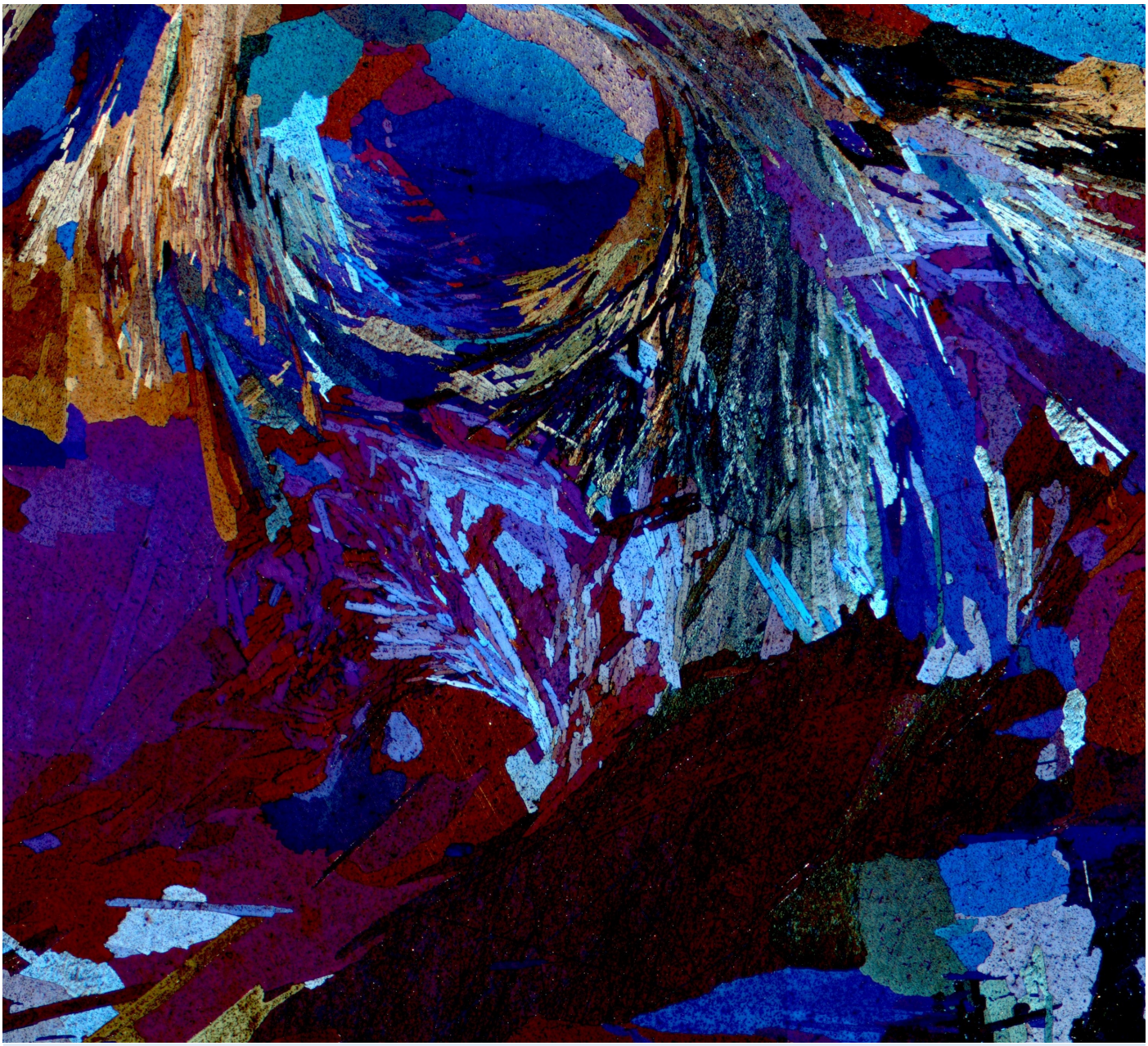
Chair of Metal Forming and Casting
TUM School of Engineering and Design
Technical University of Munich

utg Newsletter Issue 9 12/2023

Chair of Metal Forming and Casting



"The great advances in science are often, perhaps always, on the fact that a question that has not been asked before asked before, and successfully at that."

