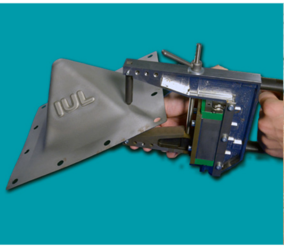
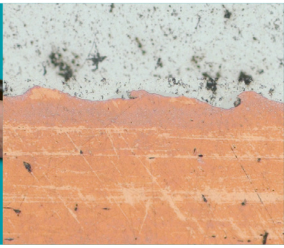
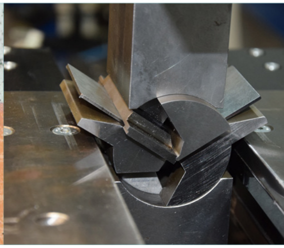


Institute of
Forming Technology and
Lightweight Components

Activity Report

18

technische universität
dortmund

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Imprint

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Inhalt

Preface

Since 2001, we have been informing you, dear readers, with an activity report on our research activities. And for the past 10 years, we have been presenting an annual report in the comprehensive version that is available to you. Here, you will find in a compact form what our highly motivated team has been working on hard for a year: results of research projects and research for engineering education, a list of publications and patents, reports from teaching and events, and much more.

Looking back on the past year, there are always special moments that will be present at the IUL. The great pleasure of hosting an honorary colloquium for Peter Haupt on the occasion of his 80th birthday is one of these moments. Peter Haupt, advisor and friend of the institute, has been working as a lecturer at the IUL since 2010 and promoted many academic careers. We are particularly grateful for his extraordinary commitment.

Another moment of great joy was the news that our former colleague Mr. Ben Khalifa, chief engineer at the IUL until April 2018, was offered a professorship at the Leuphana University of Lüneburg, together with the Helmholtz-Zentrum Geesthacht. Noomane Ben Khalifa began his career as a student assistant at the IUL while studying at TU Dortmund University. After graduating, he became a research assistant at the IUL and finished his doctoral theses in 2012 with honors with Erman Tekkaya as his supervisor. He will now continue his academic career in Lüneburg and Geesthacht and will hopefully remain in cordial terms with the IUL. We congratulate him on this exciting new challenge.

In 2018, we also had the chance to welcome various visiting scientists and students from all over the world in our already international team. The academic and personal exchange is a valuable and irreplaceable enrichment of our research activity that does not end at national borders – this is a matter of course in the research community. The chapter “International Exchange” reports in more detail on the joint research work.

We can sum up another pleasing development for 2018: the number of promotions was particularly high this year and we are very happy for the eight doctoral candidates who earned their PhD. A summary of their work can be found in this report.

Two established conference series continued in 2018: For the seventh time we invited to the International conference on tube and profile bending (DORP) and for the eighth time the “International Conference on High Speed Forming” (ICHSF), the world’s largest conference in the field the pulse-based forming, was hosted with colleague Glenn Daehn in Columbus, Ohio. Initiated in 2002 by Matthias Kleiner at TU Dortmund University, the event is regularly organized by the IUL in cooperation with the “Ohio State University College of Engineering”. We are proud to enrich the conference landscape with the events since 2005 and 2008 and to form a continuous framework for the presentation of forming innovations.

The TRR 188 has meanwhile completed half of its funding period and has taken this as an opportunity to present the previous research results to a wider audience at an industry colloquium. According to the project progress, the main focus of this first colloquium was on the characterization of damage mechanisms from the micro to the macro level and their influence on processes of sheet metal and bulk forming. The lively discussions of the participants underlined the high relevance of the topic for the production technology and provided a good occasion to reflect on the TRR 188’s scientific standing, including many suggestions for further research.

However, these results are only possible thanks to a large number of institutions that generously and sustainably supported and accompanied our work again in 2018. We would like to thank you and all colleagues of the research community and the IUL team.

A. Erman Tekkaya

Matthias Kleiner

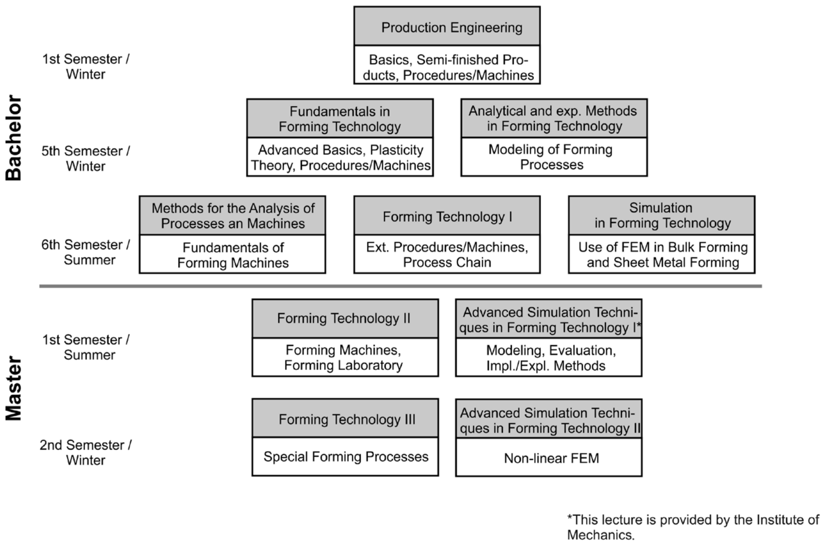
Education

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 2018:



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)“:

- Forming Technology – Bulk Forming
- Forming Technology – Sheet Metal Forming
- Advanced Simulation Techniques in Metal Forming
- Additive Manufacturing
- Aluminum – Basic Metallurgy, Properties, Processing, and Applications
- Laboratory

In the winter semester 2017/2018 TU Dortmund University participated in the "Engineers-without-Borders" challenge (Ingenieure-ohne-Grenzen-Challenge). As part of the BMBF-promoted joint project ELLI2, the challenge offers the students the possibility to discuss present problems like globalization, climate change, and social inequality. Thus, the students are able to develop a sense for the social responsibility of their future profession.

Final event of the Engineers-without-Borders challenge at IUL

In 2018, the following guest lecturers have contributed to the course offer at the IUL:

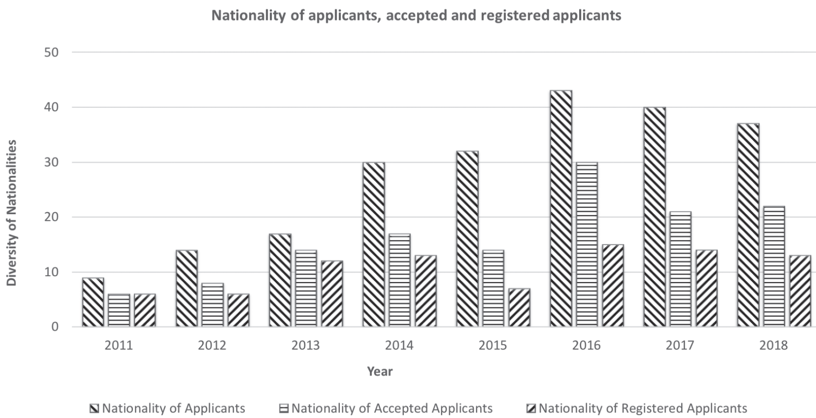
- Prof. P. Haupt, Emeritus Professor from the University of Kassel
- Prof. J. Hirsch, Hydro Aluminium Rolled Products
- Prof. K. Roll, formerly Daimler AG Sindelfingen
- Dr.-Ing. J. Sehrt, University of Duisburg-Essen

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.

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 2018/19. 29 carefully selected and excellent students out of around 1,000 applicants from 37 nations have begun their MMT studies in Dortmund. Within the scope of the cooperation with the Turkish-German–University in Istanbul, organized by the German Academic Exchange Service (German: DAAD), five students from Turkey started their MMT studies.



Diversity of nationalities of applicants, accepted and registered applicants

MMT coordination team meeting prospective students in Sofia

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 and ads were placed in cooperation with the DAAD in order to draw attention to the program and the application period. Furthermore, an education fair in Sofia, Bulgaria, was attended where prospective students were informed and advised in person.

The MMT online application portal has qualitatively improved in cooperation with the IT & Media Center of TU Dortmund University. Hence, the application procedure for the applicants as well as the processing of the applicant's data and the subsequent selection of the students to be admitted have become even more convenient and efficient.

Welcome event for the MMT batch 2018

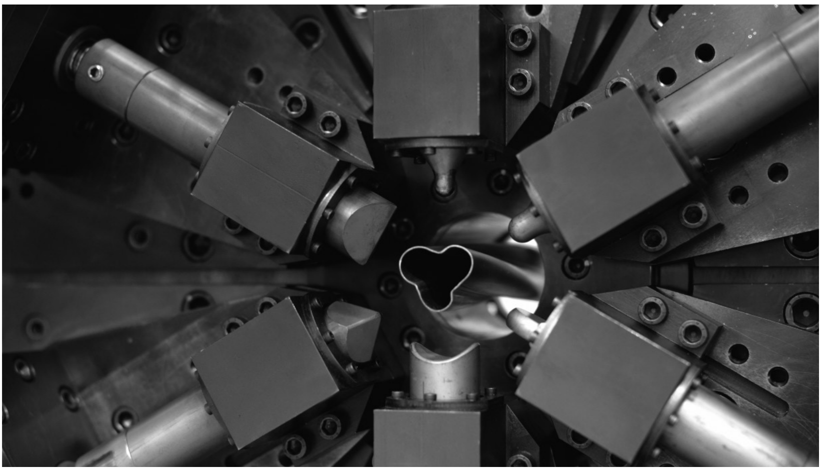
Before the start of the lecture period the new MMT students were welcomed by Professor Tekkaya as head of the MMT program within the scope of a welcome event in the lecture hall of the Mechanical Engineering Building MB III and the experimental hall of the IUL.

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

1.3 Doctoral Theses

Grzancic, Goran	Process Development and Basic Investigations for Incremental Profile Forming
Original title	Verfahrensentwicklung und Grundlagenuntersuchungen zum Inkrementellen Profilumformen
Series	Dortmunder Umformtechnik, Volume 97
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	February 2, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. D. Landgrebe (Chemnitz University of Technology)

Incremental profile forming (IPF) is a novel process for the flexible manufacturing of tubes and profiles with varying and geometrically complex cross sections. Its principle is based on the forming of tubular components by one or more tools with variable shapes, each performing local forming operations on the part by a multi-axis movement. With the objective to determine the underlying forming mechanisms and to fully tap the great potential of this process, a flexible machine system is developed first. In order to establish fundamental process understanding, significant parameters are identified and their influence on process and product properties is analyzed based on analytical, numerical, and experimental investigations.

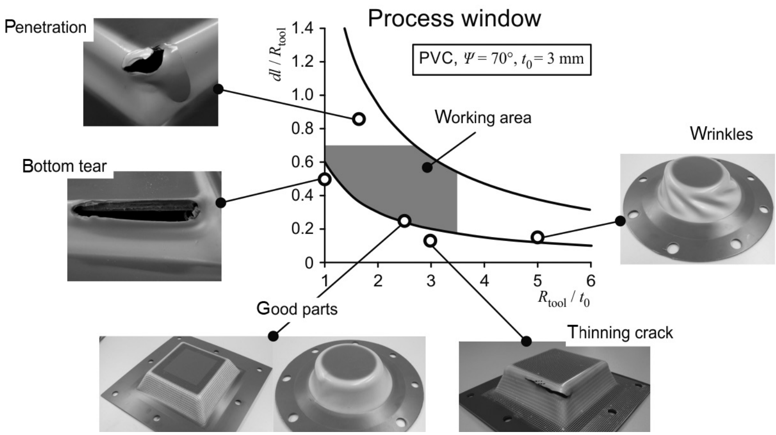


View to the IPF processing plane – Helical tubular structure, surrounded by different forming tools

Alkas Yonan, Sammer	Incremental Cold Forming of Thermoplastics
Original title	Inkrementelle Kaltumformung von Thermoplasten
Series	Dortmunder Umformtechnik, Volume 98
Publisher	Shaker Verlag, Aachen, 2017
Oral exam	February 27, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Co-examiner	Prof. Dr.-Ing. D. Drummer (FAU)

Single point incremental forming (SPIF) is characterized by high flexibility and economic efficiency due to minimal tool dependence and low forming forces. Thermoplastics are incrementally formable at room temperature. The aim of this work is to develop a comprehensive understanding of this forming process to contribute to its establishment as an alternative for prototype building and small batch production.

In this work fundamental investigations regarding the cold formability of thermoplastics as well as experimental and numerical analyses of incremental cold forming process of thermoplastics are performed. By means of a viscoplastic material model specially developed for this forming process forming mechanisms are analyzed. Based on part properties and occurring failure modes, a process window for the incremental forming of thermoplastics is presented.

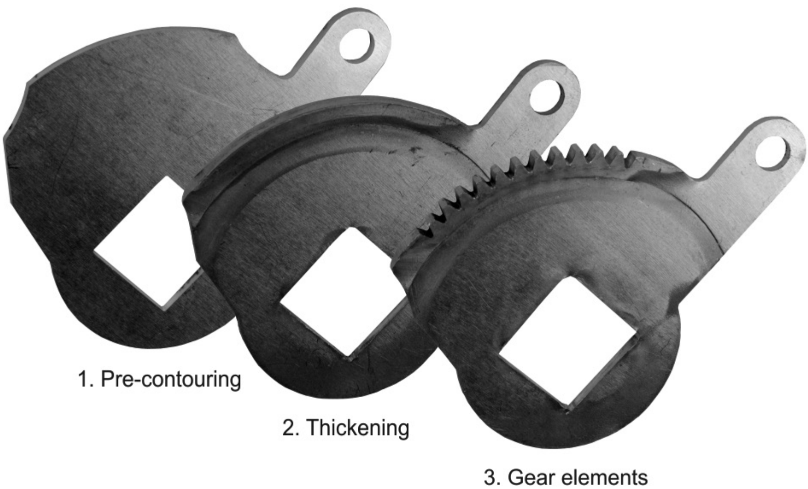


Validation of the process window for incremental cold forming of PVC

Sieczkarek, Peter	Incremental Sheet-Bulk Metal Forming
Original title	Inkrementelle Blechmassivumformung
Series	Dortmunder Umformtechnik, Volume 99
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	April 4, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. habil. M. Merklein (FAU)

With regard to the production of weight-adapted components with an identical or improved load capacity and an increased integration of different functions, the manufacturing technologies are faced with new challenges. Further, within the trend of individualization, a flexibility of manufacturing processes is necessary for a large variety of products.

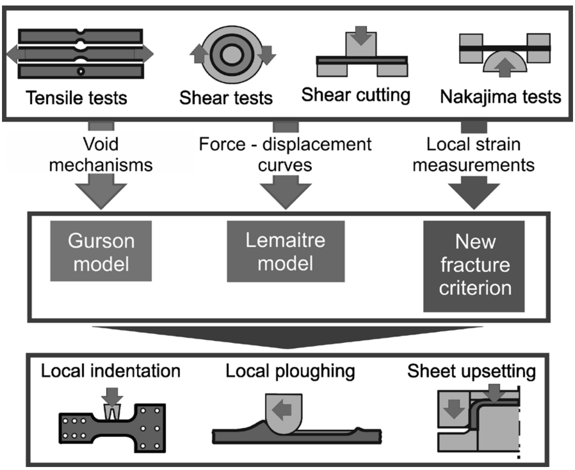
In order to meet these increasing demands and to fulfill future economical and ecological requirements, particularly in the automotive sector, a new forming class called incremental sheet-bulk metal forming (iSBMF) has been fundamentally investigated. iSBMF is defined as the incremental forming of sheets with a controlled three-dimensional material. The key innovation is the defined control of the 3D material flow in a sequence of forming operations. The local setting of the workpiece contour, the sheet thickness, and the hardening based on individual requirements are the most important advantages provided by this incremental approach.



Weight-adapted design of a seat adjuster (sample)

Işık, Kerim	Modelling and Characterization of Damage and Fracture in Sheet-bulk Metal Forming
Series	Dortmunder Umformtechnik, Volume 101
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	June 13, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr. P. A. F. Martins (Universidade de Lisboa)

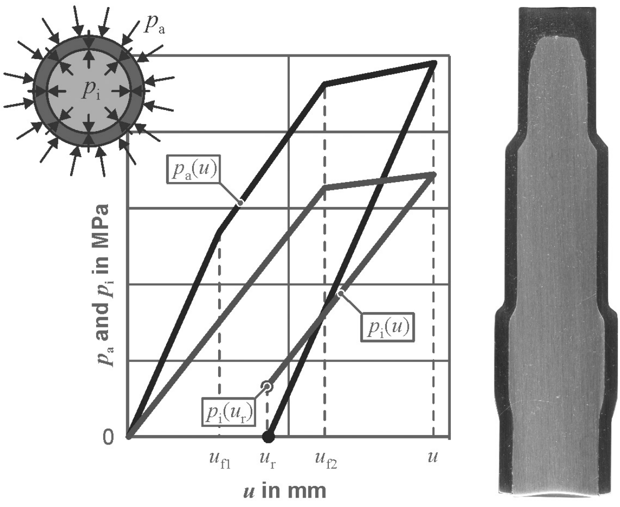
Sheet-bulk metal forming differs from conventional sheet forming processes in the application of the bulk forming operations on the sheet material. Although the initial workpiece is a sheet blank, the occurrence of three-dimensional stress/strain states requires a revise of the basic assumptions and available material models for conventional sheet forming processes. In this study, necessary material characterization techniques for the available damage models are developed to predict damage and fracture during sheet-bulk forming processes. Two continuum damage models, namely Gurson's porous plasticity and Lemaitre's continuum damage model, are investigated. A new fracture criterion originating from the experimental observations related to normal and shear fracture is introduced. The models' predictive performances are compared for three sheet-bulk forming processes, namely local indentation, local ploughing, and sheet upsetting.



General methodology

Ossenkemper, Stefan	Composite Cold Forging in Conventional Cold Forging Tools
Original title	Verbundfließpressen in konventionellen Fließpresswerkzeugen
Series	Dortmunder Umformtechnik, Volume 100
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	July 25, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. B.-A. Behrens (Leibniz University Hannover)

Composite cold forging denotes the simultaneous processing of hybrid raw parts by cold forging operations. The objective of the thesis is the development of a process for the manufacturing of composite shafts as well as the investigation of the achievable bonding properties. The composite shafts are produced by forward rod extrusion of backward extruded steel cups, into which an aluminum core is inserted. The final composite shafts possess a wear-resistant outer steel sleeve and a light aluminum core which reduces the overall component weight. The manufacturability by cold forging results in a very high material efficiency. The simultaneous forming of the two components creates a bond between the outer sleeve and the inner core. The bond properties are analyzed analytically, numerically, and experimentally with regard to form and force fit as well as metallurgical bond.

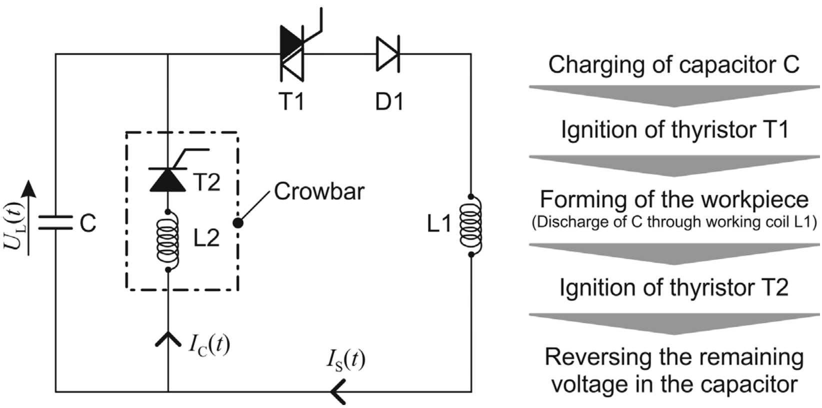


Force fit between core and sleeve

Gies, Soeren	Joule Heat Losses of Working Coils for Electromagnetic Sheet Metal Forming
Original title	Thermische Spulenverluste bei der elektromagnetischen Blechumformung
Series	Dortmunder Umformtechnik, Volume 102
Publisher	Shaker Verlag, Aachen, 2018
Oral exam	August 16, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Univ. Prof. Dr. rer. nat. habil. M. Stiemer (Helmut-Schmidt-Universität)

Joule heat losses in the coil winding can account for up to 50% of the overall losses in the electromagnetic forming process. Due to the accumulation of the Joule heat in the coil body, this loss component not only affects the process efficiency, but also the coil lifetime. Thus, the physical description of the coil losses and the development of technological approaches for the loss reduction are the objectives of this thesis.

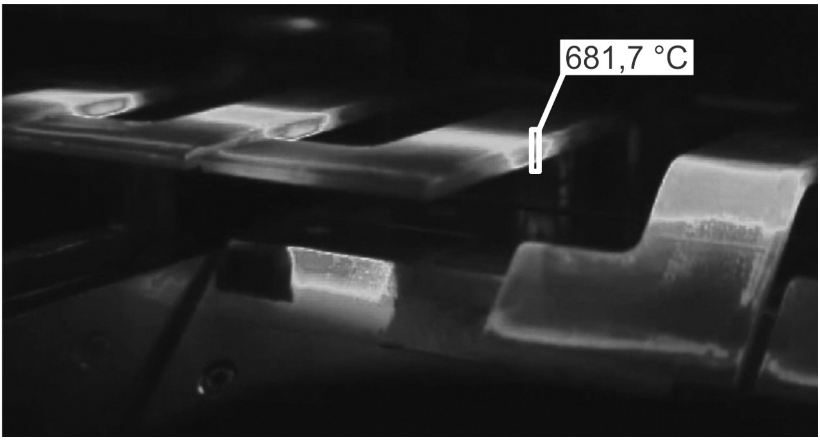
Based on the analytical modeling of the Joule heat losses, the effect of geometrical, material, and process parameters is identified. Hybrid conductors made of copper and steel as well as a new pulse generator concept with energy recuperation ability were proven as effective approaches for loss reduction. While the hybrid conductor design leads to a beneficial current density distribution, the effect of the new pulse generator concept is based on a modified temporal course of the discharge current running through the working coil.



Circuit design and operating sequence of the new pulse generator

Löbbe, Christian	Temperature-Assisted Bending and Heat Treatment in Multi-Stage Tools
Original title	Temperaturunterstütztes Biegen und Wärmebehandeln in mehrstufigen Werkzeugen
Series	Dortmunder Umformtechnik, Volume 103
Publisher	Shaker Verlag, Aachen, 2019
Oral exam	November 9, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. habil. M. Bambach (Brandenburg University of Technology Cottbus – Senftenberg)

The key for manufacturing high-strength and complex shaped sheet metal components is the combined forming and heat treatment. The investigation is dedicated to the development of multi-stage progressive and transfer tool technologies through an in-situ thermal treatment. For the compact tool set-up the single-stage inductive heating and multi-stage cooling is developed. Furthermore, the mechanisms in the in bending process are analyzed and modeled. Beside springback, the over-bending is an independent effect in the air-bending process controlling the bending result. In the die-bending process the thermal contraction leads to a stress superposition facilitating a calibration of the workpiece. Moreover, for the heat treatment of steels the austenitization and quenching is studied and covered by analytical approaches. For setting the tensile strength, the grain size and the carbon load are essential actuators. Finally, case studies illustrate the application in terms of manufacturing components with a defined geometry and strength.

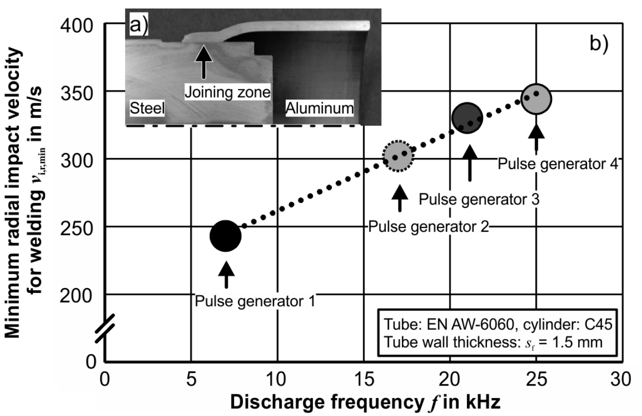


Bending in a progressive die at elevated temperatures

Lueg-Althoff, Jörn	Joining of Tubes by Electromagnetic Forming – Magnetic Pulse Welding
Original title	Fügen von Rohren durch elektromagnetische Umformung – Magnetpulsschweißen
Series	Dortmunder Umformtechnik
Publisher	Shaker Verlag, Aachen, 2019
Oral exam	December 12, 2018
Advisor	Prof. Dr.-Ing. Dr.-Ing. E.h. A. E. Tekkaya
Co-examiner	Prof. Dr.-Ing. G. Göbel (Dresden University of Applied Sciences)

In order to ensure the efficient use of resources, the ideal material should be selected for each application in manufacturing technology. Since most technical structures consist of more than one component, the challenge is to join dissimilar materials using suitable joining technologies. In collision welding processes such as magnetic pulse welding (MPW) welds are produced as a result of a high-speed impact without excessive heating of the parts to be joined, which would reduce the weld quality.

