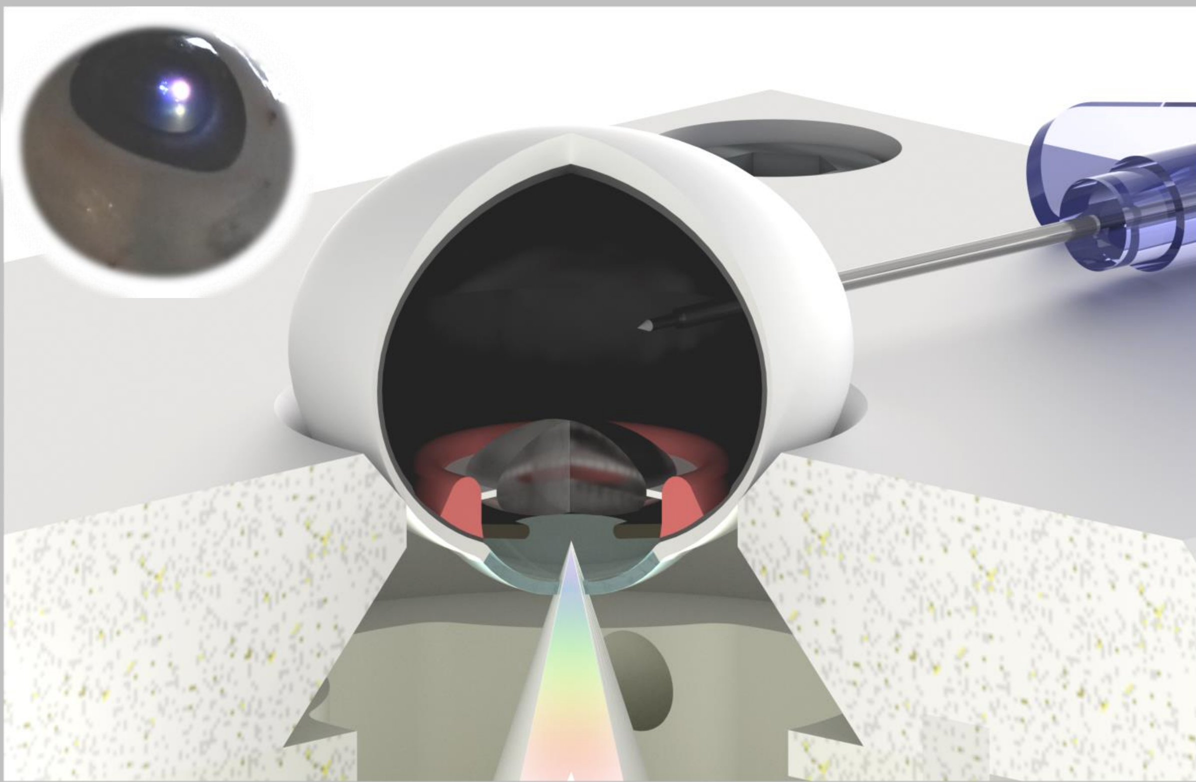
Annual Report

2018/2019



Optical intraocular pressure (IOP) measurements: Simulated test set-up

BIMAQ

Bremer Institut für
Messtechnik, Automatisierung
und Qualitätswissenschaft

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Preface

Dear friends and partners of the institute!

The year 2018/19 was a further successful year for the Bremen Institute for Metrology, Automation and Quality Science (BIMAQ). While continuing the collaborative research activities at the University of Bremen within the SFB747, SFB/TRR136 and SFB1232, several new fundamental and applied research projects started:

- thermographic flow visualization concerning stall at wind turbines in operation,
- energy flow investigations of demand and renewable energies on real measurement data in Germany,
- laser-optical flow field measurement of the cooling fluid during grinding,
- in-process nitride layer thickness measurements during nitriding with a photothermal measurement approach.

Hence, measurements and in particular optical measurements at their limits are of fundamental importance for solving fundamental questions in science as well as for industry and our society.

With a core competence in measurement techniques, a definite highlight for all BIMAQ people was hosting the 32nd Measurement Symposium of the working team of the university professors in measurement techniques in Bremen. The symposium in September 2018 was a great success since many talents working in the field of measurement techniques came together for exchanging ideas, get in touch with the strong research activities of the University of Bremen and get to know the cultural highlights of the city. As an example, the Roland statue was a must see for measurement fans, because the distance of the knees is assumed to represent the former Bremen inch and it is part of UNESCO World Heritage. The symposium was culminating with awarding the measurement prize 2019 and an evening in Bremerhaven including a visit of the German emigration centre museum. I would like to express my thanks for all members of the organization team and all contributors to the successful event.

