Chair of Metal Forming and Casting
TUM Department of Mechanical Engineering
Technical University of Munich

utg Newsletter Issue 3 12/2020

Chair of Metal Forming and Casting

When written in Chinese, the word ´crisis` is composed of two characters.
One represents danger and the other represents opportunity.

John F. Kennedy, (1917—1963, President of the US 1961—1963)

Editorial

Dear Readers,

the year 2020 is coming to an end, and we are slowly growing accustomed to the current crisis situation, which seemed unthinkable a year ago when the first newsletter was published. In this issue, we would like to give you an update on the current news at our chair.

Of course, we are not unaffected by the current circumstances. Nevertheless, we are still fully committed to our goal of a balanced funding between basic research, application-oriented research with industry involvement, and direct industry cooperation. Even if the funding programs are not being cut back noticeably at present, a significant increase in applications from all research institutions can be observed. This inevitably leads to a reduction in the funding rate and thus to the necessity of additional time investment in the application process.

We are convinced that in order to secure successful and balanced research in the future, it is necessary to promote all aspects of digital networking as well as not neglecting the technical improvement of forming and casting processes. Therefore, we are focussing our work on attractive, broad-based solutions that fulfill these aspects in all areas of our research.

I hereby invite you to convince yourself of our achievements by reading our newsletter, our website, the new image brochure, or through personal contact.

On that note, I wish you all a Merry Christmas and hopefully a "resilient" and therefore successful 2021.

Yours sincerely

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

Image front page
© utg, IGCV - Corinna Sutter, Manuel Pintore
Microscope: Zeiss Axioplan, light microscope
Magnification: 62,5:1
Etching: 2% aqueous NaOH
Material: AlNi7,5Zr0,5
Structure: (Al+Ni)- eutectic

utg News

• Seminar for doctoral students

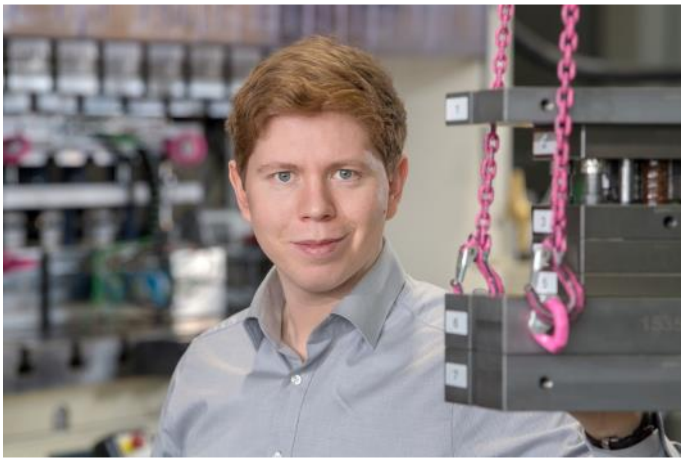
The *utg* doctoral seminar, like everything else this year, was not unaffected by the coronavirus. Therefore, we were very pleased that we were able to experience two exciting days in the “Haus der Bayerischen Landwirtschaft” with highly interesting lectures, presentations, and discussions.
In the workshops on the topics of possible applications of AI, alternative tool concepts, new simulation methods, or casting processes, there was plenty of room for exciting discussions. Here we were able to come up with some promising new ideas, which will be incorporated into new research proposals. In the future, we want to focus on the challenges and opportunities of AI and digitalization. Especially in the research fields of forming technology and casting, which are often referred to as "old economy", there is still a lot of potential.

Visit of the ground communication station in Raisting © utg

A welcome change was the visit to the ground communication station in Raisting. In bright sunshine, Mr. Herrmann Martin gave us some exciting insight into the impressive history of the ground communication station. This station already played a role during the moon landing in 1969, as well as during the Cold War and today's global satellite connections.

• Award for best dissertation

The winner of the prize for the best dissertation from the Faculty of Mechanical Engineering is from *utg*. Dr. Hannes Weiss managed to win over the jury with his thesis on the influence of the shearing process on the efficiency of electric motors which was submitted in 2019.



