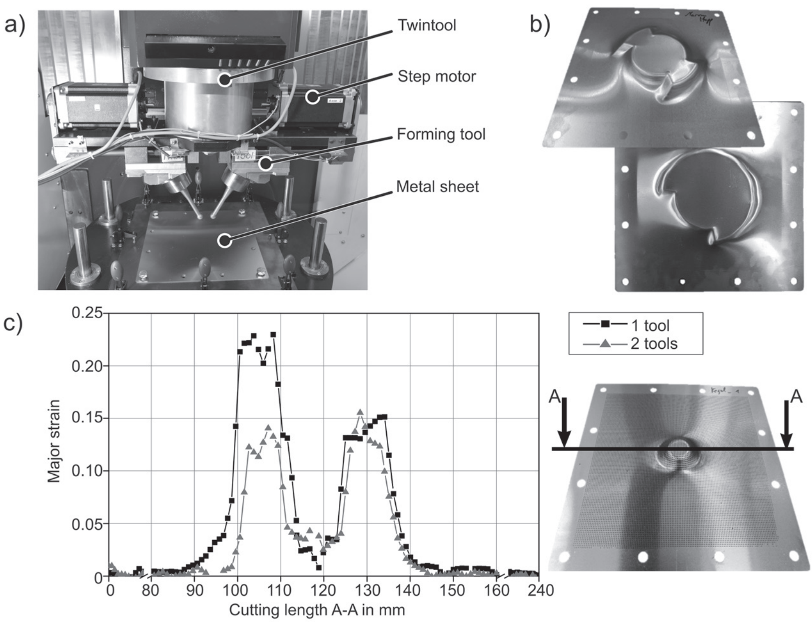


Gearing by incremental sheet bulk metal forming (a) without and (b) with synchronized rotation velocity

3.5.6 Incremental Sheet Forming by Multiple Simultaneous Forming Zones (MPIF)

Funding German Research Foundation (DFG)
Project TE 508/42-1
Contact Dipl.-Ing. Thai Dang

The main disadvantage in incremental sheet metal forming is the process time. In order to diminish this problem the Twintool (figure a) was developed. Two identical tools are used during the forming process to work on multiple zones simultaneously. Due to this, the process time can be reduced by 50%. Within the scope of this research project the interaction of the tools shall be analyzed. Therefore, the control technology of the Twintool has to be extended for an independent movement of the two tools. Consequently, the Twintool will be able to exploit its full potential. Different shapes with different forming strategy can be produced (Figure b). The result by using the Twintool shows a symmetrical major strain distribution on truncated cones. By comparison, the strain distribution with a single tool is asymmetrical (figure c). According to this, the interaction with two tools has been identified. Their influencing process parameters (e.g. tool distance, vertical step down, or tool radius) will be examined in the next stage.

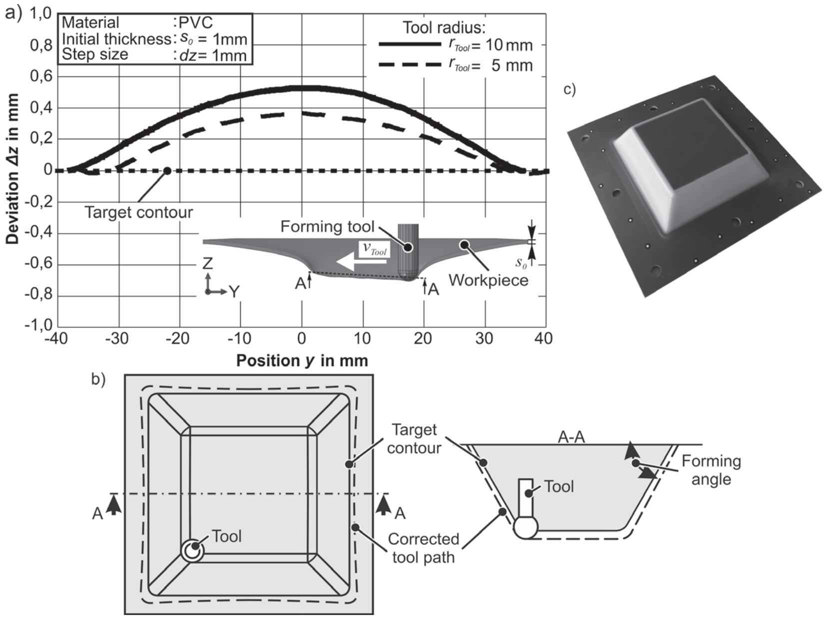


a) Twintool, b) Produced parts, c) Comparison of the strain distributions

3.5.7 Incremental Cold Forming of Thermoplastics

Funding	German Research Foundation (DFG)
Project	TE 508/20-2
Contact	Fabian Maaß M. Sc.

The main objective of this research project is to increase the geometric accuracy of incrementally cold-formed parts made of thermoplastic sheets or sandwich panels (metal-polymer-metal). In the first step improved material models are developed to consider the specific material behavior of thermoplastics in terms of a higher elastic recovery and a time-dependent strain portion. Based on this material description, analytical and numerical approaches are used to develop compensation strategies for a higher process accuracy of the single point incremental forming process (SPIF). Current investigations focus on certain process parameters and their influence on the deformation behavior of Polyvinylchloride (PVC) and high density Polyethylene (HDPE) (see figure a). Within the scope of the project, the effect of overbending as a compensation strategy to yield straight part surfaces is investigated (see figure b). The aim is to replace the experience-based process design by predictive process models commonly-used at present.

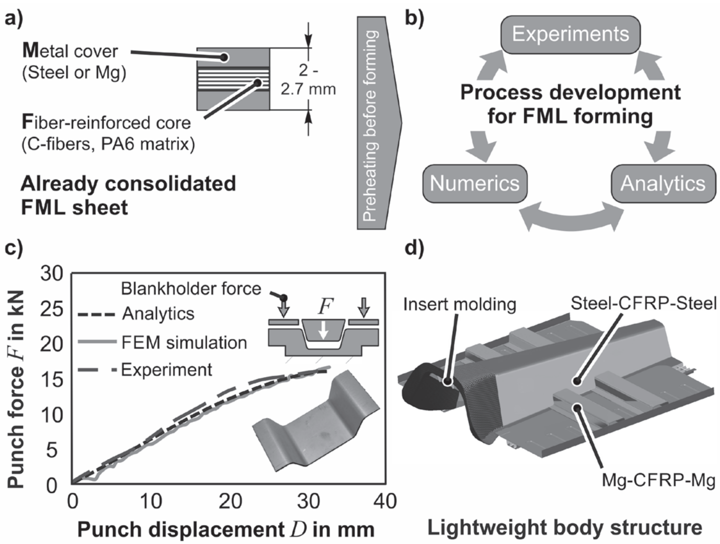


a) Influence of tool diameter on geometric accuracy, b) Overbending, c) Truncated pyramid (PVC)

3.5.8 Efficient Integral Manufacturing Processes to Form Metal-FRP Semi-Finished Sheet Products

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

Within the scope of the LEIKA project mass production-suitable forming processes for fiber metal laminates (FMLs, see figure a) developed by project partners were considered in order to increase the lightweight potential in electric vehicles. Due to the thermo-formability of the fiber-reinforced thermoplastic matrix, conventional forming processes (with adjusted temperature profiles) could be applied in combination with an integrated injection molding process. Experimental, numerical as well as analytical methods were employed within the project consortium for the manufacturing process development (figure b). At the IUL, for example, analytical models for the determination of the springback after bending, the wrinkle formation during cup deep drawing, and the punch force in non-rotationally symmetric deep drawing were developed and verified (compare example in figure c). In order to demonstrate the technological potential of the novel hybrid sheets, the car body structure shown in figure d was designed, manufactured, and successfully tested for selected load cases by the project partners.



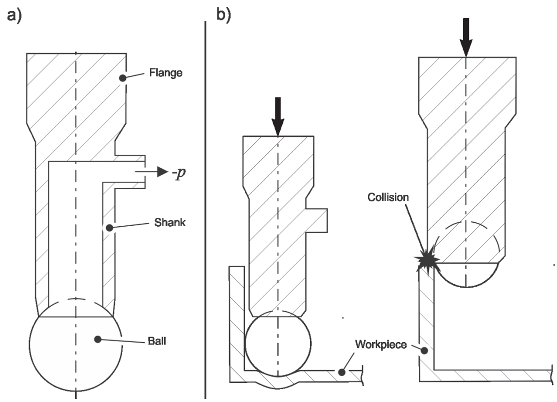
a) Fiber metal lamite (FML), b) Research methods, c) FML drawing, d) LEIKA demonstrator

3.6 Filed Patents

Process and Apparatus for Incremental Forming of Thin-Walled Workpieces, in Particular Sheet Metal Workpieces

Application number	DE 10 2016 003 840.3
Patent applicant	TU Dortmund University • The Fuel Cell Reseach Center ZBT
Status	Filed
Inventors	T. Dang • S. Gies • A. E. Tekkaya • M. Kouachi L. Kühnemann • P. Beckhaus

A particular challenge in incremental forming is the production of filigree structures on thin metallic foils. The common use of a rigid tool with a hemispherical tip is not suitable. Even in a lubricated condition the friction between tool and workpiece is too high and causes a failure of the tool tip or of the thin foils. Furthermore, the process of designing and manufacturing such very small tools is more time-consuming and complex. Due to this, a new tool concept with a moveable mounted ball tip was developed. The forming ball is kept near the shank by a vacuum (figure a) and can roll on the workpiece - relative to the tool movement. As a result, the frictional forces can be reduced in order to improve the process stability. In addition, deeper structures can be formed on the workpiece due to the design concept. The collision between the shank and the workpiece can be prevented (figure b). A further advantage is the flexibility of the tool due to the use of different ball diameters.

