# PROFESSORSHIP OF PRODUCTION TECHNOLOGY AND PROFESSORSHIP OF JOINING TECHNOLOGY AT THE FACULTY OF MECHANICAL ENGINEERING AND SHIP TECHNOLOGY AT THE UNIVERSITY OF ROSTOCK

Universität Rostock Traditio et Innovatio

# Annual Report 2015/2016

Fraunhofer IPA

## FRAUNHOFER APPLICATION CENTRE LARGE STRUCTURES IN PRODUCTION TECHNOLOGY

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# 0 Preface

Prof. Dr.-Ing. M.-C. Wanner
Prof. Dr.-Ing. habil. K.-M. Henkel

- All the planned targets for the implementation of a Fraunhofer Institute in Rostock have been attained with the year-end closing for 2015. The number of members of staff at Fraunhofer AGP has increased to 62; the operating budget was raised to 5.4 million € for a share of industry project volume of approximately 45%.
- The search for a successor to Prof. Wanner has been greatly delayed. However, we are confident that this problem will be solved quickly. The construction work for the 4th new building programme has been finalised further and is progressing well. The medium-term goal is the expansion of the facility to 100 members of staff at Fraunhofer AGP.
- A special highlight in 2015 was the commissioning of our large robot at Mecklenburger Metallguss GmbH in Waren and numerous other robot applications at various small and medium-sized companies in Mecklenburg-Western Pomerania. We are also involved to an increasing extent with projects concerning the whole topic of Industry 4.0.

# 1 Introduction to the Facilities

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Professorship of Joining Technology

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Fraunhofer IPA

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Large Structures in Production Technology

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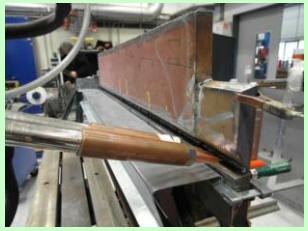
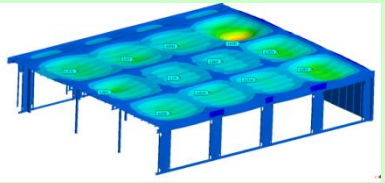
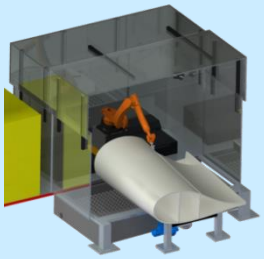
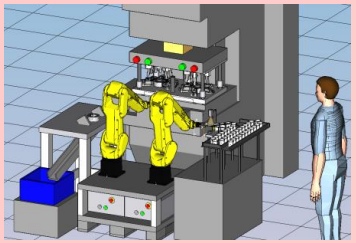
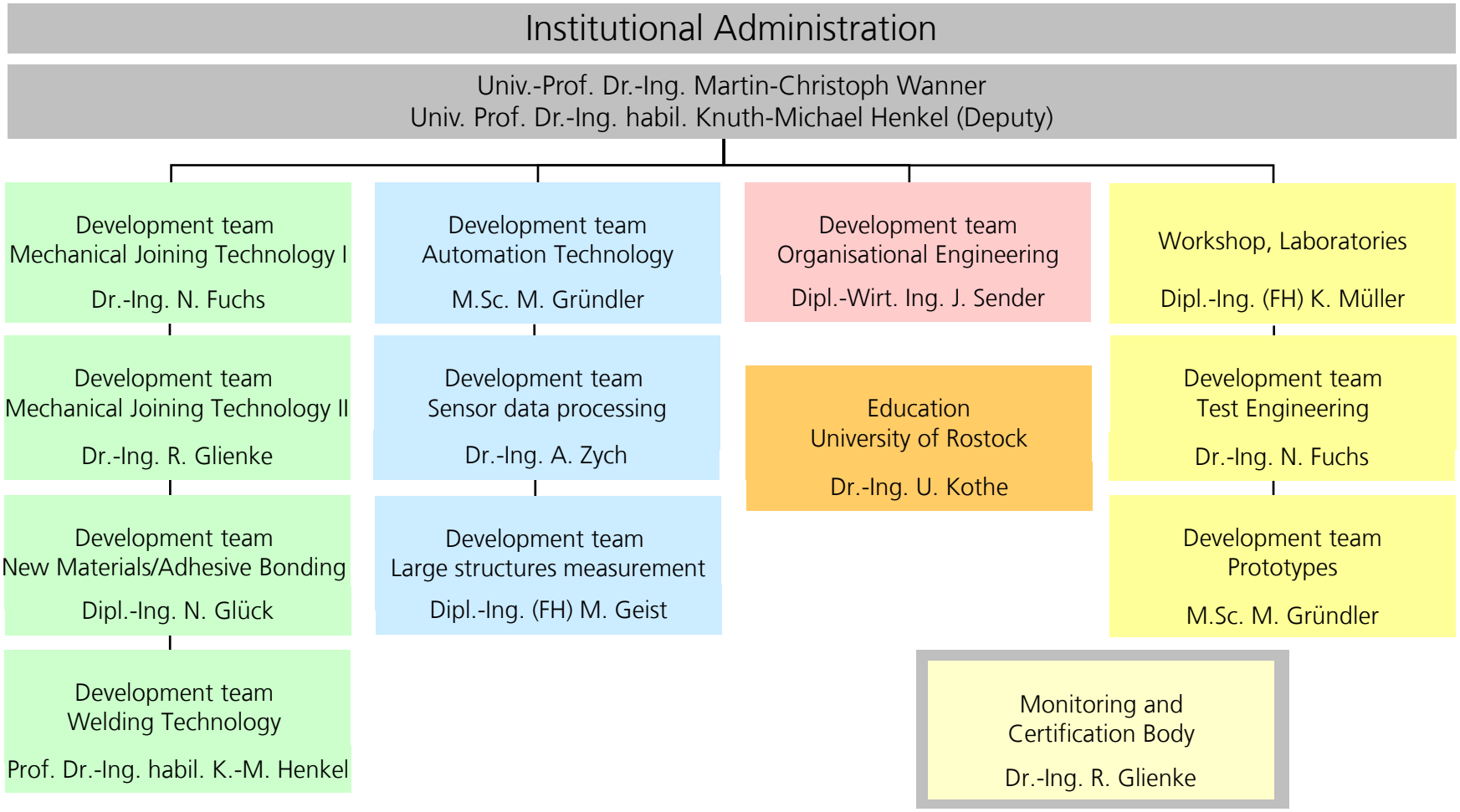
# 1.1 General

- The Fraunhofer Application Centre for Large Structures in Production Engineering (Fraunhofer AGP) is a branch of the Fraunhofer-Gesellschaft for the Promotion of Applied Research e.V., Munich.
- The Fraunhofer AGP cooperates with the Chair of Production Technology and the Chair of Joining Technology of the Faculty for Machine Engineering and Ship Technology of the University of Rostock.
- Both professorships are part of the Faculty for Machine Engineering and Ship Technology of the University of Rostock where around 1381 students are currently registered (as of winter semester 2015/16).
- The two facilities work closely together in research and education within the scope of a cooperation contract between the University of Rostock and the Fraunhofer-Gesellschaft that was renewed in 2012.
- The Fraunhofer AGP is a member of the Fraunhofer Alliance Traffic (Waterborne area) and of the MHI e.V. (Assembly–Handling Technology–Industrial Robots).

# 1.2 Research areas

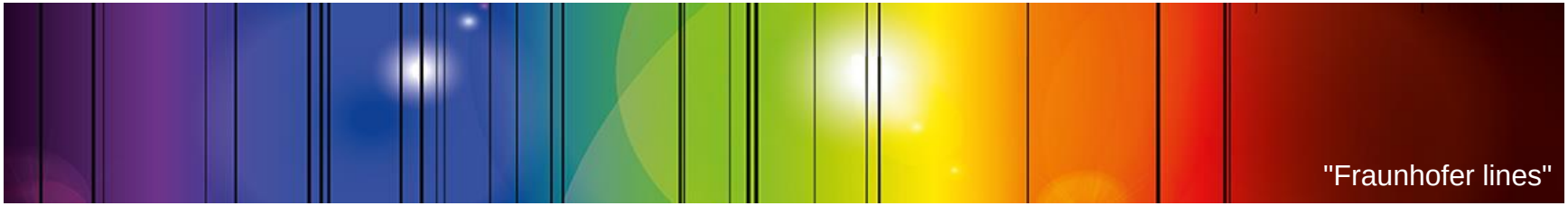
| Research area | Areas of focus | Maritime industry, offshore | Structural steelwork, aircraft, automotive and rail vehicle construction, wind energy | Regional research |
|---|---|---|---|---|
| Production Technology | Mechanical joining, welding, brazing, gluing, parting, forming, test engineering |  |  | |
| Automation Technology, Quality Technology | Measuring, sensor, robotic and control technology, measuring of large geometric structures, image processing, product development | | |  |
| Company and Production Organisation | Company concepts, cooperative networks, production organisation and logistics | |  | |

# 1.3 Organisation Chart



# 1.4 Fraunhofer-Gesellschaft
## 1.4.1 The Fraunhofer-Gesellschaft in profile 2015

- Application-oriented research which is of direct use to economy and of benefit to society
- 66 institutes and research institutions
- Around 24 000 employees
- Research volume: more than 2 billion €, of which around 1.7 billion € is in the area of research under contract
  - Fraunhofer generates more than 70% in this area from work commissioned by industry and with research projects supported by public financing
  - Around 30% is provided as basic financing by the Federal Government and the Federal States

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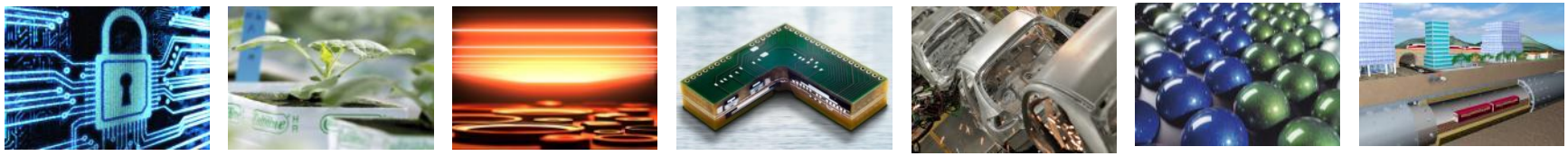
# 1.4.2 Bundling of competences through the networking of Fraunhofer Institute associations



Institutes in a similar area are organized into research associations and have a joint presence in the R&D market.

They take part in the corporate policy and also in the implementation of function and financing models of the Fraunhofer-Gesellschaft.

- Information and Communication Technology
- Life Sciences
- Light & Surfaces Microelectronics
- Production
- Material, components – MATERIALS
- Defence and Security Research VVS

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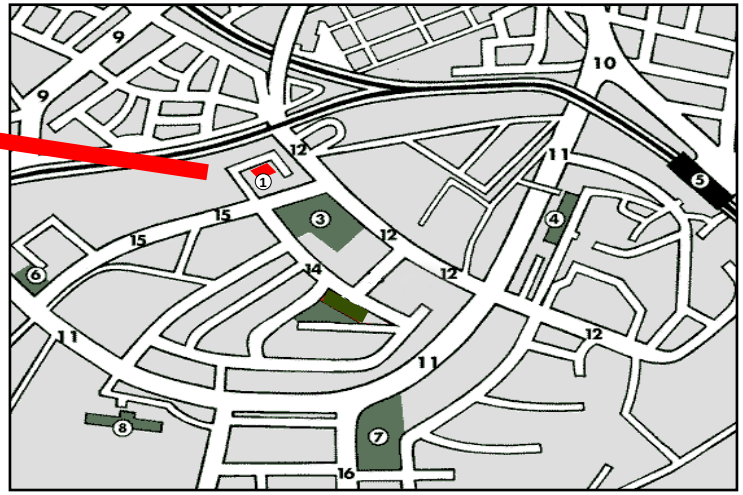
# 1.4.3 Locations of the Fraunhofer-Gesellschaft

Fraunhofer
research institutions
in Germany:

2015

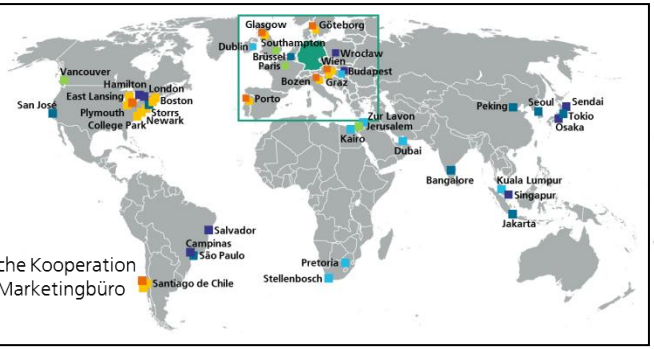
Fraunhofer Application Centre Rostock,
Albert-Einstein-Straße 30




1 **Fraunhofer AGP location Albert-Einstein-Straße 30**
3 Faculty of Mechanical Engineering and Ship Technology
4 Town hall
5 Main station
6 University library
9 Parkstraße
10 Goetheplatz
11 Südring
12 Erich-Schlesinger-Str.
14 Joachim-Jungius-Str.
15 Albert-Einstein-Str.

● Institutes and facilities
○ Further locations

Fraunhofer
locations
worldwide




- Niederlassung
- Center
- Project Center
- ICON / Strategische Kooperation
- Repräsentanz-/ Marketingbüro
- Senior Advisor

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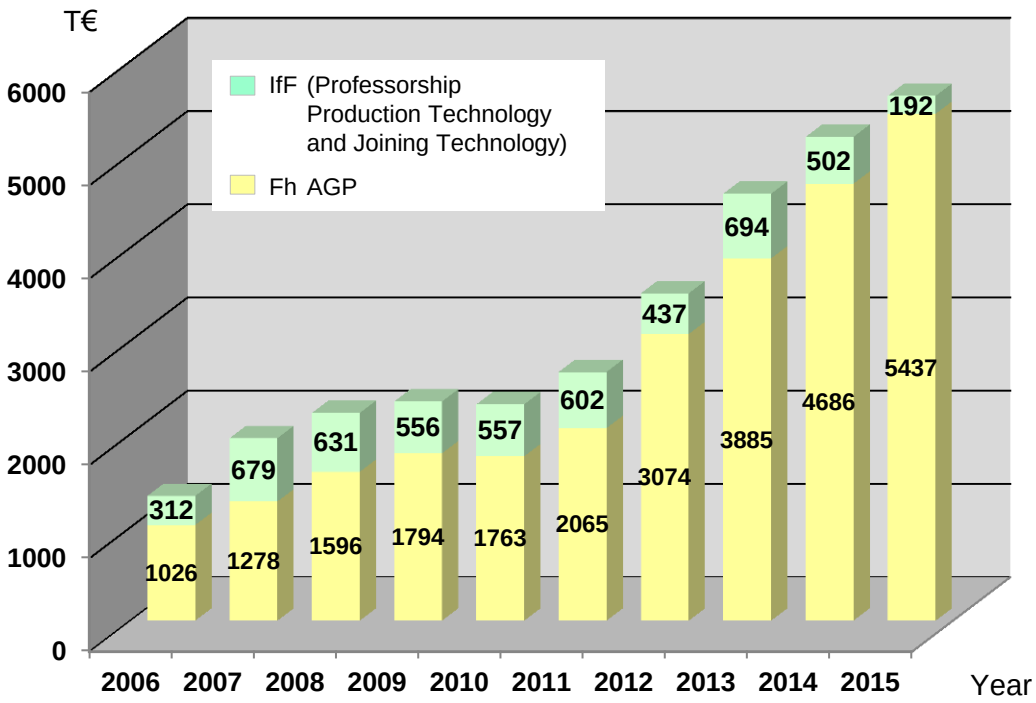
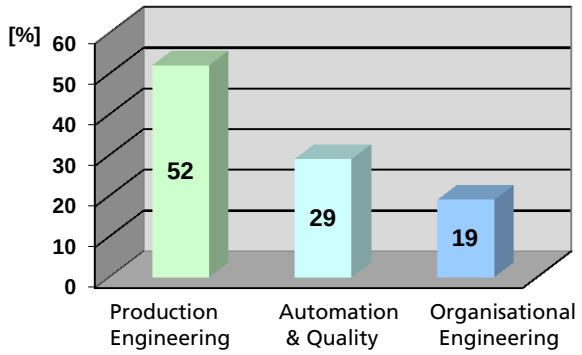
# 1.5 Development in Earnings of the facilities
## 1.5.1 Third party funding and its percentage distribution

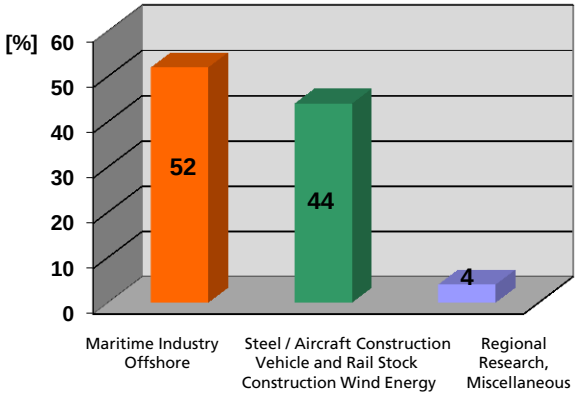
### Earnings development 2006-2015




### By research area 2015




### By branch 2015

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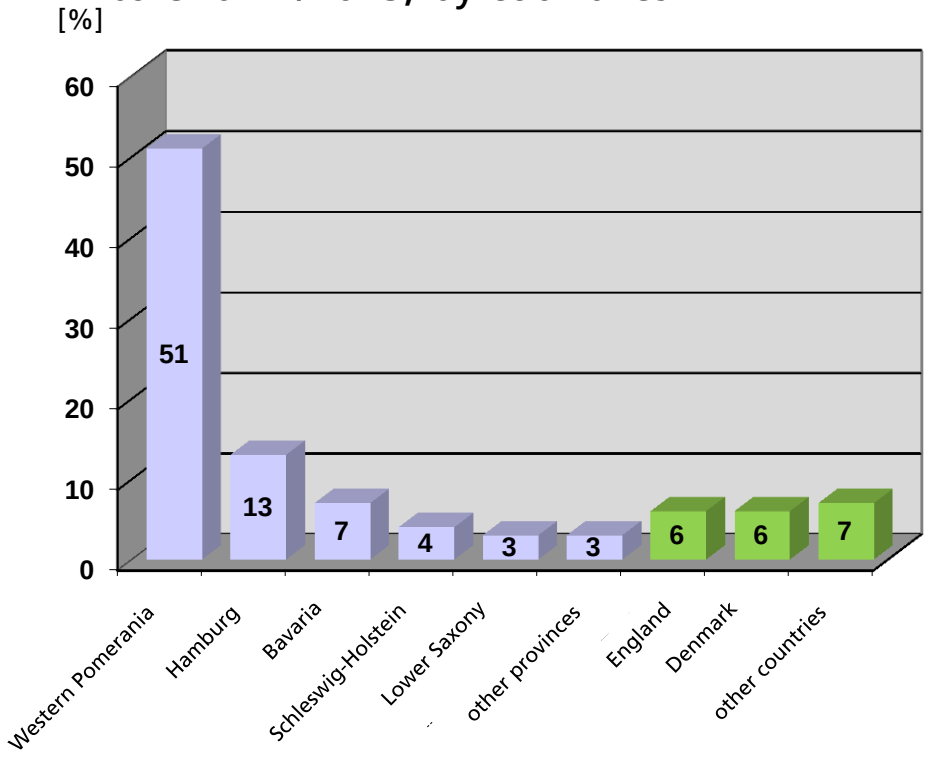
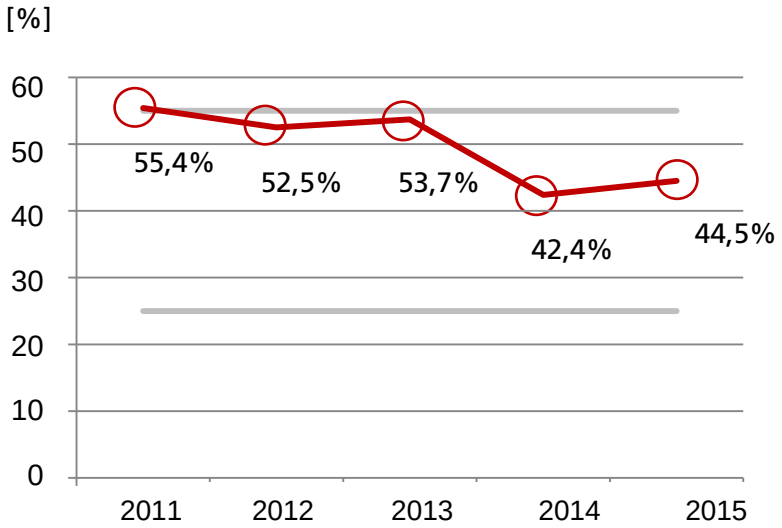
# 1.5.2 Industry project volumes

## Industry project volumes since 2006 to end 12/2015, by countries




## Share of industry project volume (ave. 49,7% in the last 5 years)



# 1.6 Staff
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* Established post Uni Rostock

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# 1.6.6 Scientific Assistants I (as of 5/16)

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**FhG and University of Rostock**

| Field: | | | Activities: | | |
|---|---|---|---|---|---|
| ET | = | Electrical Engineering | AT | = | Automation Technology |
| I | = | Informatics | FT | = | Production Technology |
| MBST | = | Machine Eng./Ship Technology | MT | = | Measuring Technology |
| WI-ING | = | Industrial Engineering | OT | = | Organisational Engineering |
| WIWI | = | Business Science | S | = | Others |

- J. Ahrndt MBST/AT
- L. Baumgart WI-ING/OT
- J. Berndt MBST/FT
- A. Bierwagen WIWI/S
- R. Bliesener MBST/FT
- D. Bludau WI-ING/OT
- K. Brandenburg WI-ING/FT
- V. Cherewko MBST/FT
- N. Cordt Geodäsie/MT
- K. Deking WI-ING/OT
- A. Dierke MBST/AT
- M.-T. Dube Lehramt/S
- D. Durain WI-ING/FT
- J. Gatzke MBST/FT
- A. Gerhards WI-ING/OT
- H. Gericke MBST/FT
- J. Graumann MBST/MT
- A. Haß MBST/FT
- F. Hauschulz MBST/FT
- M. Hayn WI-ING/FT
- P. Henke MBST/AT
- F. Holleitner MBST/FT
- C. Hoppe WI-ING/OT
- D. Humpert MBST/FT
- A. Hussein WING-ING/MT
- C. Jagow WING-ING/OT
- A. Jentsch MBST/AT
- D. Jericho MBST/OT
- M. Jeschky Geodäsie/MT
- B. Kamali MBST/OT
- O. Kappel MBST/FT
- D. Kelm MBST/FT
- J.-I. Kieser MBST/FT
- F. Knöchelmann MBST/FT
- C. Köhn WI-ING/MT
- F. Kolbe WI-ING/MT

# 1.6.7 Scientific Assistants II (as of 5/16)

**Scientific Assistants**
**FhG and University of Rostock**

| Field: | | |
|---|---|---|
| DLM | = | Management of Services |
| ET | = | Electrical Engineering |
| I | = | Informatics |
| MBST | = | Machine Eng./Ship Technology |
| WI-ING | = | Industrial Engineering |
| WIWI | = | Business Science |

| Activities: | | |
|---|---|---|
| AT | = | Automation Technology |
| FT | = | Production Technology |
| MT | = | Measuring Technology |
| OT | = | Organisational Engineering |
| S | = | Others |

- M. Koschay I/ OT
- J. Krause MBST/MT
- L. J. Kunz MBST/S
- T. Kureck MBST/AT
- D. Leingang MBST/FT
- L. Lemmermann WI-ING/OT
- J. Lindloff-Rühse MBST/FT
- H. Maaß WI-ING/AT
- T. Milbrandt MBST/AT
- P. Mönk WI-ING/FT
- T. H. Müller WI-ING/OT
- J. Neuhäuser WI-ING/FT
- S. Reiter ET/FT
- C. Reppin MBST/FT
- J. Reschwamm WI-ING/OT
- B. Ripsch WI-ING/FT
- T. Sachse MBST/OT
- S. Schankweiler MBST/FT
- F. Schmatz WI-ING/OT
- E. S. Schmidt MBST/FT
- M. Schmidt Lehramt/S
- P. Seebode MBST/FT
- R. Serduk MBST/FT
- L. Sixta MBST/FT
- R. Somodi WI-ING/OT
- N. Stepniak WIWI/FT
- A. Stöcker MBST/OT
- G. Szczypek MBST/FT
- T. von der Heyde MBST/FT
- H. Völzer MBST/OT
- C. Weinrich WI-ING/OT
- S. Witting WI-ING/OT
- J. Wollstadt MBST/FT
- F. Worschech MBST/FT
- M. Zickermann MBST/FT
- S. Zschau MBST/FT

# 1.7.1 Infrastructure (as of 5/16)

## Fraunhofer office and laboratory building

2545 m² usable area (offices, laboratories)

## Fraunhofer Laboratory

133 m² usable area (offices)
1060 m² usable area (test workshop, laboratories)

## Professorship PT and JT University

92 m² usable area (Südstadt production laboratory)
268 m² usable area (Warnemünde welding laboratory)

Laboratory and office building of the Fraunhofer Application Centre, Albert-Einstein-Straße 30

## Special Facilities

Laboratories for:

- Production Technology and machine tools
- Automation and robotics
- Production measurement technology, large structures measurement
- Test Engineering/CIT body
- Welding Technology
- Mechanical joining technology
- Adhesive bonding technology
- Refrigeration engineering, conditioning chamber
- Virtual reality
- Industry 4.0

# 1.7.2 Selected large machines and software (as of 6/16)

## Machine tools

- DMG turning-milling centre LTX beta 1250 with opposed spindle and 16x star turret
- Deckel Maho 5-axis universal milling machine DMU 100 mono Block with 32 magazine slots
- Bridgeport 3-axis machining centre VMC 600-22
- Böhringer boring mill DUS 40 ti
- Flat grinder HFS 3063VC
- Pillar drilling machine Eppler UTM80 DIGI
- Tile saw, belt grinder
- Two hydraulic laboratory presses

## Welding and cutting facilities

- Four-wire submerged arc welding unit Lincoln including peripherals
- Single-wire submerged arc manual welding unit Lincoln including peripherals
- Electro-gas welding unit Mini Vertomatic NC/W (ESAB)
- Electro-gas arc welding unit Hyundai SS-EGW DIGITAL-1W
- SMAW high-power current source Lorch (Speed Puls, Speed Arc)
- Inverter power source for SMAW tandem welding (Time Twin Digital – Fronius)
- Plasma cutting device Kjellberg with power source Hi Focus $^{plus}$ 160i and hand plasma cutting unit CUTi 31
- Plasma parting device Kjellberg with inverter power source Trans Plus Synergic 4000 from Fronius integrated into robot system KUKA KR15

## Software for calculation, simulation, design, production and signal analysis

- CAD (CATIA V5), CAM (EDGECAM)
- Electrical engineering (EPLAN)
- CAQ (3DCS Analyst, Geometric, CENIT)
- FEM (ANSYS Mechanical, LS DYNA, MSC.MARC, RSTAB)
- MKS (MSC.ADAMS)
- Modal analysis X-Modal III, SMART-Office-Analyser
- Perception S/W Package Advanced (signal analysis)
- Production simulation (Plant Simulation, Process Simulate, Robot Expert, DELMIA)
- Mobile 3D factory planning with visTable touch
- 3-D-Studio MAX, Poly Trans, Planungstisch IPA
- VR tracking system for ergonomic analysis (ICIDO)
- Processing of scatter plots (POLYWORKS)

# 1.7.3 Measuring technology and robotics (as of 6/16)

## Measuring technology

- 3D coordinate measuring machine CRISTA-APEX C574, Mitutoyo
- Measuring arm (6 axes) CIMCORE 3000i
- Laser interferometer Renishaw ML 10
- Measuring device for modal analysis VTI
- Measuring data recording device GENESIS
- Transient recorder YOKOGAWA 16 channel
- Thermal imaging camera (FLIR-Systems)
- Infrared camera Vario CAM

## Measuring of large dimensions

- 3D laser scanner, Z+F Imager 5010, range < 150 m
- 3D laser scanner, Faro Focus X130, range < 100 m
- 3D laser scanner, MENSI/TRIMBLE, GX, range < 200 m
- 3D laser scanner, MENSI/TRIMBLE, GS 26, range < 25 m
- 3D laser scanner, MINOLTA VL 9i
- Digitization system light stripe projection ATOS III, GOM
- Projection system Werklicht-Pro
- Leica laser tracker AT 901-B and AT 960 LR and T-Probe and T-Mac
- Photogrammetric measuring systems IMETRIC 610TP and AICON 3D-Studio
- Two 3D total stations SOKKIA MONMOS and SOKKIA NET 1200 (GLM)

## Robots/manipulators

- Processing and handling robot KUKA KR 500 with tools and highly flexible work piece holder
- Welding robot KUKA KR15 including sensors and peripherals (MIG/MAG Fronius) in gantry configuration (Güdel/IMG), working area 4,000 x 4,200 x 1,500 mm
- Welding robot KUKA KR5-2 arc HW
- Bosch assembly robot SR8 with image processing system force/torque sensor, various grippers and gripper changing facilities
- Lightweight robot UR 10-1,8 LV with gripper (Frei)
- Automated Guided Vehicle (AGV) Neobotix MPO-500
- Balancer Roosen (NL)

## Mechanical assembly facilities / mounting tools

- Riveting/clinching units TOX riveting pliers type TZ up to 100 kN and ultrasound-based clinching unit up to 60 kN
- Mounting tool with process monitoring 5,000 Nm
- Torque test stand Schatz up to 50 Nm and up to 500 Nm
- Eckold force former KF170 60 kN
- Pneumohydraulic press TOX 130 kN

# 1.7.4 Testing technology (as of 6/16)

## Test Engineering

- Servohydraulic test machine HB 1000 Zwick/ROELL
- Dynamic universal testing machine walter+bai LFV 63kN
- High-frequency pulsator ROELL HFP 5100 100 Kn
- High-frequency pulsator POWER SWINGMOT 100kN (Sinco Tec)
- Static testing machine Zwick Z400E 400 kN
- Compression test machine 50kN with temperature chamber
- Torque test stand Schatz 500Nm
- Imagic microscope system DM 600
- Reflected light stereo microscope OLYMPUS
- Helium leakage tester HLT 160/560
- Salt spray chambers and corrosion climate change tester (450 l and 1000 l), Weiss
- Conditioning cabinet 350 l (-70 °C to 180 °C, with humidity regulator)
- Rapid weathering device Q-Lab QUV/spray
- MHG grit-blasting unit SMG 25 S
- Atmospheric pressure plasma device Plasmatreat OPENAIR
- Precision cutting machine
- Hot bed press Opal 400
- Pendulum impact tester HIT 50P
- Pendulum impact tester PSd 450
- Hardness tester 432 SVD
- Ultrasound tester Krautkramer USN 60 and USIP 40
- Metal analysis unit SPECTROMAXx (optical emission spectroscopy)
- Layer thickness measuring device Leptoskop 2042
- Contact angle measurement device with tipping device, OCA 20
- Moisture generator Data Physics
- Tempering bath ST/Lauda
- Oxygen, nitrogen and hydrogen analyser (carrier gas melt extraction)
- Differential scanning calorimeter
- Rotation-type rheometer Thermo-Scientific Haakemars III
- Internal stress analyser Stresstech PRISM
- Dynamic-mechanical analyser (DMA)
- Sound level measuring device XL2-Akustik Analysator
- Infrared spectrometer Bruker ALPHA FT-IR
- Drop tester INSTRON-CEAST 9340
- Weld-Analyst S3

## 1.8 Purchases of new large machines

- In 2015 it was possible to make only the most urgent additions to new and existing projects.
- A main focus was on equipment for the highly precise guiding of robots in large workspaces with the aid of battery-operated laser trackers and upgrade investments for the direct determination of position and orientation (6DoF). This area is to be reinforced in future as well with activities in automated robot programming combined with image processing.
- In the plastics area an infrared spectrometer and a drop tester to determine the mechanical properties of plastics were obtained. These investments further round up our equipment for the testing of plastics.
- A system to record electrical signal characteristics during welding has become essential for various projects in this area.
- The simulation program MSC-ADAMS is now available for research in the field of dynamic behaviour and the design of the dynamics of robots and wind turbines.

