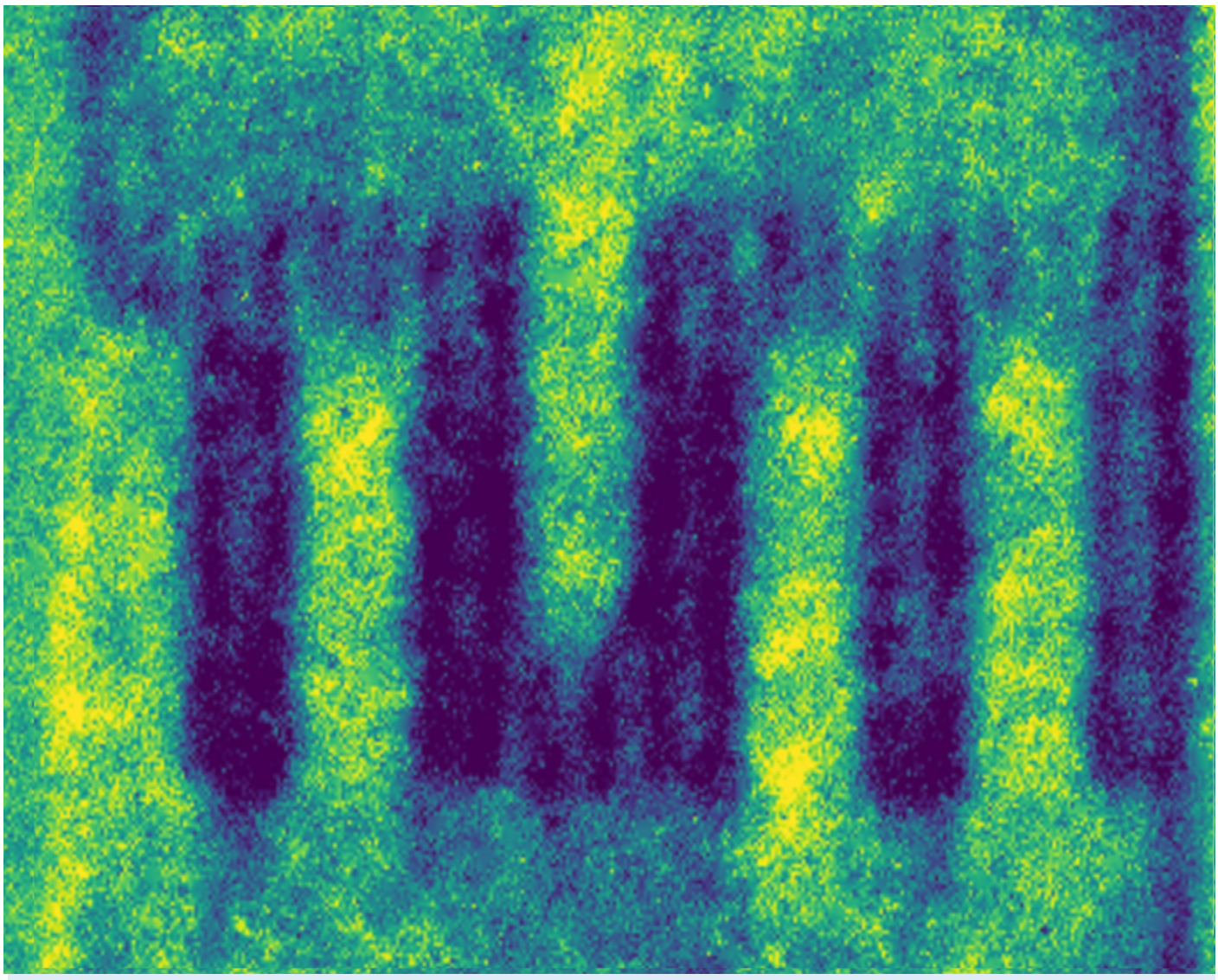
Chair of Metal Forming and Casting
TUM School of Engineering and Design
Technical University of Munich

utg Newsletter Issue 5 12/2021

Chair of Metal Forming and Casting



„Education comes not merely from reading, rather from reading and thinking about it.“

Carl Hilty, 1833 - 1909, Swiss constitutional lawyer and ethicist

Editorial

Dear friends of the *utg*,

Despite all the turbulence, the year 2021 is ending. At least Christmas falls, quite surprisingly, on 24.12. as usual.