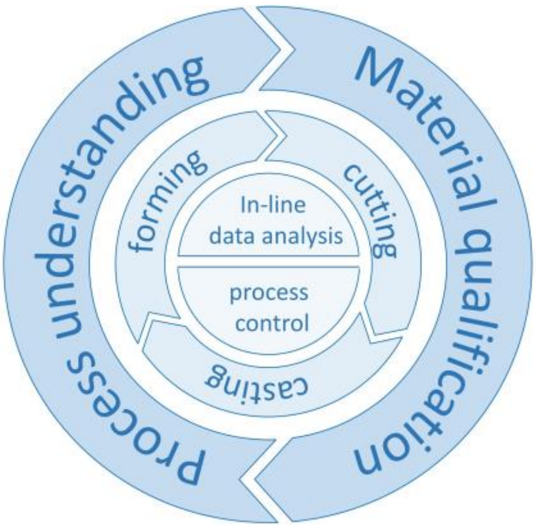
Dr. Hannes Weiss © Heddergott/TUM
Awardee of the Schmidt-Burkhardt Memorial Award 2020

Dr. Weiss states the following to the starting point of his research work "As part of the DFG-funded project, we wanted to find out whether and how the stamping process affects the magnetic properties of sheets". Whereby the magnetic properties of the electric sheet metal have a decisive influence on the efficiency and thus the energy consumption of electric motors.
In his research, Dr. Weiss was able to establish a highly interesting connection: Punching tools with small cutting gaps and sharp-edged cutting elements directly result in stronger magnetic fields and lower losses. The punching process thus offers great energy-saving potential, especially when it comes to future electric mobility concepts.
The results of the work have already been met with great interest. In addition to scientific publications that have cited the work several times, a press release issued by TUM in 2018 was also widely distributed in specialist magazines.

utg News

• Research Focus AI

Industry 4.0 was the catchword under which digitalization and artificial intelligence were to revolutionize production technology. As with many trends, the initial euphoria is now subsiding, and the big revolution has yet to take place.
With our new research focus, we would therefore like to tread an evolutionary but no less innovative path.



Currently, virtual processes and product designs base themselves on thermodynamic laws. These are solved numerically with simulation models. Experimental data gets used for the verification and validation of the calculated results. In contrast, data-driven approaches use recorded information as a basis for the construction of models.
We have set ourselves the goal of combining these two basic approaches, which we then call hybrid modelling.

For us, this begins with sensor integration and data preparation for recording the process. A hybrid process model is formed when the current process information is combined with the thermodynamic description. This model can, for example, counteract fluctuating process conditions in real-time. The hybrid models are the decisive building block for building a flexible or self-learning production - our vision of industry 4.0.

• New GOM 3D-Scan System

In September, we acquired a GOM ATOS compact scanning system for the digitalization of parts. The ATOS series delivers precise scans with detailed resolution at high speeds. The intent is to use it in all research groups.
The first time the system came into use was at an unusual event in the Bavarian National Museum. Georg Fuchs, Constantin Bauer, and Christoph Hartmann (IGCV) had the opportunity to scan the original historical plaster model of the Bavaria statue by Ludwig Schwanthaler.

Model of the Bavaria statue in 3D scan
© IGCV, Christoph Hartmann

However, the primary field of application of the scanning system currently lies in a less artistic area, namely in the research on deviation compensation of additively manufactured components. In the future, we plan to record cutting surface parameters with the semi-automated measuring system. The investment should make it possible to provide automated data for all production processes at *utg*, which will later form the basis for the training of machine learning algorithms. It is thus an important component in the expansion of this new research focus.

