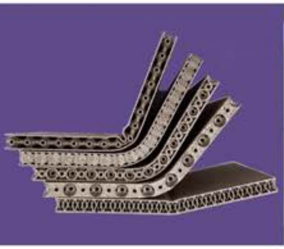
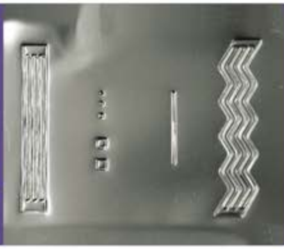
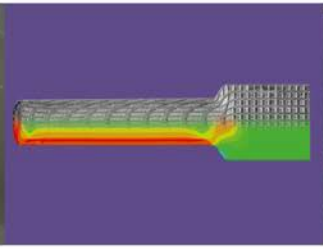


Institute of
Forming Technology and
Lightweight Components

Activity Report

17

technische universität
dortmund

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Imprint

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IUL

Preface

Dear Readers,

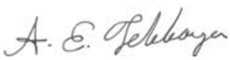
The (research) results of the demanding and exciting work at the Institute of Forming Technology and Lightweight Components in 2017 are summarized in this report: the outcome of the IUL research projects, details concerning newly filed patents, and a publications overview. We look back on the events held at the IUL and on the visits of academics who enriched our work at the IUL with their personality and their expertise and, thus, have opened up new perspectives for research and teaching. From our department of engineering education we also gathered information concerning the courses, recent results of the research activities for the improvement of engineering education, and a list of all theses of 2017. We are particularly proud of the fact that we were able to engage highly talented MMT and Master graduates as new PhD candidates at the IUL. The highlights of the research year 2017 are for certain our major projects: Tansregio 188, TR 73 with its third funding period, and the ELLI 2 project.

Together with our partners from RWTH Aachen University and TU Dortmund University as well as the other institutions involved, Brandenburg University of Technology and Max-Planck-Institut für Eisenforschung, we investigate material damage during the forming process and its impact on the product properties. Top priorities were especially the recruitment of highly qualified PhD students and their training as well as the acquisition of the technical equipment to push forward the project process. Having set up an industrial advisory board, TRR 188 benefits from the practical relevance and manufacturing-orientated know-how of the board members. And finally, TRR 188 and its promising research results were presented to the international research community within the scope of lectures and poster presentations.

At the beginning of the year the third and last funding period of the joint research project TR 73 on bulk-sheet metal forming started. The successful collaboration with our partners of the Institute of Manufacturing Technology (LFT), Friedrich-Alexander-Universität Erlangen-Nürnberg, and of the "Institut für Umformtechnik und Umformmaschinen" (IFUM) of Leibniz Universität Hannover continues. The IUL as speaker institute contributes two projects to the research association. During the kick-off meeting on the occasion of the start of the third funding period objectives of the projects and opportunities for a transfer of research results into industrial practice were discussed. In this way, the consideration and implementation of fundamental research of the Transregio 73 into manufacturing process chains was supported.

Within the ELLI project the book “Engineering Education 4.0 – Excellent Teaching and Learning in Engineering Sciences” was published in 2017. All ELLI partners, The Center for Higher Education of TU Dortmund University, RWTH Aachen University, and Ruhr-Universität Bochum summarized the results of the first funding period. Furthermore, in November 2017 the new powder bed machine was put into service for the ELLI 2 project and laid the foundations for another remote lab.

Finally, we would like to thank all institutions for their support in 2017, all research partners, and the IUL staff for the excellent und successful collaboration.



A. Erman Tekkaya

Matthias Kleiner

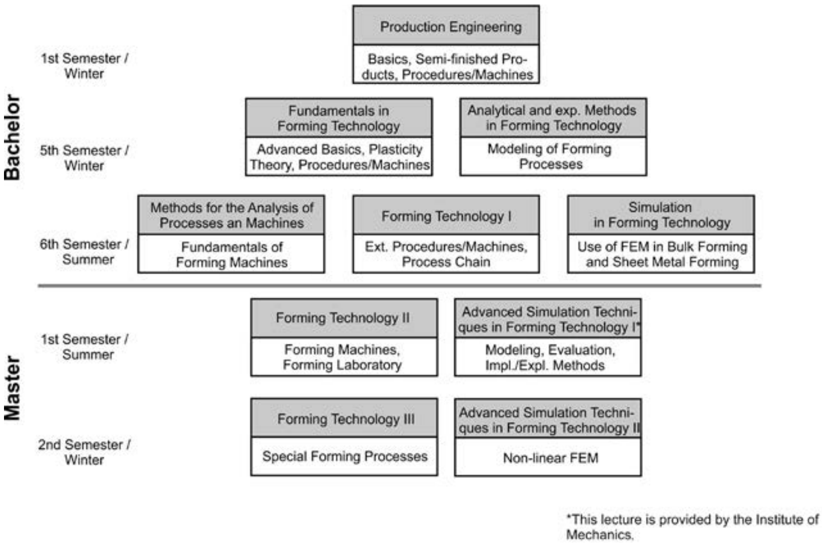
Education

01

1 Education

1.1 Offered Courses

The Institute of Forming Technology and Lightweight Components offers lectures and laboratories in the following bachelor and master programs: logistics, industrial engineering, and mechanical engineering. In addition, students of computer science, physics, and those studying to become teachers attend the courses offered by the institute as part of their minor subject. The students acquire knowledge in the field of forming technology that is necessary in order to succeed in the industrial working environment or to enter an academic career. In detail, the following lectures were offered in 2017:



Structure of lectures for the study program mechanical engineering with a specialization in production engineering

Other courses offered by the institute are:

- Lecture series on Forming Technology
- Laboratory work A as part of the Master's Program in Mechanical Engineering
- Laboratory work B as part of the Bachelor's Program in Industrial Engineering

The following courses are offered in English as part of the international Master‘s Program “Master of Science in Manufacturing Technology (MMT)”:

- MMT – Forming Technology – Bulk Forming
- MMT – Forming Technology – Sheet Metal Forming
- MMT – Advanced Simulation Techniques in Metal Forming
- MMT – High Dynamic Testing of Materials
- MMT – Additive Manufacturing
- MMT – Aluminum - Basic Metallurgy, Properties, Processing, and Applications
- MMT – Laboratory

As a preparation and measure for constant improvement of the laboratories, a workshop took place in the winter semester 2017/18 for all supervisors working at the IUL in cooperation with the Center for Higher Education at TU Dortmund University. In this context, the research group on engineering education presented an evaluation of the previous years together with a list of “Dos and Don’ts” regarding laboratories in forming technology.

Workshop in preparation for the laboratories

In 2017, the following guest lecturers have contributed to the course offer at the IUL:

- Prof. P. Haupt, Emeritus Professor from the University of Kassel
- Prof. J. Hirsch, Hydro Aluminium Rolled Products
- Dr.-Ing. E. Lach
- Prof. K. Roll, formerly Daimler AG Sindelfingen
- Dr.-Ing. J. Sehrt, University Duisburg-Essen

For further information, please visit: **www.iul.eu/en/teaching**

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. • Anna Komodromos M. Sc.
Dipl.-Ing. Tobias R. Ortelt

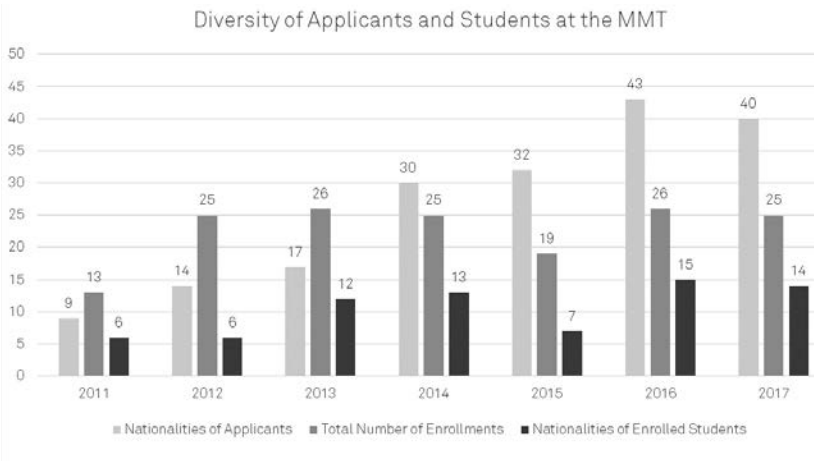
The English-taught, four-semester study program "Master of Science in Manufacturing Technology", which started in 2011, was again of much interest to international students regarding the start of studies in winter semester 2017/18. 26 carefully selected and excellent students out of around 1,000 applicants from 40 nations have begun their MMT studies in Dortmund. Within the scope of the co-operation with the Turkish-German University in Istanbul, organized by the German Academic Exchange Service (German: DAAD), four students from Turkey started their MMT studies. Thus, the new batch consists of students from 15 different nations, proving once again the program's high diversity.


Welcome event for the MMT batch 2017


MMT coordination team meeting prospective students in Moscow

In order to further increase the diversity of the MMT program, the coordination team analyzed the countries of origin of the students and, on this basis, took steps to inform more students from other countries about the study program. In this context, newsletters have been sent out to prospective students in Brazil and the U.S. in co-operation with the DAAD in order to draw attention to the application period. Additionally, the coordination team attended a virtual fair organized by the DAAD, targeting Brazilian prospective students. Here, the MMT was presented in a 30-minutes webinar. Furthermore, education fairs in St. Petersburg and Moscow were attended where prospective students were informed and advised in person. Apart from these specific marketing steps, the web page of the MMT program was redesigned. Its content was

newly structured and plenty of information about the application period, the studies itself, and organization on site in Dortmund was added. Additionally, the social media activities on Facebook were increased as another marketing channel so that weekly news from Dortmund are shared with other users.
The course catalogue was optimized as well. The former elective module “Plastics Processing Technology” is now integrated in the two-semester compulsory course “Materials Technology”. The initial sub-module “Materials Technology I” can now be chosen in the scope of the catalogue of mandatory electives.



Diversity development within the MMT program

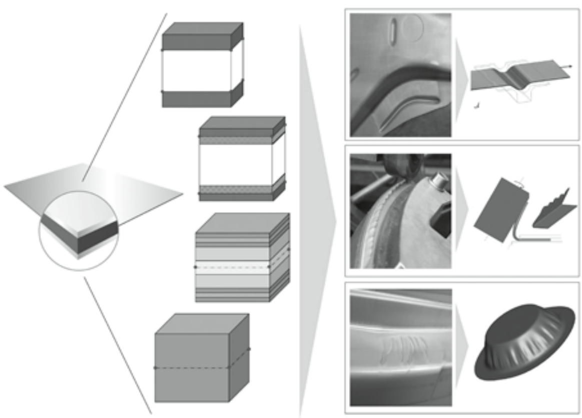
For the first time a two-hour workshop for all MMT freshmen took place in 2017 in addition to the traditional MMT welcome event and a workshop about scientific writing. In cooperation with zhb (Center for Higher Education) this seminar was especially conceptualized for the MMT program. Within the scope of this workshop international students had the chance to get to know the usual processes of a German university and to ask questions. Moreover, this workshop pointed out ways to the students how to organize their studies independently and how to integrate themselves in the German Higher Education culture.

Further information can be found at **www.mmt.mb.tu-dortmund.de**

1.3 Doctoral Theses

Afonichev, Siu Ping	Numerical Simulation of Sandwich Sheet in Sheet Metal Forming under Large Bending
Original title	Numerische Simulation der Umformung von Sandwichblechen unter Berücksichtigung großer Krümmungen
Series	Dortmunder Umformtechnik, Volume 94
Publisher	Shaker Verlag, Aachen, 2017
Oral exam	May 9, 2017
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Co-examiner	Prof. Dr.-Ing. Dr. h. c. M. Liewald (University of Stuttgart)

Lightweight sandwich sheets represent an alternative in the context of body lightweight construction in terms of reducing CO_2 emissions. The application of sandwich sheets in car bodies requires a proper forming simulation method. Observations show a different processing behavior of sandwich sheets in comparison to solid sheets due to the multi-layer construction with a soft core. It is particularly apparent when the sandwich sheet is exposed to extreme bending and curvature, for example during hemming and wrinkling. The analysis shows that the sandwich sheet is more sensitive to bending and buckling compared to solid sheet. The simplified FE modeling considering the average parameters over the entire structure can predict the feasibility of parts from a global perspective. When it comes to local effects, the layer-by-layer model is more capable of simulating the sandwich structure.

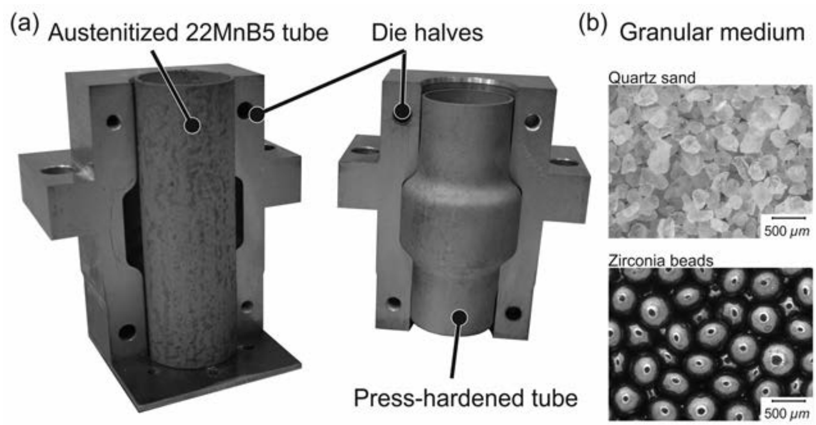


Modeling of sandwich sheet in sheet metal forming under large bending

Chen, Hui	Granular Medium-Based Tube Press Hardening
Series	Dortmunder Umformtechnik, Volume 96
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	November 30, 2017
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. habil. M. Merklein (Friedrich-Alexander-Universität Erlangen-Nürnberg)

Using granular materials as forming medium enables the press hardening process for 22MnB5 tubes and profiles, which can produce lightweight components with high strength and high stiffness. However, granular material is a conglomeration of macroscopic particles unlike a fluid medium that possesses hydrostatic properties. The aim of this thesis is to investigate the physical concept of this new metal forming process, work out and extend the process limit.

In the present work, the performance of granular material as working medium and the principle of choosing appropriate granular material is identified. A fully-coupled thermal-mechanical FE model of granular medium-based tube press hardening is established. This thesis establishes the required fundamental knowledge for an innovative granular medium-based tube press hardening process. Also, an alternative process of passive forming is proposed. The potential of producing high strength and high stiffness components offers the application of lightweight construction in the automotive industry.

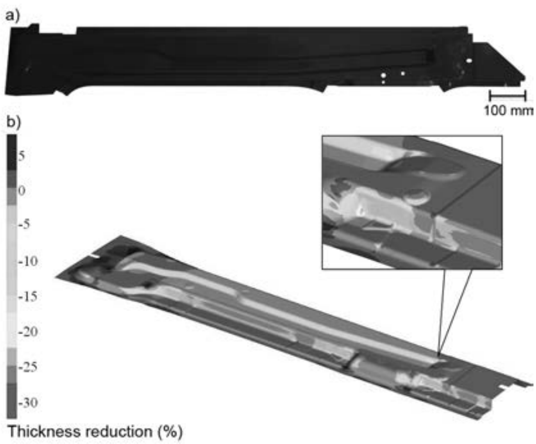


a) 22MnB5 tube before and after press hardening, b) Granular materials used as forming medium

Georgiadis, Georgios	Hot Stamping of Thin-Walled Steel Components
Series	Dortmunder Umformtechnik, Volume 93
Publisher	Shaker Verlag, Aachen, 2017
Oral exam	May 19, 2017
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. W. Homberg (Universität Paderborn)

In recent years, hot stamping has been established as a standard process for mass production of various crash-relevant body-in-white components, as a result of the rising demand for the car body's weight reduction and an increase of crashworthiness. To further exploit the lightweight potential of this forming technology, investigations on the hot stamping of thin-walled boron-manganese steel components were conducted in this thesis.

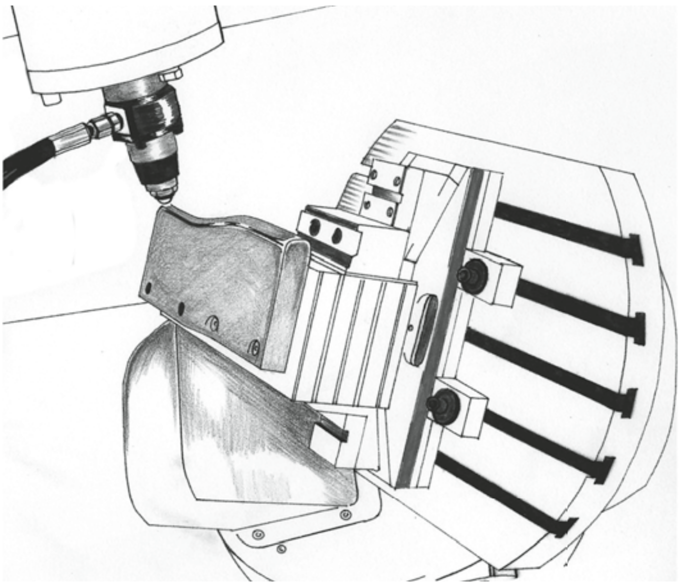
A sensitivity analysis of the entire process chain towards the sheet thickness was carried out. The flow behavior and the formability were analyzed under different thermal conditions and the effect of diverse influential parameters was evaluated. For this purpose, a novel experimental method was introduced that is able to mimic industrial conditions. The research results and outcomes were validated by manufacturing and analyzing two thin hot stamped components, a demonstrator, and a real-life automotive component. Finally, it was demonstrated that hot stamping of thin-walled boron-manganese steel components is feasible if the process chain is optimally designed and the process parameters are properly adjusted.



a) Thin hot stamped component and b) Corresponding forming simulation model

Hiegemann, Lars	Ball Burnishing of Coated Surfaces
Original title	Glattwalzen beschichteter Oberflächen
Series	Dortmunder Umformtechnik, Volume 92
Publisher	Shaker Verlag, Aachen, 2017
Oral exam	June 26, 2017
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. Dr.-Ing. E.h. Dr. h.c. Dr. h.c. F. Klocke (RWTH Aachen University)

Ball burnishing is used to smoothen surfaces by forming of the roughness peaks. In this work, a rolling process is used as a post treatment process for thermally sprayed surfaces. Thus, the tribological behavior is to be improved and adapted to its particular application. For this purpose, initially the microscopic forming processes of the roughness peaks are considered. This is followed by a macroscopic examination of the processes between rolling ball and coated surface. The investigations lead to a mathematical model able to predict the surface roughness after a ball burnishing process. This enables a process design without extensive experimental preliminary tests.

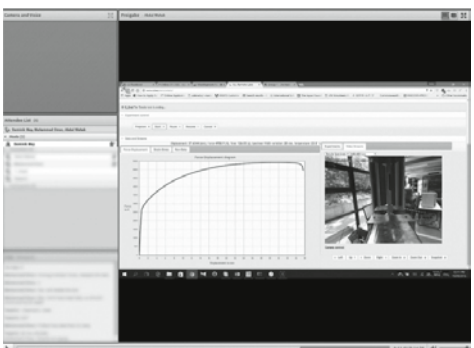


Ball burnishing of a segment of a thermally coated deep drawing die

May, Dominik	Globally Competent Engineers – The Internationalization of Engineering Education through the example of Production Engineering
Original title	Globally Competent Engineers – Internationalisierung der Ingenieurausbildung am Beispiel der Produktionstechnik
Series	Dortmunder Umformtechnik, Volume 95
Publisher	Shaker Verlag, Aachen, 2017
Oral exam	October 26, 2017
Advisor	Prof. Dr.-Ing. Dr.-Ing E.h. A. E. Tekkaya
Co-examiner	Prof. Dr. U. Wilkesmann (zhb, TU Dortmund University)

For engineering graduates the ability to think and act in international contexts plays an increasingly important role. Thus, preparing students for this work environment is one major aim of today's teaching and learning development. In this context, the thesis focuses on the empirically based development, implementation, and evaluation of a higher education course in the field of production engineering. Starting with the status quo in this area and taking into account teaching and learning theory, an engineering-specific model of intercultural competency is developed. A comprehensive literature study and expert interviews guide this work.

Within an international online course, the competence development model is applied to an explicit example and likewise being evaluated. In addition, the use of online-based communication media as well as the integration of a tele-operative testing cell at the IUL is a special aspect of the thesis. With this approach of internationalization on the web, this thesis strengthens the future-oriented engineering education in Germany.



Screenshot taken during a tele-operative tensile test conducted by students

Research for Engineering Education

02

2 Research for Engineering Education

Due to steadily progressing digitalization and with regard to the developments in the field of industry 4.0, current engineering students need new skills in order to succeed in their professional career. Excellent teaching rests upon excellent research and can only be provided by excellently trained and qualified engineers. That is why teaching needs to adapt and orient itself by excellent research in order to educate engineers excellently. The department "Engineering Education and Remote Manufacturing" at the IUL takes up different approaches to an improvement of teaching through active research on education. One main focus of this department is on scientific research oriented towards the advancement of the laboratory in engineering education. In the laboratory, by carrying out experiments, theory and practice can be brought together.

The individual projects are:

- ELLI 2 – Excellent Teaching and Learning in Engineering Science
- MINTReLab – International Manufacturing Remote Lab (project of the Faculty of Mechanical Engineering)

2.1 ELLI 2 – Excellent Teaching and Learning in Engineering Science

Funding	BMBF/DLR
Project-ID	01 PL 16082 C
Head	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Contact	Dipl.-Ing. Tobias R. Ortelt • Joshua V. Grodotzki M. Sc. Dipl.-Inf. Alessandro Selvaggio • Siddharth Upadhya M. Sc.

Since 2011, the cooperative project of RWTH Aachen University, Ruhr-Universität Bochum, and TU Dortmund University has been funded by the Federal Ministry of Education and Research as part of the "Qualitätspakt Lehre". The project is dedicated to research on teaching methods in engineering science.

ELLI 2 is divided into four core areas:

- Remote labs and virtual learning environments
- Globalization
- Student Life Cycle
- Entrepreneurship

At TU Dortmund University, research in this project is conducted and coordinated mainly by the IUL in cooperation with the Center for Higher Education.

Two activities are central for the IUL within the core area "Remote labs and virtual learning environments":

- Further development of the tele-operative testing cell and integration of new experiments
- Virtual laboratory for forming technology

The current aim is to expand the tele-operative testing cell by two additional manufacturing processes. First, an additive powder bed machine, the DMG MORI LASERTEC 30 SLM, was purchased, enabling students to "print" their own specimens in the future. An installation space of 300 mm x 300 mm x 300 mm and a laser power of 600 W are available. Different metals, such as steel, aluminum, or titan, can be processed by the machine.

New machine in the experimental hall

In addition, a rotary tube bending machine, type transfluid DB 2060-CNC-SE-F, was purchased in order to depict a manufacturing process at industrial standards for the students. The developments are geared towards a laboratory that can produce formed components with a batch size of 1 according to industry 4.0.

The Institute of Machining Technology (ISF) and the Department of Materials Test Engineering (WPT), being project partners of the IUL, each develop their own specific remote laboratory as part of the measure "Further development of the tele-operative testing cell and integration of new experiments". The respective laboratories will be integrated into the teaching of the Faculty of Mechanical Engineering. At the ISF, a miniature CNS milling machine is being set up as a remote laboratory, enabling students to operate the milling process using input parameters. They can also monitor the process through measured values and finally evaluate the surface. At the WPT, a fatigue test is being automated so that students can analyze the fatigue behavior of their printed specimens.

In April 2017, the publication "Engineering Education 4.0 – Excellent Teaching and Learning in Engineering Sciences" which had been compiled during the first stage of funding, was issued by the project supervisors. It comprises more than 78 articles and papers, presenting the results of all three project locations.

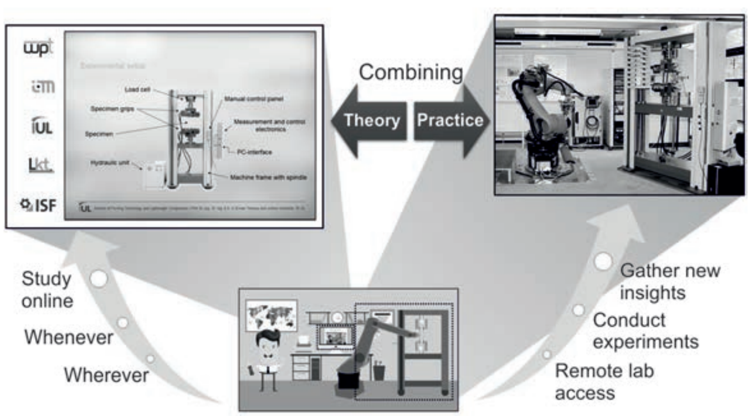
In May 2017, a conference of all researchers involved in the ELLI 2 project took place for the first time in Norddeich. The venue and the "Deichwalk" (dike walk) as a particularly rewarding method for generating ideas encouraged the creativity and the productivity of the interdisciplinary team members. Steffen Rolke, coordinator and project manager of Ingenieure ohne Grenzen e.V. ("Engineers without borders"), took part in the conference as a guest, advising the participating researchers. He also helped developing ideas and concepts for the expansion of the "Engineers without Borders" challenge from Aachen to the two other locations Bochum and Dortmund. The format of a three-day conference, tried for the first time, has once again strengthened the ties within the ELLI 2 team and has laid the foundation for a number of further activities.

