TECHNISCHE UNIVERSITÄT DARMSTADT

PtU FORMING EXCELLENCE

Our year 2024

Driving innovation, connecting knowledge - for the production of tomorrow

Dear readers,

At PtU, we are driving forward enthusiastically the vision of sustainable and intelligently automated forming and production technology. In this Annual Report, we invite you to gain an insight into our current research and the training of young scientists who will help shape the technology of tomorrow.

Our society as a whole and every company is currently challenged to balance social, economic and environmental sustainability at the same time. Production, and forming technology in particular, can make a significant contribution to meeting this challenge by producing products that use fewer resources and are affordable, thus increasing the quality of life for many people. Several new opportunities for technological progress have emerged recently. Especially digitalization, artificial intelligence and flexible machines offer manifold opportunities for innovations. Innovative sensor technology makes it possible to examine forming processes as part of the digitalization of production technology. Data-driven models use the enhanced process knowledge gained to adjust systems and tool movements and proactively respond to potential faults, thus increasing efficiency. Additional degrees of freedom in tool activation do not only allow for better process control, but also new types of processes.

Our research is closely linked to our teaching: we foster scientific progress through cooperation and synergy in our extensive network of industry and academia. Collaboration with colleagues from other disciplines enables us to successfully implement exciting interdisciplinary projects.

On the following pages, you will find fascinating highlights from our current research projects.

We would like to thank all our project partners for their excellent cooperation. Their commitment and flexibility contribute significantly to the success of our projects and enable our students to receive a practical and illustrative teaching, enriched by case studies and excursions. The numerous awards received by our scientists this year encourage us to continue to improve the education of young scientists even further. Our special thanks go to the funding organisations DFG, AiF, DLR, BMBF, BMWK, the State of Hesse and the research associations (EFB, FOSTA, FSV, GCFG, PTS, VDP). Without their support, many of our projects would not have been possible.

We look forward to the coming year 2025 with excitement and curiosity, to challenging questions and innovative solutions. We are happy to be at your disposal for research collaboration and consultancy. Visit our homepage to stay informed and get in touch with us.

Thank you for your trust and support in 2024!

Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche

“We are part of an extensive network”

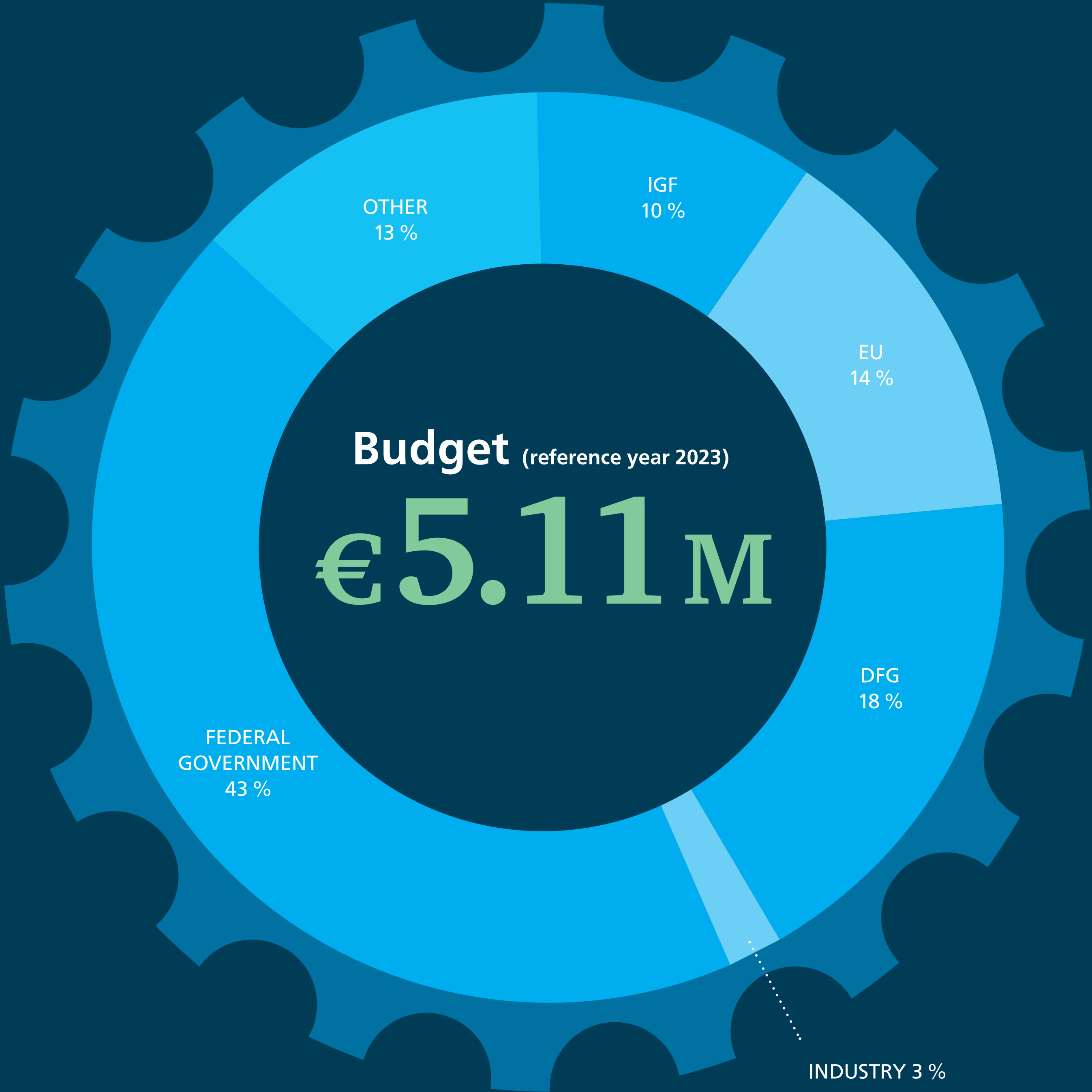
in forming and production technology, collaborating with several leading companies, research institutes and universities around the world.

Interdisciplinary, international and industrial collaboration fosters an environment conducive to the pursuit of technological solutions to tomorrow's challenges.


3D Servo Press

To shape a sustainable, efficient, and digital industry, we train outstanding young scientists for tomorrow's challenges.

This commitment has been reflected in numerous national and international awards to our Research Associates, including Best Paper Awards (ICFG, ICTMP), the Autoform Poster Award, and the “Distr@l Quality Seal”.



