



ANNUAL REPORT
2018

ANNUAL REPORT 2018
ACTIVITIES AND RESULTS OF THE
FRAUNHOFER IGP

**TOWARD THE FUTURE WITH TRADITION:
FIRST FRAUNHOFER-IGP-AWARD TO FR. LÜRSSEN WERFT**

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EDITORIAL

Dear readers, dear friends of the Fraunhofer IGP,

It has only been half a year since our last report, however despite this, we would like to provide you with information by means of a brief activity report. The background to this is the fact that in the future, we want to report about full calendar years, and with this step, we can get into the new cycle.

Despite the shorter period, the report is no less interesting than the previous ones. As such, among other things, we have launched the Fraunhofer IGP Prize, an annual award with which we honour a team from our many project partners in industry. With this, we want to reward cooperation at the level of the project which, with optimal integration, leads to excellent results in research and points the way towards further application-oriented developments.

We also provide impulses to projects that have just been launched. These are conceived in order to invite you to develop these ideas and concepts further and promptly think ahead in terms of further projects. Especially in the field of publicly funded research projects, we have to act with far-sightedness, so that the expected results are promptly available, in line with with development in the market.

As such, in this report, we're able to present you with what is, in our opinion, a multifaceted bouquet of research topics that will present you with the questions we have solutions to. The report should also demonstrate that we are quite ready, to move away from our existing research paths in order to offer you, our customers, solutions.

Enjoy reading. We hope to ignite new ideas and we will be happy to support you to put these into practice. Use the report as a source of inspiration for future innovations.

With kindest regards from the
Hanseatic and University City of Rostock



Prof. Dr.-Ing. Wilko Flügge
Director of the Fraunhofer IGP



DIRECTOR PROF. DR.-ING. WILKO FLÜGGE
AND DEPUTY DIRECTOR PROF. DR.-ING. HABIL. KNUTH-MICHAEL HENKEL

ANNUAL REVIEW

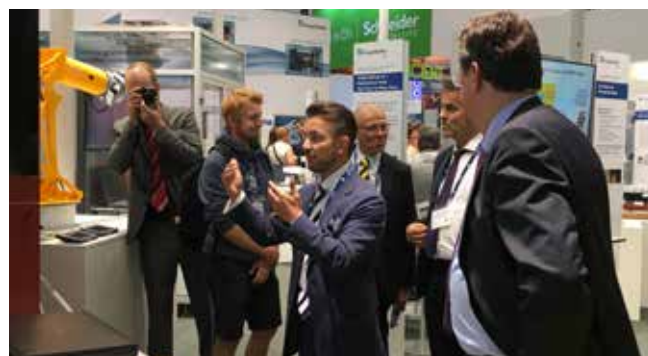
Solemn inaugural lecture by Prof. Dr. Ing. Wilko Flügge in July 2018.

Prof. Wilko Flügge, Director of the Fraunhofer IGP, demonstrated his talent as a university professor and head of the Chair of Manufacturing Engineering, marking the official start of his professorship, even though he has already been lecturing at the University of Rostock since June 2017. The Rector of the University, Prof. Dr. Wolfgang Schareck, the Dean of the Faculty for Machine Engineering and Ship Technology, Prof. Dr. Manuela Sander and representatives of the Rostock Fraunhofer-Institute were among the numerous interested guests.



Visit of State Secretary Reinhard Meyer to SMM 2018

In addition to many other exhibitors, the Fraunhofer IGP represented the maritime industry at the SMM 2018. The head of the State Chancellery of Mecklenburg-Western Pomerania, State Secretary Reinhard Meyer, also visited the joint stand of the Fraunhofer Alliance for Transport. He informed himself about new scientific approaches and solutions adopted by researchers at the Rostock-based Fraunhofer IGP. In addition to solutions for shipyard 4.0, the State Secretary was also shown a works assistance system as well as automated welding programming.



Innovations for onshore and offshore wind energy at WindEnergy 2018

In September, over 1,400 exhibitors gathered in Hamburg on the grounds of the trade fair in order to focus on dynamic markets, cost efficiency and smart energy. As such, the Fraunhofer IGP also focused on current developments in the globally expanding wind industry. Completed and current research projects concerning the topic of wind energy were presented on the M-V joint stand. Furthermore, a sample bar for the thermo-mechanical durability testing of glued joints for rotor blade attachments was also exhibited.



9. Doctoral seminar on bonding technology in Rostock

In October 2018, the Fraunhofer IGP was the venue of the 9th. doctoral seminar. The main objectives of this event included a mutual session in order to get to know the doctoral students from different research institutions and critical discussion as a building block on the way to gaining a doctorate. The seminar provided insights concerning current research into areas related to adhesive technology and, above all, it enabled young researchers to present their own work and results to a knowledgeable, professional audience.



Between Rostock and Russia - planned cooperation on the 3rd. Entrepreneurs Day

In October, the Entrepreneurs Day took place for the third time in the Rostock townhall. Under the motto "Russia in Mecklenburg-Western Pomerania" the economic conference invited attendees to current current topics and focused on the direct exchange between German and Russian companies. In addition to various rounds of talks, the Fraunhofer IGP and the Central Research Institute for Ferrous Metallurgy I.P. Barnin signed a cooperation agreement that heralded planned cooperation.



Celebratory colloquium to mark the 70th birthday of Prof. Dr.-Ing. Martin-Christoph Wanner

In honour of the former director of the institution, in November, the Fraunhofer IGP invited attendees to a celebratory colloquium concerning the topic of robotics. Robotics accompanied Prof. Wanner's entire career. He was also able to pioneer large-scale projects that have gained international recognition. As they laid the foundation for our current facility, we also used the event as an opportunity to thank our close associates, who were invited to the colloquium. Among the participants (approximately 100), there were also important representatives from business and politics.



FRAUNHOFER IGP AWARD

Into the future with tradition: first Fraunhofer IGP Award goes to Fr. Lürssen Werft

Research on behalf of the future: Fraunhofer is the largest research organisation for applied research in Europe. We create a balanced interaction between excellent research and application-oriented development. This unique selling point is motivation for us and creates added value for our partners. Now that the Fraunhofer IGP has been able to establish itself in Rostock and worldwide, our groundbreaking and creative partners will be honoured. The Fraunhofer IGP award sees itself as a 'Future and Innovation' award and is intended to characterise the technological, economic, ecological and social values that are gained through close cooperation between the research institution and partners in industry. This year, the shipbuilding industry is in the foreground.

European shipbuilding is currently experiencing a high. Nevertheless, global competitive pressure is rising inexorably. It is important to continue and expand this success by continuously strengthening the maritime industry. This need is also recognised by the Fr. Lürssen shipyard. The shipbuilder, with its headquarters in the Bremen's Vegesack district is known, among other things, for the construction of civil yachts. At the same time, ever-growing customer demands and demands on the end product force the shipyard to adopt a continuous and holistic improvement process across all stages of product development. In a targeted way, the goal has been set of being better able to steer the entire production stages by increasing process transparency. After all, necessary changes and adjustments are the rule during the construction of such ships. In addition, implementation of the subsequent wishes of the customer is part of the philosophy of Fr. Lürssen Werft. However, because the complexity of shipbuilding and the creation of a unique piece of work pose major challenges, these requirements were difficult to achieve using conventional means. Nevertheless, in order to achieve the ambitious goal,

a partner was sought is familiar with the world of large structures as well as in the implementation of future-oriented and IT-supported production systems. Fraunhofer IGP was found as a partner for the implementation of the pilot project – **the beginning of a promising partnership.**



1 The Trophy of the Fraunhofer IGP award 2018. A mock-up in front of the Fraunhofer institution acts as a model: a lattice mast structure consisting of a wind turbine, connected by maintenance-free locking ring bolts



INDUSTRY 4.0 AT FRAUNHOFER IGP:
TOOL FOR DIGITAL PRODUCTION PLANNING AND CONTROL
THE ENTIRE PRODUCTION PROCESS HAS BEEN DESIGNED FOR THE
FR. LÜRSSEN SHIPYARD

Groundbreaking cooperation between Fraunhofer IGP and Fr. Lürssen Werft

Pipe production at Lemwerder (secondary site) was defined as the first field of application. With the complex geometries, the large number of production steps and the large amount of different materials and components, this production process poses a challenge in the implementation of such a pilot project. A predominantly analogue flow of information meant a considerable amount of work for the employees in order to meet the high quality standards. This situation was considered unsatisfactory and a potential for optimisation was identified. The current status could not be accepted any further, especially against the background of the future project "Industry 4.0" and its prominent representatives such as the automotive industry.

Detailed analyses were carried out together with Fraunhofer IGP in order to further substantiate the obvious potential for optimisation with well-founded data. Goals were defined such as increasing efficiency and saving time in the implementation of necessary component modifications. Based on this, and through close cooperation, concepts for digitising the flow of information, for tracking materials and a holistic approach to production planning and control emerged.

First, however, familiar techniques for process optimisation were used in order to make the pipe production more efficient. Non-productive times have been reduced, processes have been modified and the production process has been adjusted in some procedures. In order to plan this modified manufacturing process, a digital **production planning and control tool** was developed. Linking the system with the productively deployed IT systems that have already been installed allows real-time data access. Furthermore, there is a continuous exchange of data between the systems, so that, for example, constructive adjustments are communicated in real time. Moreover, in order to be able to react to the current production status, data needs to be generated from the actual

production process. To that end, the next step was to implement **a system for comprehensive information** management.

Analyses have showed that half of the working time at German shipyards is wasted on material and information procurement and/or processing. As such, the process-dependent supply of information to workers represents a considerable potential for optimisation. Automatic identification of the components at the respective workstations allows for situational provision of the required product and production data, e.g. digital construction drawings. By using a suitable auto-identification system, data corresponding to the scan of a component are available on an industrial panel. The search for the required information is completely eliminated and the non-productive times caused by the scan are in the range of under 10 seconds. In addition to the provision of information, the data of the scan process is fed back so that the current process progress is projected using the planning and control tool. Disturbances that occur within the production process can be communicated via the panel. This guarantees real-time intervention in the process.

The first step towards increasing transparency has been done. In further development work, however, data granularity should be increased in order to raise further potential. For the holistic tracking of components **as well as the digital representation of the process progress**, the charge carriers on which finished assemblies are collected have to be located. The current position of the tagged mobile carrier is determined with the aid of a real-time locating system. The collected data allow for the detailed derivation of the current progress within the production department. Furthermore, the generation of logistic-related key figures takes place, which reveal further optimisation potentials within the manufacturing process.