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

Funding	Stifterverband
Head	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Contact	Joshua V. Grodotzki M. Sc. • Dipl.-Ing. Tobias R. Ortelt
Status	Completed

Starting with the winter semester 17/18, a new Massive Open Online Course (MOOC) called MINTReLab – International Manufacturing Remote Lab was made publically available. 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)) developed this MOOC together with experts of the Center for Higher Education (zhb). The course focuses on the uni-axial tensile test as seen from the experts' different perspectives. The insights can be applied to various subjects and problems, e.g. simulations. If the course is passed successfully, the participant is granted access to the tele-operative testing cell of the IUL, which can be used to conduct own tensile tests via the remote lab. Apart from the expert knowledge to be imparted, the MOOC also aims at preparing international students for their studies in Germany and especially at the TU Dortmund University.

News/Blog: **www.mintrelab.tu-dortmund.de**



Elements of the MINTReLab MOOC: welcome videos, online lectures, and remote lab

Research for Engineering Education

02

Research

03

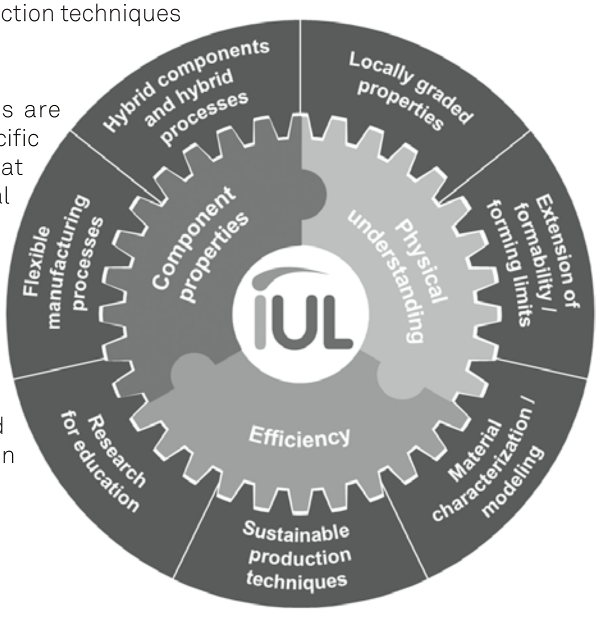
3 Research

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 aspects 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 IUL departments are complemented by ReCIMP – Research Center for Industrial Metal Processing and ReGAT – Research Group on Additive Technology.

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)

All research projects are assigned to issue-specific teams working both at an intra-departmental and inter-departmental level: One chief engineer, 43 scientists, 11 technicians and administrative staff members, and approximately 50 student assistants ensured a sustainable success in 2017.



Research objectives of the Institute of Forming Technology and Lightweight Components

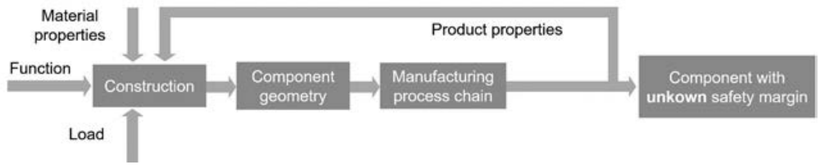
3.1 Research Groups and Centers

3.1.1 Collaborative Research Center Transregio 188 – Damage Controlled Forming Processes

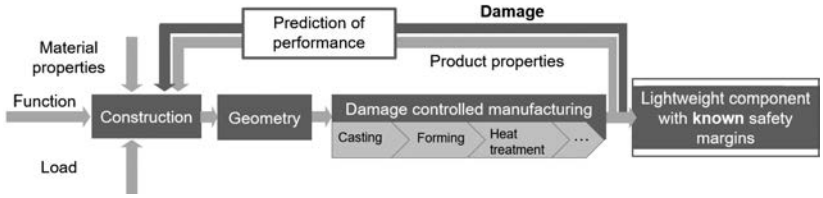
Funding	German Research Foundation (DFG)
Project	TRR 188/1-2017
Spokesperson	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Managing Director	Dr.-Ing. Frauke Maevus

The new Collaborative Research Center CRC/Transregio 188 "Damage Controlled Forming Processes" (TRR 188), which was established in January 2017, is concerned with research on the damage mechanisms during forming and their effects on product properties. On the basis of a deepened basic understanding, new methods and technologies for a quantitative prediction and control of the damage evolution are to be developed as well as the damage states with regard to the product's performance are to be adjusted in a targeted manner.

Based on the central guiding principle of "damage is not a failure", a paradigm shift aims at both the design of forming processes and the dimensioning of components. Product and process design should not only use the nominal material properties, but also take into account the production-induced component properties including damage. In addition, the process design should no longer be based solely on the manufacturability or maximum, failure-free formability, but should also aim at optimizing the microstructural damage with a view to maximizing the product's performance. Damage-controlled design of the forming process chain ensures that the component is not only macroscopically free of defects and meets conventional quality requirements, but also has the best possible mechanical properties and a higher load-bearing capacity. This means that the potential of modern material concepts and forming processes can be fully exploited and the weight of many components can be reduced significantly without sacrificing safety. In the long term, the targeted adjustment and precise quantification of the damage level and the resulting component properties make it possible to realize novel lightweight products and concepts with tailor-made and guaranteed performance. The overall objective is pursued using the example of representative process chains for solid and sheet metal forming in three successive funding periods of four years each.



Classical component and process design without consideration of damage



Damage-based component and process design

The aim of the first funding period approved by the DFG is to identify and describe the damage mechanisms involved in forming processes. In particular, the influence of process parameters and their interactions with damage in forming processes is determined. Furthermore, a general definition and description of the damage is to be elaborated. In order to characterize the initiation and evolution of damage on different scales, material-scientific measuring methods are expanded and efficient testing strategies are developed. At the same time, existing modeling approaches for damage in forming processes are evaluated. On the other hand, new models are being developed on the basis of materials science and manufacturing technology findings. Both damage characterization and modeling are carried out from the nano to the macro scale. The use of damage models initially focuses on the macro scale.

In the planned second funding period, the developed multi-scale modeling approaches are to be adapted to a scale-bridging consideration of damage in forming processes. The understanding gained in the course of the first funding period is used to modify established forming processes or, if necessary, to develop individual solutions to enable damage control. In addition, approaches to integrate the damage aspects into the design methodologies for component design are developed. In the field of characterization, new methods for quantifying damage in forming processes are being developed.

Based on this, the third funding period will be used to develop and optimize damage-reduced forming process chains that, in combination with the previously developed design guidelines, will enable more efficient components with lower weight. This is proven by selected demonstrators.

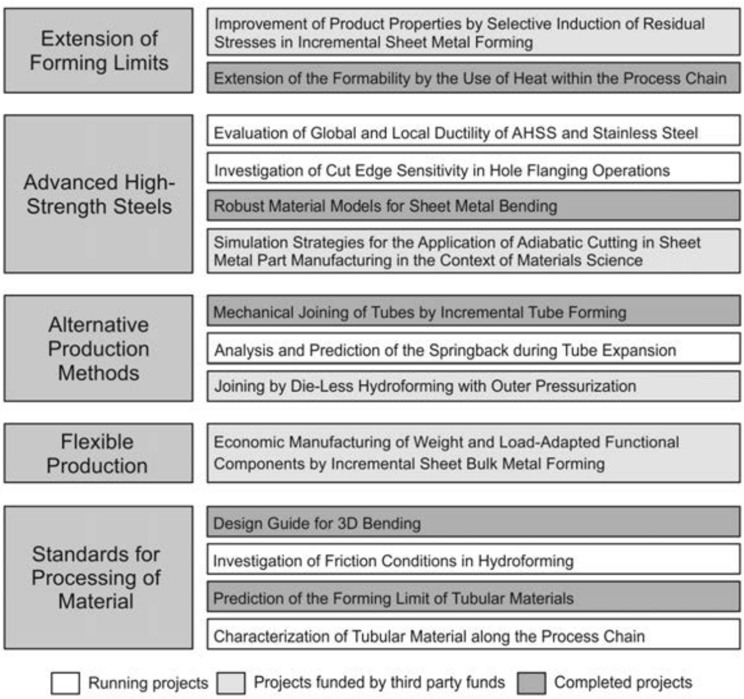
The work on the complex tasks is divided into three project areas: "Process Technology", "Characterization", and "Modeling", each including five projects. In addition, there is a comprehensive scientific service project "Model Integration", which acts as a central interface between the individual project areas, as well as three working groups in which different cross-sectional topics are dealt with. The projects are jointly carried out by scientists from TU Dortmund University (Coordinating University) and RWTH Aachen University. Specifically, the Institute of Forming Technology and Lightweight Components (IUL), the Institute of Mechanics (IM), and the Department of Materials Test Engineering (WPT) from the Faculty of Mechanical Engineering in Dortmund are involved as well as the Chair of Numerical Methods and Information Processing from the Faculty of Architecture and Civil Engineering. At RWTH Aachen University, the participating institutes are the Metal Forming Institute (IBF), the Steel Institute (IEHK), and the Institute of Physical Metallurgy and Metal Physics (IMM) from the Faculty of Georesources and Materials Technology as well as the Laboratory for Machine Tools (WZL) from the Faculty of Mechanical Engineering and the Central Facility for Electron Microscopy (GFE). In addition, there is the Chair of Mechanical Design and Manufacturing at BTU Cottbus-Senftenberg. The universities are supported by the non-university Max-Planck-Institut für Eisenforschung GmbH (MPIE) in Düsseldorf.

3.1.2 ReCIMP – Research Center for Industrial Metal Processing

Head Dipl.-Ing. Daniel Staupendahl

The “Research Center for Industrial Metal Processing” (ReCIMP) goes into its second phase: thanks to the now five year long successful cooperation with the automotive supplier Faurecia and the generated results, Faurecia extended its funding for another 5 years until the end of 2022.

ReCIMP was founded in 2013 with the aim of extending and deepening basic knowledge about innovative metal production processes, process chains, and hybrid processes, investigating new scientific trends in manufacturing technology, and networking with further companies and leading research institutions. Together with the Faurecia groups “Automotive Seating” and “Clean Mobility”, five high-priority research areas were defined.

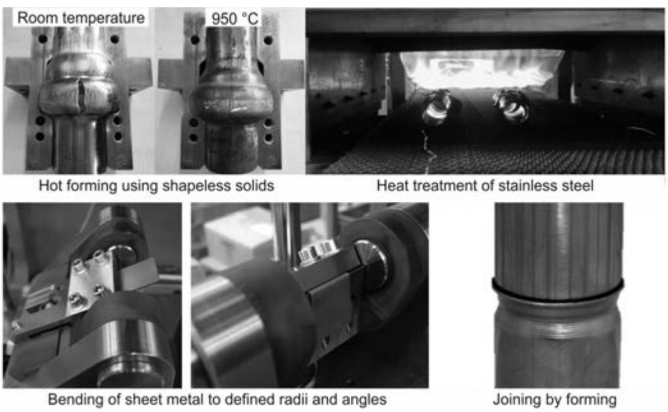


Research projects worked on in 2017, allocated to five research areas

The use of high-strength steel in the automotive field allows efficient lightweight design and can play an essential role in the reduction of CO^2 emissions of cars. These new high-strength materials necessitate new production processes that are adapted to the material behavior and actually enable their later application.

One critical property of high-strength steel which complicates manufacturing is a low ductility. Incremental forming processes can reach high global deformations by dividing the forming process into a multitude of small forming steps with complex stress states. The intelligent application of this traditionally slow process for specifically local forming elements and the reduction of process time aims at increasing its industrial relevance. To increase the forming limit of high-strength steel and ferritic stainless steel, which is a popular choice for exhaust system parts, the use of heat in processes and process chains is investigated. Especially for ferritic stainless steel the combination of heat treatment and tube hydroforming is being investigated (for a detailed description see section 3.3.9).

Tube hydroforming is influenced by a multitude of geometrical and process parameters. To enable the efficient analysis of these parameters, a new modular hydroforming tool for the flexible adjustment of the part contour by puzzle-like tool elements was developed and applied for as a patent (see section 3.7.2). Currently, tests are performed to analyze the performance of the tool concept.



A selection of research work performed in the ReCIMP

The stable handling of new high-strength steel grades in production and, consequently, the realization of robust process chains is enabled by comprehensive material characterization, robust material modeling (for a detailed description see section 3.2.6), and the evaluation of global and local ductility. Here, the knowledge of the local formability is especially relevant to evaluate the sensitivity of sheet material to edge cracks. Forming processes particularly prone to edge cracks are investigated such as flanging and hole flanging.

Tubular parts make up a large portion of exhaust systems. Since tube production processes cause tubular material to exhibit a different behavior than the raw sheet material coming from the coil, another research focus lies on the direct characterization of tubular material. To achieve this, existing testing methods are adapted and new methods are developed.

Eleven researchers and six student researchers were involved in research projects in 2017. Additionally, three master's theses and three student projects were completed while ten student projects are still in progress. All in all, fourteen research projects were worked on in 2017. Five were successfully completed in this year. From the remaining nine projects, a part was extended into the second funding period with an extended work plan, while another part was specifically set up. Under the leadership of the department of nonconventional processes, two new third-party funded projects were acquired. One on the topic of Joining by Die-Less Hydroforming with Outer Pressurization (see section 3.6.4) and one on the topic of Improvement of Product Properties by Selective Induction of Residual Stresses in Incremental Sheet Metal Forming (see section 3.6.10). Also material characterization has turned into a high priority research field in the past years and, as such, will be worked on with increased intensity in the second funding period. Here, the focus will not only be on the generation of relevant material parameters, but especially also on the time-efficient test execution. Furthermore, the standardization and industrialization of the applied testing methods will make up a relevant part of the upcoming research.

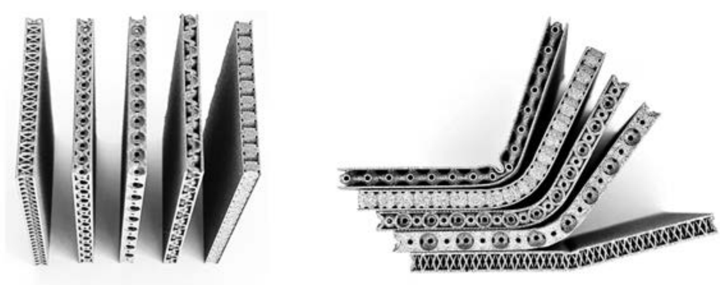
3.1.3 ReGAT – Research Group on Additive Technology

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

The "Research Group on Additive Technology" (ReGAT) aims at integrating additive manufacturing methods in traditional forming processes in order to use the advantages of each and to eliminate the disadvantages, respectively. Research topics are the process combination of formative and additive manufacturing processes, the additive manufacturing of semi-finished products, and their subsequent processing by forming technologies and additively manufactured dies for the forming technology.

The fundamentals acquired with regard to additively manufactured dies with local inner cooling for increasing the productivity during hot aluminum extrusion, previously investigated in two projects funded by the German Research Foundation (DFG), could be successfully transferred to industrial application by a collaborative research project between university and industry, founded by the Federal Ministry for Economic Affairs and Energy (BMWi). Also in the field of die technology and also founded by the DFG, tool coils for electromagnetic forming are explored. Here, the windings are manufactured by additive manufacturing. This allows a design with additional degrees of freedom.

Together with the Institute for Product Engineering (IPE) of the University of Duisburg-Essen a cooperation project dealing with the subsequent processing of additively manufactured semi-finished products was launched. In this project, additively manufactured sandwich sheets with a core structure adapted to the subsequent forming process as well as to the later workpiece function are developed (see figure).



Forming of additively manufactured sandwich sheets

In a project currently approved by the DFG a novel process combination of two processes - single point incremental forming and laser powder deposition with a nozzle - for the production of lightweight components with a high integration of functions is explored. The technological basis is a 5-axis machining center with an integrated unit for laser powder deposition which is installed at the IUL lab. In the project a combined processing, consisting of single point incremental forming, additive manufacturing, and a machining operation, can be realized in one machine and in one clamping device (see figure). Future works are supposed to allow a mechanical finishing by forming technologies of the additively or formatively manufactured surfaces by roller burnishing or deep rolling in order to functionalize the surfaces by a specific texturing. With the support of the KARL-KOLLE-Foundation different powder materials are investigated and tested with regard to their field of application in the novel process combination of additive and formative manufacturing.

This April a workshop entitled "Additive Manufacturing in Forming Technology" was organized. Approximately 50 participants could exchange views about current research activities and the newest machine technologies. In the scope of a (practical) demonstration in the lab of the IUL taking place parallel to the

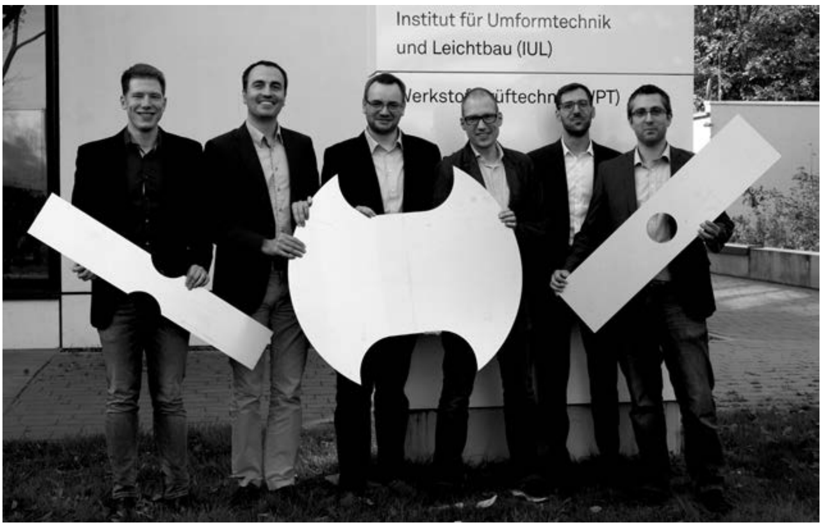
Incrementally deformed pyramid stump with additively and mechanically finished functional elements workshop, a die element, performed as a hybrid component, was manufactured additively.

By the end of the year, the IUL lab could be extended by a machine for selective laser melting of metals in the powder bed. This machine, founded by the project "Excellent Teaching and Learning in Engineering Sciences" (ELLI), shall be integrated in the remote lab for material characterization developed in the first funding period. Thus, students will be able to plan, carry out, consider, and evaluate the additive manufacturing and a subsequent characterization regardless of location and time via internet. Furthermore, the powder bed machine in the remote lab will be integrated into the teaching courses and shall be used during the lectures and exercises. In the field of research, it will provide additional opportunities to extend and complement the traditional technology of "forming technology" with the future technology "additive manufacturing" and will in this way enable the exploration of most innovative manufacturing processes.

3.2 Department of Applied Mechanics in Forming Technologies

Head Dr.-Ing. Till Clausmeyer

The team members of the department contribute to the newly granted SFB/TRR 188 since January 2017. Mr. Alexander Schowtjak boosts the department's activities in model integration for process simulation since February. The research activities of the department are expanded due to the engagement in SFB/TR73 and a DFG project on the in-plane torsion test for the characterization of damage and kinematic hardening. 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, sheet-bulk metal forming, sheet forming, and cold forging are analyzed. Team members discussed recent research results with international experts during the mini symposium "Damage and Fracture in Sheet Metal Forming" at the IDDRG 2017 conference in July. The mini symposium was organized by IUL. The team members said farewell to the Japanese visiting scientist Satoshi Sumikawa from JFE Steel Corporation in September after his two-year stay.

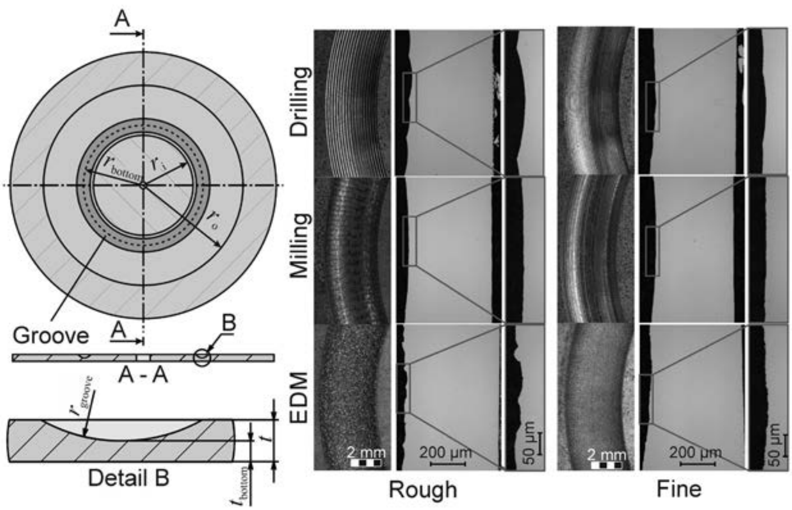


Members of the department with enlarged samples for material characterization

3.2.1 Novel In-Plane Torsion Specimen for the Characterization of Damage and Hardening

Funding	German Research Foundation (DFG)
Project	TE 508/65-1
Contact	Heinrich Traphöner M. Sc.

The focus of this project is the analysis of the in-plane torsion test with circumferential groove for the characterization of sheet materials (as shown below). The manufacturing of the groove is a central aspect. Recent investigations show that beside other aspects the method for producing the groove has a significant influence on the initiation of cracks in the groove. The determination of flow curves is also influenced by the production processes influencing the surface. In one study, grooves were produced by turning, milling, and electro-discharge machining (EDM), each in three qualities and analyzed both metallographically and in the in-plane torsion test. The specific structure of the surface (see figure), e.g. the grooves during turning, has the largest influence on the achievable fracture strains. The small grooves act as notches in the load direction, making this process not suitable for the production of the groove. For high-strength materials fine milling has proven to be the most suitable method. The increase in surface quality by alternative methods is examined.

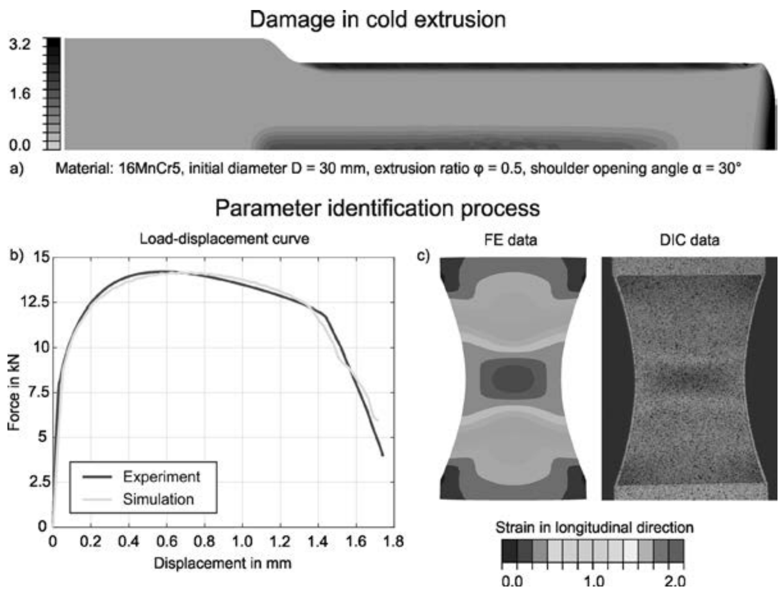


Profiles of the surfaces of grooved specimens with different manufacturing methods and qualities

3.2.2 Model Integration for Process Simulation

Funding	German Research Foundation (DFG)
Project	SFB/TRR 188 • Subproject S01
Contact	Alexander Schowtjak M. Sc.

Aim of the SFB/TRR 188 is to understand and predict damage. This project is carried out in cooperation with the Institute of Mechanics. In the first year of the project's duration established damage models and criteria are implemented in order to analyze forming processes in that regard with help of the finite element method (see figure a). The use of such models requires the identification of various material and model parameters. For their determination, an optimization-based software tool for the parameter identification of complex material models will be developed and provided for the other subprojects. To this end, experimental data is compared to simulations for several basic experiments. Local information like displacement or strain fields (see figure c), which are determined by digital image correlation software, as well as global information like load displacement curves (see figure b) are considered. Notched tensile tests with different notch radii are used in order to induce inhomogeneous deformation fields and different stress states.

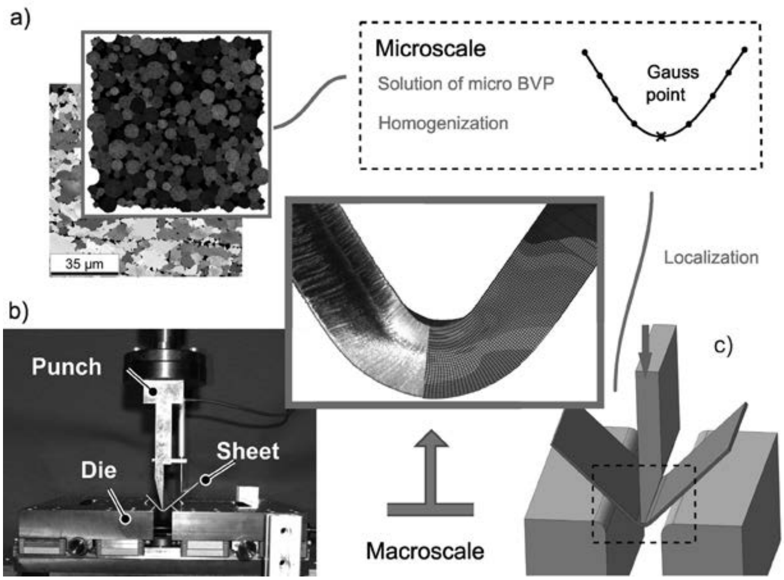


a) Damage in cold forging, b) Load-displacement curve and c) Strain field for a tensile test with notched specimen

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

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

For the prediction of the influence of microstructural parameters on the forming behavior, new micro-mechanical multiscale material models are developed. 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 in the scope of the FE2 method is accomplished. For this method beam elements are used. The project is conducted in cooperation with the Interdisciplinary Centre for Advanced Materials Simulation (ICAMS) of Ruhr-Universität Bochum and the Institute of Mechanics of the University of Duisburg-Essen. At every step the predictions of the models will be compared to experimental results. Within the project both single-phase martensitic steels as well as modern multiphase steels are investigated.