In this thesis, MPW by electromagnetic compression of tubes is analyzed from the point of view of forming technology. The collision conditions of a thin-walled aluminum tube with a steel cylinder are characterized by the radial and axial velocity components and the collision angle. Differences between different MPW structures are detected and attributed to the properties of the oscillating circuits of different pulse generators. .



a) Cross section of an aluminium-steel joint, b) Minimum required radial impact velocity for a full circumferential weld seam

Education

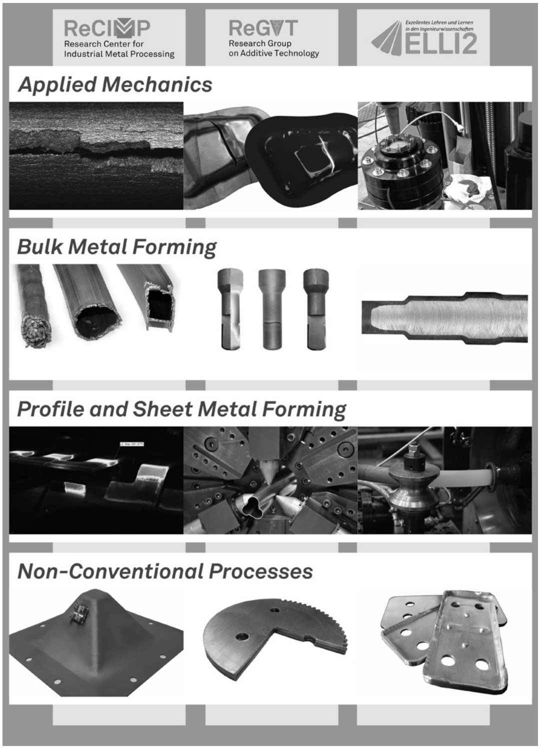
01

Research

02

2 Research

The research activities of the Institute of Forming Technology and Lightweight Components comprise the development of new forming processes and process chains as well as the extension of existing production processes. Key objectives are the achievement of a physical process description, the configuration and improvement of component properties, and a holistic approach of the process efficiency. The primarily fundamental questions are supplemented by aspects of applied research to ensure the quickest possible transfer of research results to industrial practice. 38 scientists, who are supported by 12 technicians and administrative staff members, and approximately 50 student assistants work on the institute's research projects. Especially as regards interdisciplinary research issues, the projects are often processed with national and international partners. The participation in two "Collaborative Research Centres", TRR 188 (spokesperson) and TRR 73 (local spokesperson), and in the two "Priority Programmes", SPP 1640 und SPP 2013, express this intensive networking. Besides the four departments "Applied Mechanics in Forming Technologies", "Bulk Metal Forming", "Profile and Sheet Metal Forming", and "Non-Conventional Processes" the institute structure (see figure) covers three interdivisional units: "Research Center for Industrial Metal Processing" (ReCIMP), "Research Group on Additive Technology" (ReGAT), and "Excellent Teaching and Learning in Engineering Science" (ELLI 2).



2.1 Research Groups and Centers

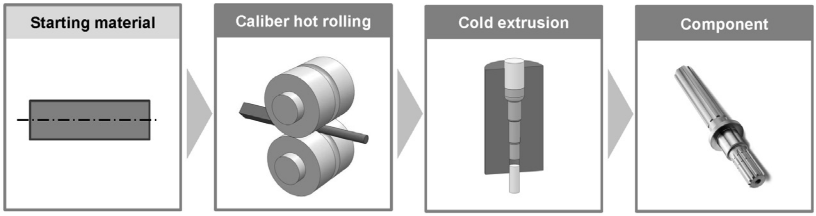
2.1.1 Collaborative Research Center Transregio 188 – Damage Controlled Forming Processes

Funding	German Research Foundation (DFG)
Project-ID	CRC 188/1-2018
Spokesperson	Prof. Dr.-Ing. Dr.-Ing. E.h. A. Erman Tekkaya
Managing Director	Dr.-Ing. Frauke Maevus

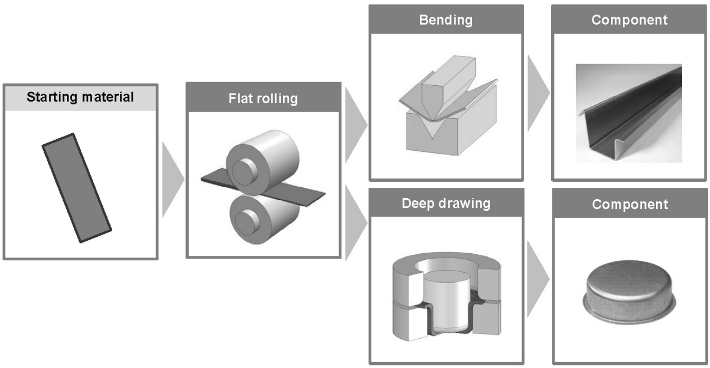
The Collaborative Research Center TRR 188 is concerned with research on the damage mechanisms during forming and their effects on product properties. It is generally known that every metal material contains damage, e.g. in the form of casting pores and non-metallic inclusions, and every plastic deformation causes additional damage, e.g. in the form of pore growth. It is not yet known how the damage can be specifically influenced in the forming process and from which critical damage margin on a failure of the component is to be expected. However, this knowledge is necessary in order to fully exploit the potential of modern material concepts and forming processes and to reduce the component weight to a minimum without sacrificing safety.

Therefore, the long-term goal of TRR 188, scheduled to run for twelve years, is to develop new methods and technologies for the control and quantitative prediction of the damage evolution as well as the targeted adjustment of the damage states with regard to the best possible component performance. Based on the guiding principle “damage is not a failure”, the aim is to ensure that production-induced damage, including its implications, is taken into account as a target variable in component and process design in the same way as other production-induced properties. This makes it possible for the first time not only to guarantee the formability of the components, but also the properties and functional safety of the components during the use phase.

The primary subject of the first funding period, which is currently under way, is to develop a fundamental physical understanding of initiation and development of damage in the forming process beyond the hypotheses generally used today. This is done using the example of representative process chains for bulk and sheet metal forming in three project areas with different focuses.



Process chain bulk forming in TRR 188



Process chain sheet metal forming in TRR 188

In project area A "Process Technology" forming processes and their influence in production process chains are investigated from a technological point of view. The focus is on researching the relationships between the forming processes, the load paths, and the resulting damage development. On the basis of these findings, an analysis and evaluation of the influence of damage on the component properties is carried out. Subsequently, technological approaches for the targeted influencing and control of the damage development are derived, which are to be converted into modified or newly designed forming processes in the second funding phase.

Project area B "Characterization" identifies and assesses the forming-induced damage mechanisms. The characterization takes place successively on the starting material, in the forming process, and on the finished formed component in order to be able to monitor the damage development over the complete process chain. Measuring methods and testing strategies for a qualitative and quantitative description of damage on various length scales are being developed. Important aspects are, on the one hand, the efficiency of the characterization methods with regard to time and effort and, on the other hand, a consistent approach for the application of the methods in order to ensure the comparability of the results.

The project area C "Modeling" deals with basic model approaches for the description of damage in sheet metal and bar material on various length scales and, building on this, recovery processes for the reduction of material damage. In detail, these are an anisotropic macroscopic material model, a coupled model of hardening, softening, and damage for hot forming, a crystal plasticity model as well as a damage model for service conditions and an approach for optimization problems. The development and verification of the approaches is carried out in close cooperation with the projects of the other two project areas. The coordination of the exchange is the task of the scientific service project "Model Integration". Further cross-sectional topics are investigated across projects and project areas by means of three working groups.

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 and the non-university Max-Planck-Institut für Eisenforschung GmbH (MPIE) in Dusseldorf.

The interdisciplinary consortium of production engineering, materials science, materials testing technology, and mechanics is supported by an industrial advisory board. The industrial advisory board advises the TRR 188 and discusses current R&D results with the researchers. The research association receives important impulses for further research activities by the experiences and suggestions from industrial practice. Members of the industrial advisory board are material and semi-finished product manufacturers, component manufacturers, technicians from sheet metal and bulk forming, component users as well as companies from the field of software and measurement technology.

In addition, first research results of the TRR 188 were presented and discussed at scientific and industry-related symposia in the national and international environment. These included ICTP, ECCM, IDDRG, ESAFORM, GAMM, MSEC, various DVM working group meetings and, not least, the 1st Industrial Colloquium organized by TRR 188 in November 2018 in Dortmund.

2.1.2 ReCIMP – Research Center for Industrial Metal Processing

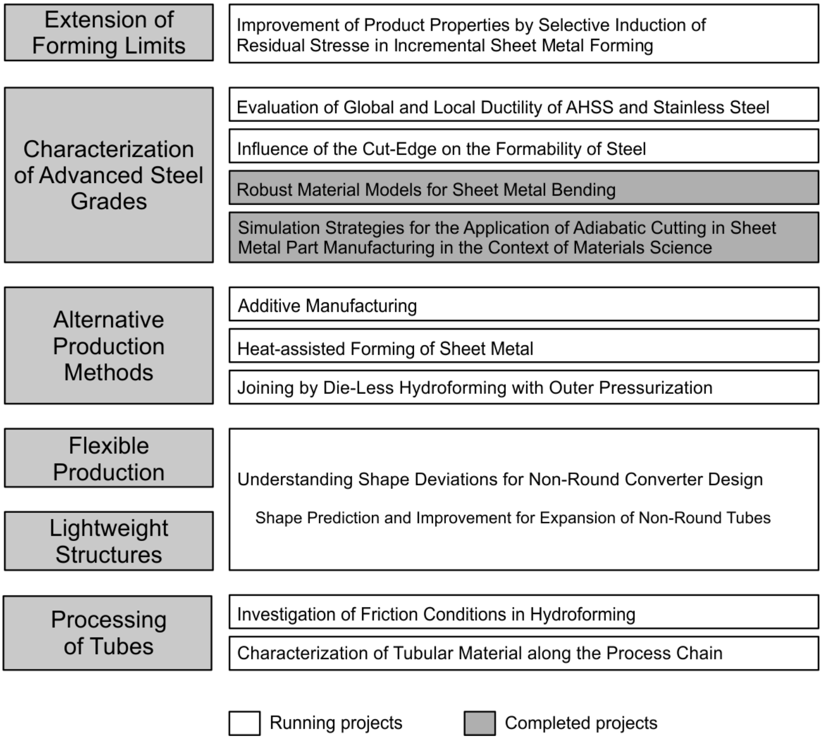
Head Dr.-Ing. Dipl.-Wirt.-Ing. Jörn Lueg-Althoff

With the beginning of 2018, the Research Center for Industrial Metal Processing (ReCIMP) entered the second project stage. The successful cooperation with the international automotive supplier Faurecia exists since 2013.

During a kick-off ceremony at the IUL on April 13, the project extension was launched in the presence of representatives of the City of Dortmund, TU Dortmund University, the Faculty of Mechanical Engineering, and the two Faurecia groups "Automotive Seating" and "Clean Mobility". The very productive cooperation with Faurecia was illustrated by project examples. Professor A. Erman Tekkaya underlined that the cooperation has already resulted in the initiation of six new, third-party-funded research projects at TU Dortmund University, in which basic knowledge about forming processes is generated.
In a subsequent meeting, the members of the ReCIMP Advisory Board discussed the framework development planning for the following five years.
The primary objective of ReCIMP is the improvement and deepening of basic knowledge about innovative metal forming processes, process chains and hybrid processes, the identification and investigation of new scientific trends in manufacturing technology, and the establishment of a competence network consisting of further research institutions and companies.

Representatives of Faurecia, the Economic Development Agency Dortmund, TU Dortmund University, and the IUL during the kick-off meeting for the second project stage of ReCIMP
Source: Schaper/TU Dortmund University

For the second project stage six priority areas were defined in which the research activities are organized. In addition to extending the forming limits of existing processes, the investigation of alternative manufacturing processes, and the flexibilization of the manufacturing of products, the focus is on the characterization of modern steel alloys and the modeling of their forming behavior. In particular, the identification and development of efficient characterization methods is in the spotlight.



Research projects worked on in 2018, allocated to six research priority areas

In some forming processes certain high-strength steel grades show a particular susceptibility to failure at sheared edges (so-called cut edge sensitivity). In the project “Influence of the Cut Edge on the Formability of Steel” (see chapter 2.4.10) the influence of the strain induced during shearing on the reduced formability in subsequent forming processes is investigated. In addition, the aim is to identify suitable methods for evaluating the sensitivity to edge failure.

In addition to sheet metal products tubes are used, especially in exhaust systems. Non-round tubes are increasingly being used for reasons of an optimum use of the available space. The influence of the various process steps in the manufacturing of oval tubes on the geometric accuracy after expansion is investigated in the project "Shape Prediction and Improvement for Expansion of Non-Round Tubes" (see chapter 2.2.8). Here, the focus is particularly on the investigation of the springback behavior.

The dissemination of the findings from the ReCIMP projects to the international community is an important goal. In 2018, the research results of the ReCIMP projects were presented at the international conferences ESAFORM (European Scientific Association for Material Forming), TIME (Technological Innovations in Metal Engineering), and IDDRG (International Deep-Drawing Research Group Conference), among others.

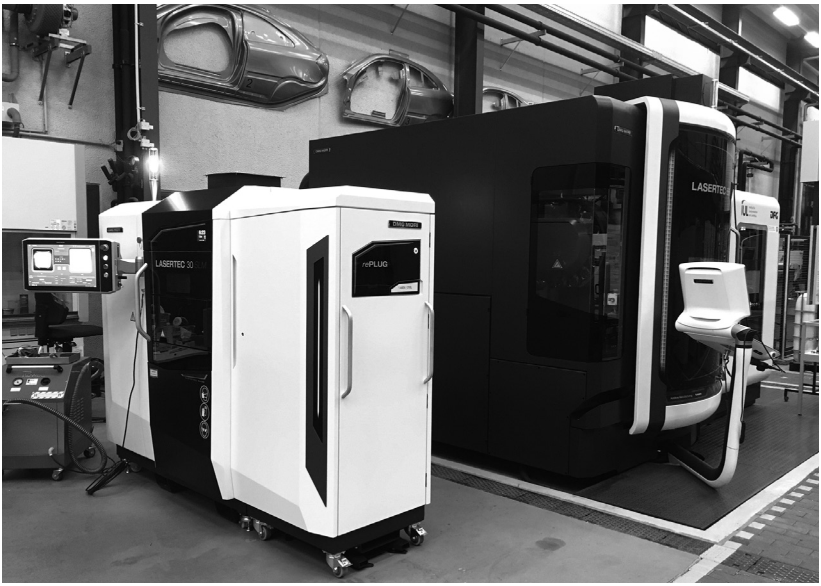
As already established in the first project stage, numerous scientific and student employees of the IUL work together in ReCIMP on a cross-departmental, project-related basis. In 2018, ten student theses (project, bachelor, and master theses) on ReCIMP-related topics were in progress.

2.1.3 ReGAT – Research Group on Additive Technology

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

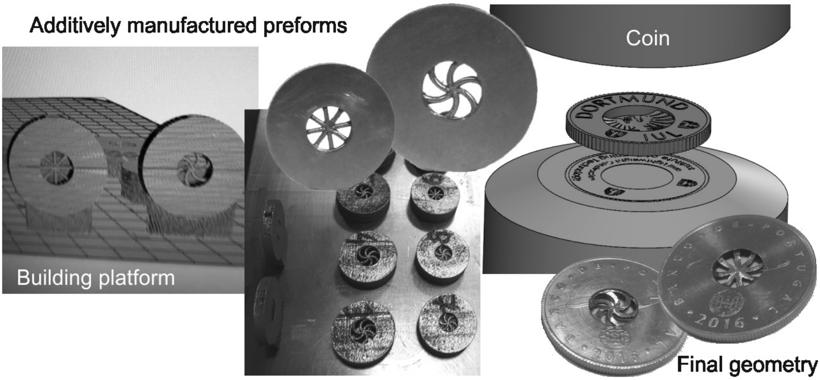
The "Research Group on Additive Technology" (ReGAT) aims at integrating additive manufacturing methods into traditional forming processes in order to use the advantages of both. Research topic is the process combination of formative and additive manufacturing processes, the additive manufacturing of semi-finished products and their subsequent processing by forming as well as additively manufactured dies for the forming technology.

With the two machines for additive manufacturing at the IUL for processing metal powder - a combined 5-axis-machining and laser deposition welding center and a laser powder bed fusion machine for selective laser melting - a large number of different semi-finished products, components, and dies can be realized for their particular application purposes by complete or only partial additive manufacturing. Current research focus is the characterization of materials and parts properties. The focus of future research activities is the development and the use of numerical methods for the investigation and prediction of properties of additively manufactured semi-finished products for a subsequent processing by forming.



Machines for additive manufacturing based on metal powder at the IUL

From March until June 2018, the working group ReGAT was supported by Professor Carlos Manuel Alves da Silva, Assistant Professor in the working group of Professor Paulo Martins, Instituto Superior Técnico, Technical University of Lisbon. During his research period Professor da Silva worked on the connection of forming technology and additive manufacturing. His idea is to manufacture blanks for collector's coins additively by selective laser melting and to coin them to their final geometry. For the design of the preform numerical simulations are used to determine the material flow during the coining process. For the year 2019 another guest stay at the IUL is planned.

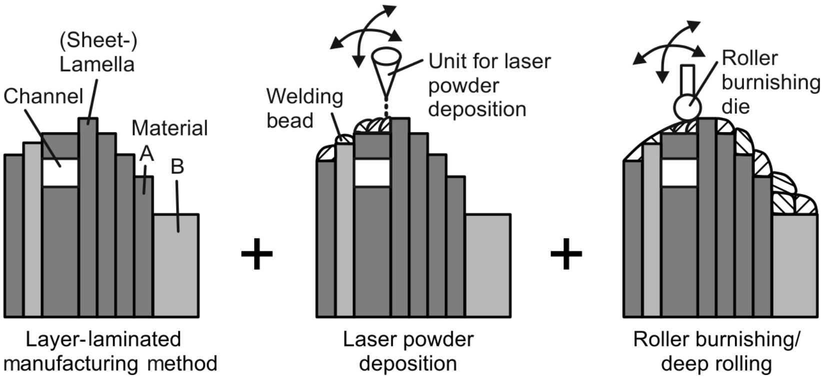


Additively manufactured preforms which will be coined to their final geometry

In the summer of 2018 a project for the investigation of a novel process combination of the 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 was launched, funded by the DFG. In this project a combined processing consisting of incremental sheet metal forming, additive manufacturing, and machining in one machine and in one setup shall be realized.

In comparison to the previously mentioned additive manufacturing methods in the field of the layer-laminated manufacturing method, a novel approach for reducing the stair step effect was developed. The idea is to manufacture the high volume base body of a die or a component from single sheet lamellas with varying thicknesses and different materials quickly and cost-effectively. The resulting so-called "stair step effect", which derives from the layers of the sheet lamellas, is filled by laser powder deposition and finally leveled by roller burnishing and/or milling. A possible application is the fast and cost-efficient fabrication of deep drawing dies.

This novel process chain was filed for a patent by TU Dortmund University (DE 10 2018 004 294.5).



Reducing the “stair step effect” during the layer-laminated manufacturing method by laser powder deposition and roller burnishing

In September 2018, a workshop on the subject of “3D Printing” was organized together with the Karl-Kolle-Foundation. 20 students at the age of 13 to 14 years from 5 schools in the north-eastern Ruhr region and the neighboring Münster region could gain insight into additive manufacturing. After an introduction to the technology and the design software the students had the chance to design their own 3D parts and to manufacture them on the polymer printers existing at the IUL.

2.1.4 Research for Engineering Education – ELLI 2

ELLI 2 – Excellent Teaching and Learning in Engineering Science

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

The term Industry 4.0 nowadays combines many recent developments and research topics which will permanently transform the way how manufacturing is done in modern facilities. In a similar fashion, the required skill sets of engineers, who are sought after to implement this revolution, will shift. Therefore, engineering education faces an equivalent challenge to modernize itself in such a way that future generations of engineers are well equipped with the required knowledge and the understanding of the game-changing technologies to drive this transformation. Such a change, especially in higher engineering education, can be achieved only with specific research dedicated to this field.

Therefore, the cooperative project ELLI 2 between RWTH Aachen University, Ruhr-Universität Bochum, and TU Dortmund University, which is being funded by the Federal Ministry of Education and Research as part of the Teaching Quality Pact since 2011, focuses on the research on teaching and learning in engineering sciences

The project consists of four core areas:

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

At TU Dortmund University, engineers from IUL together with engineering education experts from the Center for Higher Education collaborate to resolve the questions regarding how future generations of engineers should be educated best. Within the core area of “Remote labs and virtual learning environments” two activities are mainly conducted by members of the IUL: (1) further development of the tele-operative testing cell and integration of new experiments as well as (2) the virtual laboratory for forming technology.

The rotary draw bending machine by transfluid is the basis for the remote tube bending lab

With the delivery and installation of the rotary draw bending machine, transfluid DB 2060-CNC-SE-F, and the specimen handling robot, KUKA KR90 R3700 K, the development of the remote tube bending lab was moved towards the next stage. In the upcoming year, the programs currently under development will be connected with the machines and first trial runs will be performed. By incorporating the new remote lab into existing lectures as well as by the development of a novel hands-on tube bending lab with a focus on the process limits the students can combine the theory of the tube bending process with experimental observations. By such labs the understanding and, thus, eventually the control of the process is fostered beyond classical lecturing approaches.

The existing remote lab for material characterization was successfully incorporated into the forming technology lecture 2018 at the WH Gelsenkirchen. The evaluation showed that 74 % of the students involved rated the use of the remote lab as a helpful tool to connect theory with practice.

The remote labs developed by the faculty partners ISF, Institute of Machining Technology, and wpt, Department of Materials Test Engineering, are currently in their implementation phase. The remote machining lab by the ISF connects a Pocket-NC machine to the web, such that the students can gain a better understanding of machining process limits, for instance by observing surface defects. For handling the specimens of wpt's fatigue test remote lab, the IUL provided a mini-robot which can handle conventionally as well as additively manufactured specimens. Comparing the results, the students can learn about important properties of these products. Both labs will be equipped with web-streaming cameras, enabling the students to study the processes not just based on data, but also visually.

Aside from advancing the development of labs for university students, ELLI 2 also aims at bringing students and teachers from other educational institutions in contact with novel technologies. Together with the KARL-KOLLE-Foundation, the IUL ELLI 2 team hosted a workshop on 3D printing where students and teachers could learn about the possibilities and limits of this new technology. After being introduced to the necessary software, they could design and print their own individualized shopping trolley coin. Using similar concepts, ELLI 2 supported the TU Dortmund activities such as MinTU, do-camp-ing, SchnupperUni, Girls' Day as well as the ScienceNightRuhr. Here, interested students, teachers, and parents could get involved with modern manufacturing technologies as well as augmented and virtual reality technologies used in engineering education.

For the second time, ELLI 2 hosted the "Engineers-without-Borders" challenge. A total of 60 students were excited to participate together with over 25 students from partnering universities, such as Aachen, Bochum and recently joined Hamburg, Bottrop, and Mittelhessen universities. During this engineering challenge the students have to solve engineering-related problems from Kenya that have been identified by members of the Engineers-without-Borders association, based on their expertise and skills. The best solutions will be implemented by the association in the country to help people improve their living conditions.

At the Future Day of the DINI (The German Initiative for Network Information) ELLI 2 gave an impulse talk and a subsequent special topic workshop where solutions for teaching and learning with augmented and virtual reality were shown. These results were also presented at the DeLFI (E-Learning Congress of Informatics) and the DGfE Congress (German Educational Science Association). For the participants of the REV 2018 (International Conference on Remote Engineering and Virtual Instrumentation) the excursion to the experimental hall of IUL was a unique chance to actively explore the work of ELLI 2 in the fields of virtual and augmented reality as well as remote laboratories.

2.2 Department of Applied Mechanics in Forming Technologies

Head Dr.-Ing. Till Clausmeyer

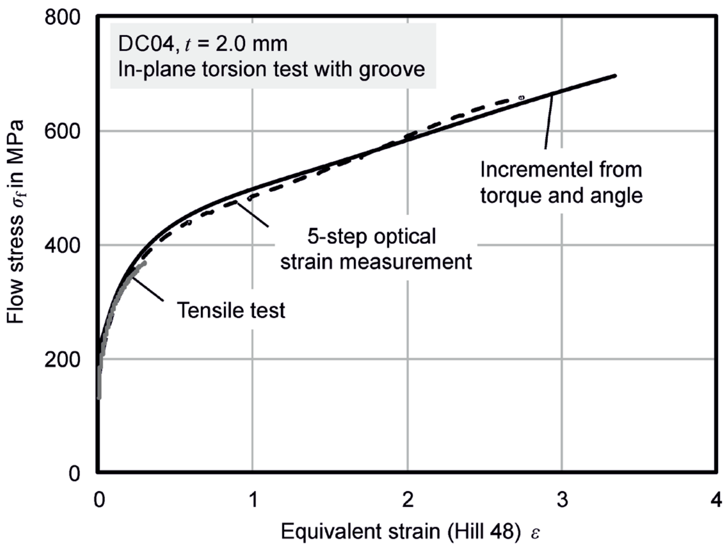
The members of the department of applied mechanics in forming technologies develop new material testing methods such as the in-plane torsion test for the characterization of damage and kinematic hardening. Experimental data from these tests is indispensable for the evaluation of the performance of metallic materials and the process analysis with the Finite-Element-Method. In particular, sheet forming, sheet-bulk forming, and cold forging processes are analyzed and material models for damage, kinematic hardening, strain and temperature sensitivity are developed. The department hosted Professor Junying Min (Tongji University in Shanghai) from April until July 2018. Members of the department presented new scientific results at international conferences (MSE 2018 in Darmstadt, IDDRG 2018 in Waterloo, Canada) and at working group meetings under the auspices of "Deutscher Verband für Materialforschung und -prüfung e. V." (DVM). The department is an active partner in the DFG-funded Collaborative Research Centers TRR 188 and TRR 73, but also in joint projects with industry.

Members of the department with Prof. Tekkaya and participants of the DVM seminar on October 9, 2018 in Dortmund

2.2.1 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.

Equivalent strains much larger than 1.0 are obtained for ductile materials in the in-plane torsion test with circumferential groove. This fact is attributed to the almost ideal simple shear stress and strain state. While the stress can be easily calculated from the measured torque, it is no longer possible to measure strains above this value by conventional optical strain measurement. The optical pattern deforms severely so that an accurate strain measurement is no longer possible. By the development of new methods for measuring very high shear strains in the in-plane torsion test the determination of flow curves of very ductile materials is made possible. On the one hand, the feasibility of applying a new undeformed optical pattern to the sample in several steps is investigated. Thus, flow curves are determined cumulatively. On the other hand, a new method allows to determine the flow curve incrementally from torque and angle of rotation. In this way, the limitations of the optical measurement can be overcome.