To uphold some continuity, I am pleased that we can send you the new newsletter in time for you to read and think about before Christmas. Life at the *utg* is not yet back to normal, of course, even though we have so far been able to maintain hybrid teaching, offering live and online lectures during the winter semester. I am convinced that the chance of direct contact between the lecturer and the student body justifies the associated testing and monitoring effort.

At the *utg*, we are otherwise fully occupied with the usual day-to-day business. As you may have already noticed, there were some organizational changes in 2021. With our fresh PhDs Christoph Hartmann and Philipp Lechner, we established two post-docs, which help meet the requirements of the agile research landscape. In the following newsletters, we will present the associated research fields in more detail.

Another well-known, recurring effect is the uncertainty of the budget planning of key funders (e.g., AIF) after a federal election. Again, I sincerely hope that a budget supported and approved by all decision-makers will soon be available so that we as research centres can better assess which applications have a realistic chance of being approved.

With that, I wish you all a peaceful holiday season and a successful start to 2022, even in turbulent times.

Stay healthy!

Yours

Wolfram Volk

Prof. Dr.-Ing. Wolfram Volk *Photo: Heddergott/TUM*

Image Cover Page
© MLZ Neutron Imaging Group – Tobias Neuwirth, Simon Sebold; *utg* – Ines Gilch; IEM – Benedikt Schauerte,
Image of the magnetic domain density distribution of an embossed electrical sheet (embossing pattern) recorded with neutron lattice interferometry at ANTARES (FRM II).

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Electrical sheet: Increasing Energy Efficiency

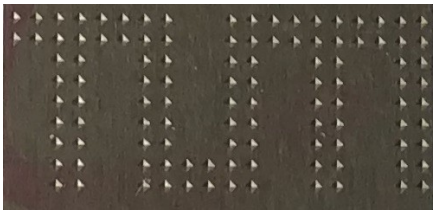
The magnetic core of electrical machines consists of stacked electrical steel laminations. The magnetic properties of this material can be adjusted by specifically introduced residual stresses, for example, by stamping.

Together with our project partners from MLZ (TUM) and IEM (RWTH), we are therefore researching "Targeted residual stress utilization in electrical sheets to increase energy efficiency." Interdisciplinary from a physical, electrotechnical, and production engineering point of view, the so-called magneto-elastic coupling is applied and investigated for targeted magnetic flux control.

Targeted guidance of the magnetic flux is fundamental for some motor topologies, whereby magnetic flux barriers are currently manufactured by cutting out areas of sheet metal. This process creates filigree structures in the rotor, which considerably weaken the mechanical strength and reduce the maximum permissible speed.

The use of stamped flow barriers allows the electric motor to be operated at higher rotational speeds, increasing energy density and efficiency.

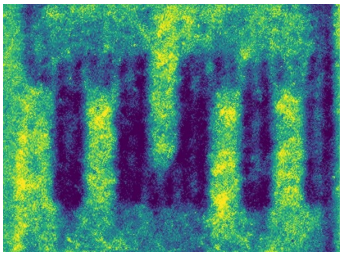
The results of the research project prove that the magnetic flow can be controlled by locally increasing residual stresses. Here, the global and local measurement of the magnetic properties of stamped sheets is fundamental. For example, neutron grating interferometry (nGI) is used to analyse the local distribution of magnetic domain density.



The cover picture shows a scatter image of an electrical sheet specimen taken with nGI.

On the embossing pattern, the magnetic flux concentration can be shown by the yellow areas, whereas the vertical strokes of the TUM logo are dark, indicating locally strong flux attenuation.

The project is part of the DFG Priority Program 2013, further information can be found on the *utg* Website.



3. Phase of SPP2013 has started

SPP 2013
www.spp2013.tum.de

Four research-intensive years are already behind us, now the third and last phase of the SPP2013 started on 01. October. The *utg* is represented here with two scientific projects. In addition, Prof. Volk was entrusted with the coordination of the entire priority program.

Twenty-eight institutes throughout Germany are investigating how residual stresses introduced by forming technology can be used specifically to improve the properties of metallic components.
The results of the first two phases have already been presented to the professional public in three special issues, 50 conference papers, 30 additional journal publications, and eight project films.