# 1.8.1 Polymer analysis – infrared spectrometer

## Technical data

| | |
|---|---|
| Device | Bruker - ALPHA FT-IR spectrometer |
| Spectral range | 375-7,500 $cm^{-1}$ |
| Spectral resolution | better than 2 $cm^{-1}$ |
| Wave number precision | 0.01 $cm^{-1}$ |
| Interferometer | RockSolid, permanently adjusted, Cubecorner, Goldspiegel |

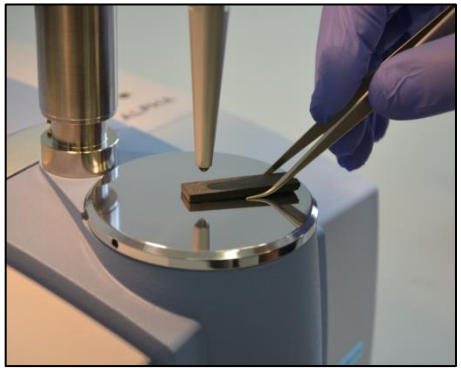
## Areas of use / applications

Structural clarification and the quantitative analysis of a mixture of substances by measuring the electromagnetic radiation

Quality control of raw materials up to the finished products
- Control of the identity of incoming substances

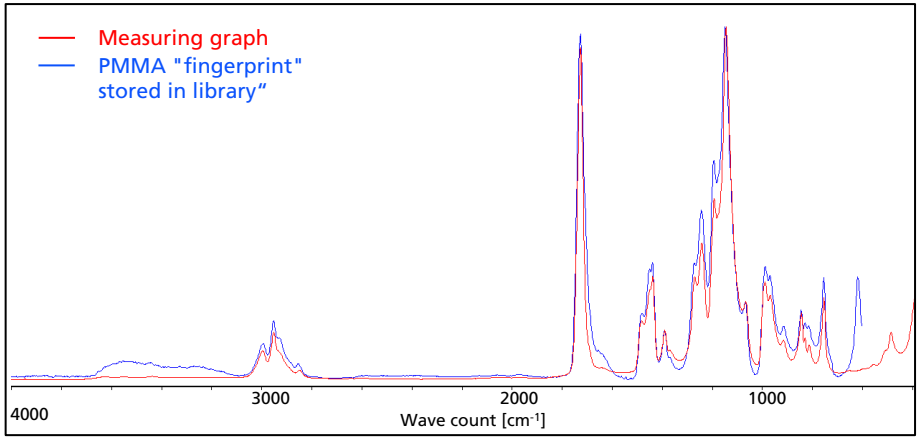
Quantification of included substances
- Determination of the concentrations of substances in a product

Identification of unknown substances
- non-destructive identification of unknown substances, e.g. in damage analysis



IR laboratory analysis of a solid

Mobile coating analysis in the field




Identification of polymethyl methacrylate (PMMA) through IR analysis

Fraunhofer IPA

# 1.8.2 Mechanical tests on plastics – drop tester

## Technical data

| | |
|---|---|
| Device | INSTRON - CEAST 9340 |
| Measuring principle | Drop tester for biaxial impact tests |
| Drop height | 30 to 1100 mm |
| Energy range | max. 405 J |
| Impact speed | 0.77 to 4.5 m/s |
| Drop weight | max. 37.5 kg |
| Special configuration | Instrumented drop bolt (up to 22kN)<br>Pneumatic anti-rebound device |

## Areas of use / applications

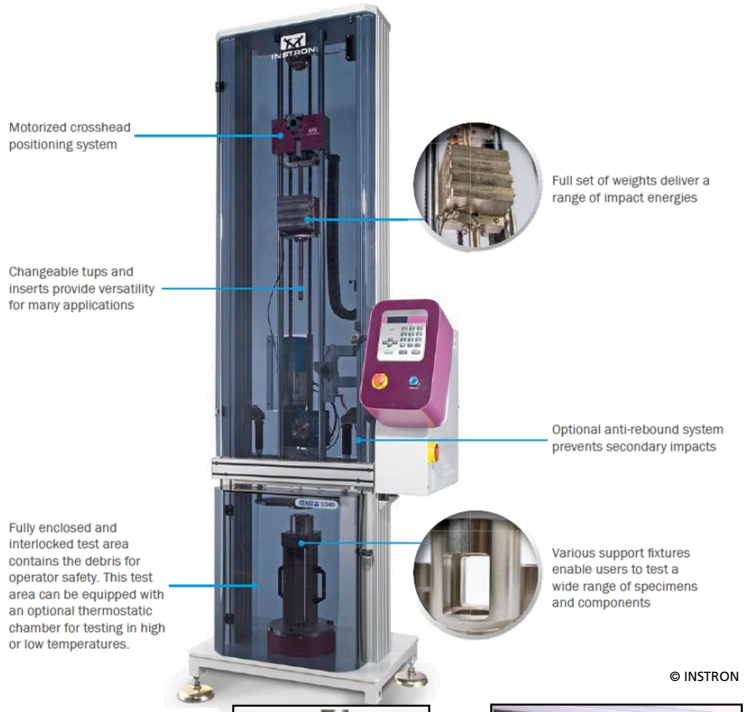
Determination of mechanical properties of polymer materials such as plastics, coating systems of composite fibre components or samples.

Investigation of the following procedures:

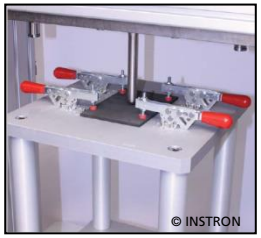
- Instrumented impact and penetration testing
- Compression After Impact (CAI)

Instrumented test results/specific values:

- Force
- Impact energy
- Deformation
- Speed vs time



Impact test on coatings and components




Compression After Impact (CAI) Test

Fraunhofer IPA

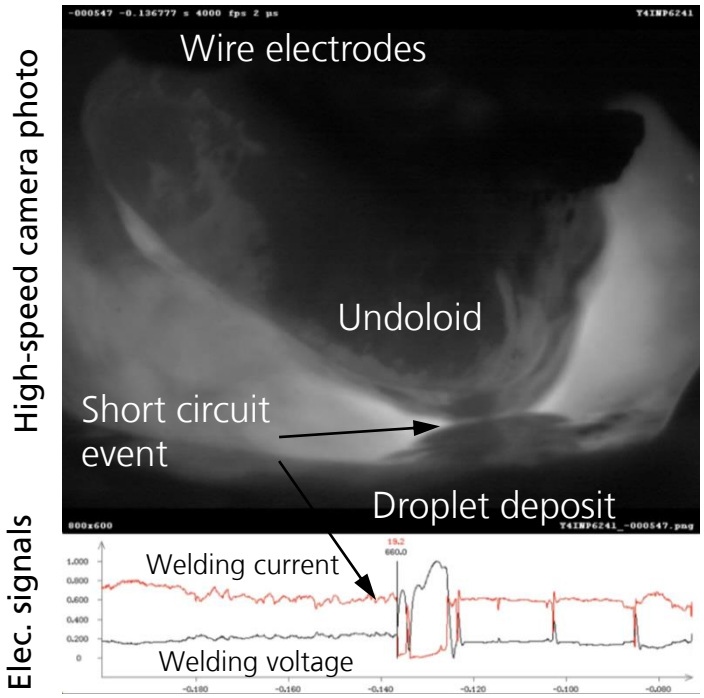
# 1.8.3 WeldAnalyst

## Technical data

- Modular system WeldAnalyst S3 to record electrical signal characteristics when welding
- Sampling rate up to 100,000 Hz
- 8 analog inputs
- 4 counter inputs for the direct recording of speeds
- Synchronisation of electrical signals/ high-speed camera

## Measuring configuration

- Two Hall sensors for measuring range 1,500 A, 100 V (HKS-P 1500-S3)
- One Hall sensor for measuring range 1,000 A, 100 V (HKS-P 1000-S3)
- Incremental encoder for filler wire speed (2 x HKS filler wire sensor DV 25 UP 3-5 mm S3, 1 x HKS filler wire sensor DV 25 ST MSG/TIG)



High-speed camera photograph during submerged arc welding (top left) with synchronised electrical signals (bottom left), HKS measuring equipment (right)

## Areas of use / applications

- Linking high-speed camera observation /electrical process behaviour of arc welding processes
- Correlation between transient electrical signal characteristics and weld seam irregularities

Fraunhofer IPA

# 1.8.4 Laser tracker for the tactile measuring of large structures

## Leica AT 960 LR

### Technical data

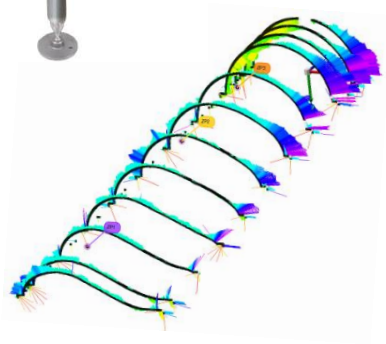
| | |
|---|---|
| Measurement volume | 160 m<br>360° horizontal<br>± 145° vertical |
| Measuring speed | 3000 pixel/s |
| Measuring precision | Distance precision (AIFM)<br>± 0.5 µm/m<br>Angle measurement<br>± 15 µm + 6 µm/m<br>Dynamic target detection<br>± 10 µm |

Leica AT 960 LR

Robot calibration and control

### Areas of use / applications

- Tactile measurement of large structures with very high precision, e.g.:
  - Master prototype, rotor blade and form
  - Alignment and testing of machine engineering elements
  - Determination of variations in shape and location
- Robot control and calibration
- Dynamic measurements with high sampling rates



Testing of rotor blade model

Fraunhofer IPA

# 1.8.5 Laser tracker extensions T-Probe and T-Mac

## Leica T-Probe

### Technical data

| | |
|---|---|
| Measurement volume | 30 m<br>360° horizontal<br>± 45° vertical |
| Measuring speed | 1000 points./s |
| Measuring precision | $U_{3D}$ = 100 µm<br>under 7 m |

T-sample

## Leica T-Mac

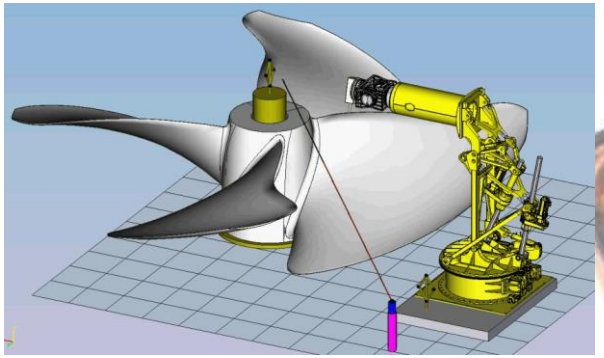
### Technical data

| | |
|---|---|
| Measurement volume | 30 m<br>360° horizontal<br>± 45° vertical |
| Measuring speed | 1000 points./s |
| Positioning precision | ± 15 µm + 6 µm/m |
| Positioning accuracy for a typical robot drilling application | 50 µm |

### Areas of use / applications

The area of application of the laser tracker can be extended in combination with the Leica AT 960 LR

- Additional determination of the orientation - measurement of all 6 degrees of freedom
- Tactile measuring of covered points on complex large structures
- 6D tracking by the robot controller in the automated machining of large components



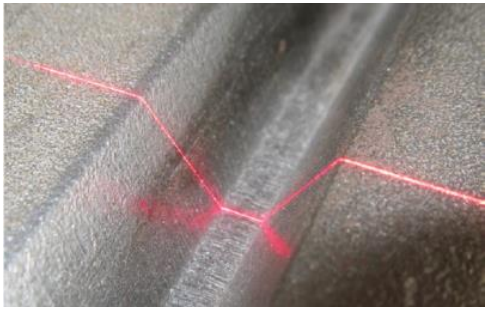
robot controller

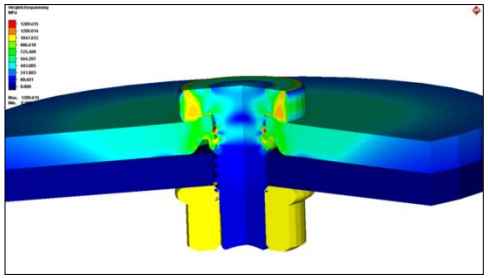
T-Mac

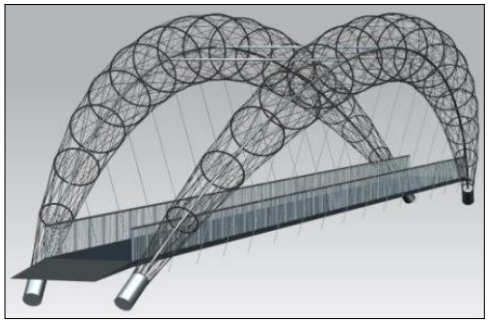
Fraunhofer IPA

# 2 Work Area:
## Production Technology

- The Welding Technology section concerns itself among other topics with the development of welding and cutting processes and systems in context with thick plates.
- The main focus of the development and work in Mechanical Joining Technology is on the qualification of procedures, new connectors, new setting devices and automated solutions, plus consulting services. Testing technology and the monitoring certification section are centralised in this area. The range of services offered covers experimental investigations in addition to consulting services.
- The adhesives, composite fibres and surface technology section develops new production and joining procedures for modern lightweight and mixed forms of construction, preferably large structures. A further main point of focus is the investigation of the efficiency and ageing of coatings under maritime environmental conditions.







# 2.1 Increase in the process reliability of SAW, procedure variations by means of optical analysis of the arc and the material transfer in the cavern – ProUP

´15 - ´16

## Problem

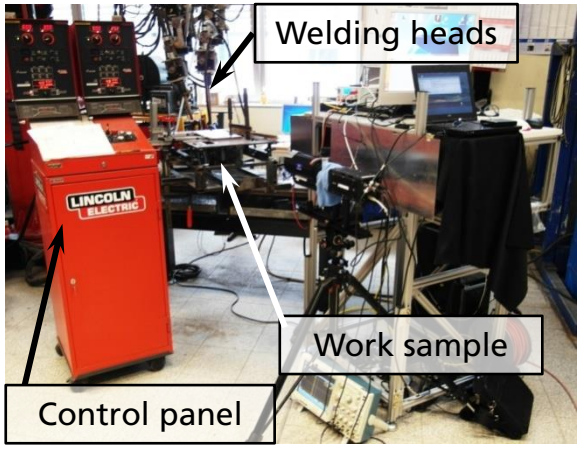
- An understanding of the process of submerged-arc welding as a widely used high-performance welding procedure in heavy steel structures is lacking due to the visual inaccessibility; this applies in particular to:
  - Correlation of electrical signal characteristics with process events
  - Chemical-physical interactions over time between droplets - slag - welding arc column; for example, the transfer efficiency of important alloying elements
  - Multi-wire processes with inverter-controlled current/voltage modulation

## Solution

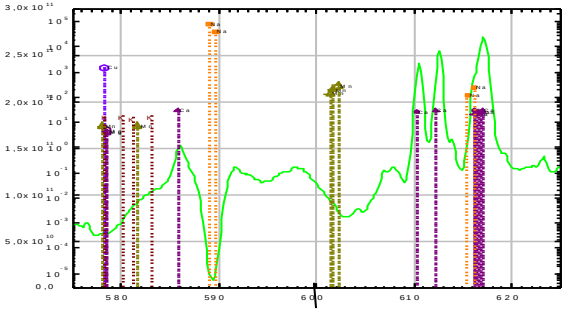
- Development of a methodology for real time welding arc diagnostics in submerged-arc welding with cinematographic high-speed photographs through a novel concept for tapping the cavern
- Correlation of the process events with the electrical signals and the welding results (mechanical technical properties; chemical composition) depending on the welding parameters

## Benefits

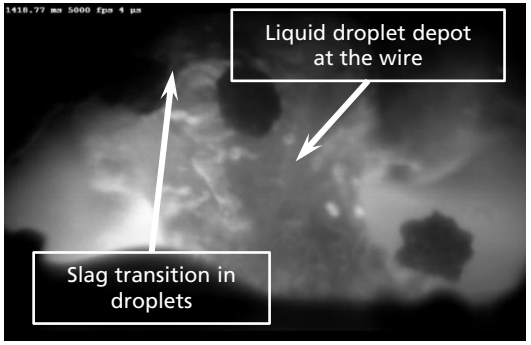
- Increase in the process reliability due to a greater understanding of the process
- Basic principles for quality assurance concepts through the correlation of the electrical signals with the welding results
- Compliance with the required chemical composition and reduction in overmatching




Test setup with high-speed camera in the foreground




Overview spectrum from the submerged arc cavern with intensities of existing elements




View into the submerged arc cavern with 5000 fps shortly before short circuiting

INP Greifswald · Fraunhofer IPA · DVS FORSCHUNG · AIF ALLIANZ INDUSTRIE FORSCHUNG

# 2.2 Development of a TIG-Twin process technology to increase productivity when welding aluminium structures

´14 - ´16

## Problem

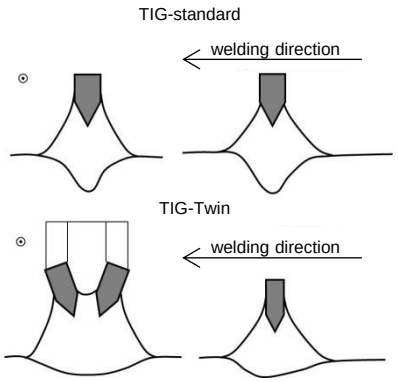
- The melting performance in TIG procedures depends on the energy of the welding arc (current strength)
- High current strengths lead to excessive high arc pressures and hence to severe turbulence and uneven penetration profiles
- As a consequence, the danger of undercuts, seam and root failures increases

## Solution

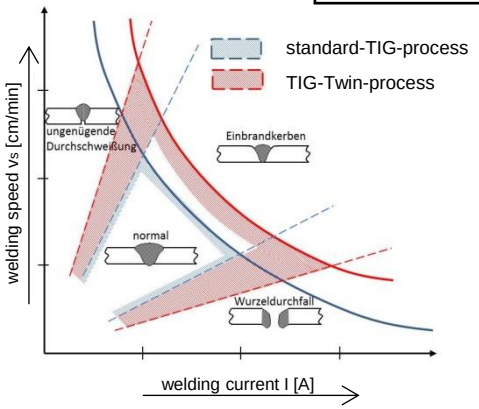
- Better distribution of the arc pressure through two electrodes
- Optimisation of media guiding and arc modulation
- Implementation of various DC and AC characteristic curves for optimal arc management

## Benefits

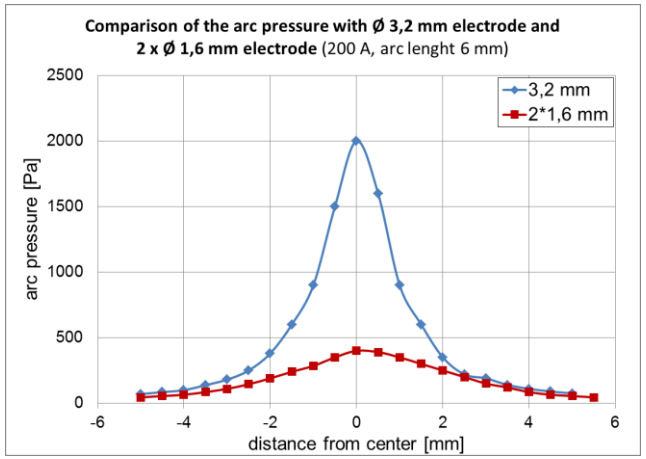
- Better flank/root formation, ability to bridge gaps, and energy coupling in aluminium joints
- Improvement in the mechanical technical properties by up to 20%
- Lower thermal stress, higher productivity and less wear




Penetration profiles of TIG standard and TIG-Twin procedures (schematic)




Expansion of the process window




Measurement of the arc pressure with single and twin electrodes for the same current

Fraunhofer IPA

MIKA SCHWEISSTECHNIK GMBH

# 2.3 Experimental investigation of welded joints for onshore wind turbines with a large hub height

´15 - ´16

## Problem

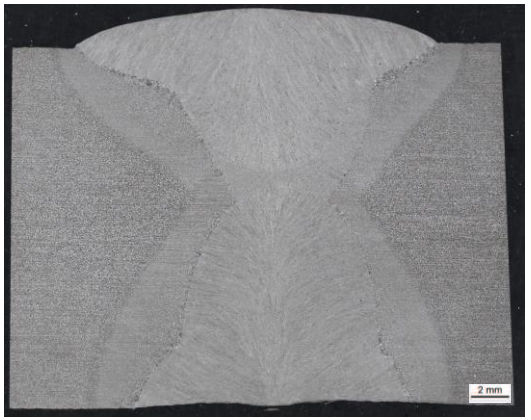
- Modern controller concepts for the operation of wind turbines, paired with large hub heights (> 140 m) place stringent demands on the lifetime of the welded joints.
- In this context it is highly desirable to increase the fatigue strength of welded joints.
- Welded joints in particular represent potential weak points.

## Solution

- Experimental investigations on the capacity to withstand static stresses and vibration of real welding details and evaluation
- Derivation of measuring rules conforming to EN 1993 (Eurocode 3)
- Increase in fatigue strength through suitable process, metallurgical and designs measures

## Benefits

- Ensuring the suitability for use of onshore wind turbines with a large hub height in conventional steel tubular tower structures
- Reductions in tower weight by reducing wall thicknesses




Macro-section of weld seam

N117/2400 Gamma
(2.4 MW, Fa. Nordex)

Fraunhofer IPA

NORDEX We've got the power.

# 2.4 Material- and process-related optimisation of cold gas sprayed cavitation erosion resistant coatings on ship rudders – WOBEKA

´15 - ´17

## Problem

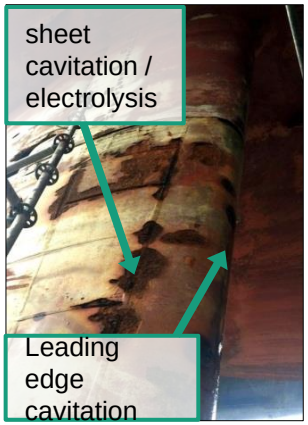
- Signs of erosion in the rudder and stern areas of fast-speed ships
- Countermeasures such as polymer coatings, build-up welding or sacrificial anodes are too time-consuming / limited.
- Docking and repair are required after 5 to 7 years high costs
- Cold gas spraying is very promising (see the BESOMA project), but requires optimisation regarding coating adhesion and residual stress conditions

## Solution

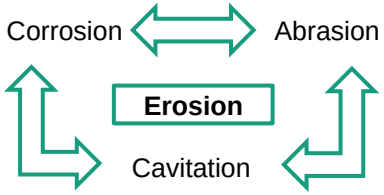
- Selection of materials of high hardness and durability such as ship propeller bronzes CuAl9Ni5Fe4Mn / CuMn13Al8Fe3Ni2
- The main focus of the research is on the subsequent heat treatment of coatings, their properties and their residual stress state
- Comparison with other coating processes, e.g. arc wire spraying

## Benefits

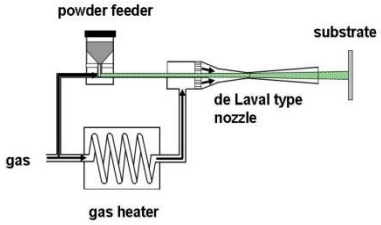
- Reduction in damage caused by erosion
  Increase of operating times and reduction of costs
- Seeking approvals with classification societies:
  Use of thermal spraying technology in the maritime industry



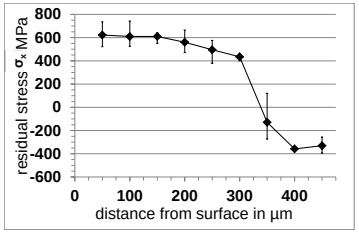

Container ship:
→ in operation since 2007
→ length ~ 210 m,
→ width ~ 28 m,
→ speeds up to ~ 18 kn




Damage due to erosion in rudder area of fast-travelling ships




Schematic diagram of cold gas spraying. The heated process gas is under high pressure and ensures the required particle acceleration to form a coating due to expansion in a Laval nozzle.




Residual stress depth profile of an arc-sprayed coating (coating thickness approx. 385 µm). Determined by means of Stresstech PRISM (modified drilled hole process using speckle pattern interferometry).

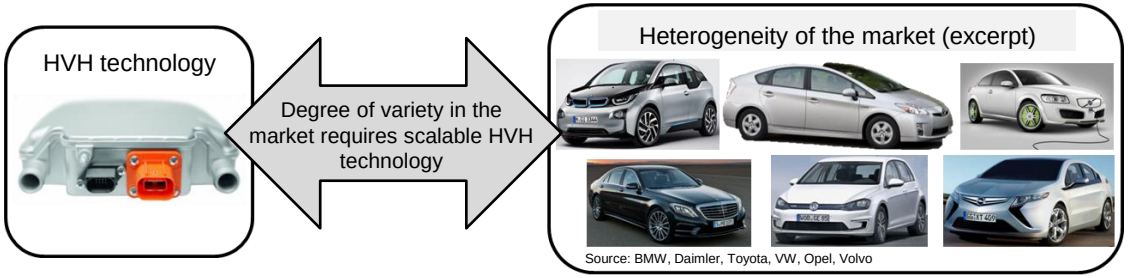
Fraunhofer IPA
Helmut Schmidt Universität Universität der Bundeswehr Hamburg
CMT
ALLIANZ INDUSTRIE FORSCHUNG

# 2.5 Technical feasibility study – scalable high-voltage heater (HVH) for the automotive industry

'16

## Problem

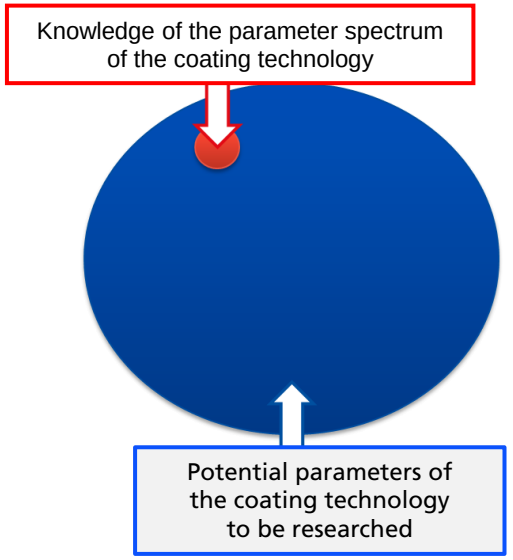
- Heterogeneous requirements of the automotive manufacturers for heating systems for electric and hybrid vehicles
- Required for widespread use
  - Scalability to suit customer requirements
  - Cost-effective production
  - Quality verification




Variety of versions in the automotive market in relation to HVH technology

## Solution

- Support in the coating characterisation for different product variations of HVH layer technology by means of conventional and novel test methodologies
- Concept development for quality assurance purposes and assistance in integration into complex production processes




## Benefits

- Flexible design of the HVH systems for various requirements is possible
- Reduction of production costs and times
- Contribution to the energy turnaround by improving innovative and environmentally-friendly products and quality assurance for the same

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Webasto Feel the Drive

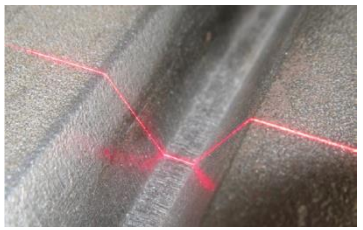
# 2.6 Production of welded structures for offshore wind installations using improved welding techniques – OWS-MV

´15 - ´18

## Problem

- The fully automated multi-layer GMA welding of thick-walled structures requires manual control of the welding torch
- Regarding submerged arc welding as a central production process for thick-walled structures, there are no real-time process monitoring and error detection systems and no comprehensive production documentation
- The resulting weld seam irregularities are only discovered after completion during testing and entail time-consuming and costly repair work
- Delays in the production cycle and throughput times

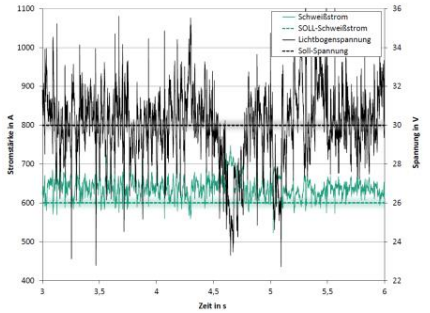
Offshore Wind Solutions Mecklenburg Vorpommern



Detection of weld joint geometry by means of laser line cutting technology for seam tracking in multi-layer GMA welding

## Solution

- Sensor-based seam tracking through laser line cutting technology for the partially automated GMA welding of thick-walled offshore structures.
- High-frequency online welding parameter analysis in submerged arc welding to monitor the behaviour of the electric arc and to detect process irregularities.
- Research into the correlation between transient current / voltage signal characteristics and the resulting weld seam irregularities.