utg News

- ## *utg* now on video

Film clip „Material characterization at utg“ *© utg*

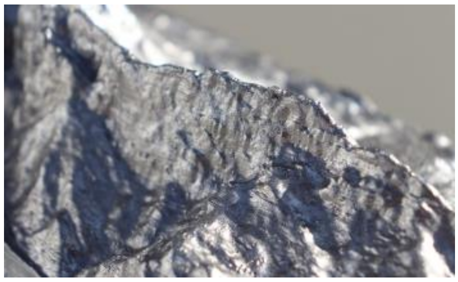
As of late, visitors to our website have been able to find a new Media section. In this section, various video contributions on different research topics at the *utg* are stored.
The first online video contains information about the material characterization with the BUP1000. This four-minute clip was produced in cooperation with the ProLehre media production of the TUM and with the support of ZwickRoell.
Initially, the film clip was intended exclusively for presentation at the ZwickRoell Virtual Testing Forum 2020, but we were so pleased with the end result that we most certainly plan on expanding on this format to include other topics and to use it in teaching.

See for yourself: **https://www.mw.tum.de/utg/medien/**

- ## All the best for Prof. Reinhart

On 30 September 2020, our esteemed colleague and friend Prof. Dr.-Ing. Gunther Reinhart retired. During Prof. Reinhart´s many years at the TUM as a professor of the Institute for Machine Tools and Industrial Management, he impacted the national and international fields of production engineering research, the main focus being management sciences, robotics, and production automation.
In recent years he expanded his area of expertise to include research on battery production.

In addition to this, he made a significant contribution to the foundation and successful establishment of the Fraunhofer Institute for Foundry, Composite and Processing Technology IGCV as head of the institute.
As a farewell gift, we decided to give him a very personal gift - motivated by his love of the Chiemgau Alps. Using our detective skills, we were able to organize the 3D geodata of the Wilder Kaiser from the internet. In cooperation with our foundry colleagues of the IGCV, we were then able to produce an aluminum cast of the 3D-printed model.



Wolfram Volk, Gunther Reinhart, Klaus Drechsler (from the left) *© IGCV*

We wish Prof. Reinhart all the best, a robust health and finally time in abundance at the Wilder Kaiser! Many thanks for the enormous commitment and inspiring cooperation over the past years.

utg News

• Half time in the SPP 2013

Understanding residual stresses, consciously controlling them, and finally implementing them in a positive manner. Is in short, the goal of the DFG Priority Program 2013.
Throughout Germany, 28 research institutions are investigating this topic and its various aspects and are working on 12 interdisciplinary projects. Prof. Wolfram Volk is the coordinator of this SPP, which is now over halfway through its term and is heading towards the third and final phase.

Kick-Off at the start of the SPP2013 in October 2017 © utg

In addition to the coordination, the *utg* is involved in two other projects. Together with the Heinz-Maier-Leibnitz Center and the Institute for Electrical Machines, Ines Moll is working on *the targeted use of residual stress in electrical sheet metals to increase energy-efficiency*.

In the second project, Jens Stahl and Anian Nürnberger, in cooperation with the TUM "Gear Research Centre (FZG)," are researching *the characterization and utilization of process-induced residual stresses in the manufacturing of functional surfaces using the near-net-shape blanking method.*

In the first research phase, all projects showed that a significant improvement in the properties of the different components was possible by the use of specific residual stresses. The individual project results of the first phase got published in "Residual Stresses in Production Technology," a highly regarded journal, in the volume Production Engineering (Vol.13, No.2, April 2019).
Currently, the main focus is on stability: residual stresses must be maintained during operation and are not allowed to dissipate. The scientific results will soon be made available to the public through appropriate publications. Building on this, the third funding phase will focus on the upgrade of processes in typical industrial plants to implement the findings.
In the Priority Program, the most different, industry-relevant components are united using massive as well as sheet metal forming. The results and experiences from the different projects are exchanged in cross-sectional expert groups and synergies.