The previously defined goals were all fulfilled within this pilot project. In addition to information provision and material tracking, which virtually eliminate search and procurement processes in both areas, the flow of digital and real-time information provides the desired, all-encompassing approach to production planning and production control. Workers now focus on value-adding processes. Production managers, who previously supplied the production department with paper-based documents containing manufacturing information, now devote their time to more complex tasks. The planning and control level can now rely on data from the production department for its tasks. The exchange of data that is realised between the individual IT systems allows the previously heterogeneous system landscape to function as a unit. **Potentials were revealed that initially seemed unachievable.** All in all, the developed system components and their subsequent combination ensure that nothing stands in the way of the implementation of special customer requirements and the development of yet another breathtaking one-off in the form of an impressive ship. Despite the successful implementation of this pilot project, further hurdles need to be cleared. Namely, these are to exploit potential, to detect further approaches and to pursue them.

Into the future with tradition: Today, the family business Fr. Lürssen is able to look back on 144 years of shipbuilding history. Founded in 1875, a shipbuilding company developed over four generations from what was a small boatbuilding workshop in Bremen to world class status. The fact that the Lürssen family does not shy away from innovations and growth is demonstrated not only by the company's broad range of products and locations, but also by the innovative and forward-looking cooperation with the Fraunhofer Research Institution for Large Structures in Production Engineering IGP.

2 Representatives of Fr. Lürssen together with the group head of corporate and production organisation at Fraunhofer IGP; (from left to right): Philipp Krüger, Dr. Jan Sender, Marius Harms, Jörg Gabriel and Imke Kappelhoff



FACTS AND FIGURES

Fraunhofer Research Institution for Large Structures in Production Engineering IGP

The research focus of the Fraunhofer Institution for Large Structures in Production Engineering IGP in Rostock is on tasks in the field of production and the manufacturing of large structures.

On the basis of applied research, concepts for product and process innovations for many industries of the future (e.g. **shipbuilding and steel-based engineering, energy and environmental technology, railway and commercial vehicle construction as well as mechanical and plant engineering**) are developed and implemented within the scope of research and development projects with our cooperation partners.

Fraunhofer IGP is recognized by the German Institute for Construction Technology (DIBt) **as a testing, monitoring and certification body** (LBO) and carries out orders in Germany and abroad. In 2018, this recognition was extended to Germany's first and currently the only testing laboratory for approval group 4.1/10.

Another important pillar of Fraunhofer IGP is the **test laboratory**. This is closely integrated into ongoing research projects through the fields of competence of the institution and it also handles orders for tests from the business sector.

Within the framework of a cooperation agreement, Fraunhofer IGP works closely with the Production Technology and Joining Technology chairs of the Faculty of Mechanical Engineering and Ship Technology at the **University of Rostock** and is a member of the **Fraunhofer Transport Alliance**, the **Fraunhofer Production Alliance** and various research associations and networks.

In addition to the university education of the students, the IGP is also dedicated to initial vocational training. We regularly of-

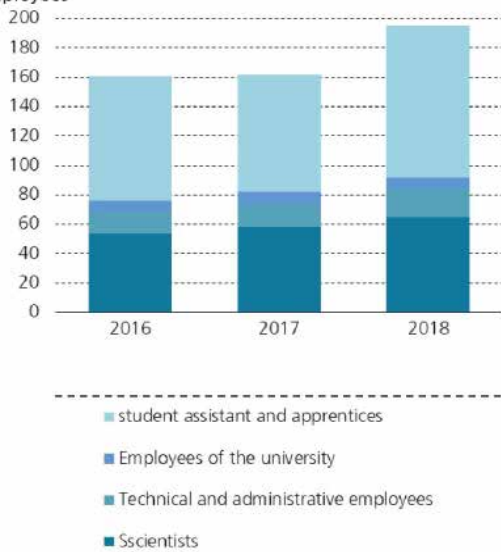
fer apprenticeships **as cutting machine operators and materials testers**, which enable our trainees to make an optimal start to their careers.

In cooperation with the Fraunhofer IGP, the training centre for Adhesive Bonding Technology of the Fraunhofer IFAM offers a one-week **course for adhesives practitioners** and a three-week course for the advanced training of master craftsmen, technicians and engineers as **adhesive specialists** in Rostock. In addition, seminars on applied industrial surveying are offered at the Fraunhofer Institution, where the theoretical foundations as well as the practical application can be learned. The **seminar on the basics of robotics** provides knowledge about the basics and the use of robot systems as well as in-depth programming knowledge and the acquisition of complex program structures.

Since 2005, over 6,000 square metres of laboratory and office space has been created at the Rostock site in order to offer industry tailor-made services for engineering tasks.

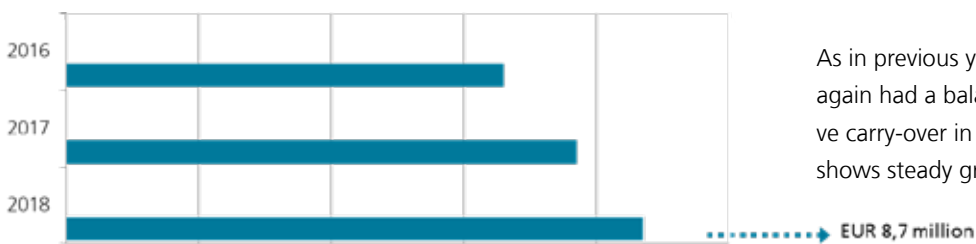


Number of employees



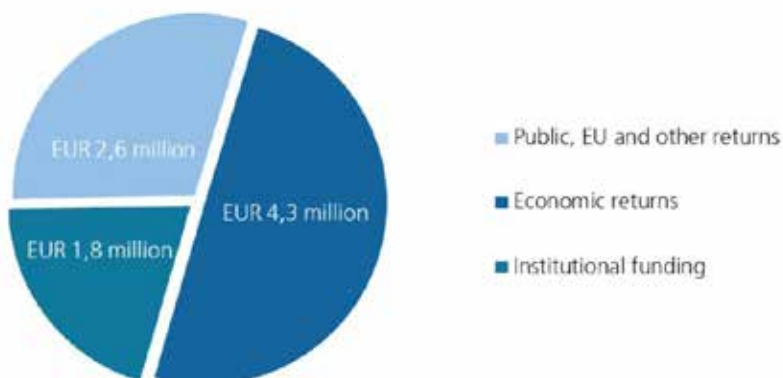
Employee development

The total number of employees at the Fraunhofer IGP rose to 195 in 2018. The majority of our scientists hold diplomas as graduate engineers or graduate industrial engineers. 103 student assistants supported the work of the Fraunhofer staff in 2018. Furthermore, the number of apprentices rose to three. In cooperation with the professorships of Manufacturing Engineering and Joining Technology, eight employees from the university work closely together with the Fraunhofer IGP in research and teaching. In addition, 34 placement contracts were concluded last year.



Overall budget

As in previous years, the Fraunhofer IGP again had a balanced budget and a positive carry-over in 2018. The overall budget shows steady growth.



Financial returns

Earnings in 2018 totalled EUR 8.7 million, and with economic returns of 50%, our targets were achieved again. For 2019 a further increase is expected as well.

ORGANISATION CHART

FRAUNHOFER RESEARCH INSTITUTION FOR LARGE STRUCTURES IN PRODUCTION ENGINEERING IGP

Director

Prof. Dr.-Ing. Wilko Flügge

Deputy Director

Prof. Dr.-Ing. habil. Knuth-Michael Henkel

Joining and Forming by Plastic Deformation

M.Sc. Pascal Froitzheim

Adhesive Bonding Technology, Fibre Composite Technology and Corrosion Protection

Dr.-Ing. Nikolai Glück

Production Organizaion

Dr.-Ing. Jan Sender

Mechanical Joining Technology

Dr.-Ing. Christoph Blunk

Automation Engineering

Dipl.-Ing. Steffen Dryba

Welding Engineering

M.Sc. Andreas Gericke

Measuring of Large Structures

Dr.-Ing. Michael Geist

Assistents

Dipl.-Ing. Sabine Wegener
Virginie Rogge

Senior Professor

Prof. Dr.-Ing.
Martin-Christoph Wanner

Administration

Birgit Latzko

University Education

Dr.-Ing. Ulrich Kothe

IT

Dipl.-Wirt.-Inf. Marcus Baier

Technical Services

Dipl.-Ing. Kay Müller

Public Relations

M.A. Silke Schulz

Test Laboratory

M.Eng. Holger Brauns

**Inspection, Monitoring and
Certification Body**

Prof. Dr.-Ing. Ralf Glienke

COMPETENCES

Joining and Forming by Plastic Deformation

The focus of the **research in joining by deformation** is on questions relating to the joining of lightweight construction materials, such as fibre reinforced plastics or wrought aluminium alloys, both as joints using purely deformation and in combination with adhesive bonding. The main fields of application for the joining methods in question are automotive and aircraft industry.

The research covers both the initial qualification of the deformation or setting process of the joint and the analysis of the load-bearing capacity of the joint under static and cyclic loading and in the event of a crash. A particular focus here is on the fracture-mechanical evaluation of the joints with respect to crack initiation, crack propagation and fracture behaviour.

Furthermore, the properties of the joints are analysed over the service life, and topics such as corrosion resistance, leak tightness, electrical conductivity or the possibilities of (non-destructive) testing are examined.

The focus of the **research into forming by plastic deformation** centres on fundamental questions of forming and deformation of component structures. The main emphasis here is on the development of prediction models and the derivation of process control concepts for cold and hot plastic forming, predominantly for the forming of large steel plates with material thicknesses of more than 5 mm. These have to be evaluated and optimised with respect to their real-time capability for integration into machine control systems.

That's new: GOM-ARAMIS measuring system for detailed investigations into forming / joining processes and the use of a computer cluster to increase numerical computing capacity; Dr.-Ing. Normen Fuchs is appointed as a professor in Stralsund. The new group head is M.Sc. Pascal Froitzheim

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Mechanical Joining Technology

Growing demands on the manufacture of energy and resource efficient products and environmental aspects are leading in many branches to an increasing use of lightweight construction concepts. The associated use of new types of material has given rise to a renaissance in particular of mechanical joining technologies in recent years. In order to give due consideration to this development, the Fraunhofer IGP is developing innovative and cost-effective solutions to the associated problems.

The field of mechanical joining technology involves various research focuses in light alloy and **steel construction, in rail vehicle construction and in general motor vehicle and machine engineering**. We elaborate branch-specific solutions together with our clients. The right choice and command of the joining methods go a long way to determining the functionality, reliability and safety of a construction right from the start of the product development. At the same time, the optimum joining technology for the particular application helps to save costs and material during production and use.

The scope of activities extends from the advice on the choice of the optimum joining technologies through the analysis of the load-bearing strength right up to the derivation of suitable dimensioning rules, depending on the demands of the particular application.