High-frequency collection and evaluation of primary submerged arc welding process data for error detection

## Benefits

- Seam tracking in multi-layer GMA welding processes allows the production of complex base frame structures of offshore platforms to be automated and hence to greatly reduce the production time.
- Reduction in the costs for repair work in the submerged arc welding of thick-walled parts.
- A quality assurance and documentation scheme throughout the entire submerged arc welding process

**Weld seam OK/ NOK ?**

Fraunhofer IKTS

Fraunhofer IPA

nordic yards

WACHSTUMSKERNE UNTERNEHMEN REGION Die BMBF-Innovationsinitiative Neue Länder

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

# 2.7 Multiple-wire submerged arc welding with cold wire infeed – MUKz

´15 - ´17

## Problem

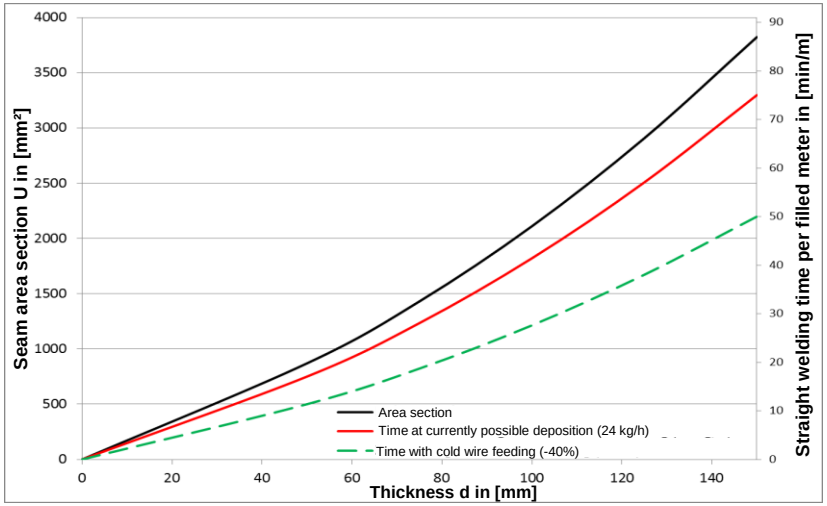
- The production of longitudinal seams on offshore foundation structures is very time-consuming
- An increase in productivity through an increase in the deposition rate and efficiency is set within narrow limits by the specification of the maximum energy input (35 kJ/cm)
- High thermal stress on the base materials and the weld metal (fusion time) lead to a reduction in the mechanical properties.

## Solution

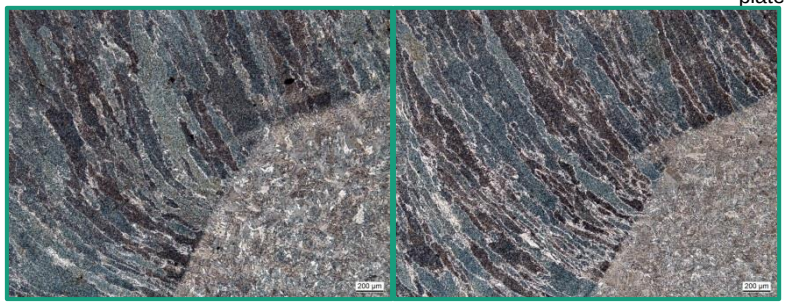
- Development of a process technology for multiple-wire submerged arc welding with cold wire infeed
- Development of a process to form a specific type of grain by means of cold wire infeed for multiple-wire submerged arc welding

## Benefits

- Increase in the deposition rate by up to 40% while at the same time reducing the energy per unit length
- Improvement in the mechanical-technical properties through grain refinement in the weld metal and the heat affected zone




Seam cross section and pure welding time depending on the thickness of the plate



Reference welding (t=15 mm) Cold wire infeed (grain refinement)

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EEW SPC

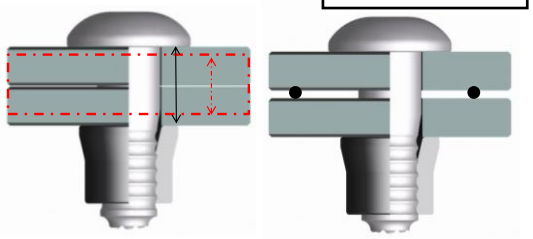
Technologie-Beratungs-Institut GmbH

# 2.8 Numerical and experimental investigation of irregularities in the installation process of lock bolt systems

´13 - ´15

## Problem

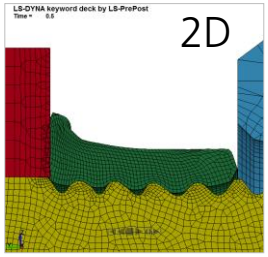
- The number of influencing factors on the lock bolt installation process is very large, as batch-dependent material and geometric properties, joint part flaws or other assembly irregularities affect the installation process.
- Current studies have not taken the influence of faults into consideration during the simulation of the lock bolt installation process
- The effects of a installation process fault on the load-bearing strength properties are unknown to date.

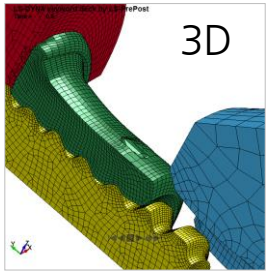


Faulty lock bolt joints

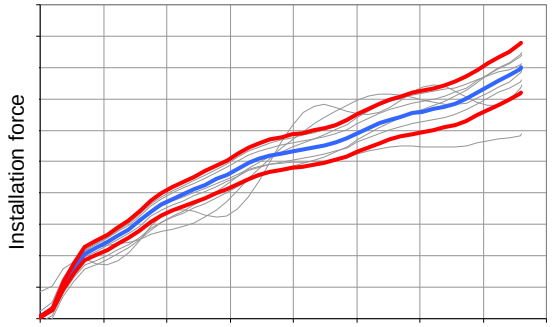
## Solution

- Selective study of the effects of an installation process fault using numerical and experimental methods
- Derivation of the installation process curves and comparison with reference curves
- Categorisation of the process irregularities according to their influence
- Sensitivity analysis with variable simulation models




Simulation models




## Benefits

- Reduction of the experimental effort involved in the definition of the installation process reference curves
- Identification of the process parameters with the greatest influence on the joint quality
- Extended process monitoring to determine the cause of the faults

Fraunhofer IWU

Fraunhofer IPA

EFB

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# 2.9 Preloaded hybrid connections with lockbolts as mechanical fastening in addition with adhesives

´13 - ´15

## Problem

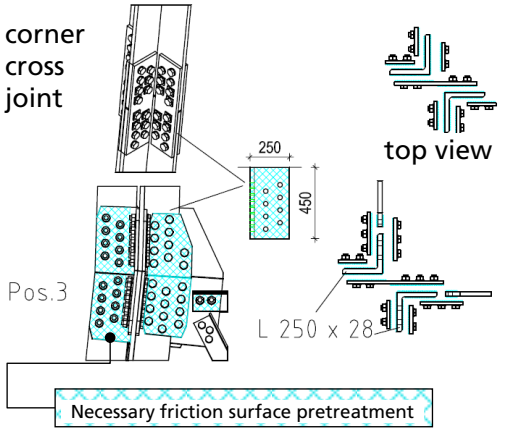
- According to relevant guidelines (DIBt, EN 1993-1-8, VDI2230, DIN 25201), where slip is not acceptable in structures (because of load reversal) preloaded bolts should be used
- Basis for the dimensioning are the preload $F_{p,C}$ and the slip factor μ (also: friction coefficient)
- Methods to increase the slip factor of over μ = 0.5 are either expensive or do not provide sufficient protection against corrosion

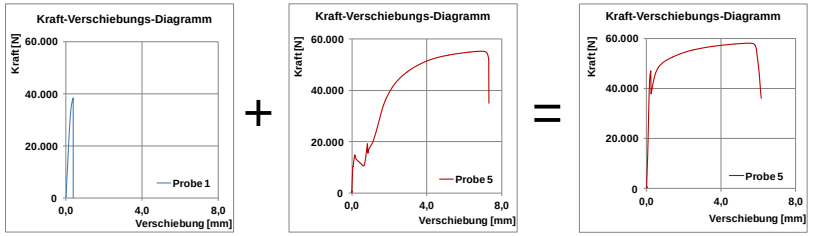
## Solution

- A "hybrid connection" is a combination of preloaded bolts (e.g. lockbolts) and adhesive (glue) in the contact area between the plates
- Preload measurement (strain-gauge BTM-6C) in the lockbolts during the slip load test
- Measurement of the displacements
- Test campaign to determine the slip factor μ according to EN 1090-2, Annex G

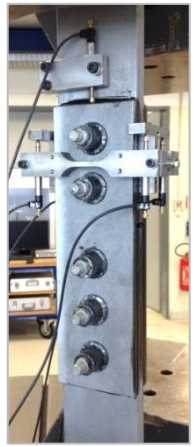
Source: www.butzkies.de

lattice wind turbine tower




elementary bonding | elementary lock bolt | lock bolt + adhesive



## Benefits

- Increase of the slip factor μ by combining gluing and preloaded bolts (e.g. lockbolt) in a slip resistant connection
- Gluing only on hot-dip galvanized steel plates will increase the slip factor
- Development of an handling guideline for "preloaded hybrid connections" for the steel structure in civil engineering, towers for wind turbines and rail way structures

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# 2.10 Stress limits for function element screwed joints

´13 - ´15

## Problem

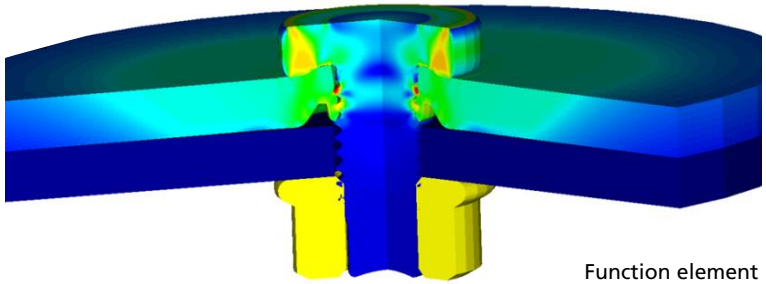
- Function elements are threaded elements that are inserted mechanically into the plate by stamping, riveting or pressing.
- The fastening section influences the screwed joint condition.
- The fastening section is difficult to describe geometrically.
- Small contact surfaces lead to local tension peaks and increased surface pressure.

## Solution

- Data collection of the fastening section by image recognition and transfer into a CAD model
- Transferability of the calculation for function element screwed joints within the meaning of VDI 2230
- Identification of excessive local stress in the area of the fastening section through numerical simulation

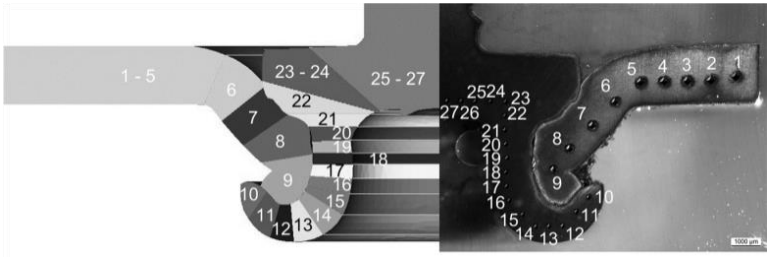
## Benefits

- Contribution to the DVS/EFB code of practice work for the reliable calculation of function element screwed joints
- Statements on the influence of the fastening section on the preloading force in cyclically and vibration-stressed function element screwed joints and small clamping lengths



Function element in FE simulation

Function element after pull-through test




Segmentation of the fastening section

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# 2.11 Join connections of lock bolts under atmospheric stress

´14 - ´17

## Problem

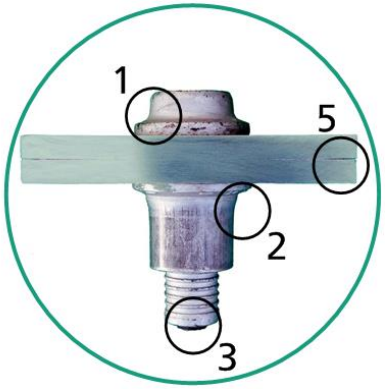
- Joints which are made of lock bolts were made in a cold forming process
- For tribological reasons this requires other surface protection systems than do screws or bolts (hot dip galvanising is not possible).
- Guidelines/codes of practice for a suitable corrosion-resistant form of lock bolt joints are not available.
- The influences of high surface pressures during the forming process on the protection against corrosion are not determined.
- Until now there had been no systematic investigation of the corrosion system for lock bolts

## Solution

- Collection of data on the relevant types of corrosion and identification of the corrosion mechanisms acting on lock bolt joints
- Comparison of the degree of corrosiveness between outdoor weathering and in laboratory tests

## Benefits

- Knowledge of the corrosion mechanisms and corrosion rate of lockbolt systems at outdoor weathering and laboratory tests
- Statements on the corrosiveness of exposure at various geographical locations




left: Lock bolt systems with critical areas for corrosion

above: Lattice tower with lockbolts

left: Outdoor weathering test

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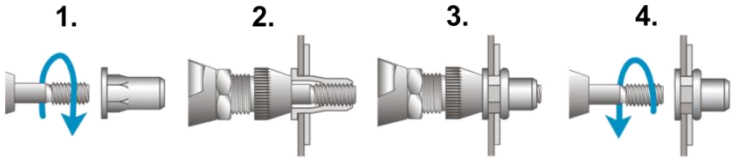
# 2.12 Comparison and analysis of various settling procedures to produce blind rivet-nut joints of appropriate quality

´15 - ´17

## Problem

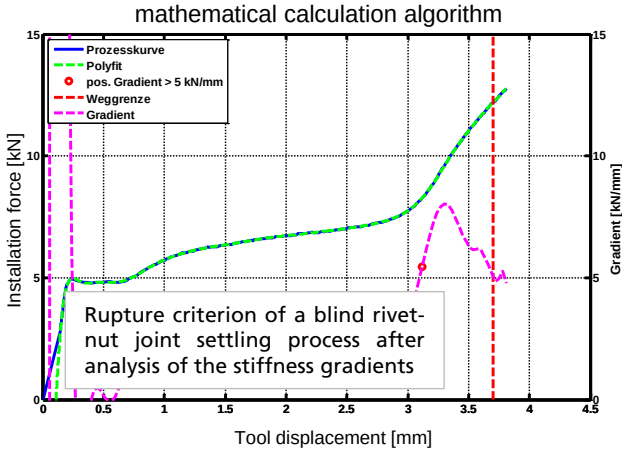
- The number of factors affecting the blind rivet-nut installation process is very high, since they depend on manual settings in processing machines the geometry of the blind rivet-nut and the properties of the joined parts.
- Previous investigations have not considered the installation process curve as a quality characteristic of a blind rivet-nut joint.
- In view of the high process forces during the shaping process, it can lead to undefined damage when using a blind rivet-nut in fibre-reinforced plastics.




Application process [Böllhoff]: 1. Spinning on of the blind rivet-nut joint, 2. Positioning, 3. Settling process, 4. Spinning off of the blind rivet-nut joint

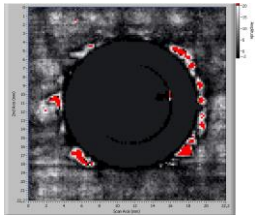
## Solution

- Specific analysis of the installation procedure with regard to varying process parameters
- Derivation of optimal process parameters from the load-bearing behaviour properties
- Process curve evaluation through mathematical calculation algorithms (stiffness analysis)
- Analysis of the damage behaviour in fibre-reinforced plastic by means of non-destructive test procedures (eddy current analysis)




## Benefits

- Optimal processing parameters with correlation to the load-bearing behaviour
- Algorithm for stiffness-monitored installation of blind rivet-nut joints
- Test concept for the non-destructive investigation of fibre-reinforced plastics by means of the eddy current process



Ultrasound reference measurement of a blind rivet-nut joint in fibre-reinforced plastic (laminate damage shown in red)

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# 2.13 Small clamping length factor

´15 - ´16

## Problem

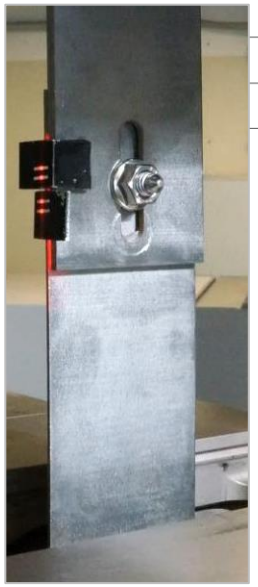
- Increasingly small clamping length-diameter-factors at slip resistant mechanical joined connections
- Uncertainty of the clamping force when using preloaded mechanical joined connections with small clamping length-diameter factors
- Dimensioning calculation of mechanical joined connections with small clamping length-diameter-factors is not possible until now

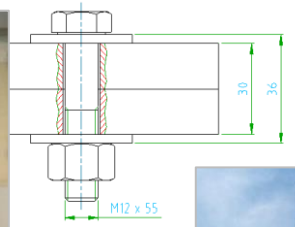
## Solution

- Development and extension of the test criteria for slip-load tests
- Experimental investigations of the effect of various parameters (temperature, hole geometry) on the individual slip load
- Measurement of the preload to describe setting and creeping effects

## Benefits

- Use of suitable joints for assembly with small clamping length-diameter-factors
- Evaluation of the suitability of various preloaded mechanical joined connections
- Achievable loading capacities of slipresistant mechanical joined connections can be calculated

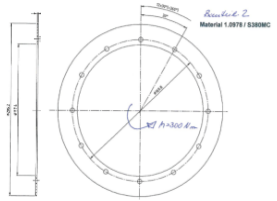





test block

Shell Tower

solar panel



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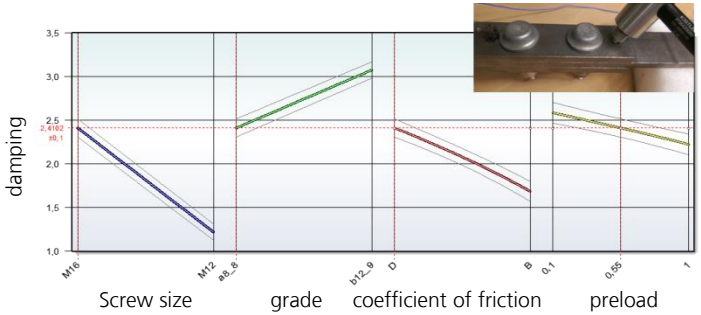
# 2.14 Use of maintenance-free lattice towers for wind turbines

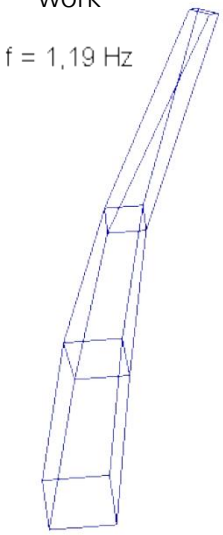
´13 - ´15

## Problem

- High cost of maintenance of the bolted connections in the lattice towers for wind turbines with large hub heights
- No targeted design of the join connection regarding optimal dynamic behaviour
- High use of materials due to a lack of consideration for the properties of the joint within the designing work




Factors influencing the damping of lockbolt connections that were investigated experimentally



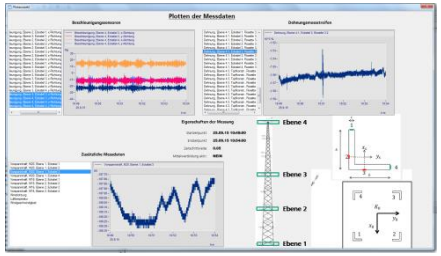

experimental modal analysis

## Solution

- Use of lockbolt systems as maintenance-free joining elements
- Characterisation of the properties of the joint in connection with an overall dynamic load simulation
- Integration of measuring monitoring through optical and mechanical measuring procedures for verification of the overall dynamic load simulation

## Benefits

- Efficient design and construction
- Simplified installation and erection
- Optimised operation through defined overall dynamic behaviour



experimental stress analysis

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STIEBLICH HALLENBAU
www.stieblich.de

Technologie-Beratungs-Institut GmbH

# 2.15 Increase of load-bearing capacity in eccentrically stressed joints due to the use of lockbolt systems

´15 - ´17

## Problem

- Eccentric stress on joints in steelwork and machine construction lead to a combined bending and tensile loading of the connecting elements that are used (e.g. bolted joints in a tubular steel tower)
- Additional bending reduces the fatigue resistance of the connecting elements
- Lockbolt system as an alternative method of joining:
  - Lack of knowledge of the load-carrying behaviour (lockbolt force function) and measurement of the eccentric stress

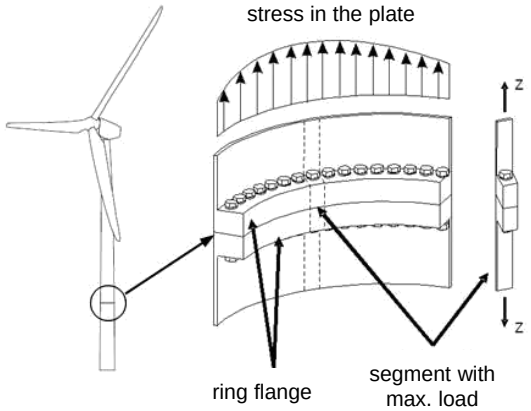
## Solution

- Characterisation of the influence of eccentricity on lockbolt joints:
  - Formulation of the lockbolt force function
  - Determination of fatigue strenght (notch type) of lockbolt joints under eccentric strain
  - Comparison with bolted joints
  - Segment settling for lockbolt joints

## Benefits

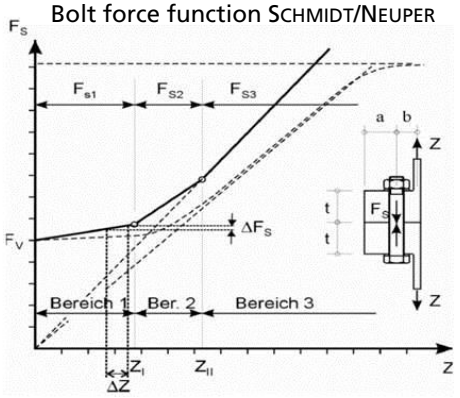
- Increase in load-bearing capacity associated with cost savings through:
  - Reduction of required nominal diameter
  - Reduction of the flange dimensions
  - Savings in manufacture and installation
  - No costs for maintenance and servicing
- Extension of DIN EN 1993 and EFB/DVS code of practice 3435-2

Modelling: Segment settling

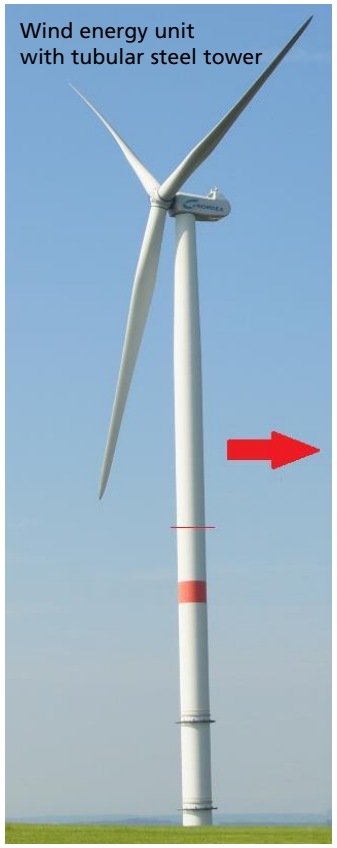



Source: SEIDEL – Design of flanged connections

Bolt force function SCHMIDT/NEUPER




Source: DIBt guideline for wind energy units (WEU)




Source: www.commons.media.de

# 2.16 Increase in joining point stiffness through Z-Pins in the mechanical joining of CFRP-metal hybrid structures – PLUGZ

´15 - ´16

## Problem

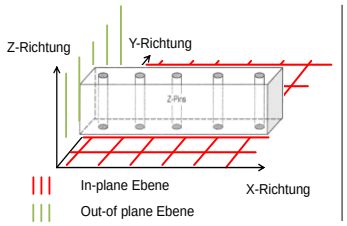
- Retardation processes in the composite fibre-reinforced plastics (CFRP) are caused in the mechanical joining of hybrid combinations of metals and CFRP materials with preloaded connectors.
- Retardation causes a drop in the preloading forces and thus places at risk the suitability of the join for use
- CFRP hybrid joins are preloaded less than metal joins and thus cannot withstand such high loads

## Solution

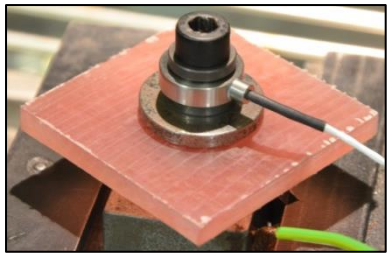
- Development of a form of reinforcement for the CFRP materials by using spot-fixing Z-Pin plates at the joining points
- Determination of suitable procedures for the production of CFRP joining points and the settling process parameters for mechanical joins

## Benefits

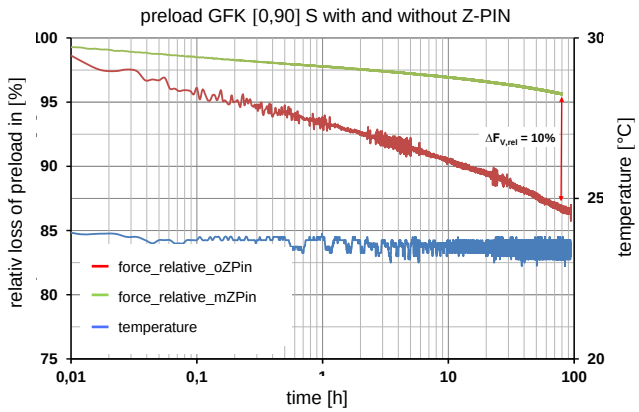
- Prevention of retardation processes and an increase in the stiffness at the point
- Increase in possible transferable loads for CFRP hybrid joins
- Increase in use of mechanical hybrid connections and hence an increased and wider use of CFRP in the construction of special machinery



Use of Z-Pin reinforcing plates in CFRP joints



Measurement of the loss of pre-loading force in CFRP hybrid joints and evaluation

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# 2.17 Execution and reliability of slip-resistant connections for steel structures using carbon steel and stainless steel – SIROCO RFCS - Project

´14 - ´17

## Problem

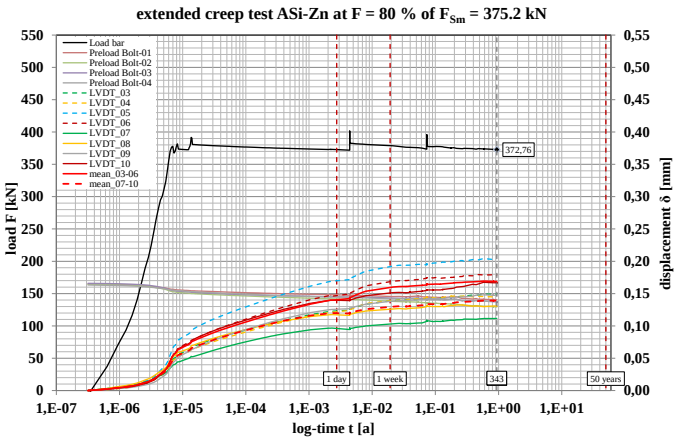
- The rules of DIN EN 1090-2, Annex G, for the determination of the friction coefficient cannot be clearly transferred for new types of coating systems and joints.
- In addition, the tests are very complex and the so-called displacement criterion to determine the slip load varies depending on the test pieces.

## Solution

- The displacement criterion will be jointly revised to ensure that the testing can be done economically.
- Developing of tightening procedures for lockbolts, H360, DTIs and new innovative surface coatings
- Extension of the use of injection bolts as an economic alternative to slip-resistant connections
- Dimensioning rules are to be drawn up for the first time for stainless steels.
- Further investigation of hot-dip galvanized structural steelwork constructions

## Benefits

- Slip-resistant connections are used in structures subjected to shear loads subject to stresses from vibration or load reversal (tensile/compressive fatigue stress), for example in wind energy units, bridges, cranes and radio masts.




left: evaluation extended creep test of a slip-resistant connection according to EN-1090-2, Annex G
right: long-term test-rig

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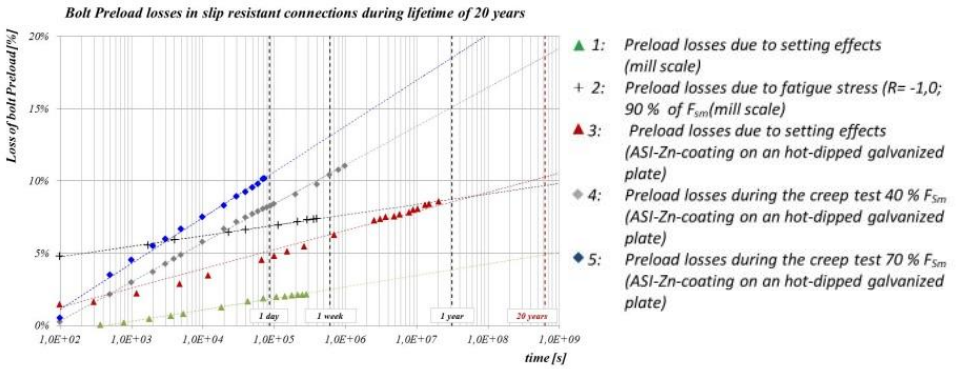
Research Fund for Coal & Steel

# 2.18 Losses of preload bolted joints under fatigue stress

´15 - ´17

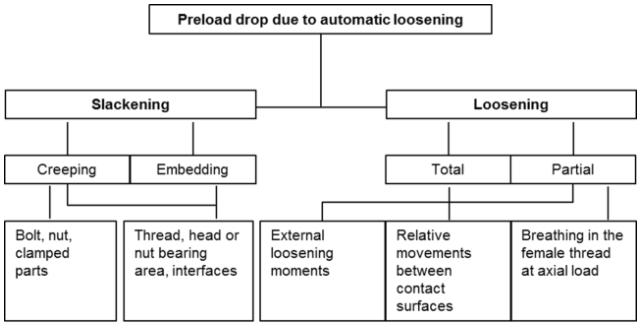
## Problem

- For bolted joints it is vitally applied that the preload remains in the joint over the working life of the structure to ensure its load-bearing capacity or suitability for the application.
- Preload losses $\Delta F_{p,C,tot}$ from various causes must consequently be estimated realistically at the stage of dimensioning a connection.
- Scientific investigations of preload losses in bolted joints under fatigue stress are not available.



## Solution

- Verification of the individual proportions of the preload losses as a result of setting and fatigue stresses for
  - Various fasteners
  - Various tightening procedures
  - Slip-resistant connections and tensile connections
  - Various forms of surface preparations



Source: Mauer & Söhne GmbH

## Benefits

- Makes the design of low-maintenance/zero-maintenance joints possible
- Optimal utilization of the remaining preload level

$$\Delta F_{p,C,total,t20a} = \Delta F_{p,C,setting} + \Delta F_{p,C,relaxation} + \Delta F_{p,C,transversal_contraction} + \Delta F_{p,C,longitudinal_tensile_force} + \Delta F_{p,C,loosening}$$

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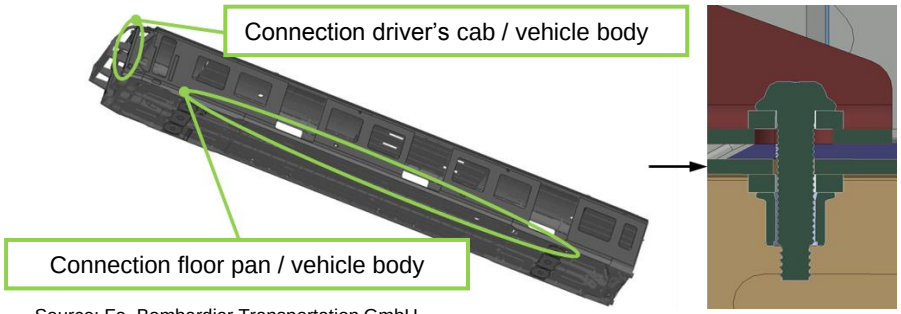
# 2.19 Analytical verification of slip-resistant connections joints with slotted holes for light metals and steel materials

´16 - ´19

## Problem

- Uncertainty concerning the loss of preload in slip-resistant connections connections with slotted holes
- The required calculation algorithms for slip-resistant connections with slotted holes that are primarily stressed by transverse forces are not available

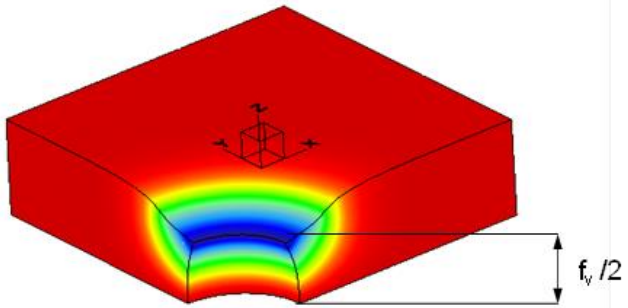



Source: Fa. Bombardier Transportation GmbH

## Solution

- Taking a combined and holistic look at the deformation cone with FEM analysis and experimental verification, the resilience of clamped parts of normal and slotted holes was determined and subsequently transferred to the calculation model within the meaning of VDI 2230-1.

Evaluation $u_{zz}$ to determine $\delta_p$




## Benefits

- Saving of costly and time-consuming individual tests for connections with slotted holes and further special joining configurations

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# 2.20 Threaded inserts for light metal screwed joints – GefüLe

´16 - ´19

## Problem

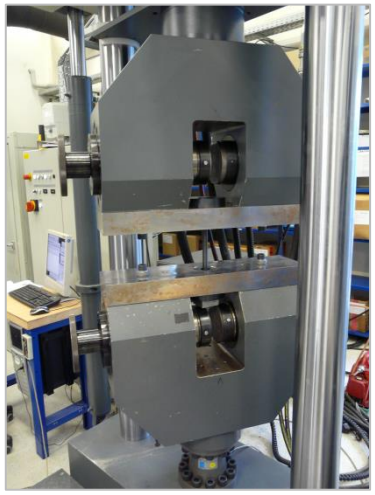
- Servicing and repair require repeatedly tightening up of the threaded insert
- The economic use of threaded inserts is only possible if the threaded inserts show technical advantages on compareson to cutted threads concerning repeatedly tightening up and the setting effects
- Verification of the design principle of the bolt or screw is not possible (lenght of engagement)!

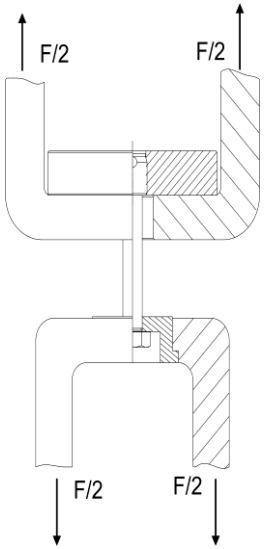
## Solution

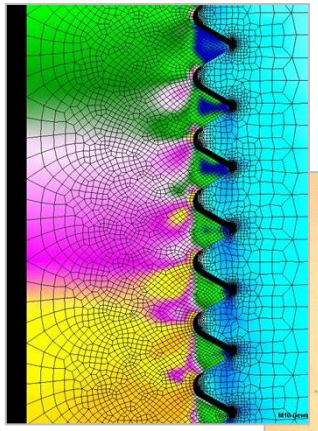
- Experimental and numerical testing of the theory of shearing cylinders for self-cutting threaded inserts
- Load-bearing capacity investigations with various lenght of engagement Torque / preload experiments to illustrate repeatedly tightening up

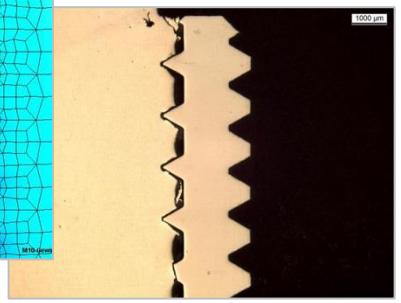
## Benefits

- Reduction of the lenght of engagement for preloaded screw fittings in light metals
- Statements on the axial load-bearing capacity based on the limit force concept
- Ensuring the load-bearing capacity of the self-cutting thread and the threaded hole







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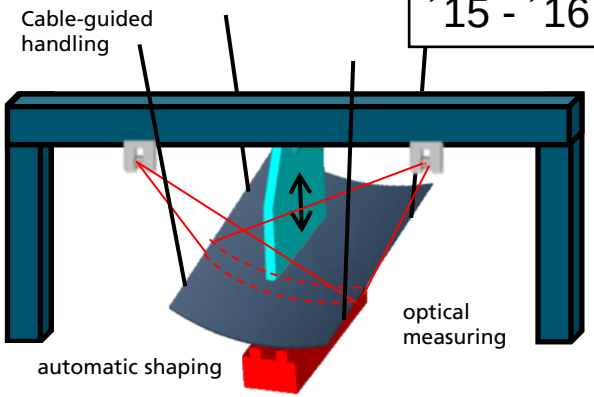
# 2.21 Feasibility study for handling system for automated cold plastic shaping – MHakU

´15 - ´16

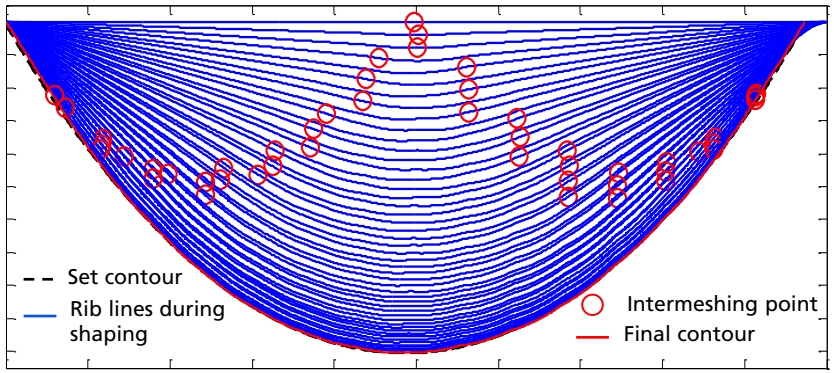
## Problem

- Efficient and dimensionally-conforming process planning to determine the bracing intermeshing point is currently based solely on the professional experience of the shaper
- The handling of the plate by purely manual control so that considerable load oscillation movements can occur
- The light gap method is used as the basis for quality control at the rib lines

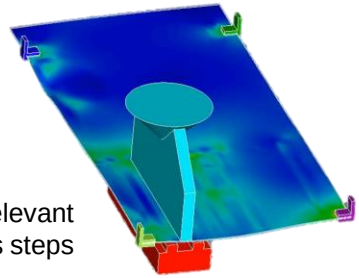



## Solution

- Analysis of the shaping process for development of an automated test sequence
- Development of substitute models to predict the plastic and elastic deformation as a basis for process planning and control
- Integration of inverse pre-control of the drives for cable-guided handling of the plate without load oscillations
- Use of 3D laser scanners to detect the actual plate geometry as a control medium for process monitoring and quality control




Example of automated process planning



FEM to reproduce relevant process steps

## Benefits

- Efficient automated and dimensionally-compliant process planning
- Implementation of any desired set contours through continuous process monitoring
- Optical measuring to make quality control more objective

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# 2.22 Holistic resources-efficient tower concept – GreT TP joining and installation concept – FüMoKo

´16 - ´19

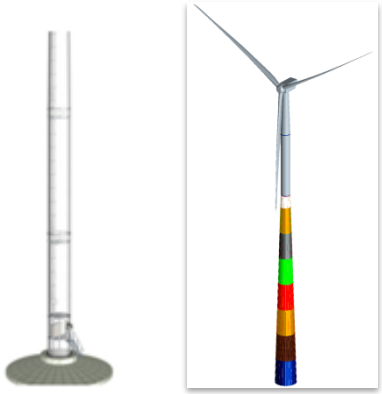
## Problem

- Current wind turbines often have very large hub heights (> 140 m) which increasingly allow economic operation even at onshore locations with weak winds
- Conventional joining and erection technologies for classical steel segment towers usually become uneconomic for the towers for wind turbines with large hub heights
- An increase in the hub height increases the costs for production, transport and erection of the wind turbine tower to more than 30% of the total costs of the unit

Extrapolation of future hub heights, depending on rotor diameter

## Solution

- Efficient solutions were developed as part of the sub-project (SP) *Joining and erection concept* (*FüMoKo*), which in addition to a longer service life also resulted in production and erection procedures for hot and cold joining technologies that can be automated and hence are more economic



Alternative segmentation of the lower tower elements

## Benefits

- Implementation of intelligent joining and erection procedures to supplement optimised system control and efficient tower design with the aim of saving weight

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# 2.23 Joining of metallic pipework in ship construction by bonding

´13 - ´15

## Problem

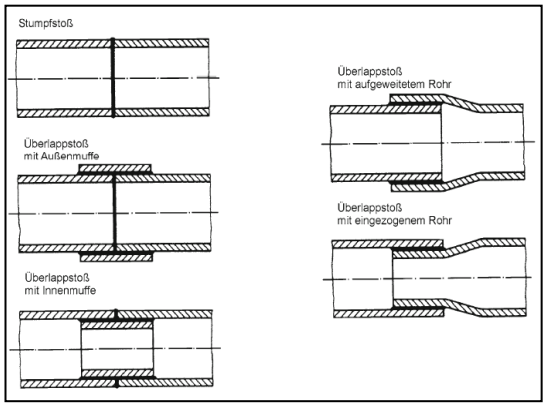
- Joints of pipework in ship construction are currently predominantly welded and in some cases mechanically produced.
- Mechanical socket systems are classified as non-maintenance-free and can therefore only be used at accessible points; they also allow only limits compensation of large tolerances.
- Use of welding methods results in destruction of the corrosion protection coatings of pipes and in the environment due to the induced heat.
- Confined spaces in the ship require welding in awkward positions which lead to higher error rates and a correspondingly higher need for repairs.

Top left: TIG-soldered double socket, top right: welded pipe connection, bottom left: mechanical pipe coupling systems

Source: www.teekaycouplings.de

## Solution

- Development of a bonding method for joining of metallic pipework
- Qualification of bonding processes suitable for the respective intended application
- Development of an application variant for the joining operation (low heat, production of maintenance-free joints, suitable for use in confined spaces, compensation of large tolerances) suitable for use under construction site conditions




Construction possibilities for joining pipes by bonding [Steinhilper, Sauer]

## Benefits

- Low heat input, thus eliminating the restraightening work
- Error rate reduced due to elimination of welding in awkward positions
- Reduction of repair and refinishing work (grinding out of flaws and rewelding)
- Time and cost-intensive installation of pipework in ships or offshore constructions simplified

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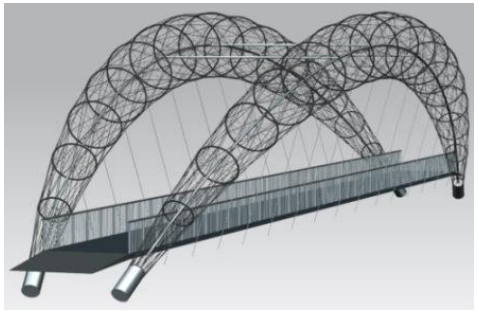
# 2.24 Development of carbon fibre-reinforced bridge systems with automatic production - E.B.a.F

´13 - ´15

## Problem

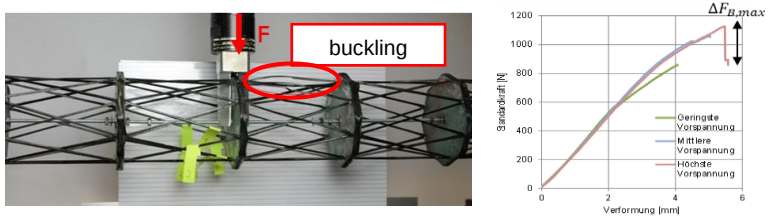
- Conventional bridge constructions using ferroconcrete required long construction times, they are sensitive to corrosion and have a high weight.
- Conventional bridges made of fibre-reinforced plastics (FRP) have a limited span (max. 50 m).
- Use of expensive semi-finished products (fabric, rovings) is required



arched bridge of cable-laying construction

## Solution

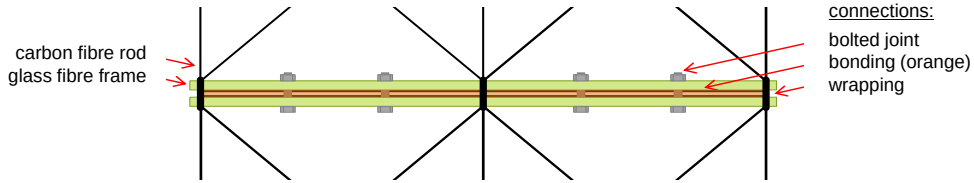
- FRP bridges on the basis of structures made of carbon fibre-reinforced plastics produced by the cable-laying process
- Development of novel joining technologies for individual bridge segments (arch and roadway) and structural adaptations
- Use of cost-effective rovings as semi-finished products




3-point bending test of an arch section for comparison of the bending progression under variable pre-loading forces

## Benefits

- Insensitivity to corrosion means lower maintenance costs
- High degree of prefabrication and weight reduction lead to a reduction in transport costs and construction time
- Longer spans are possible (> 50 m)
- Working load increased by 20%




top view: Schematic of jointing of the roadway deck

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Balti GmbH Composite Technology

ZIM impulse für wachstum Zentrales Innovationsprogramm Mittelstand

# 2.25 Small wind energy unit that can be used worldwide - GEK-WEA

´13 - ´15

## Problem

- High demand for energy generation units with high availability in regions with a decentralized power supply (e.g. Central America)
- Area of application of small wind turbines as prototypes only in temperate climatic zones up to now
- Lack of knowledge of the climatic limits in use
- Production of the rotors that are manufactured by hand is very time-consuming and results in unsatisfactory process reliability

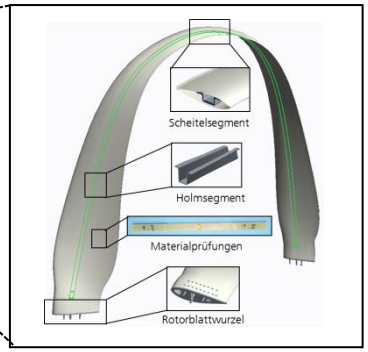
## Solution

- Development and use of new rotor materials in connection with new manufacturing procedures
- Development, testing and use of components that are appropriate for the stresses encountered (bearings, shaft, hub, etc.)

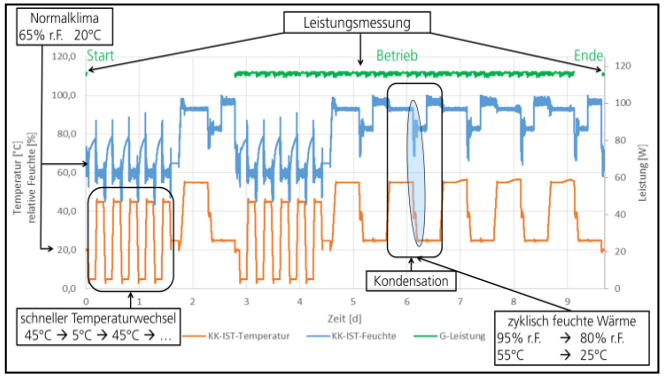
## Benefits

- Use of small wind turbines that are more resistant to climatic and ambient conditions with high availability and longer calculable lifetime
- Increase in process reliability and component quality
- Guarantee of decentralised power supply in regions with weak infrastructure

Prototype of a DELA rotor with an efficiency of approx. 40%




Production and testing of FRP rotor blade materials




Heat and humidity climatic cycles to determine the output power and the micro-climate inside the generator

Below the dew point at the surface of a component

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DELA ROTOR

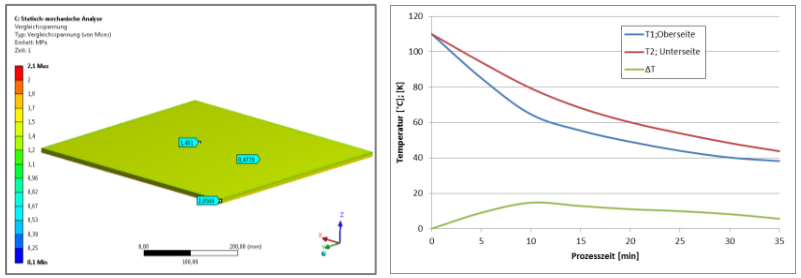
Technologie-Beratungs-Institut GmbH

# 2.26 Development of a flexible die – FLEXIFORM 1

´14 - ´16

## Problem

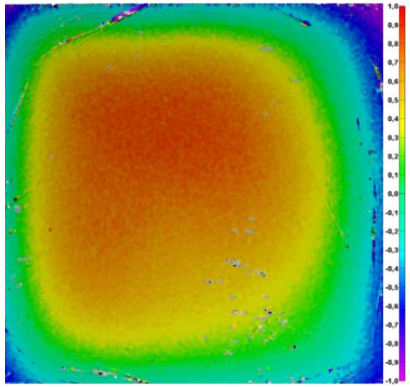
- Increasing demand in architecture for facades and roof covering with extreme shapes
- The three-dimensional direction-free shaping of thin metal sheets is technically complex
- High costs for reshaping dies lead to high production costs



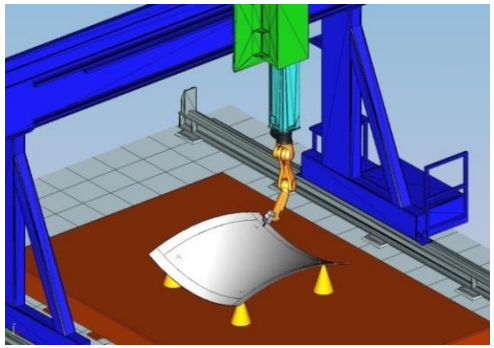

right: Simulation of the thermal internal stresses in the semi-finished product in the heating process, left: temperature gradient upper and lower side

## Solution

- Investigation of alternative materials that can be shaped on the basis of thermoplastics through empirical tests and numeric simulation
- Development of a shape-changing reshaping die
- Implementation of fully automated contour machining and dimensional compliance checking



Checking the geometrical dimensional compliance after recovery due to internal stresses, shaped semi-finished product 140°C vs. 20°C



fully automatic contour machining in the milling centre

## Benefits

- Construction of facades and roof elements with high levels of 3D shaping is possible
- Reduction of the production costs

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S+T FASSADEN GMBH
GEMEINSAM INDIVIDUALITÄT SCHAFFEN

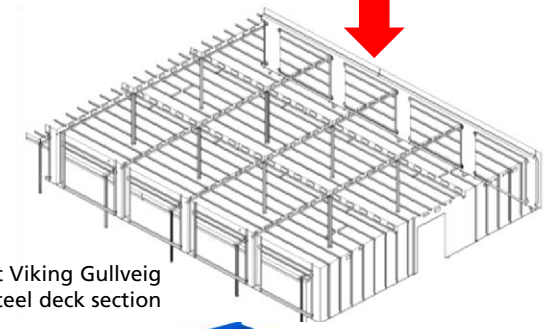
# 2.27 Integral lightweight deck sections made of composites for inland waterway passenger boats – CompDeck

´15

## Problem

- In inland waterway passenger boats both the hull and the superstructure are produced in the form of conventional structural steelwork.

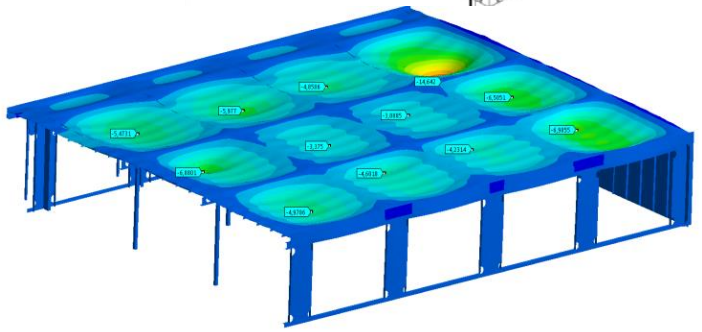
- The resulting total weight leads to an increased draught of the river passenger boat.
- In combination with low water at dry times of the year the ability to pass through certain river sections is limited.
- This shortens the cruising season, which greatly reduces the usage time of the boats.



river passenger boat Viking Gullveig with upper steel deck section

## Solution

- Development of integral lightweight deck sections of fibre-based compound materials
- Verification of approval-related requirements (strength, stiffness, fire resistance, etc.)



FEM calculation of a deck section of conventional steel construction (load case: deck load 4 kN/m²)

## Benefits

- A reduction in the intrinsic weight of the boat leads to a reduction of the draught and hence to an extension of the touring season
- Reduction in fuel consumption leads to cost savings
- Reduction in exhaust emissions contributes to better environmental compatibility

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tfc tools for composite

# 2.28 Development of a holistic, established and environmentally-friendly form of protection for offshore wind energy units – OptiWind

´15 - ´18

## Problem

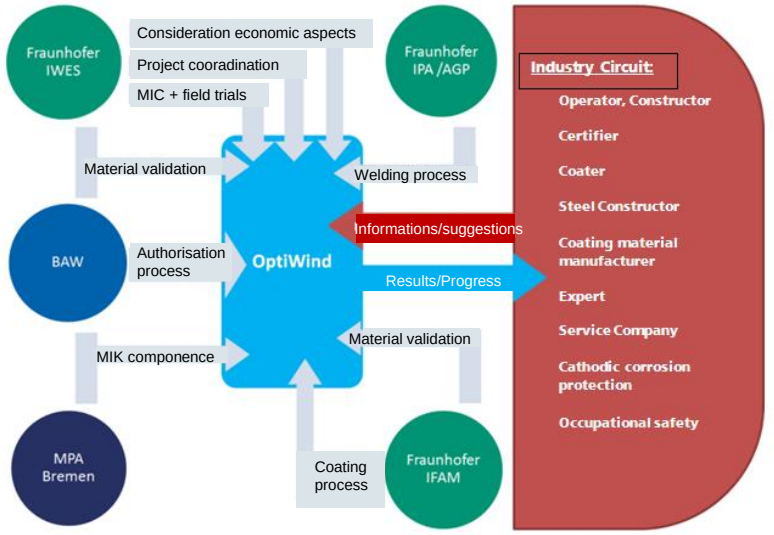
- Offshore wind energy units are exposed to harsh ambient conditions (wind, salt, wave action, etc.)
  - → The protection against corrosion must function optimally for the planned operating time of at least 25 years
- Interface problems, especially between the steel erector and the coating applicator, frequently lead to subsequent damage in the protection against corrosion as a result of the standards and guidelines not being harmonised, and this leads to high costs

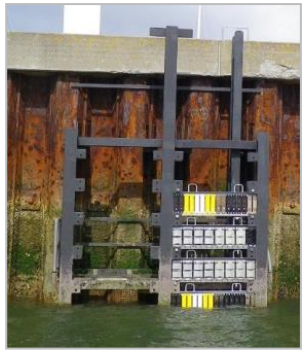
## Solution

- Development and testing of complex test bodies to verify the effect of steelwork geometries on the effectiveness of the protection against corrosion
- Development of a guideline to harmonise the requirements for the application of coating systems
- Development of a tool to estimate the cost of measures for protection against corrosion depending on the production of the structural steelwork

## Benefits

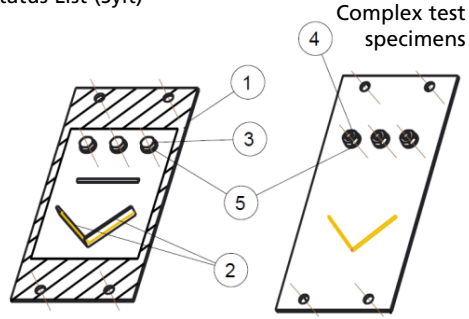
- Cost optimisation through a simplified and non-friction coating process and by avoiding subsequent damage to the protection against corrosion



Outsourcing status List (Sylt)

Complex test specimens

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MPA Bremen – Amtliche Materialprüfungsanstalt der Freien Hansestadt Bremen

BAW Bundesanstalt für Wasserbau – Kompetenz für die Wasserstraßen

# 2.29 Partial coating optimisation for the transport and installation of offshore wind turbines - OWS M-V

´15 - ´18

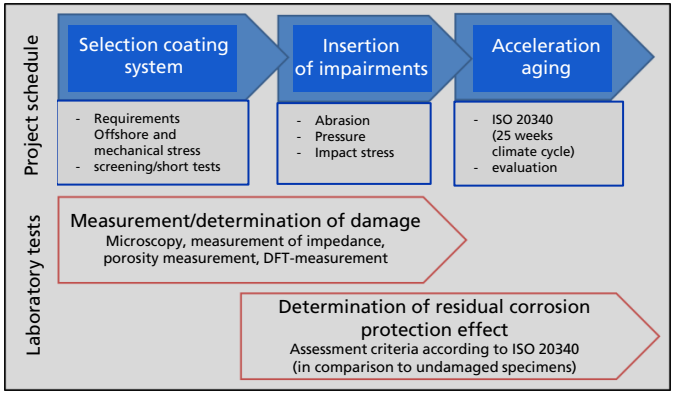
## Problem

- A large part of the coating damage on offshore wind turbines is due to mechanical stresses
- A great deal of damage, such as, for example, pressure stresses from a lifting belt, is not immediately visible, but in offshore use the reduced barrier effect of the coating system shows itself in the form of red rust
- The servicing of coating damage under offshore conditions is extremely time-consuming and expensive and can exceed the costs of a new coating by a factor of a hundred.

Damage as a result of pressure stresses during transport

## Solution

- Experimental investigations on the influence of damage that is not visible on the remaining protective action against corrosion
- Determination of possible forms of optimisation for the use of partial coating systems in highly stressed areas by the identification of the mechanisms that are at work here




Project sequence to determine the remaining protective action against corrosion after damage

## Benefits

- Basic principles for the evaluation of damage done in transport and erection
- Cost reductions by reducing the amount of damage done to coating systems during transport and the erection process

GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

# 2.30 Qualification methods for glued joints on offshore coatings – OWS M-V

´15 - ´18

Offshore Wind Solutions Mecklenburg Vorpommern

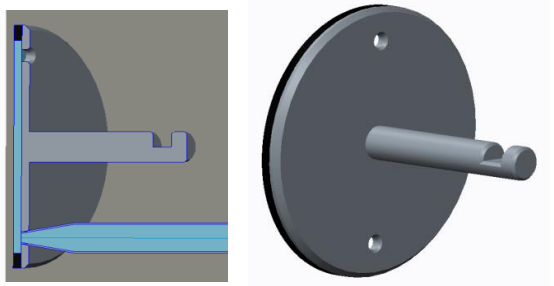
## Problem

- The subsequent installation of mounting systems for add-on parts (e.g. boxes, cabinets, stairs) by welding has technical and economic disadvantages (damage to the coating requires repair and the introduction of heat reduces the notch class)
- Adhesive bonding to components that already have their final coating as an alternative joining process is made more difficult by the lack of data concerning long-term behaviour.
- There is a lack of evaluation options for the suitability of coatings for use when gluing.

example of damage to coatings due to welded-on adhesive bonding in the offshore sector

## Solution

- Development of a qualitative evaluation method for the suitability of coated surfaces for gluing.
- Simulation of offshore conditions through accelerated laboratory ageing procedures



Concept for an injection-glued holder for coatings

## Benefits

- Increase in production flexibility (process reliability, less time required for installation)
- Joining of any desired material combinations without material changes in the substrate surface or coating damage
- Estimation of long-term resistance of offshore glued joints

Fraunhofer IPA

WACHSTUMSKERNE UNTERNEHMEN REGION Die BMBF-Innovationsinitiative Neue Länder

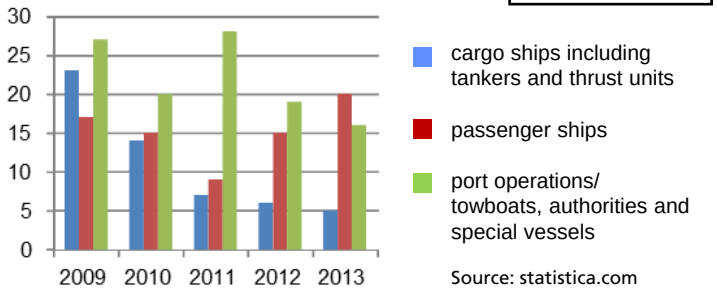
GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

# 2.31 Adhesive bonding of mounting points without reworking on ship and structural steelwork coatings – HOLDER GLUING

´15 - ´17

## Problem

- German shipbuilding is increasingly characterised by the production of passenger and special ships, whereby the requirements for shorter production times and individual customer wishes in phases towards the end of construction are increasing
  This requires the retrospective installation of items of equipment.
- In view of the following disadvantages, welding processes are not suitable for the joining of mounting points after the final coating (e.g. repair purposes, configuration modification):
  - High costs for coating removal and renewed recoating
  - Damage to coatings and the base material due to the action of heat




Number of ships supplied in German shipbuilding for inland waterway ships

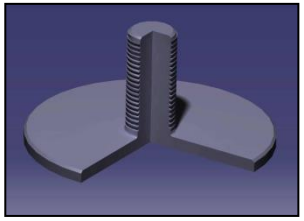
Damage to the coating over a large area due to welding as a result of the input of a large amount of heat at the mounting points and the rear wall

## Solution

- Development of adhesive-based joining procedure for the installation of holder systems and surfaces that have received their final coating
- Implementation of a non-destructive testing procedure for verification of the required minimum load-bearing capacity of the coating

## Benefits

- Avoidance of time-consuming and costly pre-working corrective post-working
- No damage to the anti-corrosion protective layer
- Greater flexibility when planning the attachment of add-on parts



CAD model
a bonded mounting point (cut)

Fraunhofer IFAM

Fraunhofer IPA

CMT

ALLIANZ INDUSTRIE FORSCHUNG

# 2.32 Development of flexible and automated production processes

´15 - ´16

## Problem

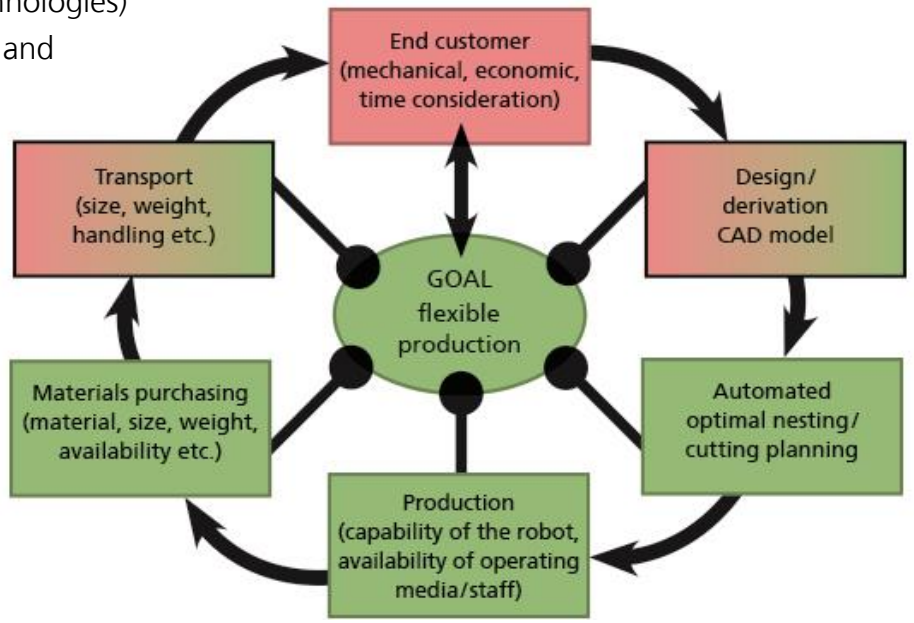
- Up to now, the production sequences in small-scale production operations have often been very inflexible and rigid (related to varying materials and the associated production and processing technologies)
- Inadequate interfaces between customers, design, suppliers and production
- The creation and implementation of a product portfolio across industrial sectors was not possible until now

## Solution

- Further development and adaptation of existing process sequences to allow flexible production
- Creation of central databases and networking of the entire value creation chain
- Integration of technical requirements (functional interface or structural properties) into existing production processes.