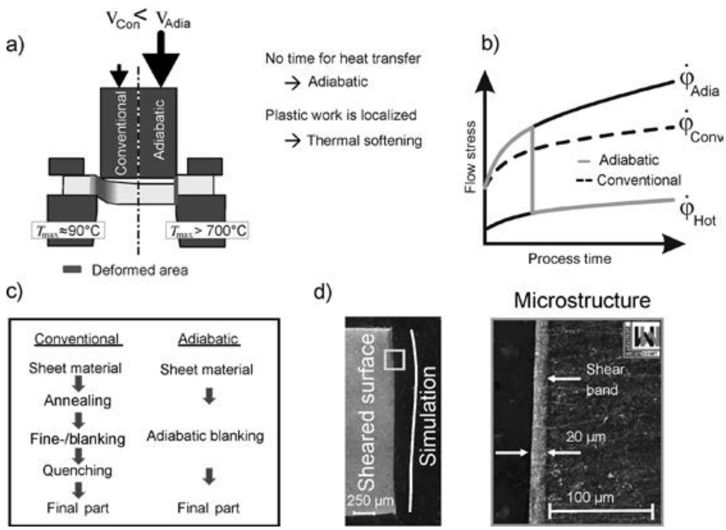


a) Microscopic image and model (provided by ICAMS), b) Air bending, c) Simulation model

3.2.4 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 (see figure a) is characterized by a high cutting quality and a short process route (see figure c) in comparison to conventional blanking methods for advanced high-strength steels. A temperature-induced softening (see figure b) occurs due to the high local rate of deformation ($\dot{\varepsilon} \geq 10^3\ s^{-1}$) and the short process time ($t<2$ ms).
The adiabatic effect occurs in a localized zone and, therefore, in order to predict the accurate development of the shear band a fine meshing of the deformed area is required. Advanced remeshing strategies, e.g. adaptive remeshing, are investigated. Here, moderate computation times for the determination of the physical conditions in the localized deformation zone can be achieved. By the use of simulation an appropriate prediction of the geometry of the sheared surface was obtained (see figure d). Experimental and numerical investigations of the adiabatic blanking are performed on industrially relevant finished parts. The project is conducted in cooperation with the Institute of Materials Science and Engineering (LWW) in Chemnitz.

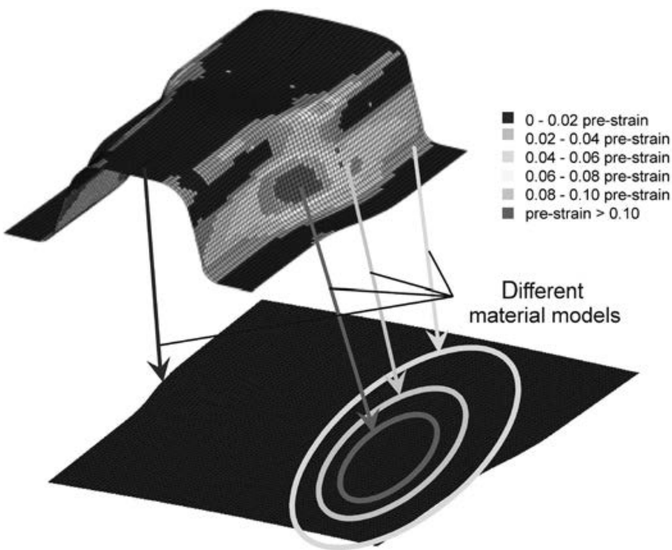


a) Process comparison, b) Material softening, c) Process routes, d) Validation of simulation

3.2.5 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 conducted in cooperation with the Institute of Manufacturing Technology in Erlangen. The focus is on the evaluation of the springback behavior of sheet metal materials. The simulation of the springback after deep drawing is examined within the framework of an extended modeling methodology. Local material parameters are to be assigned to the individual elements based on the load path, as shown in the figure. The method examines how this complex modeling can improve the predictive accuracy of a springback analysis and to what extent the additional numerical costs are justified. In LS-Dyna, two methods of analysis were implemented. For method one, a simulation with an isotropic material model is first carried out for the analysis of the load path of each element. Subsequently, the element properties are assigned in a second simulation. In the second method, a single simulation is interrupted at defined times and tested in terms of a load change criterion. The element properties are then adapted iteratively. The results of both methods are comparable with each other.

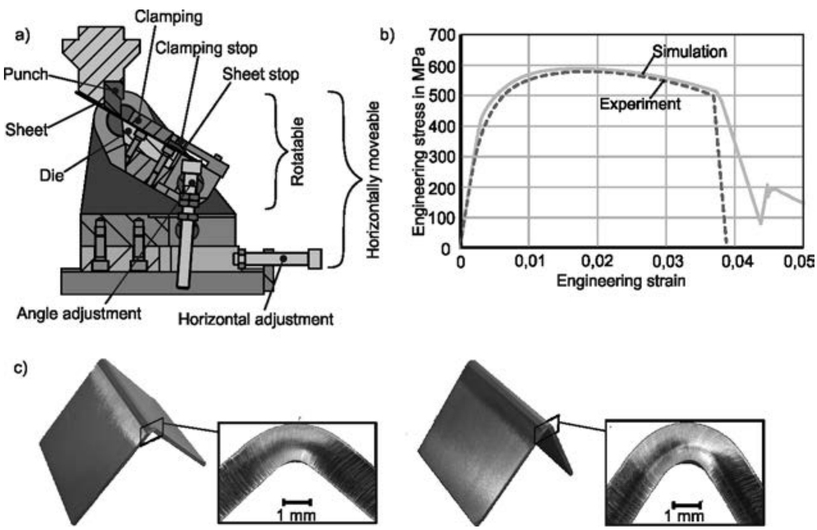


Analysis of prestrain in the component and local assignment of material parameters

3.2.6 Robust Material Models for Sheet Metal Bending

Funding	ReCIMP
Contact	Dr.-Ing. Till Clausmeyer

Advanced high-strength steels are cost-efficient materials for structural components in automobiles. Comparative investigations are conducted because there is a variety of material concepts to obtain high strength and the desired ductility. Important aspects are the determination and prediction of the behavior of bending components during re-loading. A novel bending device (see figure) has been designed and manufactured for this purpose. The device enables to set the bending angle and radius simultaneously. This is a necessary requirement to compare the performance of different steel grades, in particular for re-loading. Moreover, models to predict the failure and hardening behavior after load reversal have been identified and applied. The identification of material parameters has been performed on the basis of torsion tests with load reversal, hydraulic bulge tests, and tension tests with flat specimens as well as with a notch radius. It turns out that, depending on the material grade, yield criteria according to Barlat have to be considered.

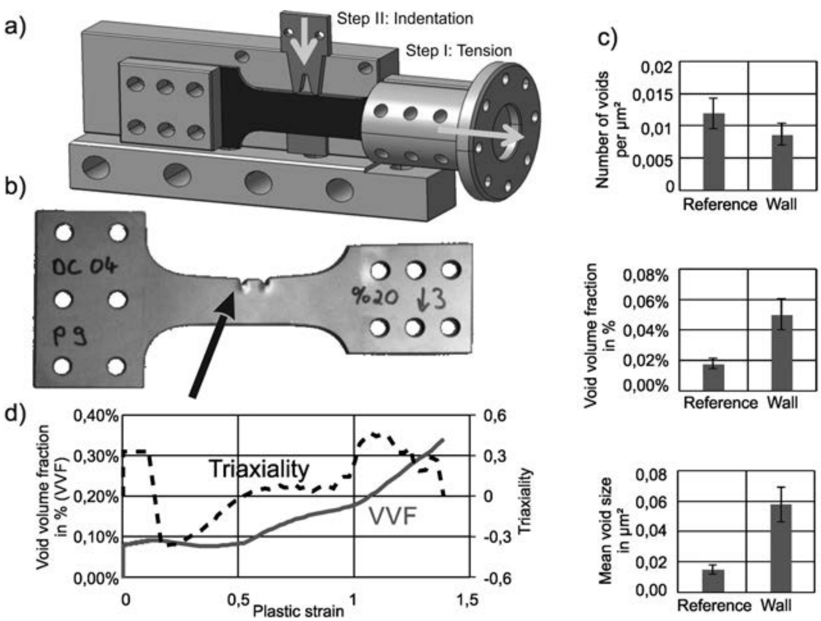


a) Bending device, b) Comparison of simulation with GISSMO damage model and experiment,
c) Samples manufactured using new device

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

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

The control of material flow in thickness direction for a precise adjustment of the component properties is characteristic for sheet-bulk metal forming. Therefore, the technical design of the process needs to take into account highly non-linear strain paths. For a detailed analysis a testing device has been developed (see figure a). Afterwards, the specimen (see figure b) is investigated in collaboration with the "Institut für Werkstoffkunde" (IW) at Leibniz Universität Hannover with respect to the microstructure (see figure c). By means of modified material models and characterization tests qualified for large plastic strains, the process is analyzed in detail (see figure d). The analysis reveals pronounced changes of loading type (triaxiality) on the one hand, but also the correlated variable growth of void volume fraction (VVF), on the other hand. Due to the observed reduction of number of voids, as well as a strong increase of the VVF and mean void size, it can be concluded that the dominating void mechanisms are growth and coalescence.

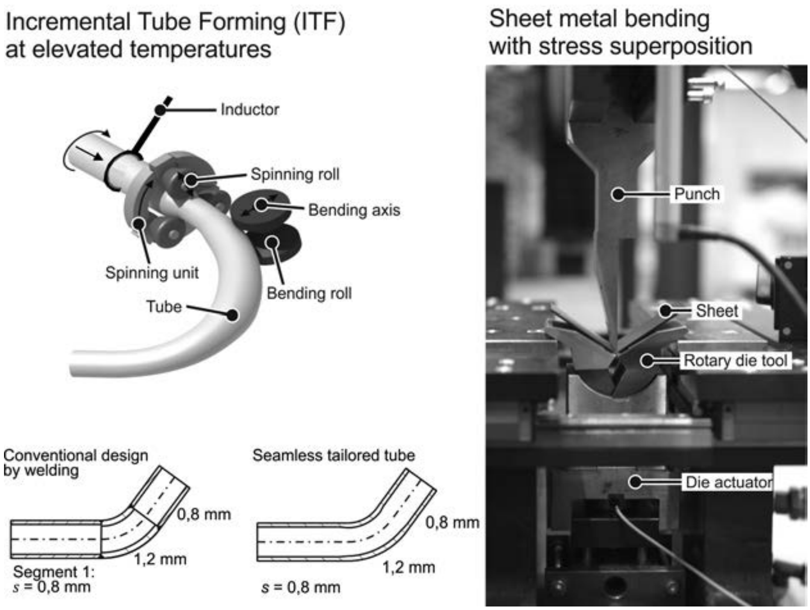


a) Testing device for Strain path change, b) Tested specimen, c) Microstructure analysis, d) Analysis by means of numerical model

3.3 Department of Bending Technology

Head Christian Löbbe M. Sc.

In the department of bending technology, methods for bending of sheet metal, pipes, profiles, and wires are investigated. The work focuses on fundamental research on processes as well as on the development of new processes. In the field of semi-finished tubes, the incremental profile forming (IPF) is being developed for the flexible production of profile structures in a kinematic bending process as well as incremental tube forming (ITF) for the reduction of the bending moment by spinning. A further development of the process is the heat support (see left figure) to facilitate the forming of light alloy metals (here: titanium alloys). To produce curved profiles, a tool technology is investigated which suppresses the wrinkling of thin-walled profile walls. In the process of wire winding, process basics as well as resulting product properties are analyzed in order to design efficient coils. Further work includes the basic research on sheet metal bending where the stress superposition reduces the damage evolution (figure right) as well as the heat assistance to set the product properties.

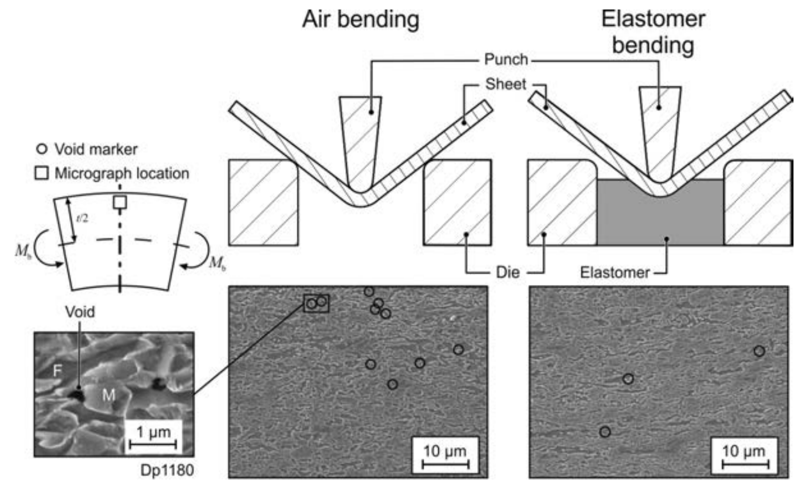


Developments in the bending department for tube and sheet metal bending

3.3.1 Damage in Sheet Metal Bending of Lightweight Profiles

Funding	German Research Foundation (DFG)
Project	SFB/TRR188 • Subproject A05
Contact	Rickmer Meya M. Sc.

Profiles consisting of high-strength and ultra-high-strength steels are manufactured by using conventional bending processes like air and die bending. The components obtain a higher strength during cold forming due to strain hardening. Besides the strain hardening and the occurrence of residual stress through inhomogeneous deformation, damage evolves during the forming operation and influences the product properties. The occurring damage depends highly on the bending procedure and, therefore, on the load path (chronology of stress, strain, strain rate, and temperature). To reduce the damage evolution, additional superposition of compressive stress can be applied, for instance by elastomer bending (see figure). By delaying the damage evolution, the product properties can be improved. Also a new bending process with controllable radial stresses is used to influence the load path. Therefore, the objective of the subproject is to predict the damage and control it in bending operations for performance-adopted profiles.

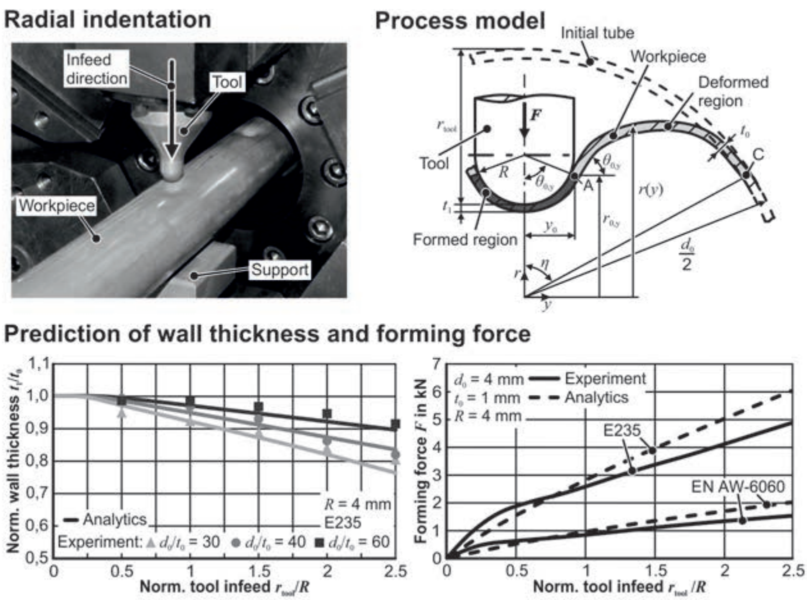


Delayed damage evolution in elastomer bending

3.3.2 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 flexible manufacture of various profile components with a very high degree of complexity. The basic principle of the forming procedure is based on the performance of local forming operations on semi-finished tubes with a simultaneous use of one or more forming tools. The project focuses on the identification and characterization of the underlying forming mechanisms of the process as well as the resulting component loads. For the general case of a locally loaded profile cross section, analytical process models, depending on all process parameters, are developed for the prediction of the wall thickness reduction as well as the acting forming force, taking part deformations in the immediate vicinity of the tool contact area into consideration. Besides numerical investigations, experimental data is used for a validation of the models, as shown in the figure.

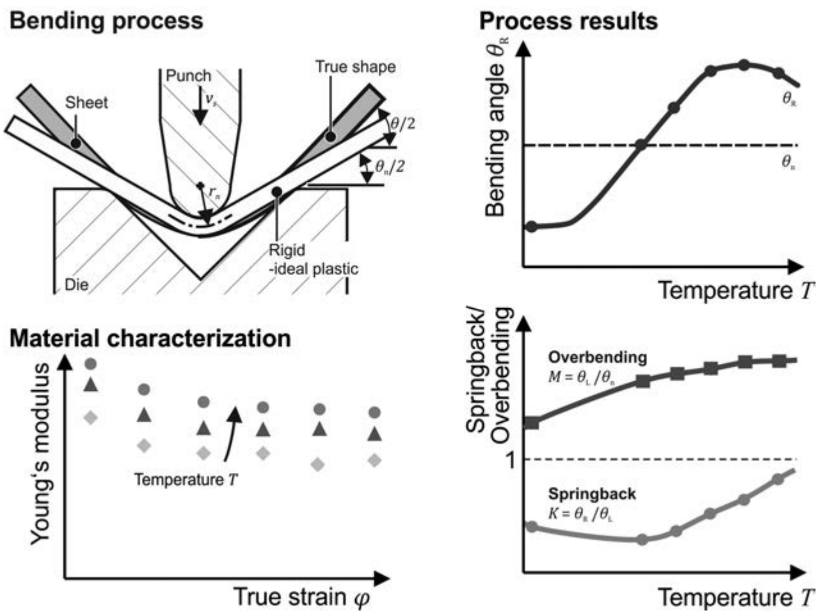


Analytical prediction of wall thickness reduction and forming force in Incremental Profile Forming

3.3.3 Development of a Model to Describe Springback and Residual Stresses Resulting from Bending at Elevated Temperatures

Funding	German Research Foundation (DFG)
Project	TE 508/59-1
Contact	Christian Löbbe M.Sc.

The project investigates sheet metal bending at elevated temperatures with regard to the final bending angle and residual stresses. For forming high-strength steels and light metal alloys more and more often heat-assisted processes are developed so that the formability increases and the process forces are reduced. Therefore, the project focuses on sheet metal bending in order to analyze the springback behavior at elevated temperatures. As the figure shows, the resulting bending angle is influenced by the two mechanisms 'overbending' and 'springback'. In addition to the material-specific effects, both mechanisms are controlled by the process parameters so that a complex behavior must be taken into account for the description of the process results. The basis for the process investigation are experiments characterizing the material in relation to the temperature, strain, and strain rate influences. Later, thermal and temporal effects are analyzed in controlled bending tests.

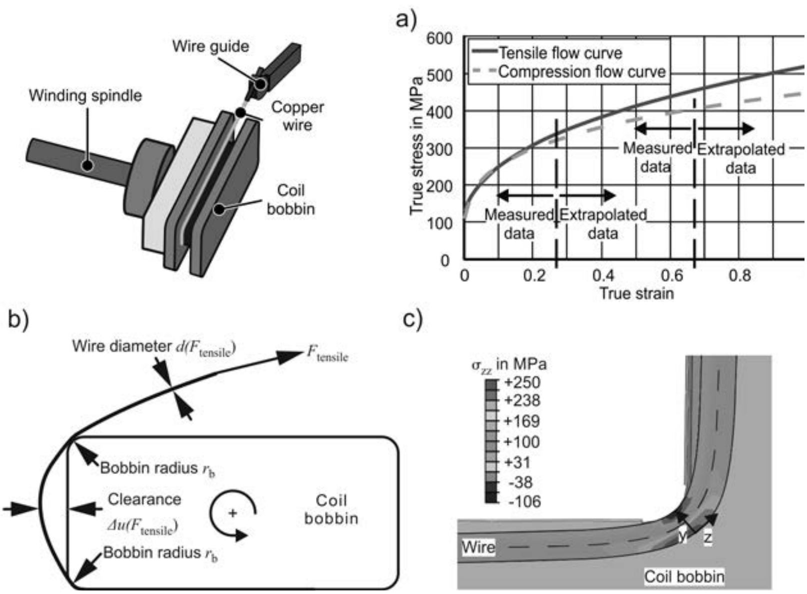


Investigation of sheet metal bending at elevated temperatures with regard to the bending angle

3.3.4 Forming-Based Process Modeling of the Linear Winding Method

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

Efficient stators for electrical motors are manufactured by linear winding of copper wire on rectangular coil bobbins for tooth coils. In this project the coil winding process is being analyzed in cooperation with the Institute of Production Science (KIT) in order to manufacture a tooth coil with adjusted product properties, like a high fill factor and a low resistance, by an optimization of the process. The fundamentals for analyzing the process are represented by the characterization of the mechanical properties of the copper wire, like the tension-compression anisotropy (see figure a).
A challenge of the winding process is the subsequent adjustment of the process parameters in such a way as to prevent a flattening of the wire due to the normal force and the intense bending (see figure b and c), which leads to an increase in the electrical resistance. The process is investigated by numerical, analytical, and experimental methods in order to identify the influences of the geometry, the material, and the process parameters.

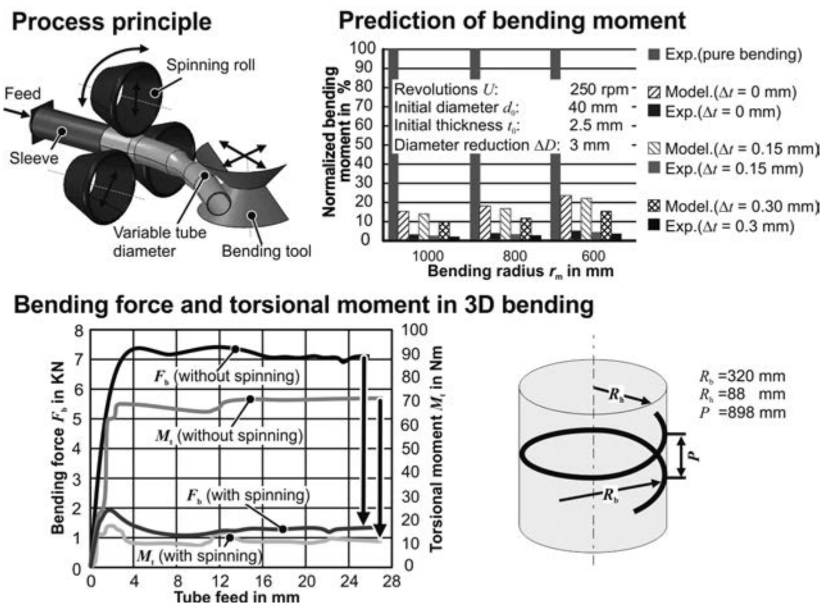


Linear coil winding: a) Flow curves of copper wire, b) Influencing parameters, c) Bending stresses at bobbin corner

3.3.5 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 combination of tube freeform bending and a spinning process to manufacture bent and tailored tubes with variable diameters and thickness over the longitudinal axis. This process combination leads to a reduction of the bending moment and springback due to stress superposition. In the current project the effect of the simultaneous diameter and thickness reduction on the bending moment is investigated experimentally and numerically. Also, an analytical model is developed to predict the bending moment in presence of radial and circumferential stresses due to a diameter and thickness reduction. The results show that the bending moment is reduced mainly by diameter reduction and it is reduced slightly more by applying thickness reduction. Furthermore, ITF is used to manufacture 3D profiles. It can also be seen that the required torsion is reduced by up to 81% by this process combination.

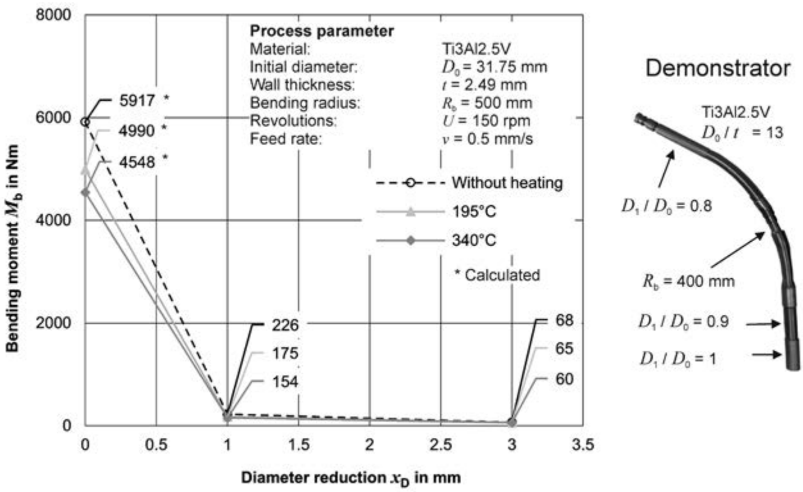


Process principle and forming forces in incremental tube forming

3.3.6 Freeform Bending of Aviation-Relevant Tubular Parts

Funding	BMWi/DLR
Project	20W1514B
Contact	Stefan Gallus M. Sc.

In aircraft construction, tubes are preferably made of titanium materials due to the high strength to weight ratio. The conventional methods for the shaping of the titanium tubes, such as rotary draw bending, encounter limits, for example in the production of very large bending radii. Therefore, in this project a kinematic bending process, the Incremental Tube Forming (ITF) process, is being developed for the production of bent titanium tubes together with the project partner PFW Aerospace GmbH.
The flexible forming of tubes made of Ti3Al2.5V with the ITF process is shown by a demonstrator (see figure right). An inductive heating unit expands the ITF process by the possibility of carrying out bending experiments at elevated temperatures. Therefore, the bending moment is reduced by both a stress superposition by the spinning process as well as by the thermal activation (see figure left). In addition to the characterization of the product properties, the process limits of kinematic bending are finally determined in the project and a process description is developed.