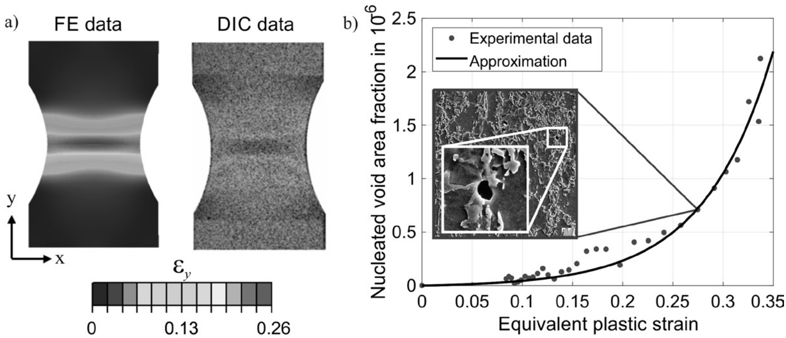


Flow curves for DC04 with 2 mm sheet thickness from the tensile test and the in-plane torsion test with groove

2.2.2 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. The identification of different material and model parameters is necessary in order to analyze forming processes in terms of damage. For their determination an optimization-based software tool for the parameter identification of complex material models is developed. To this end, experimental data is compared with simulations for several basic experiments. Local information like displacement or strain fields (see figure a), which are determined by digital image correlation software, as well as global information such as load-displacement curves are considered.
The individual material parameters serve to describe varying phenomena. Thus, certain parameters are evaluated separately through appropriate experiments and examination methods. The nucleation-related part of the Gurson-Tvergaard-Needleman-model can be identified by fitting the evolution to the experimentally determined voids obtained by microstructural investigations (see figure b).

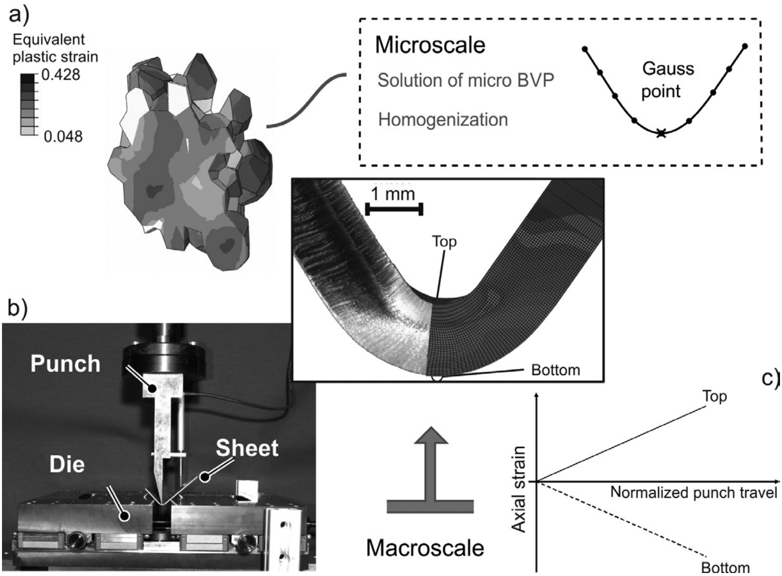


a) Strain field for a tensile test with notched specimen, b) Void area fraction due to nucleation versus equivalent plastic strain

2.2.3 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
Status	Completed

Properties such as texture and hardness of the single phases determine the forming behavior of modern multiphase steels. Modeling methods that consider the microstructure explicitly predict mechanical properties locally. Prof. Hartmaier and his team at Interdisciplinary Centre for Advanced Materials Simulation (ICAMS) developed a non-local crystal-plasticity model for this purpose (see figure a). The partners at the Institute of Mechanics at University of Duisburg-Essen provide a novel beam element formulation for the simulation of bending processes with representative volume elements (RVE). The formulation relies on the Euler-Bernoulli hypothesis. The material behavior was described using test data from experiments with high strain such as the in-plane torsion test at IUL. The springback and the local plastic strain were predicted with this method for bending parts manufactured from dual phase steel DP 600.



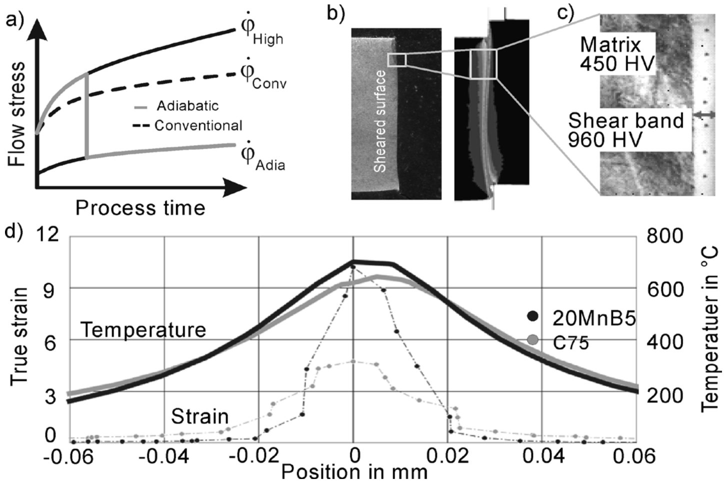
a) Microstructural model (provided by ICAMS), b) Air bending, c) Macroscopic strain (17,5 %)

2.2.4 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.
Status	Completed

Due to its high local rate of deformation ($\dot{\varepsilon} \geq 10^3\ s^{-1}$) and significant process time ($t<2$ ms) adiabatic blanking exhibits temperature-induced softening (see figure a). This results in a high cutting quality and possible shortening of the process route in comparison to conventional blanking methods for advanced high-strength steels.

The resulting sheared surface exhibits special technological properties. This includes the geometry of the shear surface (see figure b) and the mechanical properties of the material (see figure c) in particular. The adiabatic effect occurs in a localized zone and, therefore, a fine meshing of the deformed area in FE-simulation is required in order to predict the accurate development of the shear band. Advanced re-meshing strategies, e.g. adaptive re-meshing, are used. By this means, characteristics in the shear band such as temperature and strains (see figure d) are determined. The project is conducted in cooperation with the Institute of Materials Science and Engineering (LWW) in Chemnitz.

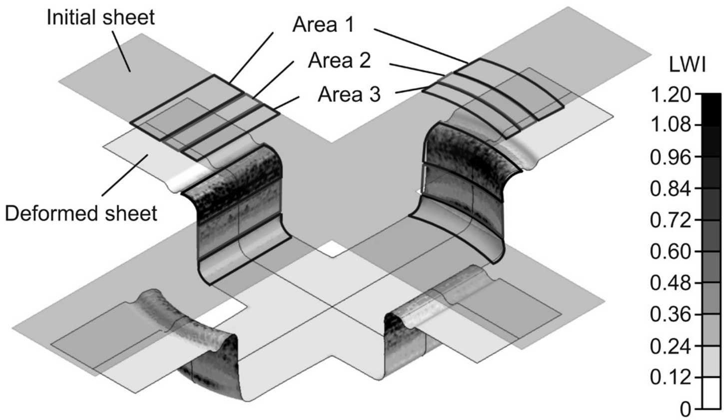


a) Thermal softening, b) Geometry of sheared surface, c) Hardness of ASB, d) Properties of ASB

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

Funding	AiF/EFB
Project	11/215/17613N
Contact	Heinrich Traphöner M. Sc.
Status	Completed

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 following knowledge was obtained in the project: It could be shown that the dependence of the rolling direction of the Bauschinger effect is negligible for the investigated materials and does not have to be considered in the modelling step. A load path-dependent local assignment of material parameters leads to a slightly better springback prediction, but this is disproportional to the increased effort that is caused by the characterization and the increased simulation time. For the analyzed load change indicators (LWI) a qualitative correlation between the amount of the indicator and the difference between isotropic and isotropic-kinematic material modeling could be determined. Under certain circumstances processes with a low value of the LWI can also be simulated with isotropic hardening and processes with a high LWI only with isotropic-kinematic hardening.

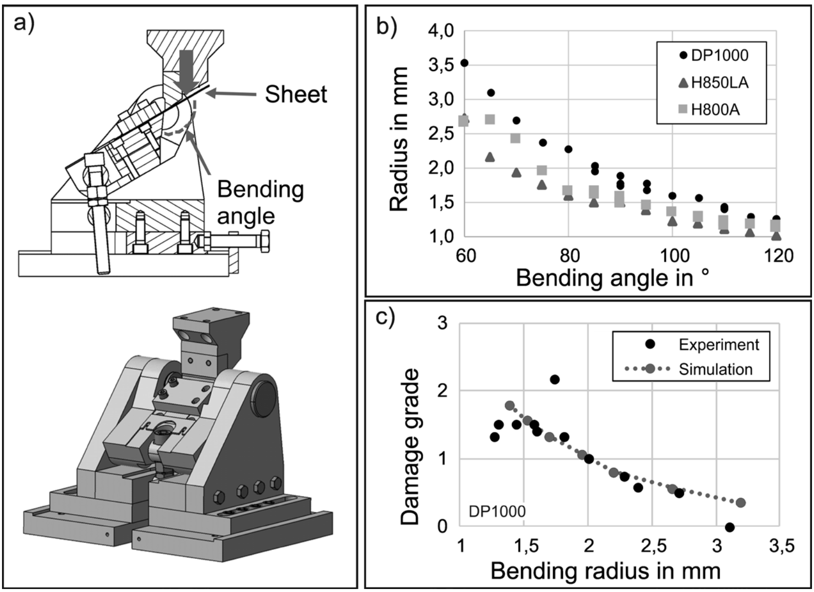


Load change indicator and areas of comparable load paths on the modular demonstrator

2.2.6 Robust Material Models for Sheet Metal Bending

Funding	ReCIMP
Contact	Fabian Schmitz M. Sc.
Status	Completed

Technical design of high-strength steels for bent structural parts in vehicles is a particular challenge. Firstly, the parts must endure a reverse bending during use; secondly, high-strength steels partially have strongly varying hardening properties. Simulations of the bending process require an accurate description of the material behavior. Initially, a new testing device (see figure a) has been developed to compare different material concepts. With the help of the new testing device bending radius and bending angle can be adjusted independently. Subsequently, another device has been used for controlled reverse bending. Additionally, air-bending tests have been conducted to determine a material-dependent correlation of bending radius and bending angle (see figure b). Furthermore, a complete parameter identification for two coupled damage models has been performed. It has been found that the predicted damage values correlate very good with the experimentally determined crack classification of the specimen surface (see figure c).

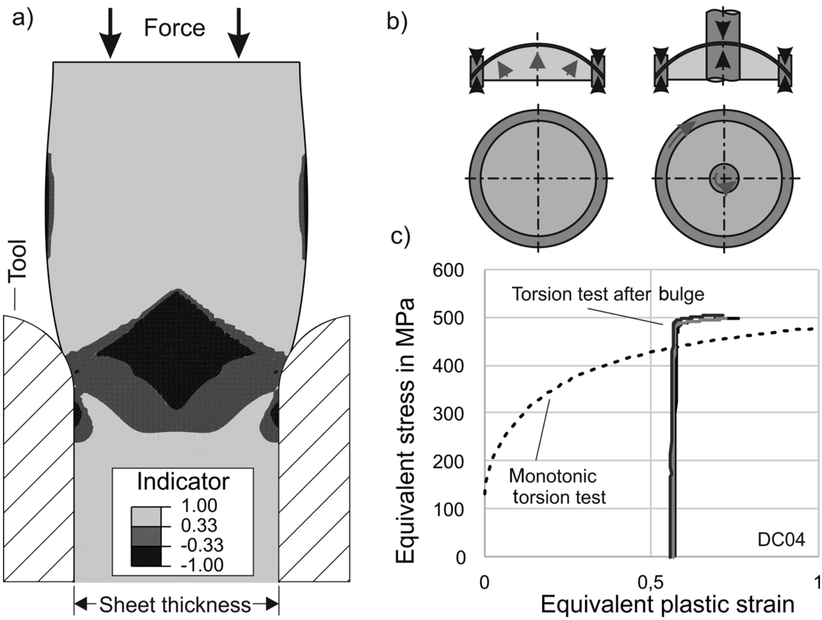


a) Bending device, b) Correlation of bending radius and bending angle, c) Prediction of bending quality

2.2.7 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	CRC/TR73 • Subproject C4
Contact	Florian Gutknecht M. Sc.

For sheet-bulk metal forming processes the sheet thickness is adapted to the loading. In this context, thickening is a typical subprocess at the sheet edge (see figure a). This process is accompanied by high plastic strains and strong non-linear strain-paths. For the reversal of the load (Indicator = -1) at high strains the in-plane torsion test is available. The torsion test for curved sheets has been developed for strain-path changes in orthogonal direction (Indicator = 0) (see figure b). This test allows characterizing effects of orthogonal strain-path changes at high pre-strains (see figure c). The microstructure of the specimen is investigated for void evolution together with the Institute of Materials Science at Leibniz University Hannover. Due to the combined approach the influence of strain-path on strength- and damage evolution can be directly determined.

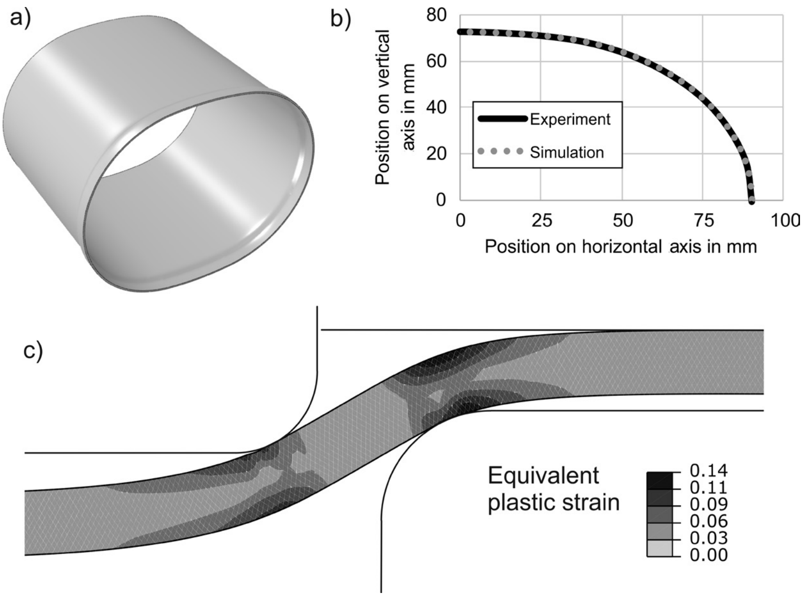


a) Strain-path change at thickened edge, b) Principle of curved torsion test, c) Experimentally determined cross-hardening

2.2.8 Shape Prediction and Improvement for Expansion of Non-Round Tubes

Funding ReCIMP
Contact Dr.-Ing. Till Clausmeyer

Increasing requirements on the utilization of assembly space result in more complex tube cross sections of containers. Consequently, fulfilling the tight shape tolerances becomes more challenging. Therefore, the technical design of the process must be improved to avoid an increase of iteration loops in manufacturing. For non-round tube cross sections there are no analytical models available. Thus, a numerical Finite-Element model is created. The model will help to analyze the mutual influence of springback after expansion and shape deviations by shape dependent pressure on the inside. Initially, the expansion of the tube at the free end is investigated (see figure a). The corresponding numerical model already predicts the shape in excellent agreement with the real tube (see figure b). Furthermore, the analysis revealed information otherwise not available, such as the plastic strain occurring in the process (see figure c), which helps to improve process understanding.

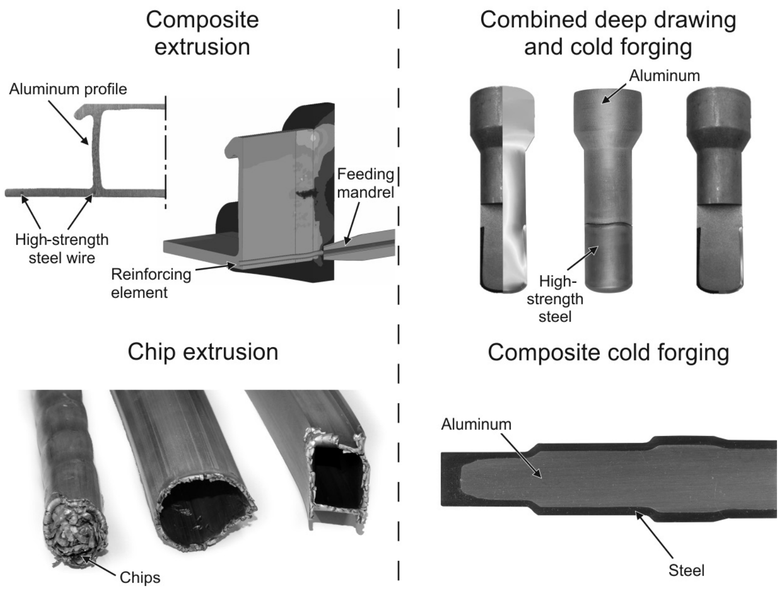


a) Expansion at free end, b) Shape comparison of simulation after springback and real part, c) Process analysis

2.3 Department of Bulk Metal Forming

Head Christoph Dahnke M. Sc.

The department of bulk metal forming predominantly works in the field of hot extrusion and cold forging. The objectives cover fundamental research on the processes mentioned as well as the new and further development of process variants (see figure). Fundamental research in the field of hot extrusion currently focuses on the occurrence of undesired longitudinal press seams during the process. In the field of cold forging the Bauschinger effect, which can occur during a stress reversal, as well as the influence of damage on the component performance are investigated. Motivated by lightweight strategies, the production of hybrid components is a pivotal issue with regard to new and further process developments. Composite extrusion, for instance, offers the possibility of a continuous embedding of high-strength steel wires, shape memory wires, or electrical conductors in lightweight profiles. Due to the hot extrusion of consolidated aluminum chips ecological aspects are considered. The process combination of deep drawing and cold forging as well as composite cold forging allows a targeted reinforcement and a weight reduction of the components.

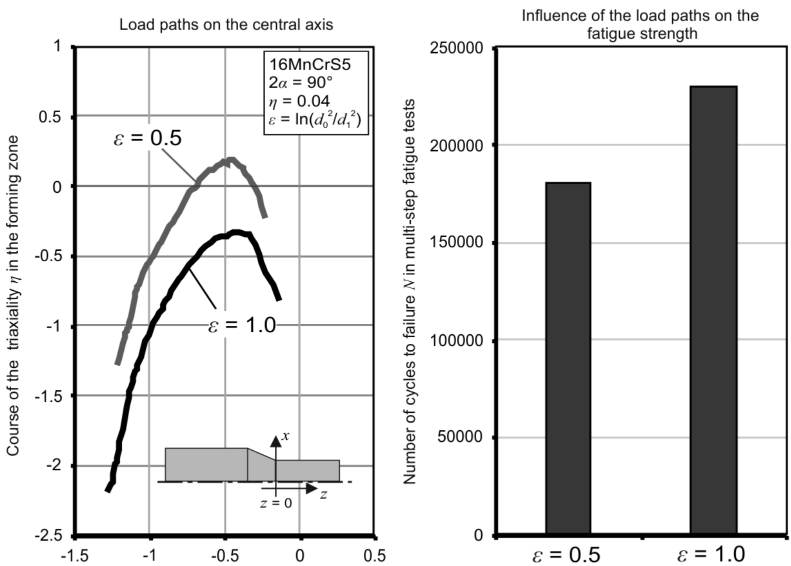


Research focuses of the department of bulk metal forming

2.3.1 Influencing the Evolution of Damage in Cold Extrusion

Funding	German Research Foundation (DFG)
Project	CRC/TRR188 • Subproject A02
Contact	Oliver Hering M. Sc.

The properties of cold forged components are a consequence 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 separated influence of damage development in cold forging to allow a production of extruded components with defined, load-adapted performance. Therefore, it is investigated to what extent the load path can be affected in forward rod extrusion. This is analyzed by the example of forward rod extrusion with 16MnCrS5 semi-finished parts. 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 is examined. The damage caused by different load paths is determined by microscopy techniques. The performance, which varies as a result of damage, is investigated by means of measurements of the Young's modulus, the impact energy, and the number of cycles to failure in fatigue tests (see figure).

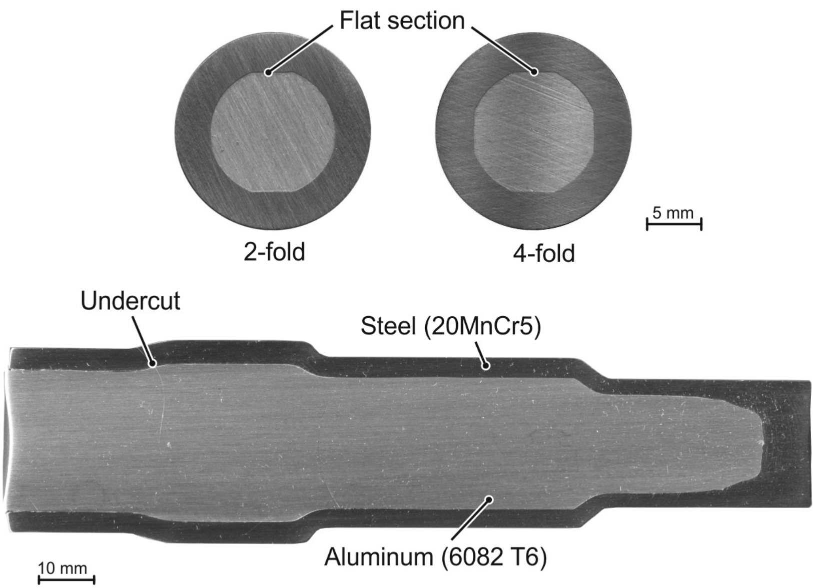


Load path due to different strains and influence on fatigue strength

2.3.2 Composite Cold Forging of Cold Forged Semi-Finished Parts

Funding	German Research Foundation (DFG)
Project	TE 508/54-1
Contact	Christoph Dahnke M. Sc.
Status	Completed

For the manufacturing of composite shafts hybrid raw parts have been processed by forward rod extrusion at room temperature. The resource-efficient raw parts consist of a steel cup produced by backward cup extrusion, in which a light metal core is inserted. Experimentally and analytically, it could be shown that due to a processing by forward rod extrusion a force fit in steel-aluminum shafts can be achieved. The force fit is caused by the different elastic spring-back of the aluminum core and the steel sleeve. Results of push-out tests show that the generation of a metallurgical bond is not achievable. However, torsion tests show that minor concentricity deviations lead to a form fit and, as a result, to an increase of the bonding strength. For this reason, the targeted design of a form fit has also been investigated. The bonding strength can be increased due to a micro form fit by the generation of a structured contact surface as well as a macro form fit caused by undercuts or oval cross sections of the core (see figure).

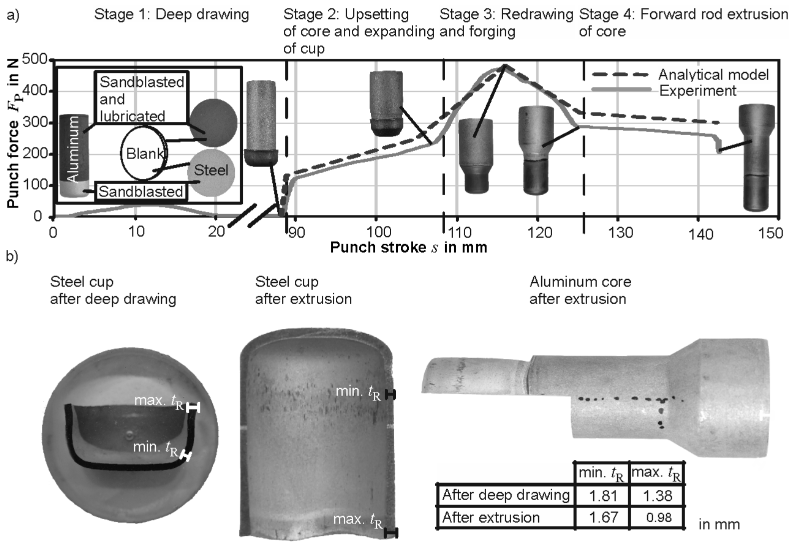


Macro form fit in composite shafts

2.3.3 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, developed and patented at the IUL, allows the production of light composite components out of a steel blank and a cylindrical aluminium core. In experimental investigations four process stages can be determined due to the interruption of the process and the ejection of the component at characteristic areas of the force-stroke curve of the punch. The analytical characterization of these process stages shows a good correlation with the experimental results (see figure a). Regarding the bonding type, a combination of a form and a force fit could be determined. The force fit is caused by the different elastic springback of the sleeve and the core. The form fit in axial direction results from the increased thickness of the blank t_R in the edge area (see figure b). Additionally, a form fit in peripheral direction is caused by the earing of the steel cup due to the anisotropic material behavior.



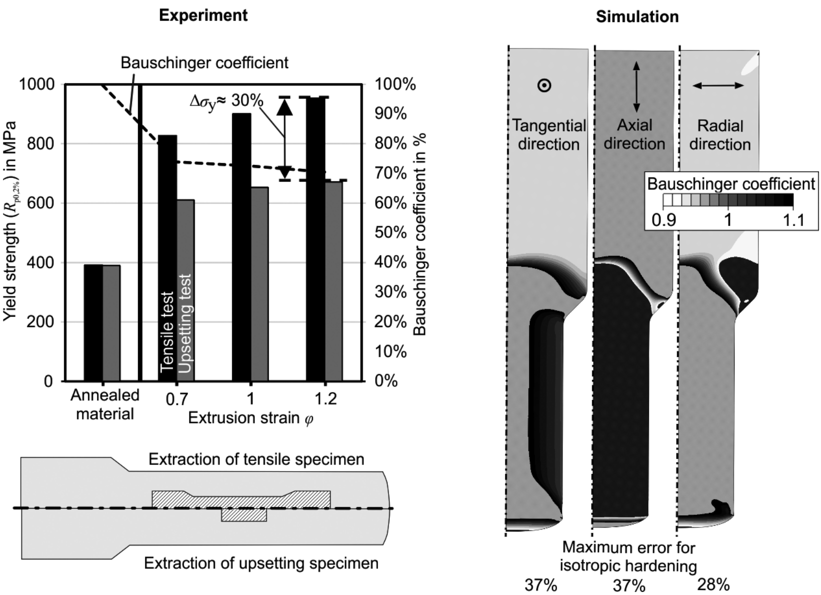
	min. t_R	max. t_R
After deep drawing	1.81	1.38
After extrusion	1.67	0.98

a) Punch-force punch-stroke curve, b) Form fit due to a varying local change of the sheet thickness

2.3.4 Prediction of Local Product Properties in FEM Forming Simulations

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

The goal of this subproject of the research project “Massiver Leichtbau” (massive lightweight construction) was the exact prediction of an exemplary process chain regarding the resulting local product properties of the produced parts. For this, the sequence of cold forging (IUL), machining (ISF, TU Dortmund University), and structural simulation (IFU, University of Stuttgart) was considered. In the field of cold forging, the focus was on the direction-dependence of the local strength, caused by the Bauschinger. By means of forward extrusion tests the influence of the Bauschinger effect was proven experimentally by conducting tensile and upsetting tests on specimens pre-strained by extrusion (see figure). In order to increase the quality of the prediction, numerous isotropic-kinematic hardening models were compared. The consideration of kinematic hardening leads to a drastic improvement of the local strength and residual stresses, which is a requirement for a comprehensive process design regarding the identification of lightweight potentials.