In November, all researchers met at the invitation of Prof. Tekkaya for a two-day exchange at TU Dortmund University.
In addition to technical discussions, interpersonal communication played a significant role. A goal of the DFG Priority Programme is that young scientists receive the opportunity to network with one another and thus further their interdisciplinary views.

utg News

Participants of the Project meeting at TU Dortmund University, Photo: IUL Dortmund

Based on research conducted as part of SPP2013, the aim now is to **transfer the knowledge gained to industrial manufacturing processes**. Research with application relevance is a prime concern, especially in production technology. Here, exchange with industry is particularly important to identify the relevant topics.

We want to discuss these topics in a **colloquium with the industry on 22 June 2022**, in Garching. There, application partners can inform themselves on the complex concept of residual stresses in lectures and live demonstrations and talk to the researchers about relevant aspects.
If you are interested in this event, you can already contact us:
spp2013@utg.de

More information about the projects, the topic-specific expert groups or the SPP2013 as a whole, and all publications can be found on the *utg* homepage:

https://www.mec.ed.tum.de/utg/spp-2013/

Successful Exhibition Appearance

The 15. Blechexpo - International Exhibition for Sheet Metal Working - was successfully held from 26 to 29 October 2021. After a long break, in an excellent atmosphere and, including a top-class supporting program, the industry celebrated the personal exchange of cutting-edge technologies for detail and system solutions in sheet metal, profile, and tube part production.

We were present at the joint booth of the European Research Association for Sheet Metal Processing (EFB) as a co-exhibitor as we have been for many years. During the four days of the exhibition, the employees were able to welcome many industrial partners and inform themselves about the latest developments at their booths.

Promoted by the new, modern booth concept of the EFB, many new contacts to companies were established, which gives hope for interesting, innovative research ideas.

It is precisely through close collaboration with industrial partners that we can continually review and align our research focus in terms of its application relevance.

Therefore, Blechexpo will continue to be on our future agenda, especially for our cutting and stamping technology focus areas.

The utg Exhibition Team at Blechexpo in Stuttgart, Photo: EFB

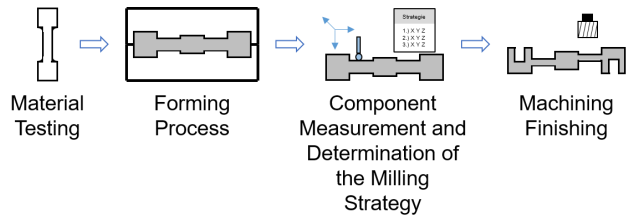
utg News

Modeling of process chains

Forming with Cutting Finishing of Thick Sheets

Due to increasingly complex geometries and the use of new materials, the qualitative demands on sheet metal components are rising, with the control of distortions playing an important role.
One problem that is currently only inadequately solved is the residual stress-induced distortion of thick sheet metal components. The residual stresses are introduced by the upstream manufacturing processes and thus influence the finishing process.
The resulting dimensional deviations pose a major problem for the industry, which can only be compensated by a cost- and time-intensive further post-processing step.

In a DFG research project started in December, we are investigating the distortion minimization of machined aluminium thick sheets in cooperation with the Institute for Machine Tools and Industrial Management (iwb).



Model of the Process Chain being studied in the DFG Project.

It is to be shown that a dimensionally accurate geometry is also possible without costly post-processing. In this research project, the residual stresses introduced during the forming process are to be characterized first by simulation and suitable measurement methods on the reference component and then taken into account during machining to minimize component distortion.

Based on numerical and experimental results, the influence of process parameters, such as forming speed, friction, removal strategy, feed rate, or plunge depth on the residual stresses and their distribution in the component is investigated.

Our contribution to the project consists of the design, simulation, and execution of the forming process on the hydraulic Dieffenbacher top piston press.
In addition, we are responsible for the residual stress measurements using the borehole method and nanoindentation. This project includes the derivation of generally applicable measures for distortion reduction.

The cooperative project is scheduled to run for 2.5 years. It aims to adapt the machining post-processing to the prevailing residual stress state and to be able to systematically manufacture dimensionally stable components by a suitable choice of process parameter values.

TUM School of Engineering and Design

As of 01.10.2021, the TUM School of Engineering and Design (SoED) has officially been established, and the long-established Department of Mechanical Engineering has ceased to exist.
A new, sizeable administrative unit has emerged due to the merger of Mechanical Engineering, Aerospace and Geodesy, Energy Engineering, and Civil Engineering and

utg News

Architecture. Prof. Dr.-Ing. Christoph Gehlen, formerly of the Department of Civil, Geo, and Environmental Engineering, was elected as the full-time founding dean.