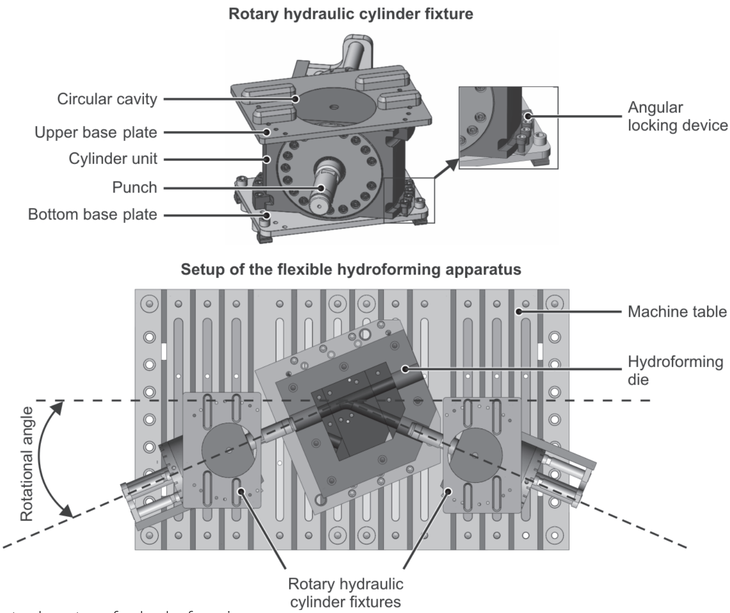


a) Tool concept with a moveable ball tip, b) Collision-free toolpath

Cylinder Fixture for a Hydroforming Apparatus as well as Hydroforming Apparatus

Application number	DE 10 2016 118 535.3
Patent applicant	Faurecia • TU Dortmund University
Status	Filed
Inventors	H. Dardaei Joghan • D. Staupendahl • A. Henke T. Keesser • F. Legat

In hydroforming, hydraulic cylinders are used to transport the hydroforming fluid into the tube to be formed and to push the tube into the hydroforming die during operation. In general, the cylinders are fixed in cylinder holders which only allow a single cylinder position, fitting exactly to one geometry of the hydroforming die. Thus, the manufacturing of new die geometries requires the additional manufacturing of new cylinder holders.
In the new tool technology, developed in cooperation with Faurecia, the cylinder holder is positioned in between two base plates and is fixed to a certain angle using angular locking devices. The base plates, in turn, are mounted on machine tables which preferably contain channels for the flexible positioning of the cylinders alongside these channels. This flexible hydroforming apparatus can thus be adapted to arbitrary tube geometries, which greatly reduces tool costs, especially when forming a large number of tube variants.

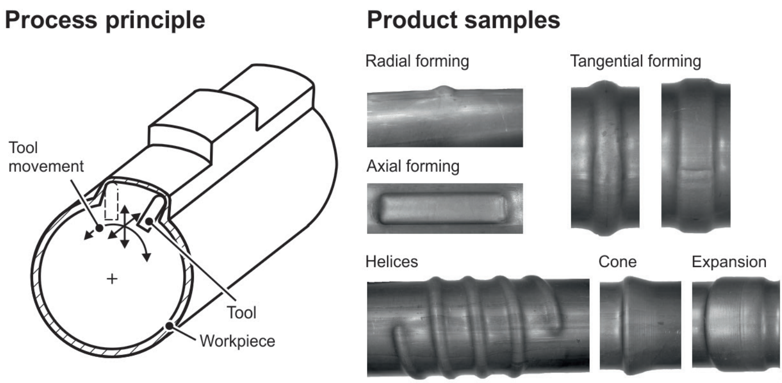


Flexible tool system for hydroforming

Method and Device for Incremental Forming of Tubular Components

Application number DE 10 2016 002396.1
Patent applicant TU Dortmund University
Status Filed
Inventors G. Grzancic • C. Becker • A. E. Tekkaya
S. Michel • M. Fuß

The objective of the invention is to manufacture tubes and profiles with arbitrary and varying cross sections along the center line of the part. For this purpose, one or more tools are positioned inside the tube, locally performing step-by-step forming operations. In doing so, each tool has several independent degrees of freedom. Beside the single movements in axial, radial, and tangential direction the invention also allows the superposition of these movements in order to manufacture highly complex geometries, as e.g. helical structures. In addition to the kinematics, the tool shape is variable, leading to a multiplicity of forming possibilities. An overview of manufactured samples showing the high degree of flexibility as well as the large variety of components is given in the figure.

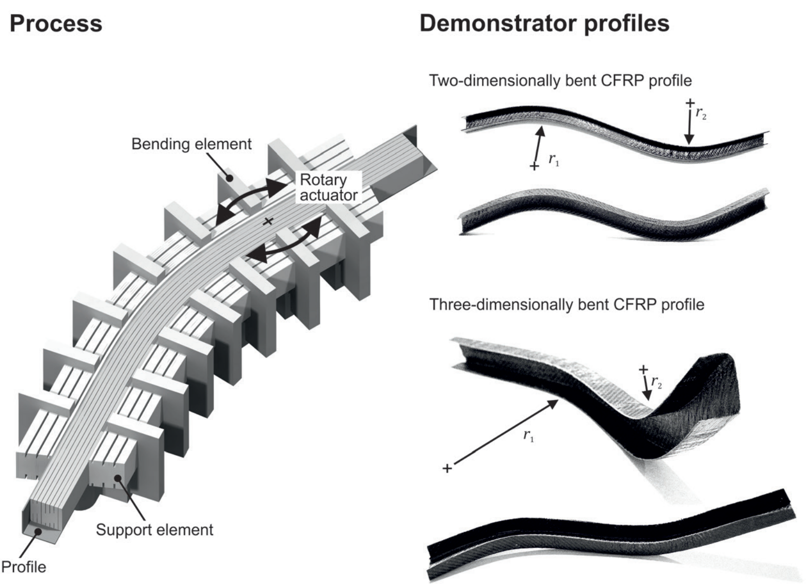


Process principle and product samples of inner incremental profile forming

Apparatus and Method for Bending of Profiles and Bar Material, in Particular Asymmetric and Open Profiles or Bar Material

Application number	DE 10 2016 012 677.9
Patent applicant	TU Dortmund University
Status	Filed
Inventors	C. Löbbe • G. Grzancic • A. E. Tekkaya

The invention concerns a procedure and an apparatus for bending of tubes or bar material as well as a solution for the stabilization of the cross section against deformation. Particularly thin-walled and open profile shapes are prone to bending failures as buckling, cracking, wrinkles, and cross sectional deformations. In consequence, conventional bending procedures are of limited use for the manufacture of these profiles. With the new method the profile is completely supported by flexible tool shapes during the entire forming process, avoiding the twisting of asymmetrically loaded profiles and supporting the cross section actively. This principle is especially important for the manufacture of lightweight design structures consisting of fiber-reinforced plastics which are normally formed in molten state. The figure shows the setup of the apparatus as well as already realized multi-dimensionally bent CFRP profiles.

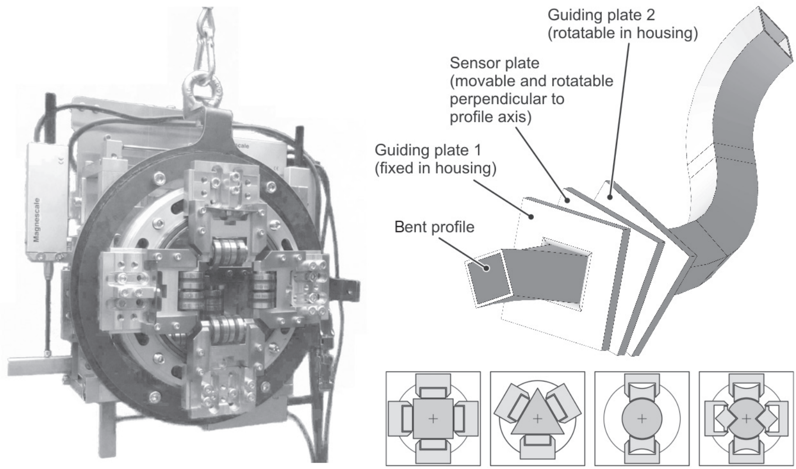


Setup of the bending apparatus and workpiece samples

Apparatus for Contact Measurement and Analysis of the Geometry of Bent Profiles or Tubes

Application number	DE 10 2016 013 144.6
Patent applicant	TU Dortmund University
Status	Filed
Inventors	D. Staupendahl • D. Schultz • A. E. Tekkaya

Today, the demand for individual design is ever increasing. In the bending industry this demand is met by kinematic free-form bending machines. The three-dimensional bending contours that can be produced with these machines present a challenge to current measurement methods. For tubes with circular cross-sections several measurement processes exist that offer a fast and efficient analysis of geometrical data. This is not yet possible for profiles with arbitrary cross-sections.
To meet this challenge, a contact measurement system was developed at the IUL. With this system the data on the profile curvature, the profile rotational angle (angle between two subsequent bending planes), and the profile torsion can be produced directly. Thus, profiles cannot only be analyzed after being bent, but also online, meaning during the actual bending process. This initiates the setup of direct closed-loop control systems for kinematic tube and profile bending machines.



Manufactured measurement setup

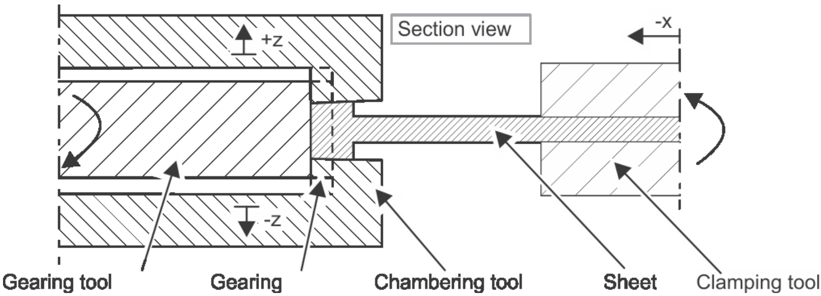
Possible profile geometries and guiding setups

Measurement principle and developed prototype

Apparatus to Control the Axial Material Flow in the Thickening and Gearing Process of Sheet Metal Components

Application number	DE 10 2016 012 270
Patent applicant	TU Dortmund University
Status	Filed
Inventors	S. Wernicke • S. Gies • A. E. Tekkaya

By using incremental sheet-bulk metal forming processes it is possible to manufacture load-adapted components with functional elements. In contrast to conventional sheet metal forming processes, a three-dimensional state of stress occurs which causes a thickening of the sheets. This thickening can be limited by the use of a chambering tool. Existing concepts to chamber the material cause a design-related burr between the gearing tool and the chambering tool. Furthermore, the chambering limits the axial dimension of the gearing tool. Combined with the high contact stresses of about 2.000 MPa, the tool lifetime is significantly reduced.
The invention enables an axial adjustment of the chambering tools to control the material flow. This allows a defined thickness of the functional elements and avoids the evolution of a burr between the tools. Additionally, an increased tool lifetime is expected since the axial tool dimension is no longer limited by the chambering. To realize this invention, the gearing tool is surrounded by one or more axially moveable chambering tools. The positioning of these tools can be realized by springs or by using a driven axis.