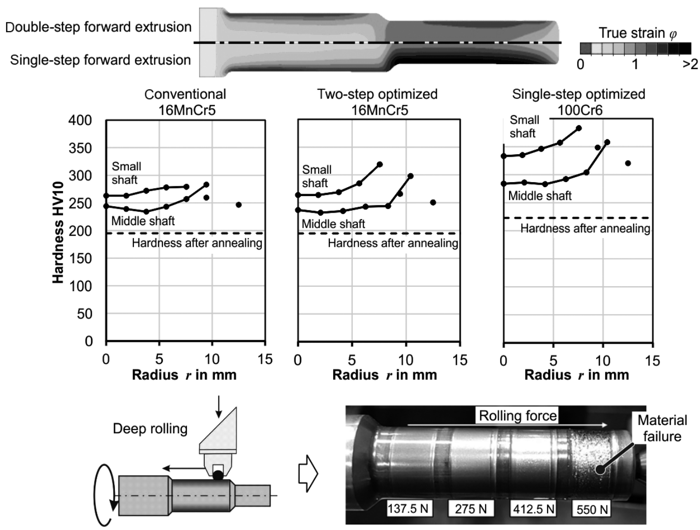


Influence of the Bauschinger effect on the local strength and resulting Bauschinger coefficient in cold forged parts

2.3.5 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

The target of this subproject of the research initiative “Massiver Leichtbau” (massive lightweight construction) was the production of gear shafts with optimized surface properties by cold forging. The research was conducted in collaboration with IFU Stuttgart and IFUM Hannover. Based on numerical simulations of single and multi-step forward extrusion, the local strains in the surface region of the shafts and, thus, the resulting increase in strength due to cold working were optimized (see figure). The main question was whether typical heat treatment processes can by partly or fully substituted. It was found that the hardness increase of appropriate heat treatments like case hardening cannot be reached by cold forging only, however, the hardness reached by quenching and tempering can be accomplished or even be exceeded. As an additional option to increase surface hardness, the incremental forming process deep rolling was investigated. While heat-treated shafts can be further improved by deep rolling, cold extruded material does not possess the necessary formability, leading to a process failure.

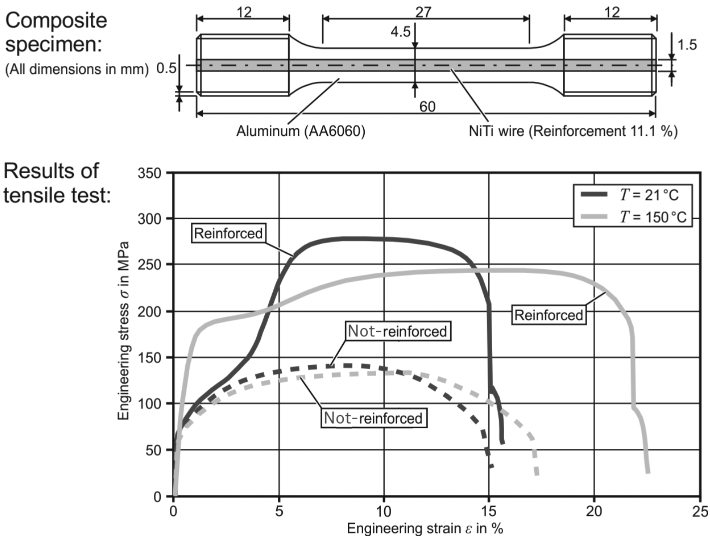


Maximizing surface hardness by optimized forward extrusion and deep rolling

2.3.6 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.

Composite extrusion allows the continuous embedding of wire into aluminum profiles. Shape-memory-alloys are currently used as reinforcing material in the project. Due to the shape-memory effect an actuator function can be generated in the extruded composite profile. Furthermore, a positive influence on the mechanical properties can be observed. Tensile tests on reinforced composite specimens (see figure), which have been carried out in cooperation with the IAM-WK of the Karlsruhe Institute of Technology (KIT), show an increased ultimate tensile strength as well as an increased fracture strain. As a result, the energy absorption capacity can be significantly increased. Due to the phase transformation of the NiTi wires the response of the composite material depends on the temperature. If the temperature is increased over the A_f-temperature of the shape memory alloy, the martensitic phase of the embedded NiTi wire changes into the austenitic phase which possesses a higher strength. As a result, the yield strength of the composite is increased. However, as the flow stress of the matrix material is decreased at elevated temperatures, the ultimate strength is lower than at room temperature.

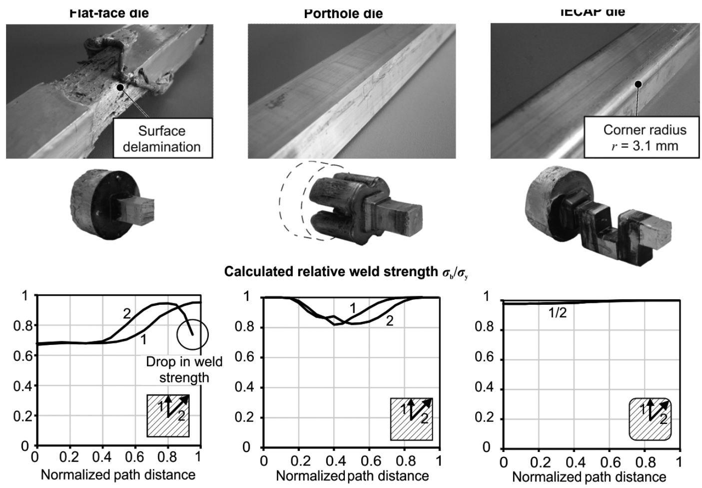


Representative stress-strain curves of reinforced and not-reinforced tensile specimens at different temperatures

2.3.7 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.
Status	Completed

In collaboration with the WPT (TU Dortmund University) the direct hot extrusion of aluminium chips was investigated. On the basis of a physically motivated weld model by Cooper and Allwood (2014), a weld model for the prediction of the process success of hot extrusion of aluminium chips was derived. The model takes all relevant process parameters (die design, extrusion ratio etc.) into account. It was adjusted by consideration of numerous literature studies regarding chip extrusion. Additional extrusion tests were carried out for a further validation of the weld model. For this, the process limits of chip extrusion were explored in detail for a typical chip type of AA6060 factors. It was shown that the model allows for a prediction of the local weld quality and, thus, for a targeted and cost-efficient optimization of the process parameters for the production of defect-free chip-based profiles (see figure). Furthermore, the influence of the heat treatment strategy on the mechanical properties of the produced profiles was investigated. It was found that the heat treatment parameters from conventional cast-based profiles can be directly utilized to improve the mechanical properties of chip-based profiles.

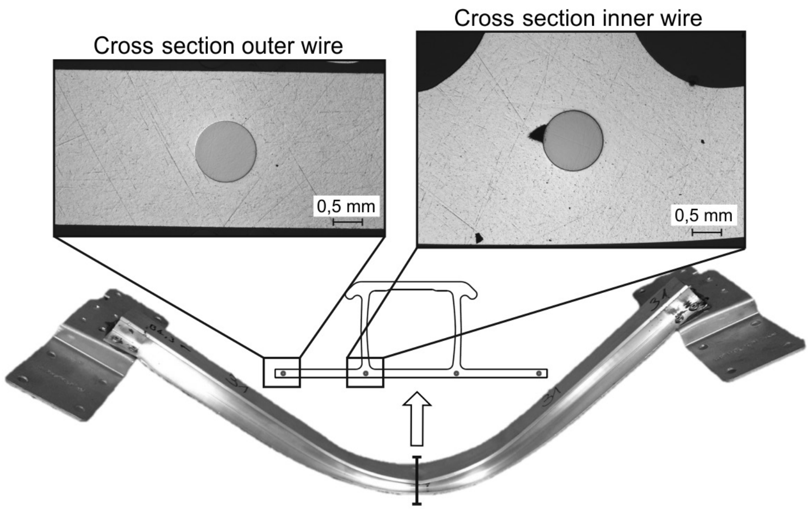


Application of weld model for the prediction of the process success in direct hot extrusion of aluminium chips

2.3.8 Production of Aluminum Profiles with Continuous Reinforcement

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

In this project the composite extrusion process was investigated for industrial applications. The resulting requirements such as complex profile geometry, limited assembly space, and poor accessibility of the extrusion presses and dies and the demand for high productivity were to be considered. Together with the industrial partners a side impact beam was designed as a composite profile with reinforcing wires made of steel and shape-memory-alloy. The corresponding tool was conceptualized, analyzed with the help of the advanced simulation software, and experimentally tested. The reinforcing wires were successfully embedded in the aluminium matrix and the influence of subsequent process steps was analyzed. With the aim of increasing the mechanical properties of the composite profiles, the profiles were subjected to performance tests. However, it has been found that under high bending loads the wires detach from the aluminum matrix and no improvement in performance could be achieved due to the low amount of reinforcing elements in the profile.

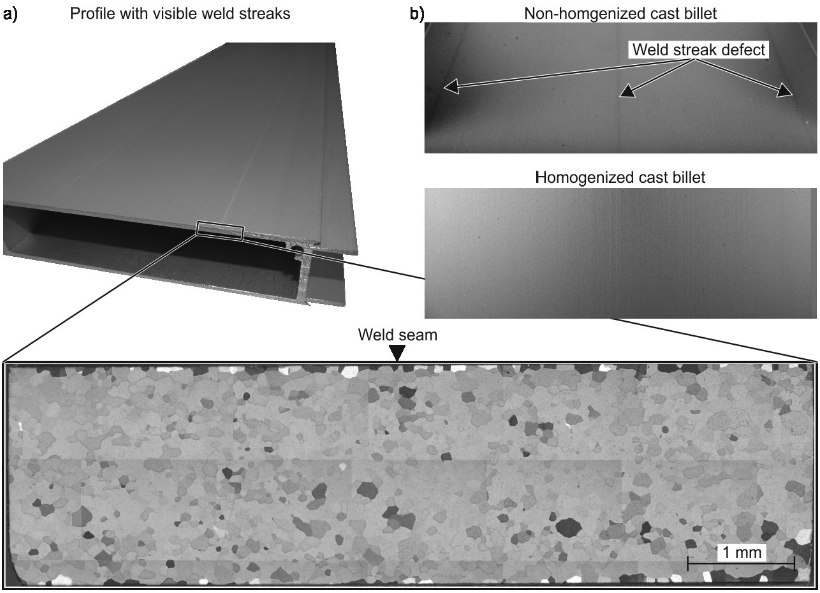


Light microscope images of the embedded reinforcing wires of a tested profile

2.3.9 Prevention of Longitudinal Weld Streak Defects on Anodized Aluminum Profiles

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

Anodized profiles are widely used as visual components. A common defect is the occurrence of longitudinal weld streaks on the surface, which depend on the whole process chain from casting of the billets to anodization of the extruded profiles. In cooperation with the companies of the industrial advisory board Hueck, Gerhardi Alutechnik, HMT Höfer Metall Technik, and Wilke Werkzeugbau, an extrusion die with the purpose of provoking weld streaks has been designed and used in the industrial facilities. The microstructure plays an important role and is examined by the IAM-WK of Karlsruhe Institute of Technology (KIT), using light and electron microscopy. Since the weld line cannot be traced with optical microscopy of the microstructure (see figure a), EBSD measurements will be used in a further approach. So far, weld streaks can only be assessed quantitatively by visual control. One important factor is the quality of the cast billets. The usage of non-homogenized billets shows visible weld lines while homogenized billets lead to no defect (see figure b).

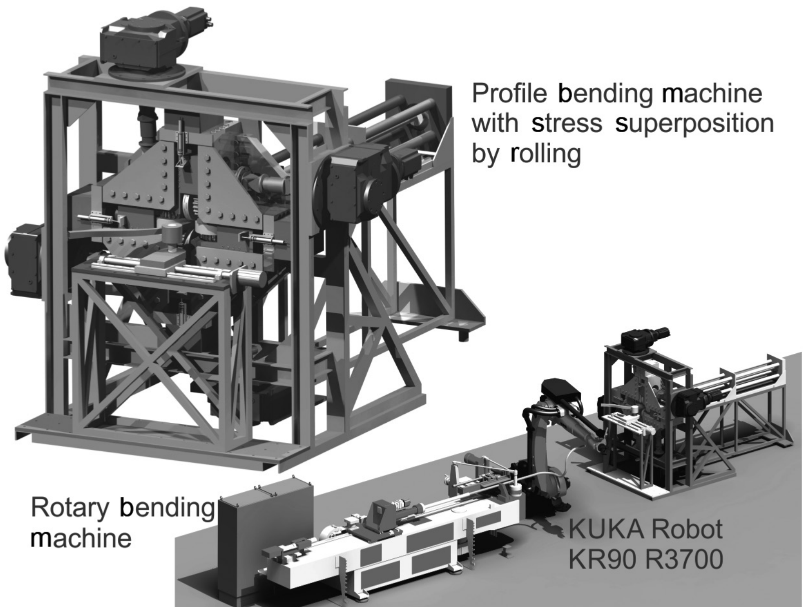


a) Microstructure at the weld seam, b) Influence of homogenization

2.4 Department of Profile and Sheet Metal Forming

Head Dr.-Ing. Christian Löbbe

The new department of profile and sheet metal forming includes the technologies for tube, profile, and sheet metal bending, the processes for further profile forming steps, and sheet metal forming such as deep drawing and shear cutting. The focus is on the process analysis of conventional and new processes, the development of processes through methods such as stress superposition and heat assistance as well as the development of completely new processes. In this context, e. g. the processes of incremental profile forming and wire winding of non-circular bobbins were investigated. Also sheet bending at elevated temperatures as well as with stress superposition have been realized and studied in order to adapt properties during forming and in the final product. In addition, incremental tube forming and tube forming by means of granular media have been adapted through advanced tooling methods to expand the process limits. Finally, the development of an automated bending cell was started which contains, amongst others, a patented profile bending machine with stress superposition (see figure).

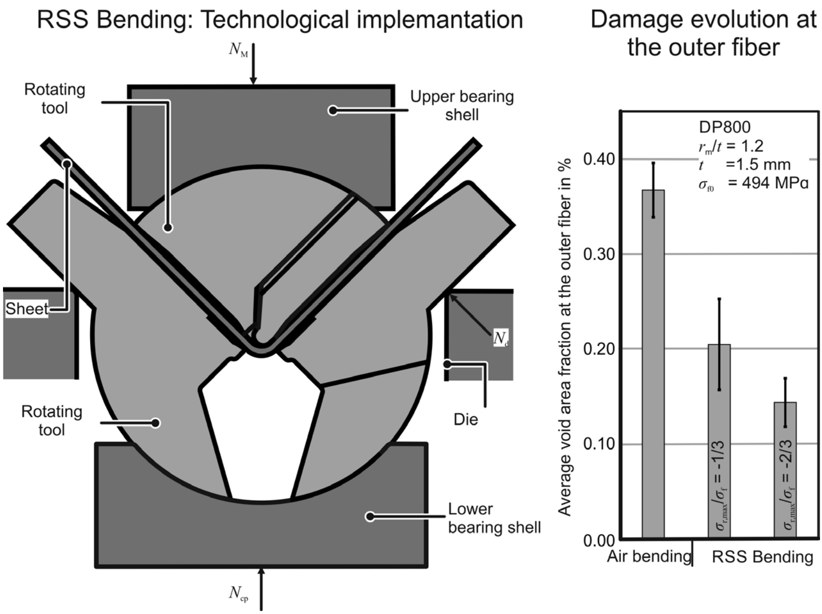


Planned automated bending cell and patented profile bending machine

2.4.1 Damage in Sheet Metal Bending of Lightweight Profiles

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

Profiles made of high-strength and ultra-high-strength steel materials are often produced by classic bending processes such as air and die bending. Characteristic for these bending processes is the inhomogeneous plastic strain distribution over the sheet thickness. The performance of bent components in use is determined by the strain hardening, the residual stresses, and the damage evolution. Damage develops at the outer tensile fibers depending on the loading condition during the plastic deformation. In order to influence the load path during bending, stress superposition must be used since conventional process parameters do not lead to a change in the stress state. For compressive stress superposition during bending a new bending process is being developed. The so-called bending with radial stress superposition (RSS bending) is able to initiate predetermined and controlled compressive stresses during bending. This leads to a delayed damage development (see figure) and, thus, to increased performance.

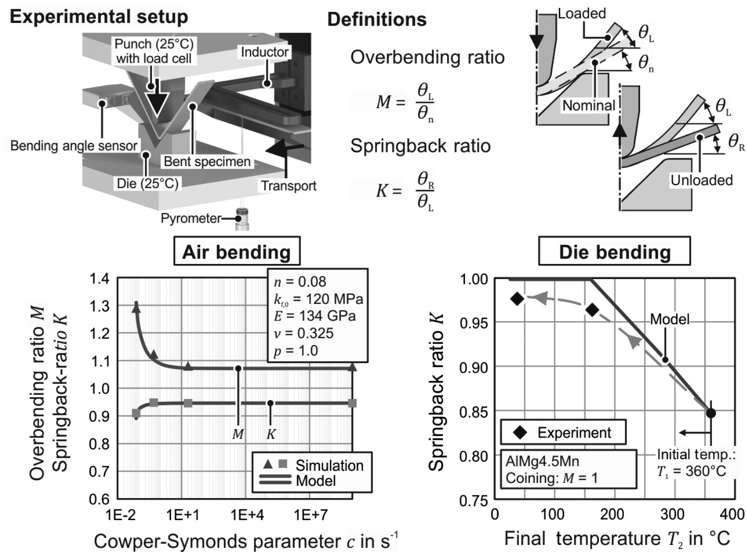


Influence of RSS bending on the damage evolution

2.4.2 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	Dr.-Ing. Christian Löbbe
Status	Completed

In order to model sheet metal bending at elevated temperatures, a process description was developed according to an experimental study. The analysis finally reveals two different models for the two process variants air and die bending. In the air bending process a closed solution of the bending line in an isothermal state is not possible when a non-linear elasto-viscoplastic material behavior is taken into account. Thus, the derived semi-analytical approach is based on the discretization along the curved line. The figure exemplarily shows overbending and springback-ratios in relation to the Cowper-Symonds parameter c compared to the FEM simulation. In addition, the die bending process was investigated for different process parameters. For a given component geometry during coining the changing elastic, plastic, and thermal strains during cooling were covered by an analytical approach which allows a qualitative description of the springback ratio (see figure).

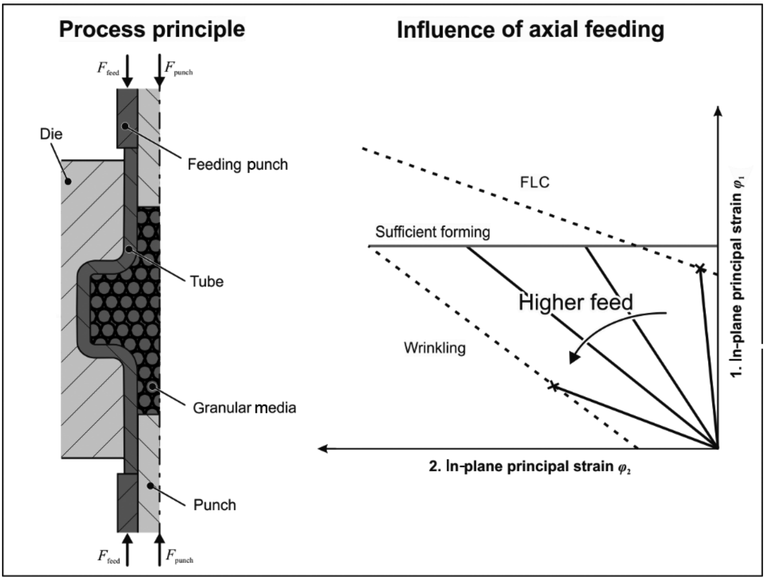


Analysis and description of the bending angle deviation after bending at elevated temperatures

2.4.3 Granular Media-Based Tube Press Hardening

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

Together with DLR (German Aerospace Center), the suitability of granular media as a forming medium for tube expansion at elevated temperatures is investigated in this project. The process is an alternative for the production of high-strength hollow profile parts through a combined forming and quenching in one tool. Due to its high compressive strength and temperature resistance zirconium dioxide is particularly suitable as a forming medium. The force transmission behavior between individual granules, the sheet, and the medium lead to a complex interaction in the tool. For the process development the procedure was analyzed using a thermo-mechanically coupled FE model and an active axial feeding axis has been added to the process. Through the feeding axis the component thickness can be adjusted and localized thinning can be prevented. Simultaneously, the reduced thinning leads to an improved formability. The effect of this measure is limited by the onset of wrinkling at high feed rates. With the aid of a newly developed tool the numerical results will be validated.

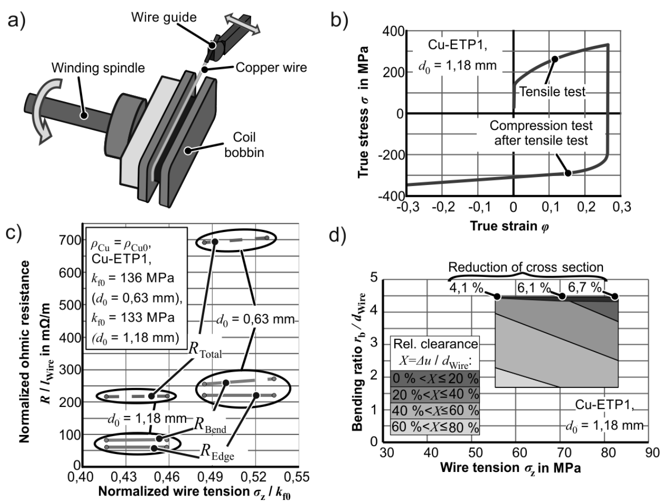


Increasing formability of tube components through axial feeding

2.4.4 Forming-Based Process Modeling of the Linear Winding Method

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

Due to the increasing importance of electromobility the linear winding of non-circular coil bobbins (see figure a) has been analyzed in cooperation with the Institute of Production Science (KIT). This was done considering the forming behavior of the copper wire: On the one hand, by the characterization of the plastic properties of the copper like the kinematic hardening (see figure b). On the other hand, by the examination of the bending process at the edge of the coil bobbin on the basis of essential influencing parameters. The tension superposed bending of the round wire results in a reduction of the cross section (flattening) in comparison to the area of the edges. Consequently, the ohmic resistance is increased and the efficiency of the electric motor is reduced (see figure c). The change in cross section contradicts the development of the clearance between wire and bobbin (see figure d). By means of the conducted examinations it was shown within which limits the process can be performed – under consideration of the influencing parameters in relation to the filling factor (see figure d).

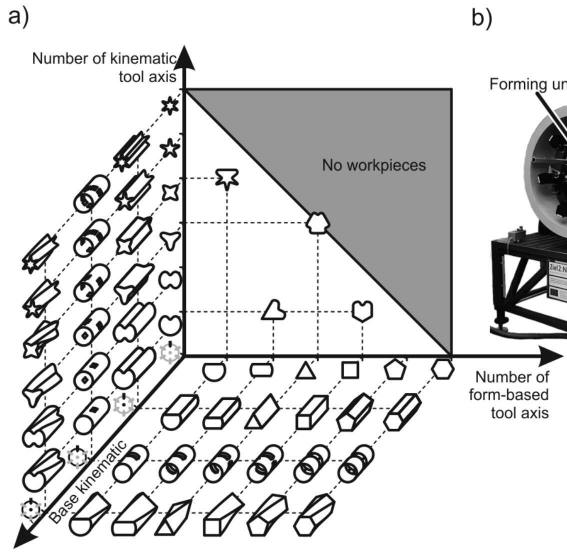


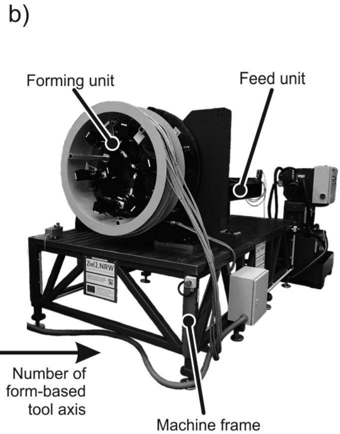
a) Process principle, b) Material characterization, c) Resistance of a coil winding, d) Clearance development

2.4.5 Fundamentals of Incremental Profile Forming

Funding	German Research Foundation (DFG)
Project	BE 5196/3-1
Contact	Dr.-Ing. Christian Löbbe
Status	Completed

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 (see figure b). The high flexibility of this process is represented by the large variety of manufactured parts (see figure a). A minimum number of 108 producible geometrical elements has been identified. They are manufactured in a kinematic, form-based as well as in a combined way of deformation. The most possibilities of deformation are achieved by the kinematic deformation. Thus, the two basic processes of radial indentation and axial drawing were examined fundamentally. A strain-based process model for the prediction of the present deformation and the resulting reduction of wall thickness during radial indentation was developed. Furthermore, a model for the calculation of the maximum effective forming force was developed and validated numerically and experimentally.