PROCESS CHAINS AND FORMING UNITS

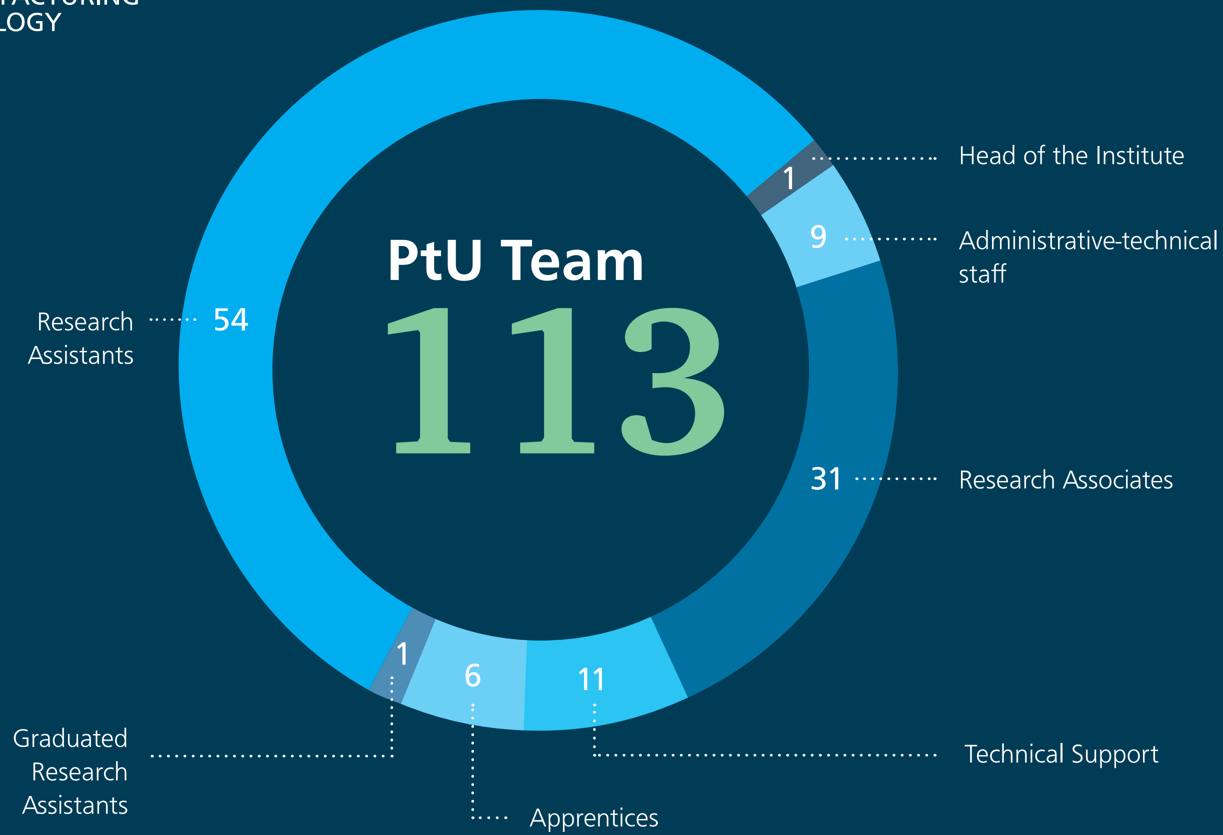
Publications

4 Research Departments

TRIBOLOGY

PROFILE MANUFACTURING TECHNOLOGY

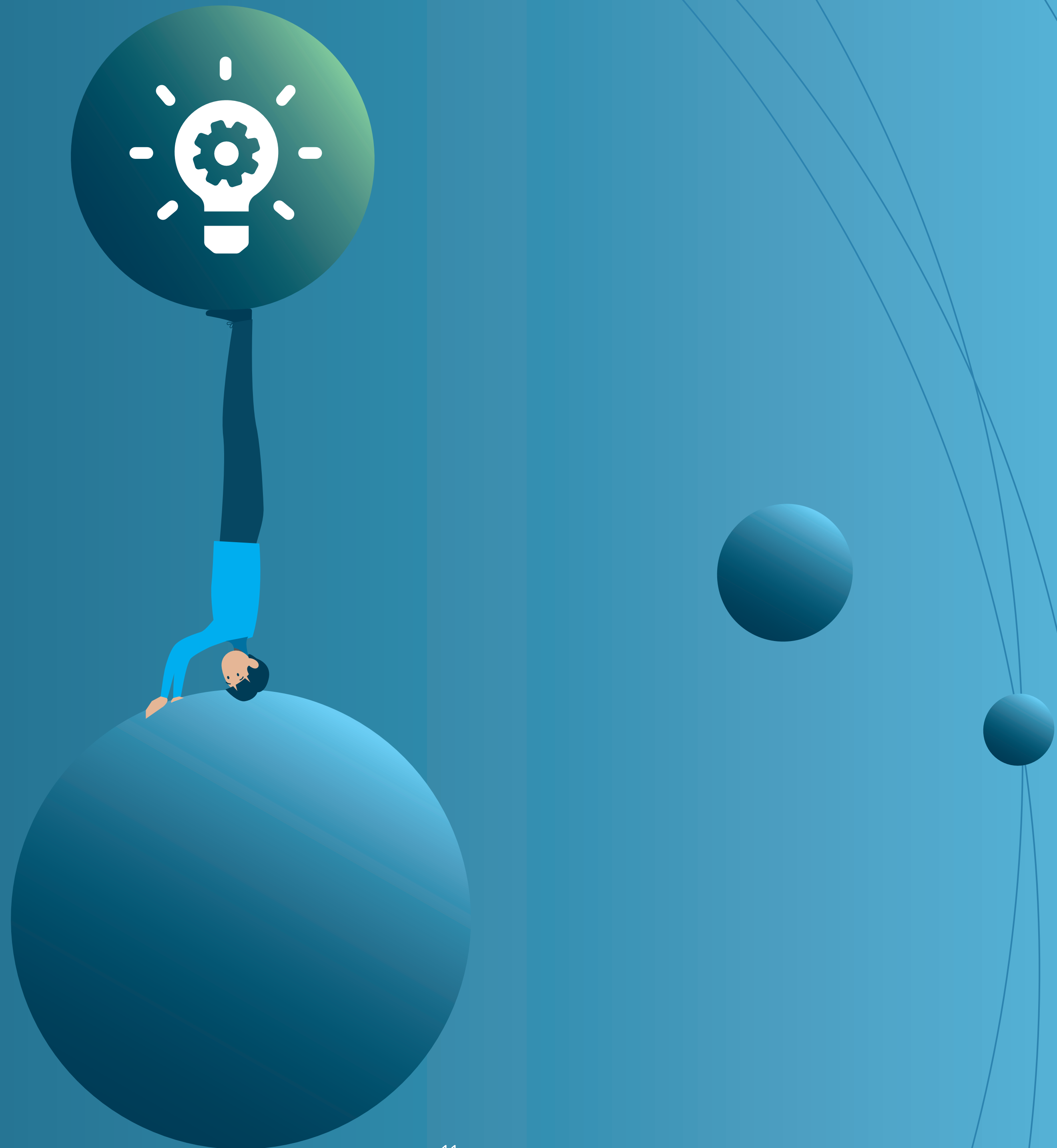
FUNCTIONAL AND COMPOSITE STRUCTURES



Space for

Innovation

Innovation shapes the future. Our latest projects show how pioneering ideas are being put into practice. Discover, how we are exploring new directions with ground-breaking research.