The theoretical considerations are backed up by the accredited test laboratory of the Fraunhofer IGP that, with its modern testing technology, is able to carry out extensive experimental studies into materials, fasteners, joints and coating systems under standardised conditions.

That's new: Doctorate for group head Christoph Blunk on the topic "Contribution to the design of shear-stressed blind riveted joints in metal and steel construction"; Team reinforcement in the form of new employees in the field of structural mechanics and sample preparation/ metrology



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COMPETENCES

Adhesive Bonding Technology, Fibre Composite Technology and Corrosion Protection

The Faculty at the Fraunhofer IGP addresses both current joining issues of lightweight and composite construction and the development and adaption of manufacturing methods for fibre composite parts. Further main research focuses are the effects of ageing on materials, adhesive bonded joints and coatings by means of laboratory ageing in an artificial climate. In cooperation with the accredited test laboratory at the Fraunhofer IGP, materials, joints and coating systems are tested and qualified under standardised conditions. In addition, new testing methods for special applications are developed and employed.

In **the field of adhesive bonding technology**, the range of services offered by the IGP extend from the bonding-optimised design of parts and assemblies, through the planning and dimensioning of bonded joints right up to the development and qualification of the whole bonding process and the joint.

In **the field of fibre composite technology**, the focus is on the holistic optimisation of large fibre composite structures such as the rotor blades of wind turbines, ship superstructures and applications in civil engineering. The work extends from the development of flame-resistant materials through production engineering up to the determination and calculation of indicators.

In **the field of corrosion protection and artificial ageing**, the focus at the IGP is on the development and qualification of innovative corrosion protection systems with improved properties and the identification of ageing influences.

That's new: Wismar project group concerning the subject of "Large-scale thermoplastic structures" in cooperation with the Institut für Polymertechnologien e.V.; Extension to the further training through the inclusion of a three-week DVS® training course concerning adhesives, accredited in accordance with DIN 2304 and DIN 6701

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Welding Technology

Thermal cutting, coating and joining processes play a central role as value-added and quality-determining manufacturing steps in a large number of production processes. In highly industrialised branches, welded joints and welding processes, in particular, have to satisfy constantly growing and changing demands with respect to cost-effectiveness, flexibility and quality. These include, for example, high-quality processing of modern materials with often high demands on the mechanical and technological properties with consistent process reliability, the assurance of the part integrity of welded components of innovative lightweight steel constructions subject to high static and cyclic loads, increases in the cost-effectiveness of welding processes through modern automation solutions, and the introduction of highly productive welding methods to increase competitiveness as an answer to the growing pressure of costs in globalised markets. In order to find long-term and sustainable solutions to the resulting technological and economic challenges, the Welding Engineering working group of the Fraunhofer IGP is continuously engaged in innovative research and development on current and future issues in the fields of shipbuilding, structural steel work, onshore and offshore wind energy. We always strive to holistically evaluate technological, metallurgical and design aspects of the respective welding applications within the value-added chain.

The combination of innovative analysis methods with modern welding equipment together with standardised and accredited testing technology ensure a flexible and holistic approach to current issues within the scope of public sector and private research projects.

That's new: Material analysis by means of scanning electron microscopy (SEM) and energy dispersive X-ray spectrometry (EDX); Process analysis by means of a high-speed camera; mobile and stationary ultrasonic contact impedance (UCI) hardness testing; M.Sc. Andreas Gericke as the new group head.



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COMPETENCES

Automation Engineering

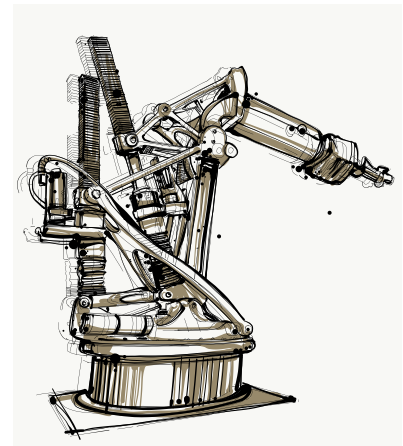
Automation plays a vital role in increasing companies competitiveness on the global market, also in the context of Industry 4.0. Particularly during the production of large structures, the challenges for the process automation derive from the large workpiece dimensions and weights in combination with large production tolerances.

Our experts are therefore working also on the subject of autonomous programming. Regarding small batch sizes during the production of large structures, efficient programming is eminently important. Our autonomous robot programming is already being successful employed in applications in the maritime industry. It is based on the evaluation of 3D sensor data or a CAD/CAM link, depending on the particular application.

Furthermore, the Automation Engineering team at the Fraunhofer IGP is also developing new processes and methods for expanding robot-aided manufacturing in order to meet the ever growing demands on quality and cost-effectiveness.

Our goal is to introduce and establish robot systems in areas of industry that until now have been unable or only partially able to benefit from this technology and to design existing and planned production lines in such a way that they can best meet the demands on quality, reliability and resource efficiency, while still observing the economic constraints.

That's new: Equipped with extensive technology packages, the Kuka KR 240 industrial robot is available for research in welding and mechanical processing.



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Measuring of Large Structures

The main emphasis of the Measuring of Large Structures development team lies on the acquisition, analysis and visualization of 3D measuring data in the field of production technology. An interdisciplinary team and a broad spectrum of digitalization methods for stationary and mobile applications are the basis of innovative solutions even under difficult conditions (e.g. underwater).

Using the latest measurement technology for capturing the shape and location of large structures, the foundation for application-specific development of analysis and evaluation methods of geometric data is laid. Together with industry partners the research focus **3D data-capturing** develops concepts of measurement and quality management capturing the as-build state of various objects. A qualification of the measurement process for quality control as well as the development of the entire process chain of data acquisition is performed, the results are presented accordingly and the information is returned to the production process.

The research field **data analysis** focuses on solving fundamental questions regarding the interpretation of multidimensional sensory data. The overall objective is customized software engineering for the automated analysis of high-resolution 3D point clouds and additional data sources. With application-specific development for automated extraction of object-relevant information of 2D, 3D or higher dimensional data, modelling techniques are developed, measurement and analysis processes are automated and the state of the object is derived.

That's new: Implementation of new technical and methodological approaches in the field of dynamic data acquisition for determining the position of moving platforms for monitoring tasks

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COMPETENCES

Production Organization

In close cooperation with industrial partners, the Production Organization team at Fraunhofer IGP develops individual solutions for the design of tomorrow's production.

In the field of factory and logistics planning, the latest methods and tools from the **Digital Factory**, such as material flow simulation, 3D-layout planning and robot simulation, are applied. Among other things, this supports industrial partners in calculating and executing their reorganisation or investment projects.

At the shop floor level, the focus is on development and implementation of individual solutions for the smart factory in the context of **Industry 4.0**. These include IT-based Production data acquisition systems, which are used in combination with the most modern positioning technology to increase the transparency of the production process. At the same time a fast and flexible delivery of digital information is becoming more important for the employee. In order to achieve these goals assistance systems such as data spectacles, tablets, and other Smart Devices. A further field of focus are **ergonomic assistance systems**. By using intelligent workplace systems and ergonomics simulation, assembly processes can be designed ergonomically correct and efficient. In addition, innovative production concepts based on human-robot collaboration are developed.

That's new: Expansion through the addition of a new robot in the field of human-robot collaboration: 35 kg load capacity, operation which is independent of safety fences, optical safety system, various grippers; Doctorate for group head Jan Sender on the topic "Methods for planning production systems for large maritime structures"

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DIGITAL SYSTEMS FOR LARGE STRUCTURES IN
PRODUCTION TECHNOLOGY AS A CORE COMPETENCE AT THE FRAUNHOFER IGP

SUPPORT SERVICES

Inspection, Monitoring and Certification Body according to LBO

Products or types for which recognised technical rules do not yet exist require building inspectorate suitability certification before they can be used in national building authority approvals applications/areas.

For national technical approvals (abZ) with approvals numbers Z-14.1-... and Z-14.4-... (connecting elements), the Fraunhofer IGP has been recognised by the German Institute for Civil Engineering (DIBt) as an inspection, monitoring and certification body (MVO08) according to the state building code since 2014. The recognition as a monitoring and certification body was successfully extended in 2018 with the approvals numbers Z-30.6-... (welded steel parts) and Z-14.9-... (structural anchorings of attachment points for anchor devices). In addition, recognition was gained for the approval group "Parts of structural steel welded using a standardised process with special application" (approval number Z-30.6-...) as **Germany's first and currently only testing body**.

The Fraunhofer IGP takes on supervision and certification orders (System ÜZ) in Germany and abroad. The functions of the supervisory body thereby comprise the inspection of the manufacturing works on site with respect to the personnel and equipment preconditions for consistently correct manufacturing. The supervisory body is also responsible for auditing the works' factory production control to ensure the product properties. External supervision thus comprises an inspection of the building products for compliance with the underlying technical approval (abZ).

The certification body then performs the final evaluation of the reports submitted by the supervisory body with regard to the granting, renewal or revocation of the certificates of conformity. If the evaluation is positive, the manufacturer is both entitled and obliged to mark the building products or building types with the symbol of conformity (Ü symbol).

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Test Laboratory

The test laboratory of the Fraunhofer IGP is closely involved in the ongoing research projects by the faculties of the Institute.

Test functions from the business sector are also handled here. In order to meet the high quality requirements from research and business, the test laboratory is accredited in accordance to DIN EN ISO/IEC 17025:2005 by the German accreditation body DAkkS.

Since the founding of the test laboratory, extensive knowhow has been built up in the fields of experimental studies into materials, fasteners, joints and coating systems. The main focus of the work is not only on accredited tests, but also on standardised and non-standardised tests and component testing. The focus in these areas lies on the high standards of quality and the reproducibility of the tests. In addition, further standardised processes are being continuously added to the portfolio. The testing services offered by the laboratory include **mechanical and technological tests, leak testing, corrosion tests, chemical and physical tests and surface characterisations**. The laboratories have a broad machine park available for these applications.

The tests in the test laboratory department are conducted by a competent team of engineers and technicians with many years of experience in the development and configuration of measuring and testing apparatus. The main focuses of the work extend from the development and performance of the tests through to their evaluation.

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SELECTED PROJECTS

Simplified analogous model for process control during the rolling of large sheet thicknesses - forming optimisation



The industrial rolling of thick plates in small batch sizes is currently solely controlled by manual operations. As a result, the efficiency and economy of the forming process depends mainly on the experience of the plant operator. In order to optimise the forming process, an objective real-time control approach based on a simplified substitute model is therefore developed within the research project. With the help of experimental and numerical investigations as well as a sensitivity analysis of the influencing factors, the substitute model can be specifically trained for an industrially relevant parameter space. Through the use of the substitute model, the controlling of the rolled rounding will be sustainably improved, especially for SMEs.

Extension of the application limits of blind fasteners for joining high-strength materials

In the field of steel and metal lightweight construction, there has been a tendency to use higher-strength materials in recent years. From the perspective of the structural engineer, the use of blind riveting technology raises questions that are addressed in the course of current research within the IGF project at the Fraunhofer IGF. The aim is to develop design rules that take higher material strengths into account when planning. These design concepts are intended to enable a more economical and resource-saving construction.



Automated handling of workpieces in the field of aircraft assembly



In the field of logistics, digitisation offers enormous potential for increasing efficiency and, through open and cooperative automation, it can significantly improve the value-adding workload of employees. Commissioned by Airbus and as part of an aeronautics research and technology project, Fraunhofer IGF is realising an automated, load-pendulum-dampened crane system with fully configurable and configurable open controls. The aim is to extend conventional crane systems to include the functionalities of industrial robots. The digitally networked control platform enables the flexible cross-system exchange of information while the innovative security concept reliably protects people within the workspace.

Non-combustible, fibre-reinforced composite components based on cold-curing, inorganic matrix systems

In principle, the use of composite materials in shipbuilding is very promising due to its great freedom of design, high resistance to corrosion and considerable weight savings. However, strict fire protection regulations prevent the use of conventional fibre-reinforced plastic composites (FRP) with organic matrices that burn in the event of fire when heat is released. The solution to the problem lies in the substitution of plastics by inorganic, non-combustible matrix systems. However, conventional manufacturing processes for FRP cannot be easily transferred to inorganic materials. The AnorKomp project therefore focuses on the processing of inorganic systems and processes for the production of corresponding composite components.

Gefördert durch:



aufgrund eines Beschlusses
des Deutschen Bundestages



Induction heating technology for improving weld quality in the field of underwater welding of fine grain steels

Gefördert durch:



aufgrund eines Beschlusses
des Deutschen Bundestages



The research project investigates the possible application of induction technology for pre- and post-heating in the field of wet manual arc welding. As a result of the medial influence, high hydrogen inputs occur and, due to the strong convection, high cooling rates also occur after welding. As a result, critical material properties can occur, as well as cracks. The contribution of effective energy by means of induction should be used for the practical compensation of specific underwater risks during wet welding and as such, for the safe joining of high-strength steels as well. This is necessary for the economical and quality-oriented repairing of structures in the field of steel construction for hydraulic engineering. Application guidelines are developed for the use of induction heating technology.

3D HydroMapper – Automated 3D structural survey and damage detection under water

As part of the collaborative project "Hybrid 3D Inventory Data Collection and Model-Based Examination of Public Waterworks for Sustainable Infrastructure / Lifecycle Management - 3D HydroMapper", Fraunhofer IGP is developing a system for the digital inspection of public waterwork structures in cooperation with Dr. Ing. Hesse and partner engineers in Hamburg (dhp:i), WKC Hamburg GmbH (WKC), Geodätisches Institut Hannover (GIH) and the port operator and service provider Niedersachsen Ports (NPorts). The unique feature is the extensive automation of the measurement, evaluation and testing process for structures above and below water. As a result, the collection speed can be increased, the scope of testing can be extended and, for the first time, a comprehensive digital construction model can be created and updated for harbour structures.



Gefördert durch:



aufgrund eines Beschlusses
des Deutschen Bundestages

SELECTED PROJECTS



Fatigue damage and failure behaviour of riveted fibre-plastic composites

The self-piercing riveting (SPR) process is a highly efficient joining technology in automatic structural assembly. Joining high-performance fibre-plastic composites requires a special consideration of the damage that is induced during the setting process (e.g. delamination, fibre and matrix fractures) when joining high-performance fibre-plastic composites (FRP). The research project that is being worked on aims to derive relationships between linkage characteristics and cyclic loading characteristics, especially the damage and failure mechanisms, which can ensure a safe design of the links.

The spread of the damage and the failure in relevant stress situations, e.g. with respect to the bearing stress, is part of the first investigation complex. Practical thermoset and thermoplastic FRP semi-finished products and aluminium materials are used which are analysed with the aid of the latest measuring technology and analysis methods. The aim of this study is a comprehensive **chemical-physical material characterisation** and the separation and evaluation of damage and failure mechanisms under cyclic loading. As such, an assessment of the individual effects can be made for the later course of the project.

By influencing **the joint characteristics in a targeted way** different states and stress situations are set in the course of the research project during a later mechanical load. In order that the most comprehensive possible assessment of different influences can be made, a selection of varying materials and material thicknesses such as joining elements are taken into account. With the connections that are produced, an assessment of the process-induced damage then takes place using established non-destructive evaluation methods. They form the basis of the damage assessment of the FRP materials in the case of subsequent cyclic loading.

For the application-oriented production of SPR with FRP, a comprehensive **analysis of the damage and failure mechanisms in the case of cyclic loading** is carried out in the further course of the project. In addition to the macro-mechanical damage phenomena of the joints, evaluation criteria especially include well-founded analyses of the micromechanical failure mechanisms using scanning electron microscopy and non-destructive analyses.

The results of the research project allow for a fatigue-oriented connection design using SPR in a structurally lightweight construction. They form the basis for the design of these connections and can also contribute to an increase in the acceptance of punched SPR-processes with FRP materials through a comprehensive evaluation of the damage and failure mechanisms.

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Sponsorship: The “Fatigue resistance of self-piercing riveted FRP-metal-hybrid joints” project is a project of the Industrielle Gemeinschaftsforschung under the funding number AiF-No. 19635BR and funded and supervised by the Forschungsvereinigung EFB e.V. and sponsored by the Association of Industrial Research Associations (AiF) as part of the programme for the promotion of industrial joint research and development (IGF) by the Federal Ministry for Economic Affairs and Energy on the basis of a resolution of the German Bundestag.

3 Self-piercing riveted joint with FRP and aluminium



Friction-based crack initiation in form-jointed connections

Due to their efficiency, non-punching, forming technology joining processes are increasingly used in the mobility sector. Due to a lack of knowledge regarding the damage resulting from the setting process as well as the effects on crack initiation during cyclical loading there is currently an acceptance problem, especially in the field of aircraft construction. The in-depth analysis of the crack initiation on clinch-bonded connections and the prediction of the location and crack-related service life of these connections is therefore the aim of the research project.

The solution concept is based on experimental investigations into the material and the clinch point as well as on the numerical simulation. The experimental investigations serve the analysis of the influencing factors in the case of friction-based crack initiation and the validation of the simulation model. Within the scope of the experimental investigations, an exact characterisation of the material is carried out, in which not only the quasistatic and cyclic characteristics, but also the surface states are determined by means of 3D visualisation. Special attention must be paid to the friction conditions between the components in contact. Fatigue tests on clinch connection and subsequent SEM and CT analyses are designed to investigate crack initiation and crack propagation and highlight the impact of frictional stress on fatigue strength.

Among other parameters, the contact stress state at the joining point (which is decisive for friction-based crack initiation) cannot be measured for such a complex geometry by metrology. Therefore, the numerical simulation tool is resorted to by means of FEM. The corresponding characteristics which are experimentally determined allow for a precise description of the material and the tribological states in the simulation and can be used to validate them.

Great importance is attached to the mapping of the entire

experimental chain. As a result of the preceding simulation of the clinching process, residual stress states and the forming history can be recorded and used as input variables for subsequent 3D structural behaviour simulations. From these simulations, values can be obtained for the computational determination of a Wöhler curve. Parallel to the experiments, the influence of fretting corrosion is analysed simulatively. Linking **the experimental and numerical simulation results** provides a detailed picture of the mechanisms leading to crack initiation and finally to the failure of the connections. Thus, the knowledge that is gained can be transferred to the complex geometry of a clinch connection and used to predict the failure, especially against the background of friction-based crack initiation.

Partner: TU Dresden

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Sponsorship: The “Friction-based crack initiation in the case of form-jointed connections of components made from aluminium wrought alloy” project is classified as a joint industrial research project under the sponsorship number AiF no. 20300BR and is funded and supported by Forschungsvereinigung Stifterverband Metalle e.V. and sponsored by the Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF) as part of the programme for the promotion of industrial joint research and development (IGF) by the Federal Ministry for Economic Affairs and Energy on the basis of a resolution of the German Bundestag.

4 Crack formation on a form-jointed connection after cyclic loading

SELECTED PROJECTS



Qualification of shear cutting

Modified shear cutting technologies reduce the negative effects of conventional shear cutting that occur on the hole wall. As such, the shear cutting of holes in DIN EN 1090-2 is not permitted for, among other things, sliding and cyclic stressed connections. However, as a result of qualified shear cutting, the vibration resistance of perforated bars with punched holes was raised above those with drilled holes.

According to DIN EN 1090-2: 2011-10, shear cutting is generally not permitted in execution classes 3 and 4. The use of sheared holes is no longer directly linked to the EXC according to the current standard, but is still excluded for the execution of non-slip connections, connections under cyclic loads and overlap connections with screws above strength class 8.8. However when using shear cutting, as an economic pre-hole process, manufacturing parameters (such as cutting clearance and punch and die geometry) have a decisive influence on the cutting surface quality and as such, also on the material and load bearing behaviour in the vicinity of the hole or the related residual cross-section of the component. **The qualification of shear cutting as a pre-hole process defines production parameters for the production of pre-holes and proves its suitability for later use with lock-bolt systems, blind rivets, as well as screw and rivet connections.**

The investigations are carried out on the basis of the following hypotheses:

1. Sheet thickness $t < d_0$ applies.
2. Maximizing the clear cut surface leads to an increase in the fatigue strength to the level of drilled holes.
3. Elimination of the reworking of sheared holes in structures subject to vibration. The findings of the research project are directly applicable due to the extension of the rules for the shear cutting of holes in DIN EN 1090-2. This saves on the need for individual examinations, which are particularly problematic, time-consuming and cost-intensive, especially for SMEs. Since

the production of the pre-holes can also be carried out by means of shear cutting (for connections subject to oscillatory stress as well) the insights that have been gained make a significant contribution to reducing costs and process times for SMEs,

Partners: Alcoa Fastening Systems Ltd., August Friedberg GmbH, Bombardier Transportation, Butzkies Windprojekt GmbH & Co. KG, FAS - FörderAnlagen Systeme GmbH, Gebr. TITGEMEYER GmbH & Co. KG, Hako GmbH, in connection with Verbindungen im Metallbau, ITM Zschaler GmbH, Nordex Energy GmbH
Salzgitter Mannesmann Forschung GmbH, STIEBLICH HALLENBAU GmbH, SUZLON Energy Ltd.

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Sponsorship: The joint project with TU Dresden, Prof. Uwe Füssel and IGF, Project no. 19481 BR "Qualification of shearing for the execution of holes in steel structures" of the Forschungsvereinigung Stahlanwendung eV (FOSTA P1216) is sponsored by the AiF as part of the programme for the promotion of industrial joint research (IGF) by the Federal Ministry for Economic Affairs and Energy on the basis of a resolution of the German Bundestag.

5 Application for sheared holes in high-bay warehouses

Analytical verification of frictional contact joints with slotted holes for light metals and steel materials

Slip-resistant screw connections are used wherever cyclic loads act and are frictionally transmitted for reasons of fatigue strength. As far as possible, the dimensioning, as well as the verification of these connections are to be realised through existing standards and regulations. However, long holes and oversized round holes still pose problems in the verification process. These are necessary in order to cost-effectively compensate for the additional demands for manufacturing tolerances through slots or oversized round holes. As part of a research project, the question of larger nominal hole plays will be looked into with regard to the flexibility and the supporting effect of high-strength pre-stressed screw connections.

Among other things, in order to realise a more economical and faster production, the shape and position tolerances are increased. In order that the hole overlaps are still given, the components of the screw connections which have to be connected are made with oversized round holes or slots. The analytical dimensioning of these frictional slot connections is basically possible in structural steel engineering and crane construction, however considerable restrictions on the load bearing capacity have to be accepted. In machine and rail vehicle construction, however, such connections are not measurable. Above all, the reason for this is based on a lack of knowledge about the height of the plate compliance and/or the spread of the tension body.

The aim is to derive design rules for prestressed slot joints from experimental and numerical investigations.

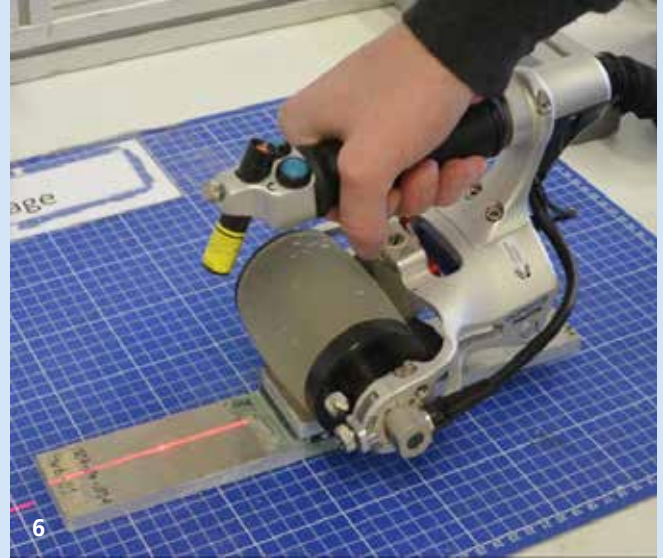
With the help of sliding load tests, the influence of the hole geometry on the sliding resistance was investigated and corresponding reduction factors were determined. With the numerical investigations, a mathematical calculation model for determining the plate compliance is created.

The test results are to be used to define design rules which allow for an economic design with minimal geometrical restrictions. For example, the end user should be shown ways to compensate or reduce load capacity reductions due to higher nominal hole play. Furthermore, the crossed longitudinal slots execution should be possible. Due to the higher and safer utilisation of the load capacities, for example, the number of screw connections can be reduced. In machine and rail vehicle design, a design should be made possible for the first time, whereby the shape and position tolerances in the designs can be made correspondingly more approximate.

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SELECTED PROJECTS



Inspection methods for the recurrent inspection of structural bonds in the field of shipbuilding

As a result of increasing lightweight construction requirements, bonding technology is becoming increasingly important as a joining process in the field of shipbuilding. Lack of long-term experience in the maritime sector, however, hinders the integration of adhesive technology in production. Therefore, the aim is to find suitable inspection procedures and intervals for ongoing operations and to gain experience with bonded joints in the field of shipbuilding.

Among other things, due to the increasing use of mixed construction in shipbuilding, innovative constructions can no longer be completely realised using classical joining methods, e.g. welding or riveting. In order to implement modern structures, the integration of new technologies is imperative. Adhesive bonding as an alternative joining technique brings many benefits. However, incorporation into the manufacturing process is hampered by the current lack of bonding experience in marine environments and the lack of reliable inspection methods for monitoring damage. In order to further establish bonding technology in the field of shipbuilding and to promote the reduction of reservations regarding this joining process, the effects of defects are to be determined and suitable methods for checking the bonds should be developed, during operation, and in a non-destructive way. As an initial measure, imperfections that are typical for adhesive joints in the field of shipbuilding should be identified and classified. These defects should be introduced into various test specimens in order to subsequently test them in static and dynamic tests. Subsequently, the various imperfections are evaluated with regard to their potential for damage and their influence on the remaining lifespan. On the basis of the data that is obtained, reasonable inspection intervals are defined for the use of adhesive bonds in shipbuilding.

Furthermore, existing non-destructive inspection methods will be compiled which are applicable for use in the shipyard and at sea. A more detailed selection will also be checked for its applicability and suitability in maritime environments.

In the static tests it was possible to prove that up to a certain extent, in the bond, the imperfections have no negative influence on the bond. From this limit, however, the effects continue to increase with increasing percentage of defects in the bond and these affect the bond.

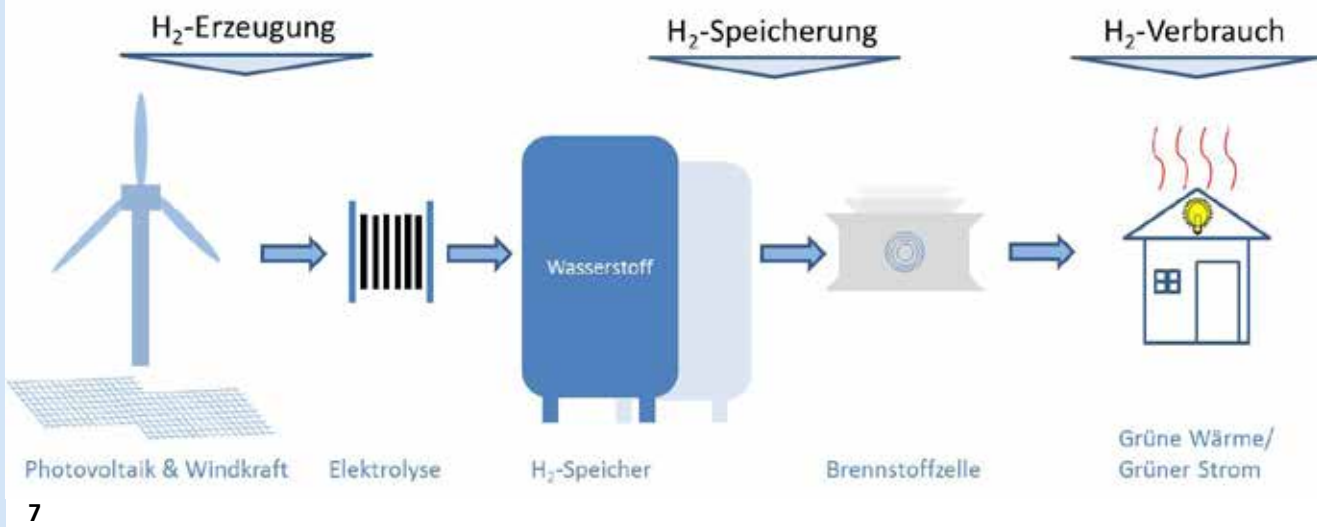
From all of the non-destructive testing methods, visual and ultrasonic testing were selected (among others) for further investigations. During operations, these inspection methods can be applied quickly and without reservations in order to monitor the condition of bonded joints. Initial tests with test specimens showed that the examined imperfections can be reliably detected with an ultrasound system.

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Sponsorship: The IGF project “Adhesive layer inspection” (IGF no.19870 BG) of the Forschungsvereinigung Center of Maritime Technolog (CMT) was sponsored by the Arbeitsgemeinschaft industrieller Forschungsvereinigungen (AiF) as part of the programme for the promotion of industrial joint research and development (IGF) by the Federal Ministry for Economic Affairs and Energy on the basis of a resolution of the German Bundestag.

6 *Ultrasound system for the detection of imperfections*



Development of pressure tanks based on rotomoulded liners with a CFRP pressure hull

The aim of the joint project is the development of market-adapted technical solutions for the storage of hydrogen which, in particular, serve the task of temporarily storing energy from solar and wind power. For this purpose, a pressurised vessel is to be designed, optimised and manufactured, consisting of a thermoplastic inner liner body, the liner and a pressurised shell made of a fibre-reinforced plastic. The overall solution is intended to be a scalable and decentralised energy storage system that can be operated in combination with an electrolyser and a fuel cell.

The subproject of Fraunhofer IGP pursues the task of improving the composition and the processing of the thermoplastic liner material with regard to its mechanical and physical properties. In addition, the project deals with the mathematical design and the optimisation of the geometry of the individual pressure vessel components. Tests on the materials and components provide necessary input variables for the calculations as well as evaluation principles for the application. The production of PA6 containers in reactive caprolactam-based rotomoulding requires the development of a process control mechanism that allows for precisely adjusted guidance of the tool over the strip via 2 axes of rotation. The extensive process technology consists of the mixing plant for the liquid supply of ready-to-use caprolactam with the associated additives. This includes a dosing and injection technique for the liquefied mixture, with which the forming tool can be filled in several shots. The tool required for reactive shaping in the rotation was equipped with resistance networks which controlled the temperature within narrow limits at approx. 160 °C.

In view of the planned use of such large containers as pressure tanks and the required achievement of a sufficient permeation barrier for hydrogen, the process was so modified that in

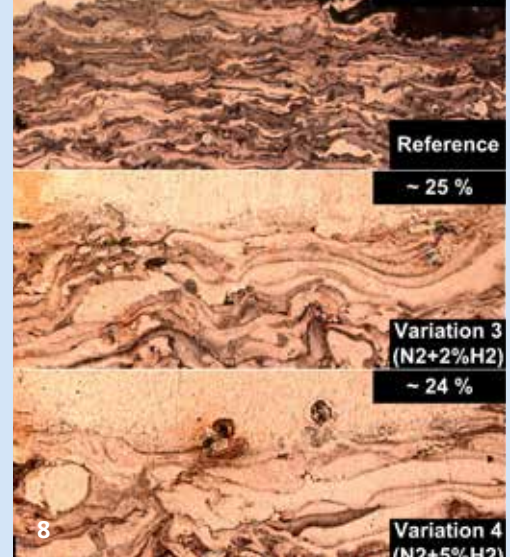
each case, several layers are applied to each other in a "shot". With a total of 6 layers of 2 mm each, it was possible to rotate a large container made of PA6, which has a uniform wall thickness with sufficiently high permeation barrier to hydrogen, and sufficient mechanical rigidity for a subsequent winding process for the production of pressure tanks. The required winding system is available from the industrial partner. The rotation process of caprolactam has been developed so far that it has been possible to achieve a homogeneous wall thickness distribution over the entire circumference of the liner with a sufficient permeation barrier. Among other things, further work on the current project relates to the modification of the geometry of Boss and connection with the aim of stress minimisation in the transition area. The structurally weight-optimised CFRP pressure sleeve will complete the product and process development in terms of its design and in terms of its implementation in suitable winding programmes.

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Sponsorship: This project is funded by the European Union through the European Regional Development Fund (ERDF).

SELECTED PROJECTS



Functional layers for modern heating technologies

The objective of the project is the thermal conditioning of batteries for alternative drive technologies via an electric heater. As a result, the maximum capacity can always be used and the range of electric vehicles can be increased. For this purpose, however, a profound analysis of the thermally sprayed functional layers for optimising layer heating technology is necessary.

The accelerated promotion of electromobility is expected to generate increasing demand, especially as the ranges of alternative drives is increased. The thermal conditioning of the battery in the range 20 °C - 40 °C can act as an important contribution to this. The aim is therefore to thermally condition batteries via an electric heater e.g. high-voltage heaters (HVH) which are currently produced in layers by thermal spraying. However, in order to be able to guarantee the quality of the product even in mass production, the adjustments to the aforementioned application make fundamental investigations necessary, especially with regard to the relationships of the layer microstructures and functional properties (e.g. electrical conductivity, temperature emission) depending on the process parameters. Furthermore, alternative thermal spray processes or process modifications are checked for suitability and cost-effectiveness and compared with the technology that is used.

As such, the highly charged contacts which have to transmit very high voltages and currents have been examined. These are produced in layers by arc spraying copper and then joined using a laser welding process with a fixed copper contact lug component. In addition to the evaluation of a non-destructive test method for the welded joints, it was possible to improve the efficiency of the injection process by reducing the number of layers to 59% (layer thicknesses approx. 51% to 55%) while improving the quality of the coating and ensuring the welding process. The use of alternative gas mixtures (e.g. N₂

+ H₂) as a nebulizer gas indicated improved coating properties for different materials which, in the case of the application, should also have a positive effect on the downstream welding process. The evaluation of the welded joints indicated the connection between an excellent microstructure with low defect densities in the layers and a better formation or connection of the weld points in the form of high electrical conductivity. A further reduction of the number of layers and layer thickness should rather be done away with, as decreasing layer thickness increasingly indicates a scattering in the layer quality and as is also believed, in the welding process as well. In addition, the measurement of electrical conductivity proved suitable for use as a quality assurance measure. Well connected welds are not only indicated by a higher value per se, but also by a lower scattering.

Partners: Webasto Neubrandenburg GmbH; Schweißtechnische Lehr- und Versuchsanstalt SLV Mecklenburg-Vorpommern GmbH

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Sponsorship: Sponsored by TBI Technologie-Beratungs- Institut GmbH. European Fund for Regional Development (ERDF) of the European Union and the Ministry of Economic Affairs, Construction and Tourism of Mecklenburg-Vorpommern (FK: TBI-V-1-181-VBW-063)

8 *Microstructures of the welded joints on the sprayed layers of the reference samples (100% of the layers, other magnification), variations 3 and 4 (59% of the layers) and the relative proportions of the defects of the sprayed layers as determined by the incident light microscope*



Influences affecting the serviceability of electric arc-brazed, galvanized steel structures $t > 3$ mm

Arc brazing is suitable due to the lower energy input for joining galvanized structures without any subsequent cost and time-intensive post-coating. The aim of the project is to create a database with areas of application and limits for the secure use of the technology and as such, to establish arc brazing as an alternative joining method in steel construction and shipbuilding.

In the case of welding, the necessity of having to join galvanized structures is associated with costly and time-consuming pre-processing and post-processing, as without the removal of the applied anticorrosive layer, no weld can be produced that is suitable in terms of quality and corrosion. In order to avoid the loss of the zinc deposit in the seam side area, the energy input has to be reduced, which can be achieved by using low-melting point copper based filler materials. However, there is insufficient knowledge about the performance of arc-brazed joints in the field of heavy plates ($t > 3$ mm). Without knowledge regarding the static and dynamic load-bearing behaviour of such connections, a mathematical design and with it, the use of the technology is not possible. For companies in the steel construction business, implementation recommendations for achieving the required connection qualities are completely absent.

Practical brazing parameters have been determined by deposition brazing of six copper-based filler materials on various surfaces. The diffusion zone has been evaluated by scanning electron microscopy (SEM) and X-ray spectroscopy (EDX) in order to determine the diffusion behaviour of the alloy elements. Butt and crest joints (S235JR, $t = 5, 8, 10$ mm) are produced, for analysing the strength and correlation to liquid metal penetration. These are analysed by tensile test and the number and length of the liquid metal penetrations in the seam cross-section are recorded. Fracture surface analyses are performed by means of SEM to draw conclusions

about the type of failure. Wöhler tests and salt spray tests provide information on the behaviour under fluctuating and/or corrosive loads.

In the current project, extensive tests have been carried out for the practical execution of arc brazing and for testing the joint strengths that can be achieved under various boundary conditions in order to generate a broad data basis for arc brazing with its areas of application and limits. It has also been possible to show that the liquid metal penetrations have no negative impact on the strength at larger sheet thicknesses. Metallographic investigations will broaden knowledge concerning the bonding mechanisms of arc brazed joints and, in cooperation with the project partners, will support the further development of brazing filler materials, taking into account the requirements of the steel construction industry and shipbuilding market. The goal is to establish arc brazing as a thermal joining process in steel construction and shipbuilding for specific areas.

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Sponsorship: The IGF project "Influence of production engineering and geometric parameters on the operational reliability of electric arc-welded galvanized steel structures $t > 3$ mm" (19894 B / DVS No. 07.085) of the Research Association for Welding and Allied Processes eV of the DVS, Aachener Straße 172, 40223 Düsseldorf sponsored by the Federal Ministry for Economic Affairs and Energy via the AiF as part of the programme for the promotion of industrial joint research (IGF) on the basis of a resolution of the German Bundestag.

SELECTED PROJECTS



Mobile robotic cell for the environmentally friendly dismantling of rotor blades

The dismantling of wind turbines is becoming increasingly important. A semi-automated system is currently being developed for the environmentally friendly cutting of rotor blades at the dismantling site, which enables the flexible dismantling of almost any rotor blade. The water jet unit used is guided by a sensor-based robot system.

Energy generation from renewable energies is still a global growth market. Wind turbines in particular make a significant contribution to the supply of electricity. In addition to age-related dismantling, the dismantling of uneconomical plants is becoming increasingly important as a result of technological advances. Due to the high logistical costs of transporting entire rotor blades, various processes are currently being developed for shredding the rotor blades at the dismantling site. Sawing processes are predominantly used in the current solution concepts, which represent a great danger to the health of the operators and the environment due to the emission of dust and vapours.

High-pressure water jet cutting is used as an alternative cutting method dismantling the rotor blades, achieving a significant reduction in harmful emissions. An additional improvement is achieved by enclosing the cutting area.

The use of water jet cutting technology enables the cutting of large material thicknesses. While conventional sawing processes cut the rotor blades slice by slice, this cutting strategy cannot be used for waterjet cutting because the blade thicknesses are too high. With the help of a 3D image acquisition system, the structure of the rotor blade is therefore measured in advance. In the next step, the essential components of the rotor blade, such as envelope geometry and internal stiffeners, are extracted from the image measurement data and the technologically optimal cutting paths are determined. This

procedure also enables a reduced-volume removal of the rotor blade segments.

To flexibly guide the water jet nozzle, an industrial robot equipped with an additional linear unit expands the working area. The limited working space requires a sectional dismantling of the rotor blade, which is transported step by step into the working space with the help of a semi-automated rotor blade feed. The required robot paths are created fully automated from the determined cutting paths, taking into account the absence of collision. The cutting parameters such as feed rate and water pressure are adapted to the measured material thickness.

The cutting cell is designed as a self-sufficient unit. In addition to the on-board energy supply, the water used is treated in a closed circuit for reuse.

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Sponsorship: This project is co-financed by the European Union from the European Regional Development Fund. Operational Programme Mecklenburg-Western Pomerania 2014 – 2020 – Investing in Growth and Employment

10 Schematic representation of the dismantling cell



Development of a flexible robotic system for machining large cast components

Aim of the joint project is the development of a novel robot-supported system for the mechanical machining of large cast components. In addition to innovative structural components of the robot, the main focus is on precision, rigidity, accuracy, flexibility and mobility as well as the implementation of the system in an industrial 4.0 environment.

Ship propellers from Mecklenburger Metallguss GmbH in Waren are specially matched and manufactured to the specific application profile. The propellers have a diameter of up to 12 m and a weight of up to 160 t. Due to these dimensions, the necessary post-processing of the cast blanks is carried out with manually controlled hydraulic manipulators. During machining, the operator receives force feedback on the contact force between tool and workpiece, which is decisive for the quality of the result. The entire process is therefore primarily dependent on the experience and skills of the operator. In order to decouple it from this factor, an automated process is being developed. **This offers ergonomic advantages over manual machining. At the same time, the economy is increased by reducing process times with high repeat accuracy of the process.**

For automated grinding, there are primarily solutions using a combination of a standard industrial robot and an active contact flange. However, available robots do not have sufficient reach and stiffness, which is why a customer-specific solution has to be developed. The focus here is on the maximum reach, rigidity and path accuracy. The results of an already completed research project and a prototype with an above-average load torque can be used as a basis.

Another aspect is the automated processing of the propellers. It requires a tool which ensures a given contact force and thus enables a defined abrasion. Offline programming is also to take place in a virtual work cell. The workpiece and

robot must be referenced for this purpose. First tests with an optical measurement system were successfully carried out in the context of a study on the marking of propellers. However, the solution must be adapted in such a way that it achieves precise results even under high dust exposure. For semi-manual operation, the operator should be relieved using an innovative control concept. By orthogonally adjusting the tool to the workpiece surface during the entire process, the operator only determines direction, speed and contact force. Thus, the operator's know-how is still used for simultaneous process automation.

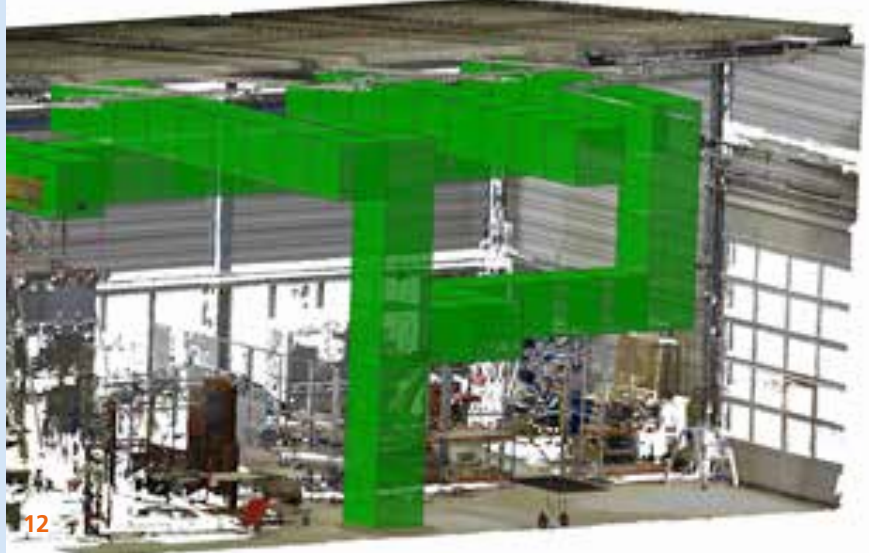
Partner: Mecklenburger Metallguss GmbH, Waren

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Sponsorship: The project "Development of a flexible robot-assisted system for machining large cast components" was funded by the European Regional Development Fund (ERDF). The support was carried out in accordance with the Directive on the Promotion of Research, Development and Innovation of the Ministry of Economics, Building and Tourism of Mecklenburg-Western Pomerania by the Project Management Organisation Technology Consultancy Institute (TBI).

11 *Metrological recording of the surface processing of the blade geometries*

SELECTED PROJECTS



Inspection, monitoring and documentation of steel structures

Structures are long-term objects that are subject to degradation in the course of their scheduled use. In order to reduce the resulting damage, structural inspections must be carried out at regular intervals, which are usually time-consuming and labour-intensive and are associated with restrictions on the use of the building. The aim of the project is the automated recording of the condition of structures by aerial survey with unmanned aerial vehicles and the subsequent processing of 2D / 3D images and image analysis through to the completion of the digital file of the structure with damage and defect indications and instructions for action.

Steel structures are flexible structures with high dynamic and static loads. These include weather conditions, overloads and signs of ageing. Sustainable construction management is necessary to maintain stability and safe use. This can only be achieved through regular audits. However this is associated with considerable financial expense and time. Highly qualified staff are required as well as aids. During inspection usage is also impaired. In this research project autonomous, unmanned aerial vehicles (UAVs) are to be used as the basis for an inspection system, which enables simple, accelerated and regular structural inspections.

The recording of the condition during the inspection of the structure should be possible without the need for on-the-spot presence. **For this purpose, the building is recorded with a laser scanner and the automated path planning and aerial survey of the building is carried out on the basis of the 3D image.** When flying, the challenge is the navigation of the UAV. While global positioning systems (e.g. GPS) can be used outdoors, navigation and collision control must be implemented indoors, using knowledge of the building

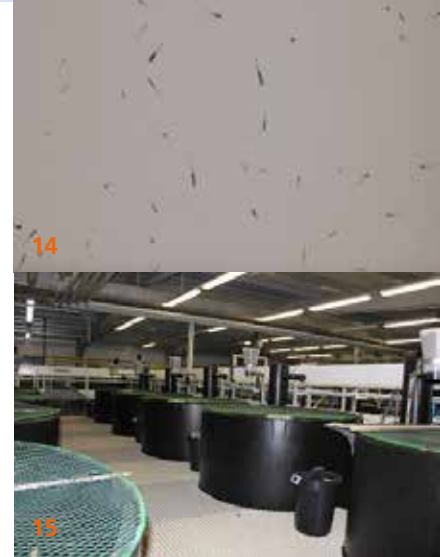
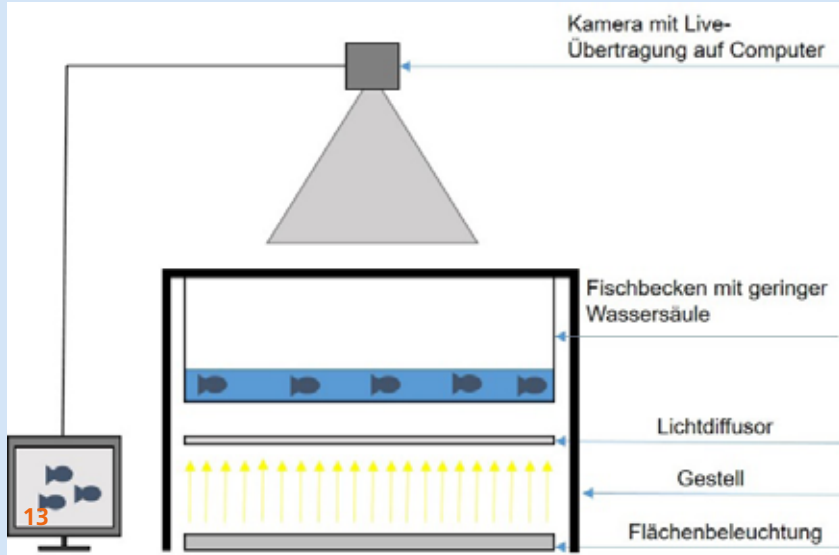
in conjunction with sensors. In the case of an autonomous aerial survey, the image-based documentation of the areas relevant to the inspection of the structure (e.g. joints) is carried out. Subsequently, a 3D model is created from this data, as the basis for the structural inspection. This model is used to automatically analyse and classify the damage. From this, an assessment of the condition of the structure is derived on the basis of applicable guidelines. Due to the developments, it is possible to economically test engineering structures as well as hall structures in an economical way and to identify safety-relevant changes at an early stage. Sustainable construction management can be implemented, which reduces the costs of maintenance and, through the documented safety standards, reduces the liability risk.

Partner: Technische Universität Dortmund

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Sponsorship: The IGF project 19988 BG / P 1326 Inspection, Supervision and Documentation of Structural Structures "of the FOSTA - Forschungsvereinigung Stahlanwendung e. V., Düsseldorf, is sponsored by the Federal Ministry of Economics and Energy through the AiF as part of the programme for the promotion of industrial joint research (IGF) on the basis of a resolution of the German Bundestag. The project is carried out at the Fraunhofer IGP and the Technische Universität Dortmund.

12 Automated flight planning



Inventory of fish larvae to reduce cannibalism-related wastage

Hardly any other sector of food production has experienced such a boom in recent years as aquaculture - and the trend is rising. As demand increases, so does the need for more efficient production. A big challenge to rearing lies in the cannibalism of piscivorous fish such as the perch. Due to the high sensitivity of the larvae, the previous selection process often led to marked losses. The goal of the project with the State Research Institute M-V (LFA M-V) is the development of an automated process for the careful inventory of larvae with the help of a multi-camera system and image / video data processing.

The LFA M-V operates the breeding stations of various fish species at the pilot plant at Born. This is where scientific studies concerning different environmental influences are carried out. The reproduction of fish is the main task of the plant and this serves as a basis for further research. A major obstacle is the cannibalistic eating behaviour of the fish, which leads to a minimisation of the stock even in the case of small size deviations of approx. 10%. In order to prevent this, the uptake and evaluation of the fish stocks begins at the larval stage. The determination of the quantity and size of the fish larvae is carried out manually, two weeks after hatching. The number of larvae is estimated through sampling and is therefore relatively inaccurate. The sensitivity of the larvae to environmental influences is very high, which leads to losses at each count. The goal is therefore to develop a system that guarantees automated counting and sizing with sufficient accuracy.

The solution for this task consists of a means for optically detecting fish larvae based on a multi-camera system and automated image analysis. An important requirement for stocktaking is sensitive handling of the fish larvae. For clear identification, the fish are recorded in a translucent and

luminescent basin. The developed software filters the image and video data, extracts the non-rigid objects and classifies the identified larvae in terms of size. The system that has been developed provides information about the inventory and the size of the fish larvae. The advantages lie in the reproducibility and comparability of the results as well as the careful handling of the fish larvae. In the course of the scientific investigations of the LFA M-V, the data that is produced can be used for statistical long-term evaluations. The system allows for automated stocktaking to increase production efficiency by preserving the larvae and is therefore suitable for transferring to fish breeding aquaculture basins.

Partners: Landesforschungsanstalt M-V – Institut für Fischerei, Rostock

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13 Schematic representation of the measurement setup

14 Fish larvae (6-8 weeks old)

15 Recirculation system of the LFA-M-V in Born

SELECTED PROJECTS



SUPER - one of a kind production in the field of shipbuilding with augmented reality

As part of the SUPER research project, digital tools and methods have been developed in cooperation with the TUHH, which significantly improve the flow of information in the equipment process between the shopfloor and the indirect areas such as quality management and production planning. Fraunhofer IGP developed a solution for making records regarding the state of construction and feedback on the shop floor.

Recording the state of construction in the ship

The shipbuilding equipment processes are characterised by a multitude of suppliers and service providers who need to install their components at the right time and in the right order. In process-related surveys at shipyards, the prevailing low level of digitisation in the field of reporting construction progress emerged as the main reason for lack of transparency. In turn, this not only leads to a lot of work in terms of coordination, but also to unplanned additional work and corresponding delays in planning the project.

In order to optimise the flow of information, a simple solution needed to be developed that allows an uncomplicated and cost-effective assessment of the state in the ship in order to serve as a database of information for all the companies involved. For this purpose, an application was developed for mobile devices. This serves the task of reporting orderly feedback concerning the construction status, faults and quality reports. After transmission, the reports that are recorded are shown in the indirect area by means of a dashboard app. This not only allows for faster intervention in the event of problems, but also the orderly documentation of the messages. Appropriate marking avoids the accidental overflow of messages.

Based on this, a simple method for recording the state of construction was developed using mobile devices instead of expensive laser scanners. In addition to lower costs, uncom-

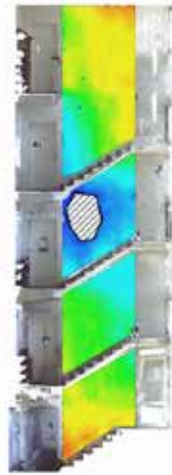
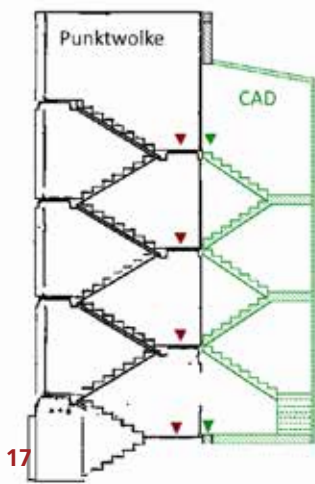
plicated operation is also an advantage. The use of specially trained staff for the registration is not necessary. This makes the method suitable for use in SMEs. A room or individual components are captured by video and then converted into 3D point clouds on a PC. These can then be compared with the present construction data in order to automatically obtain a list of installed components. The developed surveying method proved to be suitable for smaller assemblies. In order to capture an entire room, handy laser scanners (from the consumer sector) were tested and rated as more suitable. Due to the continuous development of the technologies for the acquisition of 3D data, the that has been developed will also be cost-effectively used for entire rooms in the future. Working on the automatic reconciliation of 3D point clouds against construction data in order to serve the different file formats of the shipyards and suppliers.