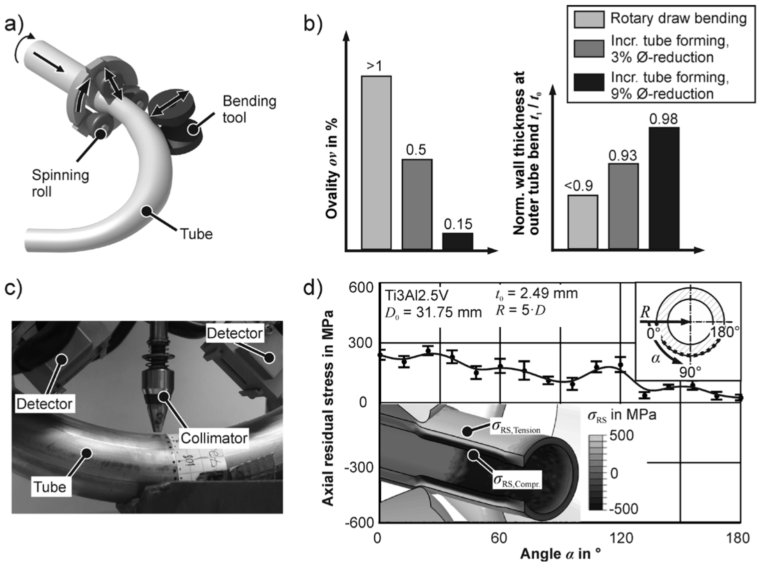


a) Variety of manufactured parts, b) Machine

2.4.6 Freeform Bending of Aviation-Relevant Tubular Parts

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

In cooperation with PFW Aerospace GmbH, Incremental Tube Forming (ITF) is qualified for the production of aviation-compatible tube structures made of titanium and titanium alloys. Incremental tube forming (see figure a) as a freeform bending process is very flexible so that the setup effort is low in comparison to conventional rotary draw bending, which is beneficial for small lot sizes such as in aviation.
It is shown that the ovality and wall thinning of the outer tube bend is lower in incremental tube forming than in conventional rotary draw bending (see figure b). In addition, in a test setup (see figure c) the residual stresses are determined by means of x-ray diffraction on the outer surface of a bent tube and their distribution over the wall thickness is calculated with thermo-mechanical simulations (see figure d). The compensation of the residual stresses does not take place completely over the circumference, but partly over the wall thickness. It creates residual compressive stresses on the inner tube wall increasing the fatigue strength in tubes subjected to internal pressure.



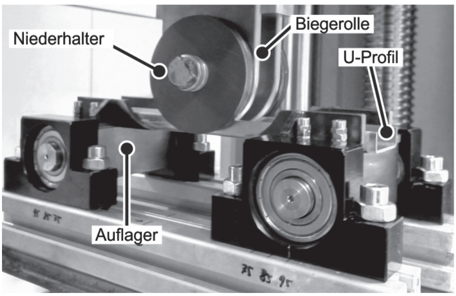
a) Process principle, b) Ovality and wall thickness, c) Test setup, d) Residual stress at ITF

2.4.7 Development of a Technology for Bending U-Profiles

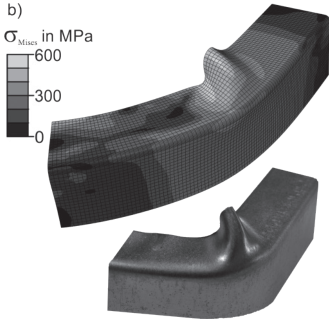
Funding BMWi/ZIM-ZF
Project ZF4101104US6
Contact Johannes Gebhard M. Sc.

Bending of metal profiles is currently restricted to high bending radii and, therefore, bent products are limited to spacious constructions. The failures that limit the bending radius are wrinkling at the profile walls and cracks. In cooperation with the company FLORA GmbH & Co. KG, a technology has been developed to bend U-profiles with small bending radii. The used three-point-bending process is investigated analytically, numerically, and experimentally and has been developed to a modular roller-bending device with additional blankholder (see figure a). The blankholder supports the profile walls at the roller and can be used with constant holding force or with a fixed distance to the roller. Reliant on the setup of the blankholder, wrinkling can not entirely be prevented because the profile wall does not move uniformly in the gap between roller and holder (see figure b). Dependent on blankholder force or distance, width and height of the profile and bending radius, the process limits can be determined.

a)



b)

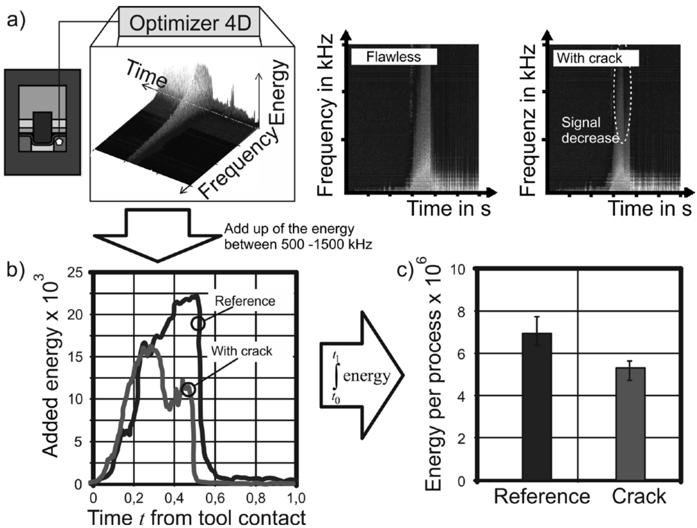


a) Bending device, b) Comparison of experimental and numerical results

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

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

The aim of this project is the determination of potentials of acoustic sensors for condition monitoring of hot stamping processes. To identify the acoustic sources, experiments were performed initially on a laboratory scale. Friction, hot forming, and phase transformations were examined separately. The comparison with signals from a press hardening process enabled the classification and filtering of the signals. For example, friction was identified as the dominant signal source during the forming process. Occurring cracks with specific characteristics resulted in a stagnant relative movement, causing a detectable signal decrease (see figure a). The summation and integration of relevant energy values enabled to set potential variable limits for the automated condition monitoring (see figure b). Thus, the project created a general understanding of the emergence of acoustic signals that occur through the various process phenomena. Furthermore, this basis can be used for quality assurance in process monitoring.

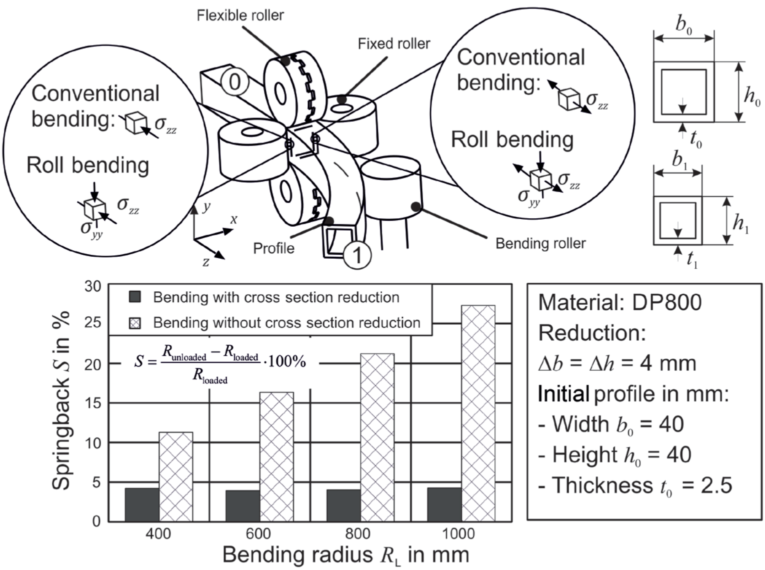


a) Recorded acoustic signal in a hot stamping process, b) Calculation at the detection of cracks

2.4.9 Development of a Profile Bending Process with Compressive Stress Superposition by Rolling

Funding	LeitmarktAgentur.NRW
Project	EFRE-0400139
Contact	Juri Martschin M. Sc.

As part of this NRW patent validation, a process is developed that enables profile bending with compressive stress superposition. The stress superposition is realized by the combination of flexible and fixed rollers (see figure). The unique feature of the process, compared to conventional profile bending processes with stress superposition, is the closed roll gap to build up an even pressure.
Numerical simulations show a significant reduction of the bending force when working with a contemporaneous cross section reduction. The direct relation to the springback also reduces the shape deviation significantly (see figure). The cause can be attributed to the shift of the yield curve to more favorable bending stresses. The aspired use of a special roll stand in combination with a mandrel system will provide the possibility to change the profile cross section over the longitudinal axis. This allows to produce load-adapted profiles with versatile contours.

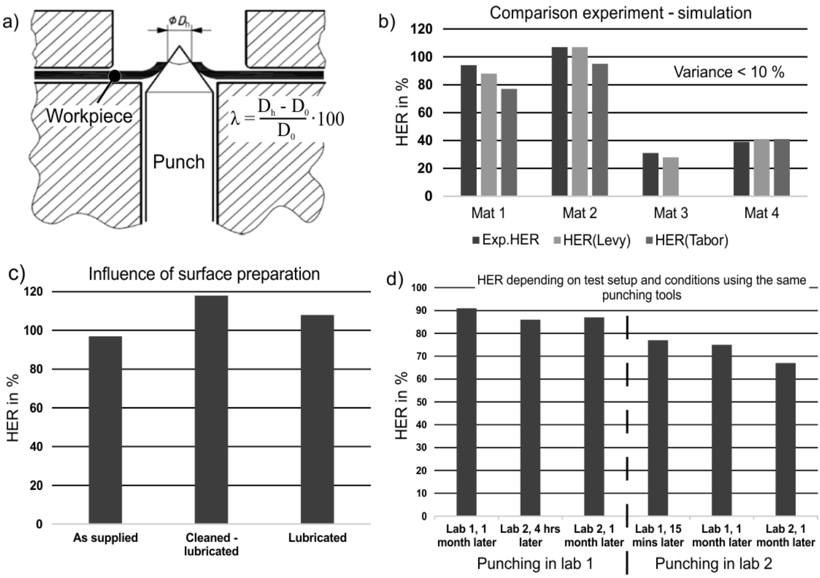


Springback S over the radius R_L with and without cross section reduction based on FEM simulations

2.4.10 Influence of the Cut Edge on the Formability of Steel

Funding ReCIMP
Contact Dr.-Ing. Christian Löbbe

The sensitivity of sheared Advanced High-Strength Steels (AHSS) to fail at the sheared edge is a critical problem for the automotive industry. The problem is exacerbated by the fact that this edge failure can not be predicted by conventional methods. To understand the edge formability of AHSS under different edge preparation conditions, the hole expansion ratio λ (HER), a measure of the engineering strain obtained by a ISO 16630 Hole Expansion Test (HET) (see figure a) is used as a comparison tool. Comparing sheared edges, 15 % cutting clearance provided the best HER. The strain induced during the shearing operation plays a key role in the subsequent reduced formability. This strain, if calculated from the hardness values at the cut edge using hardness to stress conversion rules, such as Levy, Tabor etc., and mapped onto the edge of the blank in the forming simulation allows for an accurate prediction of edge failure (see figure b). However, it is observed that the HET results are highly sensitive to the testing apparatus and conditions being used and it is essential to make the process more robust (see figure c-d).

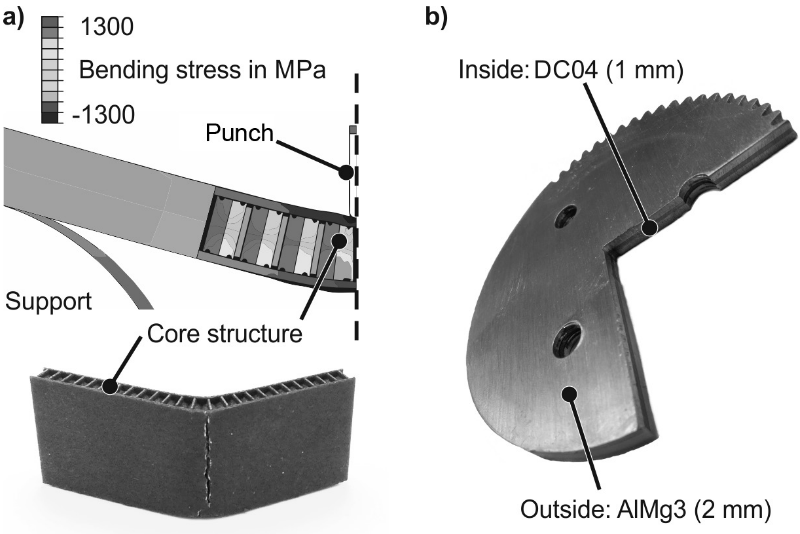


a) Schematic of ISO HET, b) Accuracy of numerical simulations, c-d) Influence of test setup and conditions

2.5 Department of Non-Conventional Processes

Head Marlon Hahn M. Sc.

The research activities of the department of non-conventional processes focus on technologies which offer distinct advantages such as extended process limits. These processes are either very new or so complex in nature that they have not yet been widely applied in industry. Current topics are forming with high strain rates, joining by forming, incremental forming, and forming of hybrid or novel semi-finished products. In the latter case, e.g. the forming behavior of additively manufactured (AM) sandwich sheets with complex core structures for lightweight design is investigated (see figure a). A technological innovation is realized through the combination of joining by forming and incremental sheet bulk-metal forming. This way, a stack of different sheets can be joined to one hybrid part with locally adjusted properties (see figure b). Within all fields of activities both numerical and analytical methods as well as up-to-date measuring techniques are used and permanently enhanced for an in-depth process analysis.

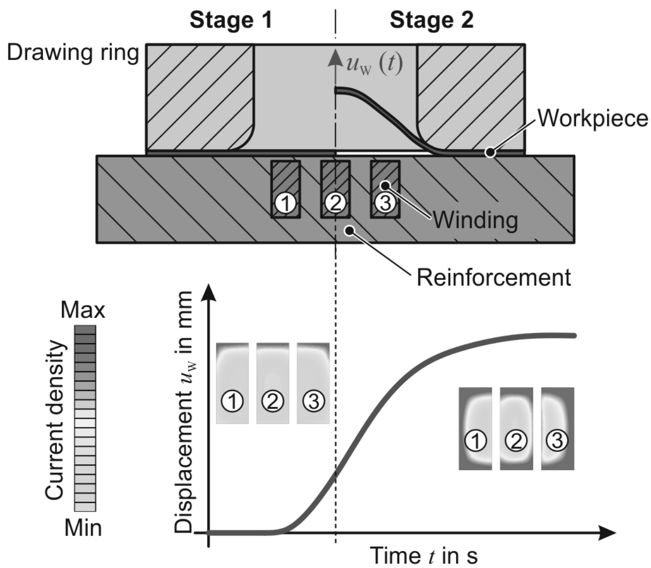


Examplary non-conventional processes: a) Bending of AM sheets, b) Hybrid sheet-bulk-formed part

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

Funding	German Research Foundation (DFG)
Project	TE 508/51-2
Contact	Siddhant Prakash Goyal M. Sc.

In the second funding period of this project, which is carried out together with the Institute of Machine Tools and Factory Management of TU Berlin, research focuses on the further development of scan-strategies and tools for the process design for electromagnetic forming. To expediently make use of the increased design freedom in additive manufacturing with regard to electromagnetic sheet metal forming, especially the thermomechanical loading of multi-turn coils needs to be investigated and described physically (see figure). In this context, a stronger separation of the functions of current conduction and mechanical support is pursued in the additive manufacturing and design of hybrid working coils. As a consequence, this will enhance the possibilities of local current concentration while at the same time reducing the risk of plastically deforming the current-carrying layer of the coil. These aspects are of particular interest when parts having a more complicated final geometry are to be formed electromagnetically.

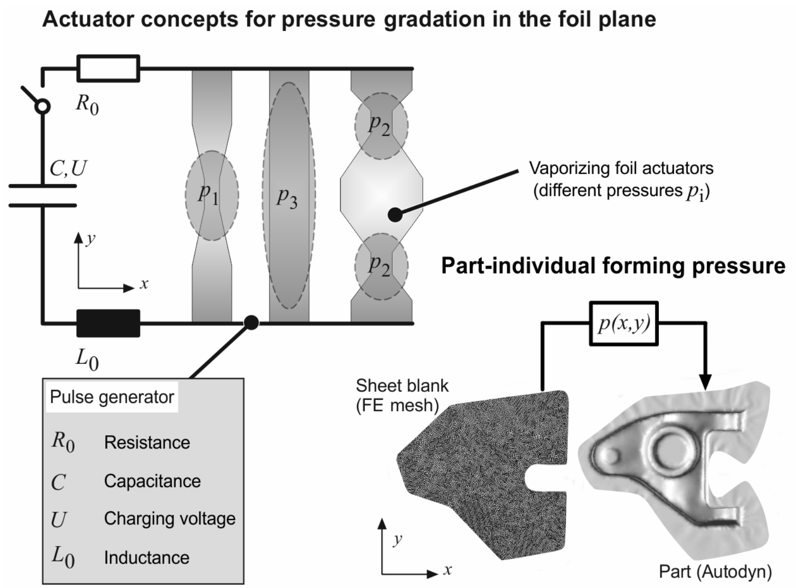


Thermal-electric loading of a multi-turn coil by ohmic heating

2.5.2 Forming by Locally Varying Vaporizing Actuators

Funding	German Research Foundation (DFG)
Project	TE 508/69-1
Contact	Marlon Hahn M. Sc.

A thin metal foil can be vaporized by an intense current generated through a rapid capacitor bank discharge (called vaporizing actuator). The pressure evolving during such a resistive heating can be used to impulsively form a sheet metal blank, for example. Thus, the foil serves as a flexible disposable forming tool. The aim of the research project is to provide predetermined pressure distributions for a part-indiviual process design (see figure). For this, a process model has to be developed to be able to deduce the required actuator concept and process parameters. The chosen modeling approach consists of two sequential steps. First, the electrical energy deposition is modeled taking into account the foil geometry, circuit schematic, and discharge characteristics of the actuators. In the second step, on the basis of the previously determined energy distribution, the mechanical interaction between the expanding foil actuator, an elastomer as forming medium, and the workpiece is analyzed.

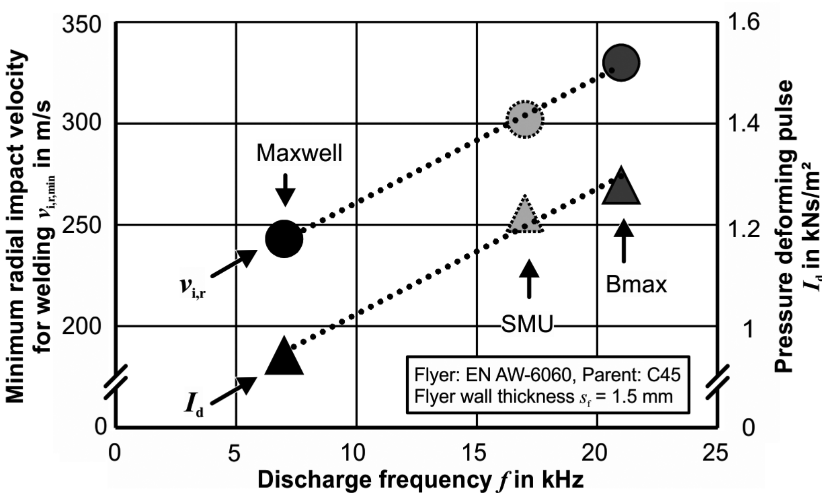


Forming by foil vaporization with adjusted pressure distribution

2.5.3 Magnetic Pulse Welding: Targeted Manipulation of Weld Seam Formation

Funding German Research Foundation (DFG)
Project TE 508/39-3 (SPP 1640 • Subproject A1)
Contact Dr.-Ing. Dipl.-Wirt.-Ing. Jörn Lueg-Althoff

Within the scope of the project cooperation with the Institute of Manufacturing Science and Engineering at Technische Universität Dresden, different pulse generators and tool coils are used for magnetic pulse welding (MPW) of aluminum tubes and steel cylinders. It can be seen that the minimum radial impact velocities $v_{i,r}$ for otherwise identical experimental configurations strongly depend on the discharge frequency of the applied pulse generator (see figure). The reason for this is a different deformation and collision behavior. Small collision angles which are favorable for the activation of the surfaces to be joined can already be achieved at low discharge frequencies with lower radial impact velocities. During the collision of the joining partners an impact pressure acts with a distinct amplitude and duration. The time integral of this pressure is defined as the pressure deforming pulse I_d and can be used for the comparison of different MPW setups. A specific minimum value I_d can be identified which must be achieved for a complete weld seam around the circumference of the samples.

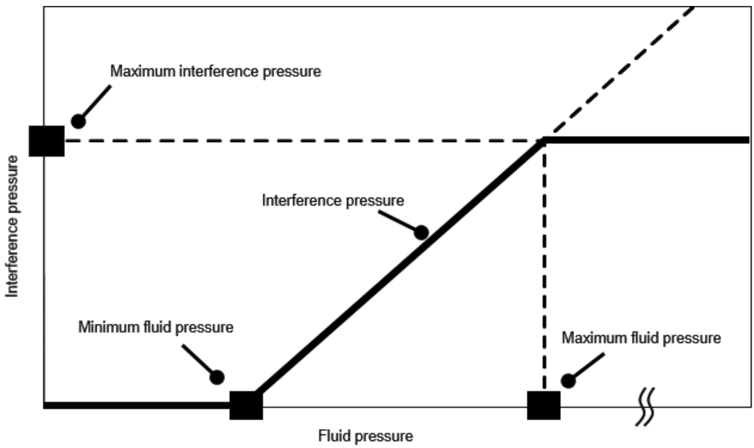


Required impact velocity and pressure deforming pulse for welds with different pulse generators

2.5.4 Joining by Die-Less Hydroforming with Outer Pressurization

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

The aim of this knowledge transfer project is to extend the process limits of joining by inner pressurization by reversing the forming direction (outer pressurization). Current investigations include the analytical derivation of a process window. Based on the plastic deformation of the outer joining partner, the elastic springback of the inner joining partner is restricted. This causes an interference pressure in the joining zone. The model enables the calculation of a minimum fluid pressure at which a force-fit joint occurs. Moreover, the calculation of a maximum fluid pressure is possible. This calculation indicates that no significant increase in the interference pressure can be observed. Besides the experimental validation of the analytical model, the numerical analysis of further process parameters as well as the influence of form-fit elements on the interference pressure are essential components of upcoming investigations.

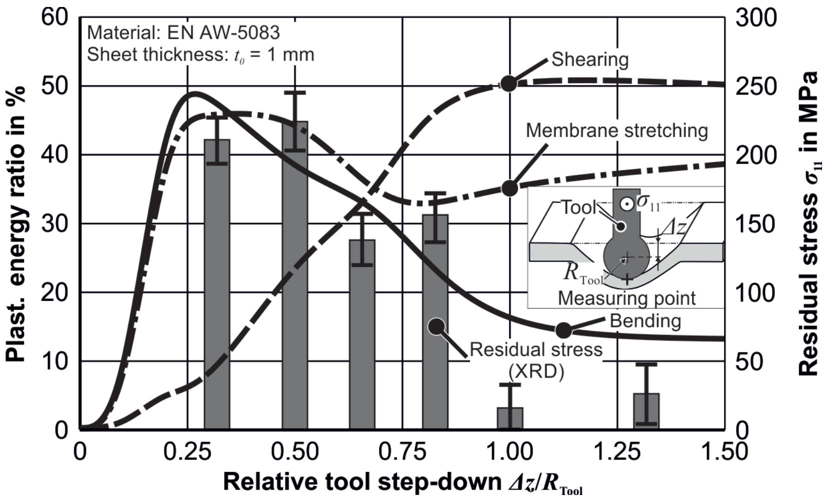


Analytically derived process window

2.5.5 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 (SPP 2013)
Contact	Fabian Maaß M. Sc.

Within the scope of the project cooperation with the Institute for Materials Science and Technology (Metallic Materials) of TU Berlin the relationship between the forming mechanisms shearing, bending, normal loading, and hydrostatic compression in Single Point Incremental Forming (SPIF) and the resulting residual stress state is analyzed. The aim of this research project is to improve the operational behavior of incrementally formed components by deliberately adjusting the residual stress state during the forming process. The residual stresses are induced locally and defined by adjusting the parameters of the incremental sheet metal forming process. The adjustment of the relative tool step-down (quotient of tool step-down Δz and tool radius R_{Tool}) influences the plastic energy fraction of each forming mechanism. This is correlated with the resulting residual stress state. It was found that particularly the bending mechanism intensifies tensile residual stresses on the tool-side.



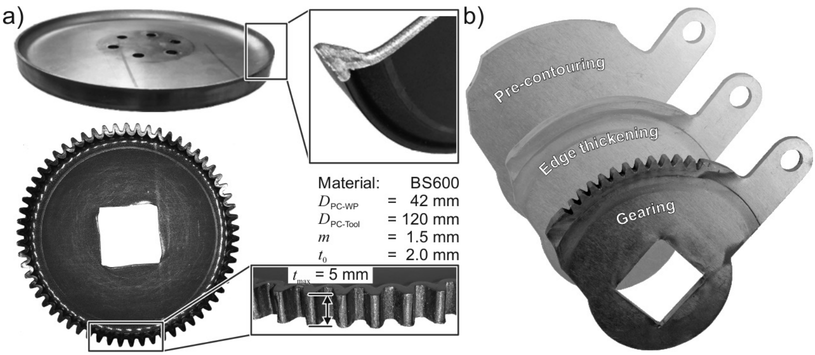
Resulting residual stress state as a function of forming mechanisms and relative tool step-down

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

Funding	AiF/FOSTA
Project	18663 N/P1064
Contact	Dr.-Ing. Peter Sieczkarek
Status	Completed

The objective of the research project was the production of industrially relevant functional components by means of incremental sheet-bulk metal forming (iSBMF). Different process routes for a defined edge thickening of blanks and a subsequent gear forming operation were investigated. Besides the targeted process acceleration for achieving economic cycle times, a major challenge was the maximization of the strain hardening and its adaptation for possible industrial applications by using materials with a pronounced strain hardening characteristic. A key aspect of the investigations was the determination and control of the conflict between the increased forming heat due to the process acceleration and the desired strain hardening at the gearing.