Principle of the concept to define the axial material flow

Further Activities

04

4 Further Activities

4.1 Conferences and Meetings

In 2016, several conferences and workshops were hosted or co-organized by the Institute of Forming Technology and Lightweight Components to present research results and to meet researchers from industry and universities. In the following, you will find more information on selected events.

Meeting of the IUL Industrial Advisory Council

Established in 2010, the Industrial Advisory Council meets twice a year with the aim of supporting the IUL in its strategic aligning of application-oriented research. In addition to the transfer of research results into industrial environments the Advisory Council is characterized by advising the institute on the implementation of collaborative research projects. Therefore, the council gives valuable input regarding industrial technologies and research needs and, in return, receives detailed results of basic research and innovation. The first meeting this year took place on April 15, 2016. The topics focused especially on innovative lightweight steel construction, trends and requirements in cold forming as well as on additive manufacturing in the field of forming technology. The twelfth meeting of the panel took place on November 11, 2016. It was initiated by the presentation of the latest developments at the Institute of Forming Technology and Lightweight Components. The subsequent constructive discussion highlighted the innovations and specialization of SMEs as well

Participants of the 12th Industrial Advisory Council as the simulation of welding processes and heat treatments. Both meetings were enriched by valuable presentations held by members of the Industry Advisory Council.

7th International Conference on High Speed Forming (ICHSF 2016)

The seventh edition of the renowned international conference took place from April 27 to 28, 2016, at TU Dortmund University. More than 80 experts from academia and industry met in the International Meeting Center (German abbreviation IBZ) to discuss the recent developments in the field of high speed forming. A total of nine sessions with numerous presentations was headed by Professor Tekkaya from the IUL as well as by Professor Glenn Daehn from The Ohio State University. Within this context, the topics "process analysis and simulation", "tools and machines", "material testing", and "joining and welding" were covered. During the breaks an exhibition provided the possibility for the sponsors to show their skills in terms of machines and measurement techniques with regard to impulse forming processes. In the evening of the first conference day a banquet at Signal Iduna Park – the "most beautiful stadium in the world" – inspired the participants coming from Europe, Asia, and North America. After the conference dinner, professor and book author Metin Tolan amusingly explained the physics of football. In his concluding remarks Professor Tekkaya thanked all participants and contributors. Finally, the eighth edition of the biannual ICHSF was announced, which will be held in the Midwestern region of the United States of America in spring 2018.

a) Group photo, b) Conference dinner at Signal Iduna Park

TU@Adam's Corner

During the summer semester 2016 and the winter semester 2016/2017 the IUL supported the initiative „TU@Adam's Corner". Within the scope of this initiative TU Dortmund University developed a program for young people who left their home country as refugees or immigrated from EU countries. During the IUL event dealing with "Live experience of advanced forming machines – Visit of the IUL lab" pupils got in touch with mechanical engineering. First, there was a short lecture about forming technology. Following this, there was a tour of the IUL lab and new technologies, like e.g. additive manufacturing or the process of press hardening, were shown.

Visit of a class in November 2016

3rd Alumni Reunion

The IUL Alumni Reunion took place on June 3rd, 2016, for the third time. Upholding this young tradition, all former employees were invited to the IUL experimental hall. After a cordial welcome and a presentation of current developments and research work at the institute by Professor Tekkaya the alumni were able to explore the experimental area in a relaxed atmosphere and to exchange information and experiences with the current employees. Inspired by a series of retrospective photographs, the attendees could revive their IUL-memories, also providing a starting point for interesting conversations. The event was organized by Tobias Ortelt and Goran Grzancic.

Impressions of the Alumni Reunion 2016

Student competition “Stahl fliegt 2016“

As an annual tradition, more than 70 young engineers faced the challenge of designing a flying object manufactured from steel. Participants from six universities gathered in the Rudolf-Chaudoire-Pavillon of TU Dortmund University on July 4, 2016 for the national competition “Stahl fliegt”. The event started with the presentations of the 17 teams. The presentations gave insights into the course from an early design stage until physical try-outs. Some designers applied physical effects of fluid dynamics to increase the aviation performance or designed objects, which resembled sports equipment (e.g. a frisbee). After a technical acceptance test the participants started the actual flight competition with their objects on July 5, 2016 in the Westfalenhalle Dortmund, the city’s largest exhibition hall. The flying objects had to fit into a cube with an edge length of 1 meter. The weight was not to exceed 400 g. Moreover, polymers were not allowed as design material. The objects were thrown from a lifting platform at an altitude of 7 m. The flight duration had to exceed 5 seconds and the flight distance had to be longer than 10 Meter for a valid attempt.

This year’s winner was team „Darmstadt 2“. Their frisbee design managed to fly an amazing distance of over 95 meters with a flight duration of 7.4 seconds. The second (Kassel 1) and third (Kassel 3) places were awarded to conventional gliders, which achieved flight durations in the range from 15 to 20 seconds and flight distances of up to 54 meters.

FOSTA committee and participants of “Stahl fliegt” 2016

1st Sino-German Workshop

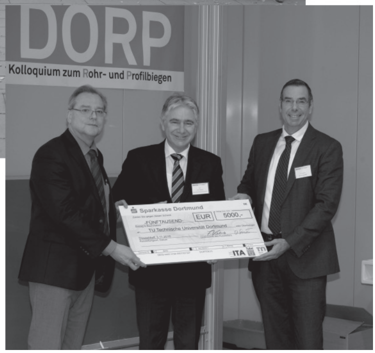
The 1st Sino-German Workshop on “New Challenges in Processing and Modeling of Lightweight Metals” was successfully held at the Sino-German Building of Tongji University from July 12 to 15, 2016. The workshop was financially supported by the Sino-German Science Center and hosted by Tongji University, TU Dortmund University, and Shanghai Jiao Tong University. Professor A. Erman Tekkaya and Professor Zhigang Yang (Dean of the School of Mechanical Engineering of Tongji University) delivered speeches at the opening ceremony. 109 participants came from 27 institutions in China, 9 institutions in Germany, and 2 institutions in the USA. At the Sino-German Workshop, the subjects “Advanced/intelligent forming process”, “Material characterization”, “Advanced constitutive models”, and “Property setting in metal forming” were discussed. Furthermore, an international platform for the exchange of ideas on advanced forming and manufacturing of lightweight materials was established.

The application of lightweight materials related to advanced manufacturing technologies is a key factor to promote the development of automobile industries and to boost the development of energy conservation and new energy vehicles, being also crucial to enhance the independent innovation strength and international competitiveness of automobile industries. With the development of more intelligent forming processes for the manufacture of lighter and safer new energy vehicles the requirements imposed by the Chinese plan “Made in China 2025” and Germany’s intentions of increased lightweight construction are also covered. The workshop was a full success and was highly commended by the participants in every respect.

Sino-German Workshop participants in Shanghai

DORP 2016 – 6th Tube and Profile Bending Conference

The sixth Tube and Profile Bending Conference took place at the Institute of Forming Technology and Lightweight Components on November 2 and 3, 2016. The conference started with an evening event where the participants could visit the machine hall and attend demonstrations of the profile forming and bending machines. On the following day, the more than 100 participants were able to see presentations including the fields of tube and profile production, tube and profile bending, innovative forming processes of tubes and profiles as well as measurement technology and Industry 4.0. Between the sessions the participants had the opportunity to exchange knowledge and experiences as well as to visit the exhibitions, which were shown by representatives from industry and associations. In order to acknowledge and further advance research in the field of tube and profile forming, Professor Tekkaya received a donation from the International Tube Association (ITA) and Messe Düsseldorf. The presentation of the donation and a group picture of the participants are shown in the figure.



Participants of the DORP 2016 and presentation of a donation to the IUL

4.2 Awards

F.W. Taylor Medal 2016

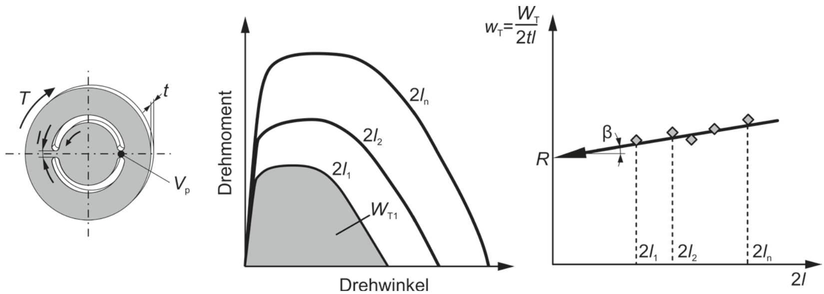
Dr. Qing Yin was awarded the „F.W. Taylor Medal 2016“ by the International Academy for Production Engineering, CIRP, for his publication „Determining cyclic flow curves using the in-plane torsion test“ – a new method which is suitable for the determination of cyclic stress-strain curves for the characterization of kinematic hardening. Dr. Qing Yin is a former research assistant of the Institute of Forming Technology and Lightweight Components and graduated with honors in 2014. Since then, he has been working for the Volkswagen AG.

The „F.W. Taylor Medal of CIRP” is the highest distinction for young scientists in the field of production technology and is presented once a year since 1958. The prerequisite for awarding the prize includes that the recipient is not older than 35 year at the time of publication. The official ceremony took place on 22 August, 2016 at the opening of the CIRP General Assembly 2016 in Guimaraes, Portugal.

Laudator Prof. E. Brinksmeier (on the left) presents the award to Dr. Yin

Journal of Strain Analysis for Engineering Design: CEGB/SAGE Best Paper Award 2015

Mr. Kerim Isik received the 2015 CEGB/SAGE Best Paper Award for the publication "A new test for technology fracture toughness in plane stress in mode II" together with his co-authors, Professor Tekkaya, Professor Atkins from England, and Professor Martins and Dr. Silva from Portugal. A new experimental method for the determination of fracture toughness under Mode II was developed in this publication (see figure). For this purpose, an in-plane torsion test with a special sample geometry was used (see figure a). During the design of sheet and sheet-bulk metal forming processes this crack type should be taken into account. The most significant contribution in the prestigious Journal of Strain Analysis for Engineering is awarded annually by the Journal Editorial Board.