The main goal of the new foundation is to bundle the competencies in the different engineering disciplines to create interdisciplinary study programs and launch cross-disciplinary research initiatives more easily.

Underneath the big School, there are eight departments, with the *utg* belonging to the Department of Mechanical Engineering. The main challenges in the early days include defining the new business processes and administrative procedures.

Now it is key to make the best possible use of the opportunities offered by the restructuring and to help shape it through personal commitment. You can find more details in the TUM press release:

https://www.tum.de/en/about-tum/news/press-releases/details/37029

Two Doctoral Prizes go to Scientists of the *utg*

Tim Mittler recieves the Hirschvogel-Prize

The Manfred Hirschvogel Prize has been awarded since 2013 in honour of Dr. Hirschvogel's life's work and is endowed with € 5,000. Every year the prize is awarded to the best doctorates in mechanical engineering from the nine leading technical universities (TU9) in Germany.

At the Technical University of Munich, Dr.-Ing. Tim Mittler received the coveted award in 2021. Dr. Mittler completed his doctorate on the topic of "Composite Casting of Copper Materials" at the *utg* under the supervision of Prof. Wolfram Volk. After his time at the chair, he moved to BMW AG in Landshut, where he works in the light metal foundry in process planning, specifically in 3D core printing and cylinder head casting.

From left: Dr.-Ing. Tim Mittler and Mr. Britzger, member of the Board of Trustees of the Manfred Hirschvogel Foundation, Photo: TUM

The WITTENSTEIN Award goes to Christoph Hartmann

Since 2009, the WITTENSTEIN Prize for the best doctorate has been awarded every year in the former Faculty of Mechanical Engineering at TUM. The prize, also endowed with € 5,000, is donated by the Wittenstein Group. In addition to the personal prize money, it includes an additional € 10,000 for the chair of the prize-winning doctorate.

2021, the jury decided to award the work of Dr.-Ing. Christoph Hartmann. He earned his doctorate at the *utg* on "Spatio-Temporal Optical Flow Methods for Process Analysis." Dr. Hartmann continues his research as a post-doc and is now responsible for the new research field "Hybrid, data- and physics-driven modelling."

Dr.-Ing. Christoph Hartmann, Photo: TUM

utg News

New Combination Bending Machine from Blech-Tec GmbH in Sauerlach

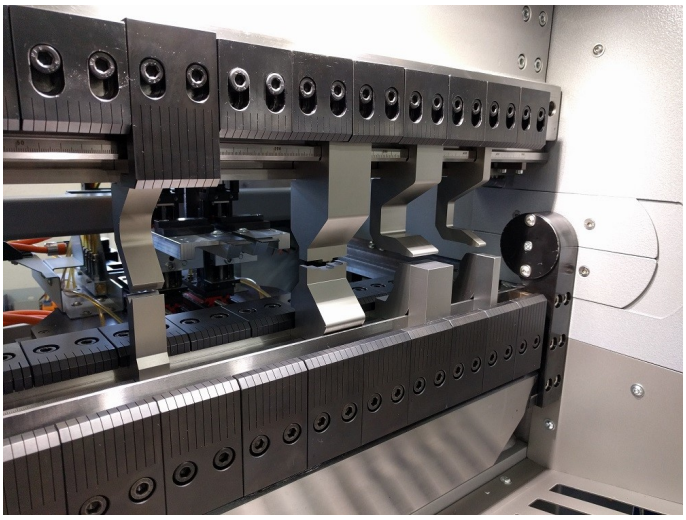
As the newest member of our machinery and equipment park, we were pleased to welcome the BT-500 bending machine from Blech-Tec GmbH to the *utg* in September of this year. Designed and manufactured in Sauerlach/ Altkirchen in Upper Bavaria, this servo-controlled bending machine is particularly impressive due to its highly rigid design, making it possible to perform bends with the highest precision.

The Compact Bending Machine BT-500 from Blech-Tec for Small Sheet Metal Parts, Photo: utg

Depending on the requirements, bending can be performed by one of the three processes - folding, swivel bending, or pressing. For example, bends that are close to each other in space can be made using a press module, while bends that are as precise as possible and have as little pressure as possible can be made using the swivel bending module.

The integration of the folding, swivel bending, and pressing processes on one machine opens up numerous possibilities in terms of the range of parts that can be realized on a single machine and offers extreme flexibility.