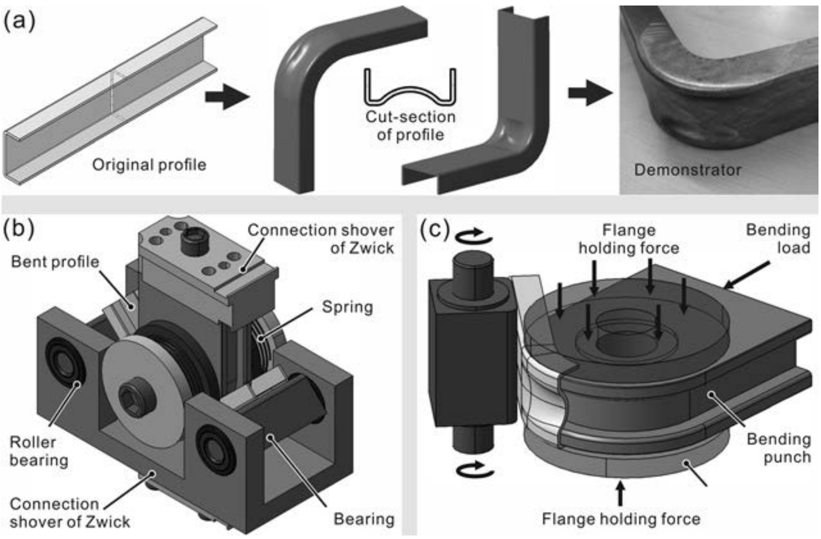


Experimental results for incremental tube forming of titanium tubes

3.3.7 Development of a Technology for Bending U-Profiles

Funding	BMWi/ZIM-ZF
Project	ZF4101104US6
Contact	Hui Chen M. Sc.

The bending of thin-walled and open profiles is often limited to large bending ratios and small bending angles by wrinkling and buckling and is mostly possible only with form-closed bending processes such as rotary draw bending. Due to this restriction, a process has to be developed in the project that allows a controlled cross section deformation to shift the neutral fiber and thereby reduce the achievable curvatures (see figure a). For this purpose, the technology relies on a tool design of die bending in which the profile walls are supported and forced to deform by a recess in the bending die (see figures b and c). Consideration is given to U-profiles with varying dimensions as well as materials of different strength and thickness. In order to analyze the process, a numerical model is first used to design and analyze the modular tooling. With experiments, the numerical model is to be confirmed and the new process limits are to be determined.

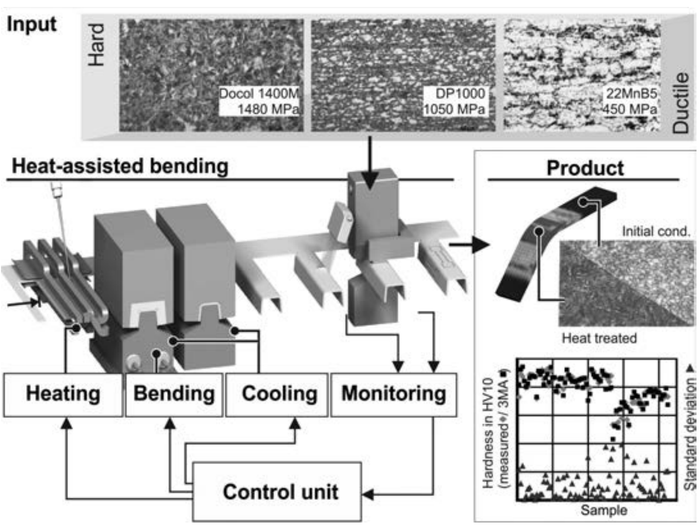


a) U-profile with deformed cross-section, b) and c) Assembly of modular bending tool and detailed view

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

Funding	BMWi/ZIM-KF
Project	KF2198138LP4
Contact	Christian Löbbe M. Sc.
Status	Completed

In the collaborative project with the company KODA a technology for heat-assisted sheet metal forming in progressive dies was developed which facilitates the setting of the geometry and mechanical properties. For the manufacturing of high-strength and tailored sheet metal components, three low-alloy steels were tested for the rapid heat treatment. Finally, suitable parameters for in-situ heat treatment with limited cooling rates were derived. Subsequently, design guidelines for the progressive die were determined and a modular prototype tool was developed which enables the process investigation based on three different demonstrators. In addition to the heating and cooling unit for the rapid process design, the core of the tool development was the monitoring unit to feed back the product properties by means of a laser and a micro-magnetic sensor. Finally, experiments demonstrated that the heat-assisted process enables the accurate manufacturing of components at a high stroke rate up to 20 min^{-1}, and the partial heat treatment and the production of customized product properties becomes feasible (see figure).

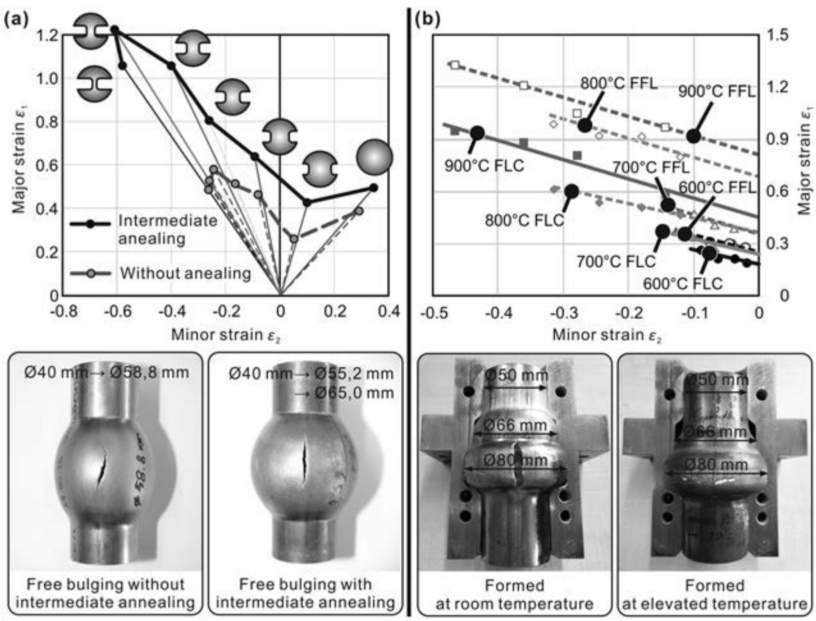


Controlled manufacturing of geometry and mechanical properties through heat-assisted forming

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

Funding ReCIMP
Contact Hui Chen M. Sc.
Status Completed

For the substitution of high-alloyed austenitic stainless steel by low-cost ferritic stainless steel, the limited forming capacity is a major challenge. Two approaches were investigated to extend the process limits for tube hydroforming. The first approach was the intermediate annealing for recrystallization and recovery between the individual cold forming steps. As the determined forming limit diagrams and the experiments of free bulging show, the achievable tube expansion is significantly increased by the intermediate annealing (see figure a). Another approach was tube forming in the hot state. For this purpose, granular media were used which allow a forming temperature of up to 900 °C. In this case as well, the formability, in particular in the case of tension-compression strain state, can be significantly improved (see figure b). Both approaches are therefore suitable solutions to extend the forming limits of ferritic stainless steel tubes during internal high pressure forming by different processes.

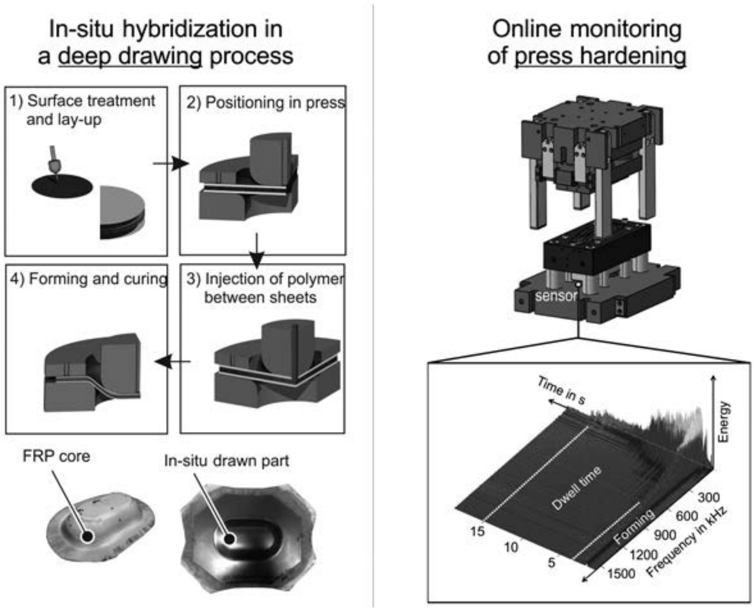


a) Extend the forming capacity by intermediate annealing, b) Granular medium-based tube hot forming

3.4 Department of Sheet Metal Forming

Head Dr.-Ing. Lars Hiegemann

The main research topics of the sheet metal forming department are in the fields of deep drawing and press hardening. In the field of deep drawing the focus is on the processing of hybrid or novel materials. For example, a combined production of magnesium components and plastic reinforcements in one step is tested. Also, a combination of deep drawing of sheet metal and, in this case, a fiber-reinforced plastic in one process step, the so-called in-situ hybridization (see figure), is investigated. In addition to this, research is carried out on the processing of additively manufactured sandwich sheets with an optimized core structure. In the field of press hardening, on the one hand, the classical press hardening process is transferred to other areas. This includes research on the active and passive press hardening of tubes. On the other hand, the online process monitoring of the press hardening (see figure) is being investigated. The aim is to detect failure already during the forming and, thus, make it possible to intervene in the process.

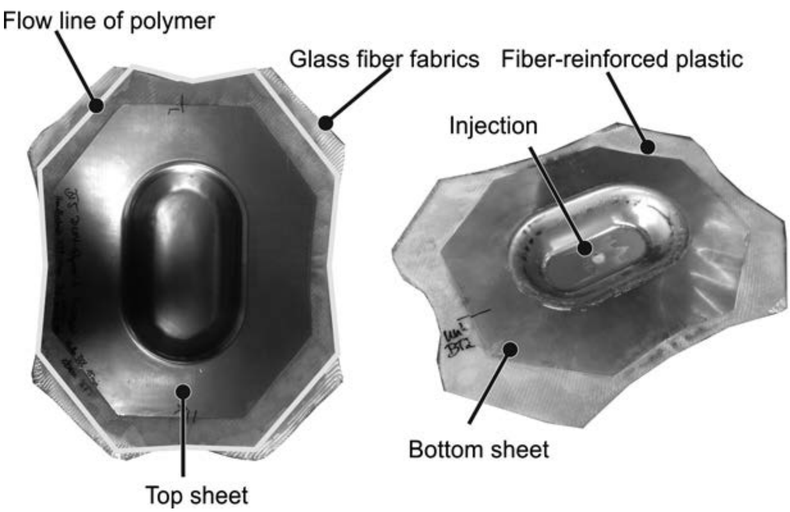


Research areas of the department of sheet metal forming

3.4.1 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

In the year 2017 new results could be obtained regarding the behavior of sandwich sheets in a “one-step” production of sandwich sheets in which polymer is injected between the sheets during deep drawing, First, forming limit diagrams have been created by conducting Nakazima tests. The formability of two metal sheets is decreased when forming two layers of metal sheets with an interlayer of dry woven fabrics. A reason is the notch effect in the surface due to the indentation of the woven structure into the surface. Furthermore, the infiltration of the fabric has been investigated in relation to the viscosity and the normal pressure on the compressed fabric. The measurement of the infiltrated medium is an important parameter for the process window to know the critical point when the infiltration in the process should be finished before the contact pressure in the radii reaches an impassable value. Furthermore, sandwich parts have been produced in the in-situ hybridization process in collaboration with the Karlsruhe Institute of Technology (see figure).

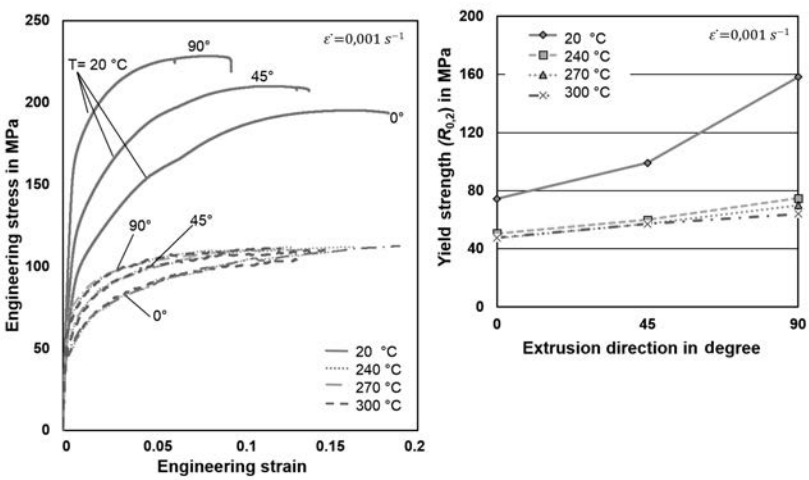


In-situ drawn sandwich sheets

3.4.2 Development of the Hybrid Plastic/Magnesium Composite Part for Ultra-Light-Construction Application

Funding	Leitmarkt Agentur.NRW
Project	EFRE-0800113
Contact	Hamed Dardaei Joghan M. Sc.

Functional integration in composite materials is obtainable by a combination of sheet forming with an injection process. The low weight of magnesium is an advantage for it to be chosen as part of the hybrid material. A reduction of the number of sequences can be acquired by combining deep drawing of the magnesium alloy with back-injection molding.
This project is based on a collaboration between the IKV at RWTH Aachen University along with the companies TWI, JUBO, and KODA. In this project, two types of sheets, one with a constant thickness and the other one with variable thick-ness or tailored sheet, are extruded from a magnesium slab. The open tubes are widened and flattened. Then the sheets are deep-drawn and finally back-injected with polymer. A material characterization analysis has been done in order to study the formability of the extruded sheets. The mechanical and microstructural characteristics of sheet have been investigated. As an example for the results of the material characterization, the results of the tensile tests at different temperatures for sheets with constant sheet thickness can be stated. The diagrams show that at room temperature the material exhibits high anisotropy but, on the other hand, at temperatures above 240 °C there is no strong influence of the temperature on the flow stress.

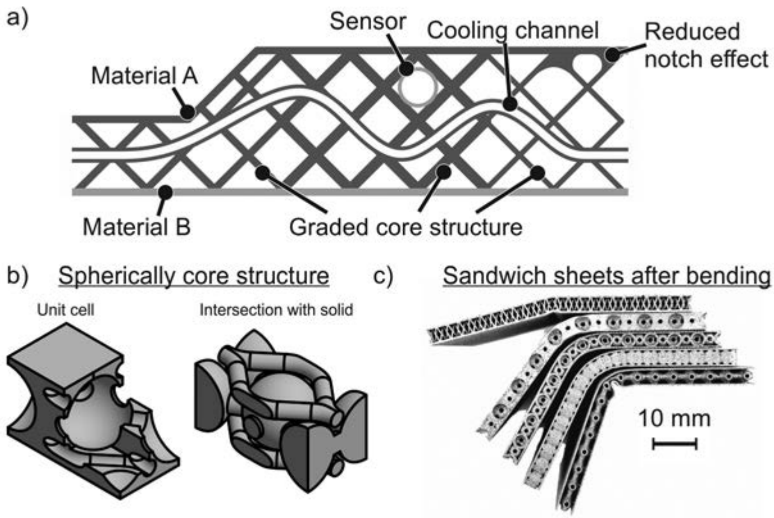


Results of a tensile test for sheets with a constant thickness made of ME20

3.4.3 Forming of Additively Manufactured Sandwich Sheet Composites with Optimized Core Structures

Funding	German Research Foundation (DFG)
Project	TE 508/63-1
Contact	Stephan Rosenthal M. Sc.

In cooperation with the Institute for Product Engineering of the University Duisburg-Essen, additively manufactured sandwich sheets with optimized core structures are developed and produced with respect to high ductility and formability, eventually aiming at the development of a combination of selective laser melting and forming technology. The figure shows the possibilities of additive manufacturing (AM). Multi-material applications, functional integration, such as complex cooling channels or integrated sensors, as well as load-adjusted graded core structures can be manufactured. With AM it is possible to combine the benefits of both processes – the flexibility and free complexity of AM plus the efficiency and productivity of forming technologies. The sandwich sheets are completely produced with SLM and show promising results in the three-point-bending test. One advantage of the aforementioned process combination is the substantial time saving of up to 50 % compared to the additive manufacturing of the final contour.



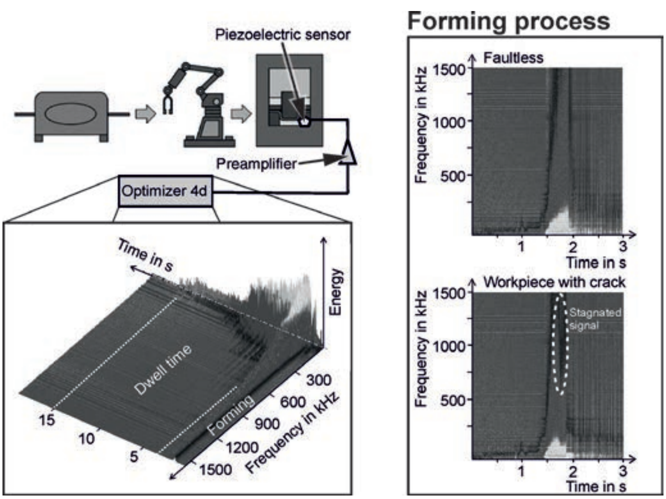
a) Schematic composition of sandwich sheets, b) Unit cell, c) Sandwich sheets after bending

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

Funding:	LeitmarktAgentur.NRW
Project:	EFRE-0800265
Contact:	Mike Kamaliev M. Sc.

In cooperation with the Qass GmbH, potentials of innovative, acoustic measurement systems as online monitoring tool for hot stamping are developed. Simultaneous unfolding of acoustic signals during the process with a Fast-Fourier-Transformation permits the analysis of frequency over time and amplitude.

The figure shows the recorded signal during the manufacturing of a demonstrator workpiece. For the characterization, potential signal sources are separated in laboratory scale experiments. The results exhibit a low frequency effect from hot forming processes while the friction at elevated temperatures produces wide-band signals which are, hence, the main component during the forming process. Furthermore, a short-time stagnate of the signal during the forming process can be considered as a passive indicator for cracks. With a low damping factor it is also possible to detect signals which arise as consequence from a microstructural phase transformation. Experiments in laboratory scale show that only the transformation to martensite and bainite leads to concise and measurable signals.

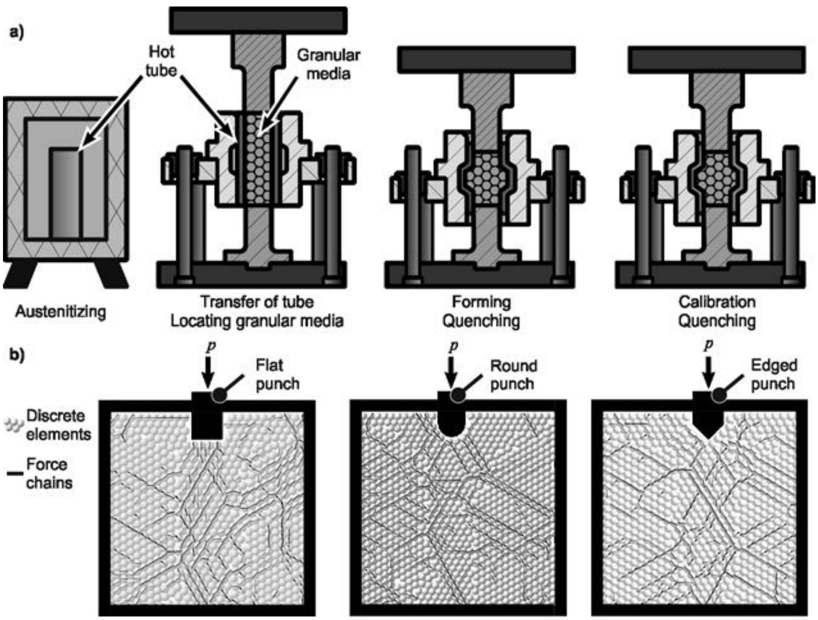


Recorded process signal during hot stamping and detailed view during the forming process of a faultless and a crack-afflicted workpiece

3.4.5 Granular Media-Based Tube Press Hardening

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

The process combination of press hardening and tube hydroforming enables the production of high-strength hollow profiles exhibiting high stiffness. Granular media are used as innovative forming media. They withstand high temperatures as well as high pressures. The pressure transfer within the media can be explained by force transmission chains between single particles. While the forces in liquids act normal to the tube walls and, therefore, the pressure is homogeneously distributed, the forces in granular media are strongly localized in force chains. These end up at single particles at the inner tube wall and generate an inhomogeneous pressure distribution. The Discrete Element Method is used to analyze the influence of the punch geometry on the force chain distribution within the granular media (see figure). The generation of many radially directed force chains as well as a low internal friction of the granular media itself ensure an effective force transmission. The project is geared to the collaboration with the German Aerospace Center (DLR) in Cologne.



a) Process scheme, b) Discrete Element Method: visualization of force transmission

3.5 Department of Bulk Metal Forming

Head Christoph Dahnke M. Sc.

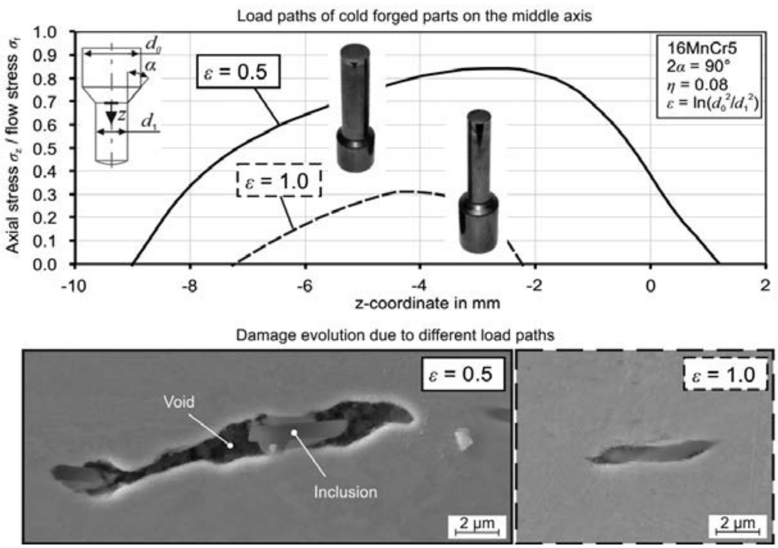
The department bulk metal forming focuses in particular on the processes hot extrusion and cold forging. The research work includes, on the one hand, the new and further development of innovative process methods and, on the other hand, fundamental research on open questions with regard to the mentioned processes. Topics in the area of fundamental research are e.g. longitudinal press seams of hot extruded aluminum profiles or the Bauschinger effect which can occur during a stress reversal in cold forging processes. With regard to new and further developments of the manufacturing processes, the production of hybrid components is a pivotal issue. By combining different materials, e.g. steel and aluminum, weight reduction as well as improvements in the local component properties can be achieved. Furthermore, continuous composite extrusion also allows the embedding of functional elements such as electrical conductors or shape memory elements. Due to the direct reuse of aluminum chips by means of hot extrusion even ecological aspects are taken into account.

Members of the department of bulk metal forming

3.5.1 Influencing the Evolution of Damage in Cold Extrusion

Funding	German Research Foundation (DFG)
Project	SFB/TRR 188 • Subproject A02
Contact	Oliver Hering M. Sc.

For the production of cold forged components, semi-finished products are used which may already exhibit material damage. This damage develops further by the cold forging process. Thus, the mechanical properties of cold forged components are the result of residual stresses, strain hardening and the resulting damage along the process chain. The aim of the subproject is to analyze, predict, and make controllable the evolution of damage in cold forging in order to allow a production of extruded components with defined, load-adapted performance. Therefore, it will be investigated to what extent the load path can be affected in cold forging and how the load path change affects the damage evolution. This will be analyzed by the example of forward rod extrusion with 16MnCrS5 semi-finished parts, damaged to varying degrees. The influence of tool geometry and process parameters like extrusion strain (see figure), shoulder opening angle, transition radii, and friction as well as the influence of different process routes on the load path and the resulting damage and product properties will be determined.

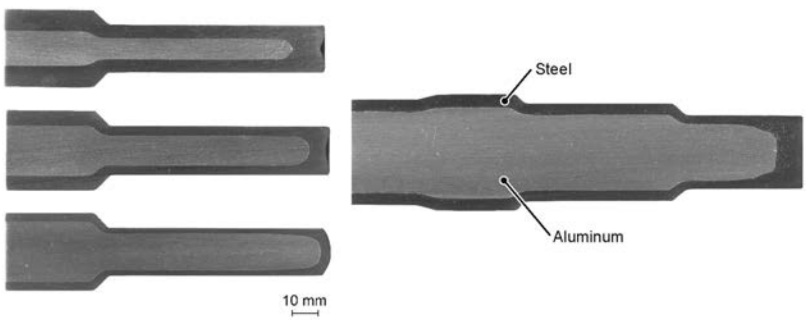


Load path due to different strains and resulting damage evolution

3.5.2 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 is the simultaneous cold forging of several semi-finished parts to one single composite component. Within the project, cups made of steel are produced by backward cup extrusion into which a light metal core, e. g. an aluminum core, is inserted. These hybrid raw parts are further processed by single- or multi-stage forward rod extrusion to composite shafts (see figure). The shafts show properties of aluminum in the core and those of steel in the sleeve. Numerically determined surface expansion and contact pressure, two relevant parameters to achieve a metallurgical bond, do not exceed certain threshold values to establish this type of bonding. By structuring the inner surfaces of the cups before inserting the cores, microform-fits can be realized by the subsequent forming of the hybrid raw parts instead. The bonding strength then exceeds the shear yield limit of the softer material, which in this case is aluminum, so that strong bonds in steel-aluminum shafts can be manufactured by this forming process.