Carl Friedrich von Weizäcker (1912-2007), german physicist, philosopher and peace researcher

Editorial

Dear friends of *utg*.

As usual at the end of the year we send you the latest newsletter from the Chair of Metal Forming and Casting. We want to provide some interesting information about academic life at *utg* and insights into current research projects before the holidays.

Overall, 2023 was a good year for us despite all the adversities and uncertainties. Of course, many questions still need to be addressed, particularly the currently unforeseeable effects of the much-discussed public funding gap. However, we are already optimistic about the new year, with a highly motivated team and many exciting projects and ideas.
We hope you will all find some peace and quiet over the turn of the year so we can start the new year with fresh energy and motivation.

The year 2024 is already casting its shadow. In April, we will again be organising the stamping congress in Dortmund; in summer, the established in-house exhibition at *utg*; and in September, we are looking forward to the Forming Technology Forum FTF in Ohlstadt on the topic of "All about blanking".

Our entire *utg* family would be delighted if you could attend one or more of these events in person.

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

Wolfram Volk and the whole *utg* team

Frontpage Image:

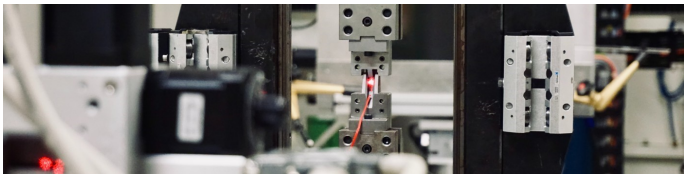
Samples from the analysis furnace. Dissolution behavior of copper and tin. "Functionally graded materials: continuous casting and forming of electrical copper conductors"

Sample preparation: etched with FeCl3 and HCl, imaged in polarized light; Zeiss Imager M2 microscope

Photo: Corinna Sutter/utg

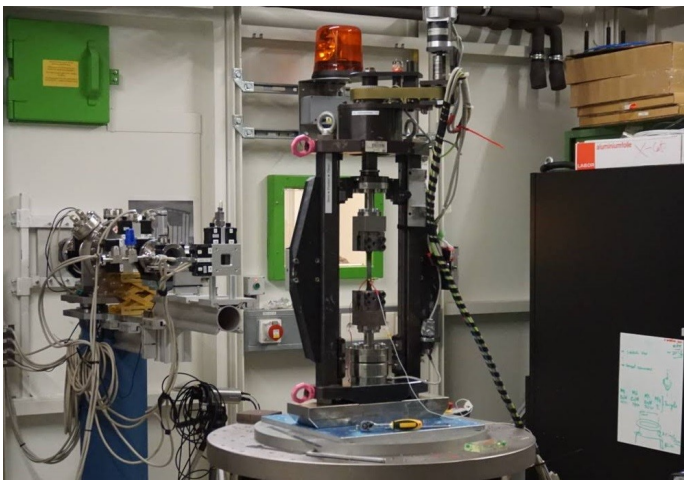
utg News

Measurements at the German Electron Synchrotron DESY



Our research has brought us to the Deutsches Elektronen-Synchrotron (DESY) in Hamburg for measurements once again, following many years of close collaboration with the team at the Munich Research Reactor (FRMII). This time, Edgar Marker and Lorenz Maier (*utg*) conducted the measurements together with Dr. Michael Hofmann (FRMII). The purpose of this measurement series was to study the elastic and anelastic deformation behaviours of dual-phase steels.