Further information, publications, and contact data can be found on www.spp2013.tum.de

• News from committees and the scientific community

On 1 April 2020, Prof. Wolfram Volk was reelected to the Production Engineering Review Board. With the responsibility for the primary and forming technology and additive manufacturing. All scientists from German universities and research institutions who had submitted eligible applications were allowed to vote for this scientific committee.
The central task of this honorary board is the selection of applications worthy of funding in basic research. This is mainly done by using the so-called DFG standard procedure based on expert opinions. In the constituent meeting, Prof. Volk was, furthermore, elected as chairman of the entire review board for production technology. With the current term of office lasting until 2024.
Due to current conditions, a significant increase in the volume of applications can be registered, while the available funds, unfortunately, remain the same. Thus, all members of the review board will face a challenge when deciding where the important state-financed research promotions end up in the next years.

Latest research news at the *utg*

Casting

Hybrid products with metallurgical bonding

Motivation

Over the last decades, academic and industrial research and development have shown interest in hybrid structural components. The advantage of such load-adapted components lies in the combination of advantageous mechanical, physical, or chemical material properties in one component. This leads, for example, to an increase in strength and wear resistance as well as a reduction in component weight.
The increase in electrification of consumer goods and the desire for light-weight components, is forcing greater interest in hybrid components consisting of aluminum and copper alloys. The continuous compound casting is a material and energy-efficient technique for the fabrication of metallurgically bonded, bilayer semi-finished products.
Within the scope of the project, a vertical composite continuous casting process for the production of rotationally symmetrical Cu-Al semi-finished products will be developed. Furthermore, research regarding the interface formations of hybrid rods is being pursued.

Fig.1 Continuous casting machine at the utg

Solution Approach

Hybrid semi-finished products consisting of CuZn37 and AA7075 are produced by using the vertical continuous casting technology. The hybrid product is formed by diffusion that results in the cohesion of the subcomponents. This formation is adjusted both by the addition of the alloying elements zinc and magnesium and by process control. Experiments, process simulations, and structural modelling are conducted in order to understand the complex relations between the process parameters, alloy composition, and the resulting interface character.

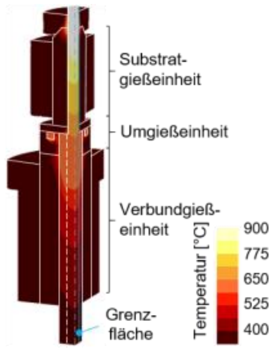


Fig.2 Simulation of vertical continuous compound casting

Results and Outlook

Continuous compound casting research of CuZn37 and AA7075, proved that the formation of a cohesive bond at the interface of layered products is feasible. It was found that the formation of intermetallic phases is controlled by thermal regulation. Furthermore, comprehensive findings on the thermophysical and mechanical properties were mainly derived from the interface of the compound partners. Future research of cast hybrid products will focus on structural mechanical behaviour and thermo-mechanical post-processing. These findings allow for the evaluation of the interface character and material potential during the entire process.

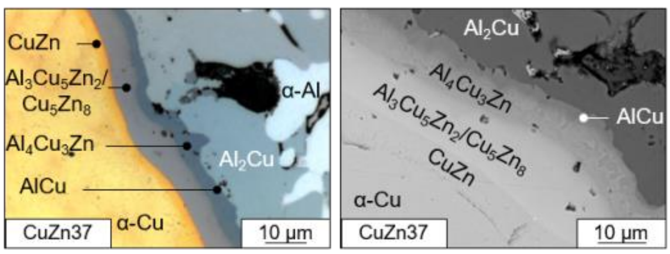


Fig.3 Interface of CuZn37/AA7075 compound

Contact: Thomas Greß

Latest research news at the *utg*

Metal forming

Innovative compensation strategy for deterministic dimensional deviations

Motivation

In massive forming, deviations from the desired component geometry regularly occur. These deviations are divided into stochastic and deterministic components. Especially the deterministic errors can be compensated by the use of a precise tool design. The compensation process currently consists of a time-consuming, iterative procedure. The conversion of parametric CAD data into discrete points is challenging. Also, the compensation algorithm plays an essential role in determining the tool geometry. To make the process more efficient, the *utg* developed an innovative compensation strategy for massive forming, which was validated together with the IFUM Hannover.