Developed method for the determination of the fracture toughness R in Mode II

Best Demonstration (Best Experiment) Award at REV 2016

From left: A. Selvaggio, Professor M. Castro, T. R. Ortelt

Tobias R. Ortelt and his co-authors Rickmer Meya, Alessandro Selvaggio, Sami Chatti, and Professor A. Erman Tekkaya won the Best Demonstration (Best Experiment) Award for their contribution “Live Demo of two Experiments using a Remote Lab for Forming Technology” at the „REV 2016 - International Conference on Remote Engineering and Virtual Instrumentation”. A live demo of a tensile and a cupping test using the tele-operative testing cell of the IUL was awarded. The award was handed out by Professor Manuel Castro (REV 2016 Co-Chair) during the closing ceremony.

Simufact Scientific Publication Award 2016

Award ceremony during the 17th Simufact RoundTable: Kerim Isik (IUL) receives the award by Dr. Ingo Neubauer (Simufact Engineering)

Since 2015, the software company Simufact Engineering has been awarding practice-relevant scientific publications in which Simufact software was deployed. In 2016, Mr. Kerim Isik, together with authors from the Institute of Materials Science and the Institute of Forming Technology and Machines of Leibniz Universität Hannover and the Institute of Manufacturing Technology of the Friedrich-Alexander University Erlangen-Nuremberg, received the Scientific Review Award. The article “Investigations of ductile damage during the process chains of toothed functional components produced by sheet-bulk metal forming” presented the collaborative work within the scope of SFB/TR 73. The article showed that the development of damage in sheet-bulk metal forming processes is dependent on the loading path. For this purpose, the development of the porosity in two forming process chains was investigated and the ductile damage was predicted using a numerical model. The award ceremony took place within the scope of the 17th Simufact RoundTable 2016 on June 2, 2016, and Mr. Isik had the opportunity to present the research results to an international audience.

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”)
- AGU – Member of “Wissenschaftliche Arbeitsgemeinschaft Umformtechnik“
- CIRP – Fellow of the “The International Academy for Production Engineering”
- Curatorship member of “KARL-KOLLE-Stiftung“, Dortmund, Germany
- DGM – Member of ”Deutsche Gesellschaft für Materialkunde“
- ESAFORM – Member of the Scientific Committee of the “European Association for Material Forming”
- GCFG – Member of the ”German Cold Forging Group”
- ICFG – Member of the ”International Cold Forging Group“
- ICTP – Member of the Standing Advisory Board of the “International Conference on Technology of Plasticity”
- I^2FG – Member of the „International Impulse Forming Group”
- JSTP – Member of “The Japan Society for Technology of Plasticity”
- Member of “DGM Regionalforum Rhein-Ruhr“
- Member of the “German Academic Society for Production Engineering” (WGP: „Wissenschaftliche Gesellschaft für Produktionstechnik“)
- Member of the advisory board, “Max-Planck-Institut für Eisenforschung GmbH”
- 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 CIRP Editorial Committee 2016, Paris, France
- Member of the Editorial Board, “CIRP Journal of Manufacturing Science and Technology“(Elsevier)
- Member of the Editorial Board, „Journal of Production Processes and Systems“

- Member of the Editorial Board, „Materials“
- 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)
- Vice Chairman of the Editorial Committee “CIRP Annals”

Further Memberships

- Member of the CIRP Communication Committee
- Member of the Scientific Committee, “The 26th CIRP Design Conference 2016”, Stockholm, Sweden
- Member of the Scientific Committee, “The 23rd CIRP Conference on Life Cycle Engineering“ (LCE2016), Berlin, Germany
- Member of the Scientific Committee, “International Conference on high speed forming” (ICHSF 2016), Dortmund, Germany
- Member of the Scientific Committee, “4th International Conference on steels in cars and trucks” (SCT 2017), Amsterdam, The Netherlands
- Member of the Scientific Committee, “The 16th International Conference Metal Forming” (Metal Forming 2016), Krakow, Poland
- Member of the Scientific Committee, “The 16th International Conference on Sheet Metal” (SheMet 2015), Erlangen, Germany
- Member of the Scientific Committee „The 12th International Conference on Numerical Methods in Industrial Forming Processes” (Numiform 2016), Troyes, France
- Member of the Scientific Committee “International Deep Drawing Research Group 2017” (iddrg), Munich, Germany

Activities as Reviewer

In Scientific Committees

- AiF – Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V. (AiF)
- Academic Council of the King Saud University
- Brandenburg University of Technology Cottbus-Senftenberg
- CIRP – International Academy for Production Engineering
- DFG – German Research Foundation, Member of Fachkollegium 401 (Review Board on Production Engineering)
- DTU, Technical University of Denmark, Lyngby
- ESF College of Expert Reviewers
- External Advisory Committee, Department of Mechanical Engineering, KAIST, Republic of Korea
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- North Carolina State University
- RWTH Aachen University
- Steel Institute VDEh
- TED University, Ankara, Turkey
- University of Cambridge
- University of Lisbon
- University of Nicosia
- University Valenciennes et du Hainaut-Cambrésis

For Journals

- Applied Mathematical Modelling
- ASME – Journal of Manufacturing Science and Engineering
- CIRP Annals-Manufacturing Technology
- CIRP Journal of Manufacturing Science and Technology
- Computational Materials Science
- Computer Methods in Applied Mechanics and Engineering
- Engineering with Computers
- International Journal for Numerical Methods in Engineering
- International Journal of Advanced Manufacturing Technology

- International Journal of Damage Mechanics
- International Journal of Machine Tools and Manufacture
- International Journal of Material Forming
- International Journal of Mechanical Sciences
- International Journal of Mechanics and Materials
- International Journal of Precision Engineering and Manufacturing
- International Journal of Solids and Structures
- Journal of Applied Mathematical Methods
- Journal of Computational and Applied Mathematics
- Journal of Manufacturing Processes
- Journal Materials Characterization – An International Journal on Materials Structure and Behavior
- Journal of Materials Processing Technology
- Journal of Mechanical Engineering
- Journal of Production Engineering
- Manufacturing Letters
- Materials & Design
- Materials and Manufacturing Processes
- Materials Science & Engineering A
- Mechanics of Materials
- Simulation Modelling Practice and Theory
- Steel Research International
- Surface and Coatings Technology
- The International Journal of Advanced Manufacturing Technology

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

Scientific Academies

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

Advisory Boards

- Global Learning Council
- Open Science Policy Platform
- Scientific Council of the European Research Council (ERC) (until Dec. 2016)
- STS Council and Board – STS-Forum Science and Technology in Society, Japan
- Member of the Supervisory Board „Futurium gGmbH, "(former "Haus der Zukunft gGmbH")
- Advisory Committee Japan Science and Technology Agency (JST) Tokyo
- Board of Trustees, Max Planck-Institute of Molecular Cell Biology and Genetics, Dresden

University Advisory Boards

- Chairman of the University Council, Johann Wolfgang Goethe-University, Frankfurt
- Excellence Initiative Board, Bremen University
- Board of Trustees, TU Berlin

Foundation Advisory Boards

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

Professional Chairs

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

Consultant and Advisory Board

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

Cooperation Advisory Boards

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

Senat Memberships

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

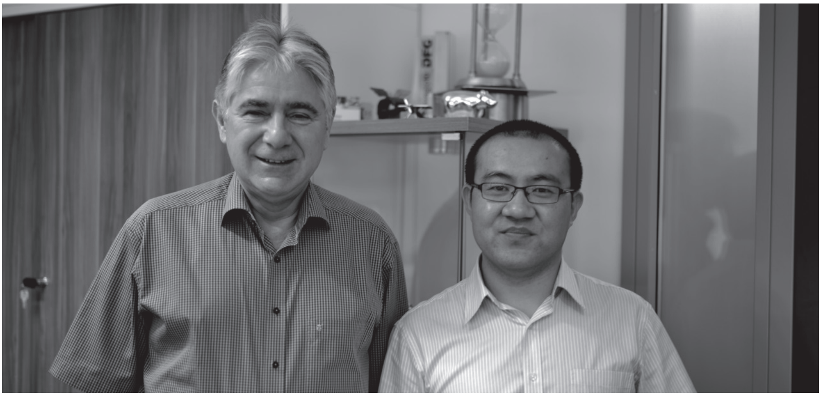
International Exchange

05

5 International Exchange

Associate Professor Chengxi Lei

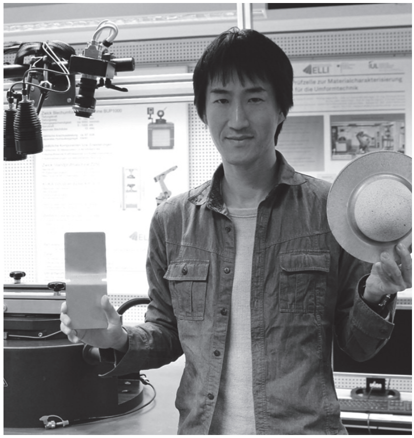
Dr. Chengxi Lei, an associate Professor from Harbin Institute of Technology (HIT, China) was working as a visiting scholar in the Department of Sheet Metal forming and Bending Technology from September 2015 until September 2016. During his stay, he carried out collaborative work with the colleagues of IUL on the topic of hot stamping processes, especially on constitutive modeling of 22MnB5 steel at elevated temperatures. Based on the Norton-Hoff model considering the strain rate and temperature dependency, he built up a new model in which the influence of thickness dependency was also integrated. The flow curves obtained by uniaxial hot tensile tests with different specimen thicknesses confirmed the hypothesis of the model. In addition to the constitutive modeling, Professor Lei also developed a novel ductile fracture criterion to predict the fracture in hot stamping of high-strength steels.



Professor A. Erman Tekkaya and Professor Chengxi Lei

Satoshi Sumikawa M. Eng.

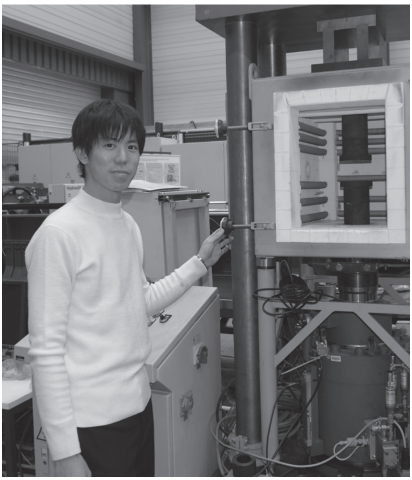
Mr. Satoshi Sumikawa, a senior researcher from JFE Steel Corporation in Japan, is working at the IUL in the applied mechanics group as a visiting researcher since October 2015. His stay will continue until September 2017. He investigates the effect of the material behavior on springback prediction during unloading under different stress states. He analyzed the unloading behavior for high-strength steel sheet and aluminum alloy sheet in different material tests such as bulge tests, plane strain tension tests, and plane torsion tests. In the remaining time at the IUL, the impact of the observed effects on springback of parts manufactured by sheet metal forming will be investigated. Based on the experiments, suitable material models will be used to predict the springback with the help of finite-element simulations. His works will also serve as a basis for his PhD thesis at Hiroshima University, supervised by Professor F. Yoshida.