## Benefits

- Opening up of new markets and high utilisation of production capacities on a long-term basis in combination with short-term reaction to delivery amounts, delivery times, orders received or additional production amounts




Linking of individual process steps to attain flexible production

Fraunhofer IPA

Tischlerei Eigenstetter

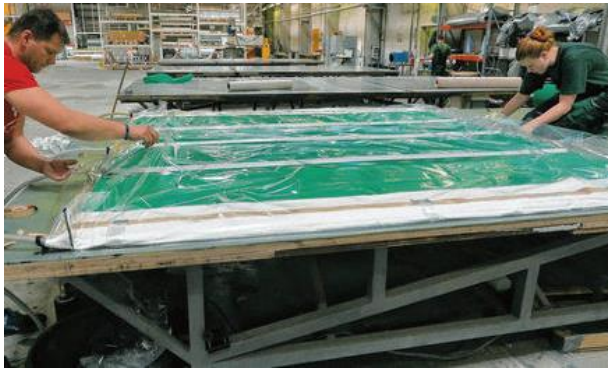
Technologie-Beratungs-Institut GmbH

# 2.33 Partially automated manufacturing process for 3D FRP hot press parts – AutoHot3D

´16 - ´17

## Problem

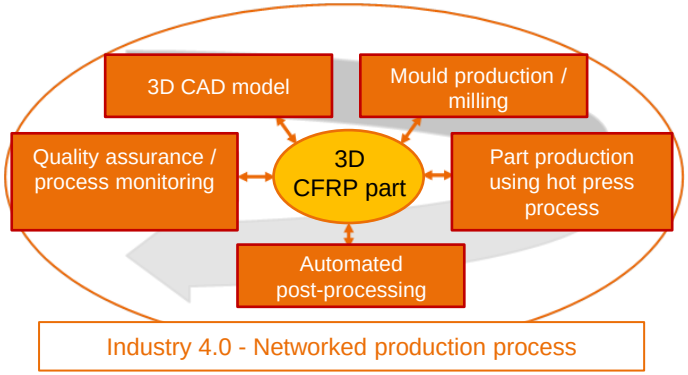
- The production of curved parts in large numbers currently employing the vacuum infusion process used by the company tfc (tools for composite) is only usable up to a certain point, since the technology has the following restrictions:
  - High proportion of manual production steps, or requiring manual intervention
  - Long curing time of the resin systems (> 8 h) and long cycle times
  - High proportion of consumable materials and only one-sided mould shaping



current production of large-area, two-dimensional (flat) parts by the vacuum infusion process at tfc – tools for composite

## Solution

- Introduction of a partially automated production process for 3D FRP hot press parts at tfc tools for composite
- Creation of a closed value creation chain from the 3D CAD model up to the finished 3D FRP part according to Industry 4.0 principles




## Benefits

- Considerable reduction in cycle times through the introduction of automated process steps and short hardening times for the FRP parts (< 30 minutes)
- Transition to large-scale series production with > 10,000 parts per year
- Considerable savings in resources, especially of consumable materials
- High surface quality on both sides and high dimensional compliance of the part by using closed mould designs

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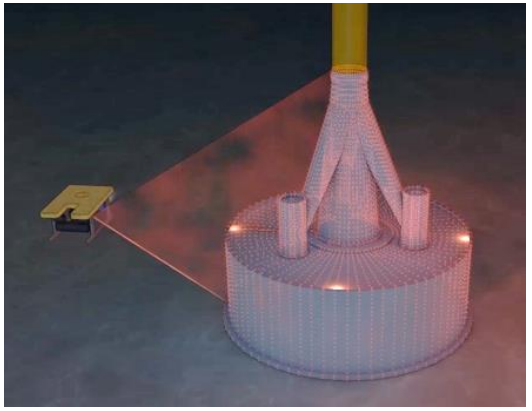
tfc tools for composite

Technologie-Beratungs-Institut GmbH

# 3 Work Area:
## Automation Technology

- Automation / sensor technology team concerns itself with the development of automation solutions and their implementation as prototypes in industry, preferably for the production of large structures. New robotic concepts with intelligent sensor guidance and image processing are points of particular interest.
- Quality technology concerns itself with the geometric measuring and modelling of large structures. Using reverse engineering, the digitisation of production layouts and the tracking guidance of robots results in very tight cutting quantities in the fields of automation and organisational engineering.



# 3.1 Drilling robot

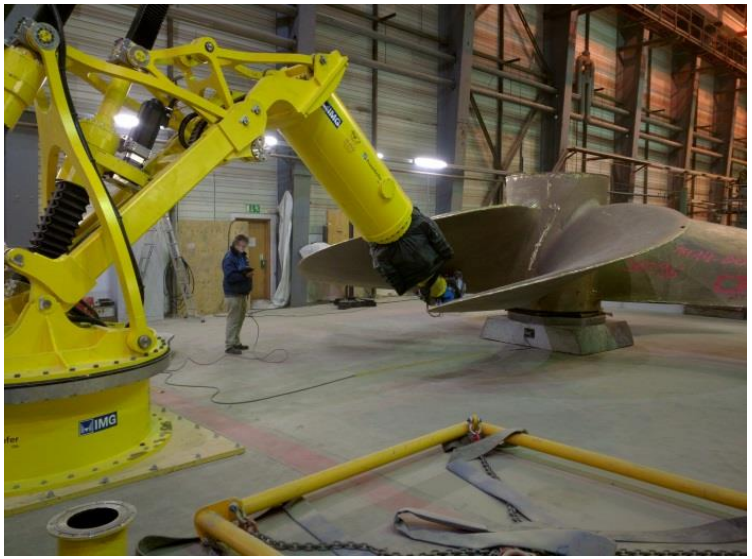
´15 - ´16

## Problem

- Ship propellers currently have diameters of up to 12 m. The finished blanks are ground to the set dimensions after casting. As a reference dimension for the grinding process, a large number (currently up to 1000 per propeller) of marking holes are drilled into all the blade surfaces in a defined grid. A drilling depth precision of better than ± 0.2 mm is aimed at so as to attain the required precision.
- Conventionally, the holes are drilled in a very time-consuming way using a manually-operated drilling machine. This operation is done in two steps. After the markings have been drilled on the pressure side the propeller that weights up to 150 tons is turned over and then the holes are drilled on the suction side.

## Solution

- Automatic drilling of markings by a large robot
- Robot programs are generated from the data of a 3D area scan of the propeller with the aid of an offline programming system
- Using a laser tracker system, the exact position of the propeller can be determined and the end-effector positioned to the millimetre



## Benefits

- Increasing in quality through automating the work step
- Reduction in production costs
- Savings in crane capacity, since it is not necessary to turn the propeller over

Fraunhofer IPA MMG Mecklenburger Metallguß TEI Technologie-Beratungs-Institut GmbH

# 3.2 End-effector for high-precision robot-based drilling on free-form areas

´14 - ´16

## Problem

- An end-effector that could achieve a drilling depth accuracy of ± 0.2 mm was required for the "Drilling robot" project.
- Compared to machine tools, serial robot systems have a lower degree of stiffness, which leads to vibration during drilling and hence limits both the attainable speed of the process and the precision of the drilling depth.
- The drill must be able to work regardless of orientation.

## Solution

- Fixing of the end effector by means of a vacuum gripper to prevent moving out of place
- Subsequent clamping against the kinematics of the robot by means of pneumatic cylinders
- Sensor-based measuring of the distance and the orthogonality of the surface for optimisation of the drilling process and readjustment
- NC drilling spindle permits very high cutting speeds and feed advance speeds

## Benefits

- Drilled holes with very high precision with respect to the location and depth for any kind of curved surface
- The system is almost completely independent of the stiffness and absolute precision of the robot
- Drilling at the edge of the blade is also possible

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MMG Mecklenburger Metallguß

# 3.3 Automated production of tubular nodes

´13 - ´16

## Problem

- The joining of tube segments at any orientation to a tube node is currently done manually and is very time-consuming.
- Tube nodes are produced in shift work by several welders. This means that welding work in difficult and uncomfortable positions is thus unavoidable.
- Tube node connections in the offshore sector are subject to stringent quality requirements regarding the weld geometry and the mechanical-technical properties of the connection.

## Solution

- Adaptive welding device to set on the tube connection to be welded (variable tube diameter and length)
- Use of a high-performance welding process (MAG tandem, parallel operation of 2 tandem welding units is possible) to increase the deposition rate
- Sensor-based measuring of the weld seam geometry for optimisation of the movement sequence programming (torch position and orientation)

## Benefits

- Improvement in weld seam quality and guarantee of reproducible process results
- Significant increase in productivity (compare to manual production)
- Unit is suitable for a wide spectrum of work pieces (tube diameters, wall thicknesses, mobile operation, etc.)

Fraunhofer IPA IMG Technologie-Beratungs-Institut GmbH

# 3.4 Automated rounding of edges of flat parts

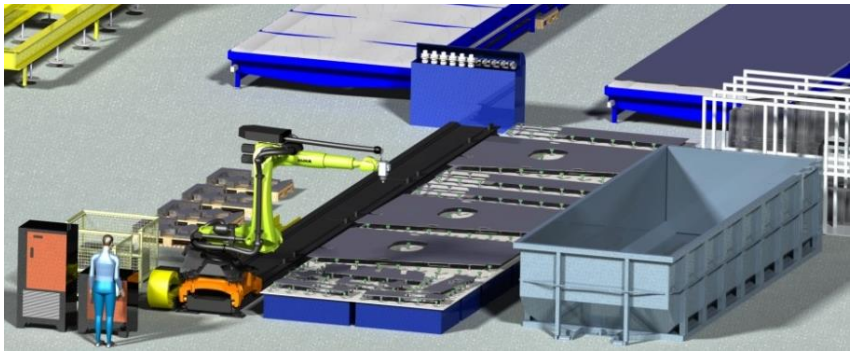
´15 - ´16

## Problem

- The economic production of thick pieces of steel plate cut to size is only possible with residual burrs, which are not wanted by the customer.
- In view of the increasing expectations for protection against corrosion and more stringent requirements concerning coating systems, finer and burr-free processing of the edges of the components to be coated is called for.
- Current shipbuilding standards demand an edge radius > 2 mm for selected areas of the ship.
- The manual post-production of cut edges requires a great deal of work and time and is physically tiring work.

## Solution

- Automated parts recognition for pieces of plate cut to size on the basis of their part identification, using sensors
- Automated fixing of the parts identification of the edges to be machined from the CAD interface / data or recognition of the similarity relationships
- Use of industrial robots for the positioning of the milling tool and to produce a rounding of the edge with a defined radius
- Optional part sorting and categorisation according to the following routing



## Benefits

- Quality assurance in prefabrication in shipbuilding through an optimal milling position in the case of complex part geometries as well.
- Better reproducibility through automated sequences
- Extension and modification of the unit to meet individual production requirements

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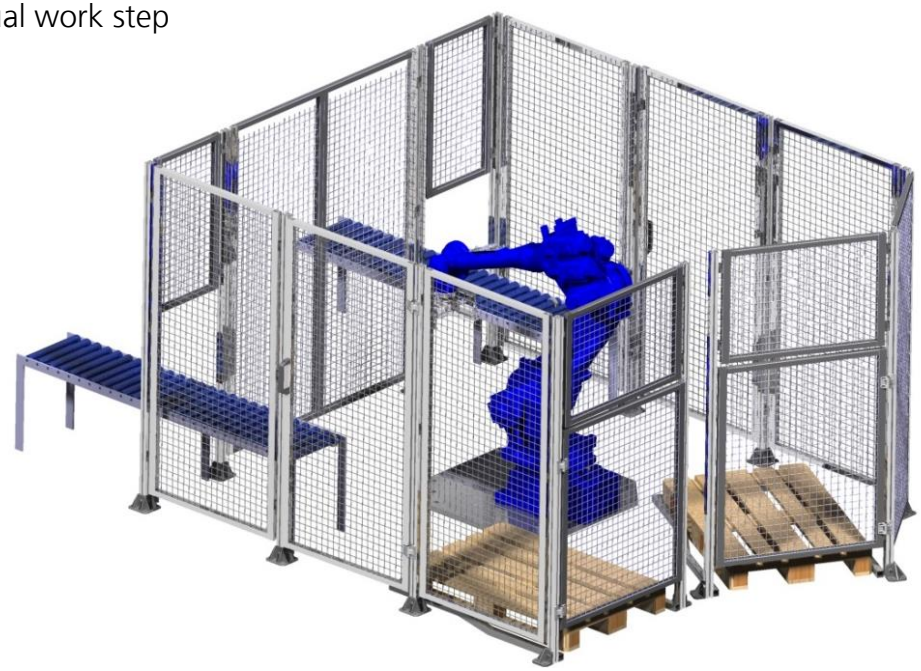
# 3.5 Palletising – INSTAMAK

´15 - ´16

## Problem

- Currently, when it comes to the filling of areas with repair asphalt, buckets with a capacity of from 20 to 30 kg are used. In conjunction with the filling, these are then sorted by hand by a worker from a conveyor in a way suitable for transport onto a pallet.
- The palletising by hand is extremely stressful physically for the workers and can cause health damage.
- The provision of the buckets is done in a previous manual work step in a discontinuous way and with an undefined position.



## Solution

- Use of an industrial robot in palletising mode
- Use of a robot program that is matched to the feeding of individual buckets and bucket palletising

## Benefits

- Increase in throughput
- Minimisation of physical stress for the worker
- Easy to set up again for various bucket formats

Fraunhofer IPA

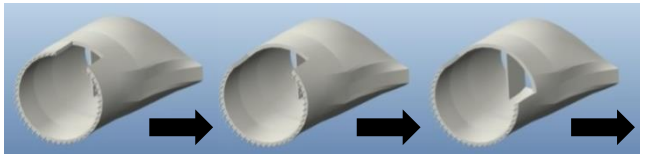
INSTAMAK®

# 3.6 Mobile disassembly cell for rotor blades – MoZzeR

´15 - ´18

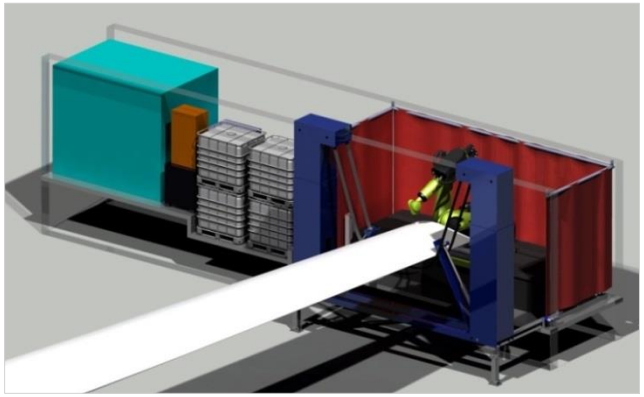
## Problem

- Many wind turbines of the first generation are currently reaching the end of their approximately 20 year working life or are being replaced by new and more efficient wind turbines as part of repowering. The amount of rotor blade material to be disposed of will thus increase dramatically in the next few years.
- Conventional, stationary rotor blade disassembly requires the elaborate transport of complete rotor blades. In previous solutions fine dust from the material and vapours that are a hazard to health were released into the environment.



## Solution

- Mobile disassembly cell that is installed on a semi-trailer
- Collection of geometric measured data of the rotor blade surface contour
- Automated disassembly by robot-controlled water jet cutting technology



## Benefits

- The disposal costs are reduced due to simple transport of rotor blades that had been dismantled on site in an automated way and since there is no longer any need for any additional cutting-up step at a stationary sawmill
- The use of water jet cutting technology prevents the escape of material fine dust and vapours that are a hazard to health

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Hanseatic Rohr GmbH

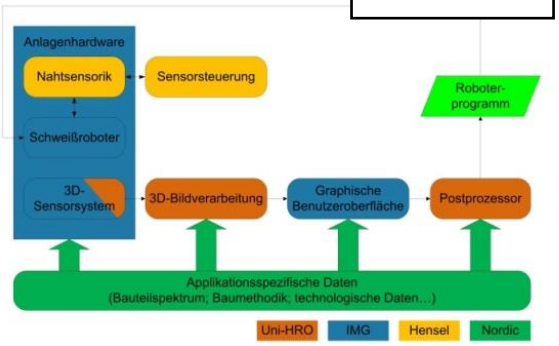
Technologie-Beratungs-Institut GmbH

# 3.7 Sensor-based robot programming for the automated production of high orthogonal volume structures – SensPro (Inno profiles)

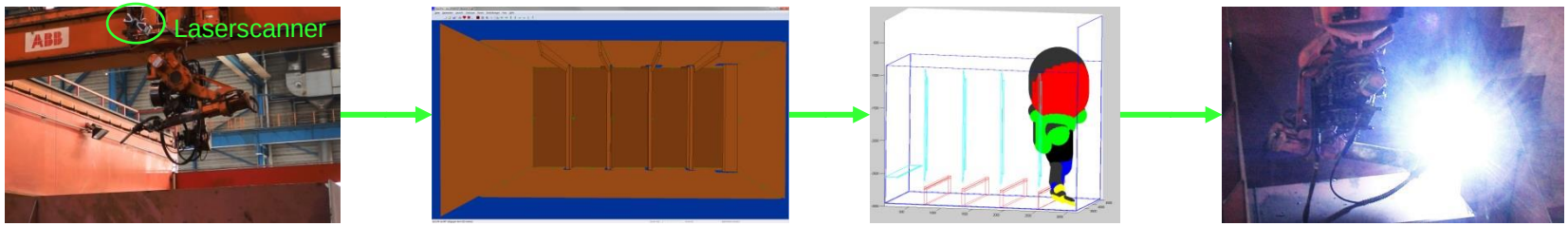
´13 - ´16

## Problem

- Conventional robot programming for the production of volume structure as structural steelwork is characterised by the large amount of time required for small numbers produced and the necessity to make adjustments to the actual location of the components in production, hence is often very uneconomic.
- In the area of flat modules automated robot programming had already been turned into a reality on the basis of 3D sensor data of the components.
- In view of the great complexity of orthogonal volume structures and the high risk of collision between robot and component, the implementation of a sensor-based procedure for robot programming in the area of the production of volume structures represents a special challenge.




system components




## Solution

- Three-dimensional collection of the data of the components at the production unit
- Automatic processing of the sensor data to determine the parameters of the seams to be welded
- Conversion of the seam parameters into unit-specific robot programs with collision monitoring
- Adaptive modification of the robot programs to the actual components on the basis of data from an intelligent seam sensor

## Benefits

- Drawing up of a research profile in the area of sensor-based robot programming
- Increasing the competitiveness of maritime companies through the use of innovative technology

# 3.8 MACH-FLEX-FORM

´16 - ´17

## Problem

- The requirements for building facades by both architects and customers have become ever more demanding due to the desire for increasingly complex forms.
- Currently form adjustment can only be done in a manual production process. In production the facade elements must heated thermally in a specific way, shaped under a vacuum and then machined.
- Each facade element is unique and requires a high degree of precision.
- The reproducibility depends on the capabilities of the workers. An automated mould for the production of facade elements that are curved in three axes is not available.

## Solution

- Using an automated stamper, the geometry for each adjustable element can be set up quickly
- The geometry is transferred via an interface between the CAD system and the stamper controller

## Benefits

- Reduction in production time and faster setup times
- Reproducible quality and increased precision
- Minimisation of manufacturing expenses and hence the associated production costs
- Facade elements with complex geometries and larger dimensions can be produced

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# 3.9 Standard geometry-based model for the interior outfitting of megayachts - IMoScan

´13 - ´16

## Problem

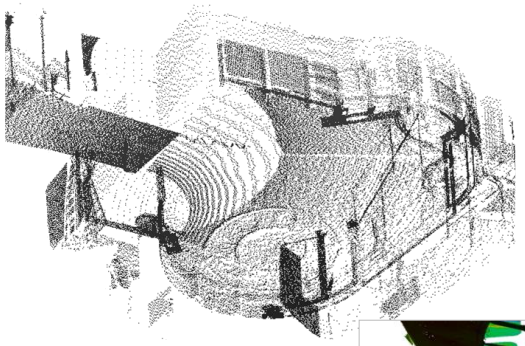
- Deviations in the steel structure results in high levels of reworking and adaptation during interior outfitting.
- Determination of the necessary dimensions in interior outfitting is time-intensive, redundant and susceptible to errors.
- Different dimension references and lack of feedback of geometric information lead to increased effort.

## Solution

- Central data acquisition using laser scanners
- Development of methods for quick referencing in the ship's coordinate system
- Standard geometry-based automated dimension generation on the basis of the CAD model
- System for mobile dimension documentation

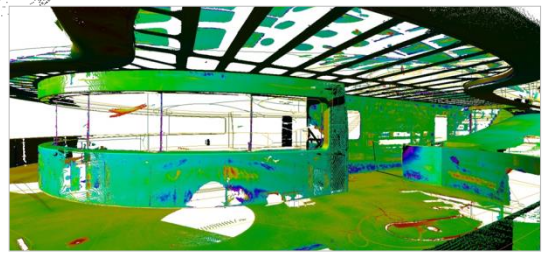
## Benefits

- Acquisition and digital preparation of actual production data
- Establishment of a uniform data basis for interior outfitting
- Acceleration of the recording, evaluation and documentation
- Increased productivity in interior outfitting

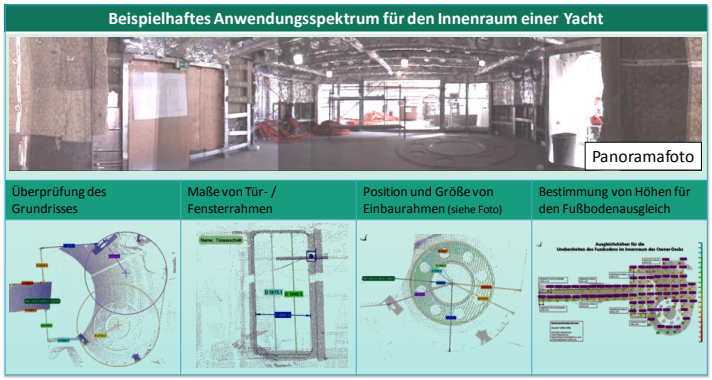


Data base
3D point cloud

Superimposition of actual and nominal data



Dimension generation in interior outfitting

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DÖLKER & VOGES YACHT INTERIOR EXPERTS
LÜRSSEN FR LÜRSSEN WERFT
Bundesministerium für Wirtschaft und Technologie
ptj Projektträger Jülich Forschungszentrum Jülich

# 3.10 3D recording and monitoring of underwater large structures – DeepInspect (internal preliminary research of the FhG)

´15 - ´17

## Problem

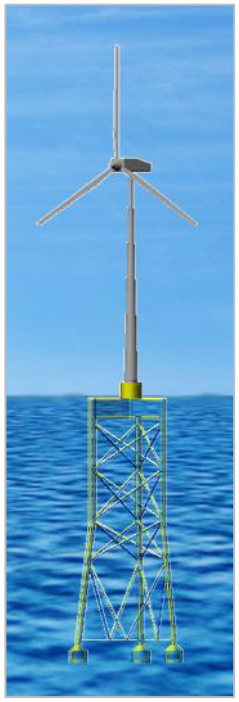
- Offshore units, dams and other underwater structures are currently mainly inspected visually and manually by the use of divers.
- When it comes to geometric monitoring and deformation analyses, regarding the state of the art in the underwater sector, the present sensors that work on a sonar basis are not adequate in view of precision, resolution, speed and data quality.

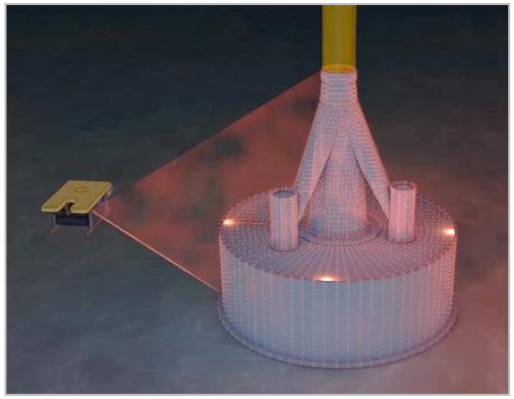
## Solution

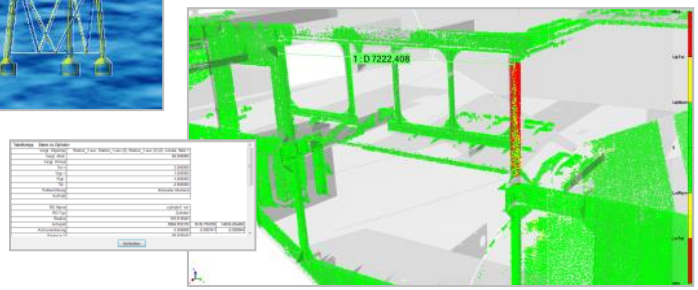
- Development of laser-based scanning systems for the underwater area
- Combination of sensor and evaluation unit for an automated inspection system
- Requirement-specific automation of the data evaluation

## Benefits

- Reliable and precise data collection for large underwater structures
- Possibility of regular objective checking and monitoring in the offshore area
- Reduction of the effort and cost required for underwater inspections







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# 3.11 Precise and rapid collection and evaluation of geometry data of ship surfaces for efficient coating processes – FINISH

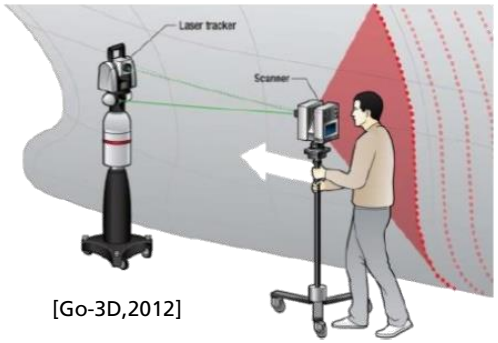
´16 - ´19

## Problem

- Extremely high quality requirements for the visible painted surfaces of yachts in the above-water area
- Present methods for controlling grouting work for large yachts are not efficient enough
- Grouting prediction on the basis of scan data is done by manual smoothing of the data and is thus subjective and also insufficiently reproducible

## Solution

- Significantly faster collection of geometry data by using kinematic scanning methods
- Development of algorithms for the automated and reproducible generation of optically sheered surfaces with regard to all relevant optimisation parameters
- Development of criteria for quality assessment of the generated areas from optical points of view

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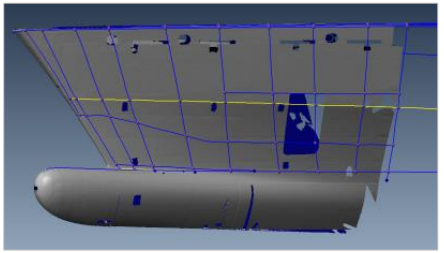
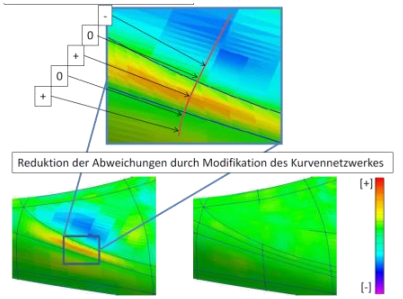





## Benefits

- Acceleration of the coating process in yacht building
- Application of grouting prediction also to complex areas for the prefabrication of built-in parts
- Qualitative assessment of the grouting coat and the contours
- Subsequent reworking and additional costs are thus avoided

IFW Institut für Fertigungstechnik und Werkzeugmaschinen · LÜRSSEN FR LÜRSSEN WERFT · dhp:i Dr. Hesse und Partner Ingenieure · Fraunhofer IPA · GIH · Bundesministerium für Wirtschaft und Technologie · ptj Projektträger Jülich Forschungszentrum Jülich

# 3.12 Developing Smart Technologies for Productivity Improvement of European Small and Medium Sized Shipyards - SMARTYards

´13 - ´16

## Problem

- Small and medium-sized shipyards often have a competitive disadvantage compared to larger yards.
- The reasons for this are:
  - Limited financial options
  - Fewer specialists
  - Older shipyard equipment (cranes, halls, etc.)
  - Uneconomic production
  - Difficult access to information and cooperation networks

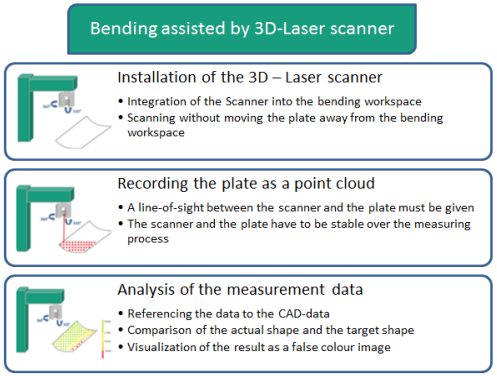
## Solution

- Optimisation of existing resources / areas with the aid of companies with leading edge technology
- Creation of design catalogues for selected technology ideas for knowledge transfer and the implementation of prototyping
- As one of the leading high-tech enterprises, Fh AGP supports the areas of geometric quality control, measuring technology in the forming process and production technology