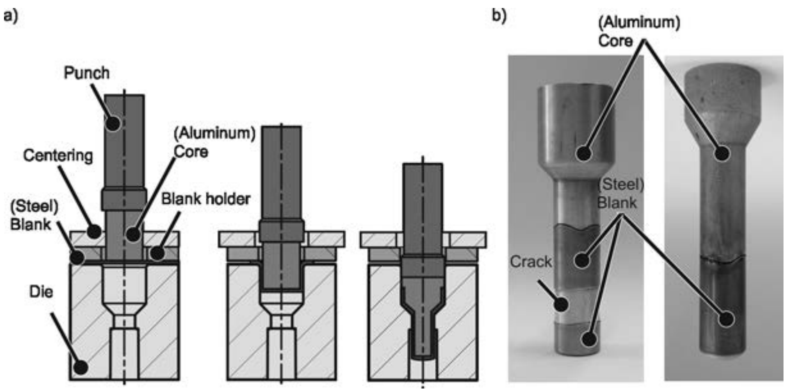


Single and multi-stepped steel-aluminum composite shafts

3.5.3 Process Combination of Combined Deep Drawing and Cold Forging

Funding German Research Foundation (DFG)
Project TE 508/61-1
Contact Oliver Napierala M. Sc.

The combination of different materials represents a possibility to adjust the local mechanical properties of a component and to reduce the weight by a suitable choice of materials. The process combination of deep drawing and cold forging, which makes it possible to produce lightweight components made of a blank and a cylindrical core, was developed and patented at the IUL. In preliminary investigations, a lightweight shaft is produced out of a steel blank and an aluminum core by deep drawing and subsequent forward rod extrusion. The conventional cold forging tool (see figure a) is supplemented by a blank holder in combination with a centering unit. The aluminum core serves as a drawing punch and pulls the blank into the extrusion die. Subsequently, the hybrid raw part is extruded to a lightweight shaft. The challenge of avoiding the cracking of the steel blank was solved by adapted deep drawing parameters and material selection (see figure b). The aim of this research is to calculate and investigate the occurring forces, stress states, and process limits analytically, numerically, and experimentally.



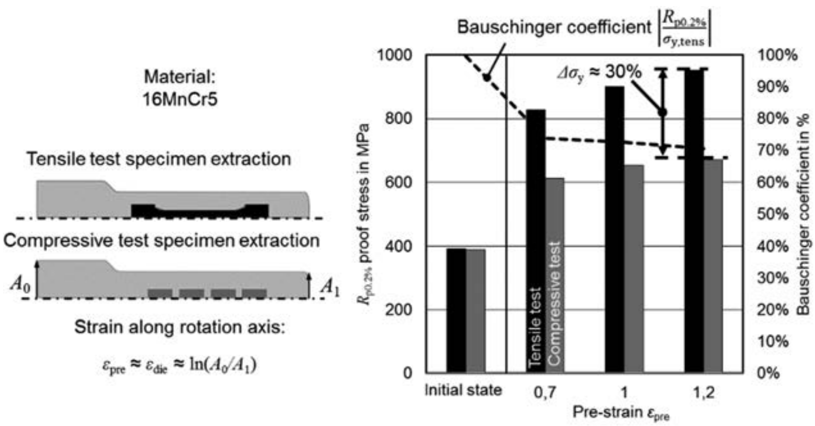
a) Process principle, b) Sample with cracked steel blank and flawless sample

3.5.4 Prediction of Local Product Properties in FEM Forming Simulations

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

The objective of this subproject of the project “Massive Lightweight Construction” was the exact prediction of local product properties of cold extruded components under consideration of the complete process chain. The subproject included the collaboration with the ISF of TU Dortmund University and the IFU of the University of Stuttgart.

In the area of cold extrusion, the forming-induced direction dependence of the local yield strength, caused by the so-called Bauschinger effect, is usually not considered. The influence of this direction dependence was proven experimentally by means of tensile and compressive tests using specimens prestrained by cold extrusion (see figure). In order to improve the numerical prediction of local product properties, various isotropic-kinematic hardening models have been evaluated. The results indicate that the consideration of kinematic hardening leads to a remarkable improvement of the prediction of local product properties, including local yield strength as well as forming-induced residual stresses.

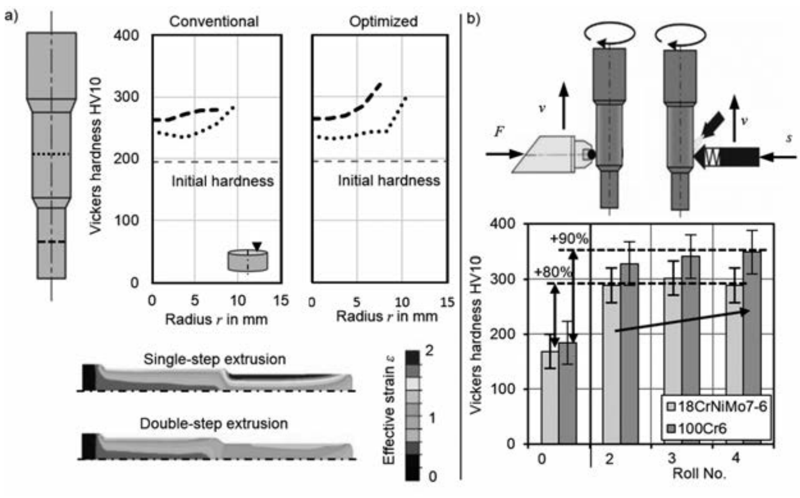


Influence of the Bauschinger effect on the local yield strength of forward extruded components

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

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

In this subproject of the project initiative "Massiver Leichtbau" the production of gear shafts by cold forging was investigated. The aim was a load-adapted downsizing by optimization of the process parameters in order to maximize the resulting surface hardness of the shafts. The research was conducted in cooperation with the IFUM Hannover and the IFU Stuttgart. By numerical variation of the process route, the tool geometry as well as the lubricant optimized parameter sets have been determined with regards to a maximization of the resulting surface strength. The generated results have been validated by means of experimental tests. It could be confirmed, e.g., that the forming process induced strains near the surface and, thus, the surface hardness can be increased by the use of single-step cold forging as compared to the conventional two-stage forging process (see figure a). Further investigations dealt with an increase of the surface hardness by means of deep rolling. Here, the investigations have shown that the surface hardness could be nearly doubled (see figure b).

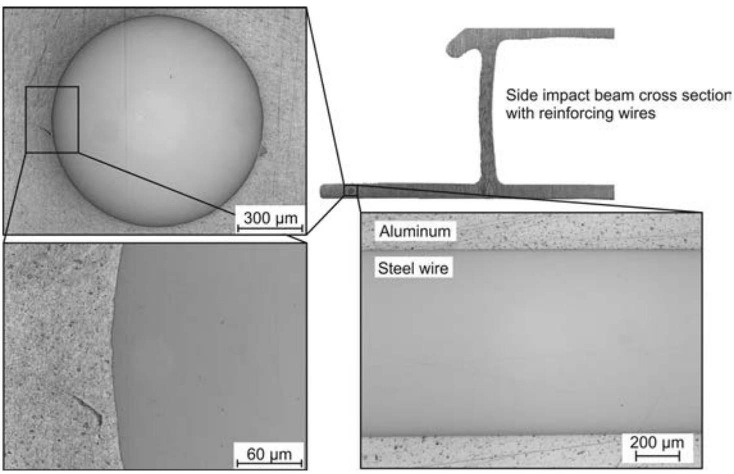


a) The influence of the process route to the degree of deformation, b) Deep rolling tool concepts

3.5.6 Production of Aluminum Profiles with Continuous Reinforcement

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

The further development of the composite extrusion process for industrial applications is investigated based on a composite side impact beam, which is reinforced with four steel wires. For the embedding of the reinforcing elements into a profile with a wall thickness of 2.5 mm, a new die concept is developed and analyzed. Based on the results of the numerical analysis, the tool was successfully tested. In the experimental investigations the wires could be embedded without any failure (see figure). Furthermore, the influence of subsequent process steps on the composite profile, such as stretching or heat treatment, is analyzed. The results show that the stretching has no negative effect on the bonding area between the reinforcements and the matrix material. With the aim of increasing the mechanical properties, the influence of different reinforcing wire materials is also investigated. Due to the different material combinations, there are differences in tensile strength and fracture strain as well as in the energy absorption capability, which is decisive for crash-relevant components.

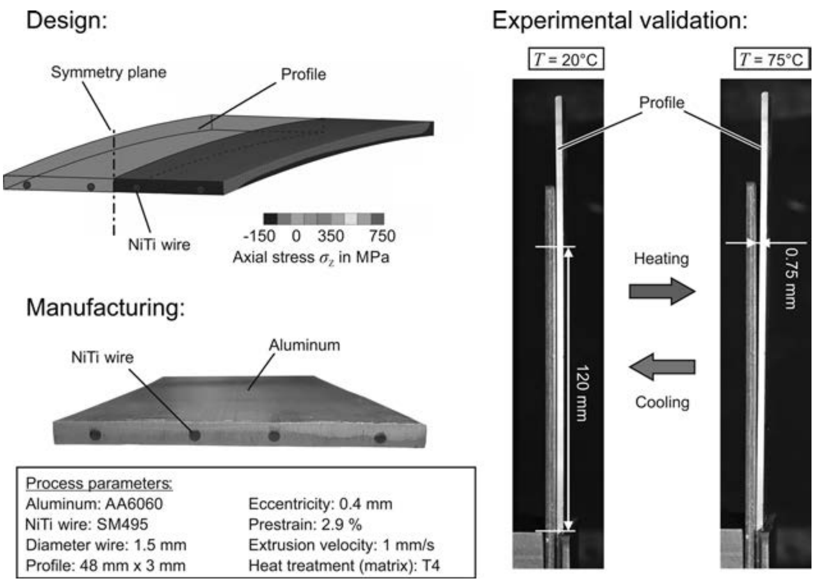


Completely embedded steel wire in longitudinal and transverse grinding after stretching

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

Funding	German Research Foundation (DFG)
Project	TE 508/45-2
Contact	Christoph Dahnke M. Sc.

Shape memory alloy wires can be continuously embedded in aluminum or magnesium profiles by means of composite extrusion. Due to the extraordinary properties of the NiTi wires, such as the shape memory effect and superelasticity, improvements of the mechanical properties of the composite can be achieved. In this project, lightweight profiles with an integrated actuator functionality are designed and tested in cooperation with the IAM-WK of Karlsruhe Institute of Technology (KIT). By means of an eccentric positioning of the wires as well as a thermomechanical treatment after the extrusion process, a bending moment is generated within the profiles. The induced force is generated by the suppression of the shape memory effect due to the material bond between wire and matrix. The aim is to design the components in such a way that the bending moment results in a purely elastic deflection of the profile. Due to this, the manufactured composite profiles have the bility of achieving different deflections depending on the temperature in repeatable cycles (see figure). For the design, analytical and numerical methods like the FEM (see figure) are used.

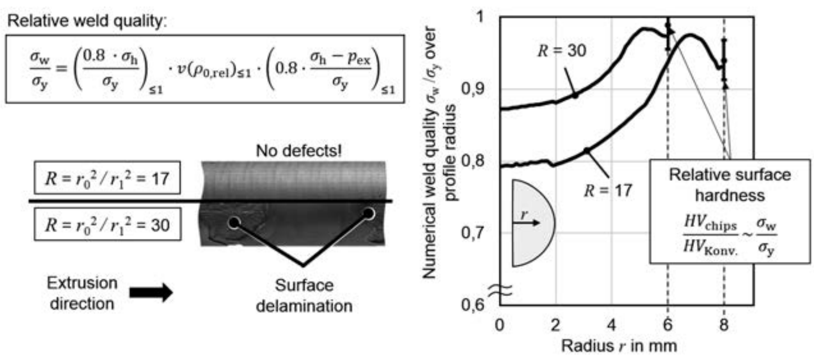


FEM-supported design, manufacturing, and experimental validation of an actuator profile

3.5.8 Analysis and Extension of the Limits of Application in Metal Forming-Based Recycling of Aluminum Chips

Funding	German Research Foundation (DFG)
Project	TE 508/60-1
Contact	Felix Kolpak M. Sc.

Direct hot extrusion of cold-compacted billets made of aluminium chips is an energy-efficient and resource-saving process for the production of semi-finished products or near net shape profiles of arbitrary complexity. In this project, the process limits of the extrusion of chip-based billets are investigated in cooperation with the WPT of TU Dortmund University.
An important part of the current research activities is the derivation of a quantitative criterion for the prediction of the local chip weld quality (see figure). In addition to the use of results from previous research projects in this field, extrusion tests are conducted using simple flat-face dies as well as complex porthole dies as a basis for a validation and modification of the proposed model. The aim is not only to predict the general process success, but also the local mechanical properties of the resulting chip-based profiles. In terms of the resulting surface hardness a good agreement between simulated and experimental results was already achieved.

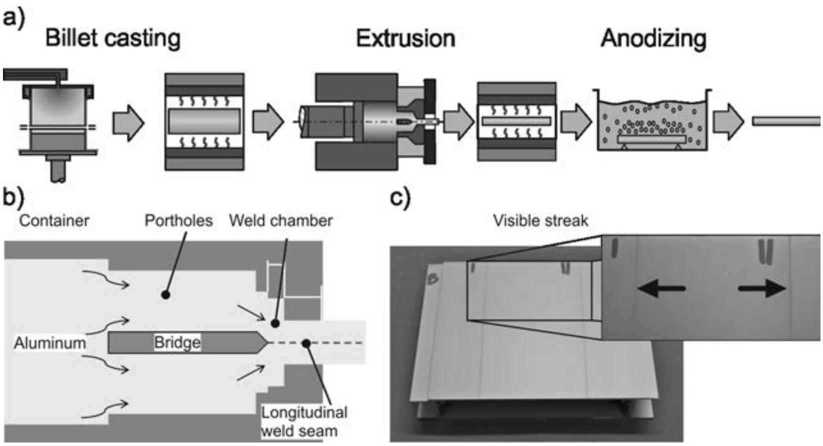


Numerical prediction of the local weld quality in hot extrusion of chip-based billets

3.5.9 Prevention of Longitudinal Weld Streak Defects on Anodized Aluminum Profiles

Funding	AiF/Stifterverband Metalle
Project	18756 N
Contact	Johannes Gebhard M. Sc.

Hot extruded and anodized aluminum profiles are widely used as visual components. A common defect is the occurrence of visible weld lines becoming apparent only after the anodization process. Aiming at a prevention of streaking effects, the whole process chain, including casting of the billet, extrusion, chilling, artificial ageing, and anodizing (see figures), will be examined within the project, since each step adds more parameters and possible interactions influencing streaking. To investigate the process under consistent conditions, hot extrusion experiments are performed at the companies involved, Hueck, Gerhardi Alutechnik, and HMT Höfer Metall Technik. An extrusion die manufactured by Wilke Werkzeugbau, designed to provoke streaking and measure temperatures close to the weld chamber, is used for the experimental application. In cooperation with the IAM-WK of Karlsruhe Institute of Technology (KIT), the profiles will be examined during every step of the process chain using light and electron microscopy. Aim of the project is the determination of guidelines for die design to prevent longitudinal weld streak defects.

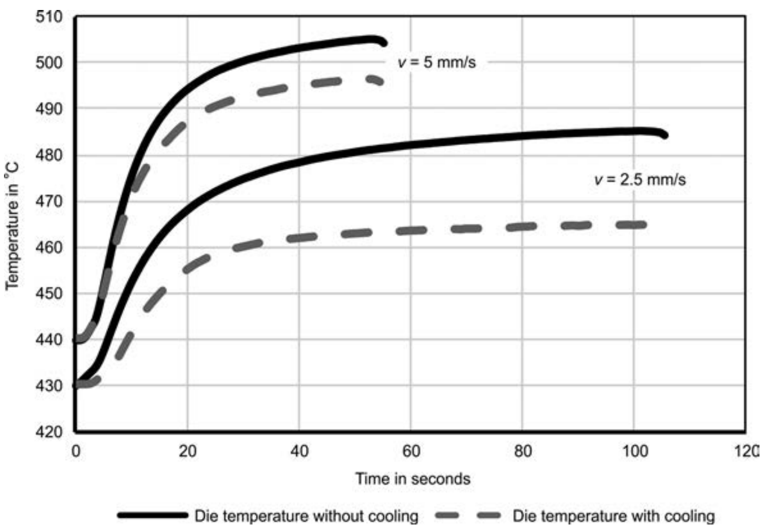


a) Process chain, b) Extrusion, c) Example of longitudinal weld seam defect

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

Funding	BMWi/ZIM-KF
Project	KF2198142KO4
Contact	André Schulze M. Sc.
Status	Completed

During the manufacturing of profiles by means of hot extrusion an increase in the extrusion speed and, thus, the productivity can be achieved by cooling of the extrusion dies. Together with the project partner WEFA Inotec GmbH, die concepts for industrial implementation were provided with cooling channels either conventionally, meaning in a substractive manner, or additively, followed by an analysis. For the production of dies, hot-tensile tests were carried out on materials which meet the requirements for thermo-mechanically high loaded extrusion dies as well as for the powder-based manufacturing. After the characterization, different die concepts were designed for different profile geometries and analyzed numerically using simulations. Based on the results of the simulations and the variation of different cooling concepts, extrusion dies were manufactured and tested in experimental trials. In dependence of the process parameters, the cooling leads to a decrease of the die temperature as well as of the profile exit temperature (see figure).

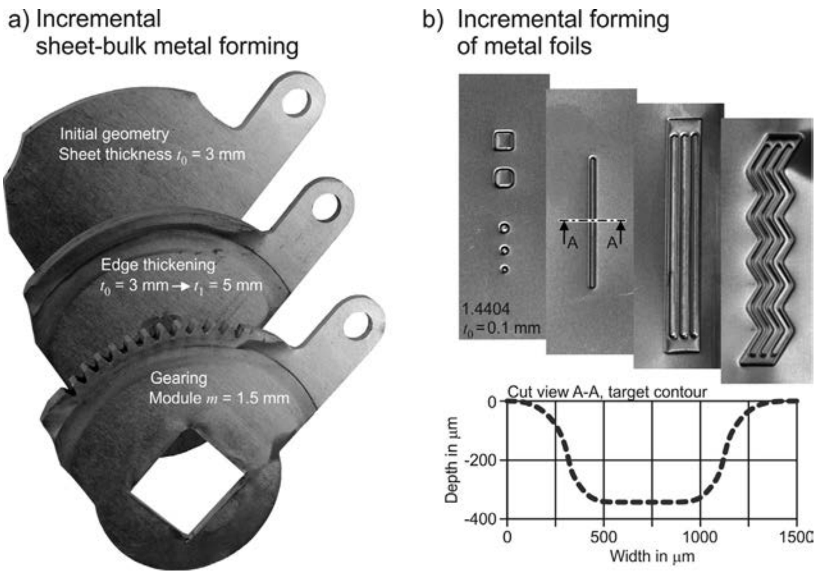


Influence of cooling on the die temperature at different extrusion speeds

3.6 Department of Non-Conventional Processes

Head Dipl.-Wirt.-Ing. Soeren Gies

Besides joining by forming and forming at high strain rates, the department of non-conventional processes focuses on incremental forming approaches. In most cases the use of incremental processes is motivated by their remarkable flexibility. In contrast to conventional processes, the workpiece geometry is not defined by the tool geometry, but by the tool trajectory. Further degrees of flexibility are the geometrical dimensions of the processed material and the formed elements.
In case of incremental sheet-bulk metal forming, the thickness of the semi-finished products ranges between 1 and 3 mm. A three-dimensional material flow is a characteristic trait for this forming technology. This facilitates the local thickening of sheet edges or the forming of gearing elements (see figure a). Within the Industrial Collective Research project 14 EWN the incremental forming technique is applied to metal foils with a thickness of 0.1 mm. By forming of filigree channel structures (see figure b), a new cost- and time-efficient prototyping approach for bipolar plates can be provided.

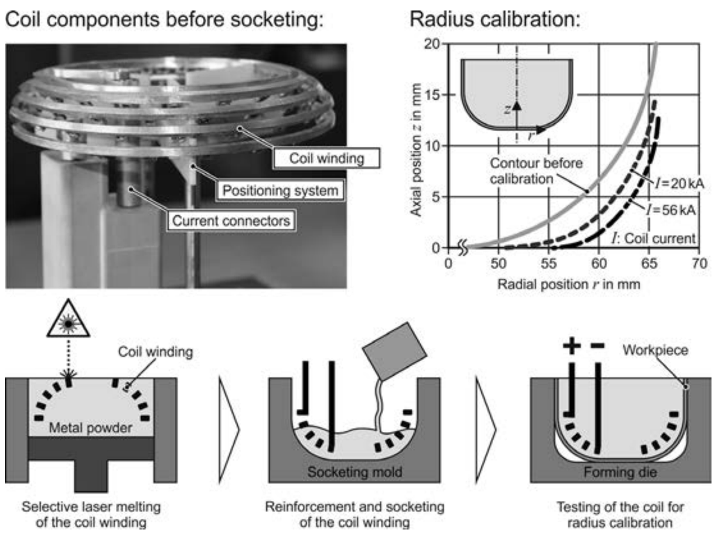


Application examples for incremental forming processes

3.6.1 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
Status	Completed

Increasing the flexibility in the production process of electromagnetic forming coils was the primary objective of the collaborative project with the Institute of Machine Tools and Factory Management of TU Berlin. The identification of processing parameters for the conductor material CuCr1Zr allowed for the manufacturing of coil windings in the selective laser melting process. Beside the increased geometrical flexibility, the process provided an additional degree of freedom when manufacturing hybrid conductors. By using a thin copper layer in combination with a steel substrate instead of a monolithic conductor made of copper, an increased efficiency of the electromagnetic forming processes could be achieved. In combination with the developed approaches for the identification of thermal coil loads the project yielded an efficient methodology for the design and manufacturing process of working coils. The final performance test of a working coil with an additively manufactured winding was performed using an electromagnetic radius calibration process of a preformed blank.

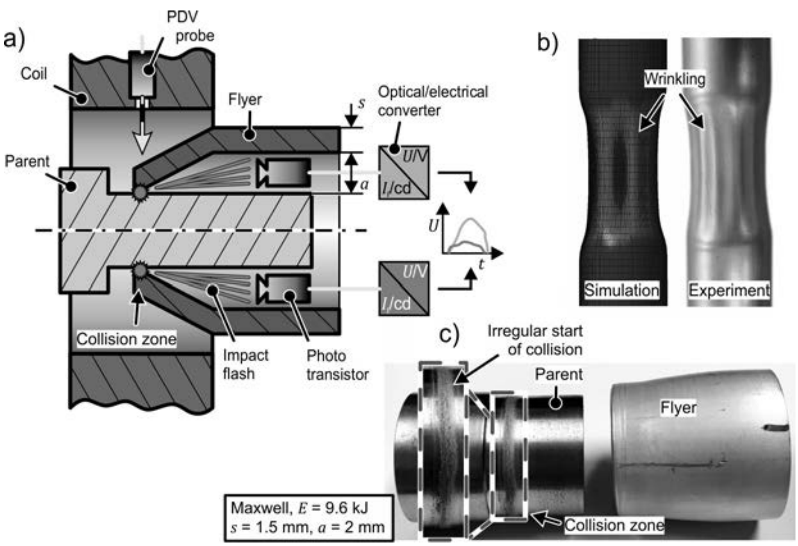


Fabrication steps and performance test of a working coil with additively manufactured winding

3.6.2 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 determination of the collision conditions is a fundamental requirement for the suitable adjustment of the weld seam formation in magnetic pulse welding (MPW) processes. In close collaboration with the Institute of Manufacturing Science and Engineering at TU Dresden, a new measurement system was further improved. This technology is based on the recording of the characteristic impact flash. Photo transistors, which are positioned near the collision zone, serve as converters and allow for the registration of the time, the intensity, and the duration of the light emission. This way, e.g. the impact velocity can be estimated. The system was verified by parallel measurements with the established PDV technique (see figure a).
Moreover, the first process phase of MPW of tubular parts, the electromagnetic compression (EMC), was analyzed regarding its effect on the joint formation. The effective strains were measured experimentally and numerically. An irregular weld formation around the circumference (see figure c) can be caused by wrinkling, a phenomenon frequently observed in EMC (see figure b).