Solution Approach

The developed strategy focuses on the application of a substitute model based on reference points and the development of a compensation algorithm based exclusively on compatible stresses. The use of the substitute model allows for a fast derivation of the boundary conditions required for the compensation. The reference points are derived from the desired geometry and represent the minimum number of points necessary to describe the geometry. The deviation of the actual from the target geometry is therefore only measured at the reference points.

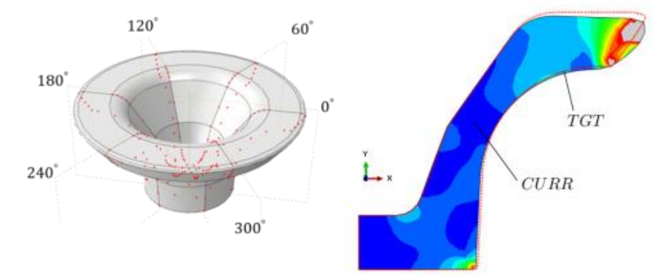


Fig.1 Substitute model based on reference points (left) and compatible stresses (right)

The developed algorithm is based on so-called compatible stresses which can be completely and unambiguously converted into a displacement field and divided into two virtual steps. First, the compatible stress field gets derived from the deviations. Then these stresses are applied to the initial geometry and relaxed. The result is a significantly improved compensated target geometry of the forming tool compared to the previous procedure. This should result in a significant improvement in quality and a reduction in scrap for solid forming.

Results

Results of the virtual compensation can be seen in Fig.2. After four iterations, the maximum mean deviations are in a range of 0.05-0.08mm. The resulting components show variations in the tolerance class IT10, which extends the usual limits of drop forging (IT13).

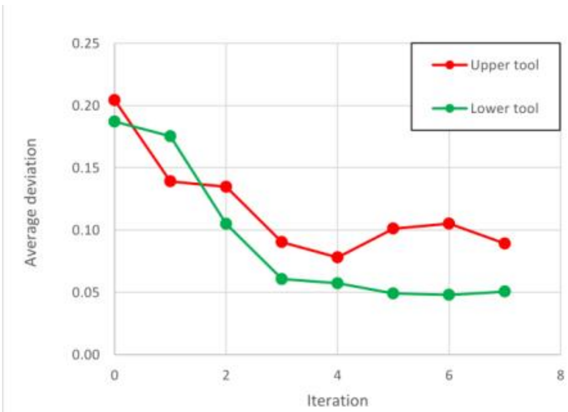


Fig.2 Average deviations in the virtual iterative process at the top and bottom die

Companies in the field of massive forming, especially many SMEs, can benefit from the developed strategy and derive the optimal tool geometry in a cost and time-effective way during an earlier design phase. Future investigations are focused on the handling of more complex geometries and the compensation of stochastic deviations by inline monitoring systems.

Contact: Lorenzo Scandola

Latest research news at the *utg*

Cutting

Optical Flow Methods for the Analysis of the Shear Affected Zone

Motivation

The optical analysis of motion in experimental mechanics is dominated by block matching approaches such as digital image correlation (DIC), which is the basis of almost all commercial software packages. In the case of complex deformation patterns, these classical evaluation algorithms often reach their limits and fail at the latest when calculating spatial and temporal derivatives of the motion quantities. However, not just since Newton and Leibniz, spatial and temporal derivatives of motion quantities have been basic components of our physical description of mechanical processes. Experiments for parameter identification, the validation of simulations, or inverse analyses are therefore dependent on the robust determination of derived motion quantities.

Solution Approach

In addition to digital image correlation, which is traditionally used in engineering, an interdisciplinary field of research exists under the term "Computer Vision", which is dedicated to the optical analysis of motion. Besides block matching, a second fundamental class of optical motion analysis is successfully implemented here - the Optical Flow Methods. We implement the underlying variation formulation and the regularization contained therein in such a way that complex deformation phenomena, as well as spatial and temporal derivatives of motion quantities, can be robustly determined using optical measurements.