The BT-500 is designed for the production of small parts with sheet thicknesses between 0.5 and 5 mm and is primarily intended for the production of prototypes. Using the sectioned tools provided by Blech-Tec, highly complex prototypes can be produced in a very short time on one machine. There is no need to manufacture additional tools.



The BT-500 with four different tools, Photo: Blech-Tec

The market for stamped and bent parts, e.g., plug-in connections, is steadily increasing due to advancing digitalization. From the strategic point of view of the chair, the new miniature bending machine closes the gap to the series production facilities (Bihler machine, Bruderer presses). E.g., to test new material and functional concepts for stamped and bent parts without individual production equipment.

Furthermore, the bending machine is excellently suited for teaching due to its intuitive and simple operating concept.

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BiZeBS
Bending Centre Bavaria South

At the end of the year, the Chair of Metal Forming and Casting, together with its industrial partners, wanted to hold a workshop on "Freeform Bending - Limits and Potentials." Unfortunately, due to the current high Corona numbers, the workshop could not be held in presence at the newly established Bending Centre Bavaria South (BiZeBS). As an alternative, we switched to the now proven virtual format and welcomed a diverse audience of research and industry partners.

In the beginning, Prof. Dr.-Ing. Wolfram Volk spoke about the activities of the chair and the motivation for the research at the Bending Centre Bavaria South. Subsequently, Mitsubishi Electric Europe B.V. presented the possibilities of updating the control system, the motors, and real-time data on a 6-axis freeform bending machine. Through this conversion, the freeform bending machine of our chair becomes an intelligent machine in the sense of Industry 4.0 and enables the application of different data-based approaches to optimize productivity and accuracy. In this sense, we would like to thank Mitsubishi Electric Europe B.V. once again for their commitment to the modernization of the freeform bending line.

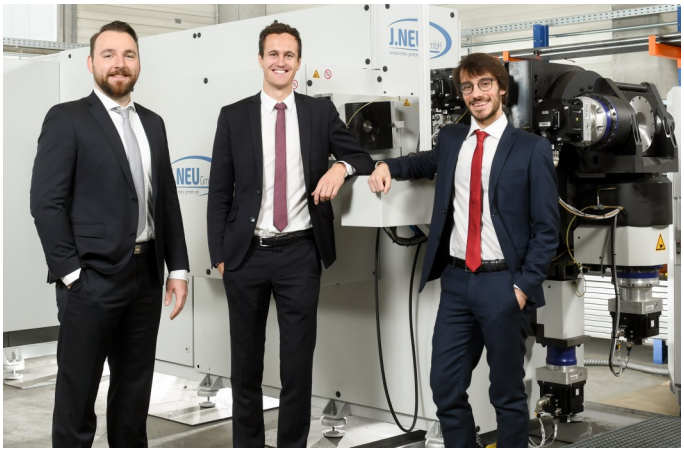
After the technical upgrades, the current *utg* research projects on freeform bending were presented. The *utg* is currently working on the bending of discontinuous curvatures (splines) and rectangular profiles made of high-strength materials. Further, the design of a control loop that reacts directly to property fluctuations in the semi-finished product during freeform bending is part of the research.

Prof. Volk then opened the discussion round led to an intensive exchange of new ideas and research approaches thanks to the different backgrounds of the participants.

The positive response confirms the current orientation of the chair in the field of freeform bending. Not only the research projects but also the industrial influence of the research are to be particularly emphasized. This is demonstrated, among other things, by the current results from the DFG priority program "Property-controlled forming processes" (SPP 2183).

In conclusion, all participants hope that this workshop will be repeated in 2022, but in presence and not only in front of the screen.

For more information on the Bending Centre Bavria South, please visit our website.



From left: ***Matthias Werner*** *- Manufacturing Specifications,* ***Daniel Maier*** *- Process Control, „****Biegfried****“ - Manufacturing,* ***Lorenzo Scandola*** *- Feasibility Analysis, Photo: utg*

Latest research news at the *utg*

Casting

Additive Processing of Copper Materials in the Material Jetting Process (MJT)

Motivation and Initial Situation

At *utg*, the MJT process with metallic materials has been researched for several years. MJT is an additive manufacturing process in which a component is built up from individual droplets. Previous research projects at the chair investigated the processing of aluminium materials and salts as support structures for aluminium printing.