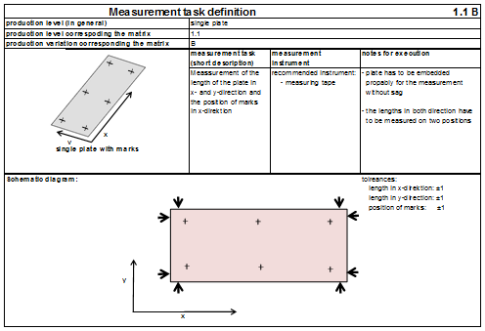
## Benefits

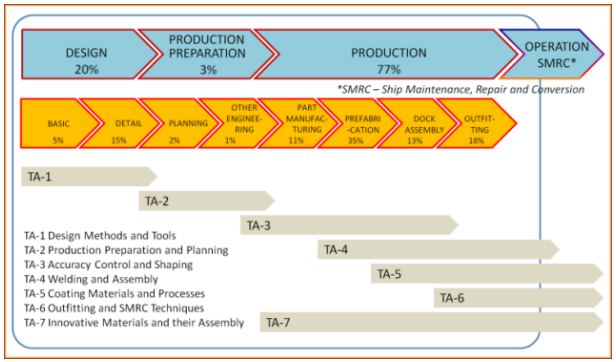
- Knowledge transfer to increase the competitiveness of small and medium-sized shipyards in Europe
- Increase in productivity and efficiency in the production process of shipyards

SMARTYards




Basic principles for the drawing up of the design catalogue in the field of forming




Technology areas of the SMARTYards project

Basic principles for the drawing up of the design catalogue in the field of the monitoring of precision

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CMT

SEVENTH FRAMEWORK PROGRAMME

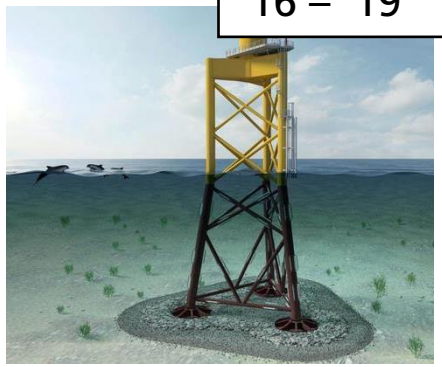
# 3.13 Development of an evaluation system for the geometric monitoring of underwater structures – OWS M-V

´16 – ´19

## Problem

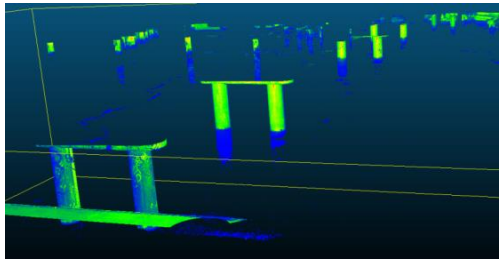
- Measuring systems and methods to determine geometric relationships can only be transferred to the underwater area to a limited extent
- External environmental conditions lead to a worsening of the accuracy and precision of geometric information from the sensors used

Offshore Wind Solutions Mecklenburg Vorpommern



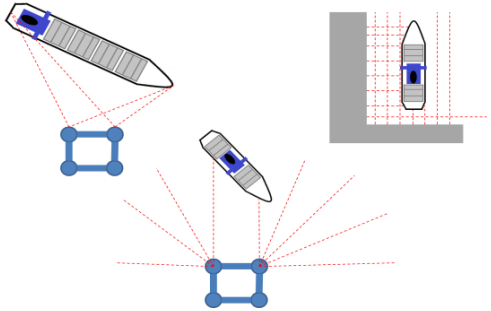
## Solution

- Analysis of the application cases and measuring requirements for the geometric parameters to be recorded in the underwater area
- Derivation of the requirement for the data collection and evaluation systems to be developed on a laser basis regarding measuring volume, measuring speed and precision.
- Development of evaluation procedures and methods for dynamic and static evaluation cases



## Benefits

- Geometric recording of large structures in the underwater area
- Provision of procedures for the collection, processing, analysis and evaluation of geometric information under water with adequate precision and speed
- Systems for the precise positioning of objects in the offshore area



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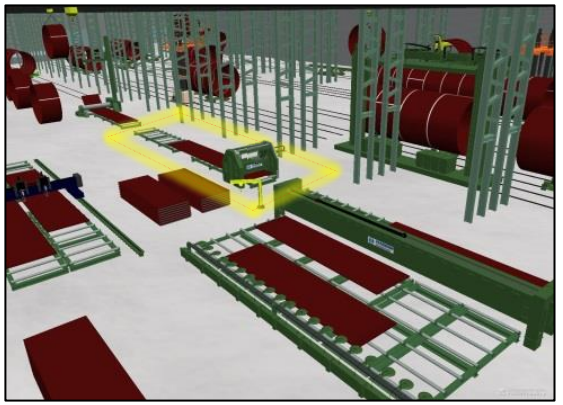
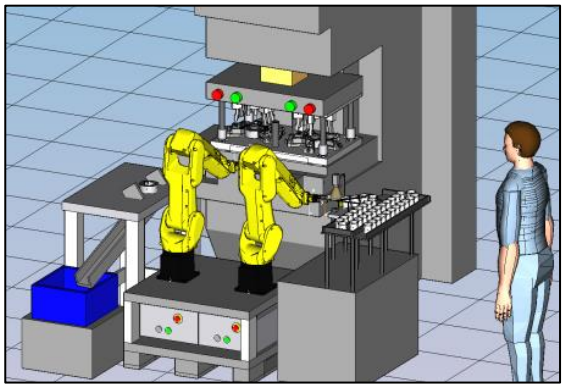
WACHSTUMSKERNE UNTERNEHMEN REGION Die BMBF-Innovationsinitiative Neue Länder

GEFÖRDERT VOM Bundesministerium für Bildung und Forschung

# 4 Work Area: Organisational Engineering

- Company and Production Organisation draws up holistic solutions for the design of efficient and flexible production systems, primarily for large structures.
- The concentration here is on the development of IT solutions for the planning and control of the production of complex one-off items (industry 4.0).
- Special assistance systems are being developed to support the workers in production, and also against the background of the emerging demographic change, so as to provide computer-supported, ergonomic work flows.
- There has been an increasing demand for productivity studies in shipbuilding. This means that the proportion of productive activities with instruments from Industry 4.0 must be increased markedly.



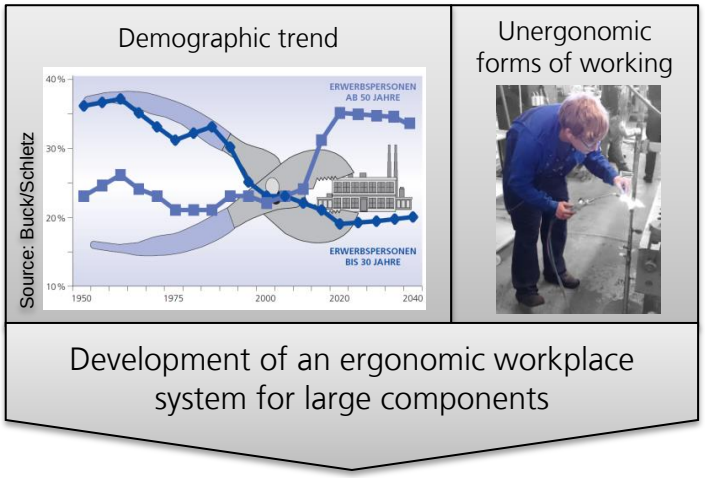


# 4.1 Development of an intelligent work table for the assembly of large components – ERGOTAB

´13 - ´16

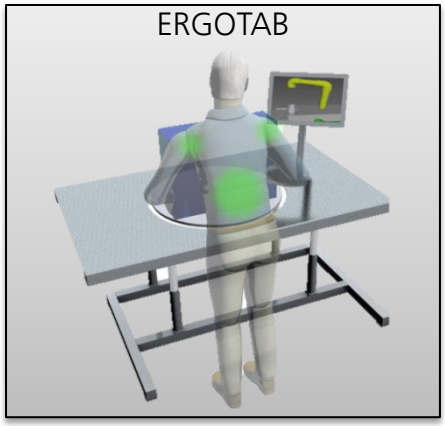
## Problem

- The demographic change leads to an ageing workforce in manufacturing companies.
- Companies that need to assemble larger components manually have to take a higher average age into particular consideration since it is difficult to avoid disadvantageous body postures during the assembly work.
- So far, workplace systems for large components only permit a limited degree of intelligent adaptivity. This leads to disadvantageous body postures and hence to unnecessary stress for the workers.




## Solution

- Development of novel kinematic concepts for adaptive work tables to support the workers during the assembly process
- Creation of intelligent controls for the kinematics
- Supporting information for the worker during the assembly process
- Merging of sub-components into a new system for workplaces suitable for older workers




## Benefits

- Reduction of stress due to ergonomically correct forms of working by manipulation of the ErgoTab
- Full provision of information through virtual production instructions

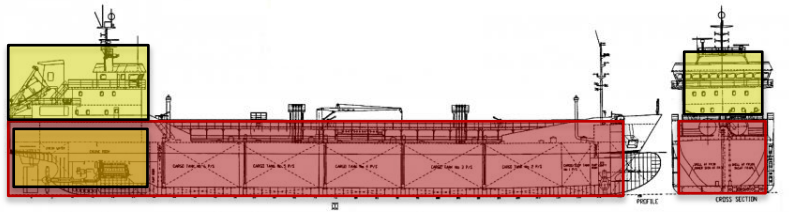
REFA MiniTec THE ART OF SIMPLICITY Fraunhofer IPA KLH SELCKGROUP HOBAS® Bundesministerium für Bildung und Forschung

# 4.2 Innovative recycling of ships

´14 - ´15

## Problem

- Currently the staff of the ship recycling processes have to work under unfavorable conditions; the use of technology to support the staff is rudimentary.
- There is no regulated procedure to deal with hazardous substances and materials.
- However, this sector will change greatly in the next few years in view of the guidelines of the IMO. Therefore suitable measures must be prepared.



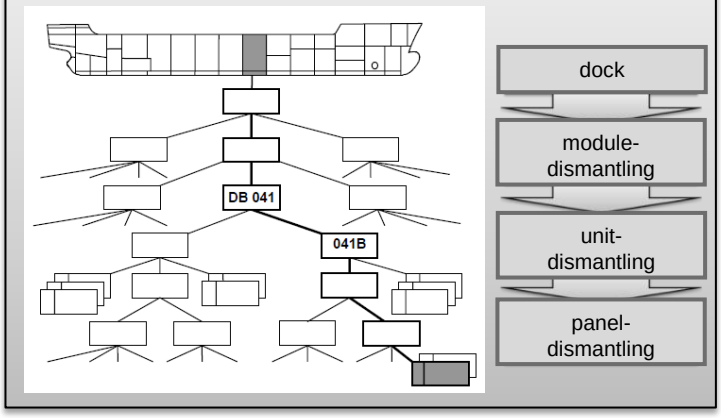
Innovative technologies

Efficient work flows

## Solution

- Creating technologies for partial automation of the disassembly processes in Ship building
- Creating process work flows and production structures for the efficient disassembly of ships
- Development of concepts for the integrated handling of hazardous substances and materials
- Processing and evaluation of the concepts with the aid of material flow simulation

A ship recycling process that is suitable for the future




## Benefits

- Reduction of the amount of stress placed on the workers in the ship recycling process and ensuring appropriate working conditions
- Implementation of a cost-efficient recycling process through the use of innovative technologies

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IMG

iem Industrie Engineering & Management GmbH

# 4.3 Study on the development of ergonomic handling devices to change batteries in AGVs

´14 - ´15

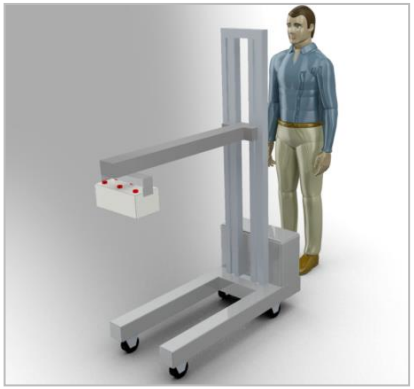
## Problem

- Currently the battery change in automatic guided vehicles (AGVs) is done exclusively manually.
- In view of the high battery weight and poor accessibility this produces unfavourable body postures and hence an increased amount of stress for the workers.

AGV and battery box in the container terminal of Hamburg harbour

## Solution

- Analysis and evaluation of the handling process with regard to ergonomic and organisational aspects
- Development of an adaptive ergonomic handling system for the specified overall geometric and environmental conditions to support the workers when changing the batteries



Approach to solving the problem: Development of a variable handling system for the ergonomically favourable changing of batteries with a reduced load on the workers

## Benefits

- The ergonomic handling system can avoid unfavourable body postures and reduced the amount of stress placed on the workers.
- The workers are spatially separated from the hazards when changing batteries (voltage bridges, escape of acid).

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HHLA

# 4.4 New generation of production control systems

´14 - ´15

## Problem

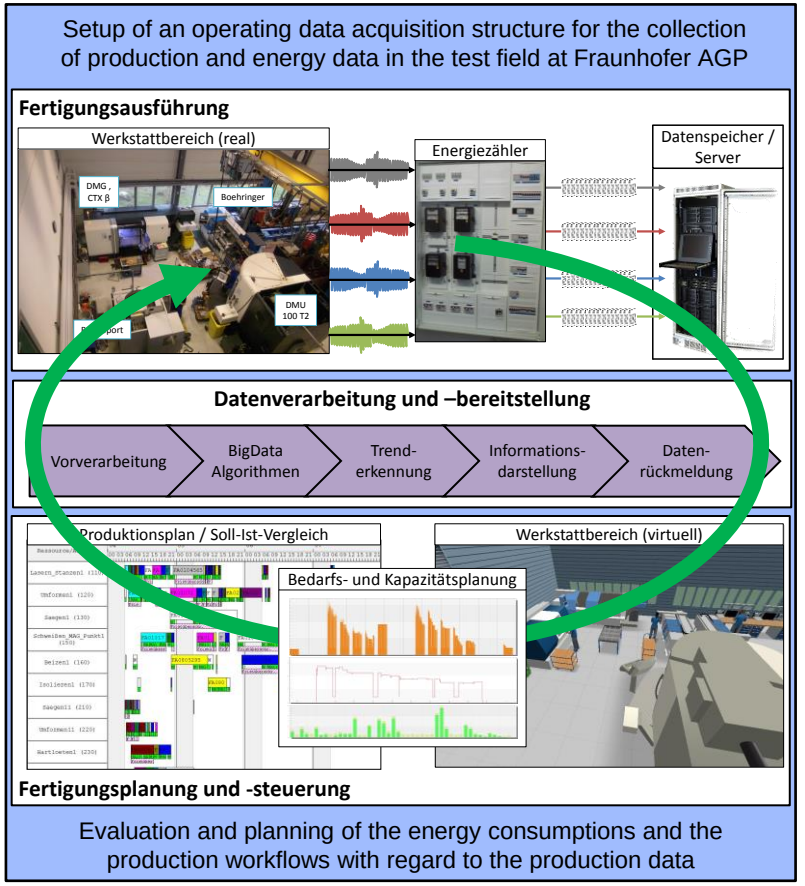
- The developments in the context of Industry 4.0 show that the mastering of the variety, quantity and speed of data flows represents a major challenge.
- Present production control systems are not able to make use of the whole data that is generated in the production process in order to optimize the production planning.

## Solution

- Development of a new generation of production control systems
- Integration of additional target aspects into the planning algorithms of production control systems taking the example of energy data

## Benefits

- Technical study to confirm the feasibility and for interface generation
- The efficient use of increasingly large amounts of data with high processing speeds (real time) in production industries
- Holistic optimisation of production processes
- Use of the data and results within the scope of energy management as defined by the EEC and in ISO 50001

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SEAR

# 4.5 Simulation study on the robot painting unit for the 65.5 rotor blade at Nordex Energy GmbH

´15

## Problem

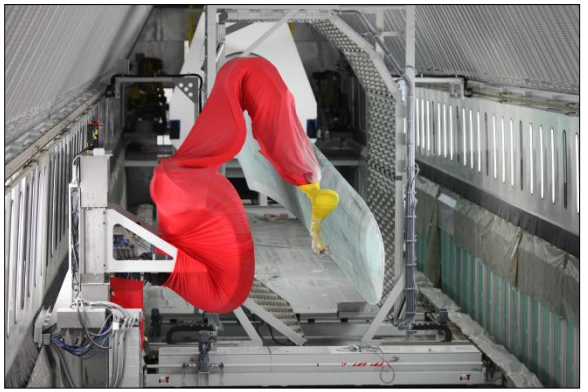
- Introduction of a new generation of rotor blades of type NR65.5
- Automated painting unit at Nordex designed only for rotor blades of type NR58.5
- Verification of the feasibility for the new type of rotor blade with a length of 65.5 m required (reachability, freedom from collisions, positioning)

## Solution

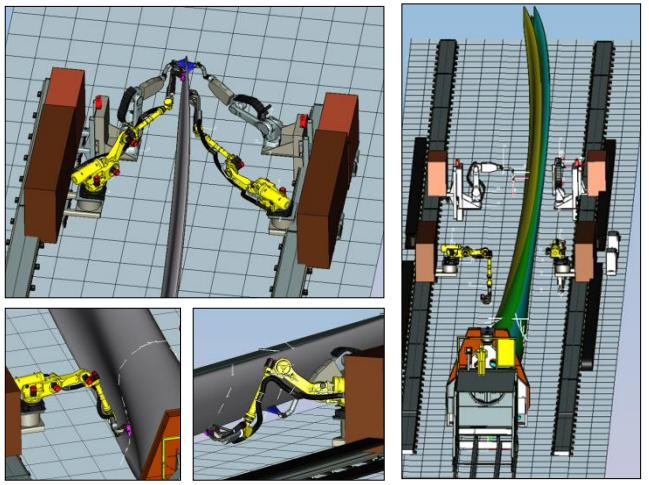
- 3D simulation study to verify reachability and freedom from collisions
- Determination of optimal positioning and alignment of the rotor blade in the painting cell
- Derivation of the required conversion measures (axis extensions, limit switches, etc.)
- Derivation of the required adaptations to the rotor blade holder

## Benefits

- Virtual determination of feasibility at an early stage
- Basis of the decision for introduction of the NR65.5 and the conversion measures to be implemented
- Reduction of time and costs in the planning and commissioning process



Source: www.nordex-online.com



Fraunhofer IPA ICARUS NORDEX We've got the power.

# 4.6 Ergonomic control room 4.0

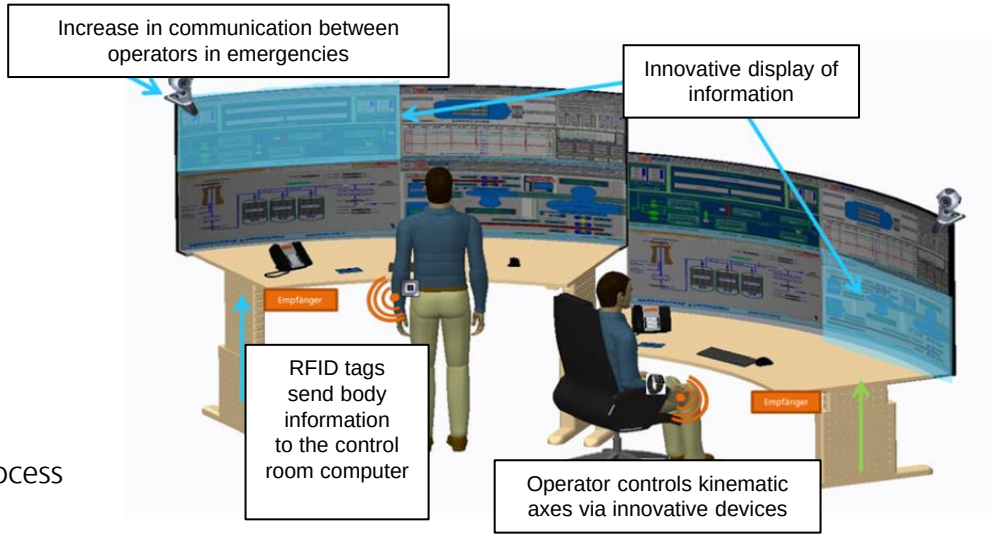
´15 - ´16

## Problem

- High level of physical and mental stress through static work processes and a high level of background noise in control rooms.
- Inadequate options for the adaptation of existing control room desks to the user.
- Inadequate consideration of legislation concerning health and safety at work.

## Solution

- Analysis of workplace design for the amount of physical and mental stress placed on the workers.
- Investigation of the influence of various material pairings on the ability to absorb background noise
- Development of intelligent kinematics to improve the ergonomics and make body postures more dynamic
- Development of novel forms of interaction between user and control room




## Benefits

- Making body postures more dynamic during the work process
- Reduction in physical and mental stress for the user by optimising the ergonomics
- Reduction in background noise
- Creation of workplaces suitable for the ageing and the aged

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KOEPKE UND KASISKE Möbel und Ladenbau GmbH Kompetenz und Qualität vereint

# 4.7 Flexibly automated switching of parts in stamping and deep-drawing presses

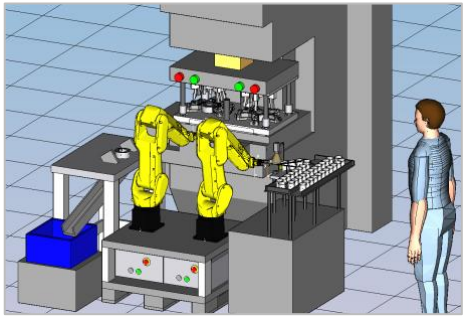
´15 - ´17

## Problem

- Several manually-operated stamping and deep-drawing presses
- The processing of parts is done in several steps at one or more workstations
- Short-term capacity fluctuations, such as workers not being available or from taking on additional orders, require cost-intensive buffer storage to ensure the ability to deliver
- Stress for the workers due to repetitive, monotonous activities
- The demographic change is leading to older workers and a lack of specialists

## Solution

- Flexible automation of manual workplaces by the use of cooperating industrial robot systems
- Robot system can be used in the entire machine park due to a mobile platform
- Integration of intelligent sensor systems for flexible use, minimisation of setup times and ensuring the safety of the workers



## Benefits

- Evening out short-term capacity fluctuations through flexible automation
  - Substitution in the event of personnel not being available at short notice
  - Handling of additional orders
- Reduction of extra work and cost-intensive buffer storage
- The load on the workforce due to repetitive and monotonous work is reduced

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# 4.8 Development of the balancer FLINT

´15 - ´16

## Problem

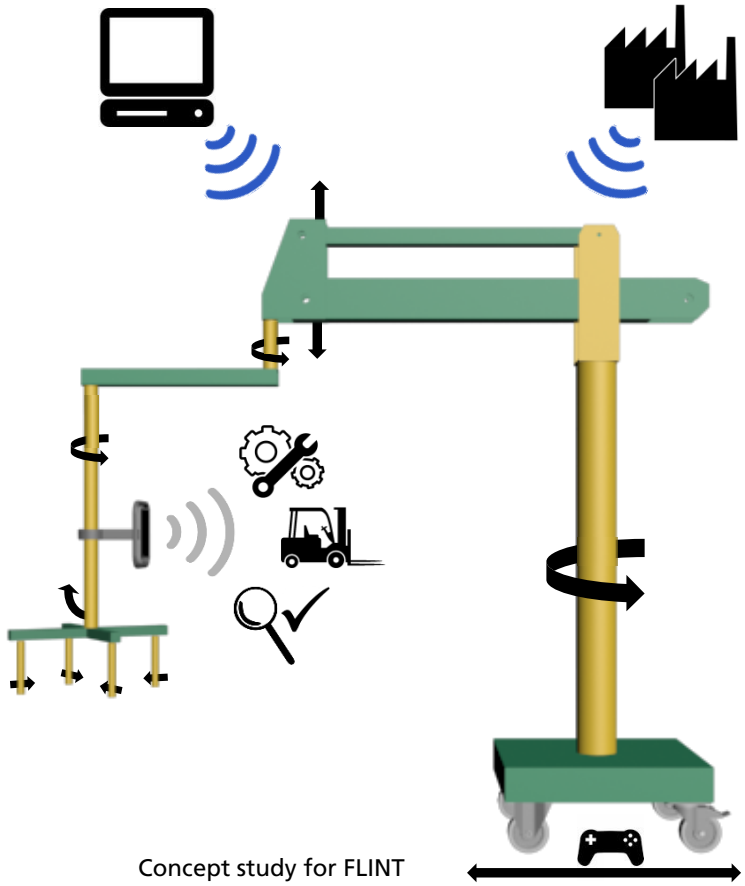
- The demographic change brings the necessity for ergonomic process design
- Increasing number of variants in the manufacturing industry makes flexible system solutions essential
- The main ideas behind Industry 4.0 (Big Data, Internet of things, etc.) have been inadequately established so far in many production sectors

## Solution

- Concept for a **fl**exible and **int**elligent handling manipulator
- Adaptable gripper system to cover a broad spectrum of parts with all kinds of geometries
- High degree of mobility due to integrated running gear
- IT interfaces to network the balancer with the ERP system
- Can be used over a wide area due to using electric power as the energy medium

## Benefits

- Ergonomic optimisation of a large number of process steps
- Lower number of different manipulators required
- No elaborate changing of grippers is required
- Production data is generated and made usable



Concept study for FLINT

Fraunhofer IPA

KIS

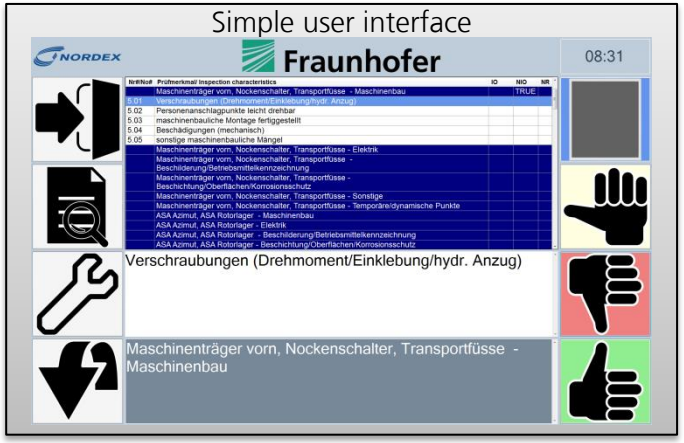
# 4.9 Mobile data collection

´15 - ´16

## Problem

- The supervision of the systems of a wind turbine is currently done solely using paper
- An enormous amount of time and work is required to transfer the analog data onto digital media.
- In addition to the potential for errors through the current media breakages, delays in the processing of defects that are found in the product occur.

Simple user interface




## Solution

- Development of a graphical user interface for the production of a digital test certificate.
- Optimization of the application for the use on mobile devices.
- Use of devices that meet the requirements of the industrial standard.

Industrial Tablet

## Benefits

- Avoiding media breakages which lead to a lowering of the potential for errors when the data is collected
- Assistance in the creation of the digital certificate by simple and guided operations through the graphical interface

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# 4.10 Material flow study to support a plant expansion

´16

## Problem

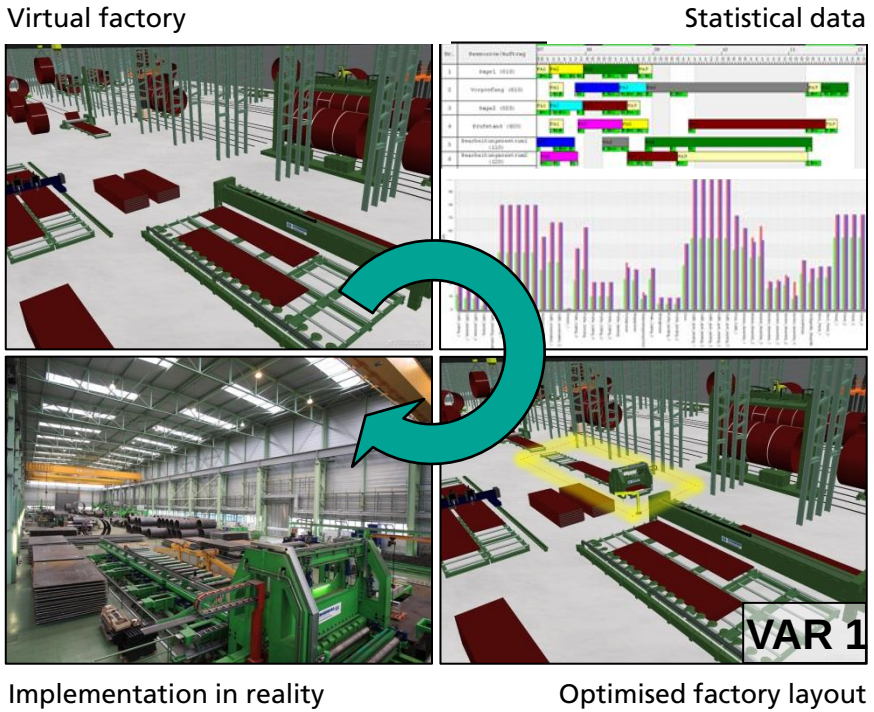
- Two different concepts for the restructuring of the existing production
- High investment volume
- There is uncertainty as to which concept is superior

## Solution

- Modelling of both systems in the form of a virtual factory
- Holistic simulation of the flow of materials for both alternatives
- Passing various production programs through the production system
- Generation of a comprehensive stock of data

## Benefits

- Avoidance of planning errors by specifically evaluating collected and reliable data
- Provision of qualitative information for the management level
- Providing assurance for the investment decision

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EEW SPC

# 5 Work Area:
## Accredited Test Laboratory, Monitoring and Certification Body

In order to meet the high quality requirements from research and industry, our test laboratory was accredited to DIN EN ISO/IEC 17025:2005 by the German accreditation body DAkkS in 2009. The testing portfolio is constantly being expanded and currently comprises the following tests:

**1. Mechanical-technical testing of base materials, welded and glued connections and mechanically-joined connections of small samples and parts made of metal and plastic**

- Tensile tests
- Long-term vibration tests
- 3-point bending tests
- Mechanically-joined connections: Friction coefficient, transverse longitudinal tensile capacity, tightening, torque and pre-loading force behaviour, vibration resistance
- Glued connections and adhesives, static and vibrating, single- and multi-shear connections, caterpillar peeling test
- Notched bar impact testing
- Vickers hardness testing

**2. Leak testing by means of the helium leak test**

- Container and tank tests
- Looking for leaks
- Testing of connections

**3. Corrosion testing**

- Vehicle painting (VDA)
- Coating systems for steel structures (ISO 12944-6, ISO 20340)

**4. Chemical-physical testing**

- Calcination of CFRP materials
- Spark emission spectroscopy of metals

**5. Monitoring and certification body**

- Outside monitoring of production plants
- Certification of construction products and types

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DAkkS Deutsche Akkreditierungsstelle D-PL-11140-01-00

# 5.1 Mechanical-technical tests – Tensile tests

Tensile testing of metals, plastics and fibre-reinforced plastics:

- Force range: 0.1 - 1000 kN
- Temperature range: -170 to 200°C

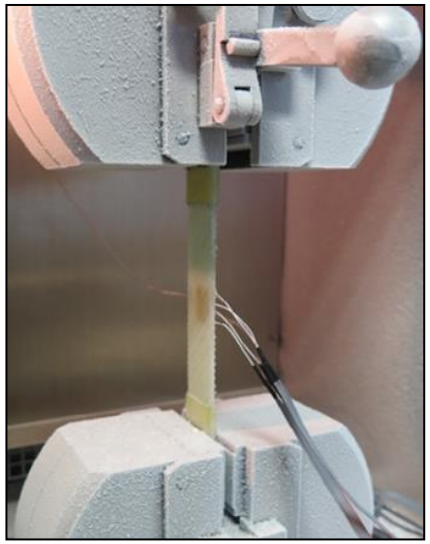
Testing in accordance with:

- DIN EN ISO 527-1-5
- DIN EN ISO 14125
- DIN EN ISO 14126
- DIN EN ISO 6892-1,3
- GL 2008
- ASTM D7078
- and many more.