Mr. Sumikawa in the IUL's laboratory

G-CADET International Exchange Program with Gifu University

To promote the cooperation in engineering sciences, a cooperation agreement exists between Gifu University, Japan, and TU Dortmund University. Within the scope of this cooperation the exchange of excellent master students from the Faculty of Engineering (Gifu University) and the Faculty of Mechanical Engineering (TU Dortmund University) was initiated. As part of this program, Mr. Shogo Inagaki from Gifu University has been a guest at the IUL since October 27, 2016. Under the supervision of Mr. Christoph Dahnke, Mr. Inagaki is part of the bulk metal forming department where he is working on the characterization of high-strength titanium alloys. Here, cylinder and ring compression tests are conducted, both at room temperature as well as at elevated temperatures. Mr. Inagaki's stay will end on January 23, 2017. At the same time, Mr. Danilo Kessler, a student from TU Dortmund University, is currently visiting Gifu University.



Mr. Shogo Inagaki

RISE (Research Internships in Science and Engineering) – Angela Varone and Henry Blount

As in previous years, the IUL took part in the program “RISE“ of the German Academic Exchange Service (DAAD). From June until September, Angela Varone from the Queen Mary University of London and Henry Blount from the University of New Hampshire visited the IUL. The RISE program gives Bachelor students from the UK and North America the opportunity to do internships at German research institutions. The stay of Ms. Varone was financed by a grant collectively funded by the DAAD and the DFG Collaborative Research Center Transregio 73. Under the supervision of Mr. Sieczkarek, Ms. Varone was engaged in the topic of incremental sheet-bulk metal forming and responsible for the construction of a workpiece fixture and the development of the necessary machine-axis movements. Mr. Blount gained insight into the technology of tube welding. He developed solutions for the reduction of unwanted deformations of the inner joining partner in magnetic pulse welding.

Angela Varone and Henry Blount at the IUL laboratory

Moreover, the IUL welcomed the following international students in 2015:

- Bihter Bilgin, Atilim University, Turkey
- Jordan Brown, Princeton University, USA
- Vildan Corumlu, Atilim University, Turkey

Bihter Bilgin and Vildan Corumlu

Technical Equipment

06

6 Technical Equipment

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, 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 moti-on (Schnupp Hydraulik)

- Hydraulic punching machine TruPunch 5000, 220 kN, RUMPF Werkzeugmaschinen GmbH & Co. KG
- Machine for Incremental Tube Forming, IRU2590, transfluid Maschinenbau GmbH
- Machine for Incremental Profile Forming
- DMU 50 – 5-Axis-millingmaschine, DMG Mori Seiki Academy GMBH

Material Testing Machines

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

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
- Infrared Camera, Infratec VarioCam HD head 680 S / 30 mm, Resolution 1280 x 960 Pixel
- GOM ATOS Triple Scan - 3D scanner
- GOM Aramis 4M Optical 3D deformation analyser
- Prism - Residual stress measurement based on hole-drilling and ESPI
- Stresstech PrismS – for the measurement of residual stresses

- 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
- Combined 5-axis-machining and laser deposition welding center Lasertec 65 3D, Sauer GmbH/DMG Mori
- Specimen blanking machine 1200 kN
- Specimen grinding machine for tension specimen

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 2016 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 2016 which have added to our joint success.

Industriebeirat des IUL | IUL Industrial Advisory Board

Das Gremium des Industriebeirates vermittelte auch im Jahr 2016 wichtige Impulse hinsichtlich des industriellen Forschungsbedarfes. An dieser Stelle möchten wir uns für diese wertvolle Zusammenarbeit bedanken.

In 2016, the Industrial Advisory Council provided yet again significant input regarding the need for research from an industrial point of view. We would like to take this opportunity to express our gratitude for this valuable cooperation.

- Gerhard Bürstner, Feindrahtwerk Adolf Edelhoff GmbH & Co. KG
- 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.
- Dr. Jens Heidenreich, PHOENIX FEINBAU GmbH & Co. KG
- Wolfgang Heidrich, GDA - Gesamtverband der Aluminiumindustrie e. V.
- Jörg Ihne, Otto Fuchs KG
- Franz Jurt, Feintool Technologie AG
- Dr. Stefan Keller, Hydro Aluminium Rolled Products GmbH
- Dr. Lutz Keßler, ThyssenKrupp Steel Europe AG
- Dr. Hansjörg Kurz, Volkswagen Aktiengesellschaft
- Prof. Gideon Levy, TTA – Technology Turn Around
- Dr. Hans Mulder, Tata Steel Research & Development
- 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
- Prof. Karl Schweizerhof, DYNAmore GmbH
- Dr. Hosen Sulaiman, Faurecia Autositze GmbH
- Sabine Widdermann, German Cold Forging Group (GCFG)
- Dr. Hans-Joachim Wieland, Stahlinstitut VDEh

Universitäre 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 Werkstofftechnologie, Technische Universität Dortmund
- Zentrum für HochschulBildung, zhb, Technische Universität Dortmund
- Chair of Micromechanical and Macroscopic Modelling, ICAMS, Ruhr-Universität Bochum
- Fachbereich Produktionstechnik, Universität Bremen
- FH Südwestfalen
- fka Forschungsgesellschaft Kraftfahrwesen mbH Aachen, Rheinisch-Westfälische Technische Hochschule Aachen
- 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 Materialien – Werkstoffkunde, Karlsruher Institut für Technologie (KIT)
- 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 Mechanik der Bauwissenschaften, Universität Duisburg-Essen
- Institut für Metallformung, Technische Universität Bergakademie Freiberg
- Institut für Metallurgie, Abteilung Werkstoffumformung, Technische Universität Clausthal-Zellerfeld
- Institut für Produktionstechnik und Umformmaschinen, Technische Universität Darmstadt
- Institut für Umformtechnik, Universität Stuttgart
- Institut für Umformtechnik und Umformmaschinen, Leibniz Universität Hannover
- Institut für Werkstoffkunde, Leibniz Universität Hannover
- Institut für Werkzeugmaschinen und Betriebswissenschaften, Technische Universität München
- Institutscluster IMA/ZLW & IfU (Lehrstuhl für Informationsmanagement im Maschinenbau & Zentrum für Lern- und Wissensmanagement), Rheinisch-Westfälische Hochschule Aachen
- Labor für Fahrwerktechnik, Hochschule Osnabrück

- Laboratorium für Werkstoff- und Fügetechnik, Universität Paderborn
- Lehrstuhl für Fertigungstechnologie, Friedrich-Alexander-Universität Erlangen-Nürnberg
- Lehrstuhl Fertigungstechnik, Universität Duisburg-Essen
- Lehrstuhl für Feststoffverfahrenstechnik, Ruhr-Universität Bochum
- 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 Werkstoffkunde, Universität Paderborn
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- Professur für Baumechanik, Universität der Bundeswehr München
- Professur Theoretische Elektrotechnik und Numerische Feldberechnung, Helmut-Schmidt-Universität, Universität der Bundeswehr Hamburg
- Professur Virtuelle Fertigungstechnik, Technische Universität Chemnitz
- wbk Institut für Produktionstechnik, Karlsruher Institut für Technologie (KIT)
- Werkzeugmaschinenlabor, Rheinisch-Westfälische Technische Hochschule Aachen

Universitäre Kooperationen auf internationaler Ebene | University cooperations at international level

- Charles Delaunay Institute, Labarotoire des Systèmes Mécaniques et d'Ingénierie Simultanée (LASMIS), Université de Technologie de Troyes, France
- Department of Mechanical and Systems Engineering, Gifu University, Yanagido, Japan
- Department of Materials Science and Engineering, The Ohio State University, Ohio, USA
- Department of Mechanical Engineering, Instituto Superior Técnico, University of Lisbon, Portugal
- Department of Mechanical Engineering, Section of Manufacturing Engineering, Danmarks Tekniske Universitet, Lyngby, Denmark
- Department of Mechanical Science and Engineering, Hiroshima University, Higashi-Hiroshima, Japan
- Ecole Nationale Supérieure d'Arts et Métiers (ENSAM), ParisTech, Paris, France
- Forming Laboratory, Faculty of Mechanical Engineering, University of Ljubljana, Ljubljana, Slovenia
- Harbin Institute of Technology, School of Mechatronics Engineering, Harbin, Heilongjiang, P. R. China
- Institut Carnot ARTS, Université de Valenciennes et du Hainaut Cambrésis, Valenciennes, France

- Institute for Manufacturing, Department of Engineering, University of Cambridge, Great Britain
- KAIST - Korea Advanced Institute of Science and Technology, Daejeon, Republic of Korea
- KIMS - Korea Institute of Materials Science, Gyeongnam, Republic of Korea
- 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
- Mechanical Engineering College of Tongji University, Jiading Campus, Shanghai, P. R. China
- Nagoya University, Nagoya, Japan
- Technological Institute, Robert, R. McCormick School of Engineering and Applied Science, Evanston, USA
- Türkisch-Deutsche Universität, Istanbul, Turkey
- Universitatea Babeş-Bolyai, Cluj-Napoca, Romania

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

- Airbus Defence and Space GmbH
- Aleris Aluminum Duffel BVBA
- alutec metal innovations 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
- C-TEC Constellium Technology Center
- CRF – Centro Ricerche Fiat S.C.p.A.
- Daimler AG
- Data M Sheet Metal Solutions GmbH
- Deutsche Edelstahlwerke GmbH
- DYNAmore GmbH
- ESI GmbH
- F.W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Faurecia Group
- Forming Technology Research Department, Steel Laboratory, JFE Steel Company, Chiba, Japan
- Forschungsvereinigung Stahlanwendung e. V. (FOSTA)

- 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
- 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 Instrumente AG
- 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
- Outokumpu Nirosta GmbH
- 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. Hydraulik 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, Sweden
- Tata Steel
- Tata Steel Strip Products UK
- TECOS – Slovenian Tool and Die Development Center
- ThyssenKrupp Steel Europe AG
- TRACTO-TECHNIK GmbH & Co. KG Spezialmaschinen
- Transfluid Maschinenbau GmbH