Use Case Shear Cutting

In shear cutting, in addition to the cut surface, the shear affected zone is increasingly included in the quality assessment of the process, so that, for example, edge cracks can be prevented or magnetic losses in electrical sheets can be reduced. In order to observe the formation of the shear affected zone with high temporal and spatial resolution and under real process conditions, we have built up a shear cutting tool with glass stops, through which the optical measurement of the cutting process is observed using a high-speed camera. For the quantification of the image sequences, spatially and temporally regularized variation approaches are applied, which for the first time made it possible to determine the strain fields, strain rate fields as well as crack initiation and crack propagation (see figure) in the shear affected zone.

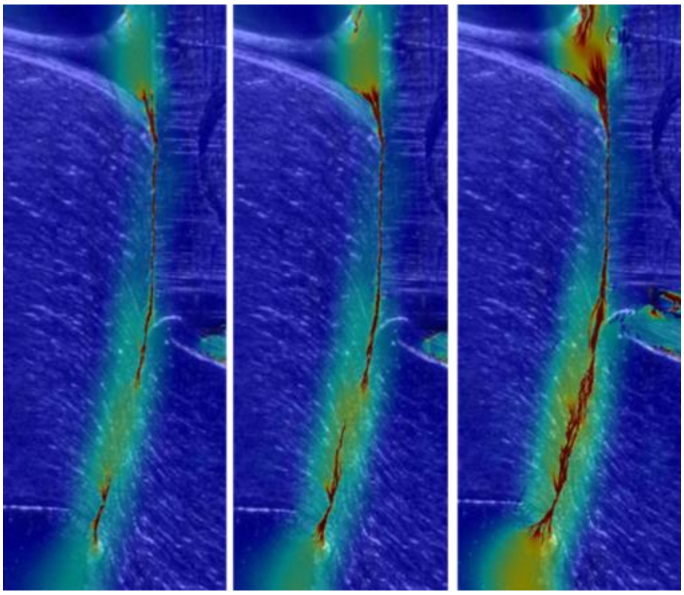


Fig.1 Crack propagation and consolidation during shear cutting evaluated with optical flow methods (crack indicator calculated based on non-classical strains)

Potentials

We consider optical flow methods as a promising complement to block-matching approaches in experimental mechanics in general. We have already shown that third-order derivatives can be determined directly by suitable variation formulations and regularization. Furthermore, robust optical measurement and evaluation systems are a core component of image-based inline process analysis and real-time adaptation, especially for data-based models, machine learning approaches, and inverse analysis.

Contact: Christoph Hartmann

Personalia at the *utg*

We warmly welcome:

Anna Bauer, M.Sc.
part of the cutting team since
15 August 2020

Max Erber, M.Sc.
part of the casting team since
1 October 2020

Lorenz Maier, M.Sc.
part of the forming team since
1 October 2020

Anian Nürnberger, M.Sc.
part of the cutting team since
1 October 2020

Max Plötz, M.Sc.
part of the casting team since
1 November 2020

We wish you all the best for the future:

Dipl.-Ing. **Martin Feistle**
left the *utg* on 25 October 2020

Dr.-Ing. **Hannes Weiss**
left the *utg* on 15 September 2020

New dissertations at the *utg*

24 **Heilmeier, Florian:** Ermittlung schwindungsbedingter Gussteilspannungen mit Hilfe eingegossener, faseroptischer Dehnungssensoren, July 2020, in German language

25 **Neumayer, Ferdinand:** Ermittlung und Auswirkungen der Durchbruchkraft beim Lochen, July 2020, in German language

26 **Pintore, Manuel:** Gießtechnische Herstellung und technologische Charakterisierung von Kupfer-Aluminium-Schichtverbunden, October 2020, in German language

27 **Mittler, Tim:** Verbundstranggießen von Kupferwerkstoffen, December 2020, in German language

All publications and dissertations of the chair are listed on the website www.utg.de
The dissertations are published as print-on-demand in the series ***Umformtechnik und Gießereiwesen***, Hrsg. Prof. Dr.-Ing. W. Volk, TUM University Press, ISSN: 2364-6942

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