As part of the AiF-funded project, the processing of copper materials using the MJT process is being investigated in collaboration with industry partners. Due to its high thermal and electrical conductivity, copper is in particular demand for applications in the electrical industry and thermal management.

If the geometry of the components has special requirements or small quantities are required, the components can often only be manufactured economically using additive processes. With the laser powder bed-based processes widely used to date, the processing of pure copper is technically complex due to the low absorption level of the laser radiation. With the MJT process, an additive manufacturing process is to be investigated with which copper components can be manufactured additively without lasers and powder.

Fig. 1: MJT Additively Manufactured Components made of Pure Copper and Bronze, Photo: utg

Solution Approach

In the research project funded by the AiF (IGF project no.: 21553 N / 1), the first step is to develop a suitable print head for processing copper materials. For this purpose, different materials for the nozzle and the crucible of the printhead are characterized concerning thermal resistance and wetting properties. This is followed by an investigation of the effects of various process parameters, such as droplet size, printing frequency, and build platform temperature, on the appearance of the printed components. For this purpose, the copper components are examined, for example, concerning component density, mechanical properties, and geometric accuracy. To identify suitable process parameters, parameter studies are also supported by simulations.

Fig. 2: Micrographs of a Bronze Cuboid Unetched and Etched, Photo: utg

Results and Outlook

In initial trials, suitable nozzle and crucible materials were identified. It was also proven that the bonding of the droplets to one another depends in particular on the temperature of the build platform. In further experiments, the influence of droplet size and pressure frequency on the component properties will be investigated to achieve better component quality, especially when processing pure copper.

Contact: Maximilian Plötz, M.Sc.

Latest research news at the *utg*

Cutting and Blanking

Reduction of Edge Crack Sensitivity through Recutting

Initial Situation

Edge cracks are sometimes one of the greatest challenges in the further processing of shear-cut component edges. Multiphase steels or microstructural steels are particularly affected by this phenomenon.
The process of recutting has established itself as a process adaptation that can significantly reduce edge crack sensitivity.

Re-cutting and the Improvement of Edge Formability

The cause for the reduced formability of shear-cut component edges is the hardening introduced by shear cutting and damage to the material caused by microcracks and/or pores in the shear-affected zone.
In addition to the microstructure, the method of shear cutting has a decisive influence on the depth and extent of the damage. For example, edges produced by an open cut are generally more resistant to edge cracking than those produced by a closed cut.
By contrast, re-cutting offers much greater potential for improving edge formability. In this process, a hole offset by the width of the re-cut allowance is pre-cut at critical points of a stamping process. In the course of this, the stiffness of the waste at the position in the subsequent re-cutting process decreases.
The deformation occurring in the shear zone is almost completely diverted into waste if the process parameters are selected appropriately, illustrated in figure 1. The occurrence of defects, e.g., pores or microcracks, can also be minimized in the shear zone by adapting the process as described.

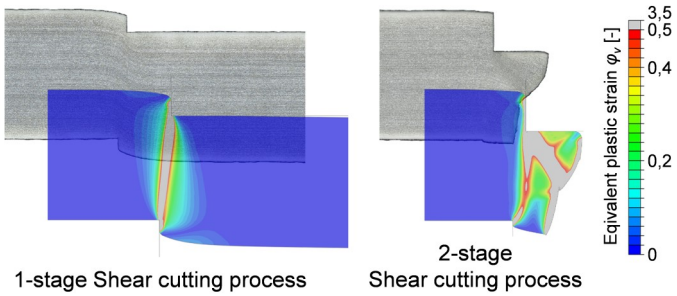


Fig. 1: Majority of Plastic Deformation Shifted to Waste due to Adjusted Recutting Parameters

Application in Mass Production

The re-cutting process can be cost-effectively and easily implemented in multi-stage shear cutting tools and has already been used successfully in the industrial environment to reduce scrap and rework and thus ensure process stability. The fatigue strength on shear-cut edges of components could also be improved using an adapted re-cutting strategy.