- TRUMPF Hüttinger GmbH + Co. KG
- TRUMPF Werkzeugmaschinen GmbH + Co. KG
- VDM Metals International GmbH
- 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 e. V.
- AGU – Arbeitsgemeinschaft Umformtechnik
- AiF Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V.
- Aluminium-Leichtbaunetzwerk
- ASM International
- CAE – Chinese Academy of Engineering
- CIRP – The International Academy for Production Engineering
- DAAD - Deutscher Akademischer Austauschdienst e. V.
- 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 e. V.
- GDA – Gesamtverband der Aluminiumindustrie e. V.
- I²FG – International Impulse Forming Group e. V.
- IBU - Industrieverband Blechumformung e. V.
- ICFG – International Cold Forging Group
- IDDRG – International Deep Drawing Research Group
- IMU –Industrieverband Massivumformung e. V.
- ITA – International Tube Association
- JSTP – The Japan Society for Technology of Plasticity
- KIST Kompetenz- und Innovationszentrum für die StanzTechnologie Dortmund e. V.
- Stahlinstitut VDEh
- VDI Verein Deutscher Ingenieure e. V.
- WGP – Wissenschaftliche Gesellschaft für Produktionstechnik

Stiftungen | Foundations

- KARL-KOLLE-Stiftung
- VolkswagenStiftung
- Werner Richard - Dr. Carl Dörken Stiftung
- Wilo-Foundation

Abgeschlossene Arbeiten | Completed Theses

08

Abgeschlossene Masterarbeiten[1] | Completed Master of Science Theses[2]

Bader, Fabian
Tekkaya, A. E. • Altan, T. (Ohio State University) • Grzancic, G.
Numerische Untersuchungen zur Rückfederungsreduktion bei hochfesten Stählen (AHSS) in verschiedenen Biegeprozessen
Numerical investigation of the springback reduction of AHSS in different bending operations

Dardaei Joghan, Hamed
Tekkaya, A. E. • Keesser T. (Faurecia) • Legat, F. (Faurecia) • Grass, J. (Faurecia) • Goliath, L. B. (Faurecia) • Staupendahl, D.
Entwicklung einer Fertigungsrichtlinie für das Innenhochdruckumformen und Validierung durch Versuche anhand eines modularen Werkzeugsystems
Development of a design guideline for tube hydroforming and validation using a modular hydroforming die design

El Jellouli, Mohamed Amine
Tekkaya, A. E. • Clausmeyer, T.
Vergleichende Untersuchungen zur Parameteridentifikation und Anwendbarkeit zweier phänomenologischer Schädigungsmodelle zum industriellen Einsatz
Comparative analysis for the parameter identification and applicability of two phenomenological damage models for industrial application

Grodotzki, Joshua
Tekkaya, A. E. • Chatti, S. • Wernicke, S. • Sieczkarek, P.
Analyse und Steuerung des inkrementellen Blechmassivumformprozesses mit rotierenden Verzahnungswerkzeugen
Analysis and control of the incremental sheet-bulk metal forming process with rotating gearing tools

Gruber, Joscha
Tekkaya, A. E. • Dang, T.
Untersuchung der Interaktion zweier Stichel bei der inkrementellen Blechumformung
Investigating the interaction of two forming tools in incremental sheet metal forming

Gutierrez, Antonio
Tekkaya, A. E. • Dang, T.
Studie zur inkrementellen Blechumformung mit Wirkmedium
Studies of single point incremental forming with back support pressurized fluid

Kolpak, Felix
Tekkaya, A. E. • Schwane, M.
Untersuchung alternativer Materialmodelle unter Berücksichtigung des Bauschingereffektes zur verbesserten numerischen Vorhersage der Bauteileigenschaften fließgepresster Werkstücke
Investigation of alternative material models considering the Bauschinger effect for the improved numerical property prediction of cold forged components

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1 Originaltitel ist fett gedruckt.
2 Original title written in bold.

Krauss, Leonard
Tekkaya, A. E. • Chatti, S. • Wernicke, S. • Sieczkarek, P.
Entwicklung und Realisierung einer Vorrichtung zur variablen Kammerung von Blechbauteilen bei der Blechmassivumformung
Development and realization of a tool for the variable chambering of sheets in sheet-bulk metal forming

Lyu, Jiuyang
Tekkaya, A. E. • Doig, M. (inpro) • Clausmeyer, T.
Materialcharakterisierung und Parameteridentifikation für die Schädigungsmodellierung hochfester Stähle
Material characterization and parameter identification for modeling damage in advanced high strength steels

Marquart, Christoph
Tekkaya, A. E. • Lueg-Althoff, J.
Untersuchung von Einflussfaktoren des Magnetimpulsschweißens von rohrförmigen Aluminium-Aluminium-Verbunden
Investigation of influencing factors on magnetic pulse welding of aluminum tubes

Mittal, Aneesh
Tekkaya, A. E. • Sieczkarek, P. • Wernicke, S.
Werkstoffflussanalyse bei der inkrementellen Blechmassivumformung von Napf-/Rohrhalbzeugen zur Herstellung offener und geschlossener Formelemente
Material flow analysis in incremental sheet-bulk metal forming of semi-finished cup and tube for production of open and closed form elements

Nikaeen, Peyman
Tekkaya, A. E. • Staupendahl, D. • Wernicke, S.
Analyse des Einflusses der Werkzeuggeometrie und Prozessparameter auf den Materialfluss beim Aufdicken des Rohrendes von dünnwandigen Rohren bei der inkrementellen Blechmassivumformung
Impact assessment of tool geometry and process parameters on material flow in end thickening of thin-walled tubes by incremental sheet-bulk metal forming

Nolte, Holger
Tekkaya, A. E. • Gutknecht, F.
Charakterisierung und Simulation des Materialverhaltens von Sandwichblechen während des Scherschneidens mittels schädigungsmechanischer Modelle
Characterization and simulation of the material behavior of sandwich panels in shearing processes by using damage models

Schulze, André
Tekkaya, A. E. • Dahnke, C.
Konstruktion und numerische Analyse von Verbundstrangpresswerkzeugen zur Einbettung oberflächennaher Funktionselemente mit geringen Festigkeiten
Construction and numerical analysis of extrusion dies for near-surface embedding of functional elements with low strengths

Schwienke, Sascha
Tekkaya, A. E. • Staupendahl, D.
Bestimmung der Prozessparameter für das 3D-Profilbiegen durch einen Soll-/Ist-Abgleich verschiedener Biegekonturen
Determination of the process parameters for 3D profile bending by target-performance comparison of different bending contours

Shapovalov, André
Tekkaya, A. E. • Dahnke, C.
Numerische Untersuchung des Umformverhaltens von Aktuatorprofilen basierend auf Formgedächtnislegierungen
Numerical analysis of the formability of shape memory alloy based actuators

Szalata, Fabian
Tekkaya, A. E. • Becker, C. • Grzancic, G.
Einfluss des inkrementellen Profilumformens auf das Profilbiegen
Effect of incremental profile forming on profile bending

Upadhya, Siddharth
Tekkaya, A. E. • Heuse, M. (Faurecia) • Staupendahl, D.
Untersuchung der Kantenrissempfindlichkeit von schergeschnittenen hochfesten Blechen und verbesserte Versagensmodellierung in Umformprozessen durch Betrachtung der eingebrachten Vordehnung
Investigation of the crack sensitivity of sheared AHSS edges and improved failure prediction in forming simulations through pre-strain mapping

Wang, Yicheng
Tekkaya, A. E. • Kibben, M. (TKS) • Mertens, O. (TKS)
Staupendahl, D.
Validierung von FE-Modellen für das Freiformbiegen von Profilen mit Sonderquerschnitten
Validation of FE models for free-form bending of profiles with arbitrary cross-sections

Wels, Christoph
Tekkaya, A. E. • Gies, S.
Entwicklung und Inbetriebnahme eines Prüfstandes zur Kennwertermittlung mittels elektromagnetischer Ringexpansion
Development of a test bench for material characterization using electromagnetic ring expansion

Yu, Qian
Tekkaya, A. E. • Isik, K.
Einfluss der kinematische Verfestigung auf das Schädigungsverhalten beim Eindrückprozess
The effect of kinematic hardening on the damage behavior for the indentation process

Der Schweigepflicht unterliegende Arbeiten wurden verfasst
von | Confidentail works by

Cakar, Sedat
Cheng, Bin
Komodromos, Anna
Maaß, Fabian
Szymanowski, Marcel
Yip, William

Abgeschlossene Bachelorarbeiten | Completed Bachelor of Science Theses

Borchardt, Boris
Tekkaya, A. E. • Müller, D.
Einfluss der Prozessparameter auf die geometrischen Kenngrößen der Schweißnaht beim Directed Energy Deposition von Stainless Steel 316L-Si-Pulver
Influence of the process parameters on the geometrical characteristics of the welding seam using Directed Energy Deposition of Stainless-Steel 316L-Si powder

Bur, Alexander
Tekkaya, A. E. • Grzancic, G.
Experimentelle Untersuchungen zur Ovalisierung und Rückfederung von Rohrquerschnitten bei lokaler Radialumformung
Experimental investigation on the ovalization and springback of tube cross sections in local radial forming

Gitschel, Robin
Tekkaya, A. E. • Heibel, S. (Daimler AG) • Gutknecht, F.
Untersuchung zur Parameteridentifikation für die Anwendbarkeit des GISSMO-Modells in der Umformsimulation hochfester Stahlwerkstoffe im Karosseriebau
Investigations on the parameter identification for the applicability of the GISSMO model in forming simulations of high-strength steel materials in car body construction

Grote, Jannik
Tekkaya, A. E. • Unruh, K. (Faurecia) • Clausmeyer, T. Staupendahl, D.
Experimentelle und numerische Untersuchung des Werkstoffverhaltens beim Biegen höchstfester Stähle für sicherheitsrelevante Strukturbauteile im Automobilbau
Experimental and numerical analysis of the material behavior in bending processes of high-strength steels for safety-relevant structural components in automotive engineering

Guezguez, Mohamed Ali
Tekkaya, A. E. • Gies, S.
Einfluss der Umformgeschwindigkeit auf das Umformvermögen von Aluminiumlegierungen bei uniaxialer Belastung
Effect of the forming velocity on the forming limits of aluminum alloys under uniaxial state of stress