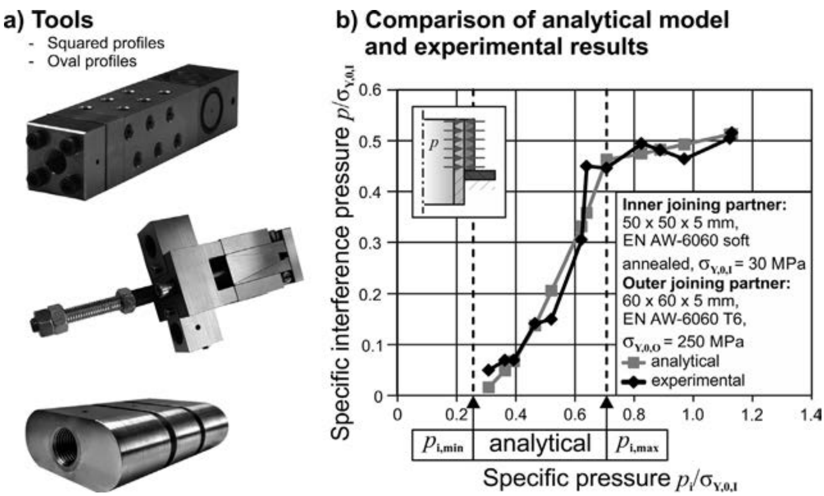


a) Recording of collision conditions, b) Simulation of EMC, c) Irregular start of collision

3.6.3 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.
Status	Completed

The aim of the project was to extend the process limits of the joining by die-less hydroforming process for joining partners with non-rotationally-symmetric cross section. Beside the development of necessary tools for squared tubes and oval profiles (see figure a), the process has been investigated experimentally and numerically. The joint formation starts when the inner joining partner is plastically deformed and if a surface contact remains after elastic recovery ($p_{i,min}$). Up from this first joint formation there is a linear relationship between the joint strength and the fluid pressure (see figure b) until plastic deformation of the outer joining partner occurs. From here ($p_{i,max}$), an increased fluid pressure does not lead to a significantly higher joint strength. To predict the fluid pressure limits ($p_{i,min}$, $p_{i,max}$) and the mean interference pressure p for squared partners, an analytical model was developed. It is based on the Euler-Bernoulli beam theory with an extension to elastic-plastic behavior. The analytical model was in good accordance with experimental results (see figure b). It allows for the calculation of the pressure limits ($p_{i,min}$, $p_{i,max}$) and of the mean interference pressure p, thus enabling a time-efficient process design.

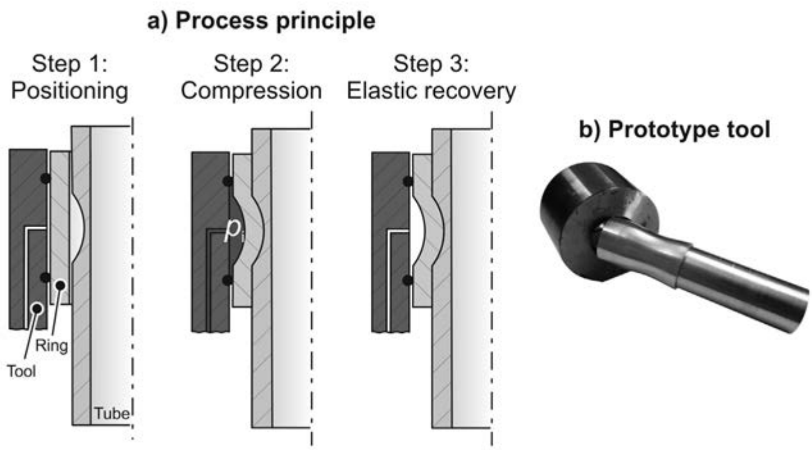


a) Developed tools, b) Comparison of analytical and experimental results

3.6.4 Joining by Die-Less Hydroforming with Outer Pressurization

Funding	German Research Foundation (DFG)
Project	TE 508/66-1
Contact	Michael Müller M. Sc.

This knowledge transfer project is based on the subproject A10 of the Collaborative Research Center Transregio 10. Its aim is to extend the limits of the joining by die-less hydroforming (DHF) process. The novelty aspect is the reversed forming direction. A radial compression by external fluid pressure is used instead of a radial expansion by internal high pressure (see figure a). Thus, the accessibility of the joining zone will be improved. The possibility of a reversed material arrangement can result in application-specific advantages in terms of mechanical, thermal, or corrosive demands. Initially, the materials are defined and tools are developed (see figure b: prototype tool). This includes the modification of the existing analytical models for the inner pressurization process and the experimental validation. Later, a transfer of knowledge is to be carried out based on joint examples derived from industrial applications. Involved industrial partners are Faurecia (Automotive GmbH and Emissions Control Technologies GmbH) and Poppe + Potthoff GmbH.

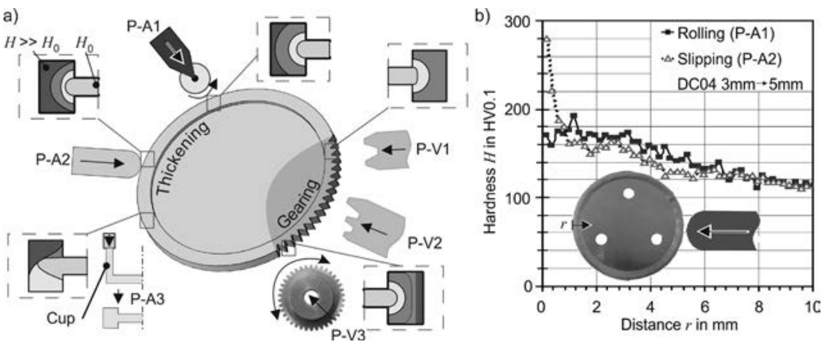


Joining by DHF with outer pressurization: a) Process principle, b) Prototype tool

3.6.5 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	Sebastian Wernicke M. Sc.

Like in the previous funding periods, the main objective of the third period is the manufacturing of geometrically complex components from sheets with integrated functional elements by forming operations. The three-dimensional material flow is characteristic for this technology and was fundamentally investigated to ensure a 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 is performed.
The aim of the current investigations is the utilization of process-dependent (P-A1 – P-A3) strain paths to manufacture semi-finished parts with an identical shape, but locally adjusted strain hardening (see figure a). In the case of the edge-thickening process, areas with high requirements on the strength can be manufactured without a subsequent hardening process. In contrast to this, subsequently geared (P-V1 – P-V3) areas can be thickened with less strain hardening which increases the tool lifetime.

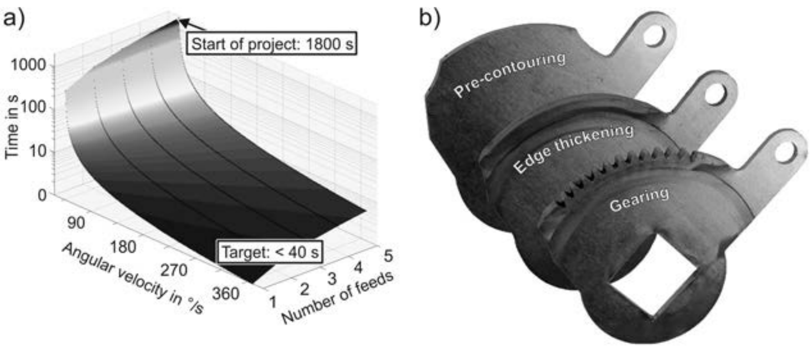


a) Processes to manufacture edge-thickened and geared semi-finished parts, b) Resulting hardness distribution

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

Funding	AiF/FOSTA
Project	18663 N/1
Contact	Dipl.-Ing. Peter Sieczkarek
Status	Completed

Aim of the project was the economic manufacturing of industrially relevant functional components by incremental sheet-bulk metal forming. The investigations focused on a defined thickening of the sheet edge followed by a subsequent gear forming operation. Beside the process acceleration, a defined setting of the strain hardening was aspired by using materials with a pronounced strain hardening characteristic. The major challenge was to investigate and control the conflict between the increased forming heat due to the process acceleration and the desired strain hardening at the gearing.
Rotationally symmetrical components, e.g. starter gears, can be produced advantageously (purely by forming) under economic cycle times by means of rotating tools (see figure a). The process combination of edge thickening and subsequent gearing allows for a weight- and load-adapted component dimensioning. Furthermore, with the rising diversity of variants a flexible and, thus, individually adaptable part design of asymmetrical functional components is possible (see figure b).

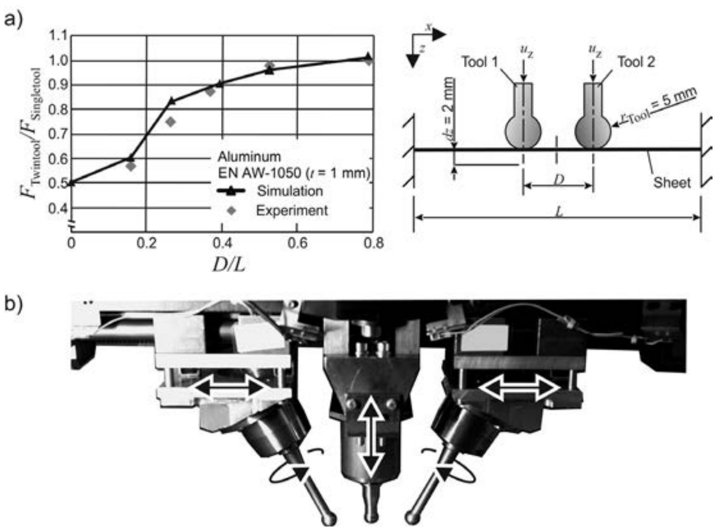


a) Influence of process parameters on cycle time, b) Asymmetric component (seat adjuster)

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

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

Decreasing the process time in incremental forming was the main objective of the research project. This was achieved by the development and implementation of the so-called Twintool, which leads to a time reduction of about 50%. Furthermore, the tool interaction was investigated. For this purpose, truncated cones were produced with the Single- and the Twintool. The results of the contour, forming forces, and strain distribution were compared. The interaction can be represented by the ratio of the forming forces as a function of the ratio of the cone diameter D and the sheet length L (see figure a). The interaction occurs especially during the forming of the first cone layer. With an increasing number of increments, the interaction decreases. Thus, the parts produced by the Single- and Twintool do not show any significant differences except for the time-saving. These findings were confirmed by the experimental tests. Based on the results, another tool concept was developed and manufactured. A third, height-adjustable tool was integrated to form different layers simultaneously (see figure b).

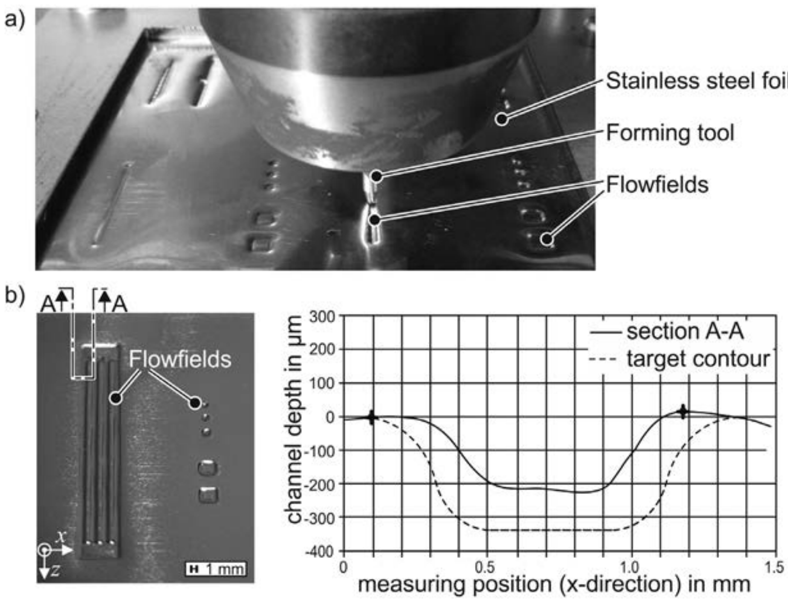


a) Effect of the tool position on the interaction, b) Extended multi-tool concept

3.6.8 Prototyping of Metallic Bipolar Plates by Means of Incremental Micro-Forming

Funding	AiF/FOSTA
Project	P 1247/IGF-Nr. 14 EWN
Contact	Dipl.-Ing. Thai Dang

A cost-effective manufacturing process for small batches of stainless steel bipolar plates (foil thickness t = 0.1 mm) will be developed in cooperation with the Hydrogen and Fuel Cell Center ZBT GmbH. For this purpose, the incremental forming process is a suitable method. In first investigations a small tool with a rollerball tip was utilized as a forming tool (see figure a). This is advantageous because the ball has a rolling motion during the forming process reducing friction effects between foil surface and tool. The experimental results have shown that the process offers great potential to form filigree structures on foils. In order to increase the contour accuracy of the flow fields (see figure b), it is necessary to redesign the size and structure of the micro-forming tool. Numerical investigations will be performed to derive a load-optimized tool design. Within the scope of these investigations the effect of the friction behavior and the tool velocity on the forming forces is analyzed.

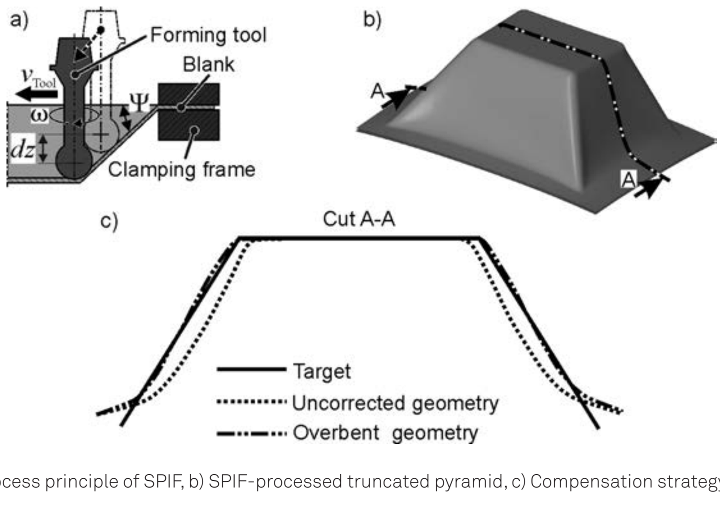


a) Incremental micro-forming process, b) Comparison of target contour and formed geometry

3.6.9 Incremental Cold Forming of Thermoplastics

Funding	German Research Foundation (DFG)
Project	TE 508/20-2
Contact	Fabian Maaß M. Sc. • Dipl.-Wirt.-Ing. Soeren Gies
Status	Completed

The main objective of the project was the production of complex parts made of thermoplastics (PVC, PE, PC) with a high geometric accuracy by the process of single point incremental forming (SPIF). Through the experimental and numerical analysis of this cold forming process the influence of the process parameters (see figure a) on the geometrical accuracy of the incremental forming process was determined. As shown in figure c), correction factors for the process design could be derived in order to compensate geometric deviations of axis-symmetrical components by local overbending. The developed compensation strategy could be transferred to increase the geometric accuracy of parts made of metal-polymer composites (Al-PE-Al). The acceptable working range of the single-stage incremental forming process is limited by high drawing angles. An analysis of the process-induced material thinning was used to develop a multi-stage incremental forming process. With this process truncated cones with a drawing angle Ψ of 85° were manufactured.

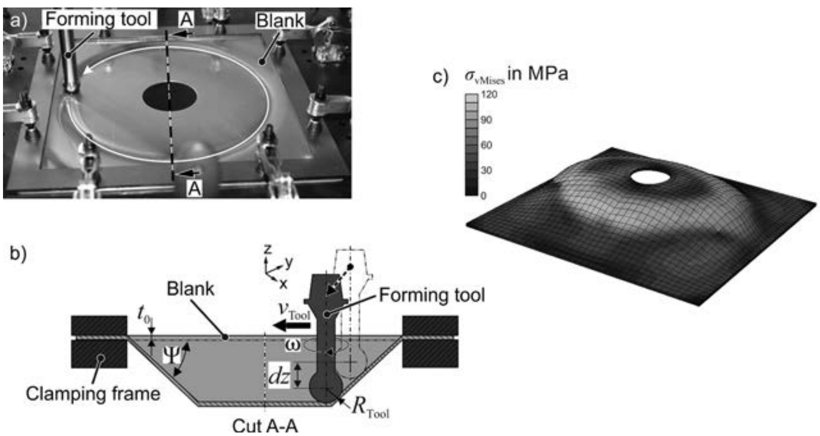


a) Process principle of SPIF, b) SPIF-processed truncated pyramid, c) Compensation strategy

3.6.10 Improvement of Product Properties by Selective Induction of Residual Stresses in Incremental Sheet Metal Forming

Funding	German Research Foundation (DFG)
Project	TE 508/67-1
Contact	Fabian Maaß M. Sc.

The residual stress state is an important influencing parameter for the operating performance of components. Within the framework of this joint project with the Institute of Materials Science and Technology of TU Berlin, the residual stress state is defined locally by the process control of single point incremental forming (SPIF) (see figure a). An aluminum wrought alloy and a duplex steel are used as materials for the investigation. Within the scope of this project, the stability of the residual stresses during the incremental forming process as well as the stability of the residual stresses during further processing and in operation are investigated. By means of a selective variation of the process parameters (see figure b), the influence of the deformation mechanisms shearing, bending, and hydrostatic pressure on the residual stress formation during the SPIF process is analyzed. In addition to the numerical analysis of the forming process (see figure c), an analysis of the residual stresses by the methods of laboratory x-ray diffraction as well as synchrotron x-ray diffraction is performed.



a) SPIF of a circular path, b) Process parameter of SPIF, c) Simulation of the residual stress state

3.6.11 Forming Technologies for Metallic and Hybrid Lightweight Structures for the Use in Electromobility

Funding	BMBF/PTKA, Promotion Platform FOREL 2
Project	02P16Z011
Contact	Marlon Hahn M. Sc.

The subproject is part of the continuation of the joint project FOREL (German abbreviation for Research and Technology Center for Resource-efficient Lightweight Structures for the Electromobility) consolidating a diverse portfolio of technology-related projects. The work contents and involved partners are given in the table below. Primary objectives of the IUL are the identification of new research topics in metal-intensive lightweight design as well as the assessment of the predictability of current simulation methods. In this context, a research study is conducted which will be published in the beginning of 2018. For this purpose, an online poll and selected expert interviews are carried out in close collaboration with the project partners. In addition, a novel parameter concept is developed which allows for an objective evaluation of the term "lightweight design". This comes along with the aim of replacing the current subjective paradigm "lightweight design means to be lighter than the previous version".

Classification	Content	Responsibility
Project control	Coordination and public relations	ILK Dresden
Technology-dominated work content	**Metal-intensive lightweight design** Joining technology Recycling- and disassembly strategies **Predictability**	**IUL Dortmund** LWF Paderborn (iwb München) IAM Freiberg **IUL** (ILK, LWF)
Analysis and synthesis	Life cycle assessment and process chain analysis Technology assessment Shared development factory	ILK (IAM) iwb ILK

Work content of the joint project

3.7 Patents

3.7.1 Published Patents

Title	Process for the Manufacturing of a Multi-Layer Sheet Metal Body
Application number	DE 10 2015 015 388 A1
Patent holder	TU Dortmund University
Status	Published June 1, 2017
Inventors	A. E. Tekkaya • S. Wernicke • P. Sieczkarek • S. Gies N. Ben Khalifa

Title	Process and Apparatus for Incremental Forming of Thin-walled Workpieces, in Particular of Sheet Metals
Application number	DE 10 2016 003 840 A1
Patent holder	TU Dortmund University • ZBT GmbH – The Fuel Cell Research Center
Status	Published October 5, 2017
Inventors	T. Dang • S. Gies • A. E. Tekkaya • L. Kühnemann M. Kouachi • P. Beckhaus

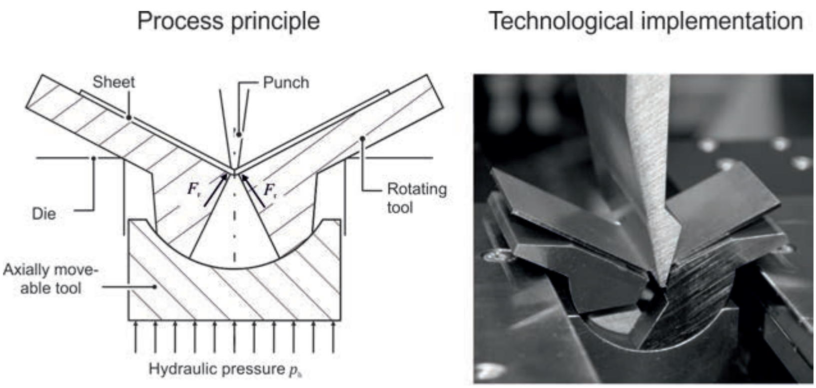
Title	Method for Producing Composite Parts by Means of a Combination of Deep Drawing and Impact Extrusion
Application number	EP 2707158 B1
Patent holder	TU Dortmund University
Status	Published November 27, 2017
Inventors	A. Jäger • S. Hänisch • S. Bröckerhoff • A. E. Tekkaya

3.7.2 Filed Patents

Apparatus and Method for Sheet Metal Bending with Compressive Stress Superposition

Application number	DE 10 2017 006 218.8
Patent applicant	TU Dortmund University
Status	Filed
Inventors	R. Meya • C. Löbbe • A. E. Tekkaya

The invention concerns a procedure and an apparatus for bending of sheet materials with the possibility of radial stress superposition during the bending operation. Particularly high strength materials are prone to failure at low bending rations. In consequence, conventional bending procedures are of limited use for the manufacture of these materials. Therefore, compressive stress superposition is applied in the bending zone. With the help of an additional axis (e.g. hydraulic cylinder) a force is applied on two rotating tools creating the stress superposition in the workpiece in the current bending zone. This stress superposition is controllable during the process so that every point on the outer fiber of the profile experiences a change in the load path. This principle is especially important for the manufacture of damage-reduced profiles because the damage evolution is delayed by influencing the load path. This results in improved product properties during use. Additionally, the stress superposition leads to a reduction in the springback.

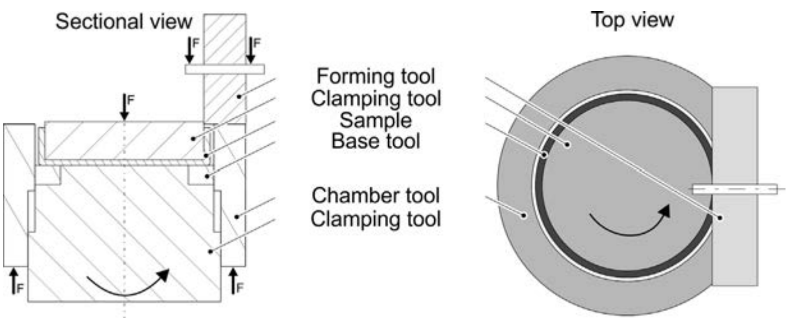


Principle of radial stress superposition and its technological implementation

Apparatus for the Incremental Manufacturing of Edge-Thickened Parts by Axial Forming of Cups or Tubes

Application number	DE 10 2017 011 441
Patent applicant	TU Dortmund University
Status	Filed
Inventors	S. Wernicke • P. Sieczkarek • S. Gies A. E. Tekkaya

By the use of sheet-bulk metal forming processes it is possible to manufacture load-adapted components with functional elements. The incremental procedure increases the flexibility of the process. This allows the manufacturing of identical geometries by using different kinematics. Changing the kinematics also causes a variation of the strain path, which allows for an adjustment of the product's mechanical properties. The invention is a further process kinematic and presents a new strain path. It allows for the axial displacement of the sheet material for a local thickening at the edge of the sheet. For this purpose, a cup or tube is clamped and a rotating, 90°-shifted forming tool moves into the direction of the cup's axis. This forming tool realizes the edge thickening as well as the axial movement of the chamber tool, which limits the radial material flow.
Unlike in existing approaches with radial feeding, the axially thickened edge presents less strain at the external diameter. As a result, the strain hardening is lower. This reduces the tool load during the subsequent gear-forming step.

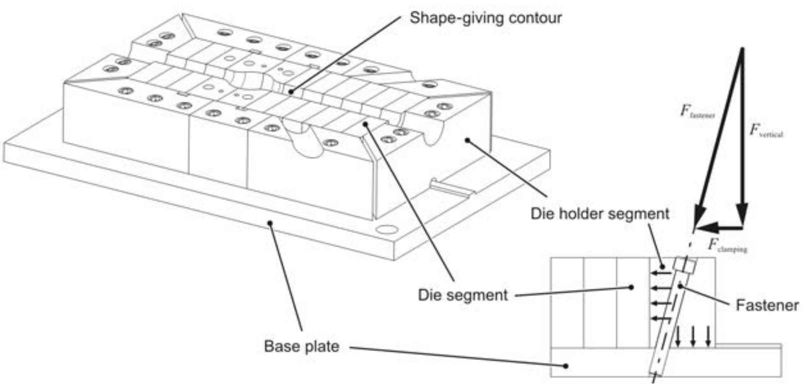


Principle for the axial edge thickening of cups

Modular Hydroforming Tool for the Flexible Adjustment of the Part Contour by Puzzle-Like Tool Elements

Application number	DE 10 2017 004 570.4
Patent applicant	TU Dortmund
Status	Filed
Inventors	D. Staupendahl • H. Dardaei Joghan • H. ul Hassan • A. E. Tekkaya

Hydroforming is a manufacturing process often applied in the automotive industry to form tubes with complex geometries. The process uses form-closed dies which need to be precisely manufactured and, depending on the size of the workpiece, can be very expensive. As the die defines the contour of the tube, new dies have to be manufactured for every contour design.
The intention of the proposed invention is to enable a flexible production of hydroforming parts with varying geometries by using a set of hydroforming dies, each defining a segment of the workpiece. The disadvantages of the modular tool designs of the state of the art are prevented by a segmented die holder which efficiently clamps the dies and can compensate tolerance variations. The tight fit between the die holder segments and the die segments is achieved by an angled positioning of the fasteners, which increases the tool stiffness and pushes the die holder segments towards the die segments. With this technology the otherwise expensive hydroforming process can be made more cost-effective and offers a cost reduction in high volume as well as in low batch production.