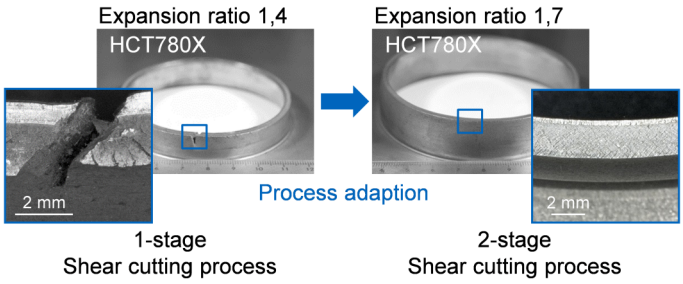


Fig. 2: Improvement of the Expansion Ratio in the Collar Tensile Test by Re-cutting

Further Investigation Focus

Further research topics address the influence of serial boundary conditions (sheet thickness, component geometry) on the choice of recutting parameters to guarantee high process reliability over long service lives while taking wear into account.

Contact: Dipl.-Ing. Isabella Pätzold

Latest research news at the *utg*

Forming

The MUC Test for the Evaluation of Material Models for Sheet Metal Forming

Initial Situation

The quality of the material model must be known and compared to the accuracy requirements to gain meaningful simulation results. Currently, there are various methods for validating material models, each of which has different advantages and disadvantages. In principle, all these methods are a comparison of experimental and simulated data.

The MUC Test

A test was designed at the *utg* chair, which allows data to be generated as the basis for efficient and effective validation of material models, the MUC test (an acronym for Material Under Control). The tool is used here in a BUP1000 sheet metal forming test machine from ZwickRoell.

The test geometries are clamped between the sheet holder and die and formed by the punch. For a com plete validation, three specimen geometries are examined in three directions concerning the rolling direction. Through the opening in the die, the occurring strains are detected over the entire test with the aid of the ARAMIS optical measuring system from *gom*.

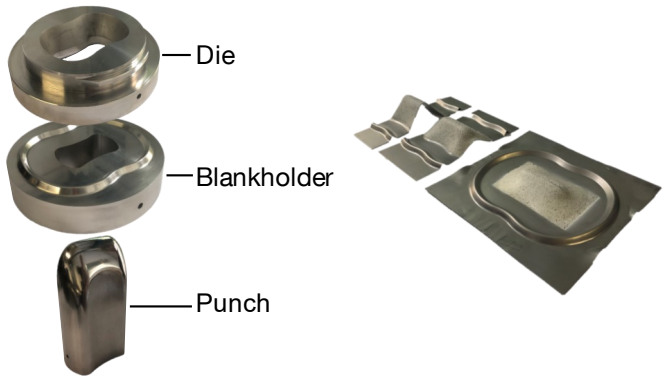


Fig. 1: From left: Tool and Specimen Geometries for the MUC Test

This results in different elongation characteristics for dissimilar materials.

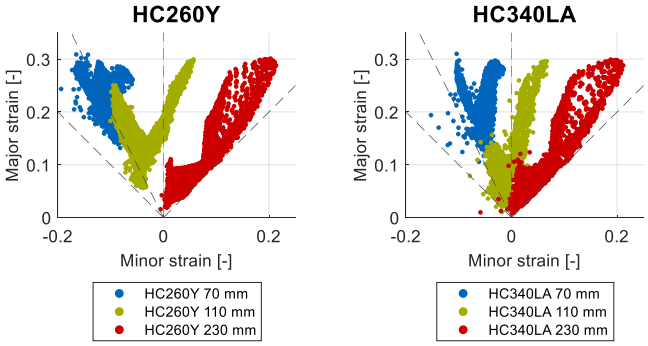


Fig. 2: Strain Characteristics of the Three Specimen Geometries for Two Different Materials.

The MUC test trials are simulated and compared with the experimental results. From this comparison, conclusions are drawn about the quality of the material model.

Investigation Focus

A main application goal of the MUC test is to evaluate the performance of existing material models over a wide strain range. The current focus is on the yield curve and the yield locus model. Within the scope of this validation, model parameters can be identified that cause inaccuracy in the simulative mapping. Thus, in addition to the validation, an optimization of the parameters shall be implemented.

In further investigations, the influence of non-linear strain paths, as can occur in multi-stage forming operations, will be investigated. Such complex forming processes represent a major challenge for material models and harbour great potential for error.

Result

The MUC test offers the possibility to examine material models with low material input. It also allows for statements about the material quality.

Contact: Matthias Eder, M.Sc.

Personnel at the *utg*

We extend a warm welcome to:

Lukas Martiniz, M.Sc.
joined the Cutting and Blanking Group
on 1 October 2021.