Herweg, Dominik
Tekkaya, A. E. • Chatti, S. • Wernicke, S. • Sieczkarek, P.
Analyse von Einflussgrößen zur gezielten Einstellung der Bauteileigenschaften am Beispiel eines durch inkrementelle Blechmassivumformung hergestellten Zahnrades
Analysis of the influencing process parameters for a defined setting of component properties using the example of geared sheets by incremental sheet-bulk metal forming

Hoffmann, Eike
Tekkaya, A. E. • Heibel, S. (Daimler AG) • Isik, K.
Experimentelle Untersuchungen zum Schädigungsverhalten hochfester Stahlwerkstoffe hinsichtlich plastischer Instabilität und Versagensverhalten bei unterschiedlichen Beanspruchungszuständen
Experimental investigations of the damage behavior of advanced high-strength steels with regard to plastic instability and failure behavior for different loading conditions

Hopp, Marvin
Tekkaya, A. E. • Dang, T.
Entwicklung eines Softwaretools zur Untersuchung des Potentials der inkrementellen Blechumformung mit zwei Umformwerkzeugen
Development of a software tool to investigate the potential of two forming tools in incremental sheet metal forming

Janeczek, Christian
Tekkaya, A. E. • Gutknecht, F.
Vergleich von duktilen Schädigungskriterien und gekoppelten Schädigungsmodellen anhand von FE-Simulationen des Scherschneidens
Comparison of ductile damage criteria and coupled damage models by FE simulations of a shearing process

Kritzler, Tim
Tekkaya, A. E. • Gutknecht, F.
Konvergenzstudie der Variation von Elementgröße und Elementformulierung beim Scherschneiden
Study of convergence examining the variation of element size and element formulation in shearing processes

Lorch, Yannick
Tekkaya, A. E. • Dahnke, C.
Experimentelle Untersuchung des Umformverhaltens von verbundstranggepressten Aktuatoren auf Basis von Formgedächtnislegierungen
Experimental investigations on the formability of shape memory alloy based actuators manufactured by composite extrusion

Ludwig, Janina
Tekkaya, A. E. • Gies, S. • Sieczkarek, P. • Wernicke, S.
Analyse von Einflussgrößen zur gezielten Einstellung der Bauteileigenschaften am Beispiel eines durch inkrementelle Blechmassivumformung randaufgedickten Blechkörpers
Analysis of influencing parameters for a defined setting of component properties using the example of a sheet edge-thickened by incremental sheet-bulk metal forming

Martschin, Juri
Tekkaya, A. E. • Staupendahl, D.
Entwicklung eines Formula Student Chassis unter Anwendung der Verfahrensmöglichkeiten des TSS-Profilbiegeprozesses
Development of a Formula Student chassis using the process potentials of the TSS profile bending process

Miederhoff, Phil
Tekkaya, A. E. • Horlacher, M. (Kirchhoff Automotive)
Staupendahl, D.
Prüfung der Machbarkeit und Wirtschaftlichkeit ausgewählter Rohr- und Profilbauteile zur Bewertung verschiedener Biegeverfahren
Investigation of the feasibility and cost effectiveness of selected tube and profile parts for the evaluation of different bending processes

Niehues, Florian
Tekkaya, A. E. • Löbbe, C.
Experimentelle Untersuchung und Optimierung des Wärmeübergangs beim Warmumformen
Experimental analysis and optimization of the heat transfer in hot stamping

Rutenhofer, Luka
Tekkaya, A. E. • Hiegemann, L.
Einfluss einer rotatorischen Bewegung und erhöhter Geschwindigkeiten auf die Einebnung beim Glattwalzen
Influence of a rotating motion and increased rolling velocities on the smoothing of the surface in a ball burnishing process

Tebaay, Lennart Manfred
Tekkaya, A. E. • Dang, T.
Untersuchung des Einflusses mehrerer Umformwerkzeuge und der Werkzeugkonstruktion zur Prozessbeschleunigung in der inkrementellen Blechumformung
Investigating the influence of multiple forming tools and tool designing to accelerate the process in incremental sheet metal forming

Triebert, Nicolas
Tekkaya, A. E. • Staupendahl, D.
Entwicklung und Einrichtung eines Prüfstands zum inkrementellen Drahtbiegen
Development and setup of a test facility for incremental wire bending

Abgeschlossene Projektarbeiten | Completed Project Theses

Aldemir, Ali
Tekkaya, A. E. • Chatti, S. • Wernicke, S.
Schadensanalyse bei der umformtechnischen Herstellung von Stromklemmen aus dem Werkstoff X10CrNi18-8
Damage analysis of current terminals made by forming of the material X10CrNi18-8

Bärens, Frederic • Wittig, Alexandra
Tekkaya, A. E. • Ortelt, T. R.
Quantitative Analyse von Schmiermittelmengen und Folienarten in einem tribologischen System bei Nakajima-Versuchen nach DIN EN ISO 12004-2
Quantitative analysis of lubricant quantities and types of films in a tribological system for Nakajima tests according to DIN EN ISO 12004-2

Cakar, Sedat
Tekkaya, A. E. • Isik, K.
Experimentelle und numerische Analyse der Rissinitiierung beim Scherschneiden des Stahls DC04
Experimental and numerical anaysis of crack initiation during shear cutting of DC04 Steel

Deiters, Alexander • Windmann, Dominik • Becker, Niels
Tekkaya, A. E. • Gies, S.
Untersuchung des Deformationsverhaltens von Druckleitern bei der elektromagnetischen Umformung
Analysis of the coil winding deformation in electromagnetic forming applications

Detzel, Andreas
Tekkaya, A. E. • Chatti, S. • Sieczkarek, P. • Wernicke, S.
Lokale Blechaufdickung mittels ebenem Walzen
Local sheet thickening by plane rolling

Dilgert, Simon • Hoffmann, Eike • Spee, Julian
Tekkaya, A. E. • Hess, S.
Entwicklung und Implementierung eines Steuerung- und Regelungskonzeptes zur Optimierung der Streifenziehmaschine und Unterstützung der Datenauswertung
Development and implementation of a control and regulation concept for the optimization of the strip-drawing machine and for the support of data evaluation

Eggemann, Timo • Classen, Leonard
Tekkaya, A. E. • Löbbe, C.
Entwicklung einer Biegevorrichtung zum temperaturunterstützten Blechbiegen
Development of an air bending device for heat-assisted forming

Ehsany, Ayda
Tekkaya, A. E. • Napierala, O.
Entwicklung und Umsetzung alternativer Prozessführungsstrategien für die Umformung von Getriebewellen
Development of alternative process chains for manufacturing gear shafts by cold forging processes

Glüer, Sven
Tekkaya, A. E. • Grzancic, G.
Ermittlung analytischer Ansätze zur Beschreibung von Rohrdeformationen beim inkrementellen Profilumformen
Determination of analytical approaches for the description of tube deformations in incremental profile forming

Hahn, Nils
Tekkaya, A. E. • Ortelt, T. R. • Hess, S.
Eine quantitative Analyse von Schmiermitteln in einem tribologischen System bei Nakajima-Versuchen nach DIN EN ISO 12004-2
A quantitative analysis of lubricants in a tribological system for Nakajima tests according to DIN EN ISO 12004-2

Hijazi, Dina • Stafylas, Stavros • Wie, Zhiyi
Tekkaya, A. E. • Staupendahl, D.
Vorhersage des Formänderungsvermögens bei der Umformung von Rohren
Prediction of the forming limit for forming operations using tubular material

Hoppe, Jan • Janeczek, Christian
Tekkaya, A. E. • Ortelt, T. R.
Entwicklung einer IUL-App für iOS
Development of an IUL-App for iOS

Kaschner, Sebastian
Tekkaya, A. E. • Chatti, S. • Sieczkarek, P. • Wernicke, S.
Werkstoffcharakterisierung für die Blechmassivumformung
Material characterization for sheet-bulk metal forming processes

Krebil, Kevin
Tekkaya, A. E. • Chatti, S. • Wernicke, S. • Sieczkarek, P.
Wirtschaftlichkeitsbetrachtung der inkrementellen Blechmassivumformung
Economic reflection of the incremental sheet-bulk metal forming process

Michel, Sebastian
Tekkaya, A. E. • Fuß, M. (ISF) • Grzancic, G.
Konstruktion, Fertigung und Einsatzvalidierung eines Umformwerkzeugs zur inkremenellen Rohrinnenumformung
Design, manufacture, and commissioning of a forming tool for inner incremental tube forming

Mittal, Aneesh
Tekkaya, A. E. • Isik, K.
Experimentelle Untersuchungen zur Formänderungsanalyse beim Tiefziehen eines Bauteils aus dem höchstfesten Stahl DP1000
Analytical and experimental trials of a deep drawing of high strength DP1000 steel

Mudalyar, Hitesh • Khan, Aamir
Tekkaya, A. E. • Löbbe, C.
Fügen von Rohren durch inkrementelles Rohrumformen
Tube joining based on incremental forming process

Schwendenmann, Nico • Stahl, Paul-Sönke
Tekkaya, A. E. • Chatti, S. • Wernicke, S. • Sieczkarek, P.
Analytische Beschreibung für das Stauchen eines Blechstreifens durch inkrementelle Blechmassivumformung
Analytical approach for the upsetting of a sheet strip by incremental sheet-bulk metal forming

Sonntag, Maximilian • Brock, Gabriel
Tekkaya, A. E. • Grzancic, G. • Staupendahl, D.
Numerische Analyse der Querschnittsdeformation beim querkraftfreien Biegen dünnwandiger Profile
Numerical analysis of the cross-section deformation during pure bending of thin-walled profiles

Wolf, Tobias
Tekkaya, A. E. • Grzancic, G.
Untersuchungen zum Reib- und Verschleißverhalten beim Inkrementellen Profilumformen
Investigations on the friction and wear behavior in incremental profile forming

Yilmaz, Oguz
Tekkaya, A. E. • Chatti, S. • Sieczkarek, P. • Wernicke, S.
Auslegung von Verschleißuntersuchungen für Verzahnungswerkzeuge bei der inkrementellen Blechmassivumformung
Wear investigations of gearing tools in incremental sheet-bulk metal forming processes

Ausgewählte Veröffentlichungen und Vorträge | Selected Publications and Lectures

09

Zeitschriftenbeiträge | For Journals (Peer Reviewed SCI-Journals)

Allwood, J. M., Duncan, S. R., Cao, J., Groche, P., Hirt, G., Kinsey, B., Kuboki, T., Liewald, M., Sterzing, A., Tekkaya, A. E., 2016. Closed-loop control of product properties in metal forming. CIRP Annals - Manufacturing Technology 65 (2), pp. 573-596.