Our aim is to identify macroscopic and microscopic material parameters and correlate them, to enhance existing models for FEM simulation. The outcome of this measurement series will also be shared with the sheet metal forming community as part of the NUMISHEET 2025 benchmark. To attain our objective, we conduct cyclic and basic tension and compression evaluations. These allow us to parallelly quantify the macroscopic stress, strain, and sample temperature while correlating them with the microscopic strains and dislocation densities. The high-energy X-rays sourced from DESY in Hamburg enable us to capture the microscopic variables during the assessments.



Foundry Excursion 2023

In October, the annual excursion of the foundry technology group of the *utg* took place together with the foundry part of the Fraunhofer Institute IGCV. The main focus was on promoting cooperation between the research groups, which are both headed by Professor Volk. In addition to joint promotion, the foundry excursion focused in particular on contact with industry, which gave us a warm welcome.

This year, the two groups travelled to the north of Germany. The first visit took place at Frankenguss GmbH & Co. KG on the way. Here, Dr Wolfgang Knothe explained the importance of casting-compatible design and load optimisation. The subsequent tour of the production facility was an impressive demonstration of how traditional foundry technology can work with modern technology.

After arriving in beautiful Münster, the next visit was no less fascinating. The Georgsmarienhütte group of companies near Osnabrück made a lasting impression on the participants with its high-performance electric arc furnace. It became clear how much knowledge and experience is required to produce high-purity steels from recycled scrap in an environmentally friendly continuous casting process. Process monitoring and quality assurance were demonstrated both in continuous casting and in the downstream rolling mill. The GMH employees were happy to answer our many detailed questions at length.

utg News

The third visit took us into the world of aluminium. Trimet Aluminium SE in Essen showed us the intricacies of aluminium electrolysis. In the course of the very intensive discussions, it became clear how important primary aluminium production continues to be for the manufacture of high-purity materials. However, targeted recycling is an increasingly important factor that needs to be expanded in order to meet the demand for high-performance aluminium in the future.

16th Bavarian Barbara Conference

The highlight of November for foundry research is, of course, the annual Bavarian Barbara Conference. After our new concept was very well received last year, we also built on it on 30 November 2023.

On the overarching topic of "**Foundry technology in the area of conflict between resource consumption and sustainability**", we were able to attract two exciting presentations from the industrial environment.

Ms **Sabine Sigle** reported on the progress and hurdles on the way to climate-neutral value creation from the perspective of **Nemak Europe GmbH**, a company in the field of lightweight aluminium solutions.
In the second presentation, Dr **Thorsten Rieck** and **Guido Rau** from **Fondium** focused on iron casting, more specifically ductile iron casting. The challenges to climate neutrality here are different but similarly great.

Research then took centre stage. At a total of nine stands, participants were able to exchange ideas on exciting projects and discuss them with the young researchers. In addition to gtm (Foundry Technology Munich), the universities from Aalen and Kempten and three small start-ups were also present in the research car park.

We would like to thank VDG Bayern and
Fill Gesellschaft m.b.H. for supporting the event.

Prizes and Awards 2023 at *utg*

Hartmut Hoffmann honored with the Kurt-Lange Medal

The Arbeitsgemeinschaft Umformtechnik (AGU) has awarded **Prof. Hartmut Hoffmann** the Kurt Lange Medal. This award honors individuals who have made a significant contribution to forming technology research in Germany.
In his laudatory speech, Prof. Volk highlighted the long scientific career of his predecessor at the *utg*. Starting with his studies in Berlin in the 1960s, through his years at Schuler Pressen in Göppingen to his appointment at the Technical University of Munich as successor to Prof. Fritz Fischer at the *utg*.
Here he established a modern chair of production engineering and forged the first close partnerships with plant manufacturers and industrial companies. Today, these partnerships are an important pillar of the *utg* for conducting application-relevant research.
We all congratulate Hartmut Hoffmann on this great honor and thank him for his tireless commitment to forming technology and wish him all the best for the future.

Prof. Mathias Liewald (IUL, University of Stuttgart) presents Hartmut Hoffmann with the certificate and medal.