Development of hole rolling process for bearing applications

Viktor Arne (TU Darmstadt, PtU), left
Daniel Spies (TU Darmstadt, PtU), right

Motivation

Roller bearings are central machine elements that keep our modern world running. By reducing friction and minimising wear, they make it possible to produce efficient and reliable machinery. It is often necessary to integrate a roller bearing into a thin-walled structure, for example in transmission cases. The additional material thickness required around the area of the bearing seat is a challenging manufacturing problem. Machining such a housing from standard ingots would come along with the need of excessive material removal. Therefore, such housings are conventionally manufactured by casting and then finished by machining. A construction from sheet metal would offer much more flexibility and drastically reduced costs. The Institute for Production Engineering and Forming Machines at the Technical University of Darmstadt has been developing Hole Rolling as a method of forming bearing seats in sheet metal for about four years.

Approach

To perform the process, a special tool was designed for use on a conventional servo motor press. Hole Rolling operates incrementally and is classified as a sheet-bulk metal forming process. In this process, a hole previously created in a piece of sheet metal is enlarged with a roller in a spiral movement. The displacement of the material at the edge of the hole forms a cylindrical collar on both sides of the sheet metal around the circumference of the orifice. Due to the high plastic strain achieved in the metal, there is significant cold hardening in this collar. TRIP steels, such as 1.4301 stainless steel, can achieve a transition from the base material to martensite. When used as a bearing seat in thin-walled structures, the collar on both sides of the sheet metal allows the stresses in the material to be evenly distributed and avoids unfavourable bending stresses. The strengthening of the material helps to withstand the stresses transferred from the bearing. Use as a bearing seat is promising, but to go one step further and reduce material waste even further, it was considered that the outer ring of the roller bearing could be omitted altogether. For the first investigation, cylindrical roller bearings were used, due to their simple race design. To broaden the application of the process, the production of deep groove ball bearings by this method was also investigated. A technique using a non-cylindrical roller has been developed. This makes it possible to produce an axially non-uniform hole, which is required for the construction of ball bearings.

Results

First tests with aluminium show promising results. The transfer to stainless steel is ongoing. It is supposed that the improvement of material properties and the incremental nature of the process make it possible to control the dimension of the hole tightly. In addition, the high quality of the rolled surface is such that roller bearing races can be produced without secondary processes such as grinding and hardening.

Acknowledgement

Hole Rolling is developed within the scope of the SPP 2183 funded by the German research foundation and in Cooperation with the IAM-WK at the Karlsruhe Institute for Technology.

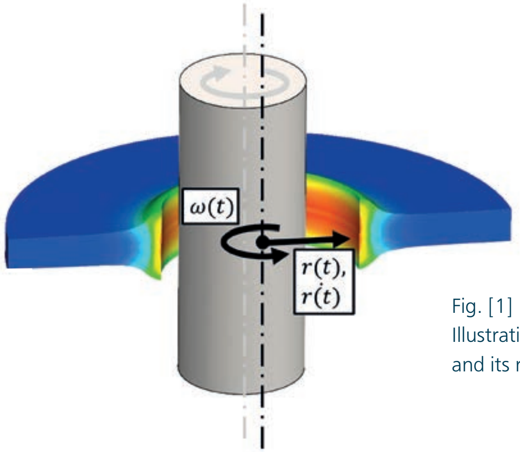


Fig. [1]
Illustration of the kinematics of hole-rolling and its relevant process parameters

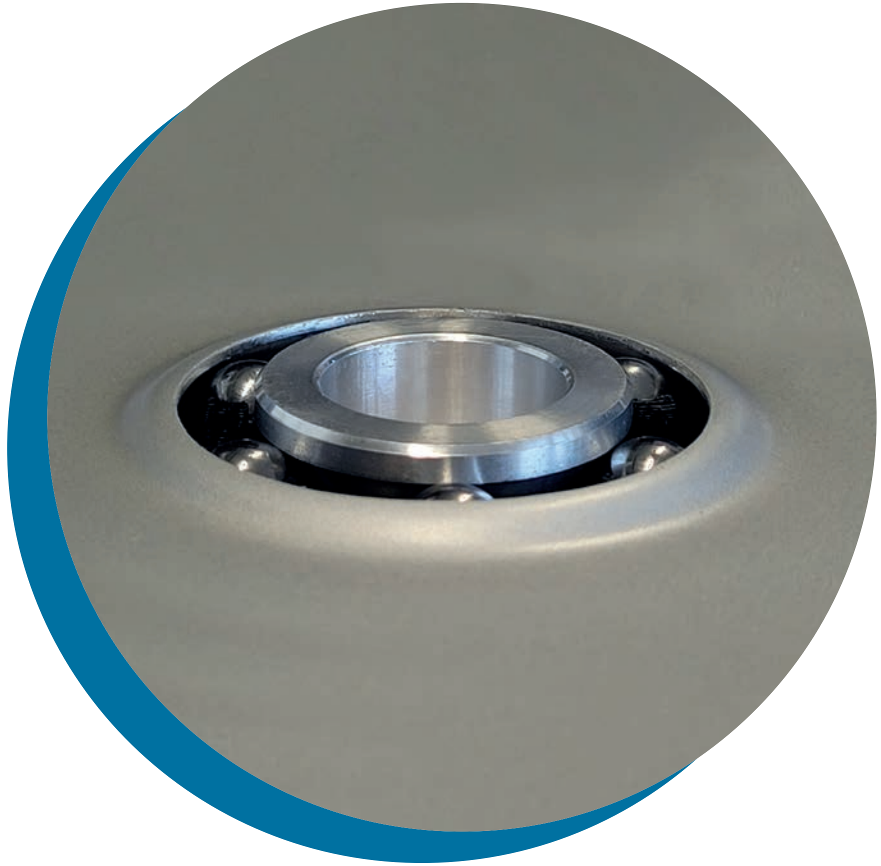


Fig. [3]
Integrated bearing with hole-rolled outer race

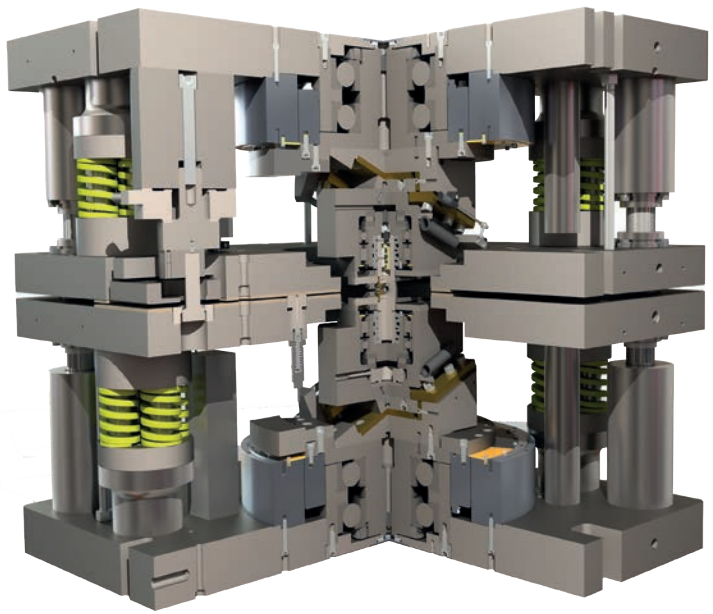


Fig. [2]
Tool for hole-rolling on conventional servomotorpresses

Innovative slewing bearings based on branched and curved sheet metal structures

Christian Thoma (TU Darmstadt, PtU), left
Benedikt Depta (TU Darmstadt, PtU), right

Motivation

In various application areas such as industrial automation, building technology and special vehicle technology, large roller bearings are required to fulfil dedicated functions. The requirements in terms of dead weight, costs and functionality are often in conflict with existing large bearing designs. This development presents a new design for large roller bearings based on branched and curved sheet metal structures. The development target is a slewing bearing produced in the shortest possible process chain and maximum material utilisation.

Approach

The design is characterised by using linear flow split and bent profiles with a special branched profile cross-section in the inner and outer ring. The manufacturing route for this bearing design differs greatly from conventional processes. In the linear flow splitting process, a flat sheet is upset at the strip edges in several stages, forming a flange on both sides. The final stage of the linear flow splitting process involves bending around the vertical axis to create the circular geometry. Due to the stress superposition applied during the process, undesirable springback effects are drastically reduced, thus increasing the accuracy of the individual components.

Results

In a first conceptual study, we produced a slewing bearing with a diameter of 2.6 m and a weight of less than 40 kg. The necessary properties for the running surfaces, such as shape, strength and hardness, are inherent in the manufacturing process. This bearing design enables various bearing types to be produced, for example with different rolling elements, contact angles and additional functions. This combination enables almost waste-free production, resulting in an excellent CO_2 footprint. The development thus opens up a promising path to the sustainable and cost-effective production of large rolling bearings.

Acknowledgment

The intellectual property of this invention is secured by the TU Darmstadt. This development is based on the BioStruX technology transfer project (03LB2011A), founded by the German Federal Ministry for Economic Affairs and Climate Action, as part of the Technology Transfer Program Lightweight Design.

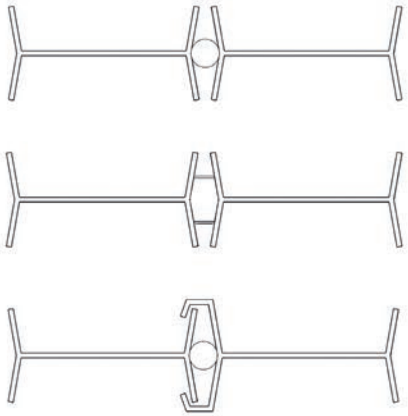
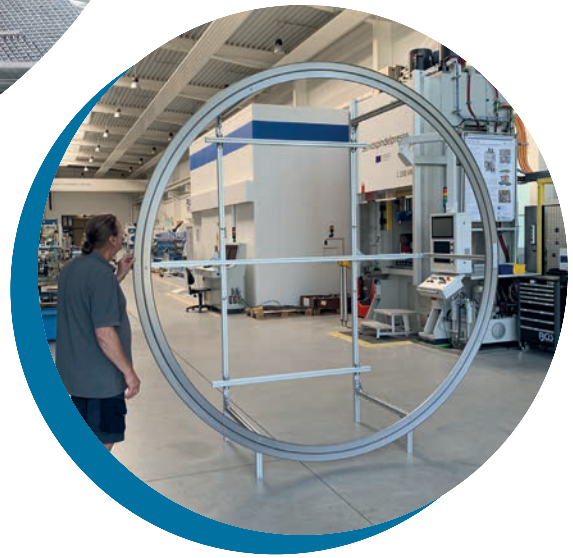


Fig. [1]
Possible bearing designs

Fig. [3]
Possible applications for large slewing bearings



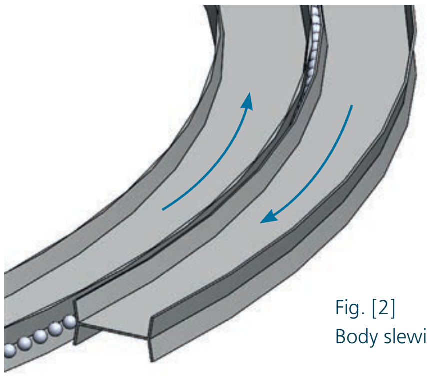


Fig. [2]
Body slewing bearing split profile

Space for

Digitalization

Digitalization is changing forming technology sustainably. We are researching solutions that accelerate processes, make data usable and make companies fit for the digital future. Find out more about our projects here.

Use of photometric stereo for inline quality inspection in high-speed forming processes

Jonas Moske (TU Darmstadt, PtU), left
Hasan Kutlu (Fraunhofer IGD), right

Motivation

Industrial companies must ensure the economic efficiency of their processes by maximizing productivity, as even short machine downtimes or minor tolerance deviations can have negative effects. A key objective in this field of technology is to minimize both planned and unplanned downtimes. Conventional inline-monitoring approaches using force envelope curves and force limit value monitoring often only focus on fault detection in order to protect machines and tools from overloading.

Approach

Photometric stereo can be used for defect inspection in the mass production of curved surfaces, such as in the stamping process. A target-actual analysis of the reflection behavior of each surface point should provide information on whether wear has occurred in the multi-stage process. To be able to illuminate the object from different directions, the lighting situation is realized using several individually controllable LEDs, which are positioned in a ring around the opening. The opening around the LED-ring allows the camera to view the lateral surface of the part. By comparing the individual normal vectors at the corresponding object points, the degree of deviation of the normal vectors within the so-called wear mask (see Fig. [1] c) can be color-coded. As part of the evaluation of the suitability and performance of the scanner in an industrial environment, the modular installation of the scanner in an existing progressive die was carried out (see Fig. [2]). The scanner is inserted as a module into the already integrated production operations, where it acts as a blank station. Fig. [1] a) shows the normal map of the TARGET measurement of a component of the unworn deep-drawn ring, while Fig. [1] b) shows the normal map of the ACTUAL measurement of a component of the artificially roughened deep-drawn ring. The red area in Fig. [1] b) shows the grooves as individual stripes, while the TARGET measurement in Fig. [1] a) shows a smooth surface. The wear mask quantifies the deviation of the normal vectors per object point in the corresponding area in color, as can be seen in Fig. [1] c). The effect shown in Fig. [1] c) was observed at all stroke rates up to 200 strokes per minute and can be described as typical abrasive wear.

Results

The method presented demonstrates the potential and effectiveness of photometric stereo for wear detection in high speed forming processes. With appropriate accessibility in the tool, the technology offers the potential to make it easier to find the causes of quality assurance failures (see Fig. [3]). This gives companies the opportunity to improve process understanding and to operate processes more efficiently and with fewer resources.