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Sponsorship: The IGF project “One of a kind production in the field of shipbuilding with augmented reality” (SUPER) of the Forschungsvereinigung Center of Maritime Technologies e.V. was sponsored by the AiF as part of the programme for the promotion of industrial joint research (IGF) on the basis of a resolution of the German Bundestag.

16 Digital survey of the state of construction in the ship



Industry 4.0-compatible approach to the data-integrated, intelligent and adaptive production of an elevator

Mobility impairment and age-related physical restrictions of tenants prevent comfortable living in apartment buildings without an elevator. However, the conventional procedure of subsequently attaching an elevator shaft to the outer facade does not allow barrier-free access to the individual floors. Therefore, in a joint research and development project together with Zurow Bau GmbH and the University of Wismar, the implementation of integrating elevators into existing stairwells was examined.

In order to ensure complete barrier-free access to all residential units and the basement in apartment blocks, a novel concept was developed for installing an elevator directly into the stairwell. A side of the stairwell is removed and this serves as space for the subsequently installed shaft. The new stairwell is mounted on the outside of the building. For the successful installation of the elevator that is introduced, the existing building and/or the installation space must have to be measured. As such, a significant part of the research work involved developing a measurement concept. This serves to determine the potential maximum dimensions of the lift shaft. Here, the peculiarity lies in the upstream measurement of the existing building, without having started with the construction measures. The use of a 3D laser measuring device allows for the evaluation and virtual measurement of the installation space within a 3D point cloud, wherein the subsequent investigation is automated with the aid of developed algorithms. Due to this, the construction project is accelerated because the design of the components is known of prior to the actual start of construction. The measurement data and final results are stored digitally. They serve as the basis for the manufacturing process. Another advantage of this measurement concept is the holistic digital recording of all information. The translation of analogue data into digital information is eliminated.

In order to further advance the digitisation of the information flow during the construction project, this was also examined. Media breaks and redundancies were detected and potentials for optimisation were revealed. Approaches to the initial digital capture of a potential construction project contribute to faster data collection. An enrichment of the data model with additional metadata increases transparency during the implementation of the construction project. **Digitalisation avoids mistakes and enables direct communication**, wherein the data model forms the basis for organisational handling during the construction phase.

A holistic view of all topics related to the implementation of this innovative approach contributed to the optimal design. In addition to the development of the measuring concept and optimisation of the technical support related to the construction projects, this included optimisation of the manufacturing processes as well as the actual realisation of the elevator.

Partners: Zurow Bau GmbH, Hochschule Wismar

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Sponsorship: The joint project "Industry 4.0-compatible approach to the data-integrated, intelligent and adaptive production of an elevator" was sponsored by the Technologie-Beratungs-Institut GmbH.

17 Holistic concept for data-related technically integrated production through to the installation of a subsequently installed elevator

NETWORKS, ALLIANCES AND COMMITTEE WORK

Fraunhofer Alliance Production

The Fraunhofer Alliance Production is a research and development partner for the manufacturing sector. More than 2200 employees from eight institutes and three Fraunhofer institutions make their know-how and experience available.

The Alliance was founded in 1998 as part of the Fraunhofer Institute, the largest organisation for applied research in Europe.

Responsibility for development and monitoring of the Alliance strategy and for cross-institutional public relations lies in the hands of the offices in Magdeburg. Chairman of the Alliance is Univ.-Prof. Dr.-Ing. habil. Prof. E. h. Dr. h. c. mult. Michael Schenk, vice-chairman is Prof. Dr. h. c. Dr.-Ing. Eckart Uhlmann. The office is managed by Prof. Dr.-Ing. Fabian Behrendt. Using the latest findings from production and engineering sciences and IT, the Fraunhofer Alliance Production offers a range of services covering the whole product life-cycle and the whole value-added chain. Research and industry have close and interdisciplinary links here. For example, the Alliance has a broad and varied offering of technologies and service to make companies fit - for the "Production of the future".

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Fraunhofer Alliance Traffic

Since March 2003, the Fraunhofer Alliance Traffic has bundled the traffic-relevant competences of various Fraunhofer institutes and institutions. The members of the Alliance have set themselves the goal of developing appropriate technical and conceptual solutions for public-sector and industrial clients through traffic-relevant research, and of making these available in practice.

Through close and topic-related cooperation, holistic system and alliance solutions and new fields of application can be opened up for customers in the traffic sector through know-

how transfer. This choice and bundling of widely differing competences ensures that solutions meeting the customers' requirements can be offered.

The member institutes are linked with traffic-relevant science and research companies worldwide through international research programmes. The offices of the Alliance help in finding the right partners.

www.verkehr.fraunhofer.de/en

Committee work

Center of Maritime Technologies

Prof. Dr.-Ing. W. Flügge – Member of the Technical Advisory Board

German Association for Welding and Related Processes e.V. (DVS)

Prof. Dr.-Ing. habil. K.-M. Henkel – Chairman of the state association M-WP

Maritime Alliance Baltic Sea Region e.V.

Dr.-Ing. J. Sender – Chairman

Kooperationsverbund RIC MAZA MV e.V.

Dr.-Ing. J. Sender – Member of the Board of Management

Technology and Innovation Group Business/Science M-WP

Prof. Dr.-Ing. M.-C. Wanner – Member

Scientific Association for Assembly, Handling and Industrial Robotics

Prof. Dr.-Ing. M.-C. Wanner – Member

Working group XXL products

Prof. Dr.-Ing. W. Flügge – Member

German Institute for Civil Engineering (DIBt)

Dr.-Ing. R. Glienke – Member of the expert committee SVA
“Metal structures and composite structures”

European Research Association for Sheet Metal Processing e.V.

M.Sc. M. Schwarz, Dr.-Ing. C. Blunk – Member – Joint committee DVS / EFB AGMF3/V10.3 “Mechanical joining” – Blind rivets and lockbolts

Dipl.-Ing. C. Denkert – Vice Chairman/Secretary – Joint committee DVS / EFB AGMF4/V10.4 “Mechanical joining” – Functional elements

Dipl.-Ing. C. Denkert – Member – Joint committee DVS / EFB AGMF7/V10.7 “Mechanical joining” – Design and calculation

Dipl.-Ing. M. Dörre – Member – Joint committee DVS / EFB AGMF4/V10.4 “Mechanical joining” – Functional elements

M.Sc. R. Staschko – Member – Joint committee DVS / EFB AGMF1/V10.1 “Mechanical joining” – Punch-riveting

Prof. Dr.-Ing. Ralf Glienke – Deputy Chairman of the Joint Committee DVS / EFB AGMF3 / V10.3 “Mechanical joining” - blind rivets and lockbolts

Society for Corrosion Protection e.V., Working Party Wind Energy (GfKORR)

Dipl.-Wirt.-Ing. M. Irmer - Member

Hanse Aerospace e. V., Hamburg

Prof. Dr.-Ing. W. Flügge – Member of the Technical Advisory Board

REFA State Association Mecklenburg-Western Pomerania e.V.

Dr.-Ing. J. Sender – Member of the Board of Management

Shipbuilding Association

Prof. Dr.-Ing. M.-C. Wanner – Head of the Expert Committee Work Organization and Production Engineering, Member of the Technical Scientific Advisory Council

DVS Committee for technology:

M.Sc. A. Gericke, M.Sc. O. Brätz – Member - Working group V 2.5 “Submerged arc and electro slag welding”

Prof. Dr.-Ing. habil. K.-M. Henkel, M.Sc. O. Brätz, M.Sc. B. Ripsch – Member – Working group V 4 “Underwater technology”

Prof. Dr.-Ing. habil. K.-M. Henkel, M.Sc. A. Gericke – Member – Working group A 6.1 “Welding in shipbuilding and marine technology - Welding processes, production”

Prof. Dr.-Ing. habil. K.-M. Henkel, M.Sc. A. Gericke – Mitglied – Working group A 6.2 “Welding in shipbuilding and marine technology - Damage to shipbuilding-related welded constructions”

Research association of DVS:

Prof. Dr.-Ing. habil. K.-M. Henkel, M.Sc. A. Gericke – Member– FA 03 “Arc welding”

Prof. Dr.-Ing. habil. K.-M. Henkel, M.Sc. P. Andreazza, M.Sc. A. Gericke – Member– FA 07 “Soldering”

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Working Groups of the International Institute of Welding

M.Sc. O. Brätz – Member – IIW Commission II “Arc Welding and Filler Metals”

M.Sc. A. Gericke – Member– IIW Commission XIII Working Group 2 “Techniques for improving the fatigue strength of welded components and structures

M.Sc. A. Gericke – Member– IIW Commission XII “Arc Welding Processes and Production Systems”

Forschungsvereinigung Center for maritime Technologies e.V (CMT)

Prof. Dr.-Ing. habil. K.-M. Henkel – Member – Member of the technical-scientific committee

NETWORKS, ALLIANCES AND COMMITTEE WORK

Expert activities

Working group of the industrial research association "Otto von Guericke" e.V.

Prof. Dr.-Ing. W. Flügge, Prof. Dr.-Ing. habil. K.-M. Henkel,
Prof. Dr.-Ing. M.-C. Wanner – Expert Assessors

Federal Ministry of Research and Technology

Prof. Dr.-Ing. M.-C. Wanner – expert assessor for the develop-
ment scheme "Innovative shipbuilding secures competitive
jobs"

Deutsche Forschungsgemeinschaft

Prof. Dr.-Ing. W. Flügge, Prof. Dr.-Ing. M.-Ch. Wanner – ex-
pert assessor

Standardisation work

Deutsches Institut für Normung e.V.

Prof. Dr.-Ing. R. Glienke – member of the Advisory Board NA
092 DIN standards committee welding and related processes
(NAS)

DIN standards committee welding and related processes

Dr.-Ing. N. Glück – member – NA 092-00-28-01: Process chain
bonding technology

Dr.-Ing. N. Glück – member – NA 092-00-28-02: Bonding of
composite fibre-reinforced plastics



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Equality and gender

For reasons of better readability, we have partly dispensed with the simultaneous use of female and male forms. However, this does not imply a discrimination of the female sex, but should be understood as gender-neutral in terms of linguistic simplification.

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