Photo: IUL

Otto-Kienzle Medal goes to Christoph Hartmann

The German Academic Association for Production Technology WGP awards the Otto-Kienzle Commemorative Medal to young researchers for outstanding achievements in the field of production engineering.

Photo: Fotoatelier Ebinger

Dr **Christoph Hartmann**, a postdoctoral researcher at the *utg*, was delighted to recieve the award on November 22nd.

One area of his research areas is the investigation, development and implementation of computer vision techniques, in particular optical flow methods, for the spatially and temporally resolved analysis of material deformation, crack formation, and crack propagation from image sequences. He excels in leading research on hybrid, data-driven and physics-based modeling and is currently establishing cryogenic materials testing and applications research.

We are thrilled that Christoph has recieved this well-deserved award! Congratulations, Christoph.

Max Plötz convinces at the copper symposium

Maximilian Plötz was delighted to receive an award at the **Kupfersymposium 2023** hosted in Jena as part of the scientific poster exhibition. His poster on "**Additive manufacturing of copper materials using liquid metal jetting**" received the first prize.

Prizes and Awards 2023 at *utg*

Liquid metal jetting is an additive manufacturing process in which a part is built up droplet by droplet. Using comparatively inexpensive system components and a wire as feedstock material, liquid metal jetting offers the potential to produce near-net-shape mono and multi-material parts cost-effectively.

There is an interesting video about this special manufacturing process on our YouTube channel: https://youtu.be/4yd_2eg5V8c?si=5uQsLTjNJjuocfCf

Prize for the Best Undergraduate Lecture

Every year, the Fachschaft Maschinenbau honors lecturers in various categories on behalf of the students. In the undergraduate lecture category, **Prof. Volk and Prof. Zäh** have now been awarded the first prize, the "Goldene Lehre".
"We are immensely proud to be honored with this award for our commitment to undergraduate studies. Together with the iwb, we try to get young people interested in process engineering and manufacturing in the lecture "Introduction to Production Engineering"." (Wolfram Volk)

Good teaching is teamwork, which is why the academic staff of both chairs deserve a big thank you for their excellent preparation and follow-up work for the lecture.

Best Paper at E|DPC

The publication "Residual stresses and magnetic material properties of embossed and cut magnetic flux barriers in nonoriented electrical steel under tensile load" was awarded the Best Paper Award by the conference participants and the program committee at the 13th Electric Drives Production Conference (E|DPC) in Regensburg.
The publication deals with magnetic flux conduction in electrical sheets due to residual stresses introduced by forming technology. The publication was written by **Ines Gilch**, Benedikt Grünhag, Christoph Hartmann and Wolfram Volk from the Chair of Forming and Casting Technology (TUM) and Benedikt Schauerte, Nora Leuning and Kay Hameyer from the Institute of Electrical Machines (RWTH Aachen University).

Ines Gilch präsentierte Ende November das Paper auf der Electric drives production Conference in Regensburg.

A research report can be found on page 9 of this newsletter.

The following two award winners were already mentioned in the last newsletter. For the sake of completeness, they are mentioned again here in the annual review:

This year's **EFB Project Award** went to **Markus Welm** for his research contribution on the topic of "Avoiding raised slugs by influencing slug friction".

Dr. Philipp Tröber was awarded the **Hirschvogel Prize** of the Faculty of Mechanical Engineering for his dissertation.

Congratulations to all those honored and many thanks for their outstanding achievements!

Current Research at *utg*

Casting

Low-pressure Die Casting of Asynchronous Rotors

Motivation

Integral rotors for asynchronous motors are largely manufactured using the pressure die casting process. The efficiency of the rotors can be influenced or impaired, for example, by the temperature input, the casting pressure and casting errors. Increased porosity of the short-circuit cage, for example, leads to a reduction in the conductor cross-sections and thus to an increase in electrical losses in the rotor. In pressure die casting in particular, some pore volumes are in the double-digit percentage range.