Acknowledgment

The IGF project 'Real-time capable wear models' of the research association EFB e. V. was funded under the funding number DLR 22250N via the German Aerospace Centre e. V. (DLR) within the framework of the program for the promotion of joint industrial research (IGF) by the Federal Ministry of Economics and Climate Protection based on a resolution of the German Bundestag. We would also like to thank the Fraunhofer Institute for Computer Graphics Research IGD Darmstadt for their excellent cooperation in this project. We gratefully acknowledge Bruderer AG for providing their BSTA 410 stamping press, which was instrumental in conducting all the experiments presented in this report.

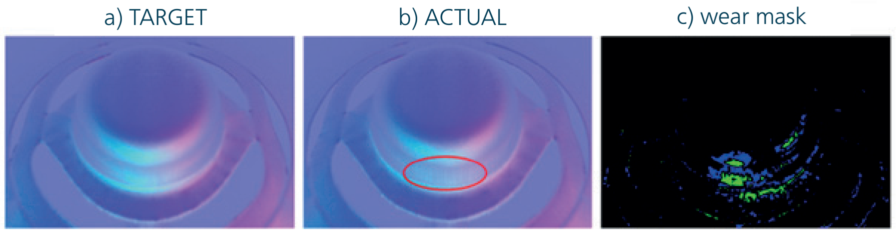


Fig. [1]
Example of a standard map of a TARGET a) and ACTUAL measurement b) with additional wear mask c). In addition, the average wear masks of the worn ACTUAL measurements are shown with the corresponding average TARGET measurements d)

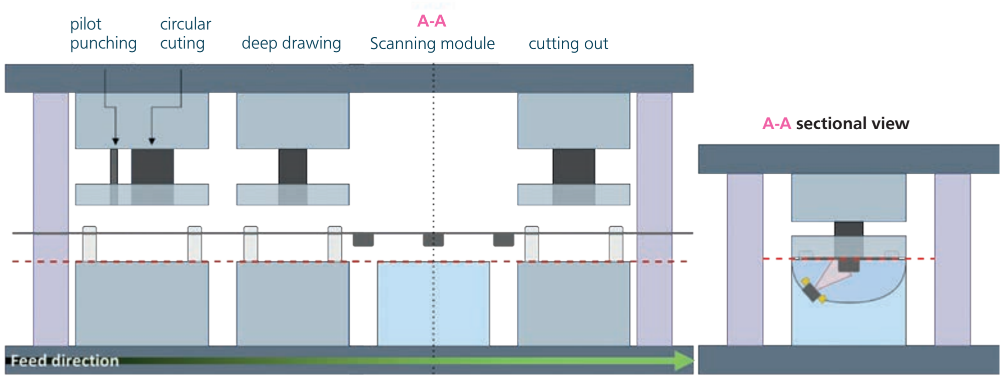


Fig. [2]
Test setup in the endurance test with pilot punching, (1) circular cutting, (2) deep drawing, scanning module and (3) cutting out

Fig. [3]
Photometric stereo scanning module lined in progressive die tool

Flexible hole rolling using 3D servo press

Daniel Spies (TU Darmstadt, PtU), left
Viktor Arne (TU Darmstadt, PtU), right

Motivation

New machine concepts, such as the 3D Servo Press (3DSP), make it possible to optimise established forming processes through additional flexibility in the ram movement, thus responding to uncertainties such as semi-finished product fluctuations, or to develop completely new forming processes such as Flexible Hole Rolling.

Approach

In current research, a combined ram movement consisting of a vertical stroke and a rotation of the ram is being used to generate a spiral movement of a tool with a double-sided supported roller. This roller movement can be used to incrementally insert a double-sided collar into a thin-walled sheet metal structure. Thanks to the flexibility in programming the tool movement on the 3DSP, any contours, such as polygonal or hypotrochoid profiles, can be created by a combination of the ram pose in sheet metal structures. This flexibility can therefore be employed to produce standardised geometries such as a P3G hub, using a forming process for the first time.

Results

Investigations have been conducted to characterise the excellent properties of hubs produced by Hole Rolling for self-centering and form-fit connections with rotating shafts. The internal surface of the profiles has an excellent surface quality that requires no further post-treatment and is directly suitable for joints with a shaft. Furthermore, it has been shown that the transmittable torque of a P3G polygon hub produced by Hole Rolling is significantly increased. Nevertheless, the necessity for high tolerance in all shaft-hub connections is inevitable. Thus, geometric dimensional accuracy represents the most crucial property of hole-rolled hubs. Given the inherent uncertainties associated with the Hole Rolling process, including roller deflection, a closed-loop control concept based on a force-based soft sensor has been successfully developed and validated. The soft sensor was employed in experimental investigations, demonstrating the potential to significantly enhance the geometric dimensional accuracy of the polygon hubs produced. Subsequent research will further advance this approach to enable the implementation of a generalised closed-loop control strategy for diverse geometries and materials in the production of batch size 1.

Acknowledgment

The presented results are achieved within the IGF-project No.01IF23257N of the European Research Association for Sheet Metal Working (EFB). The authors would like to thank the The German Aerospace Center (DLR) and the German Federal Ministry for Economic Affairs and Climate Action (Bundesministerium für Wirtschaft und Klimaschutz, BMWK) for funding.