In addition to an economic production of rotationally symmetrical thickened and/or geared components by means of rotating tools (see figure a), iSBMF enables a very flexible and individual design of weight- and load-adapted asymmetric components (figure b). This feature can become beneficial due to an increasing product diversification.

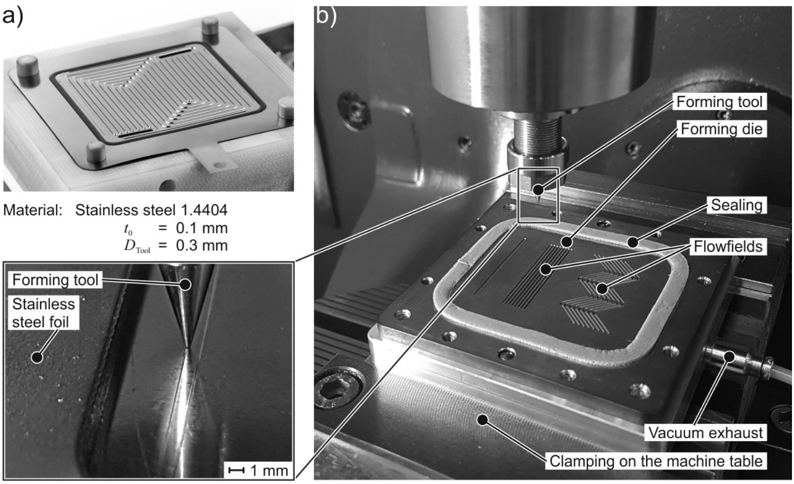


a) Rotationally symmetrical thickening and gearing, b) Asymmetric component (seat adjuster)

2.5.7 Prototyping of Metallic Bipolar Plates by Means of Inremental Micro-Forming

Funding	AiF/FOSTA
Project	14 EWN/P1247
Contact	Dr.-Ing. Peter Sieczkarek

Fuel cells offer a great potential for electromobility. So far, the production of the functional patterns of bipolar plates is performed by deep drawing or hydroforming in the development stage. Since the evaluation of the efficiency of the flowfields (see figure a) is done experimentally, the cost of the required tools represents a significant obstruction to innovation. The aim of the project is therefore the development of a cost-effective manufacturing process for the prototypical production of metallic bipolar plates from stainless steel foils (s_0 = 0.1 mm) by means of incremental forming. To minimize the friction between the tool and the foil, three different tool concepts were developed: a rigid (figure b), a rotating, and an oscillating one. In order to increase the contour accuracy of the flowfields, suitable process strategies are derived in the further course of the project. In cooperation with the Center for Fuel Cell Technology (ZBT GmbH, Duisburg) the testing of the operational behavior of the components represents the final focus of the investigations.

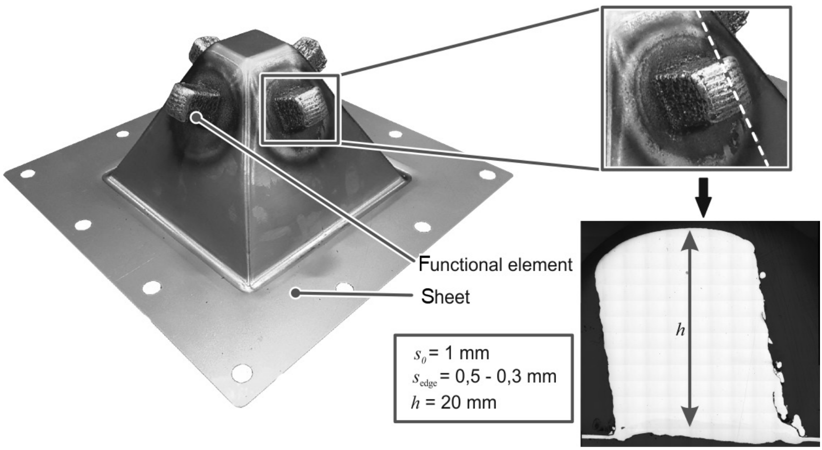


a) Bipolar plate, b) Experimental setup with rigid tool (opened, without stainless steel foil)

2.5.8 Process Combination of Incremental Sheet Forming and Laser Powder Deposition for Lightweight Manufacturing

Funding	German Research Foundation (DFG)
Project	TE 508/68-1
Contact	Lennart M. Tebaay M. Sc.

The project covers the combination of incremental sheet forming (ISF) and additive manufacturing (AM) by laser powder deposition to produce lightweight products (ISF) with functional elements (AM). Due to the integration of the tooling technology of incremental sheet forming into the milling and welding machine it is possible to manufacture specimens at one setting. The aim of this project is, i.a., the determinition of process boundaries. It is analyzed how the groove profile generated during ISF affects the welding process. Afterwards, the material compound is mechanically tested in order to characterize the weld connection. Based on the privous results, strategies for the ISF process can be deduced to receive an optimal preconditioning of the sheet for the subsequent additve process. Also, the tool path of the powder nozzle has to be studied because thermomechanical effects are likely to affect the part quality. Finally, the energy and resource-efficiency of the combined manufacturing process is evaluated.

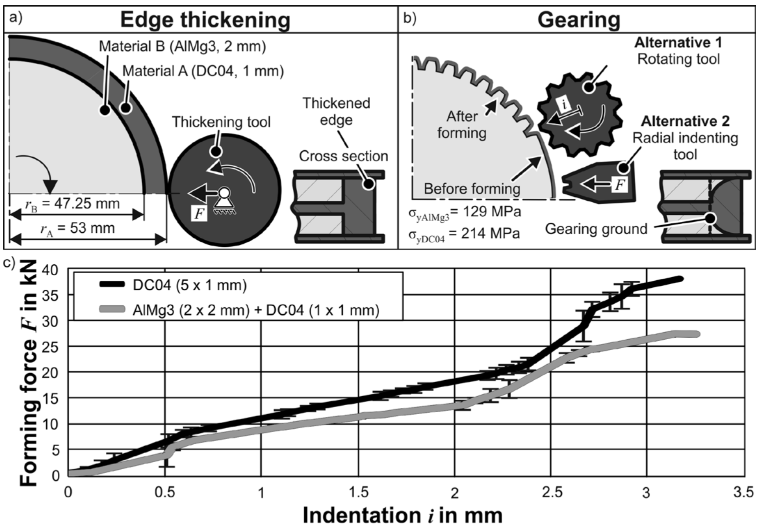


Demonstrator geometry (ISF) – pyramid and AM – cube

2.5.9 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	CRC/TR 73 • Subproject A4
Contact	Sebastian Wernicke M. Sc.

Within the subproject A4 of the Transregio 73 the main objective is the manufacturing of geometrically complex components from sheet metals with integrated functional elements by forming operations. With the incremental procedure the sheet is processed by means of a flexible arrangement of localized forming operations.
Current investigations focus on improving the mechanical property gradation through a hybridization of the components. A new process strategy has been developed where two metal sheets of lower density and strength surround a steel sheet having a higher strength. In the first step, the centered sheet is incrementally edge-thickened (figure a). Afterwards, the resulting bonded sandwich configuration is geared employing incremental sheet-bulk metal forming (see figure b). Besides a deliberately induced distribution of the local strength, a reduction of the component's weight as well as a reduced tool load can be achieved.

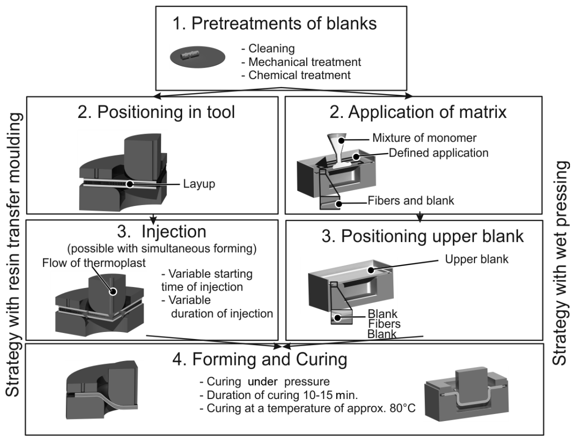


a) Edge thickening and b) Gearing of hybrid gears and c) Resulting force reduction

2.5.10 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
Head	Prof. Dr.-Ing. Noomane Ben Khalifa
Contact	Dipl.-Ing. Thomas Mennecart
Status	Completed

Within the project that was conducted in collaboration with the Karlsruhe Institute of Technology (KIT) hybrid components consisting of sheet metals and a glass fiber-reinforced core were successfully manufactured. The two strategies shown in the figure were developed: deep drawing with thermoplastic resin transfer molding and deep drawing with wet-pressing. In the in-situ hybridization experiments the influence of the fibers on the formability of the blanks was investigated. With finite element simulations it was shown that the fiber friction due to contact has a larger influence on the blank's formability than the friction due to the form-fit between the imprinted fiber structure and the blank in case of high normal loads. With this knowledge, a process strategy primarily featuring an early injection was derived. To avoid the squeezing out of the matrix during the process, another injection at the end of the forming step should be done. This way, a successful in-situ hybridization is possible.
With the former chief engineer Nooman Ben Khalifa being appointed Professor for Production Engineering at Leuphana University of Lüneburg and Helmholtz-Zentrum Geesthacht, the project will be continued in Lüneburg.

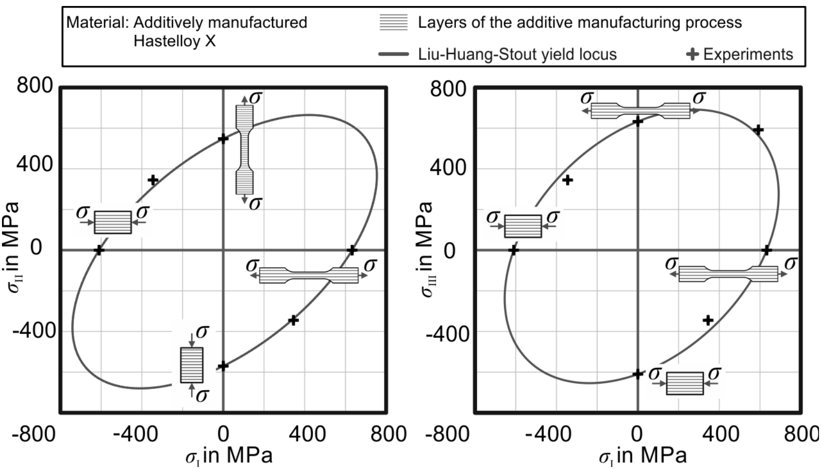


Strategies for the in-situ hybridization

2.5.11 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 of Product Engineering of the University of Duisburg-Essen sandwich sheets with optimized core structures for the use in forming technologies are developed and additively manufactured. Due to the high degree of design freedom in additive manufacturing the development of the core structure needs to be carried out with the help of numerical simulation tools. Therefore, the material and semi-finished parts used need to be characterized. The results reveal a highly anisotropic yield behavior as well as tensile-compression asymmetry. The microstructure develops, depending on the manufacturing parameters used, as a highly oriented cellular dendritic structure. Thus, a yield criterion that is capable of describing these effects is considered. The experimentally investigated yield loci in the figure show a transversal isotropy with similar properties in the build-plane of the additive manufacturing process.

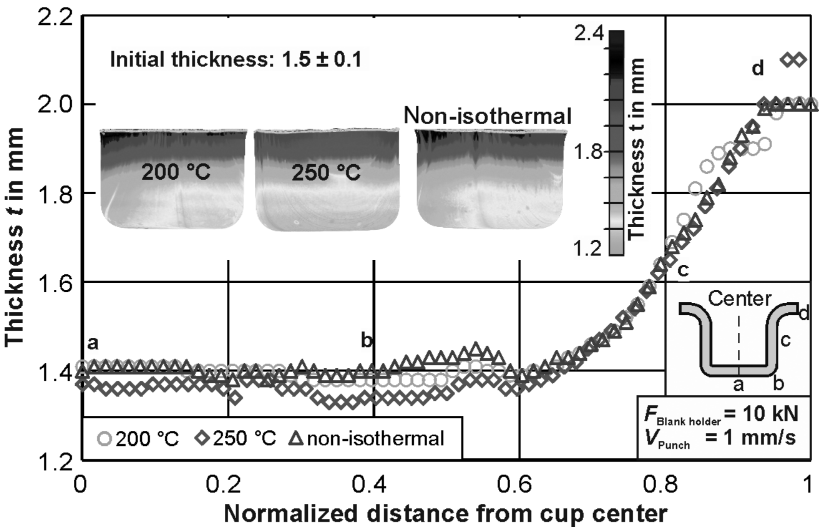


Yield loci of additively manufactured Hastelloy X with transversal isotropy

2.5.12 Development of Hybrid Plastic/Magnesium Composite Parts for Ultra-Lightweight Construction Applications

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

In cooperation with the IKV Aachen and the companies JUBO, KODA, and TWI a combined process for hybrid plastic/magnesium composite parts with the target of saving weight, time, and cost is developed. Magnesium sheets (ME20) are extruded as open-tubes and subsequently flattened. Afterwards, the magnesium sheets are warm deep-drawn and continuously back-injection-molded. A special coating needs to be applied on the surface of the magnesium sheets for improving the corrosion resistance and the adhesion between magnesium and polymer. Material characterizations for both extruded profiles and the flattened sheets are carried out. Deep drawing in isothermal and non-isothermal condition is investigated experimentally and numerically. In comparison to the isothermal condition, the non-isothermal deep drawing results show that a lower thickness reduction occurs in the transition or punch radius region. Hence, the drawability of the magnesium alloys is increased in the non-isothermal case.

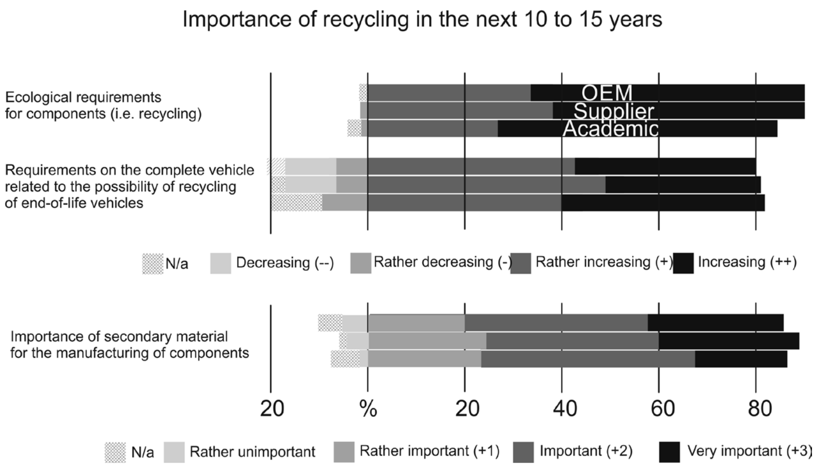


Thickness distribution along the extrusion direction after deep drawing

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

Funding BMBF/PTKA, Grant Platform FOREL 2
Project 02P16Z011
Contact Fabian Schmitz M. Sc.

In this coordination project in collaboration with TU Dresden (TUD), TU Bergakademie Freiberg, Paderborn University, and the Technical University of Munich, topics dealing with future mobility with regard to the manufacturing of lightweight components and recycling of materials are covered. With the help of a survey in which participants from the automotive, aerospace, electronics, and recycling industry are questioned about concepts for future mobility, about the requirements for new manufacturing technologies as well as about the recycling of materials, future research topics and recommendations are identified and deduced. For example, together with the Institute of Mineral Processing Machines of TU Bergakademie Freiberg the re-use of aluminum chips and scrap in manufacturing is considered. The mechanical properties of aluminum profiles made by extrusion are investigated and the influence of the chip and scrap dimensions and the method of preparation on the recycling process are analyzed.



Results of the FOREL survey 2018 on the subject of recycling

2.6 Patents

2.6.1 Published Patents

Title	Method and device for increasing the thickness of the edge of a sheet-metal body

Application number	DE 10 2016 012 270 A1
Patent holder	TU Dortmund University
Status	Published April 19, 2018
Inventors	S. Wernicke • S. Gies • A. E. Tekkaya

Title	Apparatus and method for bending of profiles and bar material, in particular asymmetric and open profiles or bar material

Application number	EP 3 320 993 A1
Patent holder	TU Dortmund University
Status	Published April 26, 2018
Inventors	C. Löbbe • G. Grzancic • A. E. Tekkaya

Title	Process and apparatus for planar or spatial bending by a rolling process

Application number	EP 3 320 994 A1
Patent holder	TU Dortmund University
Status	Published May 17, 2018
Inventors	R. Meya • A. E. Tekkaya

Title	High current pulse generator

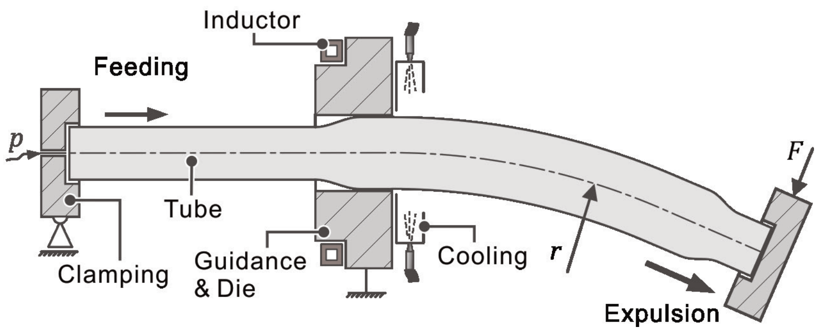
Application number	EP 2 991 224 B1
Patent holder	TU Dortmund University• Astrol Electronic AG
Status	Published November 21, 2018
Inventors	S. Gies • C. Weddeling • A. Herdt • A.E. Tekkaya A. Stöckli • F. Forster

2.6.2 Filed Patents

Method and Device for Forming and Bending of Thin-Walled Profiles

Application number	DE 10 2018 008 302
Patent applicant	TU Dortmund University
Status	Filed
Inventors	C. Löbbe • R. Meya • D. Englert • H. Chen P. Bazargan • A. E. Tekkaya

This invention concerns the forming of a profile cross section and the superposed bending in one process step. Current methods for bending of thin-walled profiles require form-closed tools for a fixed geometry and they are only applicable for small diameter to wall thickness ratios because of wrinkling, tearing, and buckling. In the proposed heat- and pressure-assisted forming technology a profile passes through a short die section while it is partially heated and expanded by an internal pressure. Concurrent to the shaping of the cross section, the curvature of the structural part is obtained by the superposed bending (see figure). Beside the high formability, the rapid heating and cooling enables an integrated heat treatment to achieve a high product strength. Hence, the new forming method offers a possibility for the flexible manufacturing of complex profile parts with tailored properties through a simple tool setup.

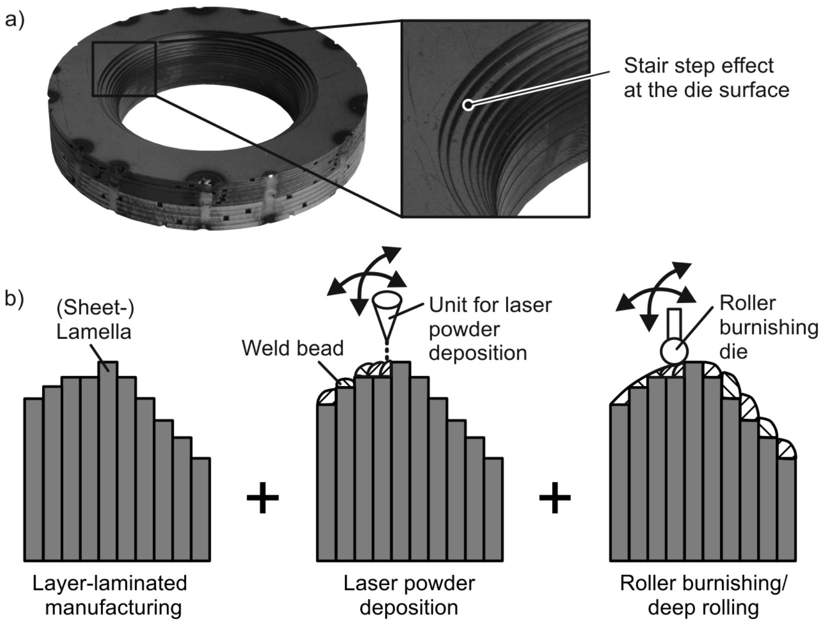


Process principle for the continuous profile forming by an internal pressure and targeted heat assistance

Process for Reducing the Stair Step Effect in Layered Dies and Components Manufactured from Single Sheet Lamellas by Additive and Formative Post-Processing

Application number	DE 10 2018 004 294.5
Patent applicant	TU Dortmund University
Status	Filed
Inventors	R. Hölker-Jäger • A. E. Tekkaya

The invention deals with a new process chain for the manufacturing of dies for e.g. deep drawing processes or also for components. The base body of the die is manufactured fast and cheap by single sheet lamellas. The resulting stair step effect deriving from the layers of the sheet lamellas is filled by laser powder deposition and finally leveled by roller burnishing and/or milling. A possible application is the fast and cost-efficient fabrication of deep drawing dies.



a) Draw ring of a deep drawing die manufactured by the layer-laminated manufacturing method,
b) Process combination

Further Activities

03

3 Further Activities

3.1 Events and Awards

In 2018, 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.

Seminar on Applied Mechanics in Forming Technologies on the occasion of Prof. Haupt's 80th Birthday

On the occasion on the 80th birthday of Prof. Peter Haupt, long-time lecturer, consultant and friend of the IUL, the institute organized a honorary colloquium on the subject of "Applied Mechanics in Forming Technologies" on April 24, 2018. Former students, colleagues, and the family of the guest of honour were invited. Since the winter semester 2010 the emeritus professor of University of Kassel works at the IUL as lecturer. So far, he has accompanied many academic careers at the institute.

Congratulation to the guest of honour

After a short welcome reception Prof. Tekkaya welcomed the honoured guest, his family, and the seminar participants with a personally addressed speech. Prof. Haupt's former PhD students Prof. Charalampos Tsakmakis of TU Darmstadt, Prof. Stefan Hartmann of Clausthal University of Technology (CUT), and Dr. Dirk Helm of Fraunhofer Institute for Mechanics of Materials IWM presented Prof. Haupt's outstanding achievements for the field of mechanics. Graduated staff members of the IUL who profited directly from the valuable discussions with Prof. Haupt emphasized the relevance of his research works for their theses and for the field of mechanics in their lectures. After the official part of the seminar a cosy lunch served in the experimental hall completed the seminar day.

Meeting of the IUL Industrial Advisory Board

The Industrial Advisory Council of the Institute of Forming Technology and Lightweight Components, established in 2010, is composed of 22 renowned representatives of industrial companies and research associations. The close collaboration within the scope of biannual meetings fosters the exchange of experience between industry and research. The current industrial need for research and education is communicated quickly to the institute and, in reverse, the industrial participants benefit from the information on research innovations that can lead to an increase in efficiency of their production. The focus of this year's meetings on May 5 and November 30 was on material characterization and the application of numerical process simulation in production as well as stamping and bending technology using progressive dies..

Participants of the 16th Industrial Advisory Board Meeting

ICHSF 2018

The 8th International Conference on High Speed Forming (ICHSF), the world's largest conference in the field of impulse-based metal forming, was held from May 13 until May 16, 2018 in Columbus, Ohio. Founded in 2002 by Prof. Kleiner at TU Dortmund University, the event is organized regularly by the IUL in cooperation with the "Ohio State University College of Engineering". The international conference takes place every two years, alternately in Dortmund and at various locations worldwide. In 2018 Prof. Glenn S. Daehn of "The Ohio State University" hosted the conference and welcomed approximately 80 conference delegates from all over the world.

Dr. Gies holding a lecture

The ICHSF 2018 presented current research results concerning impulse-based forming and its current and future (industrial) applications. Representatives of universities and companies discussed process technologies, tools, materials, and measurement techniques as well as modelling and simulation of processes concerning high-speed forming.

Forming Colloquium 4.0

This year's "Forming Colloquium 4.0" was dedicated to the topics of "Industry 4.0". The focus was on the accordingly changing requirements forming technology faces and measures to be initiated. After a short welcome by the heads of institute, current and former staff members of the Institute of Forming Technology and Lightweight Components (IUL) participated in diverse lectures and an issue-specific lab tour. The guests took the opportunity to network in a relaxed and familiar atmosphere. Subject of the discussions were the conflicting aspects of mass production and batch size one as well as the chances of networked sensor systems in forming machines. Finally, another important element to improve forming technology in connection with the fourth industrial revolution is the targeted use of the advantages of additive technologies as supporting factor for forming technologies.

Welcome by Prof. Tekkaya (left) and Prof. Kleiner

DORP 2018
7th Tube and Profile Bending Conference

The 7th Tube and Profile Bending Conference (DORP – Dortmunder Kolloquium zur Rohr- und Profilumforung) took place from September 11-12, 2018. After the reception evening in the Signal Iduna Stadion with an exciting speech by Prof. Tolan dealing with the physics of football, the IUL welcomed the guests from industry and academia on September 12,2018 at the facilities of TU Dortmund University. More than 75 participants, four exhibiting companies, and twelve presentations – eight from industry and four from research – provided a forum to exchange topics related to tube and profile forming. New processes, for example for the production of large pipes, innovative sensors for continuous profile measurement, or the networking of different manufacturing steps in the field of Industry 4.0 were major issues. The wide range of topics demonstrates the versatility of current research and development trends which lead to intensive discussions among all participants and highlight the need for close networking between companies and universities. The DORP conference serves as a venue and actively takes part in meeting the requirements expressed by the attendants.

Participants of the 7th Tube and Profile Bending Conference

1. Industrial Colloquium of the CRC/Transregio 188

On November 15, 2018, the CRC/Transregio 188 invited to its first industrial colloquium in the Dortmund Congress Centre, Germany. Latest research results on the subject of "Damage controlled forming processes" were presented to more than 100 international participants in 12 lectures and an accompanying poster presentation. The focus was on the analysis and characterization of damage on different scales as well as the influence of damage evolution in sheet metal and bulk forming processes. The application-oriented use of the knowledge gained ranged from the simulation of individual forming processes to the virtual optimization of the entire production chain, including the evaluation of the product with regard to its application and crash behavior. The variety of application examples presented by the invited speakers from industry and renowned research institutes as well as the great response from the participants underlined the high relevance of the topic for manufacturing technology and beyond.

We would like to thank the German Research Foundation (DFG) for making this event possible by supporting the research association and the Economic Development Agency Dortmund (Wirtschaftsförderung Dortmund) for kindly supporting the event financially.

Participants of the industrial colloquium 2018

Best Paper Award EDPC 2018

During the annual Electric Drives Production Conference Janna Hofmann (wbk – Institute of Production Science at KIT) and Anna Komodromos (IUL) have been awarded the Best Paper Award for their joint paper entitled "Optimization of the linear coil winding process by combining new actuator principles on the basis of wire forming analysis". The conference took place in Schweinfurt on December 4 and 5, 2018. The paper resulted from the joint project "Forming-based process modeling of the linear winding method" funded by the German Research Foundation (project TE 508/56-1). It examines the application of new actuators for linear winding in order to improve the winding result and reduce the copper losses of the electric motor. One important aspect is the influence of the wire guide on the forming behavior of the wire because the clearance between wire and coil bobbin is increased. Therefore, a concept for a movable wire guide preventing the pre-deformation of the wire is presented.

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

- Engineers-without-Borders • February 5
- Girls' Day 2018 • April 26
- Student competition "Stahl fliegt" (Flying steel) • July 3-4
- Summer party of TU Dortmund University • July 5
- do-camp-ing • July 16-19
- SchnupperUni • August 23
- Science Night Ruhr • September 28
- MinTU • November 9
- Open Day of TU Dortmund University • November 10

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

Memberships of Research Boards

- acatech – Member of the "German Academy of Science and Engineering" ("Deutsche Akademie der Technikwissenschaften")
- AGU – Chairman of the "German Metal Forming Association" ("Wissenschaftliche Arbeitsgemeinschaft Umformtechnik")
- CIRP – Fellow of "The International Academy for Production Engineering"
- Council member of the "European Society of Experimental Mechanics"
- Curatorship member of "KARL-KOLLE Stiftung", Dortmund, Germany
- DGM – Member of "Deutsche Gesellschaft für Materialkunde"
- FOSTA – Member of the Advisory Board of the "German Steel Federation" ("Forschungsvereinigung Stahlanwendungen e. V.")
- GCFG – Member of the "German Cold Forging Group"
- I²FG – Member of the "International Impulse Forging Group"
- ICFG – Member of the "International Cold Forging Group"
- ICTP – Advisory Member of the Standing Advisory Board of the "International Conference on Technology of Plasticity"
- JSTP – Member of the "Japan Society for Technology of Plasticity"
- Member of "DGM-Regionalforum Rhein-Ruhr"
- MPIE - Member of the Scientific Advisory Board of the "Max-Planck-Institut für Eisenforschung"
- Vice president of the german consortium of "Türkisch-Deutsche Universität" (Turkish-German University)
- WGP – Member of the "German Academic Society for Production Engineering" ("Wissenschaftliche Gesellschaft für Produktionstechnik")

Journals/Editorship

- Chairman of the Editorial Committee, "CIRP Annals"
- 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 Scientific Editorial Board, “Computer Methods in Materials Science”
- Member of the Scientific Editorial Board, “International Journal of Precision Engineering and Manufacturing”
- Member of the Scientific Editorial Board, “Romanian Journal of Technical Sciences – Applied Mechanics”

Further Memberships

- Chairman of the Scientific Committee, “International Conference on High Speed Forming” (ICHSF 2018), Columbus, USA
- Member of the CIRP Communication Committee
- Member of the Scientific Committe, “International Deep Drawing Research Group 2018” (iddrg), Waterloo, Canada
- Member of the Scientific Committe, “International Deep Drawing Research Group 2019” (iddrg), Enschede, Netherlands
- Member of the Scientific Committee, “International Conference on Sheet Metal” (SheMet 2019), Leuven, Belgien
- Member of the Scientific Committee, “The 13th International Conference on Numerical Methods in Industrial Forming Processes” (NUMIFORM 2019), Portsmouth, USA
- Member of the Scientific Committee, “The 28th CIRP Design Conference 2018”, Nantes, Frankreich

Activities as Reviewer

In Scientific Committees

- AiF – Arbeitsgemeinschaft industrieller Forschungsvereinigung "Otto von Guericke" e. V.
- CIRP – International Academy for Production Engineering
- DFG – German Research Foundation, Member of Fachkolleqium 401 (Review Board on Production Engineering)
- DTU, Technical University of Denmark, Lyngby
- ESF College of Expert Reviewers
- Massachusetts Institute of Technology, Boston
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- Middle Eastern Technical University, Ankara
- National Research Council Canada
- Oakland University
- Steel Institute VDEh
- The Ohio State University
- University of Cambridge
- University of Cyprus
- University of Lisbon
- WGP – German Academic Society for Production Engineering
- Xi'an Jiaotong University

For Journals

- Applied Mathematical Modelling
- ASME – Journal of Manufacturing Science and Engineering
- CIRP Annals – Manufacturing 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 Material Characterization – An International Journal on Materials Structure and Behavior
- Journal of Applied Mathematical Methods
- Journal of Computational and Applied Mathematics
- Journal of Manufacturing Processes
- Journal of Manufacturing Science and Engineering
- Journal of Materials Processing Technology
- Journal of Mechanical Engineering
- Journal of Pressure Vessel Technology
- Journal of Production Engineering
- Manufacturing Letters
- Materials
- Materials & Design
- Materials and Manufacturing Processes
- Materials Science and Engineering A
- Mechanics of Materials
- Simulation Modelling Practice and Theory
- Steel Research International
- Strain: An International Journal for Experimental Mechanics
- Surface and Coatings Technology
- The International Journal of Advanced Manufacturing Technology

3.3 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

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- Chairman of the University Council, Johann Wolfgang Goethe-University, Frankfurt
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- 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, Swizzerland

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
- Member of the Jury for the “Deutscher Innovationspreis”
- Member of the Jury of the Georg von Holtzbrinck Prize for Science Journalism
- Board of Trustees of the “Zukunftspreis” of the Federal President

Cooperation Advisory Boards

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

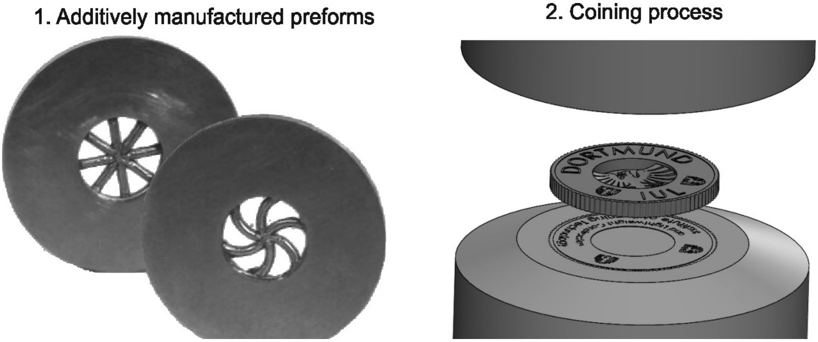
International Exchange

04

4 International Exchange

Prof. Carlos Manuel Alves da Silva

Professor Carlos Manuel Alves da Silva, Assistant Professor in the working group of Professor Paulo Martins, Instituto Superior Técnico, Technical University of Lisbon, was hosted at the IUL from March 14 to June 29, 2018. During his research stay Professor da Silva worked on the connection between forming technology and additive manufacturing. His idea is to manufacture preforms for collector's coins additively and to coin them to their final geometry. To test this manufacturing strategy, blanks were fabricated additively made of a stainless steel alloy using a machine for selective laser melting (in a powder bed). Furthermore, Professor da Silva numerically investigated the material flow in the coining process, focusing on the design of the preform. For the year 2019 another guest stay at the IUL is scheduled.

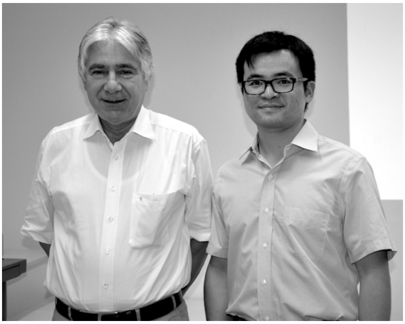


Process of an additively manufactured pre-form which was delivered to the final geometry by a coining operation

Prof. Junying Min

Professor Junying Min conducted joint research in the field of material characterization and modeling with the members of the Applied Mechanics group from May 1 until July 28, 2018. He developed new analytical approaches for the evaluation of material tests such as the hydraulic bulge test and the biaxial tension test at the School of Mechanical Engineering of Tongji University (Shanghai). Professor Min collaborated closely with Mr. Traphöner to test sheet metals with the in-plane torsion test during his stay at IUL. Mr. Gutknecht und Dr. Clausmeyer are looking forward to the continuing cooperation in the field of loading path changes. The former Alexander von Humboldt scholar presented the results of his research stay at IUL and previous projects

(Ruhr-Universität Bochum, the research and development center of General Motors in Warren, among others) in his final presentation “Mechanical Behavior and Characterization of Sheet Metals: Onset of Necking and Yield Surface Evolution” to colleagues of TU Dortmund University on July 26.



Prof. Min (right) and Prof. Tekkaya

Prof. Kanetake (right) and Prof. Tekkaya

Alexander von Humboldt scholar Prof. Naoyuki Kanetake

From June 12 to September 14, 2018 Professor Naoyuki Kanetake, Emeritus of Nagoya University Japan, was a guest of IUL. His stay was funded by a Alexander von Humboldt scholarship. During his stay an intense collaboration with the staff of the department of bulk metal forming was developed. The exchange led to the generation of new ideas in the field of direct recycling of aluminium chips through the consolidation with the „Compression Torsion Process“ (CTP) and the process development of aluminium foam production. Due to the growing demands in the field of lightweight design and resource-saving manufacturing processes these topics gain more importance and the need for international cooperation increases. At the end of his stay in Dortmund Professor Kanetake presented research results generated during his research activities in Japan to interested students and scientists.

RISE (Research Internships in Science and Engineering) – Shemmar Jackson

As in previous years, in 2018 the IUL took part in the program "RISE" of the German Academic Exchange Service (DAAD). From May until August, Shemmar Jackson from the Rochester University (New York) visited the institute. The RISE program gives Bachelor students from the UK and North America the opportunity to do internships at German research institutions. The stay of Mr. Jackson was financed by a grant collectively funded by the DAAD and the DFG Collaborative Research Center Transregio 73. Under the supervision of Mr. Wernicke, Mr. Jackson was engaged in the topic of incremental sheet-bulk metal forming. He investigated hybrid gears formed by incremental sheet-bulk metal forming with the focus on assessing the bond properties.

Shunyi Zhang (NSF travel grant)

With Shunyi Zhang an "old friend" visited the IUL in summer 2018 for a two-month research stay. Mr. Zhang completed his Master's degree in 2015 as part of the MMT program at the TU Dortmund University and now pursues his PhD at the University of New Hampshire under Professor Kinsey. In close cooperation with Mr. Lueg-Althoff, Mr. Zhang investigated the characteristic wave formation in the interface layer between the welded joining partners during magnetic pulse welding. In addition to experimental investigations on the pulse generators of the IUL, a meshless numerical simulation method, SPH (Smoothed Particle Hydrodynamics), was used for this purpose. The stay of Mr. Zhang was financed by a grant of the National Science Foundation (NSF), USA.

Exchange with The Ohio State University

The project „Forming and manufacture of lightweight high-performance components – International Research Experiences for Students at the TU Dortmund University", funded by the National Science Foundation (NSF), enables an exchange research internship for up to five students from The Ohio State University (OSU) at the IUL during the summer break. Undergraduate as well as graduate student, can apply for the program. During their stay the exchange students gather insights into the characteristics of research at a leading German manufacturing research institute. They can directly apply what they have learned to their work and research back home. At the IUL they are actively involved in an ongoing research project under the supervision of an associate researcher of the institute. During the second period of the program in summer 2018 four students took the opportunity to do research at the IUL.

Madhura Athale

After graduation in Mechanical Engineering at The Ohio State University, Ms. Madhura Athale started her Ph.D. studies in the Materials, Mechanics, and Manufacturing Lab of OSU. In her second year she deals with the modeling and simulation of tool wear during forming processes. The results are taken into account during the evaluation of different agile tooling approaches. During her research stay at the IUL she analyzed the wear of additively manufactured tools for sheet forming operations based on experiments and simulations. The results were compared to previous analyses of tools manufactured by conventional approaches.

Denielle Ricciardi

As part of her Ph.D. research at the Center of Accelerated Maturation of Materials of OSU, Ms. Denielle Ricciardi investigates statistical uncertainties of materials and their properties which are often used in forming operations. For instance, texture evolution during a forming process can be predicted by such tools. At the IUL she used numerical simulations to forecast the statistical distribution of material properties, such as yield stress, of cold extruded 16MnCrS5. Later, the results were validated by experimental analyses.

Angella Volchko

Ms. Angella Volchko is currently a mechanical engineering undergraduate student at OSU. As part of her research internship, she dealt with the extension of the machine control of the incremental profile forming machine which was developed at the IUL. The project is part of the joint collaboration between the IUL and her supervisor Professor Srinivasan who is the head of the department of Mechanical and Aerospace Engineering.

Ryo Nakahata

Enhancing the incremental profile forming machine was also part of Mr. Ryo Nakahata's research stay at the IUL. He is also a mechanical engineering undergraduate student. He investigated which optical sensor system is best suited for a real-time closed-loop control for the incremental profile forming machine. Eventually, a laser-based triangulation sensor was chosen and implemented into the machine. First experimental results show a promising use of this system.

During their stay at the IUL their supervisors from OSU visited the exchange students. As part of their trip to Germany, the professors used the opportunity to give talks on their current research topics. Professor Srinivasan, the coordinator of the student exchange research program at OSU, presented his latest results on „Incremental Profile Forming: Process, Sensing, and Control Innovations: Challenges and Proposed Solutions". This subject is part of a collaboration between his institute and the IUL regarding the research that was done by Dr. Grzancic during his dissertation. Furthermore, Profesor Niezgoda also visited the IUL while his student, Denielle Ricciardi, was working on quantifying statistical uncertainties during forming operations. He gave a talk on "Mechanics and structures at the mesoscale: Challenges and opportunities for ICME". The IUL is looking forward to welcoming next year's batch of research exchange students in summer 2019.

Technical Equipment

05

5 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

- CNC rotary draw bending machine, DB 2060-CNC-SE-F, Transfluid Maschinenbau GmbH
- 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 (recuperationalble), self-built at IUL
- Machine for electromagnetic forming, 6 kJ, Poynting SMU 0612 FS
- Machine for electromagnetic forming, 32 kJ, Maxwell Magneform 7000
- Machine for Incremental Profile Forming, self-built at IUL
- 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, self-built at IUL

- Profiling machine RAS 24.10, Reinhardt Maschinenbau GmbH, Sindelfingen
- Spinning machine, Leifeld APED 350NC, CNC Siemens 840 D
- Swivel bending machine, FASTI 2095
- 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
- FDM-based 3D-Printers for thermoplastic materials (2x Ultimaker 3, 1x Ultimaker 3 Extended)
- 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 (2 x)
- Plastometer, 800 kN, self-built
- Sheet metal testing machine Zwick BUP1000

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
- Borehole device, Milling Guide RS 200 for residual stress measurement by strain gauges
- Digital storage oscilloscope, 4 measuring channels, Tektronix TDS 420A
- Optical 3D digitizer: GOM ATOS Triple Scan (2 x), GOM TRITOP
- Optical 3D deformation analysis: GOM ARAMIS 5M (2 x) and 4M (1 x), GOM ARGUS
- Optical 3D motion analysis: GOM PONTOS 4M

- Infrared Camera, Infratec VarioCam HD head 680 S, 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
- Near infrared pyrometer, sensotherm Metis M 318
- Near infrared pyrometer, Sensortherm Metis M 316
- 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 Xstress 3000 – X-ray diffractometer for measuring residual stresses
- Thickness measuring device, Krautkrämer CL 304

Miscellaneous

- 6-axes robot, industrial robot KUKA KR 90 R3700 prime K
- Belt grinding machine, Baier PB-1200-100S
- different machines for machining purposes
- Etching and polishing station - LectoPol-5, Struers GmbH
- High-frequency generator, 10 kW, Hüttinger Axio 10/450
- 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
- Medium-frequency generator, 40 kW, Trumpf TruHeat 3040 und 7040, with coax transformer
- Roll seam welding machine, Elektro-Schweißtechnik Dresden UN 63 pn
- Tensile testing grinder, Schütz + Licht GmbH, PSM 2000
- Tensile testing punch press, 1200 kN, Schütz + Licht GmbH ZS1200 CN
- Turning machine, Weiler Condor VS2

Kooperationen | Cooperations

06

Kooperationen | Cooperations

Auf diesem Wege möchten wir uns für die vielfältige Zusammenarbeit im Jahr 2018 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 2018 which have added to our joint success.

Industriebeirat des IUL | IUL Industrial Advisory Board

Das Gremium des Industriebeirates vermittelte auch im Jahr 2018 wichtige Impulse hinsichtlich des industriellen Forschungsbedarfes. An dieser Stelle möchten wir uns für diese wertvolle Zusammenarbeit bedanken.

In 2018, 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, Ing.-Büro Gerhard Bürstner
- Marius Fedler, Kunststoff-Institut für die mittelständische Wirtschaft NRW GmbH
- Dr. Frank O. R. Fischer, Deutsche Gesellschaft für Materialkunde e. V.
- Dr. Georgios Georgiadis, Volkswagen AG
- Reiner Hank, TRUMPF Werkzeugmaschinen GmbH & Co. KG
- Dr. Jens Heidenreich, PHOENIX FEINBAU GmbH & Co. KG
- Wolfgang Heidrich, GDA – Gesamtverband der Aluminiumindustrie e. V.
- 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
- Dr. Hans Mulder, Tata Steel Research & Development Product Application Centre
- Franz-Bernd Pauli, Franz Pauli GmbH & Co. KG
- Dr. Hendrik Schafstall, simufact engineering GmbH
- Dr. Joachim Schondelmaier, Schondelmaier GmbH
- Prof. Karl Schweizerhof, DYNAmore GmbH
- Dr. Hosen Sulaiman, Faurecia Autositze GmbH
- Robert Strehle, Zwick GmbH & Co. KG
- Adolf Edler von Graeve, KIST Kompetenz- und Innovationszentrum für die StanzTechnologie Dortmund e. V.
- Sabine Widdermann, Industrieverband Massivumformung e. V.
- Dr. Hans-Joachim Wieland, Forschungsvereinigung Stahlanwendung e. V. (FOSTA)

Universitäre Kooperationen auf nationaler Ebene | University cooperations at national level

- Chair of Micromechanical and Macroscopic Modelling, ICAMS, Ruhr-Universität Bochum
- Cybernetics Lab IMA & IfU, Rheinisch-Westfälische Technische Hochschule Aachen
- Fachbereich Produktionstechnik, Universität Bremen
- Fachgebiet Maschinenelemente, Technische Universität Dortmund
- Fachgebiet Metallische Werkstoffe, Institut für Werkstoffwissenschaften und -technologien, TU Berlin
- Fachgebiet Werkstoffprüftechnik, Technische Universität Dortmund
- Fachhochschule Südwestfalen
- Fraunhofer-Institut für Werkstoff- und Strahltechnik IWS, Dresden
- Fraunhofer-Institut für Werkzeugmaschinen und Umformtechnik IWU, Technische Universität Chemnitz
- Fraunhofer-Projektgruppe am Dortmunder Oberflächen-Centrum DOC, Dortmund
- Gemeinschaftslabor für Elektronenmikroskopie, Rheinisch-Westfälische Technische Hochschule Aachen
- IngenieurDidaktik (Professur), Technische Universität Dortmund
- Institut für Angewandte Materialien – Werkstoffkunde, Karlsruher Institut für Technologie (KIT)
- Institut für Bildsame Formgebung, Rheinisch-Westfälische Technische Hochschule Aachen
- Institut für Eisenhüttenkunde, Lehr- und Forschungsgebiet für Werkstoff- und Bauteilintegrität, 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
- Institut für Werkzeugmaschinen und Fabrikbetrieb, Technische Universität Berlin
- Labor für Fahrwerktechnik, Hochschule Osnabrück
- Laboratorium für Werkstoff- und Fügetechnik, Universität Paderborn
- Lehrstuhl Baumechanik, Technische Universität Dortmund
- 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 Produktentwicklung und 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 Hybrid Additive Manufacturing, Ruhr-Universität Bochum
- Lehrstuhl Werkstoffwissenschaft, Ruhr-Universität Bochum
- Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf
- Professur für Baumechanik, Universität der Bundeswehr München
- Professur für Theoretische Elektrotechnik und Numerische Feldberechnung, Helmut-Schmidt-Universität, Universität der Bundeswehr Hamburg
- Professur Virtuelle Fertigungstechnik, Technische Universität Chemnitz
- Professur Werkstoffwissenschaft, Technische Universität Chemnitz
- wbk Institut für Produktionstechnik, Karlsruher Institut für Technologie
- 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
- École Nationale Supérieure d'Arts et Métiers (ENSAM), ParisTech, Paris, France
- 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
- 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 Helicopters
- Alfred Konrad Veith GmbH & Co. KG
- 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
- Centroplast Engineering Plastics GmbH
- C-TEC Constellium Technology Center
- Daimler AG
- Danieli Germany GmbH
- data M Sheet Metal Solutions GmbH
- Deutsche Edelstahlwerke GmbH
- DYNAmore GmbH
- ElringKlinger AG
- ESI GmbH
- F. W. Brökelmann Aluminiumwerk GmbH & Co. KG
- Faurecia Group
- Franz Pauli GmbH & Co. KG
- Freudenberg Sealing Technologies GmbH & Co. KG
- FRIMO Group GmbH Composites & Tooling Technologies
- Gerhardi AluTechnik GmbH
- Goekeler Messtechnik GmbH
- Grundfos GmbH
- GSU Schulungsgesellschaft für Stanz- und Umformtechnik mbH
- HELLA GmbH & Co. KGaA
- Hirschvogel Umformtechnik GmbH
- HMT Höfer Metall Technik GmbH & Co. KG
- HUECK Extrusion GmbH & Co. KG
- Hydro Aluminium Deutschland GmbH
- inpro Innovationsgesellschaft für fortgeschrittene Produktionssysteme in der Fahrzeugindustrie mbH
- JFE Steel Corporation
- Johnson Controls Hilchenbach GmbH
- Kirchhoff Automotive GmbH
- Kistler Instrumente AG

- KODA Stanz- und Biegetechnik GmbH
- KraussMaffei Group GmbH
- Kunststoff-Institut Lüdenscheid
- LEIBER Group GmbH & Co. KG
- MATFEM
- MK Metallfolien GmbH
- 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
- SSAB Svenskt Stål AB
- STURM GmbH
- Tata Steel
- TECOS – Slovenian Tool and Die Development Centre
- thyssenkrupp Steel Europe AG
- TM Lasertechnik GmbH
- 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
- wefa GmbH
- Welser Profile GmbH
- Westfalia Presstechnik GmbH & Co. KG
- Wilke Werkzeugbau GmbH & Co. KG
- WILO SE
- Zentrum für BrennstoffzellenTechnik GmbH

In addition several companies with disclosure agreements

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

Stiftungen | Foundations

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

Abgeschlossene Arbeiten | Completed Theses

07

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

Baqerzadeh Chehreh, Abootorab
Tekkaya, A. E.; Staupendahl, D.
Untersuchung der Querschnittsumformung von dünnwandigen Rohren mittels eines mehrstufigen Walzprofilierprozesses
Investigation of reshaping the cross-section of thin-walled steel tubes by a multistage roll forming process

Beu, Marcel-André
Tekkaya, A. E.; Lueg-Althoff, J.; Güzel, A. (Airbus Helicopters); Rohr, T. (Airbus Helicopters)
Experimentelle und numerische Studie des elektromagnetischen Fügens von Aluminiumrohren für Luftfahrtanwendungen
Experimental and numerical study of joining by electromagnetic forming of aluminum tubes for aeronautical applications

Cwiekala, Nils
Tekkaya, A. E.; Clausmeyer, T.
Analytische Beschreibung des ebenen Torsionsversuchs für finite Deformationen und anisotropes Werkstoffverhalten
Analytical description of the in-plane torsion test for finite deformations and anisotropic material behavior

Detzel, Andreas
Tekkaya, A. E.; Wernicke, S.
Untersuchung elektro-plastischer Effekte bei der Herstellung von Funktionselementen durch inkrementelle Blechmassivumformung
Investigation on electro-plastic effects during manufacturing of functional components by incremental sheet-bulk metal forming

Dixith, Akshatha Chandrashekar
Tekkaya, A. E.; Traphöner, H. (thyssenkrupp AG)
Vorhersage von Kantenrissen bei hochfesten Stählen für eine A-Säulenverstärkung mit der Finite-Elemente-Methode
Prediction of edge cracks for high strength steels for an A-pillar reinforcement using the Finite Element Method

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

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

Gala, Vijal Premchand
Tekkaya, A. E.; Chen, H.
Untersuchung der Biegeumformung von U-Profilen mit kleinem Biegeradius
Investigation of small-radius bending process for U-profile

Ganesh, Vishnu
Tekkaya, A. E.; Dahnke, C.
Einfluss von formgedächtnislegierungsinduzierten Spannungen auf die mechanischen Eigenschaften eines NiTi-/Al-Verbundes, hergestellt durch Verbundstrangpressen
Influence of shape memory alloy induced stress on the mechanical properties of NiTI/Al composities manufactured by composite extrusion

Goyal, Siddhant Prakash
Tekkaya, A. E.; Hahn, M.
Analyse der erreichbaren Energieeinbringung und -verteilung in vaporisierenden Folienaktuatoren
Analysis of achievable energy deposition and its spatial distribution in vaporizing foil actuators

Grote, Jannik
Tekkaya, A. E.; Staupendahl, D.
Analyse des Einflusses der Rohrherstellungsstrategie auf nachfolgende Innenhochdruckoperationen bei Komponenten in der Automobilindustrie
Analysis of the impact of tube manufacturing strategies on subsequent hydroforming operations for automotive components

Hoffmann, Eike
Tekkaya, A. E.; Kamaliev, M.
Einfluss des axialen Nachschubs auf die Prozessgrenzen beim IH-Presshärten mit granularen Medien
Influence of axial feeding on the process limits in granular media based tube press hardening

Izadyar, Seyed Ahmad
Tekkaya, A. E.; Dardaei, H.
Charakterisierung der stranggepressten Magnesiumbleche
Characterization of extruded magnesium-sheets

Janeczek, Christian
Tekkaya, A. E.; Hering, O.
Untersuchung des Grenzseitenverhältnisses beim Napf-Rückwärts-Fließpressen von prismatischen Aluminiumbechern
Investigation of the aspect ratio limit in backward extrusion of rectancular aluminium cups

Kencham Padmanabharao, Madhu Sudhan Rao
Tekkaya, A. E.; Nazari, E.
Entwicklung eines FEM-Modells für das Rundkneten von Hohlwellen
Development of FEM-Model for rotary swaging of hollow shafts

Kimmich, Lukas
Tekkaya, A. E.; Lueg-Althoff, J.; Peterschilka, F.-J. (Integral Accumulator)
Konzept einer zerstörungsfreien Prüfung von magnetpulsgeschweißten Verbindungen in der Druckspeicher-Serienfertigung
Concept of a non-destructive testing procedure for magnetic pulse welded joints in the series production of accumulators

Krishna Potluri, Venkata Vamshi
Tekkaya, A. E.; Ortelt, T. R.
Untersuchung zum Presshärten von hochfesten Aluminiumlegierungen
Investigation of hot stamping of high strength aluminium alloys

Martschin, Juri
Tekkaya, A. E.; Löbbe, C.
Drucküberlagerung beim Profilbiegen: Verfahrensentwicklung und Prozessanalyse
Compressive stress superposition in profile bending: Process development and analysis

Niehues, Florian
Tekkaya, A. E.; Löbbe, C.
Entwicklung des FlexBend-Verfahrens zum Biegen von dünnwandigen und offenen Profilen
Development of the FlexBend-technology for bending thin-walled and open profiles

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

Okolo, Chukwuemeka Daniel
Tekkaya, A. E.; Staupendahl, D.
Untersuchung der durch den Schneidprozess in der Schnittkante induzierten Dehnungen und deren Einfluss auf nachfolgende Lochaufweitoperationen
Investigations of the strains induced in the cut edge of AHSS by shearing and its influence on subsequent hole expansion operations

Ortelt, Dominik Markus
Tekkaya, A. E.; Gies, S.; Sieczkarek, P.
Entwicklung einer kraftbasierten Prozessregelung für die inkrementelle Mikroumformung metallischer Bipolarplatten
Development of a force-based process control for the incremental micro-forming of metallic bipolar plates

Schenk, Alexander
Tekkaya A. E.; Ortelt, T. R.
Entwicklung einer Werkzeugeinheit für die inkrementelle Profilumformung mit oszillierender Werkzeugbewegung
Development of a tool unit with oscillating tool movement for the incremental profile forming process

Sharma, Sumeet Ranjan
Tekkaya, A. E; Nazari, E.
Numerische und experimentelle Analyse des dreidimensionalen Rohrbiegens anhand des inkrementellen Rohrumformens
Numerical and experimental analysis of three-dimensional tube bending by incremental tube forming process

Sun, Chenfeng
Tekkaya, A. E.; Mennecart, T.
Untersuchung des Drapierverhaltens von Geweben unter Normaldruck
Analysis of the drape-behaviour of woven fabrics under normal pressure

Tebaay, Lennart Manfred
Tekkaya, A. E.; Sieczkarek, P.
Entwicklung und Erprobung von Umformsticheln für die inkrementelle Mikro-Blechumformung
Development and testing of different forming tools for the incremental micro-forming process

Thiery, Sebastian
Tekkaya, A. E.; Löbbe, C.
Einstellung von Produkteigenschaften bei der temperaturunterstützten mehrstufigen Blechumformung mittels Mehrgrößenregelung
Multi-variable control of product properties in heat-assisted sheet metal forming based on progessive tools

Wei, Hailong
Tekkaya, A. E.; Mennecart, T.
Untersuchungen zum Einfluss eines Glasfasergewebes auf die Umformbarkeit von Sandwichblechen unter hohen Kontaktdrücken
Analysis of the influence of glass fibers on the formability of sandwich sheets under high contact pressures

Wu, Jiang
Tekkaya, A. E.; Selvaggio, A.
Entwicklung eines Modellversuches zur Materialcharakterisierung
Development of a model test for material characterization

Abgeschlossene Bachelorarbeiten | Completed Bachelor of Science Theses

Ambrosy, Niklas
Tekkaya, A. E.; Ortelt, T. R.
Validierung von OPC UA TSN als neuer Kommunikationsstandard für die Produktion am Beispiel der AUDI AG
Validation of OPC UA TSN as a new communication standard for manufacturing using the example of AUDI AG

Bandura, Philip
Tekkaya, A. E.; Komodromos, A.
Numerische und experimentelle Analyse des Drahtbiegens mit überlagerter Zugkraft auf Basis des Linearwickelns unrunder Spulenkörper
Numerical and experimental analysis of wire bending with a superposed tensile force on the basis of linear winding of non-circular coil bobbins

Bergen, Christian
Tekkaya, A. E.; Rosenthal, S.
Numerische Analyse von Sandwichblechen im 3-Punkt-Biegeversuch
Numerical investigations of sandwich sheets in three point bending

Christiansen-Lenger, Sean Paul
Tekkaya, A. E.; Löbbe, C.
Einfluss der Wärmekontraktion auf die Rückfederung beim temperaturunterstützten Gesenkbiegen
Impact of heat expansion on springback in the bending process at elevated temperatures

Denter, Kevin
Tekkaya, A. E.; Hering, O.
Untersuchung von Methoden zur Bewertung der Schädigung in fließgepressten und gebogenen Bauteilen
Investigation of methods for the evaluation of damage in cold forged and bent parts

Efendioglu, Emin
Tekkaya, A. E.; Napierala, O.
Experimentelle Untersuchung des Tiefzieh-Verbundfließpressens mit Spänekern
Experimental investigations of combined deep drawing and cold forging with chip core

Elshof, David
Tekkaya, A. E.; Meya, R.
Entwicklung und Erprobung einer Einrichtung zur Rückfederungsmessung bei verschiedenen Blechbiegeverfahren
Development and testing of a springback measurement tool for different bending processes

Germer, Fabian
Tekkaya, A. E.; Maaß, F.
Vergleichende Analyse von Röntgendiffraktometrie und Bohrlochmethode zur Eigenspannungsmessung an inkrementell hergestellten Blechbauteilen
XRD and hole drilling method for the residual stress analysis of parts processed by SPIF

Izydorczyk, Martin
Tekkaya, A. E.; Napierala, O.
Prozessauslegung des Tiefzieh-Verbundfließpressens mit gelochten Ronden
Process design of combined deep drawing and cold forging with pierced blanks

Kortum, Nico
Tekkaya, A. E.; Wernicke, S.
Herstellung hybrider Funktionsbauteile mittels inkrementeller Blechmassivumformung
Manufacturing of hybrid functional components by incremental sheet-bulk metal forming

Kramer, Thilo
Tekkaya, A. E.; Ortelt, T. R.
Umformtechnische Einflussfaktoren auf die automatisierte Fertigung walzprofilierter Profile bei kleinen Stückzahlen
Influence of forming technology related parameters on the automated small batch-size production of roll-formed profiles

Kubasinski, Steffen
Tekkaya, A. E.; Komodromos, A., Sell-Le Blanc, F. (Aumann GmbH Espelkamp)
Experimentelle Analyse des Linearwickelprozesses unter Variation unterschiedlicher Prozessparameter auf Basis der Drahtführung
Experimental analysis of the linear winding process with variation of different process parameters on the basis of the wire guide

Meyering, Kevin
Tekkaya, A. E.; Traphöner, H.
Analyse des Einflusses der Querkontraktion durch die innere Einspannung beim ebenen Torsionsversuch
Analysis of the influence of the tranverse contraction by the inner clamping in the in-plane torsion test

Panusch, Frederic
Tekkaya, A. E.; Staupendahl, D.
Untersuchung des lokalen und globalen Umformverhaltens von rostfreien Stählen und Mehrphasenstählen mit normalen und verbesserten Umformeigenschaften
Investigation of the local and global forming behavior of stainless steels and multi-phase steels with normal and improved forming characteristics

Patrick, Johnsan
Tekkaya, A. E.; Komodromos, A.; Gremmel, D. (Robert Bosch GmbH Hildesheim)
Experimentelle Untersuchung des Rückfederungsverhaltens von Profildrähten für Stator-Wickelelemente dreidimensionaler Geometrie
Experimental analysis of the springback behavior of profile wires for three-dimensional stator-winding elements

Reicherz, Marek
Tekkaya, A. E.; Löbbe, C.
Entwicklung der temperaturabhängigen Fließspannung verschiedener Metalle unter quasistatischer Last
Evolution of the temperature-dependent flow stress of various metals under quasi-static loads

Schwenken, Jörn
Tekkaya, A. E.; Rosenthal, S.
Erprobung des Widerstandsschweißen zum Fügen additiv gefertigter Sandwichblechverbunde
Resistance spot welding for joining additively manufactured sandwich sheets

Stennei, Markus
Tekkaya, A. E.; Löbbe, C.
Experimentelle Untersuchung und Modellierung der temperatur- und dehnartabhängigen Fließspannung verschiedener Metalle
Experimental analysis and modeling of the temperature- and strain rate-dependent flow stress of various metals

Urbanczyk, Julia
Tekkaya, A. E.; Rosenthal, S.
Untersuchung des Zusammenhangs zwischen den topographischen Merkmalen dressierter Oberflächen von rostfreiem, austenitischem Stahl und dessen Glanzgrad
Examination of a correllation between the surface topography of cold rolled austenitic steel and its glossy surface finish

Wolf, Tobias
Tekkaya, A. E.; Ortelt, T. R.
Untersuchung rollenbasierter Werkzeugsysteme für die inkrementelle Profilumformung
Investigation on cylindrical tools for the incremental profile forming process

Abgeschlossene Projektarbeiten | Completed Project Theses

Alves da Silva Neto, Acendino
Tekkaya, A. E.; Dardaei, H.
Bestimmung des Reibwerts von austenitischem und ferritischem Edelstahl durch Innendruck für die Innenhochdruckumformung von Rohren
Determination of the friction coefficient of austenitic and ferritic stainless steels with internal pressure in tube hydroforming process

Bandura, Philip
Tekkaya, A. E.; Napierala, O.
Verbundcharakterisierung des Tiefzieh-Verbundfließpressens
Bonding characterization of components manufactured by combined deep drawing and cold forging

Baumgartner, Leon
Tekkaya, A. E.; Mennecart, T.
Infiltrierung eines Glasfasergewebes unter Normaldruck
Infiltration of woven glass fibers under normal load

Bittencourt Lima, Victor
Tekkaya, A. E.; Dardaei, H.
Bestimmung des Grenzformänderungsdiagramms bei erhöhter Temperatur einer ME20-Magnesiumlegierung mit dem Argus-System
Determination of the forming limit curve at elevated temperature of the ME20 magnesium alloy with Argus system

Caliskan, Enver
Tekkaya, A. E.; Mennecart, T.
Einfluss von Fasern auf das Umformvermögen von Metallen unter Nutzung des Nakazima-Tests
The influence of fabrics on the formability of metals by using Nakazima test setup

Chandra Kumar, Aakash
Tekkaya, A. E.; Maaß, F.
Mehrstufige Umformstrategien für das „Single-Point-Incremental-Forming" thermoplastischer Werkstoffe
Multi-stage forming strategy for single point incremental forming of thermoplastics

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

Dayasagar, Jaswanth
Tekkaya, A. E.; Kolpak, F.
Untersuchung der Späneverschweißung in stranggepressten Aluminiumprofilen
Investigation of chip fusion in hot extruded aluminum profiles

Dixith, Akshata Chandrashekar; Patange, Sarang Chandrashekhar
Tekkaya, A. E.; Nazari, E.
Analyse der mechanischen Eigenschaften von Rohrbauteilen, hergestellt durch das inkrementelle Rohrumformen
Evaluation of mechanical properties of bent tubes manufactured by incremental tube forming

Dogan, Ömer Can
Tekkaya, A. E.; Traphöner, H.
Entwicklung und Erprobung eines Werkzeugkonzeptes für die ebene Warmtorsion von Magnesiumblechen
Development and testing of a tool concept for the warm in-plane torsion test of magnesium sheets

Engels, Luca
Tekkaya, A. E.; Napierala, O.
Experimentelle Untersuchung des Tiefzieh-Verbundfließpressens
Experimental investigations of combined deep drawing and cold forging

Gala, Vijal Premchand
Tekkaya, A. E.; Chen, H.
Untersuchung der Umformbarkeit von ferritischen Edelstahl-Rohren bei erhöhten Temperaturen
Determination of formability for ferritic stainless steel at elevated temperature

Goyal, Siddhant Prakash
Tekkaya, A. E.; Grodotzki, J.
Entwicklung eines analytischen Modells zur Kraftberechnung bei der inkrementellen Zahnradfertigung
Determination of an analytical model for force prediction in incremental gear forming processes

Hassan, Kardo
Tekkaya, A. E.; Mennecart, T.
Untersuchungen zum Formänderungsvermögen mehrlagiger Verbunde
Analysis of the formability of multi-layered sheets

Hensel, Raphael; Heringhaus, Mark; Markworth, Cedric
Tekkaya, A. E.; Komodromos, A.
Experimentelle Untersuchung umformtechnischer Effekte im Linearspulenwickelprozess
Experimental analysis of forming-based effects in the linear winding process

Hoffmann, Eike
Tekkaya, A. E.; Löbbe, C.; Meya, R.
Erarbeitung eines Steuerungskonzeptes für ein Prüfwerkzeug zur Bestimmung der Reibungsverhältnisse bei der Innenhochdruckumformung mit granularen Medien
Influence of axial feeding on the process limits in granular media-based tube press hardening

Jahn, Robert; 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

Karagöz, Tuba
Tekkaya, A. E.; Grodotzki, J.
Numerische Untersuchung des Rastagaev Druckversuchs mithilfe klassischer Langranger-, gekoppelter Euler-Langranger-Analyse (CEL) und „Smooth Particle Hydrodynamics“ (SPH)
Computation of Rastagaev compression test by classical Lagrangian, coupled Eulerian-Lagrangian Analysis (CEL), and Smooth Particle Hydrodynamics (SPH)

Kencham Padmanabharao, Madhu Sudhan Rao
Tekkaya, A. E.; Nazari, E.
Numerische und experimentelle Analyse von Bauteilfehlern beim inkrementellen Rohrumformen
Numerical and experimental analysis of failure modes in incremental tube forming

Keskin, Ezgi Yagmur
Tekkaya, A. E.; Mennecart, T.
Untersuchung des Faltenwurfs beim Tiefziehen von Faser-Metal-Laminaten
Wrinkling behavior of deep-drawn fiber metal laminates

Kuhlmann, Christoph
Tekkaya, A. E.; Kolpak, F.
Charakterisierung des Bauschingereffektes für Werkstoffe der Kaltmassivumformung
Characterization of the Bauschinger effect for cold forging materials

Lennemann, Philipp
Tekkaya, A. E.; Rosenthal, S.
Ermittlung von spannungszustandsabhängigen Fließkurven und Einfluss verschiedener Oberflächengüten auf die mechanischen Eigenschaften von Hastelloy X
Stress-state dependent flow curves and influence of surface roughness on the mechanical properties of Hastelloy X

Lissek, Christopher; Rickert, Niklas
Tekkaya, A. E.; Gebhard, J.
Konstruktive Erweiterung und Erprobung einer stempelfreien Biegevorrichtung
Extension and testing of a punch-free bending device

Lowo, Olabode; Okolo, Chukwuemeka Daniel
Tekkaya, A. E.; Nazari, E.
Untersuchung der Befeuchtung von Vulkan-Fasern auf die Anisotropie und die Umformbarkeit
Investigation of the effect of moisturization on the anisotropy and formability of vulcanized fiber

Martschin, Juri
Tekkaya, A. E.; Löbbe, C.
Einstellung der Festigkeit durch lokales elektrisches Erwärmen beim Profilbiegen
Setting the flow stress through the local electrical heating in a profile bending process

Meghana Arun, Joshi
Tekkaya, A. E.; Nazari, E.
Numerische und experimentelle Analyse von Bauteilfehlern beim inkrementellen Rohrumformen
Numerical and experimental analysis of failure modes in incremental tube forming

Mirzaei, Yasamin
Tekkaya, A. E.; Chen, H.
Numerische Untersuchung des Stopf-Prozesses für ovale Katalysator-Konverter
Numerical simulation of stuffing process for oval shape calalytic converter

Omer, Mohammed
Tekkaya, A. E.; Maaß, F.
Mehrstufige Umformstrategien für das „Single-Point-Incremental-Forming“ thermoplastischer Werkstoffe
Multi-stage forming strategy for single point incremental forming of thermoplastics

Patrick, Johnsan; Tran, Nam Markus
Tekkaya, A. E.; Dardaei, H.
Entwicklung und Erprobung eines Werkzeugkonzeptes für die ebene Warmtorsion von Magnesiumblechen
Development and testing of a tool concept for the warm in-plane torsion test of magnesium sheets

Pylaeva, Aleksandra
Tekkaya, A. E.; Selvaggio A.; Ortelt T. R.
Implementierung des vollautomatisierten Druckversuchs in das IUL-Remote-Labor
Implementation of the fully automated compression test in the IUL remote laboratory

Reihani Masouleh, Alborz
Tekkaya, A. E.; Mennecart, T.
Formänderungsanalyse mehrlagiger Bleche mit Variation der Zwischenschicht bei AA5182
Forming analysis of multi-layered AA5182 sheets with variation of the inner layer

Rozo Vasquez, Julian
Tekkaya, A. E.; Dardaei, H.
Untersuchung des Einflusses von unterschiedlichen Prozessparametern auf den Reibwert der ME21-Magnesiumlegierung bei erhöhten Temperaturen
Investigation of the effect of different process parameters on friction coefficient of ME21 magnesium alloy at elevated temperatures

Sarafraz, Yashar
Tekkaya, A. E.; Dardaei, H.
Materialcharakterisierung der stranggepressten Magnesiumlegierung ME20 bei Raumtemperatur
Material characterization of the extruded magnesium alloy ME20 at room temperature

Sepehri, Pedram
Tekkaya, A. E.; Gallus, S.
FEM-Simulation der temperaturunterstützten inkrementellen Rohrumformung
FEM simulation of heat assisted incremental tube forming process

Spee, Julian
Tekkaya, A. E.; Mennecart, T.
Simulative Untersuchung des Formschlusses zwischen Aluminiumblechen und ausgewählten Glasfasergeweben
Numerical analysis of the form-fit between aluminum blanks and woven glass fibers

Wapande, Sadam Hamis
Tekkaya, A. E.; Mennecart, T.
Einfluss von Fasern auf Umformvermögen von Metallen unter Nutzung des Nakazima-Tests
The influence of fabrics on the formability of metals by using Nakazima test setup

Wei, Hailong
Tekkaya, A. E.; Mennecart, T.
Umformverhalten eines Verbundbleches bei Nutzung eines ungetränkten Glasgewebes
Formability of fiber-metal laminates using non-infiltrated woven glass fibers

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

Yang, Wei
Tekkaya, A. E.; Chen, H.
Wärmeübergangskoeffizient zwischen granularem Material und 22MnB5-Stahl unter Druck
Heat transfer coefficient between granular media and 22MnB5 steel under pressure

Zia, Danish
Tekkaya, A. E.; Gallus, S.
Inkrementelle Rohrumformung hochfester Rohre mit unterstützter Induktionserwärmung
Incremental tube forming of high strength tubes with the help of induction heating

Ausgewählte Veröffentlichungen und Vorträge | Selected Publications and Lectures

08

Zeitschriftenbeiträge | For Journals (Peer Reviewed)

Allwood, J., Tekkaya, A. E., 2018. The Journal of Materials Processing Technology 2007-17. Journal of Materials Processing Technology 251, pp. 387-388, DOI: 10.1016/j.jmatprotec.2017.09.009.

Bellmann, J., Lueg-Althoff, J., Schulze, S., Gies, S., Beyer, E., Tekkaya, A. E., 2018. Parameter Identification for Magnetic Pulse Welding Applications. Key Engineering Materials 767, pp. 431-438.

Grzancic, G., Ben Khalifa, N., Löbbe, C., Tekkaya, A. E., 2018. Analytical prediction of wall thickness reduction and forming forces during the radial indentation process in Incremental Profile Forming. Journal of Materials Processing Technology. https://doi.org/10.1016/j.jmatprotec.2018.12.003

Groche, P., Ubelacker, D., Stein, P., Steinbach, F., Tekkaya, A. E., 2018. Experimental and Analytical Investigation of the Force Requirements in Shear Cutting of Metal-Polymer-Metal Composites. International Journal of Material Forming 2 (11), pp. 213-224.

Hahn, M., Ben Khalifa, N., Shabaninejad, A., 2018. Prediction of Process Forces in Fiber Metal Laminate Stamping. Journal of Manufacturing Science and Engineering 140, DOI: 10.1115/1.4038369.

Hahn, M., Gies, S., Tekkaya, A. E., 2018. Light enough or go lighter? Materials & Design 163C, DOI: 10.1016/j.matdes.2018.107545

Heibel, S., Dettinger, T., Nester, W., Clausmeyer, T., Tekkaya, A. E., 2018. Damage Mechanisms and Mechanical Properties of High-Strength Multiphase Steels. Materials 5 (11), DOI: 10.3390/ma11050761.

Hopmann, C., Schild, J., Wurzbacher, S., Tekkaya, A. E., Hess, S., 2017. Combination Technology of Deep Drawing and Back-moulding for plastic/metal hybrid Components. Journal of Polymer Engineering 6 (38), pp. 583-589, DOI: 10.1515/polyeng-2017-0354.

Isik, K., Yoshida, Y., Chen, L., Clausmeyer, T., Tekkaya, A. E., 2018. Modelling of the Blanking Process of High-Carbon Steel Using Lemaitre Damage Model. Comptes Rendus Mécanique 8 (346), pp. 770-778.

Löbbe, C., Tekkaya, A. E., 2018. Mechanisms for Controlling Springback and Strength in Heat-Assisted Sheet Forming. CIRP Annals – Manufacturing Technology 67, pp. 273-276.

Lueg-Althoff, J., Bellmann, J., Gies, S., Schulze, S., Tekkaya, A. E., Beyer, E., 2018. Influence of the Flyer Kinetics on Magnetic Pulse Welding of Tubes. Journal of Materials Processing Technology 262, pp. 189-203.

Müller, M., Gies, S., Tekkaya, A. E., 2018. Joining by Die-Less Hydroforming of Profiles with Oval Cross Section. Key Engineering Materials 767, pp. 405-412.

Nazari, E., Staupendahl, D., Löbbe, C., Tekkaya, A. E., 2018. Bending Moment in Incremental Tube Forming. International Journal of Material Forming, DOI: 10.1007/s12289-018-1411-x.

Ossenkemper, S., Dahnke, C., Tekkaya, A. E., 2018. Analytical and Experimental Bond Strength Investigation of Cold Forged Composite Shafts. Journal of Materials Processing Technology 264, pp. 190-199.

Staupendahl, D., Tekkaya, A. E., 2018. Mechanics of the Reciprocal Effects of Bending and Torsion During 3D Bending of Profiles. Journal of Materials Processing Technology 262, pp. 650-659.

Traphöner, H., Clausmeyer, T., Tekkaya, A. E., 2018. Material Characterization for Plane and Curved Sheets Using the In-Plane Torsion Test – An Overview. Journal of Materials Processing Technology 257, pp. 278-287.

Traphöner, H., Heibel, S., Clausmeyer, T., Tekkaya, A. E., 2018. Influence of Manufacturing Processes on Material Characterization with the Grooved In-Plane Torsion Test. International Journal of Mechanical Sciences 146, pp. 544-555.

Yang, D. Y., Bambach, M., Cao, J., Duflou, J. R., Groche, P., Kuboki, T., Sterzing, A., Tekkaya, A. E., Lee, C. W., 2018. Flexibility in Metal Forming. CIRP Annals – Manufacturing Technology 2 (67), pp. 743-765.

Beiträge in Konferenzbänden & weiteren Zeitschriften | Publications in Proceedings and further Journals

Bellmann, J., Lueg-Althoff, J., Schulze, S., Gies, S., Beyer, E., Tekkaya, A. E., 2018. Effects of Reactive Interlayers in Magnetic Pulse Welding. In: Proceedings of the 8th International Conference on High Speed Forming, Columbus, USA, (Digital).

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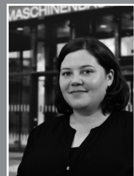

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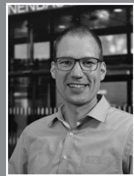

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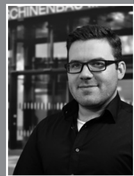

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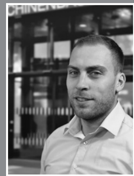

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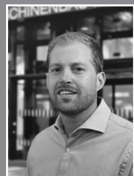

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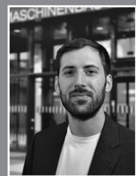

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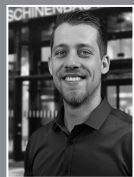

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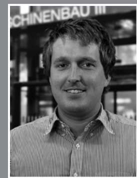

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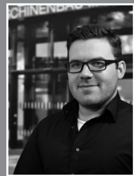

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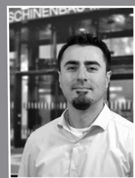

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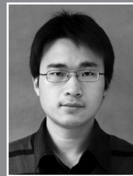
Dr.-Ing. Hui Chen


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Dipl.-Ing. Eilina Levin


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Dr.-Ing. Stefan Ossenkemper


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