Several works of the BIMAQ received high recognition. Dr.-Ing. Christoph Dollinger was awarded with the OLB science award, which is one of the highest endowed awards in the north of Germany, and Daniel Gleichauf, M.Sc. received the VDI Engineering award. Congratulations! I am further very grateful for the continuing support of the Deutsche WindGuard GmbH, which again donated an award to honour excellent student theses at BIMAQ. To all members, students, partners and supporters of the institute I would like say thank you for the contribution to the achievements in 2018/19.

Bremen, June 2019

Prof. Dr.-Ing. habil. Andreas Fischer

BIMAQ - the institute

Vision, topics and infrastructure

The research focus of the Bremen Institute for Metrology, Automation and Quality Science (BIMAQ) is the holistic investigation of optical measurement systems, which includes the design, realization, modelling, characterization and, finally, the application of novel measurement techniques. By applying a rigorous system-based analysis of the measurement systems, the limits of measurability and the respective uncertainty principles are investigated in order to determine and to surpass the limits of state-of-the-art approaches. Beyond pure measurement tasks, automation aspects and the application of quality controls is investigated as well. However, the core competence of BIMAQ is measurement system engineering, which is a key discipline for solving technical and overall social challenges.

A key challenge is to obtain information in situ or in-process from highly unsteady or complex technical processes. For this purpose, model-based, dynamic measurement systems are a key topic of the BIMAQ research, which includes interdisciplinary fundamental and application-oriented research on the measurement methods and their applications. Current research topics cover task from production engineering, materials science, wind energy systems and fluid mechanics.

In addition to methodical innovations for instance based on multi-sensor-system approaches, one highlight at the BIMAQ is a unique laboratory for large gear metrology with a coordinate measurement device for gears up to a few meters. This illustrates the unique BIMAQ expertise regarding the metrology of large gears and geometrical measurements with a high dynamical range. Further laboratories and equipment exist in the BIMAQ main building and the BIMAQ technical centre, for instance for the analysis of the surface topography and strain down to the nanometre scale, for thermographic flow analyses from long distances of several hundred meters and for laser-based flow measurements in optically non-cooperative fluids.

Research
Teaching
Knowledge

Metrology

Automation | Quality Control

Methods

Measuring System Theory
- Modelling and Simulation
- Uncertainty Relations
- Limits of Measurability

Measuring System Technology
- Optical High Speed Measuring Systems
- Multi-Sensor-Systems
- Coordinate Measuring Systems

➔ modelbased, dynamic Measuring Systems

Application

Produktion Engineering & Materials Science
- Geometrical and Roughness Metrology
- Optical In-Process-Metrology
- Thermography, Edge Zone Analyses

Wind Power Systems & Flow Processes
- Gear Measuring Technology
- Gear Metrology
- Flow Measurement Technology

BIMAQ competences

BIMAQ - the institute

Staff

Director

Prof. Dr.-Ing. habil. Andreas ***Fischer***

Emeriti

Prof. Dr.-Ing. Gert ***Goch***

Administration

Hiltrud ***Kallasch*** (until 4/2019)
Sylvia ***Rosenhagen*** (until 2/2019)
Eva ***Schultze***

Research Scientists

Dipl.-Phys. Gabriela ***Alexe***
M. Sc. Matthias M. ***Auerswald*** (until 12/2018)
M. Sc. Gert ***Behrends*** (since 9/2018)
Dr.-.Ing. Christoph ***Dollinger*** (until 3/2019)
Dipl.-Ing. Axel von ***Freyberg***
M. Sc. Daniel ***Gleichauf***
M. Sc. Merlin ***Mikulewitsch***
M. Sc. Jan ***Osmers***
M. Sc. Marc ***Pillarz***
M. Sc. Volker ***Renken***
M. Sc. Yannik ***Schädler*** (since 3/2019)
Dipl.-Ing. Michael ***Sorg***
M. Sc. Johannes ***Stempin***
Dr.-Ing. Dirk ***Stöbener***
Dr.-Ing. Gerald ***Ströbel***
Dipl.-Phys. Andreas ***Tausendfreund***
M. