

Fraunhofer IGP

**Fraunhofer Institute for Large Structures in Production Engineering IGP**

# Annual Activity Report 2024

# Greeting



**Dear Readers,**

2024 was characterized by many events at Fraunhofer IGP. In this annual activity report, we would like to look back together on the most important events of recent months.

A first highlight was the visit of the new president of the Fraunhofer-Gesellschaft, Prof. Dr. Holger Hanselka to Rostock as part of his inaugural trip. Fraunhofer IGP presented itself, its main site and the Hydrogen Application Center in Warnemünde and gave a comprehensive overview of the institute's diverse research topics, particularly in shipbuilding and wind energy. Together with Fraunhofer IGD and IZI, we were able to present all Fraunhofer activities in Mecklenburg-West Pomerania, as well as shedding a light on the joint projects Smart Ocean Technologies, Biogenic Value Creation and Smart Farming. At the beginning of May, we celebrated the opening of the Hydrogen Application Center in the presence of Reinhard Meyer, Minister of Economics of Mecklenburg-West Pomerania, Rostock's Mayor Eva-Maria Kröger, Prof. Dr Elizabeth Prommer, Rector of the University of Rostock, Dr Jan Meyer, Managing Director of Meyer Werft, and Joan Bosch as representative of the Fraunhofer-Gesellschaft. This officially marked the start of research into sustainable, hydrogen-based technologies for the maritime industry here in Mecklenburg-West Pomerania, and in June, the MV 2024 State Technology Conference was held at the Fraunhofer IGP under the motto "Production of the future – cutting-edge technology from MV in mechanical and plant engineering". This event was organised in co-operation with the Rostock Chamber of Industry and Commerce and the Ministry of Economic Affairs, Infrastructure, Tourism and Employment. Together with universities, colleges and other research institutes such as the Mecklenburg-West Pomerania Welding Training and Research Institute (SLV), we were able to present our services to companies in our federal state. Another highlight was the joint presentation of the Fraunhofer Institutes in Mecklenburg-West Pomerania during the nationwide celebrations to mark the Day of German Unity in Schwerin in October. At a joint booth, visitors had the opportunity to talk to researchers, experience robotics and find out about selected research projects. Our interactive exhibits and information programmes were very successful, which also enabled us to appeal to young scientists and get them interested
in technical professions and sustainable topics.

We have a lot planned for the future and hope to convey an impression of our activities in this report. We look forward to exchanging ideas with you, our partners from industry, politics and research, so that we can continue to tackle the right issues in the coming years.

Yours faithfully

Prof. Wilko Flügge
Director of the Fraunhofer IGP

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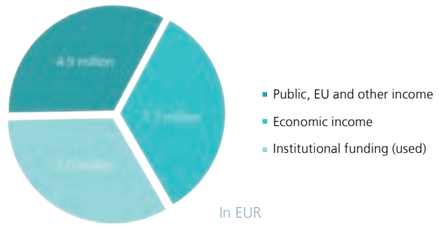
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# The institute at a glance

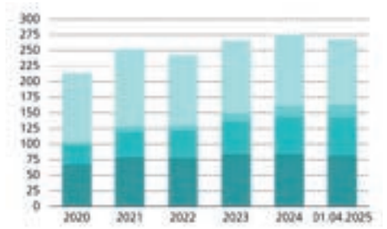
## Facts and figures

Yields




In EUR

Number of employees



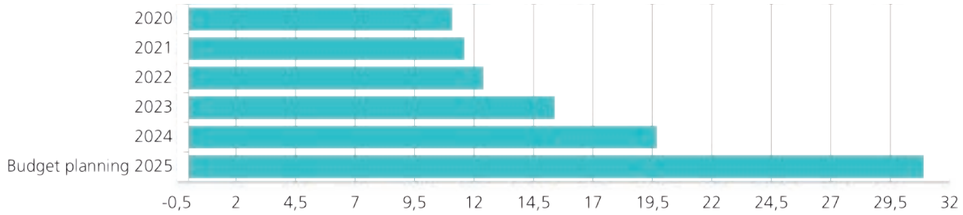

### Income

Income for 2024 totalled €19.7 million. With an economic yield of 43.9 per cent, the planned targets were also achieved in 2024. The Rostock Fraunhofer Institute also generated a balanced budget with a positive carryover in 2024.
The overall budget continues to grow steadily.

### Employee numbers

Fraunhofer IGP has a total of 276 employees in 2024. The majority of our scientists hold a degree in engineering or industrial engineering or a Master of Science. This year, 115 research assistants supported the work of the Fraunhofer staff. As in the previous year, four trainees also joined the team. In co-operation with the chairs of Manufacturing Technology, Joining Technology, Production Organization and Logistics and the Chair of 3D Measurement, Analysis and Monitoring in the Production Environment, 17 employees from the University of Rostock work closely with the Fraunhofer IGP in research and teaching.

Growth in the overall budget and planning for 2024




in million euros





# Organizational chart

**Last updated: November 2024**

**Institute Director**
Prof.
Wilko Flügge

**Deputy Director**
Prof.
Knuth-Michael Henkel

**Assistants to the Institute Management**
Sabine Wegener
Virginie Rogge

**Pre-competitive research at University of Rostock**

**Manufacturing Technologies**
Dr. Andreas Gericke

**Production Systems and Logistics**
Prof. Jan Sender

**New Materials and Processes**
Dr. Michael Irmer

**Strategic Tasks**

**Administration**
Lisa Knaack

**Joining Technology**
Prof. Knuth-Michael Henkel

**Joining and Forming by Plastic Deformation**
Dr. Pascal Froitzheim

**Industrial Robotics**
Konstantin von Haugwitz

**Polymer Laboratory**
Dr. Michael Irmer

**Energy Converters**
Dr. Björn Henke

**Human Resources**

**Production Engineering**
Prof. Wilko Flügge

**Mechanical Joining Technology**
Dr. Maik Dörre

**Measuring of Large Structures**
Prof. Michael Geist

**Adhesive Bonding Technologies**
Linda Fröck

**Quality Management**

**Communications**

**Production Organization**
Prof. Jan Sender

**Thermal Coating Systems**
Dr. Michél Hauer

**Production Planning and Control**
Dr. Konrad Jagusch

**Fiber Composite Technology**
Dr. Stefan Schmidt

**Special Tasks**
Special functions, building management, teaching

**Purchasing**

**3D Measurement, Analysis and Monitoring**
Prof. Michael Geist

**Thermal Joining Engineering**
Dr. Oliver Brätz

**Factory and Work Organization**
Florian Beuß

**Corrosion Protection Technology**
Valeska Cherewko

**Controlling/ Order Management**

**Automation and Production Systems**
Steffen Dryba

**Travel/ Accounting**

**Testing, Monitoring and Certification Body According to the State Building Regulations (Landesbauordnung (LBO))**
Prof. Ralf Glienke

**Workshop/Sample Fabrication**
Martin Brandes

**IT Services**
Markus Baier

**Test Laboratory**
Holger Brauns



# Large-scale robotics in Rostock – from rod kinematics to heavy-duty robotic systems for MMG

Development of a large-scale robotic system began in 2009 at Fraunhofer IGP, which was then operating as the Application Center for Large Structures in Production Engineering Rostock (AGP). The initial objective was to improve an existing prototype designed for truck assembly. The original system—a rod-kinematics robot—featured two parallel kinematic chains arranged sequentially and driven entirely by linear axes. This configuration resulted in a relatively low dead weight for a robot of its size. However, the system's maneuverability was limited. While it performed effectively in its intended application—installing power packs (engine-transmission modules) into truck frames—it was not suitable as a versatile, general-purpose robotic solution. The restricted angular ranges of its individual axes further limited its flexibility.

In 2011, Fraunhofer AGP launched a joint TBI project to enhance the performance of the large rod-kinematics robot while eliminating its inherent limitations. The development team collaborated closely with IMG GmbH, which manufactured many of the robot's key components. The goal was ambitious: to develop a large-scale robot with a reach exceeding five meters and a nominal payload of approximately 4,000 kilograms. The use of linear drives for the two primary axes (axes 2 and 3) was retained. Engineers developed a new kinematic structure based on Watt's linkage principles. However, they moved away from the parallel kinematics concept and eliminated the mechanical coupling of the main axes.

*For MMG GmbH in Waren, the large robot (here with drilling application) brings a significant increase in efficiency in the processing of ship propellers.*

The system, completed in 2014, offered a significantly expanded workspace compared to the original prototype and achieved a payload capacity that remains unmatched among electrically powered robotic systems. The newly designed kinematic structure enabled exceptionally high torque transmission while substantially improving overall structural rigidity. Following initial laboratory testing, an opportunity arose in 2015 to collaborate with Mecklenburger Metallguss GmbH (MMG) in Waren to adapt the robot for a specific industrial application.

## Large robot 1.0 – from development to industrial application

MMG manufactures ship propellers for large cargo vessels and cruise ships. Because each propeller is custom-designed for a specific vessel, production runs are typically very small. Although the basic geometry remains similar, every propeller is unique. As a result, much of the manufacturing process historically relied on manual labor—particularly during the finishing of propeller blanks. These blanks, cast from a bronze alloy with excess material allowance, are brought to their final geometry through grinding using a hydraulic master-slave manipulator. To determine where and how much material must be removed to achieve precise machining accuracy, each blank is measured and compared to its target geometry.

*Sponsored by:*

Technologie-Beratungs-Institut GmbH

EUROPÄISCHE UNION
Europäischer Fonds für Regionale Entwicklung



*First test vehicle – fully assembled and commissioned large rod kinematics robot in the Fraunhofer IGP Technical Center (May 2010)*

Thousands of marking holes are then drilled to guide the grinding process. Traditionally, this step was performed manually and required significant time and effort.

This presented an ideal opportunity to apply the capabilities of the large robot in a real-world production environment. The Fraunhofer IGP engineering team proposed automating the marking process using the electrically driven large-scale robot equipped with a robotic drilling system. The sheer size of the workpieces—propellers with diameters of up to 12 meters—posed a significant challenge. To access every point on the propeller surface, the robot required both extended reach and precise maneuverability. At the same time, increasing robot size typically makes maintaining accuracy more difficult. To address these challenges, multiple research groups at Fraunhofer IGP collaborated across disciplines, integrating expertise in automation technology, metrology, and production organization. A specialized adaptive drilling head was developed for the application. To enhance absolute positioning accuracy, the team integrated a laser tracking system. Additional sensors on the drilling head monitored both its alignment relative to the propeller surface and the penetration depth of the drill bit, allowing for dynamic adjustments during operation. The research team integrated a laser tracker system to increase the absolute accuracy of the robot. The drilling tool mounted on the robot flange enables marking holes to be produced with millimeter-level precision. The entire system was programmed so that, after training, on-site personnel at MMG could operate it independently. This successful implementation marked a major milestone in the advancement of large-scale robotics at Fraunhofer IGP.

## Continuous improvement – second generation large robots

Following the successful deployment of the first system and building on the operational experience gained at MMG, a follow-up project was initiated in 2017.

Large-scale robotics in Rostock – from rod kinematics to heavy-duty robotic systems for MMG

The objective was to qualify the large robot for grinding applications, automating an additional production step in propeller manufacturing. Grinding, however, places substantially higher demands on both structural rigidity and positional accuracy than drilling. While the drilling process required high absolute accuracy at discrete points, grinding demands precise control of the robot's pose throughout continuous toolpath motion. Maintaining absolute pose accuracy during sustained movement presented a new engineering challenge. As a result, the second-generation development focused heavily on improving structural rigidity—particularly torsional stiffness around the vertical axis. Key structural components were significantly reinforced. The previously asymmetrical hydraulic counterweight system was replaced with a symmetrical configuration. The mechanical connection between the two robot arms was also fundamentally redesigned. To increase stiffness without adding excessive moving mass, the team moved away from welded assemblies of simple steel profiles. Instead, cast aluminum structural components were introduced, providing improved rigidity while maintaining manageable weight. The second-generation large robot is scheduled to be assembled and commissioned at MMG in Waren in 2024.

## Outlook

Research in large-scale robotics at Fraunhofer IGP continues to evolve. Additional follow-up projects are already in development, with a particular focus on expanding robotic applications. Over the long term, further improvements in performance are planned, including exploration of new drive concepts to enhance capability and efficiency. For MMG in Waren, the large robotic system represents a significant increase in efficiency in the processing of ship propellers—demonstrating how advanced large-scale robotics can successfully transition from research to industrial practice.


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**Large robot 1.0**
**Assembly and commissioning at Fraunhofer IGP**

**2014**



**Drilling robot**
**Commissioning of the drilling robot cell at MMG GmbH**

**2017**

**2011**
Launch of the "Large rod kinematics robot" project

**2015**
Launch of the "Drilling robot" project

**2018**
Launch of the "FlexGrind" project





**Large robots 2.0 (1)**
**Assembly and commissioning at MMG GmbH**

**2024**

**Large robots 2.0 (2)**
**Assembly and commissioning at Fraunhofer IGP**



*From rod kinematics robots to large robots 2.0 and beyond – Overview of the development of large robotics at Fraunhofer IGP*

**From 2026**
Follow-up projects

| Development of further applications: | Methods for further improving the applications: |
|---|---|
| Grinding application | Collaboration |
| Cleaning of castings | Calibration |
| Milling of castings | Structural optimization |
| Measuring application | Alternative drive concepts |

# Research for practice

**Focus topic:**

## Solutions for steel construction in onshore and offshore wind energy

# Solutions for steel construction in onshore and offshore wind energy

In view of Germany's prospective infrastructure goals, the need to expand buildings and even more so structures for low-cost and sustainable energy generation – especially wind energy – there is currently a great need to further develop the design and manufacture of such large steel structures. In the wind energy sector, these structures are primarily the foundations and tower components of wind turbines, which pose challenges in terms of the high demands placed on quality, safety and component integrity. Another important goal in the production of these large steel structures is to save on materials and resources while maintaining functionality and component safety. New approaches to dimensioning and design could help to realize unused potential, for example, with lightweight construction approaches. This relates primarily to the area of mechanical or thermal joints, which, in contrast to the base material, traditionally represent a potential weak point within a large structure.

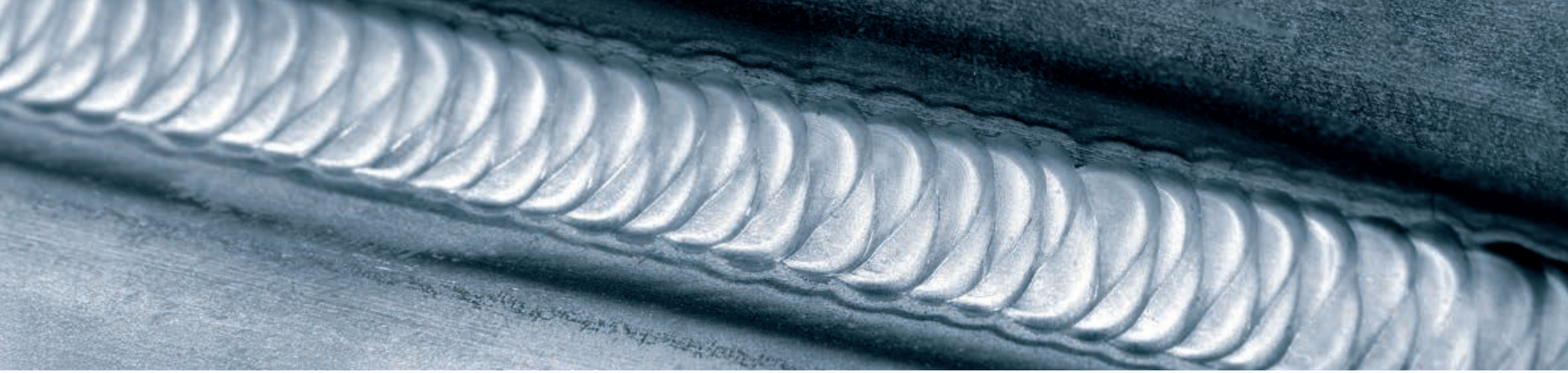
Fraunhofer IGP uses a wide range of experimental and numerical methods to develop new approaches, for example, for bolted and welded joints, which lead to new design approaches for steel structures, generating considerable potential savings in terms of material, mass and production costs and significantly increases the service life of the structures.
In addition to developing new design approaches for joint details, Fraunhofer IGP is also researching innovative methods for the post-treatment of joints to improve component properties. In addition, new coating systems are being developed to prevent corrosion, which can contribute to significantly longer service lives for steel structures, e.g. steel foundations for offshore wind turbines.

Due to the predominantly unique character or small batch sizes, the production of large steel structures is often characterized by individualised processes. In addition to the manufacturing constraints with comparatively high variance in assembly tolerances and massive sheet thicknesses, a low degree of automation in the manufacturing processes and long throughput times results. Therefore, the Manufacturing Technologies department at Fraunhofer IGP is developing innovative and highly productive joining processes in combination with new material concepts for improved processability, which should enable more economical and ecological production. At the same time, approaches are being developed to digitalise and simulate the individualised and manual production steps, which will enable new and globally unique approaches to the automated production of large structures.

In the following sections, Fraunhofer IGP research groups from the field of manufacturing technologies provide an overview of their research approaches and present individual research and innovation projects that they are working on with regard to steel construction for offshore wind turbines.




*Monopiles stored for transport for installation in an offshore wind farm*



*Close-up of a weld seam*

# Ways to optimize welded and mechanically joined connections in heavy steel construction

**With the ongoing expansion of renewable energies to achieve the goals of the energy transition, there is a continuing high demand for new wind turbines. With their investigations into joint and material properties and the development of new processes and standards, the scientists at Fraunhofer IGP are making a decisive contribution to optimizing the technical performance of wind turbines and improving them with regard to turbine safety and service life.**

## Challenges for the design and dimensioning of wind turbines

Towers for wind turbines are realised in various designs, but tubular steel towers still make up the majority of the structures currently planned and used. Compared to other construction concepts, the tower concept is characterized by comparatively low production costs and high scalability, as well as a low level of effort required for assembly on site.
In the production of towers for wind turbines, heavy plates with a thickness of up to 80 mm are formed from structural steel into sections and welded into individual segments. During construction, the segments are mechanically joined by means of flanges and bolts.

Increasing tower heights pose particular challenges for designers when constructing these systems. Towers with very high hub heights generate a significantly higher yield due to greater wind stability and reduced turbulence. To ensure sufficient buckling safety, the diameter of the tower tube and the width of the tower base increase the higher the tower is dimensioned. Diameter limitations arise, among other things, from the transport of the prefabricated tower segments (ship sizes, bridge clearance heights, etc.), which is why longitudinally divided tower concepts are increasingly coming into focus.
The tower structure is manufactured in individual segments and mechanically joined and erected on site to form large-diameter tubes. Depending on the design, several thousand mechanical connecting elements are used. On the one hand, this places high demands on the tolerance of the individual segments to each other. On the other hand, it requires a safe and, at the same time, economical dimensioning of the mechanical connections. Here in particular, the dimensioning of the connecting elements determines the cost-effectiveness, system safety and performance of the concepts over the entire service life. This has been proven at Fraunhofer IGP through a variety of studies and demonstrated in numerous projects.

## Creating new data bases for the dimensioning of wind turbines

Many specifications for the design and construction of such towers, as well as the design of the joints, are regulated by standards. However, the specifications are often still based on old and not always well-documented data sets, which can only be transferred to today's materials and boundary conditions to a limited extent. In order to create a more up-to-date data basis here and to exploit previously untapped potential in terms of material utilisation and cost-effectiveness, the scientists at Fraunhofer IGP are carrying out numerous tests on a wide variety of fasteners, thus providing evidence of the exact fastening properties of screw connections, for example. The actual dimensions, framework conditions, such as the coating and material properties and loads are analysed with regard to the prestressing forces to be applied as well as static and dynamic load-bearing capacity. The resulting data basis can be used to derive new and more efficient design models for the mechanical connections and, in collaboration with customers, experts and certifiers, can be translated into new design specifications, leading to more efficient designs with frequently improved sustainability due to material savings or longer service lives of the systems.

## Increasing the fatigue strength of joints

The loads acting on the tower of a wind turbine – due to operation and other external factors – are enormous over the entire service life of the turbine. Regardless of which design concept is chosen for the tower of a wind turbine, joints are always a critical point in the structure. It must therefore be ensured and verified that the joints can withstand the stresses acting on them. With a planned service life of approx. 20 years, onshore towers usually have to withstand well over ten million load cycles with intensities up to the yield strength of the material used. Due to this dynamic stress, it is therefore essential to demonstrate sufficient fatigue strength, i.e. resistance to material fatigue.

Since joints normally have a lower fatigue strength than the base material due to geometric and, in the case of weld seams, metallurgical notch effects, these areas can become decisive for the design and determine the design of the overall system. On the one hand, this can influence the sheet thickness to be used and thus both the material consumption and the weight of the tower. On the other hand, it can influence coating systems, screw diameter, and number of screws in the flange area. Weld seams are, depending on the design, particularly critical areas in dynamically loaded structures due to their high notch effect. Geometric irregularities in the weld seam in combination with changes in the properties of the material resulting from the thermal effect of welding (e.g. changes in microstructure, welding tensile stresses) have a negative effect. They reduce the resistance to crack initiation and growth, thereby reducing the load-bearing capacity of the joint and thus of the entire structure. This can be compensated for with material surcharges, but in turn has an influence on the mass, costs and Eigenfrequency properties of the tower. In order to enable more efficient designs and reduce manufacturing effort and costs at the same time while increasing sustainability and system performance, Fraunhofer IGP is developing, qualifying and testing mechanical and thermal processes that eliminate the negative effect of weld seams on fatigue strength. For example, sharp-notched seam transitions are rounded off, which improves the flow of force by reducing the geometric notch. With other processes, such as blast cleaning, the material strength is increased locally and residual compressive stresses are introduced, which leads to a significant increase in fatigue strength. In applications that have already been implemented and used worldwide, it has been possible to increase the service life to over 600% after this type of post-treatment and to reduce the usual masses of tubular steel towers by up to 50 tonnes per tower. In addition to the experimental investigations into fatigue strength and material behaviour, procedures for simple and reliable quality assurance are developed at Fraunhofer IGP and implemented with customers worldwide.

Through the work presented here, Fraunhofer IGP is currently contributing to increasing the economic efficiency, technical performance and plant safety of towers for wind turbines, while simultaneously conserving resources through material savings and extended service lives.

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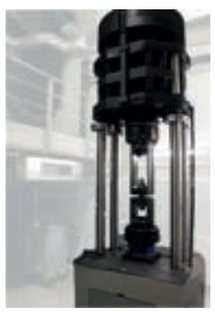
*Sections of a wind turbine joined together with large diameter bolts (detailed view)*

# Further development of the notch case catalogue for large diameter screws

Renewable energies should ensure a share of at least 80 percent of the electricity supply by 2030, with wind energy playing a key role in achieving these targets. The necessary increase in the nominal capacity to be installed in order to meet the expansion targets and, at the same time, the reduction in the levelised cost of energy (LCOE) is associated with a steady trend in plant growth and lifetime extensions. These trends can be found worldwide for onshore and offshore wind turbines in the coming years.
"The average turbine configuration in Germany for onshore wind turbines in 2023 grew to almost 4.78 MW turbine capacity (+10 percent) and 141 m rotor diameter (+3 percent) compared to the previous year. A comparable trend can be observed in the offshore wind energy sector, whereby, by 2025, the turbine outputs will increase from the current 9.5 MW to 15 MW, the rotor diameters from 174 m to up to 236 m and the hub heights from 107 m to up to 145 m, depending on the project. Nowadays, high-strength bolts in dimensions up to M80 are used to connect the tower sections to each other, but also to connect the so-called transition piece (TP) to the monopile (MP)," says Dr. Mathias Schwarz, illustrating the current development. The ever-increasing dimensions of the systems make it all the more important that the connecting elements can safely withstand the increasing stresses.

This is where the work of the "Mechanical Joining Technology" research group at the Fraunhofer IGP comes in. With a view to the forces to which fasteners are exposed, including wind power, they are investigating the fatigue behavior of large-diameter bolts under the influence of size, manufacturer, medium stress and the condition of the coating and surface layer in a holistic approach together with colleagues from Wismar University of Applied Sciences in the "Further development of the notch case catalogue for large-diameter bolts in steel and plant construction" research project.



*Left: Screw set with large diameters*
*Right: Large-scale testing machine (2MN resonance pulsator) at Fraunhofer IGP*



*Self-lifting installation vessel during the assembly of an offshore wind turbine*

Dr. Schwarz, an expert in bolted connections, explains why this is necessary: "In the design principles for the construction, these influencing factors have so far been taken into account very inconsistently, depending on the respective set of rules used. In the past, an experimental basis for evaluating various influences was only available to a very limited extent, particularly for large-diameter bolts, such as those used in large numbers in wind turbines. For engineering offices, this often results in considerable conservatism in the design or cost-intensive certification processes with elaborate individual tests."

To create a better basis for assessment, the scientists carry out fatigue strength tests in the HCF and VHCF ranges, among others. This is accompanied by an in-situ acoustic emission measurement to monitor crack initiation and crack growth in combination with non-destructive µ-computed tomography. In addition, X-ray diffraction and measurements of the µ-magnetic properties provide information about the residual stress behavior in the thread root before and after cyclic loading. In this way, the level of knowledge about the fatigue behaviour of bolt sets in the VHCF range is expanded due to the small database. The research project thus represents an important contribution to the expansion and adaptation of the EC3 notch case catalogue*.

** In the field of steel construction, this verification is regulated in Eurocode 3 with fixed fatigue resistances for certain construction details (= EC3 notch catalogue).*

*Sponsored by:*

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG IGF

FOSTA Forschungsvereinigung Stahlanwendung e. V.

DLR

Project organiser for

Bundesministerium für Wirtschaft und Klimaschutz

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# Modification of welded joints

Welding of heavy plates with high material thicknesses is a key process in the production of steel support structures for wind turbines. Typically, large tubular structures, such as tower or offshore foundations, are manufactured by welding with various longitudinal and transverse seams. Due to the large component dimensions and sheet thicknesses of up to 150 mm in some cases, this results in enormous seam volumes that have to be welded highly productively and reliably. Submerged arc welding is usually used for this purpose, which enables the melting of several wire electrodes with high currents. At Fraunhofer IGP, the "Thermal Joining Engineering" working group is developing suitable welding processes to meet the high requirements of these joints.

## Connection integrity and increased productivity

The aim of the research and development activities is to optimise the weldability of the component. In addition to production engineering aspects to increase productivity and design aspects to ensure joint integrity, this also includes material engineering aspects to ensure suitable metallurgical processes during welding. The highest mechanical-technological material properties, such as strength and toughness, can be guaranteed in the joint by adapting the process and specifically influencing the composition of the weld metal.
For example, the research group develops and validates suitable weld metal alloys and welding processes, taking into account the suitability of the base materials for welding. Possible applications for alternative materials, such as high-strength structural steels, are also being analysed. A further objective of the researchers is to expand the possibilities of manufacturing technology to increase productivity. To this end, work is being carried out on the use of modified welding processes to influence the deposition rate, as well as on automation approaches and increasing process reliability. The group is developing customised characteristic curves and process evaluation methods, for example. Another field is the definition of suitable production strategies, which includes the optimisation of welding sequence planning and the development of suitable approaches for thermal straightening by predicting the distortion and material properties caused by welding with the aid of thermo-mechanical FE simulations.

## Making systems usable for longer – increasing fatigue strength

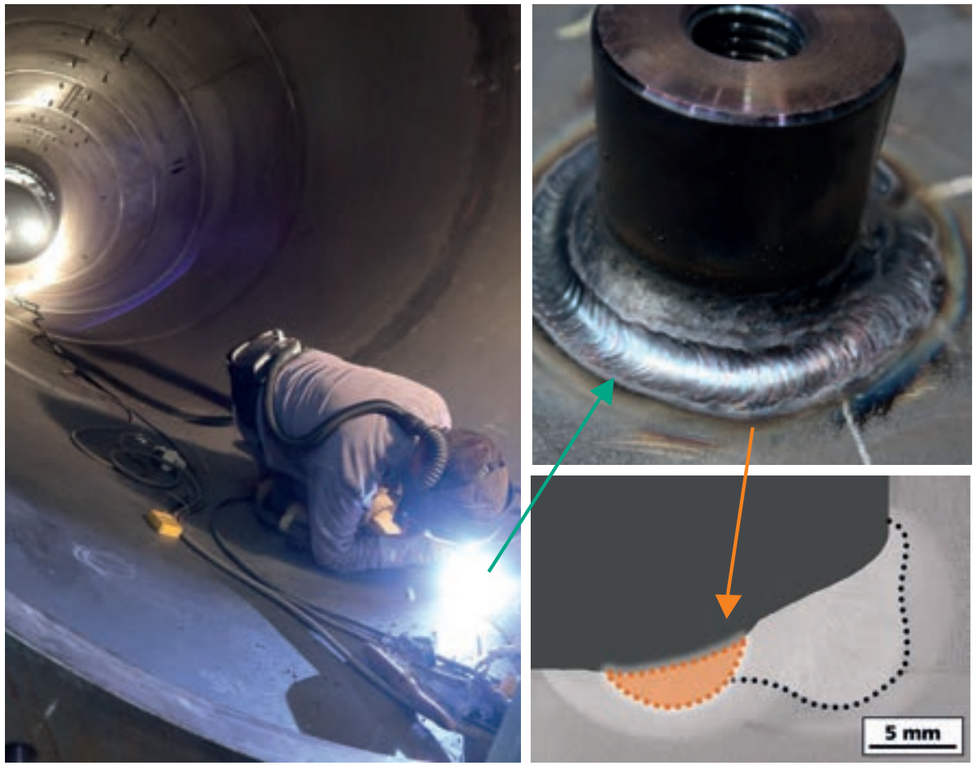
During the operation of the systems, the building structures are often subject to changing loads. Material fatigue and, thus, a reduction of the service life of the systems can result. Welded joints are particularly critical areas here. Through targeted modification of the welded joints, a significant improvement in fatigue strength can be achieved and property- as well as resource-optimized structures can be implemented. An effective improvement of the welded joint can be achieved using special post-treatment methods, among other things. To this end, the working group is developing practical procedures, taking into account the possible manufacturing conditions. This includes the testing and validation of suitable technologies such as high-frequency hammering, shot peening, grinding or remelting of weld seam transitions. Secondly, quality assurance concepts (including qualification and quality testing measures) are developed to guarantee the specified execution quality.

## Contact

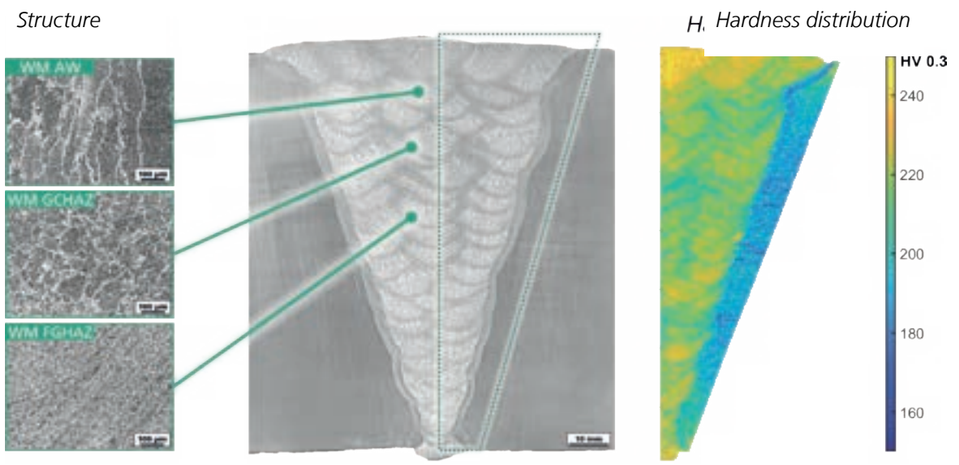
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igp.fraunhofer.de








*Post-treatment of the weld seam transition using TIG remelting to increase the fatigue strength: Realisation in wind turbine tower production (left) and connection in cross-section (right)*




*Multi-layer weld seam in cross-section with metallographic analysis: Microstructure of the weld metal (left) and hardness distribution (right)*

# Effective corrosion protection – thermal spraying in offshore wind energy



*Large-scale application of thermal spraying in the coating of monopiles. (left in the picture: coating halls for monopiles, centre: uncoated monopiles, right: coated monopiles)*

Offshore wind turbines (OWTs) are currently designed for a service life of more than 25 years. Long-lasting and effective corrosion protection is crucial for avoiding or reducing cost-intensive maintenance intervals on the systems. To this end, metallic coatings (aluminum, zinc or zinc-aluminum alloys) are increasingly being used on steel structures, which have superior mechanical and technological properties to organic systems. These coatings are applied with a high surface effect using thermal spraying processes (for example when coating monopiles, see photo p. 25 above). In addition, interactions between the coating and the base material can be specifically adjusted.

At Fraunhofer IGP, the Thermal Coating Systems team is investigating the effects of thermal spraying on characteristic properties such as the fatigue strength of the base materials (here the steel components of the wind turbines) or the quasi-static load-bearing capacity of the coatings in various contexts. In numerous tests, the team was able to identify relevant advantages by using thermal coating as corrosion protection for offshore installations.
It was shown, for example, that Al99% coatings applied to welded structural steel samples by thermal spraying (see Figure a) below) lead to a significant improvement in the fatigue strength of the base structure with sufficient adhesion. Dynamic tests on the blasted and coated test specimens with welded transverse stiffeners showed that the fatigue strength could be increased by 40 percent compared to uncoated reference specimens. When cracking did occur, it occurred in the area of the base material and not at the weld seam, which indicates a reduction in the notch effect of the weld seam (see below, Figure b)). The increase in fatigue strength is also independent of the abrasive used for surface preparation. The thermally sprayed coating itself also helps to improve fatigue strength, which can hypothetically be attributed to the closing of notches on the base material surface and/or to the stress equalisation effects between the coating and the base material (see Figure c) below).

The accompanying corrosion tests showed that thermally sprayed Al99% coatings exhibit high corrosion resistance in seawater environments and are suitable as sacrificial anodes. The combination of improved fatigue strength and corrosion protection makes the thermally sprayed coatings particularly promising for the construction and operation of offshore wind turbines.

There is currently a trend on the market towards XXL offshore wind turbines with diameters of up to 15 metres and lengths of up to 125 metres. These large steel structures with very thick plates of up to 150 mm are primarily subject to material fatigue. At the same time, the structures are already subjected to a certain elastic-plastic deformation during production due to their mass. The effects of the enormous structure size on the properties of the corrosion protection (e.g. adhesion, strength) are still completely unknown and can also potentially lead to premature failure.

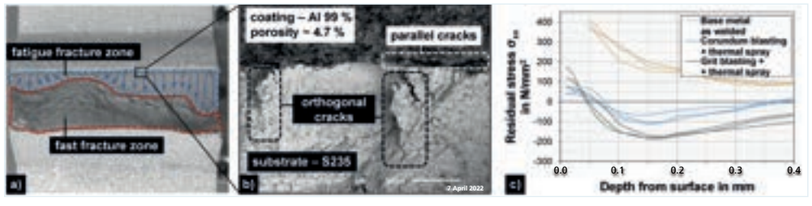
Building on these findings, the researchers at Fraunhofer IGP are currently working on a holistic approach to developing corrosion protection for XXL monopiles with superior mechanical properties and digital traceability as part of the joint project “CorroSpray”.

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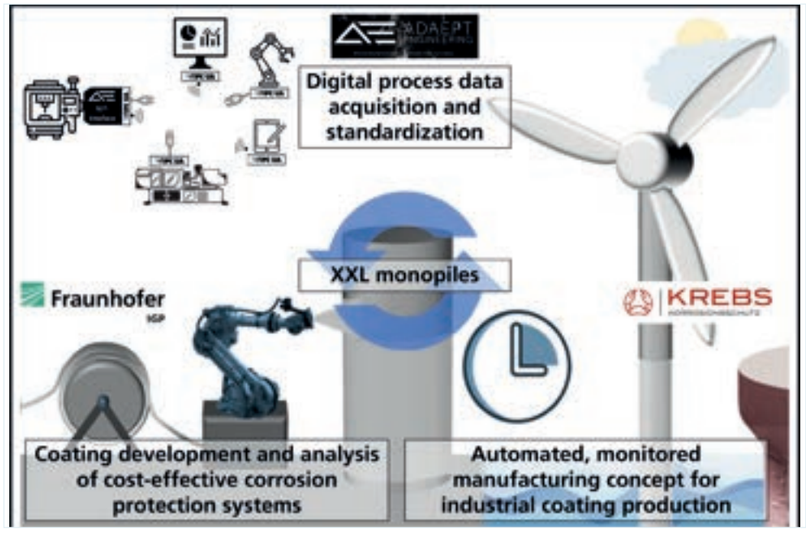
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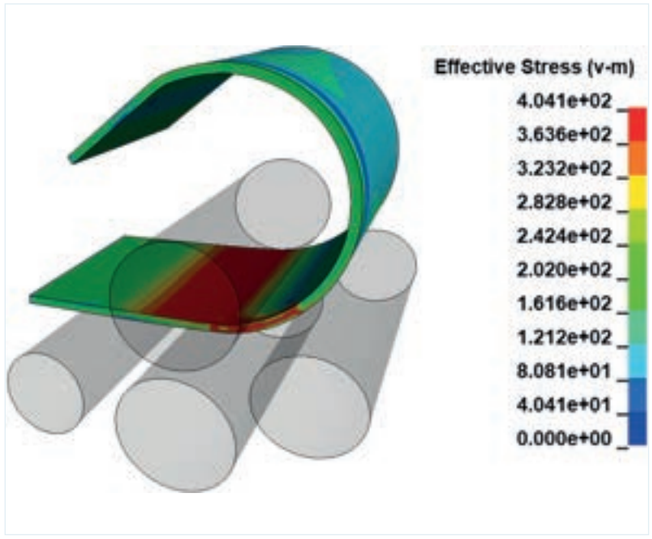

*Test results of the fatigue strength test of structural steel samples coated by thermal spraying*




*In the “CorroSpray” joint project, the parties involved (Fraunhofer IGP, Adaept Engineering GmbH and Krebs Korrosionsschutz GmbH) are working together on a holistic approach to the development of corrosion protection for XXL monopiles*

# Precision and sustainability – research enables precise production of formed components for wind turbines






*Left: 4-roll round bending machine; right: FE simulation of roll rounding with a 4-roll round bending machine*

Several pipe segments are welded together in the manufacturing of wind turbine towers. In practice, these pipe segments are manufactured by roll rounding using roll bending machines, which typically consist of three or four rolls. Due to strong fluctuations in sheet metal properties, controlling the forming process is a major challenge. The process control must be individually adapted to each sheet and cannot be determined in advance. In industry, this task is mainly performed by the machine operator on the basis of experience, which is why the Joining and Forming by Plastic Deformation working group at Fraunhofer IGP is focusing its research on the targeted investigation, standardisation and automation of the basic rolling process.

## Simulation enables precise production planning

A significant part of the working group's research involves the targeted use of numerical simulation methods (FEM) to simulate the process. To this end, the rolling mills used in production are recorded and digitalised in their entirety on site using state-of-the-art optical measurement technology. Thanks to the digital image created in this manner, simulation models can then be built and experimentally validated. The modelling strategies in use vary depending on the focus of the research and the aim of achieving an optimum balance between simulation accuracy and computing efficiency. In this way, Fraunhofer IGP has been able to build up sound expertise in the numerical simulation of forming processes with large sheet thicknesses over the last few years.

Finally, the use of numerical simulation makes it possible to analyse and evaluate different production scenarios. One application, for example, is the simulation of the rolling process with consideration of the welding-induced material embrittlement in relevant forming areas. Specific statements can be made about the formability and the occurrence of possible damage during production.
Another application is the development of process control models that can calculate an objective forming strategy for the system operator so that the desired forming result can be achieved precisely and efficiently. For this purpose, extensive numerical simulation studies are carried out to generate synthetic process data. The results obtained are then used to develop models in the field of artificial intelligence. This approach to data-based process control for roller rounding has already been registered for a patent throughout Europe due to its degree of novelty.

## Solutions for the recycling of wind turbines

Global strategies for saving resources and increasing the use of recycled materials in international value chains also affect key areas of the wind energy sector. While the development trend in recent decades has led to ever more powerful wind turbines, research is now focussing on recycling the components used as economically as possible once the wind turbines have reached the end of their service life.
One approach to the direct reuse of wind turbine components, for example, is to straighten the round-rolled pipe segments after they have been dismantled. By developing and qualifying appropriate technologies, the straightened sheets can be returned directly to the material cycle and, depending on their condition, used in the manufacture of suitable products.
This type of value chain offers considerable potential for saving thermal energy for remelting the pipe segments.

## Contact

**Joining and Forming by Plastic Deformation**
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# Outlook

The work of the Manufacturing Technologies department contributes in many ways to sustainability and increased efficiency in heavy steel construction. In the past, many experimentally supported approaches for the design of mechanical connections and manufacturing technologies for increasing the fatigue strength of welded structures have already been put into practice worldwide. Depending on the framework conditions, these innovative developments can, for example, achieve mass savings of up to 50 tonnes of steel per tubular steel tower for wind turbines or drastically reduce the dimensions and number of bolts.

Manufacturing and thermal coating technologies developed or qualified at Fraunhofer IGP are already helping to increase the productivity of welding processes in heavy steel construction by up to 300 percent and enable the saving of approx. 60 tonnes of sacrificial anodes on offshore foundations with the same corrosion protection effect and increased fatigue strength. The digitalisation and simulation of conventional manual forming processes also enable increasing automation and prediction of component properties, which leads to reduced waste and a potential increase in the production of components for wind turbines.

In the future, these developments for the construction of wind turbines will also be transferred to other areas of heavy steel construction, e.g. the construction of new bridges and supporting structures.

In the field of structural steel components for wind turbines, more efficient design concepts for a slim tower and foundation design will continue to be required in the future. This requires the development and qualification of cost-efficient and effective post-treatment methods that enable high notch classes, which on the one hand save mass and on the other hand increase service life.

In the area of foundation structures for offshore wind turbines, the combination of post-treatment methods and corrosion protection also plays an important role in extending their service life.

Recycle and reuse/refit approaches for wind turbine structures will also become increasingly important in the future. This concerns, for example, the reuse and reconditioning of mechanical connecting elements and entire tower segments, but also the evaluation of the actual physical service life (before crack initiation) using innovative non-destructive testing methods and work on improving digital twins.



# Science meets practice: Innovations in tower design for wind turbines



*Dr. Marc Seidel, Principal Engineer Support Structures at Siemens Gamesa Renewable Energy GmbH & Co. KG*

**In conversation with Dr. Marc Seidel, Principal Engineer Support Structures at Siemens Gamesa Renewable Energy GmbH & Co. KG**

**What topics are Siemens Gamesa Renewable Energy currently focussing on in the area of steel construction?**

"The wind energy industry is faced with the constant challenge of further developing tower designs to meet the increasing demands for efficiency, sustainability and cost-effectiveness. The fatigue of the connecting elements is a particular focus here: Wind turbines are exposed to changing and sometimes extreme loads over their entire service life. This places the highest demands on the fatigue strength of both bolted and welded connections. The aim is to optimally utilise all connections while also taking into account production aspects such as ease of assembly and cost-effectiveness."

**To what extent has the co-operation between your company and Fraunhofer IGP helped to overcome the challenges mentioned?**

"In collaboration with IGP, significant technological progress has been made in recent years. Particularly in the case of bolted flange connections and welded seams in tower constructions, new insights have been gained through joint research and development work, which are directly incorporated into practice. The combination of scientific expertise and state-of-the-art testing equipment at IGP has made it possible to develop innovative solutions and test them under realistic conditions. For example, new design concepts for bolts in flange connections have been developed, which allow a more precise design and therefore better material utilisation.

The results of this co-operation are of particular importance to Siemens Gamesa: They create the basis for lighter tower constructions, which go hand in hand with considerable savings in steel mass. This not only has a positive effect on the economic efficiency of the systems, but also makes an important contribution to conserving resources and reducing the CO2 footprint. The close cooperation with IGP impressively demonstrates how scientific excellence and practice-orientated development can go hand in hand to create innovative solutions for the challenges of the energy transition. The knowledge gained will strengthen Siemens Gamesa's competitiveness and help to further advance wind energy as a key pillar of a sustainable energy supply."



*Offshore installation of the foundation for the tower of a wind turbine*

# Review of the year 2024



# Clear the stage for a year full of event highlights

**As in previous years, Fraunhofer IGP organized or played a key role in a large number of events in 2024 – from specialist symposia and public science events to networking events and showcases for politics and business. However, some of them are particularly memorable.**

## March 2024 - New President of the Fraunhofer-Gesellschaft visits the Fraunhofer IGP in Rostock on his dialogue tour

Prof. Holger Hanselka took office as the 11th President of the Fraunhofer-Gesellschaft in August 2023. President of the Fraunhofer Society. On his inaugural trip, he will visit selected Fraunhofer sites and seek an open dialogue with employees and managers at the institutes. Fraunhofer IGP was one of his stops along the way.
The visit on 5 March started at the Hydrogen Application Center in Warnemünde. Dr. Björn Henke, Head of the Energy Converters Group, informed Prof Hanselka about the development of the new site, its research focus and cooperation with customers. The Fraunhofer president must have been particularly impressed by the huge engine test benches and the brief commissioning of a large engine during the tour.

*Prof. Holger Hanselka, new President of the Fraunhofer-Gesellschaft, visits Fraunhofer IGP as part of his dialogue tour*





Prof. Hanselka also exchanged views with representatives from the Ministry of Science and the Ministry of Economics of Mecklenburg-West Pomerania and the regional economy. On the way to Rostock city centre, they passed the Ocean Technology Campus, home to the Fraunhofer Smart Ocean Technologies (SOT) research group, and Fraunhofer IZI. Prof. Dr.-Ing. Hanselka then met with employees of Fraunhofer IGP, IGD-R and IZI in the new Technical Centrer of Fraunhofer IGP, where he answered questions and suggestions in detail. At various stations focussing on wind energy and shipbuilding, he was also informed about current projects of the individual research groups during the subsequent tour of our institute. As a mechanical engineer and materials scientist, he asked many technically motivated questions, but also repeatedly sought personal dialogue with the employees, including those from the supporting technical areas and administration, and Fraunhofer IGD-R, Fraunhofer IZI, the Smart Ocean Technologies research group and the Fraunhofer Biogenic Value Creation and Smart Farming Initiative (BWSF) also presented selected projects.

## May 2024 – The Hydrogen Application Center is officially inaugurated

In the presence of Reinhard Meyer, Minister of Economics of the State of Mecklenburg-West Pomerania, Rostock's Mayor Eva-Maria Kröger, Prof. Elizabeth Prommer, Rector of the University of Rostock, Dr. Jan Meyer, Managing Director of Meyer Werft and Joan Bosch from the Executive Board of the Fraunhofer-Gesellschaft, we celebrated the official inauguration of the Hydrogen Application Center on 8 May.

The Hydrogen Application Center is an external site of the Fraunhofer IGP and part of the Hydrogen Research Factory MV. In the latter, Fraunhofer IGP and the Leibniz Institutes for Catalysis (LIKAT) in Rostock and for Plasma Research and Technology (INP) in Greifswald have joined forces to pool their expertise and develop application-related solutions for the development towards a climate-neutral hydrogen economy. “There is a lot of talk about hydrogen, but it is crucial that we come up with application examples and that is exactly what will happen here in the next few years. The Hydrogen Research Factory project plays a decisive role for Mecklenburg-West Pomerania in mastering the energy transition. The development of research and research infrastructure on the topic of hydrogen applications is particularly important in order to be able to actively shape this energy transition locally and also generate added value in the state,“ emphasised Economics Minister Meyer in his speech at the inauguration of the application center.

*From left to right: Economics Minister Reinhard Meyer presents IGP Institute Director Prof. Wilko Flügge with funding approval for the further expansion of the Hydrogen Application Center; symbolic start at the push of a button (Prof. Flügge, Economics Minister Meyer and Dr. Jan Meyer, Managing Director of Meyer Werft); opening speech by Dr. Benjamin Illgen, Project Manager Hydrogen Research Factory MV*













*The MV 2025 State Technology Conference at Fraunhofer IGP offered an extensive programme for more than 100 participants with best-practice presentations (left), a panel discussion (centre) and an exhibition on innovation projects in mechanical and plant engineering (right)*

With a subsidy of around €10 million provided by the Ministry of Economic Affairs, additional engine test benches will be set up at the site and a separate multifuel engine will be purchased for development purposes. The aim is to work on research and development for various alternative drive systems. "We are convinced that different technologies and fuels will be used in parallel in the future. We will therefore organise our research activities in a way that is open to all technologies," explains Dr. Benjamin Illgen, project manager of the Hydrogen Research Factory MV.

Prof. Wilko Flügge, Director of the Fraunhofer IGP, Economics Minister Meyer and Dr.-Ing. Jan Meyer concluded the ceremony with the symbolic start of a large engine at the push of a button.

### June 2024 – State Technology Conference MV at Fraunhofer IGP

Under the motto "Production of the future – Cutting-edge technology from MV in mechanical and plant engineering", the Mecklenburg-West Pomerania State Technology Conference took place at the Fraunhofer IGP on 17 June. As the co-ordinator of Action Area 3 "Mechanical and Plant Engineering", which was the focus this year, our institute organised the event in close cooperation with the Rostock Chamber of Industry and Commerce and the Ministry of Economics, Infrastructure, Tourism and Labour.
"With today's format, we have succeeded in bringing together colleges and universities, as well as non-university research institutions such as Fraunhofer IGP and the Mecklenburg-Vorpommern Welding Training and Research Institute (SLV) in a meaningful showcase. We are also demonstrating to the commercial enterprises in our federal state how they can obtain support for their research topics," summarised Prof. Flügge, who kicked off the event with a panel discussion on the topic of "Transformation of industry – opportunities and risks for production and value creation in MV", in which State Secretary Jochen Schulte was joined by stakeholders from business and interest groups, as well as industry representatives. Industry partners from Mecklenburg-West Pomerania then presented successful projects and best-practice examples from their companies in a pitch format. The programme was rounded off by an exhibition of innovation projects with business-science cooperation in mechanical and plant engineering.












*Left: Crowd favorite SPOT, Center: young (and old) visitors were able to try out controlling an underwater robot at the Fraunhofer booth, Right: during her tour of the MV-Mile, Minister President Manuela Schwesig also found time for a brief discussion with our colleagues at the joint Fraunhofer booth.*

The Mecklenburg-West Pomerania State Technology Conference is regularly organised by members of the Mecklenburg-Vorpommern State Strategy Council for Business and Science, which was appointed by the state government in 2010. The Strategy Council advises and supports the state with the aim of increasing technology and innovation expertise and is committed to improving the framework conditions for cooperation between business and science.

### October 2024: Fraunhofer IGP at the Citizens' Festival for the Day of German Unity 2024 in Schwerin

In 2024, the nationwide celebrations for the Day of German Unity took place in Schwerin. The Fraunhofer Institutes in Mecklenburg-West Pomerania (Fraunhofer IGP, Fraunhofer IGD and Fraunhofer IZI) took this opportunity to introduce themselves to citizens from all over Germany with a joint booth on the MV Mile at Schwerin's Pfaffenteich and to provide an insight into their research work.
During the Bürgerfest from 2 to 4 October, visitors young and old were able to control an underwater robot (ROV – remotely operated underwater vehicle) at the Fraunhofer booth and find out about selected research projects at the three institutes at information terminals. However, the highlight and crowd favorite by far was our SPOT, a dog-like walking robot. Controlled by our scientists, he walked across the visitor mile at regular intervals, often attracting curious passers-by and forming a large crowd.

The joint Fraunhofer booth was part of the presentation of Mecklenburg-West Pomerania's research landscape. In addition to the country's universities, numerous institutes from other research organisations were also represented there – located in two futuristic-looking domed tents. The aim of this event was to make the work of the researchers more tangible and to make research topics accessible to the general public, and our interactive exhibits and information offerings were a complete success. Perhaps we have even awakened or strengthened the interest in science and technology in one or two of our young visitors.

# Monopile manufacturer EEW SPC receives innovation and technology award from Fraunhofer IGP

**Fraunhofer IGP's in-house innovation and technology prize, the IGP Award for short, was awarded this year to EEW Special Pipe Constructions GmbH (EEW SPC). Institute Director Prof. Wilko Flügge presented the award in person at the company's site in Rostock's overseas port. The award was accepted by Dr. Robert Staschko (Calculation Engineer) and Andreas Dörge (Head of Welding Technology)**

EEW Special Pipe Constructions GmbH, part of the EEW Group, was founded in 2008 and manufactures foundation piles for offshore wind turbines, so-called monopiles, at its site in Rostock's overseas harbour. These pipes have diameters of up to twelve metres, a unit weight of up to 2,500 tonnes and a total length of up to 120 metres. With the production of over 2,500 monopiles, EEW SPC has since established itself as the market leader in this segment, and our researchers are working together with the development engineers at EEW SPC on forming optimization and optimised process control when rolling thick sheets, among other things. “Thanks to the productive collaboration, we were able to gain valuable insights into the further development of welding technologies and jointly develop a deep understanding of the process for the round rolling of thick sheets,” says Andreas Dörge.
“Fraunhofer IGP and EEW SPC have been working closely together for many years, from factory planning to welding technology. This is to be honoured once again with this award. In close co-operation with EEW SPC on the subject of round rolling, we have recently even succeeded in developing a unique position in forming technology on the research side, which has gained international visibility,” explains Prof. Flügge, once again underlining the choice of the award winner.




*Andreas Dörge (right), Head of Welding Technology, accepts the IGP Award 2024 on behalf of EEW Special Pipes Construction GmbH from the institute director Prof. Wilko Flügge.*





*From left to right: Anton Konstanz (Research Associate at Fraunhofer IGP), Prof. Wilko Flügge (Head of Fraunhofer IGP), Andreas Dörge (EEW SPC, Head of Welding Technology), Doris Hasselfeldt (EEW SPC, Head of Research & Development), Dr. Robert Staschko (EEW SPC, Calculation Engineer), Lukas Kappis (Research Associate at Fraunhofer IGP)*

In the field of thermal joining technology, work was also carried out jointly on developing new process technologies for joining high-strength offshore foundation structures (monopiles), taking into account material properties, welding processes and construction methods. A particular focus was placed on high structural integrity/durability as well as time and cost efficiency.

In the near future, the Production Planning and Control, Measuring of Large Structures and Thermal Joining Engineering research departments at Fraunhofer IGP are planning further projects together with EEW SPC to advance the digitalisation of the company. This will include process development and optimization, quality assurance and increased automation, for example, with the help of continuous data acquisition and evaluation for quality monitoring and documentation and the use of digital twins.
“The co-operation between EEW SPC and Fraunhofer IGP has grown steadily over the past few years. Many graduates of theses and doctorates supervised at IGP have now found a professional home at EEW,” says Prof. Flügge. This is always accompanied by a transfer of specialist knowledge and expertise – a fact from which both sides benefit.

Since 2018, Fraunhofer IGP has chosen the winner of its Technology Award every year. The prize is awarded for special achievements in the field of production technology. The technological, economic, ecological and social benefits gained through close cooperation between research institutions and industrial partners are emphasised.





*Production of monopiles at EEW SPC's company site in Rostock's overseas harbor*

# Events and participation in trade fairs




*Rostock Large Engine Conference (RGMT) 2024*



*Dr. Stefan Schmidt, Dr. Simon Backens and Nicco Stroetmann at the JEC 2024 in Paris*




*Dr. Michél Hauer, Nils Peters, Lukas Möhrke, Pratidhwani Biswal and Susanne Kersten present the Fraunhofer IGP at the ITSC Milan 2024*



*International consortium meeting of the PeneloPe project (closed-loop digital pipeline) at the Fraunhofer IGP in May 2024*



*Nele Kayser (Adhesive Bonding Technologies Group) at the E2MUT symposium in Rostock in June 2024*



*Alexander Holch (left, Mechanical Joining Technology group) received an EFB project award at the EFB colloquium in Würzburg in April.*



*Participants of the Baltic Sea Business Day 2024 visited the Fraunhofer IGP as part of an excursion*



*Girls'Day 2024 at the Fraunhofer IGP*

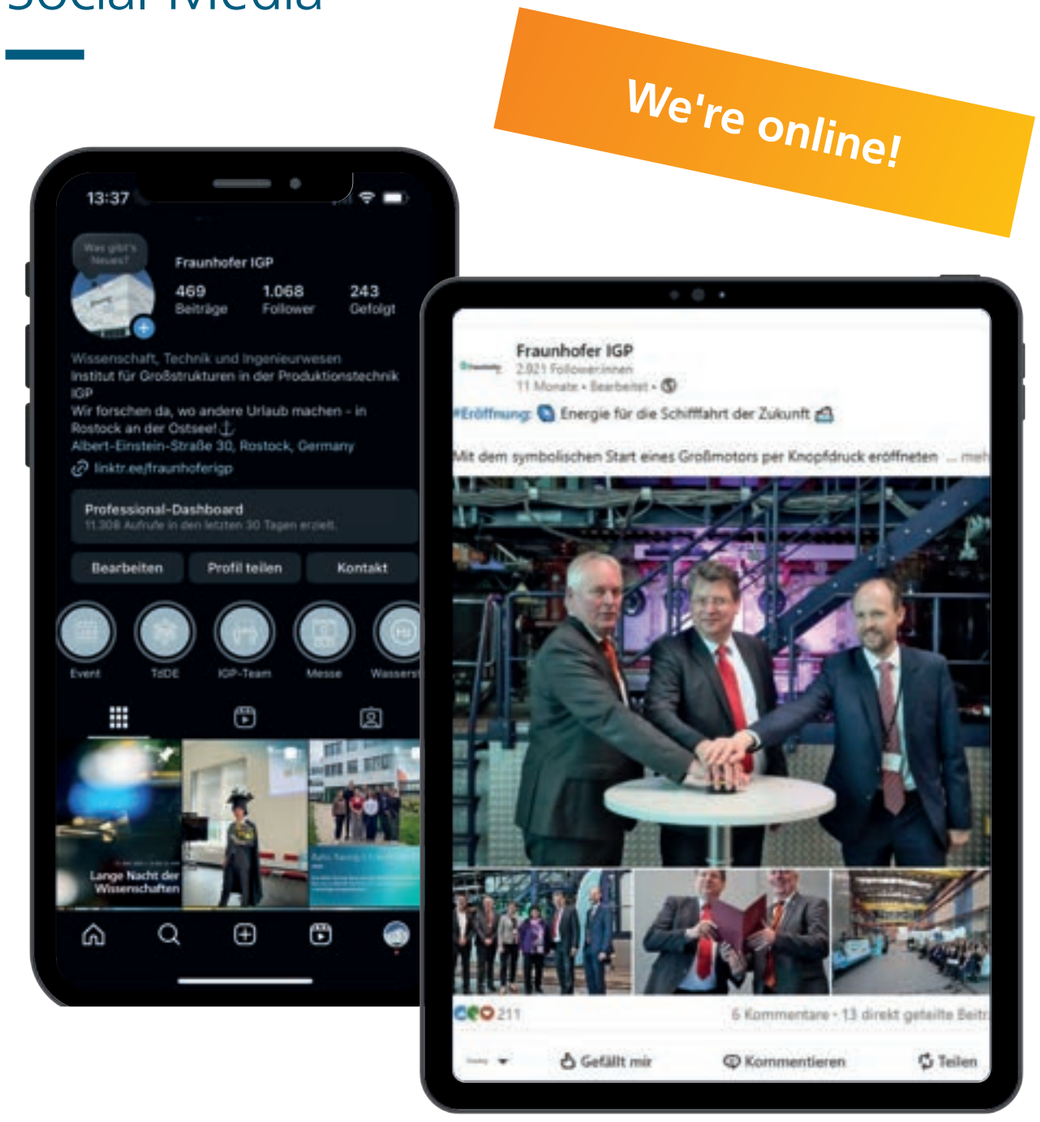


*Fraunhofer IGP also took part in the Rostock company run as a team in 2024*





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# “Exactly the right combination of science and practice”

## An interview with Julius Magritz, who trained as a materials tester at Fraunhofer IGP

**Julius Magritz completed his training as a materials tester (specializing in plastics technology) at Fraunhofer IGP and successfully completed it in June of this year. We asked him why he wanted to do his apprenticeship at Fraunhofer Institute for Large Structures in Production Engineering IGP and what particularly appealed to him:**

### Why did you decide to train at Fraunhofer IGP?

I have always been very interested in chemistry and could well imagine working in the scientific field. However, it was also important to me to have a strong practical focus in my work. I then realised that I found the field of materials technology particularly exciting.
When I saw the Fraunhofer IGP advertisement for a training position in the fibre composite and adhesive bonding technology laboratory, I naturally applied straight away.



*Sample preparation in the Adhesive Bonding Technoloies Laboratory*

### What were the biggest challenges during your training?

I completed my training at Fraunhofer IGP in two departments of the institute, in the New Materials and Processes department and in the Testing Technology department. This definitely brought with it a wide variety of tasks, but was also associated with some organizational challenges.

### What did you particularly like about your training at Fraunhofer IGP?

I particularly liked the practical relevance and, above all, the variety of different tasks. At vocational school, I realized that many of my fellow students in other training companies often have very uniform tasks. That wasn't the case during my training at Fraunhofer IGP. Due to the various research topics and areas, the Institute is extremely broadly based and this was also reflected in the tasks I took on during my training. It was never boring.

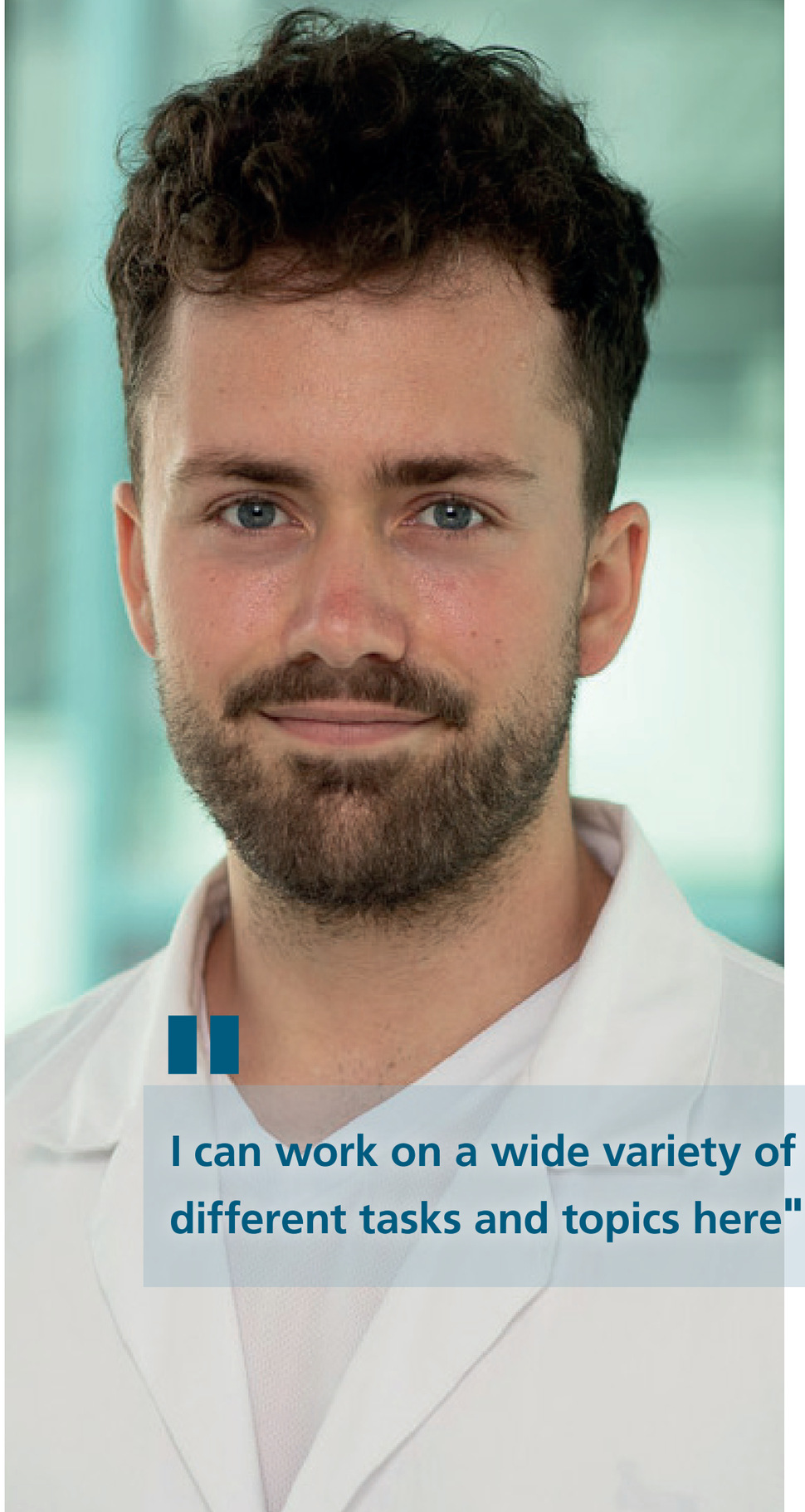
### What do you remember most about your time at the Fraunhofer IGP so far?

I particularly liked and still like the working atmosphere at the institute. Interaction here is very relaxed and at eye level. I was always able to find someone to talk to in every specialist area, partly because the different research areas in the company are relatively close to each other. My colleagues always took the time to explain things to me. For me as a trainee, that was of course really good and I have very positive memories of it.

### You have just completed your apprenticeship. What are your future plans?

I would like to continue working in the laboratory at the Fraunhofer IGP. I really like the variety of tasks and the cooperation with my colleagues here.





**I can work on a wide variety of different tasks and topics here"**

**Julius Magritz**
Materials tester
at the Fraunhofer IGP

# Project overview 2024

Selected projects 2024

# Selected projects 2024

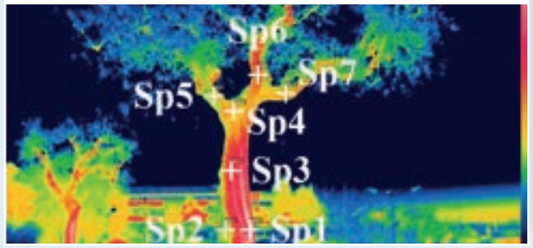
## GrETa – Total hull Eco-efficient technology application

In the GrETa project, a self-punching lockbolt is being further developed and qualified for use in aircraft fuselage assembly. A setting tool is designed to suit the joining system and the geometric restrictions in the fuselage assembly. The focus here is on a fully automated handling concept for robots and setting tools using optical measuring methods



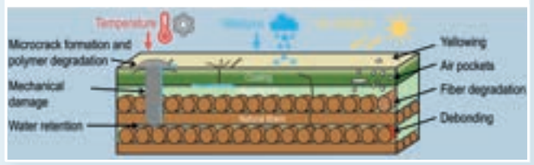
## TherMoBaum – Thermal monitoring of trees near railway tracks to detect damaged areas

In the feasibility study, stem damage was analysed using thermography. A quick assessment of the trees on the track enables maintenance as required and increases the reliability of train services




## BioFKVSchiff – Increasing the long-term durability of bio-based fibre-reinforced plastic composites for use in shipbuilding

The aim is to develop fully bio-based fibre-reinforced plastic composites whose properties and weather resistance enable long-term use in the maritime sector




## PeneloPe – Closed-loop digital pipeline for a flexible and modular manufacturing of large components

PeneloPe develops a closed-loop digital pipeline for modular production of large precision parts, trialled in pilot lines in the oil, marine, aerospace and bus industries

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 958303



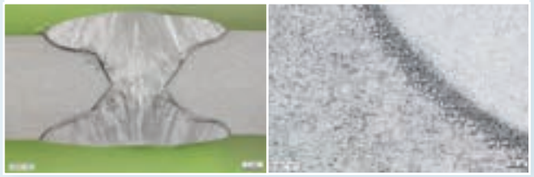
## Further development of the notch catalogue for large-diameter bolts in steel and plant construction

Research on the fatigue strength of large-dimensioned bolt sets to extend the design rules according to DIN EN 1993-1-9 and the re-evaluation of the size effect



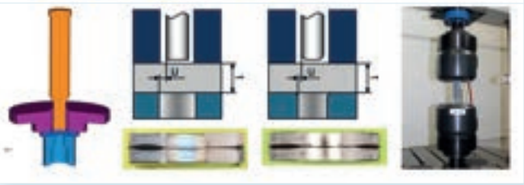
## Cryomanganese – Processing and qualification of medium and high manganese austenitic steels for the storage of cryogenic energy sources

Development of processing recommendations for medium and high manganese austenitic steels using submerged arc and GMAW welding. In addition to the properties of the joint and the welding technology, the focus is also on repairability, automatability and the occupational safety of the welders with regard to welding fumes



## Production and use of shear-cut holes in mechanically joined connections using high-strength steels in steel construction under cyclic loads

Qualification of a shear cutting process to enable economical hole production in conjunction with safe component design for fatigue-loaded steel structures



## AutoFenster – Development of an automated system for assessing the N supply of winter cereals for agricultural practice via scalable application windows

The aim of the project is to further develop the well-known principle of the fertiliser window in such a way that application windows can be automatically created with commercially available application technology in graduated quantities, enabling the nutrient supply status to be precisely determined during the course of vegetation



| Project name | Researchers |
|---|---|
| QS-Riveting – Cross-life cycle quality assurance of forming joints of wrought aluminum alloys | David Loer |
| Frau-GrETa – Fraunhofer development modules for total hull Eco-efficient technology application | Felix Holleitner, Jacques Biltgen |
| Smart process chain – Forming, clamping and joining with automated machine learning | Lukas Kappis |
| OptiFüLa – Fatigue-oriented optimization of the use of forming joining processes using the local concept (AIF/EFB) | Maximilian Schlicht |
| AIF_EFB_Ampere-Clinch – Resource-saving, current-conducting connections for the energy transition | Maximilian Schlicht |
| AIF_EFB_Preloaded connections on end-coated components for applications in mechanical engineering and railway vehicle construction | Fritz Wegener |
| AIF_EFB_Lockstud – Load-bearing behaviour of lockstud systems subjected to tensile forces | Dr. Mathias Schwarz |
| AIF_EFB_BN nut – Joining with high-strength pretensioned blind rivet nut fittings for constructions made of aluminum profiles | Jörg Ganschow |
| AIF_FOSTA_Pre-stressed hybrid joints for hot-dip galvanised steel structures subject to complex loads | Justus Mantik |
| EC3 synthetic – Further development of notch classes according to EC3 for non-welded construction details using the synthetic Wöhler line and taking into account typical steel construction manufacturing practice | Florian Kalkowsky |
| AiF_EFB_Economical joining by analysing the fatigue strength of stamped functional elements | Alex-Leon Holm |
| Production and use of shear-cut holes in mechanically joined connections using high-strength steels in steel construction under cyclic loads (formerly VP 1517) | Alexander Holch |
| Extension of the design rules for mechanical connections of lightweight steel structures according to Eurocode 3, Part 1-3 | Florian Kalkowsky |
| FOSTA_Further development of the notch case catalogue for large diameter bolts in steel and plant construction | Jonas Hinrichs |
| Assembly and load-bearing behavior of high-strength prestressed bolted joints for hydraulic engineering and offshore applications | Alex-Leon Holm |



| Project name | Researchers |
|---|---|
| EFB_Powerful blind fasteners – Using future-proof mechanical joining technology for existing infrastructure and new product developments | Florian Kalkowsky |
| SBR fatigue strength – Fatigue strength of lockbolts for mechanical engineering fatigue strength verifications | Alexander Holch |
| AIF_FOSTA_Bonus Fatique – Notch case classification of HFH post-treated welded joints made of high-strength structural steels under consideration of geometric manufacturing imperfections. AiF application in cooperation with KIT, University of Stuttgart as part of the FOSTA initiative HOCHFEST | Benjamin Ripsch |
| KryoMangan – Storage of cryogenic energy sources: Processing and qualification of medium and high manganese austenitic steels for the storage of cryogenic energy sources | Christoph Reppin |
| AIF-FSM_SpectroStraight – Non-contact temperature monitoring for qualifying the flame straightening of aluminum in shipbuilding | Anton Constance |
| AIF_FVG_KorroGuss – Qualification of GJS materials and thermally sprayed corrosion protection systems for underwater use under fatigue loading | Carsten Wickmann/ Benjamin Ripsch |
| DLR_DVS_UW-Schwingfestigkeit II – Increasing the fatigue strength of wet-welded joints under water | Carl Christian Nehls |
| MariSteel – Sub-project: Development of resource-saving high-performance welding technologies for HRSS materials in maritime production (MariWeld) | Christoph Reppin |
| DLR_DVS – AluDetect – Development of intelligent image processing algorithms for quality monitoring during automated MIG welding of aluminum materials for external and non-surface irregularities | Henning Credet |

| Project name | Researchers |
|---|---|
| Application Center H2 – Establishment of a hydrogen application centre at the Rostock seaport site | Dr. Benjamin Illgen |
| PENELOPE – Closed-loop digital pipeline for a flexible and modular manufacturing of large components | Klara Pejić |
| Modular robot system for potato sorting | Klara Pejić |
| PTJ_DiGoCheck – Digital geometric quality assurance in shipbuilding | Jacob Ahrens |
| BIM-Leb – BIM-supported life cycle management of a building for automated virtual stock analysis | Dr. Christoph Heinze |
| DIKUQ – Digitalisation of cold plastic forming through continuous quality control | Christopher Karberg |
| SMART OCEAN | Christopher Karberg |
| Container Monitoring System (CMS) – Predictive movement modelling of container stacks | Dr. Christoph Heinze |
| DataWeld-CurvedWeld – New methods for in-process data acquisition and digital information management | Christian Scharr |
| TherMoBaum – Thermal monitoring of trees near railway tracks to detect damaged areas | Dr. Christoph Heinze |
| Digital Shipbuilding Platform – Digital twin of the shipbuilding process | David Jericho |
| H2GO ViR – National Action Plan Fuel Cell Production – Technology Network ViR (ViR = virtual reference architecture) | Jan Tschirner |
| RUBIN-E2MUT-VP1-TP1.4 – Emission-free electric mobility for maritime urban transport, VP1 – Mobility and infrastructure, TP1.4 – Development of novel simulation tools to optimize electric mobility and infrastructure planning | Jakob Trappel/ Florian Beuß |
| EnergieControl – Development and validation of energy control and planning methodology for energy self-sufficient production halls with office buildings | Lennart D'Laclaverie/ Florian Beuß |



| Project name | Researchers |
|---|---|
| X-KIT – Transfer project for the systematic networking of intelligent systems and projects in the fields of agriculture, rural areas and foodstuffs | André Sigrist/ Kai Potthoff |
| AutoFenster – Development of an automated system for assessing the N supply of winter cereals for agricultural practice via scalable application windows | Kai Potthoff/ Karl Simon |
| BWSF MV – Smart Farming | Motitz Schröder |
| RUBIN-E2MUT-VP3-TP3.1 – Emission-free electric mobility for maritime urban transport, VP3 Electric ship, TP3.1 Development of innovative lightweight construction and joining technologies for electric ships | Dr. Stefan Schmidt/ Lukas Steinmetz/ Alex Liebau/ Nele Kayser |
| SmartBond – Joint project: smartBOND – Joining of innovative materials in shipbuilding production using an automated bonding process; sub-project D: Development and qualification of bonding processes and smart connection to quality management | Linda Fröck |
| AIF_CMT_Klebschichtalterung – Development and validation of laboratory ageing cycles for the approval of shipbuilding adhesive bonds | Linda Fröck |
| AIF_CMT_HybridComp – Fire-resistant hybrid fibre composites based on optimised organic-inorganic systems | Arthur Wieland |
| DOM4Composites – (Dis)assembly of optimized modular construction of thermoplastic fibre composites | Nicco Stroetmann/ Dr. Stefan Schmidt/ Felix Holleitner |
| FSM_BioFKVSchiff – Increasing the long-term durability of bio-based fibre-reinforced plastic composites for use in shipbuilding | Alex Liebau |
| RUBIN-E2MUT-VP2-TP2.10 – Emission-free electromobility for maritime urban transport, VP2 Drive systems and energy supply, TP2.10-Qualification of automated coating processes on multi-material structures in the interior by demonstrating the corrosion-protective and electro-specific properties | Daniel Kelm |

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Bundesministerium für Wirtschaft und Klimaschutz

Bundesministerium für Bildung und Forschung

EUROPÄISCHE UNION
Europäischer Fonds für Regionale Entwicklung

Bundesministerium für Ernährung und Landwirtschaft

Bundesministerium für Verkehr und digitale Infrastruktur

DLR

ptj Projektträger Jülich Forschungszentrum Jülich

INDUSTRIELLE GEMEINSCHAFTSFORSCHUNG IGF

AiF

FOSTA Forschungsvereinigung Stahlanwendung e. V.

EFB

DVS FORSCHUNG

MV tut gut.

TZN Technologie-Beratungs-Institut GmbH

FSM

RUBIN Regionale unternehmerische Bündnisse für Innovation

STIFTERVERBAND

# Associations, alliances and committee work 2024

## Fraunhofer Group for Production

The Fraunhofer Group for Production is a research and development partner for the manufacturing industry. More than 2,200 employees from eight institutes and three Fraunhofer organizations make their knowledge and experience available. Utilising the latest findings from production and engineering sciences, as well as computer science, the Fraunhofer Group for Production offers a range of services that covers the entire product life cycle and the entire value chain. Research and industry are closely and interdisciplinarily networked here.
**www.produktion.fraunhofer.de/en**

## Fraunhofer Transport Alliance

Since March 2003, various Fraunhofer institutes and facilities have been pooling their transport-related expertise in the Fraunhofer Transport Alliance. The members of the alliance have set themselves the goal of developing suitable technical and conceptual solutions for public and industrial clients through transport-related research and transferring them into application. Through close, topic-related cooperation, it is possible to develop integrated system and network solutions for clients from the transport sector. Further, new areas of application can be explored through the transfer of expertise. This selection and bundling of a wide range of expertise ensures that needs-based solutions can be offered to customers.
**www.verkehr.fraunhofer.de/en**

## Fraunhofer Network “Science, Art and Design”

How can science be inspired by Art and Design - and vice versa? What do researchers, artists and designers have in common? How can they enter into a creative dialogue and take a stand side by side on overarching issues? The Fraunhofer Network “Science, Art and Design”, which was founded in spring 2018 and aims to promote interdisciplinary discourse between applied research, art and design, deals with these and other questions. Joint research projects, ideas competitions, residencies and exhibitions bring together participants from the various fields of knowledge and give rise to new perspectives on complex social challenges. The network currently comprises 28 institutes and organizations as well as the headquarters of the Fraunhofer-Gesellschaft. They all contribute their diverse expertise and contacts in the fields of Art and Design.
**www.art-design.fraunhofer.de**

## Committee work (alphabetical order)

**ASIM Specialist Group Association for Simulation of the German Association for Informatics**
Prof. J. Sender – Member
**XXL products work group**
Prof. W. Flügge – Member
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Prof. W. Flügge – Member of the Board - DECHEMA Functional Materials Division
**German Society for Materials Science (DGM)**
Dr. A. Gericke – Member – Joint Committee “Materials Technology Steel”
Dr. A. Gericke – Member – Working Group “Material fatigue”
**Deutsches Institut für Bauchtechnik**
Prof. R. Glienke – Member – Expert Committee SVA Metal Construction and Composite Construction
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J. Ganschow – Member – AK Schraubmontage
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K. Potthoff – Board Member for Technology Rostock District Association
**DVS Technical Committee**
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Dr. A. Gericke – Member – WG V 2.5 Submerged Arc and Electroslag Welding
Prof. K.-M. Henkel – Member – WG V 4 Underwater technology
Dr. A. Gericke – Member – WG A 6.1 Welding in shipbuilding and marine technology – Welding processes, fabrication
Dr. A. Gericke – Member – WG A 6.2 Welding in shipbuilding and marine technology – Damage to shipbuilding welded structures
Dr. A. Gericke – Member – WG Q 1 Design and calculation

**European Research Association for Sheet Metal Working (EFB)**
Prof. R. Glienke – Chairman – Joint Committee EFB AGMF3/V10.3 Mechanical Joining – Blind Rivets and Lockbolts
Dr. M. Schwarz – Deputy Chairman – Joint Committee EFB AGMF3/V10.3 Mechanical Joining – Blind Rivets and Lockbolts
J. Ganschow – Member – Joint Committee EFB AGMF4/V10.4 Mechanical Joining – Functional Elements
Dr. K. Nowak – Member – Joint Committee EFB AGMF8/V10.8 Mechanical Joining Technology Testing and Joining Properties

**Forschungsvereinigung des DVS**
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Dr. A. Gericke – Member – Technical Committee 03 Arc Welding
L. Fröck – Member – Technical Committee 08 Adhesive Bonding Technology
Dr. A. Gericke – Member – Technical Committee 09 Design and Strength
Prof. K.-M. Henkel – Member – Technical Committee V4 Underwater Technology

**Forschungsvereinigung für Stahlanwendungen e.V. (FOSTA)**
Prof. W. Flügge – Member of the Technical Board of Trustees

**Forschungsvereinigung Schiffbau und Meerestechnik e.V. (FSM)**
Prof. W. Flügge – Member of the Technical Advisory Board
Prof. K.-M. Henkel – Member of the technical-scientific committee

**Association of Thermal Sprayers (GTS)**
Dr. M. Hauer – Member

**gfkorr - Gesellschaft für Korrosionsschutz e.V., Arbeitskreis Windenergie**
Dr. M. Irmer – Member

**Hanse Aerospace e.V., Hamburg**
Prof. W. Flügge – Deputy Chairman of the Scientific Advisory Board

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**Internationaler Verband für den Metallleichtbau (IFBS)**
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Prof. M. Geist – Member

**Competence Network Ocean Technologies@Fraunhofer**
Dr. M. Irmer – Member

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Prof. W. Flügge – Advisory Board Member

**Maritimes Cluster Norddeutschland e. V.**
Dr. Konrad Jagusch – Member

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Prof. W. Flügge – Member

**REFA Landesverband Mecklenburg-Vorpommern e.V.**
Prof. J. Sender – Chairman of the Board

**Rostock denkt 365° e. V.**
Prof. K.-M. Henkel – Member

**The German Society for Maritime Technology (STG)**
Prof. J. Sender – Head of the FA Work Organization and Production Technology and member of the Technical – Scientific Advisory Board

**Strategierat Wirtschaft - Wissenschaft Mecklenburg-Vorpommern**
Prof. W. Flügge – Head of Action Area 3 "Mechanical and Plant Engineering" of the Regional Innovation Strategy for Mecklenburg-Western Pomerania (RIS)

**Verband für Schiffbau und Meerestechnik e.V. (VSM)**
Prof. W. Flügge – Member

**Wissenschaftliche Gesellschaft für Montage-Hanhabungstechnik-Industrieroboter (MHI/WGMHI)**
Prof. M.- C. Wanner – Member

**Wind Energy Network e.V.**
Dr. M. Irmer – Member of the Executive Board

**Working Groups of the International Institute of Welding**
Dr. O. Brätz – Member – IIW Commission II Arc Welding and Filler Metals
Dr. A. Gericke – Member – IIW Commission XII Arc Welding Processes and Production Systems
Dr. O. Brätz, Dr. A. Gericke – Member – IIWCommission IX Behaviour of Metals Subjected to Welding
Dr. A. Gericke – Member – IIW Commission XIII Working Group 2 Techniques for improving the fatigue strength of welded components and structures;
Dr. O. Brätz – Member – IIW Commission XV Design, Analysis, and Fabrication of Welded Structures





## Expert activity

**Allianz für Industrie und Forschung (AIF)**
Prof. W. Flügge, Prof. K.-M. Henkel,
Prof. M.Ch. Wanner – Expert assessor

**Federal Ministry of Economic Affairs and Energy**
Prof. M.-Ch. Wanner – Expert assessor for the funding programme "Innovative shipbuilding secures competitive jobs"

**German Research Foundation**
Prof. W. Flügge, Prof. M.-Ch. Wanner – Expert assessor

## Standardization work

**Deutsches Institut für Normung e.V. (DIN)**
Prof. R. Glienke – Member of the Advisory Board NA 092 DIN Standards Committee on Welding and Allied Processes (NAS)

**DIN Standards Committee for Welding and Allied Processes (NAS)**
L. Fröck – Member – DIN Working Committee NA 092-00-28 AA: Adhesive Bonding Technology (DVS AG V 8); DIN working group NA 092-00-28-01 AK: Process chain adhesive bonding technology; DIN working group NA 092-00-28-02 AK: Bonding of fibre-reinforced plastics

# Publications 2024

## Book

Schwarz, M.; Henkel, K.-M.; Hagemann, M.; Schröder, M.; Glienke, R.; Schwerdt, D.: **EFB-Forschungsbericht Nr. 167 – Tragverhalten von zugkraftbeanspruchten Lockstud-Systemen zur Herstellung wartungsfreier Verbindungen**, Europäische Forschungsgesellschaft für Blechverarbeitung e.V. (EFB), Hanover, 2024.

## Journal article

Ambrosat, T.; Krueger, S.; Geist, M.; Kluess, D. Flügge, W.: **A new approach to identify wear regions on bearing surfaces of retrieved endoprostheses.** In: Journal of the Mechanical Behaviour of Biomedical Materials, Volume 156 (1), 2024, DOI:10.1016/j.jmbbm.2024.106567

Backens, S.; Schmidt, S.; Flügge, W.: **Influence of stitching on the interlaminar fracture toughness energy - modes I and II - of unidirectional GFRP.** In: Materials Testing, Vol. 66 (12), 2024, pp. 2045-2054, DOI:10.1515/mt-2024-0208

Backens, S.; Schmidt, S., Flügge, W.: **Influence of baking layers on the interlaminar fracture toughness energy - mode I - of quasi-unidirectional GFRP**. In: Materials Testing, Vol. 66 (7), 2024, pp.1031-1040, DOI:10.1515/mt-2024-0020

Banaschik, R.; Brätz, O.; Gericke, A. Henkel, K.-M.: **Modification of electro gas weld metal microstructure reflecting mechanical property specifications in cruise vessel shipbuilding.** In: Welding in the World, Vol. 68, 2024, pp.1625-1639, DOI:10.1007/s40194-024-01779-5

Dörre, M.; Glienke, R.; Kalkowsky, F.; Wegener, F.; Flügge, W.: **Numerische Untersuchungen zum Einfluss des Nennlochspiels auf die Plattennachgiebigkeit von hochfest vorgespannten Schraubenverbindungen** In: Materialwissenschaft und Werkstofftechnik, Band 55 (12), 2024, S.1687-1706, DOI: 10.1002/mawe.202300382

Gabriel, G.; Brätz, O.; Gericke, A.; Huysmannc, E.; Kahnfeld, M., Henkel, K.-M.: **Effektive Prozessauslegung des induktiven Vorwärmens beim Schweißen von Großstrukturen mithilfe der numerischen Simulation**. In: DVS Berichte, 2024, Band 395, S.240-250

Gerds, P., Robl, L.; Jagusch, K. und Sender, J.: **Generative Künstliche Intelligenz als Assistenz in der Instandhaltung.** In: Zeitschrift für wirtschaftlichen Fabrikbetrieb, Band 119 (12), 2024, S. 934-938. DOI:10.1515/zwf-2024-1175

Gericke, A., von Borstel, T., Gabriel, G., Strandberg, M., Henkel, K.-M.: **Fatigue strength of blast cleaned and stress relief annealed butt joints made of structural steel S355J2+N for offshore wind support structures steel**. In: International Journal of Fatigue, Volume 192 (Article No. 108711), 2024.

Gericke, A., Brätz, O.: **Qualitätssicherung durch Prozesskontrolle und Parameteraufzeichnung beim Hubzündungsbolzenschweißen (783)**. In: DVS Berichte, Band 395, 2024, S.117-124.

Glienke, R.; Kalkowsky, F., Hobbacher, A.F.; Holch, A.; Thiele, M., Marten, F.; Kersten, R.; Henkel, K.-M.: **Evaluation of the fatigue resistance of buttwelded joints in towers of wind turbines – A comparison of experimental studies with small scale and component tests as well as numerical based approaches with local concepts.** In: Welding in the World, vol. 68, 2024, pp.1143-1168, 2024, DOI: 10.1007/s40194-023-01630-3

Hauer, M.; Schmidt, S.; Gericke, A.; Brätz, O.; Möhrke, L.; Biswal, P.; Stroetmann, N.; Henkel, K.-M.: **A novel design approach: increase in storage and transport efficiency for liquid hydrogen by using a dual concept involving a steel-fibre composite tank and thermal sprayed insulating coatings.** In: Frontiers in Energy Research. Section: Hydrogen Storage and Production, Volume 12, 2024, DOI: 10.3389/fenrg.2024.1441746

Holleitner, F., Schlicht, M.; Froitzheim, P., Flügge, W.: **Erweiterung der Einsatzgrenzen von Vollstanznieten aus höchstfesten Al-Legierungen (Aluminium Vollstanznieten II)**. In: Stifterverband Metalle e.V. 2024.

Irmer, M.; Kelm, D.; Marquart, T.; Momber, A.; Eiben, K.; Buchbach, S.: **The performance of a self-adherent foil system for the corrosion protection of steel substrates for offshore wind towers structures.** In: Materials and Corrosion, Vol. 75, 2024, DOI: 10.1002/maco.202314218





Jagusch, K.; Jericho, D.; Bernd; Zimmer, C.J.; Krüger, Ph.; Sender, J.: **Prozessoptimierung durch Digitalisierung im deutschen Schiffbau – Werft 4.0.** In: Schiff und Hafen, Ausgabe November 2024, S. 24-27.

Mantik, J.; Glienke, R.; Dörre, M.; Denkert, C.; Vallée, T.; Fricke, H.; Henkel, K.-M.: **Aktuelle Erkenntnisse zum Einsatz von Klebstoff in vorgespannten Schraubverbindungen unter Berücksichtigung von Fertigungseinflüssen**. In: Stahlbau, Volume 93 (5), 2024, S. 306-320, DOI:10.1002/stab.202300055

Mantik, J.; Denkert, Ch.; Wesling, V.; Leicher, M.; Dörre, M.; Treutler, K., Flügge, W.: **Verhalten des Haftreibungskoeffizienten in vorgespannten Verbindungen bei schlagartiger Beanspruchung**. In: Schweissen und Schneiden, Ausgabe 6, 2024, S. 48-57, DOI:10.53192/SUS20240648

Mantik, J.; Dörre, M.; Wegener, F.; Holm, A.-L., Flügge, W.: **Erhöhung der Querkrafttragfähigkeit geschraubter Verbindungen**. In: EI – Der Eisenbahningenieur, Ausgabe 9, 2024.

Margel, E; Ambrosat, T.; Hack, D.; Geist, M.; Jagusch, K.; Jakubzyk, J.; Sender J.: **Digitalisierung des Aufmaßprozesses von Treppenläufen und -podesten**. In: GFaI Tagungsband 2024, hrsg. v. Böhm, F.; Hohnhäuser, B.; Bauer, M., Gesellschaft zur Förderung angewandter Informatik e. V. (GFaI), Berlin, 2024

Möhrke, L.; Hauer, M.; Gericke, A.; Breitrück, A.; Kreikemeyer, B.: **Copper Coatings for Antibiotics Reduction in Fattening Livestock**. In: Journal of Thermal Spray Technology, Vol. 33, 2024, pp.771-785, DOI:10.1007/s11666-024-01742-2

Momber, A.; Marquart, T.; Kelm, D.; Irmer, M.: **Effects of impact damages on the performance of offshore wind power coatings after accelerated aging.** In: Corrosion Engineering Science and Technology, Volume 59 (5), 2024, pp. 311-320, DOI: 10.1177/1478422X241246345

Neef, Ph.; Reppin, Ch.; Treutler, K.; Gericke, A.; Wesling, V.; Henkel, K.-M.: **Influence of nitrogen-doped shielding gas for welding of medium manganese austenites for cryogenic applications**. In: Welding in the World, Volume 68 (3), 2024, pp. 593 - 603, DOI:10.1007/s40194-023-01656-7

Nehls C., Andreazza P., Gericke A., Brätz O., Klötzer-Freese C., Henkel, K.-M.: **Additive Fertigung von Schiffspropellern aus seewasserbeständigen Bronzen mittels WAAM**. In: DVS Berichte, Band 395, 2024, S.405-415

Reppin, C.; Gericke, A.; Neef, P.; Teutler, K.; Wesling, V., Henkel, K.-M.: **Welding Processing of Medium-Manganese Austenitic Steels for Cryogenic Applications**. In: Journal of Heat Treatment and Materials, Vol. 79 (1), 2024, pp.35-50, DOI:10.1515/htm-2023-0034

Ripsch, B.; Gabriel, G.; Gericke, A., Henkel, K.-M.: **Investigations on the influence of angular and linear misalignment on the fatigue strength of HFMI-treated structural steel butt joints**. In: Welding in the World, Vol. 68, 2024, pp.1211-1224, DOI: 10.1007/s40194-024-01728-2

Tschirner, J.; Stepputat, M.; Jagusch, K., Sender, J.: **Digitale Kranwartung - clever gelöst. Auf der Suche nach einer schnellen, einfachen und papierlosen Methode**. In: Technische Logistik, Ausgabe 5, 2024, S. 32-34.

## Conference proceedings

Biltgen; J.; Haugwitz, K. von; Sender, J.: **Potential of the system retrofit to increase the level of automation and the use of robots in shipbuilding**. Conference: 18. CIRP Conference on Intelligent Computation in Manufacturing Engineering (ICME), Naples, 2024.

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