Alina Reimer, M.Sc.
joined the Forming Group
on 1 November 2021

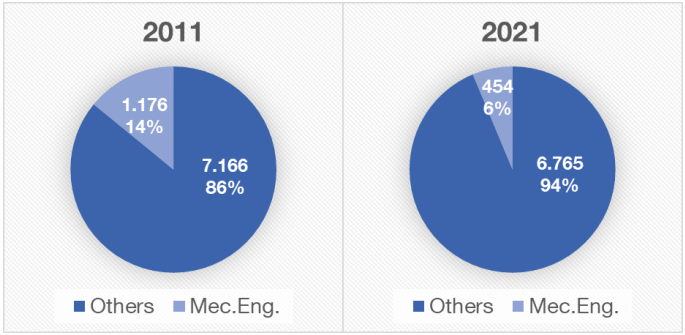
Dipl.-Ing. **Andreas Tertel**
joined the Forming Group
on 1 December 2021.

2011 to 2021—10 years Wolfram Volk

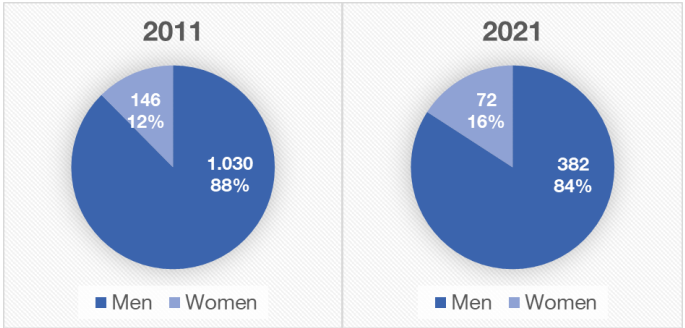
Prof. Wolfram Volk took over the chair from his predecessor Prof. Hartmut Hoffmann in 2011. That was ten years ago. It is time to show the changes of the last decades with a small statistical comparison:

In 2011, a double Abitur cohort entered Bavaria's universities, with one in seven enrolling in mechanical engineering. By 2021, the number of first-year students in MW studies had decreased significantly (1), with only one in sixteen choosing mechanical engineering. Two reasons for this are the more diverse range of courses on offer and a noticeable migration to computer science subjects.
Unfortunately, the proportion of women in mechanical engineering has changed only slightly (2), whereas there are more female scientists working at *utg* than ever before (3).

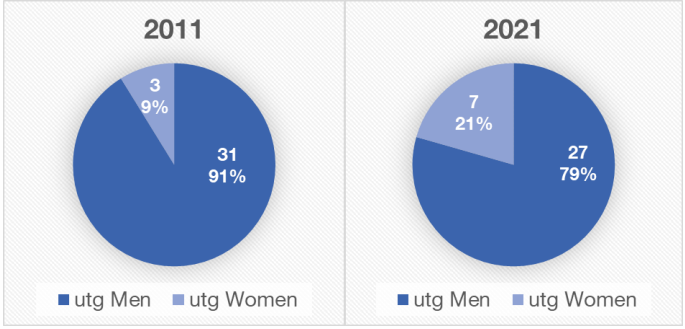
For the next decade, our main goals are to contribute to science and society by focusing on current research needs while maintaining the same size.
Against the background of an ever more demanding funding landscape, this will only succeed through joint efforts and intensive exchange with industry and academia.



(1) Proportion of first-year students in mechanical engineering compared to all other degree programmes



(2) Proportion of female first-year students in mechanical engineering



(3) Proportion of women among academic staff at utg

New Dissertations at the *utg*

32 **Martin Feistle**: Edge-Fracture-Tensile-Test, July 2021

33 **Thomas Greß**: Vertical Continuous Compound Casting of Copper Aluminium Semi-Finished Products, July 2021

34 **Jens Stahl**: Residual Stresses Induced by Precision Shear Cutting Processes, August 2021

35 **Florian Ettemeyer**: Charakterisierung des Entkernverhaltens anorganisch gebundener Formstoffe, October 2021

36 **Lucas Schulte-Vorwick**: In-Line-Richten von Fahrzeugstrukturteilen aus Leichtmetalldruckguss, October 2021

All publications and dissertations of the chair are listed on the website www.mec.ed.tum.de/utg

The dissertations appear as print-on-demand in the series „**Schriftenreihe Umformtechnik und Gießereiwesen**“, ed. Prof. Dr.-Ing. W. Volk, TUM University Press, ISSN: 2364-6942

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