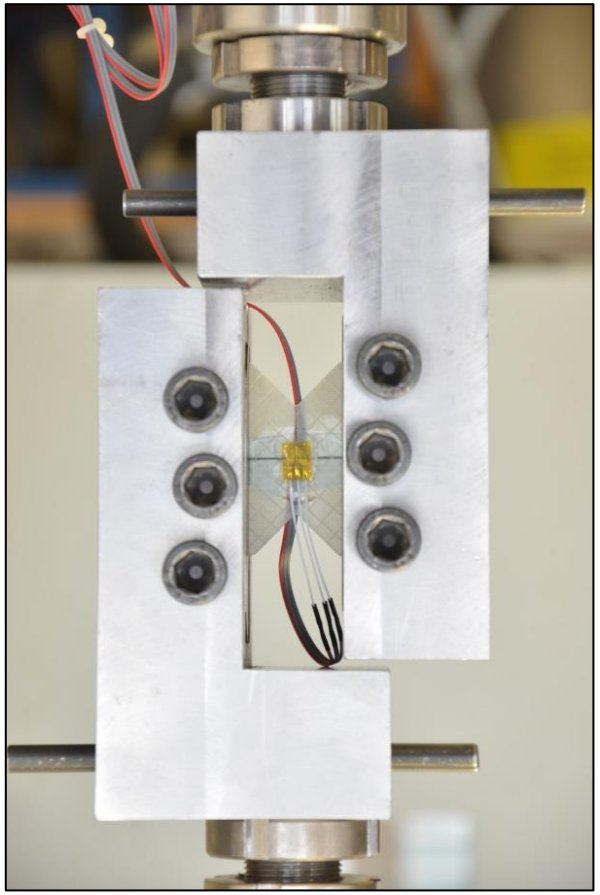
Test machines:

- Zwick/Roell Z400E
- Zwick/Roell Z50
- Zwick/Roell HB 1000

Tensile test on GFRP samples



Shear strength testing on GFRP samples



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DAkkS Deutsche Akkreditierungsstelle D-PL-11140-01-00

# 5.2 Mechanical-technical tests – Long-term vibration tests

Long-term vibration testing to determine the working life and dynamic indicators:

- Force range: 0.1 - 1000 kN

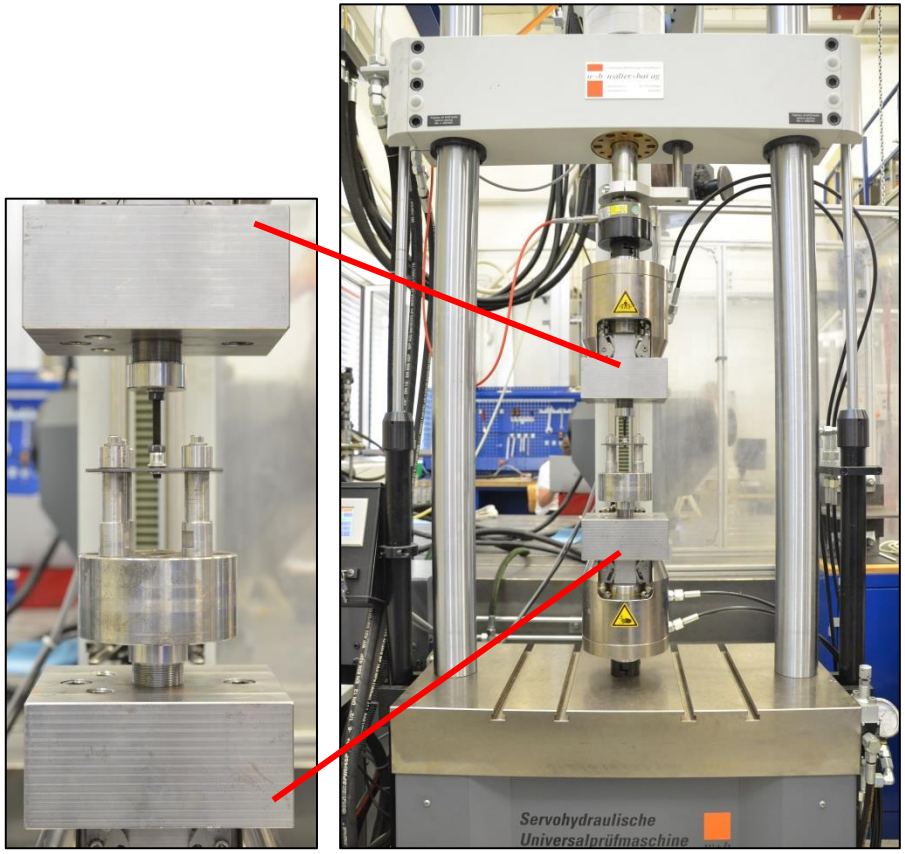
Testing in accordance with:

- DIN 50100
- DIN EN ISO 12737
- HV 1.5-01
- and many more.

Test machines:

- High-frequency pulsator Zwick/Roell HFP 5100
- Servohydraulic test machine Zwick/Roell HB 1000
- Pneumatic pulsator SINCOTEC 6kN + 10kN
- Powerswing 100kN
- Walter&Bai LFV 63kN

Long-term vibration test on blind rivet nuts

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# 5.3 Mechanical-technical tests – 3- and 4-point bending tests

3- and 4-point bending tests to determine the load-bearing capacity of large and small structures:

- Force range: 0.1 - 1000 kN

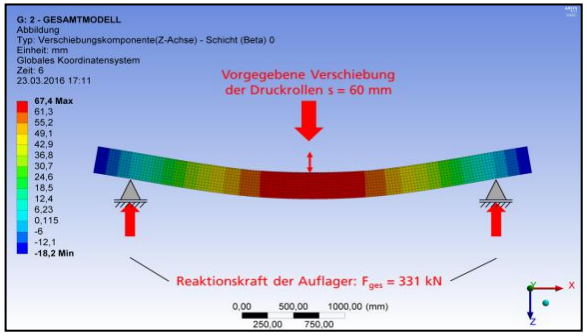
Testing in accordance with:

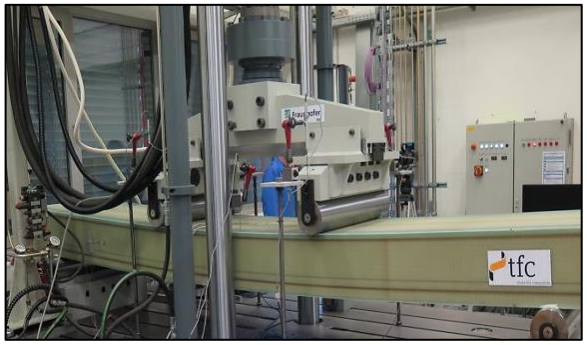
- DIN 50100
- DIN EN ISO 12737
- HV 1.5-01
- and many more.

Test machines:

- High-frequency pulsator Zwick/Roell HFP 5100
- Zwick/Roell Z400E
- Powerswing 100kN
- Walter&Bai LFV 63kN
- and many more.

4-point bending test on a GFRP large structure



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# 5.4 Mechanical-technical tests – Testing of mechanically-joined connections

Testing of mechanically-joined connections, i.e. with lockbolts and blind rivets:

- Force range: 0.1 - 1000 kN

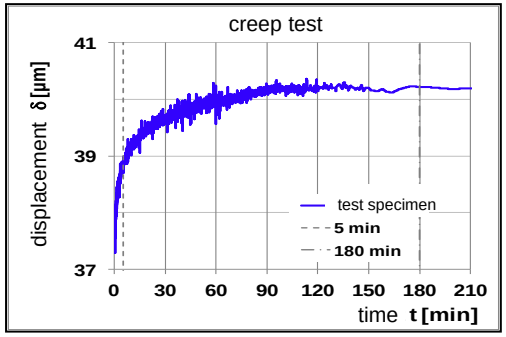
Testing in accordance with:

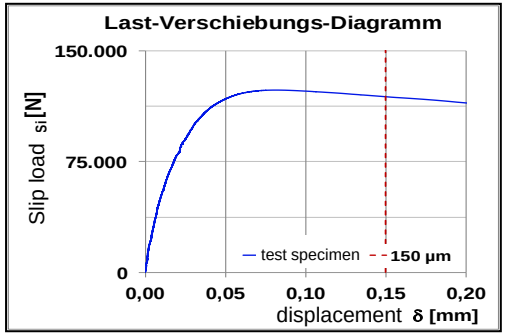
- Friction coefficient in accordance with DIN EN ISO -2
- Blind rivets in accordance with DIN EN ISO 14589
- Torque/preloading force in accordance with DIN EN ISO 16047
- and many more.

Test machines:

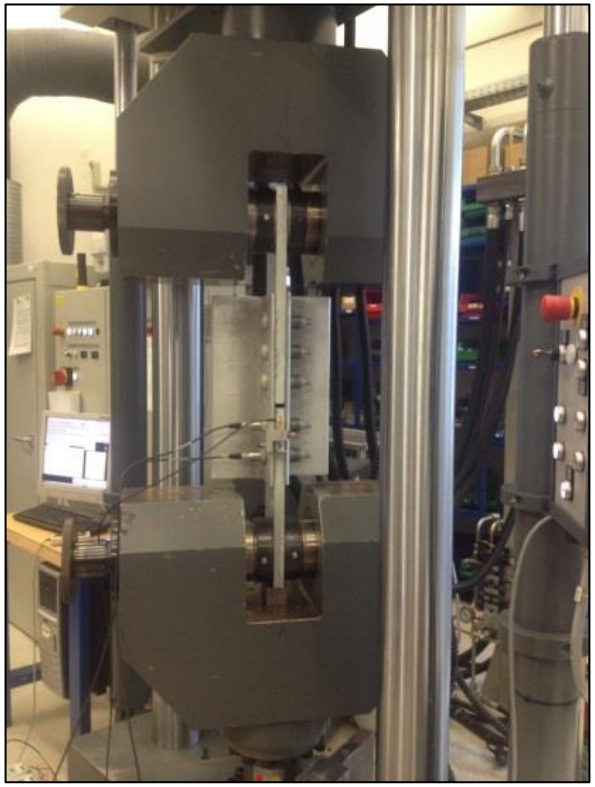
- High-frequency pulsator Zwick/Roell HFP 5100
- Servohydraulic test machine Zwick/Roell HB 1000
- Zwick/Roell Z400E
- Powerswing 100kN
- Walter&Bai LFV 63kN

Extended creep testing and slip load testing




Zwick/Roell HB 1000



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# 5.5 Mechanical-technical tests – Testing of glued joints and adhesives

Testing of glued connections and adhesives (static and vibrating, single- and multi-shear connections, caterpillar peeling test):

- Force range: 0.1 - 1000 kN

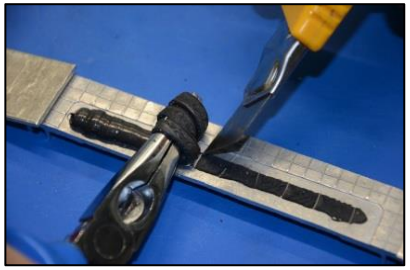
Testing:

- Tensile shear strength in accordance with DIN EN ISO 1465
- Production of samples in accordance with DIN EN ISO 9664
- Caterpillar peeling test in accordance with DIN 53281
- Adhesive strength of two-cut overlapping samples ASTM D 3528, and many more.

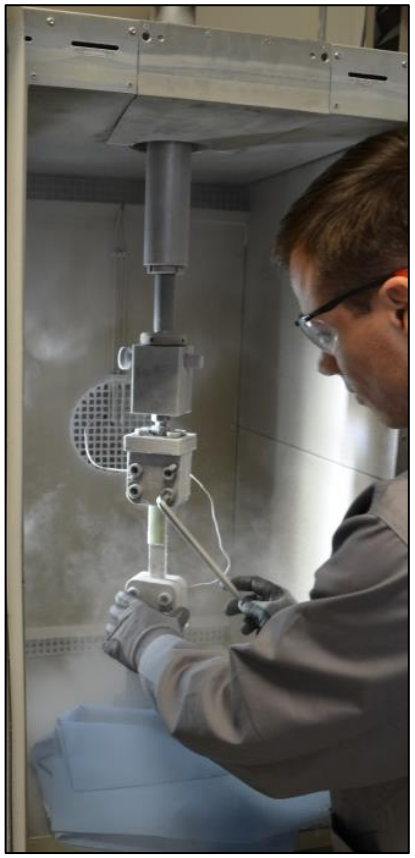
Test machines:

- High-frequency pulsator 5100 — Zwick/Roell HFP
- Servohydraulic test machine
  - Zwick/Roell HB 1000
- Zwick/Roell Z400E
- Powerswing 100kN
- Walter&Bai LFV 63kN

Preparation of samples and caterpillar peeling tests



Tensile shear strength testing of GFRP samples at low temperatures



Fraunhofer IPA

DAkkS Deutsche Akkreditierungsstelle D-PL-11140-01-00

# 5.6 Mechanical-technical tests – Notched bar impact testing

## Notched bar impact testing:

Testing:

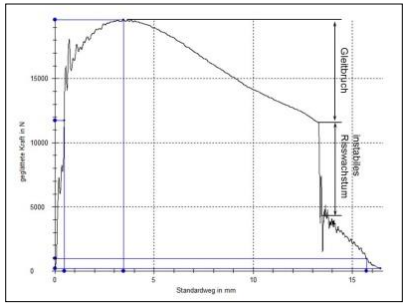
Notched bar impact testing on welded steel samples in accordance with GL 2008-07.

- Instrumented pendulum impact tester to record the force progression during the testing

Test machine:

- Zwick/Roell Hit 50 P
- WPM PSd450

Evaluation of welded steel samples




Zwick/Roell PSd 450

Fraunhofer IPA

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# 5.7 Mechanical-technical tests – Vickers hardness testing

## Vickers hardness testing

Testing:

- Hardness testing for arc-welded joints and micro-hardness testing in accordance with
  DIN EN ISO 9015-1,2
- Hardness testing of welds in accordance with GL2008-07

Test machine:

- Wolpert 432SVD

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# 5.8 Leak testing by means of the helium leak test

Leak testing of parts or test bodies using the helium leak test

Testing:

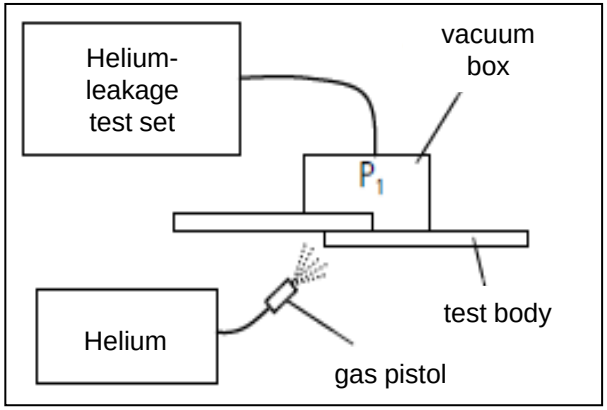
- HV 30 in conjunction with DIN EN 1779

Test machines:

- Pfeiffer Vacuum Smart Test

Pfeiffer Vacuum Smart Test

Test schematic layout for helium leak tests

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# 5.9 Testing of protection against corrosion

## Testing of protection against corrosion

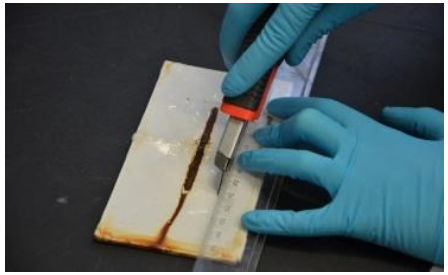
Testing:

- Corrosion testing in an artificial atmosphere – salt spray testing (DIN EN ISO 9227)
- Investigation of coating systems regarding the corrosion resistance of coating systems for steel structures, adhesive strength and coat thickness (DIN EN ISO 2409, 2808, 4624)
- Evaluation of coating damage such as the degree of formation of blisters, rust, cracks, etc. (DIN EN ISO 4628-1-5,8)

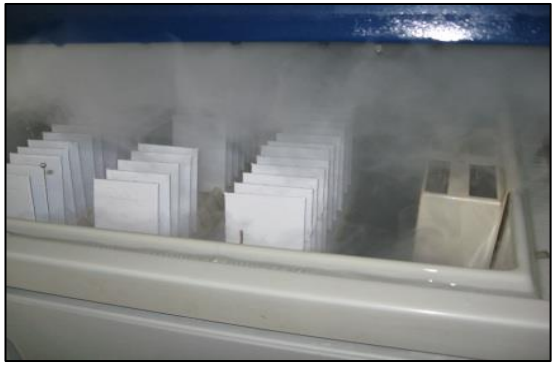
Test machines:

- Weiss Umwelttechnik SC/KWT 450 and SC/KWT 1000

Assessment of artificially weathered coating materials



Artificial weathering of coating systems



Fraunhofer IPA

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# 5.10 Chemical-physical tests

## Optical spark emission spectrometry, calcination

Testing:

- Destructive testing of parts made of steel materials, copper, aluminium and chrome nickel alloys in accordance with HV 4.0-01
- Determination of alloying constituents and the corresponding concentrations
- Destructive testing of parts made of fabric-reinforced plastics (Prepregs, moulding compounds and laminates) in accordance with DIN EN ISO 1172
- Determination of the content of glassfibre fabric and mineral fillers
- Calcination procedure

Test machines:

- Spectromaxx LMM04

Spectromaxx LMM04

CFRP specimen before, during and after thermal calcining

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# 5.11 Recognised monitoring and certification body MVO08

´14 - dato

## Area of application

- The Fraunhofer ACLSPE was recognised by the German Institute for Civil Engineering (DIBt) as monitoring and certification body MVO08 in 2014. The recognition covers construction products (joining elements) with national technical approvals in approval areas Z-14.1-… and Z-14.4-… in accordance with the national state building regulations (LBO).

## Tasks of the monitoring body

- Inspection and evaluation of the manufacturing plants and their in-house production control system regarding the staffing and technical prerequisites for proper production.
- Regular routine inspection and evaluation of the manufacturing plants and their in-house production control system
- Random checking of samples taken from the manufacturing plant, the market or, in special cases, from a construction site
- Production of outside monitoring reports and passing them on to the relevant certification body
- Taking suitable measures if the construction product does not satisfy the requirements of the general construction approval

## Tasks of the certification body

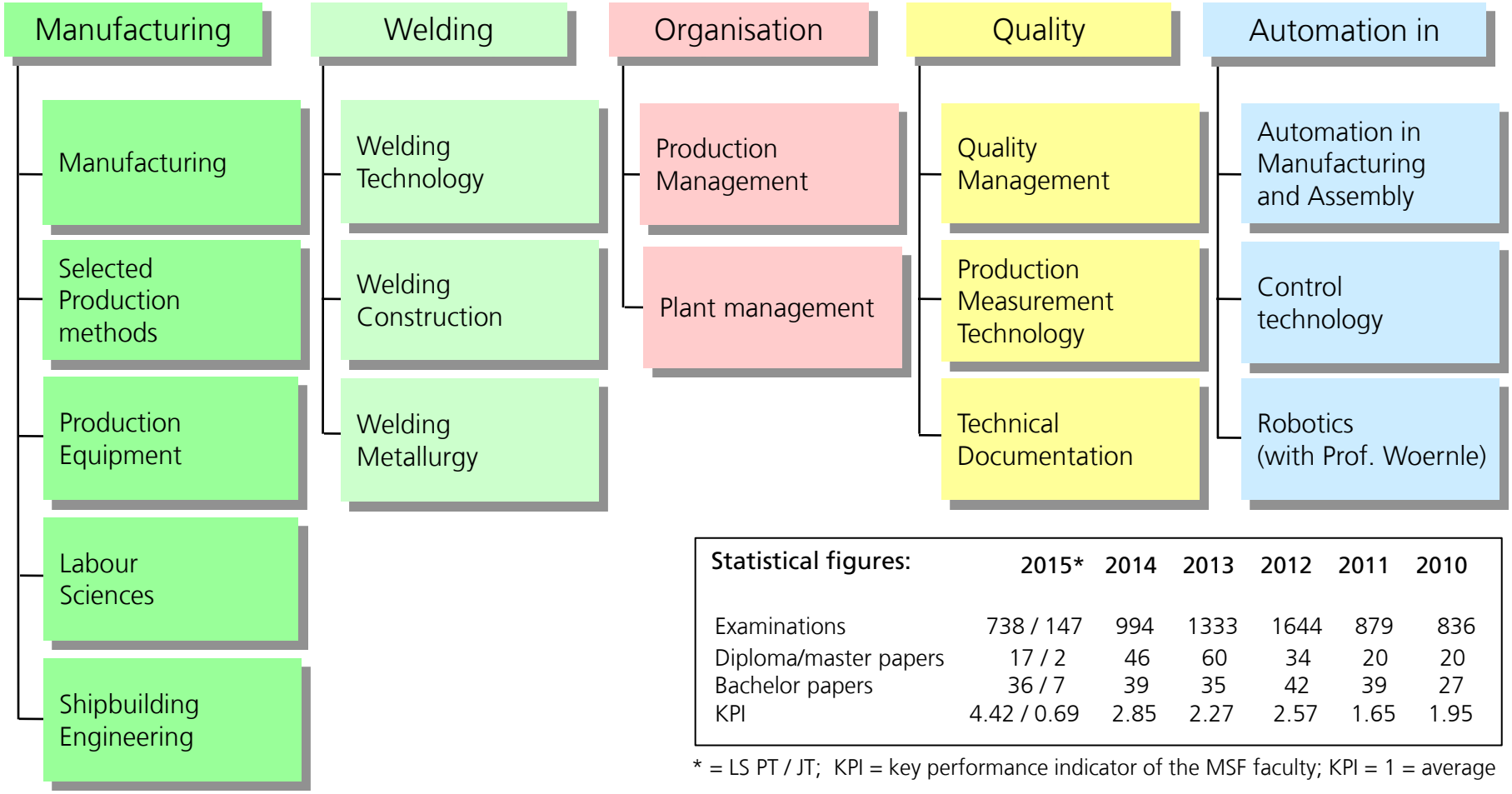
- Evaluation of supervisory reports
- Decision on granting and renewing of compliance certificates

Compliance mark (sample)

Non-regulated construction products in the building industry

Fraunhofer IPA | Deutsches Institut für Bautechnik DIBt

# 6 Work Area: Academic Programs Professorships Production Technology (PT) and Joining Technology (JT)




| Statistical figures: | 2015* | 2014 | 2013 | 2012 | 2011 | 2010 |
|---|---|---|---|---|---|---|
| Examinations | 738 / 147 | 994 | 1333 | 1644 | 879 | 836 |
| Diploma/master papers | 17 / 2 | 46 | 60 | 34 | 20 | 20 |
| Bachelor papers | 36 / 7 | 39 | 35 | 42 | 39 | 27 |
| KPI | 4.42 / 0.69 | 2.85 | 2.27 | 2.57 | 1.65 | 1.95 |

* = LS PT / JT; KPI = key performance indicator of the MSF faculty; KPI = 1 = average

# 7 Projects in Progress (2015-2018)

As of 5/16

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| | **Production Engineering** | | |
| 1. | Defined preloaded hybrid joint with lockbolts and blind rivet bolts | 2013-2015 | EFB/AiF |
| 2. | Numerical and experimental investigation of settling process irregularities with lockbolt systems | 2013-2015 | EFB/AiF |
| 3. | Load limits for FE investigations | 2013-2015 | EFB/AiF |
| 4. | Joining of pipework by bonding | 2013-2015 | CMT/AiF |
| 5. | Development of carbon fibre-reinforced bridge systems with automatic production | 2013-2015 | ZIM cooperation with BaltiCo and HS Wismar |
| 6. | Development and qualification of a small wind turbine plant for regions with demanding climatic conditions | 2013-2015 | Joint project with Dethloff & Lange/TBI |
| 7. | Use of maintenance-free lattice masts for wind turbines with large hub heights | 2013-2015 | Joint project with Stieblich/TBI |
| 8. | Feasibility study for the development of function-integrated floors made of FRP | 2014-2015 | PMC, Rhena |
| 9. | Roto PA | 2014-2015 | Emano Kunststofftechnik, Teterow |
| 10. | Development of a test environment for qualified hydrogen investigation by means of an implant test | 2014-2015 | EEW, Rostock |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 11. | Development of a bonding process for a rubber liner and qualification of the adhesive joint | 2014-2015 | Faber Industrie SPA, Udine |
| 12. | Determination of the structural behaviour of Bobtail lockbolts of large diameter | 2014-2015 | Alcoa Huck, Telford |
| 13. | Feasibility study: Customer-made, free-form interior element one-off examples made of coloured mineral materials | 2014-2015 | Eigenstetter, Rhena |
| 14. | Support for the development of a TIG twin process technology | 2014-2016 | MIKA, Stralsund |
| 15. | Requirements profile for blind rivet joints with carbon fibre | 2014-2016 | EFB/AiF |
| 16. | Design concept for structural blind rivet joints in structural steelwork and machine construction | 2014-2016 | EFB/AiF |
| 17. | Execution and reliability of slip-resistant connections for steel structures using LS and SS (VP SIROCO) | 2014-2016 | EC: Research Fund for Coal and Steel, Joint Project |
| 18. | Development of a handheld tool for solid punch rivet installation, Part I and II | 2014-2017 | Airbus GmbH, Hamburg |
| 19. | Join connections of lockbolts under atmospheric stress | 2014-2017 | EFB/AiF |
| 20. | Feasibility study: Implementability of integral lightweight sections made of composites for inland waterway passenger ships | 2015 | tfc, Güstrow |
| 21. | CTOD testing | 2015 | EEW, Rostock |
| 22. | Utilisation of preloaded connecting elements for thin clamping areas under suitable conditions for installation | 2015-2016 | EFB/AiF |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 23. | Increase in process reliability of submerged arc, AC /AC process variations by means of optical analysis of the electric arc and the material transition in the cavity area | 2015-2016 | DVS FA-V3/AiF |
| 24. | Evaluation of the bolted connections of the "TEREFLEX" concept for wind turbine towers with large hub heights | 2015-2016 | ThyssenKrupp Steel, Europe |
| 25. | Experimental investigations for obtaining a general certificate of suitability for use in accordance with the statutory building regulations | 2015-2016 | Butzkies wind project, Hamburg |
| 26. | Comparison and analysis of various setting procedures to produce blind rivet-nut connections of suitable quality | 2015-2017 | EFB/AiF |
| 27. | Development of a joining process for a PET Liner | 2015-2016 | Faber Industrie SPA, Udine |
| 28. | Spot-type laminate support by Z -Pins to increase the joining point stiffness when using mechanical joining elements | 2015-2016 | EFB/AiF |
| 29. | Consultation of CRM Group for static and fatigue test of slip-resistant joints for a specified towers for wind turbines | 2015-2016 | CRM Group, Liège, Belgium |
| 30. | Wöhlerlinie IHF-System size M27 | 2015-2016 | IHT-Meschede |
| 31. | Selection and testing of connecting elements for the connection of copper strands in FRP sandwich attachments | 2015-2016 | Nordex, Rostock |
| 32. | Experimental investigation of preloading force time behaviour and vibration resistance of MTH girder clamping connections according to the general construction approval Z-14, 4-493 | 2015-2016 | MTH-Befestigungstechnik, Arnsbach |
| 33. | Experimental investigations of welding details to determine the notch classes in accordance with DIN 1993-1-9 for Soft-Soft tower technology | 2015-2016 | Nordex AG, Hamburg |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 34. | Support in the investigation of the technical feasibility of a handling system | 2015-2016 | Ostseestaal, Rostock |
| 35. | Multiple-wire submerged arc welding with cold wire infeed | 2015-2017 | Joint project with EEW/TBI |
| 36. | Development of a concept to record the preloading force losses in preloaded bolted connections under fatigue stress | 2015-2017 | FOSTA/AiF |
| 37. | Increase in load-bearing capacity of eccentrically-stressed connections by the use of lockbolt systems | 2015-2017 | EFB/AiF |
| 38. | Material- and process-related optimisation of cavitation-erosion-resistant coatings on ship rudders by means of cold gas spraying | 2015-2017 | CMT/AiF |
| 39. | Development of a holistic, established and environmentally-friendly form of corrosion protection to reduce the overall costs for offshore wind turbines through optimised and suitably matched manufacturing segments. | 2015-2018 | VP, PT BMWi/PTJ - energy research program |
| 40. | Wachstumskern Offshore Wind Solutions-MV<br>Sub-project TP 1.E | 2015-2018 | VP, PT BMBF/PTJ |
| 41. | Wachstumskern OWS-MV<br>Sub-project TP 2.E | 2015-2018 | VP, PT BMBF/PTJ |
| 42. | Wachstumskern OWS-MV<br>Sub-project TP 3.7 | 2015-2018 | VP, PT BMBF/PTJ |
| 43. | Wachstumskern OWS-MV | 2015-2018 | VP, PT BMBF/PTJ |

| | | | |
|---|---|---|---|
| | Sub-project TP 4 F | | |
| Serial No. | Project Theme | Duration | Customer / Project Manager |
| 44. | Wachstumskern OWS-MV<br>Sub-project TP 5.D | 2015-2018 | VP, PT BMBF/PTJ |
| 45. | Qualifying the Sure Set System with BOM blind-bolts for checking integrity of installed fasteners after pin break | 2016 | Alcoa Huck, Telford |
| 46. | Experimental investigations to determine the dimensioning values for the tensile and transverse force capacity for joints with Goebel Multigrip blind rivets in PV modules | 2016 | Goebel, Erkrath |
| 47. | Climatic testing floor covering | 2016 | Egger Retail Products, Wismar |
| 48. | Determination of the influence of laboratory ageing on the mechanical properties of FRP | 2016 | Nordex, Rostock |
| 49. | Development of automated and flexible manufacturing processes | 2016 | Tischlerei Eigenstetter, Rhena |
| 50. | Scalable high-voltage heater for the automotive industry | 2016-2017 | Webasto, Neubrandenburg |
| 51. | Stair plug-in system for rational production and installation | 2016-2017 | Tischlerei Ebert, Prohn |
| 52. | Optimization Study and Manufacturing of the SPR hand tools functional prototype for stringer coupling | 2016-2017 | Airbus GmbH, Hamburg |
| 53. | Partially automated manufacturing process for 3D FRP hot press parts | 2016-2017 | tfc, Güstrow/TBI |
| 54. | Analytical verification of frictional contact joints with slotted holes for light metals and steel materials | 2016-2018 | EFB/AiF |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 55. | Holistic, resources-efficient tower concept for wind turbines with large hub heights at onshore locations with weak winds | 2016-2018 | VP, PT BMWi/PTJ - energy research program |
| | **Automation and Quality Engineering, Prototyping** | | |
| 56. | Technology and system development for the automatic production of pipe nodes, TP2:. Orbital welding system | 2013-2015 | Joint project with IMG GmbH/TBI |
| 57. | Standard geometry-based model for the interior outfitting of megayachts – IMOScan 3D joint project | 2013-2016 | Joint project with Lürssen, Dölker + Voges/PTJ |
| 58. | Low Cost Flexible Automation and Mechanisation in Small and Medium Shipyards (project SMARTYards) | 2013-2016 | EU joint project |
| 59. | Development of a mobile mobile disassembly cell for rotor blades - feasibility study | 2014-2015 | Hanseatic Rohr, Rostock |
| 60. | Development of an automated palletising device for storage containers | 2014-2015 | Instamak, Selmsdorf |
| 61. | Coast model Darß | 2015 | Deutsches Meeresmuseum, Stralsund |
| 62. | 3D testing of a rotor blade master prototype | 2015 | Tamsen Maritim, Rostock |
| 63. | Technology study: Development of a system concept for the automated marking of ship propellers | 2015-2016 | MMG Waren |
| 64. | Study on the re-engineering of an automatic tank-filling system | 2015-2016 | HHLA, Hamburg |
| 65. | Robots for new application fields in the Industry 4.0 area | 2015-2016 | IMG, Rostock |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 66. | Automatic rounding of edges of flat parts | 2015-2016 | HIT, Rostock |
| 67. | Development of a cleaning system for an industrial pizza oven | 2015-2016 | Dr. Oetker, Wittenberg |
| 68. | 3D data collection and monitoring of large underwater structures | 2015-2017 | MAVO-FhG with IPM Freiburg |
| 69. | Development of a novel mobile disassembly cell for rotor blades | 2015-2018 | Joint project with Hanseatic Rohr, Rostock/TBI |
| 70. | Precise and rapid collection and evaluation of geometry data of ship surfaces for efficient coating processes (FINISH) | 2016-2019 | VP, PT BMWi/PTJ |
| | Organisational Technology | | |
| 71. | Development of an intelligent workbench suitable for older workers for the manual assembly of large components (ERGOTAB) | 2013-2016 | Joint project with REFA, MiniTec, Hobas and Selck/BMBF-PTJ |
| 72. | Technology study: Innovative recycling of ships | 2014-2015 | IMG GmbH, Rostock |
| 73. | Analysis of dynamic floor deflection | 2014-2015 | Airbus GmbH, Hamburg |
| 74. | Technical feasibility study for a new generation of production control systems | 2014-2015 | SEAR, Rostock |
| 75. | Basic research into new technologies to support installation, maintenance and training | 2014-2015 | Siemens AG, Erlangen |
| 76. | Technical feasibility study for the ergonomic control room 4.0 | 2014-2015 | Koepke & Kassiske, Garz |

| Serial No. | Project Theme | Duration | Customer / Project Manager |
|---|---|---|---|
| 77. | Simulation study for the robotic painting unit for the 65.5 rotor blade at Nordex Energy GmbH | 2015 | Icarus Consulting, Lüneburg |
| 78. | Mobile data collection | 2015-2016 | Nordex AG, Rostock |
| 79. | Productivity studies | 2015-2016 | Peene-Werft, Wolgast |
| 80. | Flexible and intelligent balancer | 2015-2017 | KIS, Wismar |
| 81. | Flexibly automated switching of parts in deep-drawing presses | 2015-2017 | Lang, Woldegk |
| 82. | Conceptual design for an IT-based BDE | 2016 | MGT Maschinen- und Gerätebau, Groß Wokern |
| 83. | Study Industry 4.0 | 2016 | WiMi-MV |
| | INNO PROFILE | | |
| 84. | Sensor-based robot programming for the automatic production of high, orthogonal volume structures | 2013-2016 | INNO PROFILE transfer: Joint project with IMG, Hensel Electronic and Nordic Yards / BMBF-PTJ |