Fig. [1]
Example application of a spur gear with
a hole-rolled polygon hub

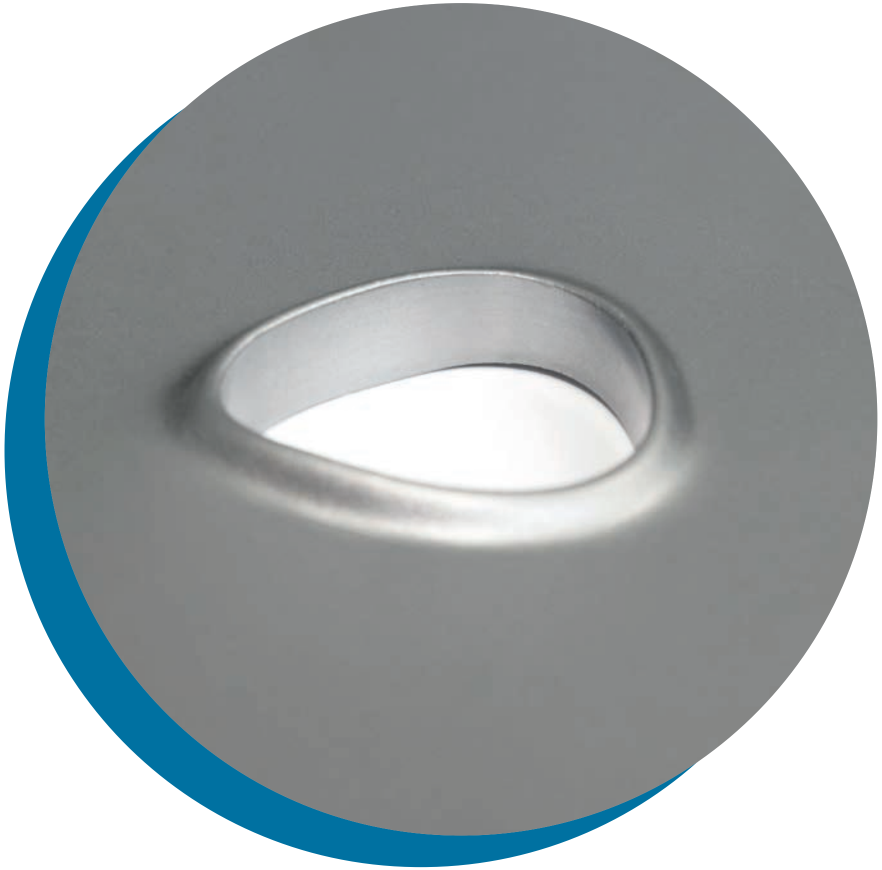


Fig. [3]: Close-up view of the double-sided collar

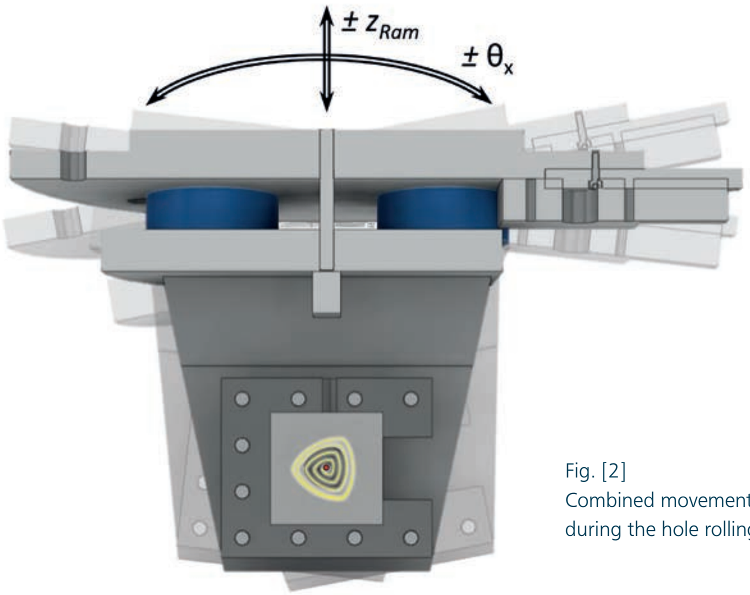


Fig. [2]
Combined movement of the upper tool
during the hole rolling process

Space for

Artificial Intelligence

Artificial Intelligence (AI) enables the development of intelligent processes that are transforming the forming industry. Our research demonstrates how AI is revolutionising forming technology by optimising processes, increasing efficiency and discovering new applications from engineering to production.

ProKI – Implementation of digitalisation and AI applications in the production technology industry

Leonie Meldt (TU Darmstadt, PTW), left
Sven Varchmin (TU Darmstadt, PtU), middle
Dr.-Ing. Benjamin Brockhaus (TU Darmstadt, PTW), right

Motivation

AI applications are playing an increasingly important role in our daily lives, and tools such as large language models (LLM)-based chat environments (e.g., ChatGPT) and AI-based image generators are becoming integral to the workplace. However, machine learning offers much more than just generating text and images; data processing and pattern recognition are also significant strengths that can bring substantial benefits to manufacturing companies. The processing of large volumes of sensor data through AI applications enable industries to automatically monitor and optimise processes over time. However, implementing these processes is challenging and requires expertise in data processing and industrial practices.

Approach

Supporting companies in the transition to qualified AI users at this interface is the goal of the ProKI project. ProKI is a network of eight German universities and colleges dedicated to integrating AI applications into various aspects of production technology, with a strong focus on transfer instruments, including workshops, hands-on implementation projects, and collaboration formats such as conferences. Within ProKI, new methods and tools for technology transfer are continuously developed and made available to partners in industry. The institutes in Darmstadt focus specifically on forming technology, assisting companies and employees in this field with adopting and understanding machine learning. In 2024, Darmstadt's efforts have centered on implementing AI in real-world scenarios to help companies address specific challenges with practical AI applications. It is important that AI applications are not introduced for their own sake but are always deployed with a clear, predefined purpose.

Results

A number of significant transfer achievements have been made over the past year. These include advancements in quality monitoring (e.g., using cameras, force, and acceleration data) that have allowed early intervention in cases of quality degradation. This technology has not only optimised production, but has also enabled employees to shift focus to more critical tasks by reducing the need for close process supervision.
It has also laid the foundations for predictive quality monitoring and predictive maintenance, helping to reduce waste and optimise production processes.
In the area of knowledge transfer, employee training sessions, including workshops, played a crucial role.
Efforts to foster stronger connections between academia and industry were also emphasized, particularly at events such as the Smart Factory 2 conference in Darmstadt.

Acknowledgement

Our thanks go to the Federal Ministry of Education and Research (BMBF), which funds this project through the program "Future of Value Creation – Research on Production, Services, and Work" (FKZ 02P22A030).

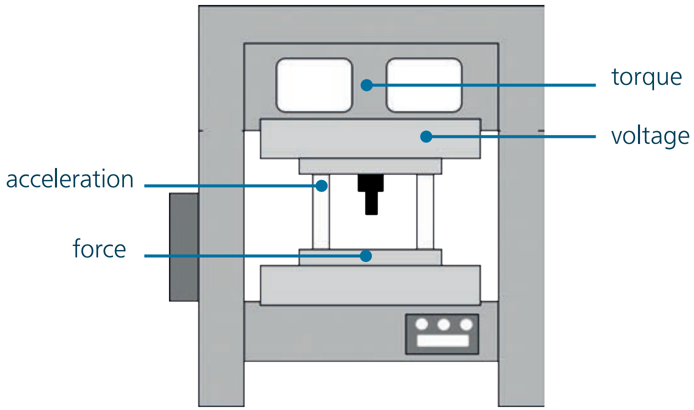


Fig. [1]
Data aquisition in production through
sensor integration

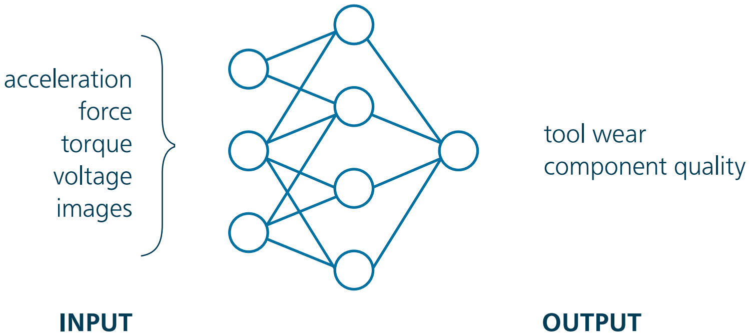


Fig. [2]
Process monitoring using AI algorithms
and relevant production process data

Fig. [3]
Sensor retrofit of a blanking press
for monitoring force and acceleration

TriboAI – Advanced friction modelling in cold forging using machine learning

Stefan Volz (TU Darmstadt, PtU), left
Jonas Launhardt (TU Darmstadt, PtU), right

Motivation

In cold forging, the resulting friction conditions play a central role, as they significantly influence both the dimensional accuracy of the components produced and the stability of the process, which in turn has an impact on sustainability in terms of scrap rates, energy consumption along the entire production chain, and the use of environmentally harmful lubricants. Therefore, precise friction modelling is essential for the optimal design of these forming processes. However, the tribology of cold forging is extremely complex due to the high loads involved and numerous non-linear influencing variables, as shown in Fig. [1]. This makes modelling with conventional approaches, such as Coulomb's friction law, more difficult and requires numerous process-specific tribometer tests to account for the various influencing variables.

Approach

This project aims to develop an innovative approach based on "black box" machine learning (ML) models. In contrast to traditional models, ML models offer an exceptional ability to take into account a larger number of influencing variables and to map complex, non-linear dependencies in the cold forging tribological system, as shown in Fig. [2]. In addition, the use of time series in conjunction with ML can reduce the testing effort compared to conventional friction models.

Results

In first projects, "black box" friction models have been developed based on experimental and simulative data, taking into account process variables such as sliding distance, contact normal stress, contact temperature surface enlargement and velocity. The integration of these friction models into finite element (FE) simulations has significantly improved the accuracy of friction force calculations. The increase in FE accuracy enhances the process design quality, e.g. by increasing the material flow and the accuracy of the tool stress calculation. The aim of future work is to expand the friction model to include additional system variables such as surface parameters and material properties in a data-efficient manner. This will further increase the accuracy of the model while improving the applicability and user-friendliness of the model. By using modern machine learning methods, this research project offers a promising approach to overcoming tribological challenges in cold forging and opens up new possibilities for industrial applications.

Acknowledgement

We would like to thank the International Cold Forging Group, in particular the Lubrication Subgroup, for their support.

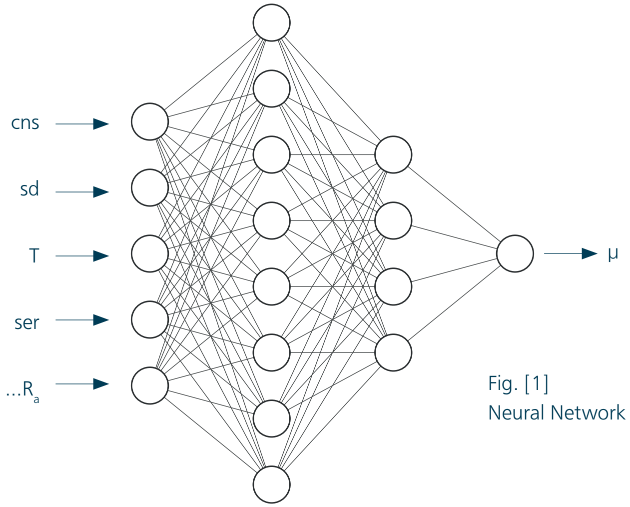


Fig. [1]
Neural Network based friction model

cns = Contact normal stress
sd = Sliding distance
R_a = Roughness

T = Temperature
ser ψ = Surface expansion ratio
μ = Friction coefficient

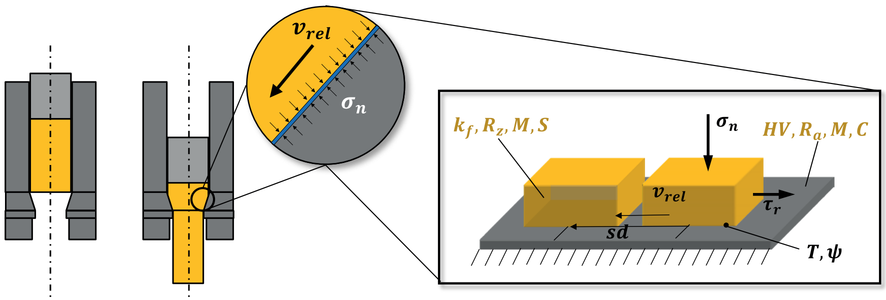
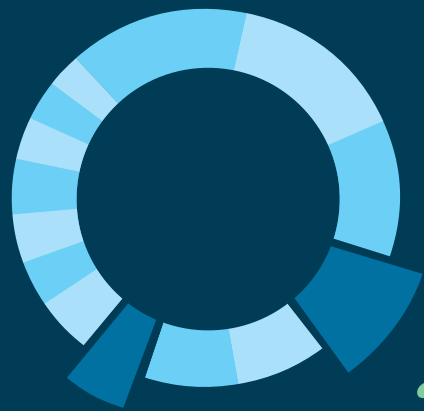


Fig. [2]
Tribological system in cold forging

Fig. [3]
Workpieces in cold forging coated with ZnPh and soap

51 **Bachelor & Master Theses**



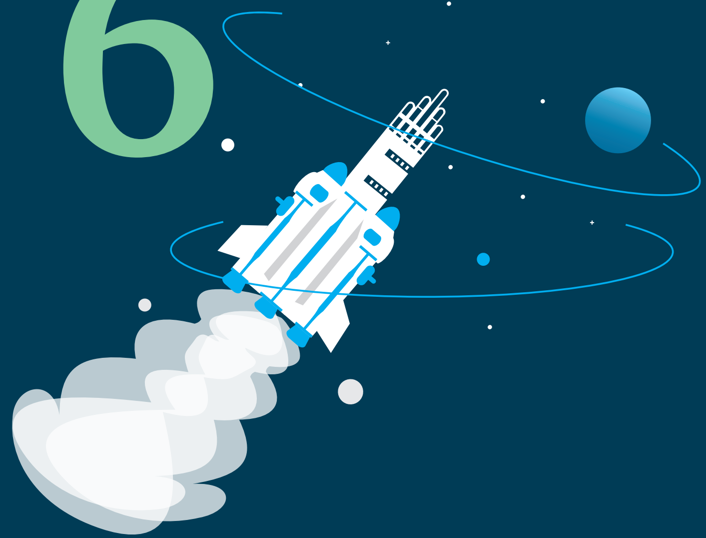
1,312 **Business Administration and Engineering - Mechanical Engineering**