For this reason, the Deutsche Bundesstiftung Umwelt (DBU) sponsored a project to investigate alternative casting methods for producing asynchronous rotors.

Procedure

Due to its potential for producing high-quality castings and ist suitability for large-scale production, the low-pressure die casting process was chosen and studied in the project for casting the rotors. Hereby the small cross-sections in the rotor bars and large cross-sectional transitions from the bars to the short-circuit rings present a challenge.

Fig. 1: Low-pressure casting system for casting asynchronous rotors, photo: utg

A low-pressure casting machine was created at the institute for casting asynchronous rotors. Two different rotor geometries were employed, one of which faciliated magnetic measurements allowing the investigation of the casting process‘s effect on the magnetic properties. The second rotor geometry, provided by AMK Motion and currently produced through pressure die castig, enables a direct comparison of the two casting methods.

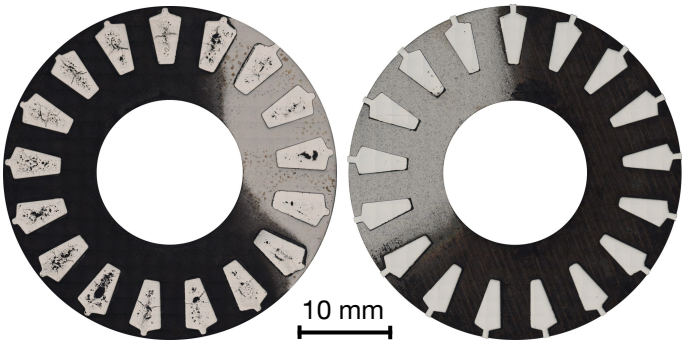


Fig. 2: Cross-section of the in series produced geometry through the middle of the bars of the short-circuit cage, left: pressure die cast, right: low-pressure die cast, photo: utg

Results

The casting process did not negatively impact the magnetic properties of the electrical steel sheets. Additionaly, the proportion of defects of the rotors decreased from an average of 13 % to 1 % compared to the in series produced pressure die cast rotor. The primary reason for the defects present in the low-pressure die cast rotor is due to oxides being washed in as a result of the casting system‘s lack of a filter.

Through utilising the alternative casting process, a noteworthy decrease in the defects of the rotors can be achieved.

Contact: Georg Fuchs, M.Sc.

Current Research at *utg*

Casting

Research stay in California

Lawrence Livermore National Laboratory
This summer, our scientific colleague Benedikt Kirchebner undertook a research stay at the Lawrence Livermore National Laboratory (LLNL). Located approximately 60 km east of San Francisco, LLNL was established in 1952 and has recently become renowned for its advancements in nuclear fusion. The laboratory also conducts research on a variety of materials and production technology topics, including liquid metal jetting (LMJ). LMJ is an additive manufacturing method whereby a component is built up from individual droplets of molten metal. In contrast to powder, a wire-shaped semi-finished product is used, providing benefits in terms of both handling and expenses.

LMJ has been a topic of investigation at *utg* for several years, with a current focus on developing support structures and processing copper materials. A process video on LMJ can be viewed through the QR code provided at the end of this newsletter article. Publication of the research visit results to LLNL is planned for mid-next year.

Fig. 1: Entrance of the Lawrence Livermore National Laboratory (LLNL) in Livermore, California, photo: utg/bek

Solid Freeform Fabrication Symposium
During the research stay, it was also possible to participate in the Solid Freeform Fabrication Symposium (SFF) in Austin, Texas. The conference on additive manufacturing offered an ideal opportunity for networking in the field of LMJ research. In addition to Benedikt Kirchebner with a presentation on water-soluble support structures for the LMJ of aluminium, Maximilian Plötz - also from *utg* - presented the latest developments in the processing of copper materials in LMJ. The corresponding articles can be downloaded free of charge from the University of Texas at Austin website.