# 8 Committee Membership, Further Lectureships 2015

**Working group of the industrial research association "Otto von Guericke" e. V.**
Prof. Dr.-Ing. K.-M. habil. Henkel – Expert assessor
Prof. Dr.-Ing. M.-C. Wanner – Expert assessor

**Federal Ministry of Research and Technology**
Prof. Dr.-Ing. M.-C. Wanner – Expert assessor for the development scheme "Innovative shipbuilding secures competitive jobs"

**Center of Maritime Technologies (CMT)**
Prof. Dr.-Ing. M.-C. Wanner – Member of the Technical Advisory Board

**German Society for Quality (GSQ)**
Dr. rer. pol. A.-K. Schröder – Deputy head of the Rostock section

**German Association for Welding and Related Processes e. V. (DVS)**
Prof. Dr.-Ing. habil. K.-M. Henkel – Chairman of the state association M-V

**German Institute for Civil Engineering (DIBt)**
Dr.-Ing. R. Glienke – Member of the expert committee SVA "Metal structures and composites structures"

**European Research Society for Sheet Processing e. V.**
Dr.-Ing. R. Glienke – Deputy chairman of the working group Mechanical joining AGMF3/V10

**Hanse Aerospace e. V., Hamburg**
Prof. Dr.-Ing. M.-C. Wanner – Member of the Technical Advisory Board

**Maritime Alliance Baltic Sea Region e. V.**
Dipl.-Wirt. Ing. J. Sender – Board of Management

**REFA State Association Mecklenburg-Western Pomerania e. V.**
Dipl.-Wirt. Ing J. Sender – Member of the Board of Management

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

**Technical University of Hamburg-Harburg**
Prof. Dr.-Ing. M.-C. Wanner – Lecturer for the subject "Principles of Production and Assembly in Ship Construction"

**Technology and Innovation Group Business/Science M-V**
Prof. Dr.-Ing. M.-C. Wanner – Member

# 9 Guest Lecturers and Guest Scientists 2015

Dr.-Ing. N. Fuchs, Fraunhofer AGP, Lecture Selected Production Procedures – Joining Technology
Dipl.-Ing. (FH) M. Geist, Fraunhofer AGP, Exercises Production Measuring Technology
Dr.-Ing. R. Glienke, Fraunhofer AGP, Lecture Welding Construction
Dipl.-Ing. N. Glück, Fraunhofer AGP, Lecture Selected Production Procedures – Gluing Technology
Dipl.-Phys. J. Hoffmann, SLV-MV Rostock, Lecture Selected Production Procedures – Laser Technology
Prof. Dr.-Ing. K. Ortlieb, Dürr AG Stuttgart, Lecture Selected Production Procedures – Painting Technology
Dr. rer. pol. A.-K. Schröder, Fraunhofer AGP, Lectures and exercises Plant Management and Production Management
Dipl.-Wirt. Ing. J. Sender, Fraunhofer AGP, Lecture on labour sciences; exercises in shipbuilding technology 2
Dr.-Ing. B. Weidemann, TKMS Blohm+Voss, Lecture Automation in Production and Assembly – Information Systems
Dipl.-Ing. O. Wurst, Fraunhofer AGP, Lecture Control Engineering
Dr.-Ing. A. Zych, University of Rostock, externally funded, exercises in automation technology

# 10 Scientific Events, Exhibitions 2015

**Scientific Society Installation, Handling and Industrial Robotics (MHI)**
Members meeting 08.05.2015, Rostock

**EFB Work Group Session "Mechanical Joining"**
18.06.2015, Rostock

**Working party XXL products**
Seminar 21.10.2015, Rostock

# 11 Publications, Articles, Presentations 2015

## 11.1 Books

Wanner; M.-C.; Ebert; A.; Glienke, R.:
**Conditions for a production and repair-oriented design of lockbolt joints while complying with the minimum load-bearing strength**
EFB research report No. 406, Hanover, 2015, ISBN 978-3-86776-451-3

Wanner, M.-C.; Fuchs, N.; Nehls, T.;Landgrebe, D.; Kropp, T.:
**Numerical and experimental investigation of settling process irregularities with lockbolt systems**
EFB research report No. 426, Hanover, 2015, ISBN 978-3-86776-473-5

Wanner, M.-C.; Glienke, R.; Blunk, C.:

**Experimental determination of the fatigue strength of shear-stressed lockbolt and blind rivet joints without component influence**
EFB research report No. 410, Hanover, 2015, ISBN 978-3-386776-456-8

## 11.2 Magazine Articles, Proceedings

Banaschik, R.; Herholz, H.; Henkel, K.-M.:

Filler wire electrodes for electro-gas welding in the European economic area - current state of development

In: Schweißen und Schneiden 67(2015)5, pp 245-249

Blunk, C.; Glienke, R.; Wanner, M.-C.:

Reducing costs, increasing efficiency

In: DVS reports vol. 315, pp 789-794, 2015, ISBN 978-3-945023-46-4

Denkert, C.; Süße, D.:
**Using the F-element for the correct bolted joint**
In: proceedings: 16. Round Table "Simulating Manufacturing", 16 p, 2015, ISBN 978-3981381443

Denkert, C.; Wanner, M.-C.; Glienke, R.; Busch, M.:
**Hybrid joints - using preloading and bonding intelligently**
In: Proceedings TechnoBond, 2nd Industrial Gluing Technology symposium, pp 144-148, 2015

Fröck, L.:

Joining of pipework by bonding in shipbuilding

In: Ingenieur-Spiegel (2015)2, pp 71-72

Fröck, L.; Glück, N.; Nagel, C.:

Joining of metal pipes in shipbuilding by bonding (part 1)

In: adhäsion 59(2015)10, pp 42-47

Fröck, L.; Nagel, C.:

**Joining of pipework by bonding in shipbuilding**

In: DVS reports vol. 315, pp 149-152, 2015, ISBN 978-3-945023-46-4

Fröck, L.; Nagel, C.; Brede, M.; Glück, N.:

**Dimensioning on the basis of analytical methods**

In: adhäsion 59(2015)12, pp 38.43

Fröck, L.; Nagel, C.; Brede, M.; Glück, N.:

**Determination and validation of indicators**

In: adhäsion 59(2015)11, pp 36-41

Fröck, L.; Wanner, M.-C.:

**Joining of pipework by bonding in shipbuilding**

In: Proceedings TechnoBond, 2nd Industrial Gluing Technology symposium, pp 162-165, 2015

Fuchs, N.; Wanner, M.-C.:

**Recording and evaluation of the tension state of bolted connections by acoustic resonance analysis**

In: TM – Technisches Messen 82(2015)10, pp 526-535

Geist, M.; Meister, M.; Knaack, L.; Gierschner, F.:

**Local modelling for the determination of surface shape discrepancies using a terrestrial laser scanner**

In: Photogrammetry-laser scanning-optical 3D measuring technology. Contributions of the Oldenburger 3D days, pp 2-13, 2015,

ISBN 978-3879075539

Gericke, A.; Banaschik, R.; Henkel, K.-M.:

**Increase in toughness through melt bath vibration of submerged arc-welded fine-grain construction steels**

In: Proceedings DVS reports 315, pp 695-700, 2015

Gierschner, F.; Geist, M.; Knaack,L.; Meister, M.:

**Partially automated quality control in construction of structural steelwork using laser scanners**

In: Proceedings Go-3D Computer graphics in practice, pp 129-140, 2015

Glienke, R.; Blunk, C.; Denkert, C.; Wanner, M.-C.:

**Dimensioning and execution of joints with lockbolts in structural steelwork**

In: Stahlbau 84(2015)12, pp 980-997

Glienke, R.; Ebert, A.; Wanner, M.-C.:

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Glück, N.:

**Optimisation of the application of force in trusses made of composites**

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Glück, N.; Schumann, M.:

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Innovative rudder coatings through cold gas spraying processes
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Application of small robots in GMA welding of large tubular nodes
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Knaack, L.: Geist, M.; Gierschner, F.; Meister, M.:
Use of laser scanners in construction of structural steelwork
In: Schiff & Hafen 67(2015)8, pp 36-39

Meißner, J.-P.; Schulz, J.-P.; König, A.; Fleßner, H.:
**New team in simulation - robots and optical sensors**
In: ZWF - Zeitschrift für wirtschaftlichen Fabrikbetrieb (2015)3, pp 94-97

Meißner, J.; Sender, J.; Weidemann, B.; Wanner, M.-C.:
**Simulation Environment for the Integration of 3D-Sensors into Automated Maritime Production Facilities**
In: Proceedings 14th International Conference on Computer and IT Applications in the Maritime Industries, Ulrichshusen, 11-13 May 2015, pp 556-562

Nehls, T.; Wanner, M.-C.; Landgrebe, D.; Kropp, T.:

**Numerical and experimental investigation of settling process irregularities with lockbolt systems**

In: Proceedings Joint research in mechanical joining technology, pp 51-57, 2015

Staschko, R.; Fuchs, N.; Glück, N.:

**Damage in the semi-hollow punch riveting process in hybrid FRP joints**

In: Joining Plastics – Fügen von Kunststoffen 9(2015)3-4, pp 204-211

Stranghöner, N.; Afzali, N.; Berg, J.; Schiborr, M.; Bijlaard, F.; Gresnigt, N.; De Fries, P.; Glienke, R.; Ebert, A.:

**Influence of different testing criteria on the slip factor of slip-resistant connections**

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Wanner, M.-C.; Glück, N.; Schumann, M.; Schornstein, B.:

**Truss-type lightweight structures made of FRP**

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## 11.3 Presentations, Posters

Banaschik, R.:
**State of development of electro-gas welding**
Presentation, Thermal joining and parting technology on large structures, 08.01.2015, Rostock

Gericke, A.:
**Development and application perspectives for submerged arc welding from the research point of view**
Presentation, 2nd Joining Technology Seminar, Thermal joining and parting technology on large structures, 08.01.2015, Rostock

Beuß, F.:
**ErgoTab. Development of an intelligent workbench suitable for older workers for the manual assembly of larger components**
Presentation, InHouse, Schönenberg-Kübelberg, 16.04.2015

Banaschik, R.:
**Filler wire electrodes for electro-gas welding**
Presentation, Industrial colloquium "Welding filler materials - Current questions and new developments", 24.04.2015, Aachen

Schröder, A.-K.; Nebl, T.:
**Productivity factor production organisation**
Presentation, commemorative event and symposium "25 years REFA Mecklenburg-Western Pomerania e. V.", 05.05.2015, Neubrandenburg

Fuchs, N.; Froitzheim, P.:
**Long-term monitoring of structural components and lockbolt connections in wind turbine lattice towers**
Presentation, 4th Future Conference Wind & Maritime on 06. and 07.05.2015, Rostock

Ehrich, K.;Fröck, L.:
**Joining of pipework by bonding in shipbuilding**
Presentation, TechnoBond - Second industrial gluing technology symposium, 06.06.2015, Memmingen

Gründler, M.:
**Large robots in propeller production**
Presentation, Technology and industrial policy conference, 18.06.2015, Wismar

Wanner, M.-C.:
**Production 2000 – was concerns us today and awaits us tomorrow**
Presentation, Technology and industrial policy conference, 18.06.2015, Wismar

Henkel, K.-M.; Glienke, R.; Ebert, A.:
**Innovative structural steelwork joints in tower structures**
Presentation, WindEnergy Network, 22.06.2015, Rostock

Gericke, A.; Henkel, K.-M.; Gött, G.; Uhrland, D.:
**Optical Study of a SAW Cavern**
Presentation, Study Group 212 "Physics of Welding", June 29-July 1, 2015, Helsinki

Meißner, J.:
**Simulation and offline programming of a large robot for the machining of ship propellers**
Presentation, 5th WGP annual congress, 07.-08.09.2015, Hamburg

Wanner, M.-C.:
**State of automation technology in M-V**
Presentation, "Start of CNC training and further training", 08.09.2015, Technology Centre Schwerin

Fröck, L.; Nagel, C.:
**Joining of pipework by bonding in shipbuilding**
Presentation, DVS Congress - Large Welding Congress, 14.-17.09.2015, Nuremberg

Gericke, A.; Banaschik, R.; Henkel, K.-M.:
**Increase in toughness through melt bath vibration of submerged arc-welded fine-grain construction steels**

Presentation, DVS Congress - Large Welding Congress, 14.-17.09.2015, Nuremberg

Herholz, H.:
**Application of small robots in GMA welding of large tubular nodes**
Presentation, DVS Congress - Large Welding Congress, 14.-17.09.2015, Nuremberg

Blunk, C.; Glienke, R.; Wanner, M.-C.:
**Reducing costs, increasing efficiency**
Presentation, DVS Congress - Large Welding Congress, 14.-17.09.2015, Nuremberg

Meißner, J.:
**Simulation and offline programming of a large robot for the machining of ship propellers**
Presentation, 1st session of the study group "Simulation technology in the MHI", 22.09.2015, Dortmund

Glück, N.:
**Optimisation of the application of force in trusses made of composites**
Presentation, German Aerospace Congress, 22.-24.09.2015, Rostock

Herholz, H.:
**Application of small robots in GMA welding of large tubular nodes**
Presentation, SOLUCIONES EN SOLDADURA ROBOTIZADA PARA CONSTRUCCIÓN NAVAL, 22.10.2015, O Porrino, Spain

Glienke, R.; Ebert, A.:
**Current requirements concerning mechanical joining technology in steel and metal lightweight construction for solar systems and wind turbines**
Presentation, 25th Welding symposium at the SLV Halle (85 years SLV Halle), 04.11.2015, Halle

Nehls, T.:

**Punch riveting of Al-Al and Al-FVK in aircraft construction**
Presentation, 8th Rostock Welding days, 10. and 11.11.2015, Rostock

Glienke, R.:

Lockbolt systems - areas of application and calculation

Lecture, FOSTA symposium - Towers and masts made of steel, 18.11.2015, Düsseldorf

Wanner, M.-C.:
**Further development of future fields taking the example of machine construction**
Presentation, Strategy council economics science, 26.11.2015, Rostock

Nehls, T.; Kropp, T.:
**Numerical and experimental investigation of settling process irregularities with lockbolt systems**
Presentation, 5th Colloquium on Joining Technology, 08.-09.12.2015, Paderborn

Glienke, R.; Blunk, C.; Wanner, M.-C.:
**Experimental determination of the fatigue strength of shear-stressed lockbolt and blind rivet joints without component influences**
Presentation, 5th Colloquium on Joining Technology, 08.-09.12.2015, Paderborn

## 11.4 Concluding reports

Henkel, K.-M.; Hauer, M.; Gärtner, F.; Krebs, S.:
**Damage-resistant surface coatings of maritime structures under typical operating and environmental conditions, taking the example of a rudder (BESOMA)**
AiF concluding report IGF project17135 N, 2015

Wanner, M.-C.; Fuchs, N.; Froitzheim, P.:
**Use of maintenance-free lattice masts for wind turbines with large hub heights**
**TP 5: "Development of low-maintenance connections with regard to the effect of the joints on the overall dynamic behaviour of the construction TP 6: Verification of the overall dynamic load calculation by contact and optical measuring procedures"**
TBI concluding report V-630-F-168-2013/104

Wanner, M.-C.; Gründler, M.; Herholz, H.; Klötzer, C.:

**Automated pipe node production. Production of large to very large pipe nodes**
ARF project, concluding report AZ v-630-S178-2013/233, AZ v-630-S178-2013/234

Wanner, M.-C.; Henkel, K.-M.; Hein, R.:
**HoGfOS - High-strength foundation structures for the offshore Industry**
TBI concluding report V-630-S-153-2012/186

# 12 PhD thesis 2015

Grewe, O.:
**Detection and evening out of geometric imperfections in yacht surfaces**
Defense on 20.05.2015

Fuchs, N.:
**Contribution on the testing of the tension state of special bolted connections by acoustic resonance analysis**
Defense on 12.11.2015

# 13 Master papers 2015

*Course of study Master in Machine Construction*

Bauermeister, Alexander – Supervisor: M.Sc. S. Schmidt

Investigation of compressive strength of corrugated composite fibre structures in experimental tests

Becker, Malte – Supervisor: Dipl.-Ing. R. Banaschik

Contribution on the injection treatment of large weld fusion baths by means of mechanical and chemical modifiers

Bienasch, Richard – Supervisor: Dipl.-Ing. M. Schumann

**Investigation of the influence of a bonded connection in a shell structure on its bending stiffness**

Bradler, Björn – Supervisor: M.Sc. M. Hauer

**Qualification of an implant unit to determine the cold cracking behaviour of selected UP-/GWA-welded samples**

Bredt, David – Supervisor: Dr.-Ing. N. Fuchs

**Automation of a stack assembly for fuel cells with regard to the influencing parameters**

Breinlinger, Paul – Supervisor: Dr.-Ing. N. Fuchs

**Investigation of the influence of the weld seam geometry and execution on the validation of CTOD samples to determine the quasi-static fracture toughness**

Dörre, Maik – Supervisor: Dipl.-Ing. C. Denkert

**A contribution to the assessment of the material and mechanical properties of bolts of specified strength classes**

Drisga, Ivo – Supervisor: Dipl.-Ing. S. Dryba

**Production of a flexible MBS model of a redundant manipulator for the evaluation of offline track planning**

Hendzlik, Kevin – Supervisor: Dr.-Ing. U. Kothe

**Process optimisation of a setting pressure distribution test stand for product testing within series production**

Hermsdörfer, Jörg – Supervisor: M.Sc. M. Hauer

**Development and production implementation of a high-temperature spraying head for surface treatment with resistant media**

Hintze, Christian – Supervisor: Dr.-Ing. U. Kothe

**Correlation between susceptibility to cold cracking and welding temperature cycles in the submerged arc welding of offshore structures**

Hübner, Julius – Supervisor: M.Sc. T. Nehls

**Experimental determination of the creep properties of fibre-reinforced plastics when using mechanical joining elements**

Kelling, Robert – Supervisor: Dr.-Ing. R. Glienke

**Development of a test device to determine the coefficient of friction of non-slip connections under static long-term load in accordance with DIN EN 1090-2, Annex G**

Kempke, Felix – Supervisor: Dipl.-Ing. R. Hein

**Comparison of the mechanical properties of soldered butt joints in 5 mm S355 with the solders CuAl5M2, CuMuI2M2, CuSn6 and CuSi3Mn**

Klatt, Benjamin – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Drawing up of a concept for the standardization of setup processes in highly automated production lines in the automotive supplier industry with the aid of lean tools**

Kraus, Daniel – Supervisor: Dipl.-Ing. N. Glück

**Development of a lightning conductor for rotor blades made of fibre-reinforced composites**

Krüger, Paul – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Investigation of the change in production work flow and quality assurance through the introduction of DIN EN 1090, taking the example of a structural steelwork company**

Mausolf, Christian – Supervisor: Dr.-Ing. N. Fuchs

**Development of the standard interface of an AC platform between Topside and Jacket**

Meyer, Kristian – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Chemical and calorimetric investigation of submerged arc welding processes with various forms of polarity modulation**

Tim, Milbrandt – Supervisor: Dipl.-Math. M. Meister

**Development of a simulation environment for the digital illustration of various underwater structures with a novel 3D sensor**

Pauluhn, Eik – Supervisor: M.Sc. M. Hauer

**Laser deposit welding of tin-based alloys with a higher proportion of copper (Cu > 15%) for composite plain bearings**

Rater, Hannes – Supervisor: Dipl.-Ing. M. Schumann

**Experimental determination and modification of the static load-bearing characteristics of lattices made of carbon fibre-reinforced plastics**

Sanchez Huerta, Alvaro – Supervisor: M.Sc. Wirt.-Ing. M. Eggert

**Trend and potential analysis for ship repairing and recycling**

Schober, André – Supervisor: M.Sc. M. Hauer

**Influence of process kinematics on the internal stresses, microstructure and mechanical properties of electric arc-sprayed NicAl-bronze coatings**

Schornstein, Benjamin – Supervisor: M.Sc. S. Schmidt

**Investigation of the feasibility of a lightweight construction deck section made of composites regarding constructional and structural aspects**

Schröder, Waldemar – Supervisor: Dipl.-Ing. C. Denkert

**Determination of the influence of the joining part on the joining properties in the case of self-punching lockbolts**

Seedorf, Erik – Supervisor: Dr.-Ing. U. Kothe

**Development of an inline measuring procedure for the thickness measurement of various Airlaid materials**

Torlopp, Lars – Supervisor: Dipl.-Ing. N. Glück

**Numerical simulation of force application elements for composite structures**

Treichel, Georg – Supervisor: Dipl.-Ing. F. Gierschner

**Measuring system analysis of spatially distributed 3D sensors for the determination of shape deviations in free-form areas**

Westphal, Erik – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Development of a process-integrated welding parameters analysis**

Wiek, Stefan – Supervisor: Dr. rer. pol. A.-K. Schröder

**Development of a methodology to determine the added value of an audit**

Wilhelmsen, Arne – Supervisor: M.Sc. S. Schmidt

**Investigation of the transient conduction of heat of a press mould**

Wosar, Udo – Supervisor: Dipl.-Wirt. Ing J. Sender

**Conceptual design and optimisation of a manufacturing warehouse between structural steelwork fabrication and the structural steelwork**

Wulf, Max – Supervisor: M.Sc. B. Illgen

**Implementation of a data cockpit within a materials flow simulation to support strategic and operative production planning and control tasks within the meaning of Industry 4.0**

## *Course of study Master in Business Engineering*

Fischer, Markus – Supervisor: Dipl.-Wirt. Ing J. Sender

**Analysis of then optimisation potential and development of planning methods with regard to feedback from values based on experience into the planning phase, taking the example of maritime cranes**

Hempel, Florian – Supervisor: M.Sc. Wirt.-Ing. Martin Eggert

**Increase in productivity and efficiency in the Hamburg production centre of DB Schenker Rail AG by using multi-functionally-qualified staff**

Schuh, Cedric – Supervisor: Dr.-Ing. N. Fuchs

**Development of a scalable overall assembly process for the fitting of high-voltage batteries, taking the example of an automotive manufacturer**

Stangl, Tanja – Supervisor: Dr. rer. pol. A.-K. Schröder

**Development of a marketing strategy for diesel and gas engines in the High Speed Power Generation sector**

Tekniepe, Sven – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Development of a standardised project management process and integration into a software-based project controlling tool in the Central Engineering and Technical Service Center of TMD Friction Services GmbH**

Weinrich, Christian – Supervisor: Dipl.-Ing. F. Beuß

**Development of ergonomic workplaces in module installation in yacht construction**

# 14 Bachelor Papers 2015

*Course of study Bachelor in Machine Construction*

Ahrndt, Johannes – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Simulation-based track planning for a welding application for the joining of pipe nodes with a redundant manipulator application**

Boyens, Oliver – Supervisor: M.Sc. K. Jagusch

**Development of a system to control a driverless transport system**

Gatzke, Johannes – Supervisor: Dipl.-Ing. A. Harmel

**Construction and evaluation of a mechanism for the simultaneous adjustment of the variable length between two coupling rods running in parallel**

Haß, Annika – Supervisor: Dipl.-Ing. N. Glück

**Experimental investigation of force application elements for composite structures**

Heide, Dennis – Supervisor: Dr. rer. pol. A.-K. Schröder

**Optimisation of the collaboration between the plant logistics and the logistics of the technical development section in the VW plant in Osnabrück**

Herold, Arne – Supervisor: Dr.-Ing. N. Fuchs

**Optimisation of a holder system for the 3D laser cutting of deep-drawn sheets**

Jericho, David – Supervisor: M.Sc. K. Jagusch

**Development of a control concept for an intelligent working table based on non-contact data collection**

Kibellus, Tom – Supervisor: M.Sc. L. Fröck

**Investigation of the influence of liquids on adhesives**

Kruschinski, Felix – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Investigation of complex electrochemical and thermochemical reactions in submerged arc welding with various material combinations**

Nickel, Paul – Supervisor: Dr.-Ing. N. Fuchs

**Development of a die concept for the formed joining of of plate of greater thicknesses**

Prochnow, Oliver – Supervisor: Dr. rer. pol. A.-K. Schröder

**Comparison and interface examination of the of functional safety in the machine and process industry**

Schramm, Nils – Supervisor: Dipl.-Ing. N. Glück

**Development of a methodology for the selection and design of clamping technology for RIM shaping dies**

Voß, Paul – Supervisor: M.Sc. S. Lauer

**Development and design of a lightweight robot arm with an axial connection for a load of 250 kg**

Yang, Fan – Supervisor: Dipl.-Wirt. Ing K. Ehrich

**Determination of the properties of adhesives that do not burn / are only sparingly inflammable for industrial use**

## *Course of study Bachelor in Business Engineering*

Baumgart, Luciano – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Analysis and development of propeller class-specific strategies for the automated drilling of ship propellers with the aid of 3D robot simulation**

Bludau, Danny – Supervisor: Dr. rer. pol. A.-K. Schröder

**Analysis and evaluation of algorithms in machine capacity planning**

Brandenburg, Kay – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Cinematographic and thermal process investigation when welding with the targeted application of vibration into the fusion bath and derivation of production management effects**

Franz, Jan-Eric – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Perspectives of additive manufacturing procedures with special consideration of arc welding and economic points of view**

Ganschow, Jörg – Supervisor: Dr. rer. pol. A.-K. Schröder

**Analysis of options for the collection of hazardous substance-specific information within the scope of the IMO guideline for ship recycling**

Girbardt, Leonie – Supervisor: M.Sc. Wirt.-Ing. A. Gericke

**Technological and economic investigation of slag recycling in submerged arc welding**

Götting, Sören – Supervisor: Dr. rer. pol. A.-K. Schröder

**Requirements in shipyards when drawing up a register of hazardous substances - An analysis in connection with the IMO guideline for ship recycling**

Heise, Susanne – Supervisor: M.Sc. Wirt.-Ing. M. Eggert

**Optimisation of an application for the collection of operating data for touch-controlled non-portable devices**

Hollmann, Matthes – Supervisor: M.Sc. K. Jagusch

**Development of an innovative operating concept for virtual installation manuals**

Maaß, Nicholas – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Analysis, evaluation and selection of localisation systems and strategies for the storage of large steel parts in the indoor and outdoor area with the aim of planning the storage capacity**

Nielson, Esko – Supervisor: Dr. rer. pol. A.-K. Schröder

**Industry 4.0 - Analysis of the requirements for Quality Management**

Prause, Christoph – Supervisor: Dipl.-Wirt. Ing J. Sender

**Conceptual design of versatile production layouts in shipbuilding**

Redemund, Klaus – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Analysis and experimental implementation of the automated handling of parts placed in no particular order - at random**

Schmatz, Frederik – Supervisor: Dipl.-Wirt. Ing. J. Meißner

**Conceptual design and implementation of a software-based resources capacity and allocation system for the mechanical test laboratory at Fraunhofer AGP Rostock**

Soehring, Philipp – Supervisor: Dipl.-Wirt. Ing J. Sender

**Simulation-based optimisation of shipyards**

Stegmann, Lennart – Supervisor: M.Sc. R. Staschko

**Investigations of the influence of the settling process steps on the delamination of punch-riveted composite fibre parts**

Wirths, Wim – Supervisor: M.Sc. P. Froitzheim

**Investigation of ultrasound-based punch-riveting for sheet, plate and CFRP joints**