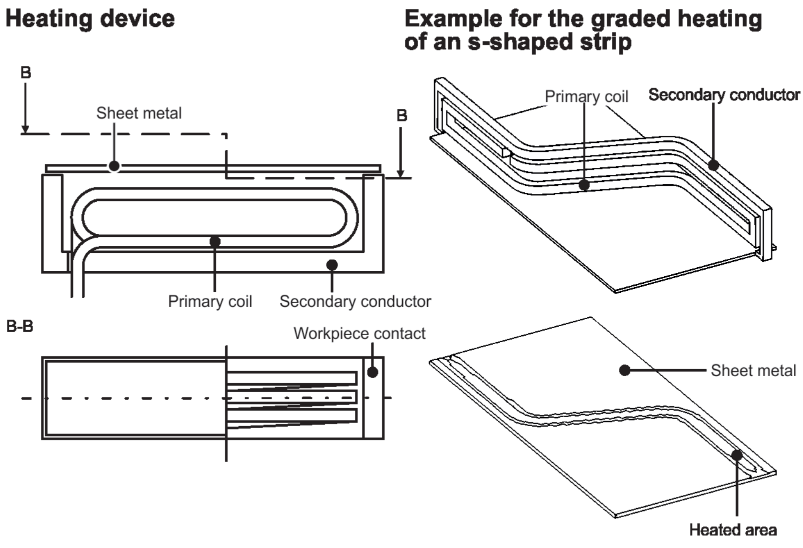


Segmented hydroforming tool concept

Device for the Electromagnetic Heating by Combining Resistance and Induction Heating

Application number	DE 10 2017 004 935.1
Patent applicant	TU Dortmund University
Status	Filed
Inventors	C. Löbbe • R. Meya • A. E. Tekkaya

The invention covers a device for the induction of an electrical current and controlled joule heating in thin-walled sheet metal or tube components. Typically, high generator frequencies are necessary for the inductive heating of thin-walled sheet metals if a longitudinal field is necessary for the uniform heating over a surface. In order to achieve a high efficiency of the heating process despite low generator frequencies and a non-pronounced skin effect, the device closes the circuit through an additional secondary conductor within the induction coil itself. The figure shows the device as well as an application example for the graded heating of an s-shaped strip.



Device and example for the heating by combined induction and resistance heating

Further Activities

04

4 Further Activities

4.1 Conferences and Meetings

In 2017, diverse 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.

International Seminar on Metal Forming on the Occasion of A. Erman Tekkaya's 60th Birthday

In honour of the 60th birthday of the head of institute Professor A. Erman Tekkaya the “International Seminar on Metal Forming” was held at the IUL on February 27, 2017, in an informal atmosphere. International experts of the forming community and industry, among them many PhD students of Professor Tekkaya, and the IUL staff met in Dortmund to congratulate the jubilarian on his birthday. Host Professor Matthias Kleiner welcomed speakers and guests in the lecture hall on the south campus of TU Dortmund University. The keynote speeches given by Professor Julian Allwood (University of Cambridge), Professor Paulo Martins (Universidade de Lisboa), and Professor Marion Merklein (LFT Erlangen) outlined a comprehensive and personal overview of Professor Tekkaya’s previous scientific achievements and gave an outlook on new challenges that forming technology will have to master in the near and further future. Former PhD students of professor Tekkaya helped preparing the speeches of the renowned scientists, which was a very special way to honor his exceptional strong commitment to both teaching and research.

Professor M. Merklein

Professor J. Allwood

The second, more informal part of the seminar took place in the IUL experimental hall with a decent musical background provided by a Jazz trio. Professor Jian Cao (Northwestern University), Professor Nils Oluf Bay (Technical University of Denmark), and Professor Karl Roll conveyed congratulations to the jubilee via video messages, which were moderated by Professor Brosius, TU Dresden. As a surprise gift after dinner the IUL staff served various homemade cheesecakes to the guest of honour for dessert.

AGU Meeting at the IUL

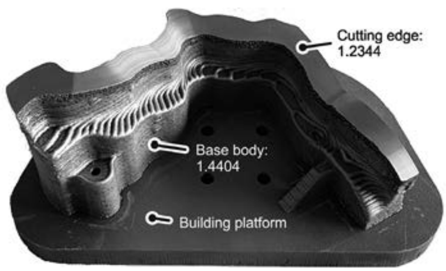
The meeting of the “Arbeitsgemeinschaft Umformtechnik” (AGU, The German Metal Forming Association) was held in Dortmund on February 28, hosted by Professor A. Erman Tekkaya. German professors of forming technology chairs and institutes belong to this association, which was founded in 1974. The association represents its field of expertise, being part of production engineering, and promotes the further development of forming technology technically and economically by using scientific methods. Since April 2016, Professor Birgit Awiszus from Chemnitz University of Technology chairs the AGU. The AGU was delighted to welcome Professor Markus Bambach (BTU Cottbus) as a new member. During the final tour of the IUL lab the institute’s current research activities were presented. The highlight was a live demonstration of additive manufacturing.

Workshop on Additive Manufacturing in Forming Technology

On April 27, 2017 a workshop on “Additive Manufacturing in Forming Technology” was hosted by the IUL. During the workshop a hybrid cutting knife was manufactured in the combination machine “Lasertec 65 3D” for additive and subtractive manufacturing which is founded by the German Research Foundation (DFG) and the federal state NRW. A part having the dimensions 193 mm x 124 mm x 78 mm (see figure), consisting of a base body made of stainless steel (1.4404) and a cutting edge made of hot working steel with a hardness of 55 HRC (1.2344), was manufactured by laser powder deposition in less than 7 hours and also machined in the clamping device of the same machine in less than 1 hour.

Group photo of the participants

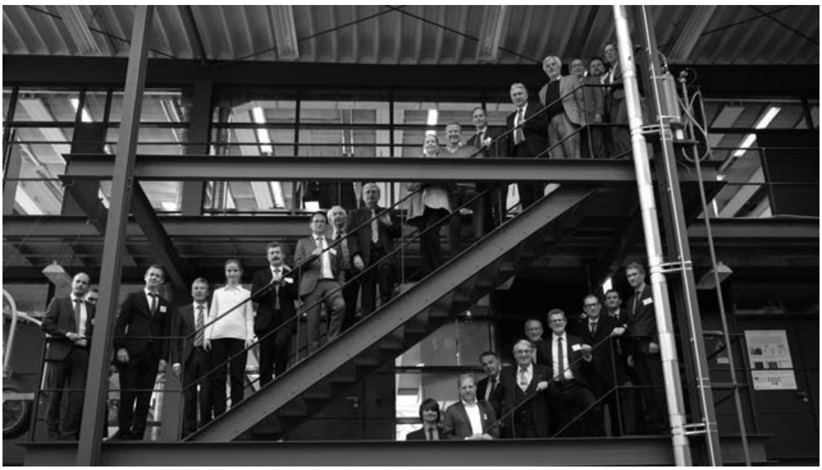
Mr. Tim Wicke gave a presentation on additive manufacturing at Volkswagen AG, Mr. Andreas Wank (GTV Verschleißschutz GmbH) held a speech on powder materials for additive manufacturing, and Mr. Heinz-Ingo Schneider from Siemens AG on CAD-CAM solutions of additive manufacturing machines. Dr. Ramona Hölker-Jäger (IUL) reported about the research project dealing with the process combination of single point incremental forming and additive manufacturing. Finally, the future and application of powder bed and powder nozzle machines was discussed and the demonstrator part, which was manufactured simultaneously to the workshop, was inspected.



Additively manufactured hybrid cutting die

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 alignment 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 of the year took place on May 5, 2017. The topics of the discussions focused especially on different drive concepts for servo presses and material characterization to predict the behavior during hot forming. The implementation of industry 4.0 in current research projects and industrial applications was another topic that was carried on in this year's second meeting on December 1, 2017, the 14th session so far. Both meetings were enriched by valuable presentations held by members of the Industrial Advisory Council.



Participants of the 13th Industrial Advisory Council Meeting

TRR 188 PhD Seminars

The TRR 188 "Damage Controlled Forming Processes" offers seminars and workshops for the professional further training of doctoral students. Doctoral researchers from research institutions participating in the TRR as well as interested non-TRR members can attend the seminars.

In the one-day or several-day events, methodological and specialist knowledge from various disciplines is imparted in the form of block lectures, talks, and practical exercises in order to strengthen the interdisciplinary exchange and mutual understanding of the departments involved in forming technology, materials sciences, materials testing technology, mechanics, and civil engineering participating in the TRR 188. The PhD seminars and workshops take place alternately at the participating research institutions and are organized by the host's principal investigators. The series of events is coordinated by the management of TRR 188.

The kick-off event took place at TU Dortmund University on June 28 and 29, 2017. It was organized by the Institute for Forming Technology and Light-weight Components (IUL) and the Chair of Numerical Methods and Information Processing (NMI) from the Department of Architecture and Civil Engineering. The topics covered were "Scientific Publishing", "Introduction to Optimization", and "Virtual Exchange Platform".

Participants of the 1st PhD seminar in Dortmund

The second series of events, which took place at RTWH Aachen University from September 6 to 8, 2017, focused on materials technology for metals and small-scale materials testing. The event was hosted by the Aachen Steel Institute (IEHK) and the Institute of Physical Metallurgy and Metal Physics (IMM) as well as the Central Facility for Electron Microscopy (GFE) of RWTH Aachen and the Max-Planck-Institut für Eisenforschung GmbH (MPIE) Düsseldorf.

This topic was continued with an "Introduction to Macro Materials Testing" as part of the 3rd PhD seminar, which again took place at the TU Dortmund University on October 12 and 13, 2017. It was organized by the Department of Materials Test Engineering (WPT) and the Institute for Forming Technology and Lightweight Components (IUL). The latter offered an "Introduction to the use of the finite element method". The events were well-liked by the doctoral students, with the number of participants ranging between 15 and 20.

IUL Excursion

The basis for innovations at IUL is a close contact to partner institutes and industry. Only in this way the needs and developments in metal forming can be fully recognized and taken into account. For this reason, the Institute of Forming Technologies and Lightweight Components organized a two-day excursion with 39 employees in September 2017. The first station was Philips Consumer Lifestyle B.V. in Drachten where a guided tour along the process chain from the raw material to the finished product during the production of shavers was offered. Subsequently, current research topics were presented and discussed based on presentations by the host and visitors. The first day ended with a collective Grachten cruise through the canals of Amsterdam, including dinner aboard. On the second day, the group visited the factory site of the steel company Tata Steel in IJmuiden. An insight into the strip galvanizing plant and the research and development center was given. Finally, the IUL group was welcomed by the Chair of Non-linear Solid Mechanics of Professor van den Boogaard at the University of Twente in Enschede. A lively exchange between the scientists developed on current research topics based on presentations and a guided tour through the laboratory.

Group photo of the IUL employees at Tata Steel in IJmuiden

Furthermore, the IUL participated in the following events in 2017, some of which were also open to a non-scientific audience of different target groups:

• Student competition “Stahl fliegt” (Flying steel) • July 5 – 6
• SchnupperUni • August 24
• Open Day of TU Dortmund University • November 11
• MinTU • November 17

4.2 Awards

EFB Project Prize 2017

The European Research Association for Sheet Metal Working (EFB) awarded the “EFB Project Prize 2017” to Mr. Heinrich Traphöner, an employee of the Institute of Forming Technology and Lightweight Components, and Mr. Martin Rosenschon of the Institute of Manufacturing Technology at Friedrich-Alexander-Universität Erlangen-Nürnberg for the work on the joint EFB project “Identification of stress-dependent Bauschinger coefficients”.

The EFB project prize is awarded for the top rated EFB research projects of the previous year. It addresses young scientists who have worked on and completed an EFB project in the field of sheet metal processing both scientifically and organizationally in an outstanding way. The award was handed over in Fellbach during the EFB colloquium on March 28, 2017.

Award ceremony of the EFB project prize 2017; from left to right: Heinrich Traphöner, Martin Rosenschon, Wilfried Jakob (EFB President)

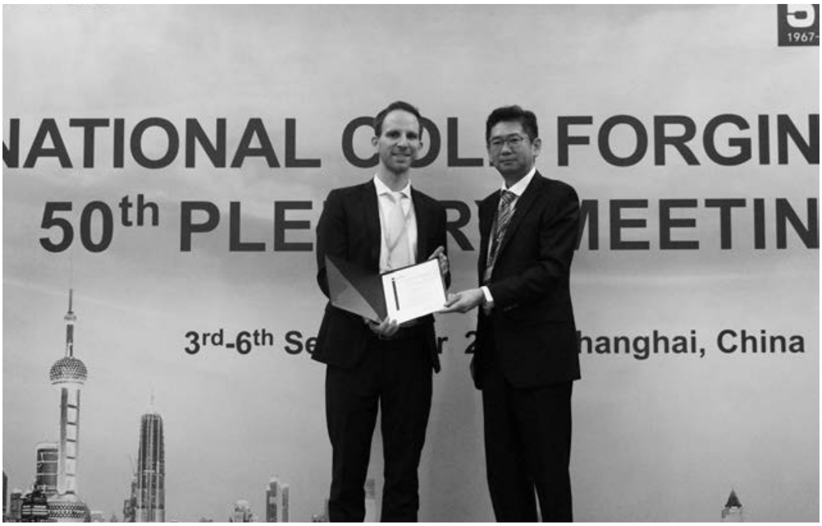
"Best Paper Prize" ICEB 2017

During the "International Conference on Extrusion and Benchmark" (ICEB 2017), which took place this year together with the conference "Aluminium 2000" from June 20 to 24 in Verona/Italy, Mr. André Schulze was awarded the "Best Paper Prize" in the category "Extrusion" for his publication entitled "Developments in composite extrusion of complex profiles for automotive applications". In his paper and presentation Mr. Schulze showed the results of the industrial implementation of the composite extrusion process. The aim of the work is to realize and evaluate the design of dies and profiles for the composite extrusion process under industrial conditions.

Award ceremony during the gala dinner; from left to right: Dr. Walter Dalla Barba (Italtecno/Inter-all), André Schulze (IUL), and Prof. Luca Tomesani (University of Bologna)

ICFG International Prize 2017

At the 50th Plenary Meeting of the International Cold Forging Group (ICFG) Mr. Stefan Ossenkemper, member of the Bulk Metal Forming Department, was honored with the “ICFG International Prize 2017” for his paper on steel-aluminum-composite shafts. Since 1998 the “ICFG International Prize” is awarded to young scientists for outstanding scientific contributions in the field of cold forging. The conference took place in Shanghai from September 3 to 6, 2017. Following the award ceremony, Mr. Ossenkemper gave an insight into his research topic by a 20-minute presentation to the approximately one hundred attendees.



Award ceremony “ICFG International Prize 2017”

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 "National 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

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.
- Beihang University, Beijing
- 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, Daejeon
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- North Carolina State University
- RWTH Aachen University
- Steel Institute VDEh
- TED University, Ankara
- The Royal Society, London
- University of Cambridge
- University of Georgia, College of Engineering, Athens
- 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 Computations

- Engineering with Computers
- HTM Journal of Heat Treatment and Materials
- 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 (Chair)
- Open Science Policy Platform
- STS Council and Board – STS-Forum Science and Technology in Society, Japan
- Member of the Supervisory Board Futurium gGmbH (Vice-chair)
- 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
- 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 Grou

Senat Memberships

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

International Exchange

05

5 International Exchange

Satoshi Sumikawa M. Eng.

Mr. Satoshi Sumikawa, a senior researcher from JFE Steel Corporation in Japan, worked at the IUL in the Department of Applied Mechanics in Forming Technologies as a visiting researcher for two years (from October 2015 until September 2017). His research topic was the "Effect of stress-state dependency of unloading behavior on springback prediction". During his stay, he investigated the unloading behavior for high-strength steel and aluminum alloys in different material tests such as bulge tests, plane-strain tension tests, and in-plane torsion tests. Based on these experiments, he determined the impact of the observed unloading behavior under various stress states on the springback prediction by finite element analyses. He presented his results at international conferences, among them the prestigious 12th International Conference on Technology of Plasticity (ICTP) 2017 in Cambridge. His works will also contribute to his PhD thesis at Hiroshima University, supervised by Professor Fusahito Yoshida.

Satoshi Sumikawa (3. from left) taking part in an excursion to the Netherlands

RISE (Research Internships in Science and Engineering) – Logan Gable

In 2017, the IUL has once again taken part in the "RISE" program offered by the German Academic Exchange Service (DAAD). From May until August, Logan Gable from Ohio State University visited TU Dortmund University.
The RISE program gives British and North American students the opportunity to intern at German research facilities. Mr. Gable's visit was financed by a scholarship defrayed by the DAAD and the Collaborative Research Center

Transregio 73 of the DFG. Supervised by Peter Sieczkarek and Sebastian Wernicke, Mr. Gable was engaged in the technology of incremental sheet-bulk metal forming and in this context especially the incremental gear forming process. His activities included the extension of the process control by an in-situ geometry measurement.

RISE exchange student Logan Gable in front of the five-axis forming press for incremental sheet-bulk metal forming operations

REACH Program – Nonravee Benjapibal

From June until August 2017, Nonravee Benjapibal, from Princeton University in New Jersey, USA, visited TU Dortmund University. Under the supervision of Christian Löbbe and Rickmer Meya, Ms. Benjapibal supported research conducted on bending technology. Her activities included programming in Matlab in order to determine the curvature of a bent component based on measured x-y-coordinates. These coordinates were acquired, for instance, through tactile or optical measurements. The bending tests were also conducted with different bending ratios as well as at various temperatures and strain rates. Moreover, Ms. Benjapibal programmed a LabVIEW program which allows for an automated analysis of microstructural images from the scanning electron microscope with regard to pores. The program indicates the location of the detected damage (pores) as well as the relative area covered by the pores.

Exchange with The Ohio State University

In the summer of 2017, the student exchange program between the IUL and Ohio State University (OSU) took place for the first time. From 2017 until 2019, the project "Forming and manufacturing of lightweight high-performance components – International Research Experiences for Students at the TU Dortmund University", funded by the National Science Foundation, enables up to five OSU students each summer to stay and conduct research in Dortmund. The program is open for undergraduate, graduate, and PhD students. The guest students will be involved in the current research tasks at the IUL and each of them will be supervised by IUL scientists working on the same project. During the first run in 2017, three OSU students participated:

Bhuvi Nirudhoddi

Ms. Bhudi Nirudhoddi holds a bachelor degree in aerospace engineering from Purdue University and a master degree in material science and engineering. Since 2015, she is doing her PhD as part of Professor Glenn Daehn's group on "Lightweight Innovations for Tomorrow". During her guest stay from June until August 2017 she was supervised by Michael Müller. She was engaged in the preliminary analysis for joining of additively manufactured components. In this context, she used simulations and conducted experiments as well.

Steven R. Hansen

Mr. Hansen studied chemistry at Mount Vernon Nazarene University and holds a master degree in material science and engineering from OSU. As a PhD student in Professor Glenn Daehn's research group, he focuses on high-speed forming technology. Within the scope of his stay at the IUL from June until August 2017, he conducted experiments for his work on vaporizing foils. For this purpose, he used equipment of the IUL that is not available at the OSU. Mr. Hansen was supervised by Marlon Hahn who is scientifically involved in the same field of research.

Jonathan Morrison

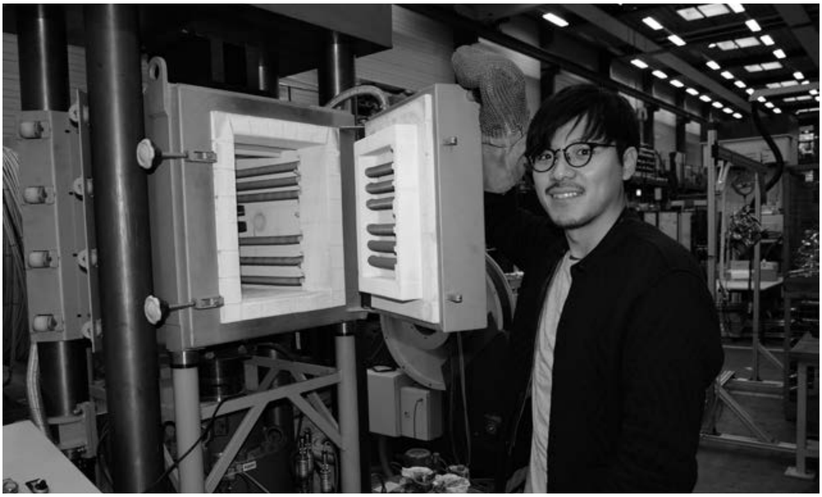
Mr. Morrison is an undergraduate student who is currently enrolled in the material sciences and engineering program at OSU. From June until August 2017, he worked under the supervision of Alexander Schowtjak on the implementation of a software to combine FEM and digital image correlation analysis. In this context, a script for parameter identification was developed and tested. The results will be incorporated in the TRR 188.

Besides the excellent research work at IUL, all three students used the weekends to get to know Dortmund and other parts of Europe. During an excursion to the thyssenkrupp steel plant in Duisburg and the coal mine Zeche Zollverein in Essen, they also met other American exchange students, an MMT student, and employees of the IUL and received an interesting impression of the Ruhr area. The exchange program was concluded by a collective visit of the Signal Iduna Park stadium on the occasion of the Supercup match Borussia Dortmund vs. FC Bayern Munich.

The group at thyssenkrupp

G-CADET International Exchange Program with Gifu University

Japan is among the world leaders in the areas of materials science as well as metal forming research. In order to strengthen the international cooperation in engineering sciences, a cooperation agreement was established between TU Dortmund University and Gifu University (Japan). In this context, an exchange program for excellent students from the Faculty of Engineering (Gifu University) and from the Faculty of Mechanical Engineering (TU Dortmund University) was initiated. Under the supervision of Christoph Dahnke, Mr. Ryosuke Shimaji was an active part of the department of bulk metal forming at IUL from November 2017 until January 2018. During this time he did research in the field of material characterization at elevated temperatures. For this, he used a special compression press allowing for the implementation of hot compressive tests. He uses these experimental data for parameter fitting of models used in FEM forming simulations.



G-CADET exchange student Ryosuke Shimaji in front of the hot compression press

Technical Equipment

06

6 Technical Equipment

Experimental Area

Presses

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

Further Forming Machines

- DMU 50 – 5-Axis-milling maschine, DMG Mori
- Hydraulic punching machine TruPunch 5000, 220 kN, TRUMPF Werkzeugmaschinen GmbH & Co. KG
- Machine for electromagnetic forming, 1,5 kJ, PPT SMU 1500
- Machine for electromagnetic forming, 32 kJ, Maxwell Magneform 7000
- Machine for electromagnetic forming, 6 kJ, Poynting SMU 0612 FS
- Machine for Incremental Profile Forming
- Machine for Incremental Tube Forming, IRU2590, transfluid Maschinenbau GmbH
- Multi-axes forming press TR 73, 100 kN, prototype with five axes of motion (Schnupp Hydraulik)
- Press brake, 1300 kN, TrumaBend V 1300X
- 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
- Swivel bending machine, FASTI 2095
- Three-roll bending machine, Irle B70 MM
- Three-roll bending machine, Roundo R-2-S Special
- Three-roller bending machine, FASTI RZM 108-10/5.5

Additive Manufacturing Machines

- Combined 5-axis-machining and laser deposition welding center Lasertec 65 3D, Sauer GmbH/DMG MORI
- Powder bed machine for additive manufacturing DMG MORI "Lasertec 30 SLM"

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
- Plastometer, IUL 1 MN
- Sheet metal testing machine Zwick BUP1000
- Zwick Roell Z250 universal testing machine

Measurement Technique and Electronics

- 3D-coordinate measurement machine, Zeiss PRISMO VAST 5 HTG (in cooperation with the "Institut für Spanende Fertigung", TU Dortmund University)
- 3D-video measuring system, Optomess A250
- 3MA-II Measurement System
- 4-channel-digital-oscilloscope, Tektronix TDS 420A
- ARAMIS 4M, GOM, optical 3D-deforming analysis
- GOM Aramis 4M Optical 3D deformation analyser
- GOM ATOS Triple Scan - 3D scanner
- GOM: Argus, Atos, Tritop, 3 x Aramis – optical measuring systems for geometry and strains

- Hardness testing device, Wolpert Diatestor 2 RC/S
- High-speed camera, HSFC pro of the company PCO Computer Optics GmbH
- Infrared Camera, Infratec VarioCam HD head 680 S / 30 mm, Resolution 1280 x 960 Pixel
- Infrared measuring device, PYROSKOP 273 C
- Keyence Laser: non-contact distance measurement
- Large volume SEM, Mira XI by Visitec (in cooperation with the "Institut für Spanende Fertigung" and "Lehrstuhl für Werkstofftechnologie", TU Dortmund University)
- Laser-based Photon-Doppler Velocimeter for the measurement of high workpiece velocities
- Laser Surface Velocimeter (LSV): non-contact velocity measurement
- Light optical microscope AxioImager.M1m adapted for polarization, Zeiss AG
- Multi-wavelength pyrometer, Williamson pro 100 series
- Optical frequency domain reflectometer ODiSI-B10 from Luna Technologies. System for the space- and time-resolved measurement of temperature and strain
- Pontos 4M, GOM, dynamic 3D analysis, solution 2358 x 1728 pixel
- Prism - Residual stress measurement based on hole-drilling and ESPI
- Residual stress measurement devices using borehole method
  - Air-abrasive procedure
  - High-speed procedure
- Stresstech PrismS – for the measurement of residual stresses
- Thickness measuring device, Krautkrämer CL 304
- X-ray diffractometer for measuring residual stresses – StressTech Xstress 3000

Miscellaneous

- Belt grinding machine, Baier PB-1200-100S
- Borehole device, Milling Guide RS 200
- different machines for machining purposes
- Etching and polishing station – LectoPol-5, Struers GmbH
- High-performance metal circular saw, Häberle AL 380
- Hydraulic power units and pressure intensifiers up to 4000 bar (3 x)

- Hydrostatic roller burnishing tool, Ecoroll, HG13 and HG6
- Industrial robot KUKA KR 30-3
- Industrial robot KUKA-KR 5 sixx R650, 6-axes robot
- Laser processing center, Trumpf LASERCELL TLC 1005
- Measuring rack, Boxdorf HP-4-2082
- Plastic injection molding machine, Arburg Allrounder 270 C 400-100
- Roll seam welding machine, Elektro-Schweißtechnik Dresden UN 63 pn
- Specimen blanking machine 1200 kN
- Specimen grinding machine for tension specimen
- Turning machine, Weiler Condor VS2

Kooperationen | Cooperations

07

Kooperationen | Cooperations

Auf diesem Wege möchten wir uns für die vielfältige Zusammenarbeit im Jahr 2017 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 2017 which have added to our joint success.