2,160 **Mechanical Engineering**

9 **PhDs**

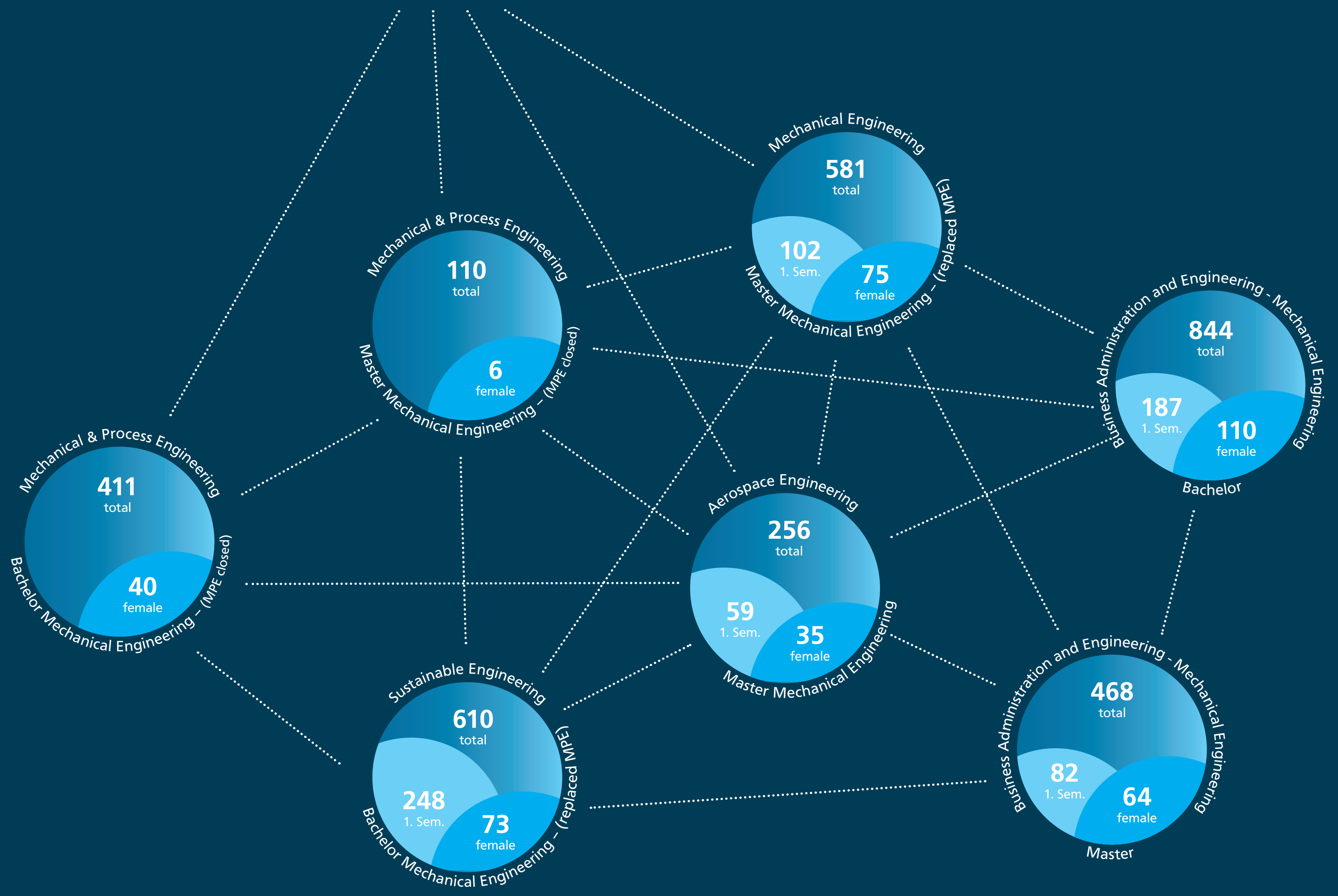
Nassr Al-Baradoni, Alexander Breunig, Lukas Kluy, Maximilian Knoll, Christian Kubik, Dirk Molitor, Christiane Preuschoff-Gerlitzky, Lukas Schell, Timon Suckow

6 **Awards & Prizes**



Markus Schumann: Distr@l-Qualitätssiegel "Silber" as part of the selection of the best,
Stefan Volz: Best Paper Prize 1st ICFG,
Christoph Kuhn: Best Paper Award 2nd ICTMP,
Philipp Schumann: Best Paper Award 3rd ICTMP,
Felix Georgi: Winner AutoForm Poster Award Forming Technology Forum,
Lukas Schell: Manfred Hirschvogel Prize

24,008 TU Darmstadt Students in total



Institute Life

01

02

03

05

04

01 WGP Tournament
02 ProKI Smart Factory
03 Research Workshop
04 TU Meet & Move
05 Forming Future

Our Team

Team Excursion

AiF
Forschungsnetzwerk Mittelstand

INDUSTRIELLE IGF
GEMEINSCHAFTSFORSCHUNG

PTS

GCFG
GERMAN COLD FORGING GROUP

DLR

DFG

FOSTA

EFB

LOEWE
Exzellente Forschung für Hessens Zukunft

IfF
Institut für Fertigungsforschung e.V.

digitales.hessen
DISTR@L

HESSEN

Forschungsgesellschaft Stahlverformung e. V.
FSV

ZIM
Zentrales Innovationsprogramm Mittelstand

Bundesministerium für Bildung und Forschung

Bundesministerium für Wirtschaft und Klimaschutz

Follow us

LinkedIn

Our Sponsors

Imprint

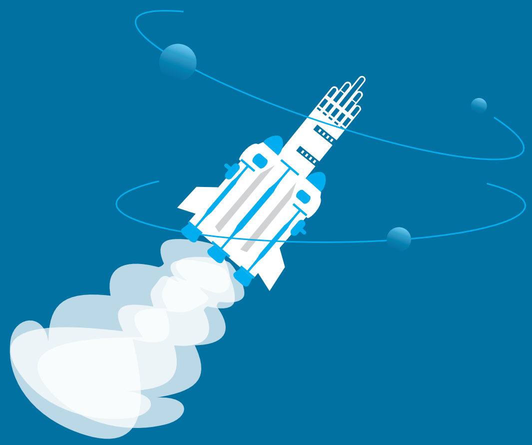
Publisher
Technical University of Darmstadt
Institute for Production Engineering and Forming Machines
Prof. Dr.-Ing. Dipl.-Wirtsch.-Ing. Peter Groche
Otto-Berndt-Straße 2
64287 Darmstadt
Telefon +49 61 51 16 231 43
Telefax +49 61 51 16 231 42
E-Mail info@ptu.tu-darmstadt.de
Web www.ptu.tu-darmstadt.de

www.linkedin.com/company/ptutudarmstadt

Editor
Jonas Launhardt M. Sc.,
the administration and all other Research Associates of PtU

Concept, Layout
Dipl.-Des. Heike Lunkenheimer
Dipl.-Des. Angelika Philipp

Image rights
PtU/TU Darmstadt
P. 15, 27: Adobe Stock
P. 30 ProKI_SmartFactory: PTW/TU Darmstadt



Technical University of Darmstadt
Institute for Production Engineering
and Forming Machines

Otto-Berndt-Straße 2
64287 Darmstadt

info@ptu.tu-darmstadt.de
www.ptu-darmstadt.de