Stanford University with Dr Tim Bombosch
During the research trip, a noteworthy event was the meeting with TUM San Francisco Liaison Officer, Dr Tim Bombosch, at Stanford University. This private university, founded in 1891, is situated in Silicon Valley, an hour's drive from LLNL. Dr Bombosch, who himself is an alumnus of Stanford, offered insight into the renowned institution.

Fig. 2: Benedikt Kirchebner (left) and TUM San Francisco Liaison Officer Dr Tim Bombosch (right) in front of the Memorial Church at Stanford University.

The research stay received financial support from the TUM Graduate School as part of its internationalisation funding.

LMJ Video

Contact: Benedikt Kirchebner, M.Sc

Current Research at *utg*

Cutting and Punching Technology

Targeted magnetic flux guidance in electric drives

Motivation

In order to increase the energy efficiency of electric drives, it is necessary to guide the magnetic flux in the non-grain-oriented electrical steel as precisely as possible to reduce stray fluxes. At present, the magnetic flux guidance is achieved by cutouts in the electrical laminations, which lead to a reduction in the mechanical strength of the sheet metal. By utilizing the magneto-elastic effect, which enable the creation of magnetic flux barriers by locally induced mechanical stresses, the magnetic field can be guided with small impact on the mechanical strength and higher rotational speeds can be achieved. The induction of such residual stresses is realized by embossing the electrical steel sheets.

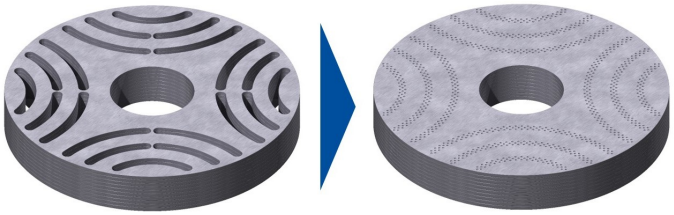


Fig.1: Rotor of a synchronous reluctance machine with conventional flux barriers (left) and with embossed flux barriers (right)

Results

Over the course of the six-year project, the targeted and reproducible introduction of residual stresses into electrical steel was demonstrated and their effect on the local magnetic properties, especially the magnetic permeability, was proven. It was shown that residual stresses are decisive for the change in magnetic properties. Embossing with a large number of microscopic embossing points (< 0.3 mm) has been promising, leading to a locally adjustable stress distribution and reduced deformation of the sheets. The further development of magneto-mechanical measurement technology has made it possible to determine the magnetic properties with the magnetization direction and the mechanical tensile and compressive stress direction twisted in relation to each other. This allows the detailed simulation and evaluation of the direction-dependent influence of mechanical stresses on the operating behavior of rotating electrical machines.

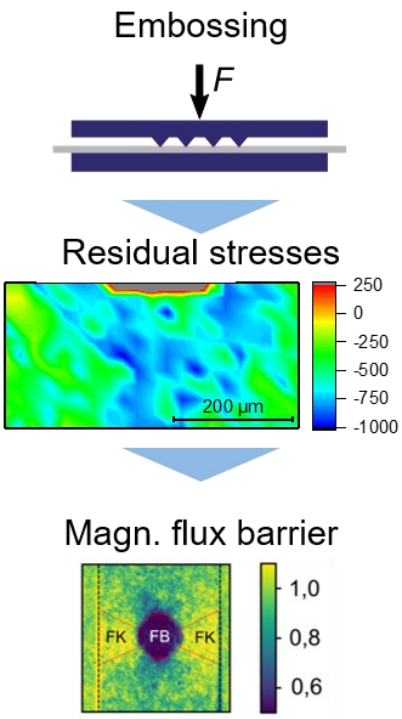


Fig.2: Embossing induced residual stresses as magnetic flux barriers (measured with neutron grating interferometry)

Outlook

Due to the excellent results, a DFG knowledge transfer project with the project partners MLZ (TUM) and IEM (RWTH Aachen) as well as the industrial partner MUBEA was successfully applied for. The transfer of basic research results to the application of embossed flux barriers in a permanent magnet synchronous machine will be investigated.