Industriebeirat des IUL | IUL Industrial Advisory Board

Das Gremium des Industriebeirates vermittelte auch im Jahr 2017 wichtige Impulse hinsichtlich des industriellen Forschungsbedarfes. An dieser Stelle möchten wir uns für diese wertvolle Zusammenarbeit bedanken.

In 2017, 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.
- Rainer Hank, TRUMPF Werkzeugmaschinen GmbH & Co. KG
- 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. Lukas Kwiatkowski, Otto Fuchs KG
- Prof. Gideon Levy, TTA – Technology Turn Around
- Hans Mulder, Tata Steel Research & Development Product Application Centre
- 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 Presswerk
- Prof. Karl Schweizerhof, DYNAmore GmbH
- Dr. Hosen Sulaiman, Faurecia Autositze GmbH
- Sabine Widdermann, Industrieverband Massivumformung e. V.
- Dr. Hans-Joachim Wieland, Forschungsvereinigung Stahlanwendung e. V.

Universitäre Kooperationen auf nationaler Ebene | University cooperations at national level

- Chair of Micromechanical and Macroscopic Modelling, ICAMS, Ruhr-Universität Bochum
- Fach Numerische Methoden und Informationsverarbeitung, Technische Universität Dortmund
- Fachbereich Produktionstechnik, Universität Bremen
- Fachgebiet Maschinenelemente, Technische Universität Dortmund
- Fachgebiet Werkstoffprüftechnik, Technische Universität Dortmund
- Fachhochschule 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 am Dortmunder OberflächenCentrum (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 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 Mechanik, Technische Universität Dortmund
- 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 Spanende Fertigung, Technische Universität Dortmund
- Institut für Umformtechnik und Umformmaschinen, Leibniz Universität Hannover

- Institut für Umformtechnik, Universität Stuttgart
- Institut für Verbrennung und Gasdynamik – Reaktive Fluide, Universität Duisburg-Essen
- 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 & An-Institut für Unternehmenskybernetik e. V.), Rheinisch-Westfälische Hochschule Aachen
- Labor für Fahrwerktechnik, Hochschule Osnabrück
- Laboratorium für Werkstoff- und Fügetechnik, Universität Paderborn
- Lehrstuhl Fertigungstechnik, Universität Duisburg-Essen
- Lehrstuhl für Fertigungstechnologie, Friedrich-Alexander-Universität Erlangen-Nürnberg
- Lehrstuhl für Feststoffverfahrenstechnik, Ruhr-Universität Bochum
- Lehrstuhl für Konstruktion und Fertigung, Brandenburgische Technische Universität Cottbus-Senftenberg
- 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 Werkstofftechnologie, Technische Universität Dortmund
- Lehrstuhl Werkstoffwissenschaft, Ruhr-Universität Bochum
- 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
- Zentrum für HochschulBildung, zhb, Technische Universität Dortmund

Universitäre Kooperationen auf internationaler Ebene | University cooperations at international level

- Department of Materials Science and Engineering, The Ohio State University, Ohio, USA
- Department of Mechanical Engineering, Gifu University, Yanagido, Japan
- Department of Mechanical Engineering, Instituto Superior Técnico, University of Lisbon, Portugal
- Department of Mechanical Engineering, Section of Manufacturing Engineering, Technical University of Denmark, 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
- 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 Microstructure Studies and Mechanics of Materials, Arts et Métiers ParisTech (Metz Campus), France
- Loewy Chair in Materials Forming and Processing, Lehigh University, Bethlehem, Pennsylvania, USA
- Mechanical Engineering College of Tongji University, Jiading Campus, Shanghai, P. R. China
- Nagoya University, Nagoya, Japan
- School of Mechatronics Engineering, Harbin Institute of Technology, Harbin, Heilongjiang, P. R. China
- Türkisch-Deutsche Universität, Istanbul, Turkey

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
- Apparatebau M. Becker
- ASCAMM Technology Centre
- ASERM – Asociación Española de Rapid Manufacturing
- AUDI AG
- Auerhammer Metallwerk GmbH
- AutoForm Engineering GmbH
- Benteler International AG
- Bilstein GmbH & Co. KG
- BMW AG
- BÖHLER-UDDEHOLM Deutschland GmbH
- borit Leichtbau-Technik GmbH
- CARL BECHEM GMBH
- CRF – Centro Ricerche Fiat S.C.p.A.
- C-TEC Constellium Technology Center
- Daimler AG
- Danieli Germany GmbH
- 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 Corporation, 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
- JFE Steel Corporation, Japan
- Johnson Controls Hilchenbach GmbH
- Kirchhoff Automotive GmbH
- Kistler Instrumente AG
- KODA Stanz- und Biegetechnik GmbH
- KraussMaffei Group GmbH

- Kunststoff-Institut Lüdenscheid GmbH
- LEIBER Group GmbH & Co. KG
- LG Corporation
- 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 Precision GmbH
- Schnupp GmbH & Co. Hydraulik KG
- Schondelmaier GmbH Presswerk
- Schuler AG
- Schwarze-Robitec GmbH
- simufact engineering gmbh
- SIMUFORM Search Solutions GmbH
- SMS Meer GmbH
- Société Tunisienne des filtres (MISFAT), Jedeida, Tunesia
- Sparkasse Dortmund
- SSAB Swedish Steel GmbH
- SSAB Tunnplåt AB, Sweden
- Tata Steel
- TECOS – Slovenian Tool and Die Development Centre
- 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.
- I^2FG – 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 Stanz-Technologie 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]

Brambrink, Mario
Tekkaya, A. E. • Wernicke, S.
Parameterstudie zur Herstellung eigenschaftsangepasster hybrider Funktionsbauteile mittels inkrementeller Blech-massivumformung
Parameter study for the production of property-adapted hybrid functional components produced by incremental sheet-bulk metal forming

Dahm, Moritz
Tekkaya, A. E. • Müller, M.
Experimentelle sowie simulative Untersuchung für das Innenhochdruckfügen von Ovalrohren
Experimental and numerical investigations of the joining by die-less hydroforming process for profiles with oval cross section

D'Souza, Loreen Jovita
Tekkaya, A. E. • Dardaei, H.
Experimentelle und numerische Untersuchung des Einflusses von Reibung auf die nichtlineare Dickenverteilung im IHU
Experimental and numerical investigation of the effect of friction on the non linear thickness distribution in tube hydroforming

Gebhard, Johannes
Tekkaya, A. E. • Clausmeyer, T. • Staupendahl, D.
Entwicklung und Erprobung einer Biegevorrichtung mit einstellbarem Biegewinkel und -radius
Development and experimental evaluation of a bending device with adjustable bending radius and bending angle

Han, Ziqi
Tekkaya, A. E. • Clausmeyer, T. • Traphöner, H.
Numerische und experimentelle Analyse der Werkstoffcharakterisierung von Rohren mit dem ebenen Torsionsversuch
Numerical and experimental analysis of the characterization of tubular specimens in the in-plane torsion test

Hijazi, Dina
Tekkaya, A. E. • Staupendahl, D. • Traphöner, H.
Experimentelle Untersuchung der Formänderungsgrenzen von Rohrmaterial unter Verwendung des Zugversuchs, des Doppelstegtorsionsversuchs und des Rohraufweitversuchs
Experimental investigation of the formability limits of tubular material using the tensile test, the twin bridge torsion shear test and the bulge test

Khan, Aamit
Tekkaya, A. E. • Heibel, S. (Daimler AG)
Versagensanalyse von tiefgezogenen Bauteilen aus hochfesten Multiphasenstählen
Failure analysis of deep drawing parts made of high strength multiphase steels

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

Marques Bezerra, Diego
Tekkaya, A. E. • Staupendahl, D.
Untersuchung des Kragenziehens von hochfestem Stahlblech und des damit einhergehenden Entstehens von Kantenrissen
Investigation of the occurrence of cracks in AHSS sheet material during hole flanging operations

Mergel, Fabian
Tekkaya, A. E. • Hölker-Jäger, R. • Hering, O.
Konzepterstellung und Inbetriebnahme der Werkzeugkühlung einer Strangpressmaschine
Concept development and experimental testing of an extrusion die with cooling

Möller, Christian
Tekkaya, A. E. • Heibel, S. (Daimler AG)
Versagensanalyse bei der Blechumformung von modernen hochfesten Stählen mittels experimenteller und simulativer Methoden
Failure analysis of modern high-strength steels in sheet metal forming by experimental and numerical techniques

Nitze, Tobias
Tekkaya, A. E. • Staupendahl, D.
Systematische Analyse und Ableitung von Maßnahmen zur Steigerung der Anlagenverfügbarkeit von Drahtwalzwerken
Systematical analysis and derivation of measures for the increase of plant availability of rod rolling mills

Ossenberg, Philipp
Tekkaya, A. E. • Ortelt, T. R.
Entwicklung einer Online-Lehrveranstaltung zur Bestimmung von Fließkurven durch einen teleoperativen Druckversuch
Development of an online seminar to determine flow curves through remotely operated compression tests

Otroshi, Mortaza
Tekkaya, A. E. • Hussain, M. (Hirschvogel Umformtechnik GmbH) • Clausmeyer, T.
Optimierung von geometrischen Größen und Reibparametern in Schmiedeprozessen
Automatic optimization of shape parameters and friction coefficients in forging process

Pajonk, Daniel
Tekkaya, A. E. • Ossenkemper, S.
Untersuchung des Stahl-Aluminium-Verbundes kaltfließgepresster Hybridwellen
Bonding zone investigation of cold-forged steel-aluminum composite shafts

Perez Castañeda, Marco Antonio
Tekkaya, A. E. • Hölker-Jäger, R.
Verfahrenskombination aus inkrementeller Blechumformung und Laserpulverauftragsschweißen zur Fertigung von Leichtbauteilen
Process combination of single point incremental forming and laser powder deposition for the manufacturing of lightweight components

Schilling, Bastian
Tekkaya, A. E. • Lueg-Althoff, J.
Experimentelle und numerische Analyse der Formänderung von Rohren bei der elektromagnetischen Kompression unter Berücksichtigung der Faltenbildung und des Einflusses auf das Magnetpulsschweißen
Experimental and numerical analysis of the electromagnetic compression of tubes considering wrinkling and its influence on magnetic pulse welding

Schowtjak, Alexander
Tekkaya, A. E. • Ostwald, R. (IM, TU Dortmund) • Clausmeyer, T. Schmitz, F.
Analyse von Schädigungsformulierungen für die Finite-Element-Simulation von Umformprozessen
Analysis of damage formulations for the finite element-based simulation of forming processes

Schumacher, Michael
Tekkaya, A. E. • Dang, T.
Entwicklung und Erprobung eines Mehrfachwerkzeugs für die inkrementelle Blechumformung
Development and experimental evaluation of a multitool for the incremental forming process

Sedes, Elif
Tekkaya, A. E. • Ipekoglu, M. (TDU) • Isik, K.
Numerische Untersuchung des Einflusses von Prozessparametern zur Optimierung eines superplastischen Umformprozesses
Numerical investigation of the effect of process parameters to optimize a superplastic forming process

Walke, Matthias
Tekkaya, A. E. • Tschierschke, M. (thyssenkrupp) • Ortelt, T. R.
Vergleichende Untersuchungen verschiedener Biegeverfahren unter Anwendung hochfester Stahlwerkstoffe am Beispiel von V-Profilen
Comparative investigations of different bending processes during V-profile bending of high-strength steels

Weber, Florian
Tekkaya, A. E. • van Putten, K. (SMS-Group) • Grodotzki, J. V.
Analytische Beschreibung des spannungsüberlagerten Rohrziehens mit fliegendem Dorn
Analytical description of the stress-superimposed tube drawing process with floating mandrel

Der Schweigepflicht unterliegende Masterarbeiten wurden verfasst von | Confidential works (M. Eng.) were written by

Gessner, Victor
Saleem, Maimoon
Shabaninejad, Arash

Abgeschlossene Bachelorarbeiten | Completed Bachelor of Science Theses

Beierle, Eugen
Tekkaya, A. E. • Gies, S.
Analyse der Leiterdeformation bei der elektromagnetischen Umformung
Analysis of the conductor deformation of electromagnetic forming coils

Detzel, Andreas
Tekkaya, A. E. • Wernicke, S.
Vorrichtung zum axialen Randaufdicken von Napfbauteilen mittels inkrementeller Blechmassivumformung
Development of an experimental device for axial edge thickening of cup components by incremental sheet-bulk metal forming

Eitner, Matthias
Tekkaya, A. E. • Dang, T.
Numerische Untersuchung des Zustellvorgangs bei der inkrementellen Blechumformung mit zwei Umformwerkzeugen
Numerical investigation of the step-down procedure in the incremental forming process with two tools

Göppert, Pascal
Tekkaya, A. E. • Napierala, O.
Einflussanalyse unterschiedlicher Werkzeugkinematiken und Prozessparameter beim Festwalzen
Effect analysis of different tool kinematics and process parameters during deep rolling

Hater, Sebastian
Tekkaya, A. E. • Löbbe, C.
Analyse der Korngrößen- und Mikrostruktur-Entwicklung beim kurzzeitigen Austenitisieren mittels mikromagnetischer Messungen
Evolution of the grain size and microstructure during the rapid austenitization analyzed by micromagnetic measurements

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

Kaya, Deniz
Tekkaya, A. E. • Mennecart, T.
Numerische Untersuchungen zum Umformverhalten mehrlagiger Bleche
Numerical investigations on the formability of multi-layered sheets

Kleina, Julian
Tekkaya, A. E. • Dahnke, C.
Untersuchung der Grenzschicht an stranggepressten Aluminium-NiTi-Verbundprofilen
Investigation of the boundary layer of extruded aluminum-NiTi composite profiles

Kotzyba, Patrick
Tekkaya, A. E. • Tschierschke, M. (thyssenkrupp) • Ortelt, T. R.
Untersuchungen von Längsdehnungen beim Walzprofilieren mit hochfesten Stahlwerkstoffen
Investigation of the longitudinal strains during profile rolling of high-strength steels

Morosow, Witali
Tekkaya, A. E. • Mennecart, T.
Entwicklung und Konstruktion eines Prüfstandes zur Ermittlung des Flanscheinzuges beim Biegen von U-Profilen mittels Lasertriangulation
Design and construction of a test device for the analysis of the flange movement in bending processes by using laser triangulation

Sonntag, Maximilian
Tekkaya, A. E. • Maaß, F.
Charakterisierung des Beulverhaltens von Kunststoffwerkstoffen bei der inkrementellen Kaltumformung von Thermoplasten
Analysis of bulge formation for single point incremental forming of thermoplastics

Steinwachs, Tim
Tekkaya, A. E. • Mennecart, T.
Beschreibung und Analyse des Umformverhaltens von Sandwichblech-Bauteilen
Characterization and analysis of the forming behavior of sandwich-sheet components

Sultane, Faten
Tekkaya, A. E. • Wernicke, S.
Einfluss einer Dehnpfadänderung auf die Bauteileigenschaften eines inkrementell-blechmassivumgeformten Zahnrades
Analysis of the influence of a strain path change on the component properties of a geared sheet by using incremental sheet-bulk metal forming

Thier, Ulrich
Tekkaya, A. E. • Gutknecht, F.
Bestimmung der Werkstoffschädigung in Metallen mit Hilfe elektrischer Messverfahren
Characterization of material damage by means of electrical measurements

Wolf, Tobias
Tekkaya, A. E. • Grzancic, G.
Untersuchung rollenbasierter Werkzeugsysteme für die Inkrementelle Profilumformung
Investigation of roll-based tool systems for incremental profile forming

Der Schweigepflicht unterliegende Bachelorarbeiten wurden verfasst von | Confidential works (B. Eng.) were written by

Schwendenmann, Nico

Abgeschlossene Projektarbeiten | Completed Project Theses

Adams, Tom • Hartung, Michael
Tekkaya, A. E. • Traphöner, H. • Schmitz, F.
Bewertung unterschiedlicher Verfahren zur optischen Messung hoher Dehnungen im ebenen Torsionsversuch
Evaluation of different methods for the optical measurement of high strains in the in-plane torsion test

Bärens, Frederic
Tekkaya, A. E. • Ortelt, T. R.
Eine quantitative Analyse von Schmiermittelmengen und Folienarten und -dicken in einem tribologischen System bei Nakajima-Versuchen nach DIN EN ISO 12004-2
A quantitative analysis of the tribological influence of lubricant thickness, type and thickness of the plastic disc in a DIN EN ISO 12004-2 Nakajima test

Baqerzadeh Chehreh, Abootarab
Tekkaya, A. E. • Staupendahl, D.
Untersuchung des inkrementellen Biegens von dünnwandigen Rohren
Investigation of incremental bending of thin-walled tubes

Cwiekala, Nils
Tekkaya, A. E. • Clausmeyer, T. • Traphöner, H.
Einfluss selektiver Zuordnung von Materialparametern auf die numerische Rückfederungsvorhersage
Influence of selective assignment of material parameters on the numerical springback prediction

Denter, Kevin
Tekkaya, A. E. • Mennecart, T.
Aufbau eines Picture-Frame Tests mit Möglichkeit der Aufbringung einer Normalspannung
Design of a picture-frame test with the possibility of applying a normal stress

D'Souza, Loreen Jovita
Tekkaya, A. E. • Hess, S. • Staupendahl, D.
Steigerung des Umformvermögens ferritischen Edelstahls durch einen mehrstufigen Umformprozess mit Zwischenglühschritten
Increasing the formability of ferritic stainless steel by intermediate annealing and stepwise forming

ElBaradei, Mohamed Ahmed
Tekkaya, A. E. • Staupendahl, D.
Untersuchung des inkrementellen Biegens von dünnwandigen Rohren
Investigation of incremental bending of thin-walled tubes

Fork, Dennis
Tekkaya, A. E. • Gutknecht, F.
Charakterisierung der Eigenschaften von Sandwichblechen
Characterization of the mechanical behavior of sandwich panels

Gala, Vijal Premchand
Tekkaya, A. E. • Chen, H.
Ermittlung der Umformbarkeit von ferritischem Edelstahl bei erhöhten Temperaturen
Determination of formability of ferritic stainless steel at elevated temperatures

Ganesh, Vishnu
Tekkaya, A. E. • Dahnke, C.
Umformverhalten von Formgedächtnis-Metall-Matrix-Verbundwerkstoffen
Forming behaviour of shape-memory-metal matrix composites

Göppert, Pascal
Tekkaya, A. E. • Kamaliev, M.
Presshärten: Einfluss von Prozessparametern auf die Bauteilhärte
Hot stamping: influence of the process parameters on the workpiece hardness

große Beilage, Georg
Tekkaya, A. E. • Gutknecht, F.
Entwicklung eines Versuchsaufbaus zur Aufnahme von Fließkurven für Blechwerkstoffe bei hohen Umformgeschwindigkeiten
Development of an experimental device for the characterization of flow curves of sheet metals at high strain rates

Izadyar, Seyed Ahmad
Tekkaya, A. E. • Nazari, E.
Numerische Untersuchung der inkrementellen Rohrformung mit Fokus auf Dickenanpassung
Numerical investigation of incremental tube forming with focus on thickness adjustment

Jahn, Robert
Tekkaya, A. E. • Gies, S.
Fertigung und Erprobung einer Werkzeugspule für die elektromagnetische Umformung
Manufacturing and testing of a working coil for electromagnetic forming operations

Jaiswal, Sumant
Tekkaya, A. E. • Chen, H.
Ermittlung der Umformbarkeit von ferritischem Edelstahl bei erhöhten Temperaturen
Determination of formability of ferritic stainless steel at elevated temperatures

Karakas, Sercan • Sarioguz, Özgün
Tekkaya, A. E. • Staupendahl, D. • Dardaei, H.
Untersuchung des Einflusses von Fügen durch inkrementelle Rohrumformung und Hartlöten auf die Verbindungsfestigkeit von ferritischen Edelstahlrohren (Güte 1.4509)
Investigation of the effects of joining by incremental tube forming and brazing on the joining strength of ferritic stainless steel tubes (grade 1.4509)

Keßler, Danilo
Tekkaya, A. E. • Yoshida, Y. (Gifu University) • Ortelt T. R.
Konstruktion und Fertigung von Umformwerkzeugen im G-Cadet-Programm
Design and manufacturing of a forming product line at G-Cadet

Kotzyba, Patrick
Tekkaya, A. E. • Gutknecht, F.
Ermittlung von Spannungs-Dehnungs-Diagrammen beim Stauchversuch mittels optischer Konturmessung
Determination of stress-strain diagrams for the upsetting test by means of optical edge measurement

Kröll, Felix
Tekkaya, A. E. • Chatti, S. • Sieczkarek, P. • Wernicke, S.
Verschleißuntersuchungen an Verzahnungswerkzeugen für die inkrementelle Blechmassivumformung
Investigations on the wear behavior of gear forming tools in incremental sheet-bulk metal forming

Lu, Yongchao
Tekkaya, A. E. • Chen, H.
Experimentelle Untersuchung der Warmrohrumformung durch granulare Medien
Experimental investigation of tube hot forming using granular medium

Maschlanka, Jonas
Tekkaya, A. E. • Traphöner, H.
Numerische und experimentelle Analyse der Form der inneren Einspannung im ebenen Torsionsversuch
Numerical and experimental analysis of the shape of the inner clamping in the in-plane torsion test

Peter, Alexander
Tekkaya, A. E. • Dang, T.
Untersuchung des Einflusses der Werkzeuggeschwindigkeit auf die Bauteilqualität bei der inkrementellen Blechumformung
Investigation of the influence of the tool velocity on the workpiece quality in incremental sheet metal forming processes

Potluri, Venkata Vamshi Krishna
Tekkaya, A. E. • Dahnke, C.
Analyse des thermomechanischen Verhaltens von mit Formgedächtnisfaser verstärktem Aluminium-Metallmatrix-Verbundwerkstoff
Analysis of the thermo-mechanical behaviour of a shape memory alloy fibre reinforced aluminium metal matrix composite

Rahmani, Mohammad
Tekkaya, A. E. • Chen, H.
Numerische Untersuchungen des Rückfederungsverhaltens von Ovalrohr
Springback simulation of catalytic converter oval tube

Ranjan Sharma, Sumeet
Tekkaya, A. E. • Hess, S. • Staupendahl, D.
Steigerung des Umformvermögens ferritischen Edelstahls durch einen mehrstufigen Umformprozess mit Zwischenglühschritten
Increasing the formability of ferritic stainless steel by intermediate annealing and stepwise forming

Schreiner, Felix
Tekkaya, A. E. • Kolpak, F.
Qualitative Untersuchung der Schweißnaht beim Strangpressen durch optische Analyse
Automatic weld strength evaluation in direct hot extrusion by means of optical microscopy

Steinhauer, Timo
Tekkaya, A. E. • Gutknecht, F.
Entwicklung eines Versuchsaufbaus zur Aufnahme von Fließkurven für Blechwerkstoffe bei hohen Umformgeschwindigkeiten
Development of an experimental device for the characterization of flow curves of sheet metals at high strain rates

Stennei, Markus
Tekkaya, A. E. • Hahn, M.
Reibungsbeschreibung für Umformvorgänge von Metall-CFK-Sandwichen
Description of frictional behavior for the forming of metal-FRP sandwiches

Stiebert, Fabian
Tekkaya, A. E. • Heibel, S. (Daimler AG) • Ortelt T. R.
Quantifizierung der Schädigung hochfester 1000 MPa Stähle
Damage quantification of high-strength 1000 MPa steels

Weißenfels, Stefan
Tekkaya, A. E. • Chatti, S. • Sieczkarek, P. • Wernicke, S.
Verschleißuntersuchungen an Verzahnungswerkzeugen für die inkrementelle Blechmassivumformung
Investigations on the wear behavior of gear forming tools in incremental sheet-bulk metal forming processes

Wiese, Tobias
Tekkaya, A. E. • Gies, S.
Fertigung und Erprobung einer Werkzeugspule für die elektromagnetische Umformung
Manufacturing and testing of a working coil for electromagnetic forming operations

Winkelmann, Jonas
Tekkaya, A. E. • Kamaliev, M.
Konstruktion und Erprobung einer modularen Spannvorrichtung für Verfahren der Eigenspannungsmessung
Construction and testing of a modular clamping tool for residual stress measurement devices

Wittig, Alexandra
Tekkaya, A. E. • Ortelt, T. R.
Eine quantitative Analyse von Schmiermittelmengen und Folienarten und -dicken in einem tribologischen System bei Nakajima-Versuchen nach DIN EN ISO 12004-2
A quantitative analysis of the tribological influence of lubricant thickness, type, and thickness of the plastic disc in a DIN EN ISO 12004-2 Nakajima test

Ye, Hui
Tekkaya, A. E. • Chen, H.
Untersuchung der Dickenwirkung auf die Mikrostruktur von 22MnB5 unter verschiedenen Abschreckbedingungen
Investigation of thickness effects on the microstructure of 22mnB5 under diffferent cooling conditions

Ausgewählte Veröffentlichungen und Vorträge | Selected Publications and Lectures

09

Zeitschriftenbeiträge | For Journals (Peer Reviewed)

Bellmann, J., Beyer, E., Gies, S., Lueg-Althoff, J., Schulze, S., Tekkaya, A. E., 2017. Measurement of Collision Conditions in Magnetic Pulse Welding Processes. Journal of Physical Science and Application 7 (4), pp. 1-10.

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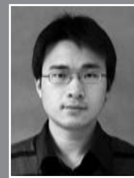

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