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Beese, S., Beyer, F., Blum, H., Isik, K., Kumor, D., Rademacher, A., Tekkaya, A. E., Willner, K., Wriggers, P., Zeller, S., Löhnert S., 2016. Simulation of Sheet-Bulk Metal Forming Processes with Simufact.forming using User-Subroutines. In: ESAFORM 2016, AIP Conference Proceedings. Nantes, France, DOI: http://dx.doi.org/10.1063/1.4963457.

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Behrens, B. A., Bouguecha, A., Huskic, A., Diefenbach, J., Labanova, N., Tekkaya, A. E., Ben Khalifa N., Napierala, O., 2016. Herstellung von Leichtbauteilen aus Stahl mittels der Massivumformung, In: XXXV. Verformungskundliches Kolloquium, Zauchensee, Austria, pp. 129-134.

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Mitarbeiter | Staff

10

Professoren | Professors

Prof. Dr.-Ing. Dr. h.c. Matthias Kleiner
(beurlaubt)
0231 755 2680
matthias.kleiner@udo.edu

Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
0231 755 2681
erman.tekkaya@iul.tu-dortmund.de

Sekretariat | Office

Dipl.-Dolm. Jeanette Brandt
0231 755 2660
jeanette.brandt@iul.tu-dortmund.de

Nina Polak M. A.
0231 755 5846
nina.polak@iul.tu-dortmund.de

Oberingenieure | Chief Engineers

Dr.-Ing. Nooman Ben Khalifa
Oberingenieur Forschung
Abteilungsleiter Technische Abteilung
0231 755 2630
nooman.ben_khalifa@iul.tu-dortmund.de

Dr.-Ing. habil. Sami Chatti
Oberingenieur Lehre
0231 755 7852
sami.chatti@iul.tu-dortmund.de

Abteilungsleiter | Heads of Department

Dr.-Ing. Till Clausmeyer
Abteilungsleiter Angewandte Mechanik
in der Umformtechnik
0231 755 8429
till.clausmeyer@iul.tu-dortmund.de

Lars Hiegemann M. Sc.
Abteilungsleiter Blech- und Biegeumformung
0231 755 8437
lars.hiegemann@iul.tu-dortmund.de

Dipl.-Ing. Tobias R. Ortelt
Abteilungsleiter Ingenieurausbildung
und Remote Manufacturing
0231 755 4735
tobias.ortelt@iul.tu-dortmund.de

Christoph Dahnke M. Sc.
Abteilungsleiter Massivumformung
0231 755 8441
christoph.dahnke@iul.tu-dortmund.de

Dipl.-Wirt.-Ing. Soeren Gies
Abteilungsleiter Sonderverfahren
0231 755 5238
soeren.gies@iul.tu-dortmund.de

Abteilung Massivumformung | Bulk Metal Forming

Christoph Dahnke M. Sc.
Abteilungsleiter Massivumformung
0231 755 8441
christoph.dahnke@iul.tu-dortmund.de

Oliver Hering M. Sc.
0231 755 8432
oliver.hering@iul.tu-dortmund.de

Felix Kolpak M. Sc.
0231 755 8433
felix.kolpak@iul.tu-dortmund.de

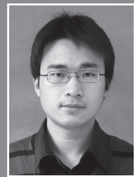
Oliver Napierala M. Sc.
0231 755 6923
oliver.napierala@iul.tu-dortmund.de

Dipl.-Ing. Stefan Ossenkemper
0231 755 7431
stefan.ossenkemper@iul.tu-dortmund.de

André Schulze M. Sc.
0231 755 2654
andre.schulze@iul.tu-dortmund.de

Abteilung Blech- und Biegeumformung | Sheet Metal Forming and Bending

Lars Hiegemann M. Sc.
Abteilungsleiter Blech- und Biegeumformung
0231 755 8437
lars.hiegemann@iul.tu-dortmund.de



Hui Chen M. Sc.
0231 755 8449
hui.chen@iul.tu-dortmund.de

Hamed Dardaei M. Sc.
0231 755 7851
hamed.dardaei@iul.tu-dortmund.de

Dipl.-Ing. Goran Grzancic
0231 755 2499
goran.grzancic@iul.tu-dortmund.de

Sigrid Hess M. Sc.
0231 755 8451
sigrid.hess@iul.tu-dortmund.de

Mike Kamaliev M. Sc.
0231 755 8440
mike.kamaliev@iul.tu-dortmund.de

Anna Komodromos M. Sc.
0231 755 8420
anna.komodromos@iul.tu-dortmund.de

Christian Löbbe M. Sc.
0231 755 8431
christian.loebbe@iul.tu-dortmund.de

Abteilung Blech- und Biegeumformung | Sheet Metal Forming and Bending

Dipl.-Ing. Thomas Mennecart
0231 755 2410
thomas.mennecart@iul.tu-dortmund.de

Rickmer Meya M. Sc.
0231 755 2669
rickmer.meya@iul.tu-dortmund.de

Esmaeil Nazari M. Sc.
0231 755 6926
esmaeil.nazari@iul.tu-dortmund.de

Dipl.-Ing. Daniel Staupendahl
0231 755 7174
daniel.staupendahl@iul.tu-dortmund.de

Abteilung Angewandte Mechanik in der Umformtechnik | Applied Mechanics in Forming Technologies

Dr.-Ing. Till Clausmeyer
Abteilungsleiter Angewandte Mechanik
in der Umformtechnik
0231 755 8429
till.clausmeyer@iul.tu-dortmund.de

Thorben Bender M. Sc.
0231 755 4751
thorben.bender@iul.tu-dortmund.de

Florian Gutknecht M. Sc.
0231 755 8483
florian.gutknecht@iul.tu-dortmund.de

Kerim Isik M. Sc.
0231 755 6918
kerim.isik@iul.tu-dortmund.de

Fabian Schmitz M. Sc.
0231 755 8498
fabian.schmitz@iul.tu-dortmund.de

Heinrich Traphöner M. Sc.
0231 755 8439
heinrich.traphoener@iul.tu-dortmund.de

Abteilung Sonderverfahren | Non-Conventional Processes

Dipl.-Wirt.-Ing. Soeren Gies
Abteilungsleiter Sonderverfahren
0231 755 5238
soeren.gies@iul.tu-dortmund.de

Dipl.-Ing. Thai Dang
0231 755 8434
thai.dang@iul.tu-dortmund.de

Marlon Hahn M. Sc.
0231 755 8415
marlon.hahn@iul.tu-dortmund.de

Dipl.-Wirt.-Ing. Jörn Lueg-Althoff
0231 755 6922
joern.lueg-althoff@iul.tu-dortmund.de

Fabian Maaß M. Sc.
0231 755 2607
fabian.maaß@iul.tu-dortmund.de

Michael Müller M. Sc.
0231 755 2608
michael.mueller@iul.tu-dortmund.de

Dipl.-Ing. Peter Sieczkarek
0231 755 6917
peter.sieczkarek@iul.tu-dortmund.de

Sebastian Wernicke M. Sc.
0231 755 7429
sebastian.wernicke@iul.tu-dortmund.de

Ingenieurausbildung und Remote Manufacturing | Engineering Education and Remote Manufacturing

Dipl.-Ing. Tobias R. Ortelt
Abteilungsleiter Ingenieurausbildung
und Remote Manufacturing
0231 755 4735
tobias.ortelt@iul.tu-dortmund.de

Joshua V. Grodotzki M. Sc.
0231 755 7852
joshua.grodotzki@iul.tu-dortmund.de

Dipl.-Inform. Alessandro Selvaggio
0231 755 7228
alessandro.selvaggio@iul.tu-dortmund.de

MMT | Master of Science in Manufacturing Technology

Dr.-Ing. habil. Sami Chatti
Oberingenieur Lehre
0231 755 7852
sami.chatti@iul.tu-dortmund.de

Frigga Göckede B. B. A.
Koordination Internationale Studiengänge
Fakultät Maschinenbau
0231 755 6462
frigga.goeckede@iul.tu-dortmund.de

Anna Komodromos M. Sc.
0231 755 8420
anna.komodromos@iul.tu-dortmund.de

Oliver Napierala M. Sc.
0231 755 6923
oliver.napierala@iul.tu-dortmund.de

Dipl.-Ing. Tobias R. Ortelt
Abteilungsleiter Ingenieurausbildung
und Remote Manufacturing
0231 755 4735
tobias.ortelt@iul.tu-dortmund.de

Projektierung | Project planning

Dr.-Ing. Nooman Ben Khalifa
Oberingenieur Forschung
Abteilungsleiter Projektierung
0231 755 2630
nooman.ben_khalifa@iul.tu-dortmund.de

Dr.-Ing. Dipl.-Wirt.-Ing. Ramona Hölker-Jäger
0231 755 6915
ramona.hoelker@iul.tu-dortmund.de

Dr.-Ing. Thomas Kloppenborg
0231 755 2402
thomas.kloppenborg@iul.tu-dortmund.de

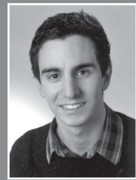
Dipl.-Wirt.-Ing. (FH) Kerstin Lenschen
0231 755 2034
kerstin.lenschen@iul.tu-dortmund.de

Dr.-Ing. Frauke Maevus
0231 755 8193
frauke.maevus@iul.tu-dortmund.de

Dominic Müller M. Sc.
Persönlicher Referent Prof. Tekkaya
0231 755 8453
dominic.mueller@iul.tu-dortmund.de

Technische Mitarbeiter | Technical Staff

Dipl.-Des. (FH) Patrick Cramer
0231 755 2456
patrick.cramer@iul.tu-dortmund.de



Ilias Demertzidis
0231 755 6606
ilias.demertzidis@iul.tu-dortmund.de

Werner Feurer
0231 755 2609
werner.feurer@iul.tu-dortmund.de

Dipl.-Ing. (FH) Andreas Herdt
0231 755 7288
andreas.herdt@iul.tu-dortmund.de

Dirk Hoffmann
0231 755 6605
dirk.hoffmann@iul.tu-dortmund.de

Dipl.-Ing. (FH) Michael Prüfert
0231 755 6924
michael.pruefert@iul.tu-dortmund.de

Frank Volk
0231 755 5247
frank.volk@iul.tu-dortmund.de

2016 ausgeschieden | Staff who left in 2016

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

Dipl.-Fachübers. Andrea Hallen

Christian Pleul M. Sc. M. Eng.

Dipl.-Ing. Martin Schwane