Contact: Ines Gilch, M.Sc.

You can watch the video on the project by scanning the QR code or following the link provided: https://youtu.be/DmL7kut_JYk?feature=shared

Current Research at *utg*

Forming

Tryout-Manager for Toolmaking

Initial situation and goals

The tryout phase in toolmaking for forming technology is heavily influenced by human experience and often requires several correction loops, leading to high costs and loss of time. However, the increasing pressure for shorter product development cycles requires more efficient and precise processes.

The *utg* research project aimed to solve these problems by introducing a tryout manager. This manager should reduce the tryout time through structured data collection and systematic evaluation. A developed procedure should make it possible to compare data during the tool manufacturing and tryout process, analyze differences in dimensional deviations, and optimize the tryout process. Ultimately, the tryout manager should create a uniform data basis to make different data sources comparable and improve process quality by systematizing the correction of deviations.

Solution Approach

The integration of simulation data, the use of a mathematical surface description utilizing B-spline surfaces and the systematic analysis of deviations in deterministic and stochastic distributions were central aspects of the project.

An essential part of this approach is the utilization of these B-spline surfaces to represent the deep-drawn components. This technique reduces the amount of data by a factor of up to 341, while allowing precise and flexible modeling of complex shapes. As a result, statistical analyses can be carried out more efficiently without relying on extensive computing time.
Furthermore, control point representations and mapping algorithms have been developed to ensure consistent comparability of data, systematically analyze deviations, and optimize the training process. The tryout manager uses the displacement of simulated and measured components' B-spline surface control points for precise tool corrections.

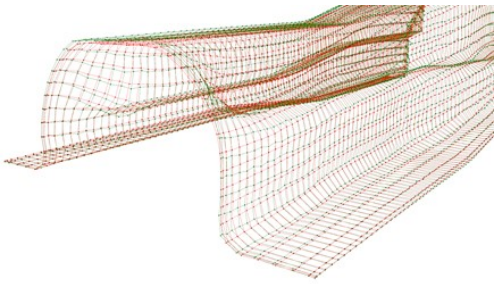


Fig.1: Data-reducing control point display using B-splines of a target and an actual geometry

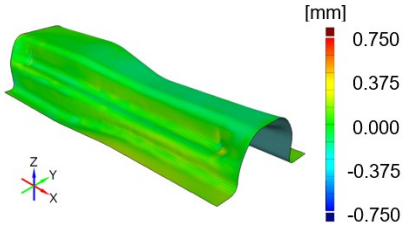


Fig.2: Compensated component after six iterations by shifting the control point

The simulation and measurement data can be used individually or in combination to compensate for deviations. These can be utilized to generate a new tool surface. The Tryout Manager saves the tool surface in the widely used .stp format. This file can be opened and, if required, edited using standard CAD software.

The individual packages of the Tryout Manager were written in Python and are, therefore, easy for the user to implement. A graphical user interface was created to make the tryout manager easy to use.

Outlook

Especially for small and medium-sized companies in forming technology, using the tryout manager can save costs in the tool preparation process. Because this necessary process step requires up to 20 % of the total investment for a tool, there is an exceptionally high savings potential available here. Furthermore, by using the tryout manager, knowledge about the work steps and their effects during the tryout process can be preserved. This knowledge transfer is crucial to their competitiveness, especially for small and medium-sized companies, which are often more affected by fluctuations in personnel.

Contact: Lorenz Maier, M.Sc.

Events

14. Kongress Stanztechnik
08. und 09. April 2024
Dortmund

From Monday, 8 April to Tuesday, 9 April 2024, cutting and punching technology from all over Germany will once again meet at the Westfalenhallen Dortmund. This year's main topics are:

- **Green Production** - In the area of conflict between political targets and real production requirements
- **Connected Processes** - Automation solutions: Tools to peripherals
- **Intelligent tool concepts** - standardisation to active tool control

In addition to a large number of specialist presentations, the congress also offers an in-depth trade exhibition. The conferece language is german.

We look forward to informative presentations, inspiring discussions and personal contacts.

Registration for the congress is possible via our partner KIST e.V.

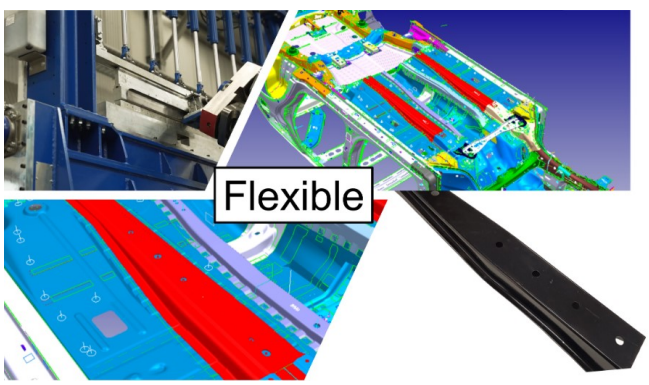
iddrg
Australia, 11 - 14th March 2024

Our colleagues from Deakin University invite to the **43rd Conference** of the International Deep Drawing Research Group, IDDRG 2024, held on the **12th - 15th March 2024 in Melbourne, Australia.**

Take a look at the **keynote speakers** for this event:

- **Yannis Korkolis**, USA
- **Heng Li**, China
- **Takayuki Hama**, Japan
- **Jeong Yoon**, South Korea
- **Ton van den Boogaard**, Netherlands
- **Ming Wang Fu**, Hong Kong
- **Wolfram Volk**, Germany

For more information and registration go to the conference website



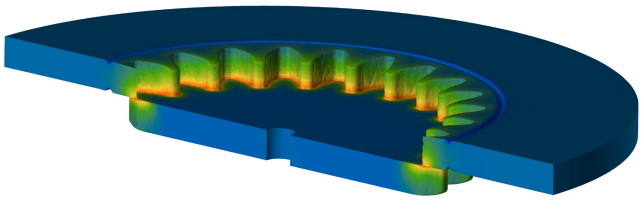
Events

Forming Technology Forum 2024

All About Blanking

11th-12th September, 2024

Ohlstadt, Bavaria



We are pleased to announce the 15th edition of the **FTF - Forming Technology Forum**. The motto of this edition of the FTF is "**All About Blanking**".

In addition to the presentations, there will again be a **poster session**. Students and doctoral candidates are invited to present their research work in a speed dating session. The best poster will be honoured with the **2nd AutoForm FTF Poster Award**.

We have chosen **Ohlstadt** as the venue for the conference. It is located about 70 km south of Munich and offers a breathtaking view of the Alps and the beautiful Bavarian countryside.

You can find more information at
https://www.mec.ed.tum.de/utg/veranstaltungen/

If you would like to support us as a **sponsor**, please give us a call (+49-89-289-13791) or send an e-mail to ftf@utg.de

Personnel at *utg*

We extend a warm welcome to:

Thomas Spörer
joined the forming group at *utg* on 16 August 2023

Tanja Enthofer
joined the *utg*-administration on 20 November 2023

We wish all the best for the future:

Dipl. oec. trop. **Ulrike Brodbeck** left *utg* on 30 September 2023.

New Dissertations at *utg*

42 **Erhard, Patricia**: Slurry-based 3D printing of ceramic casting cores, October 2023

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

The dissertations appear printed in the **series Metal Forming and Casting**, ed. Prof. Dr.-Ing. W. Volk, Kollemosch Verlag & Kommunikation, ISSN: 2364-6942

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Imprint

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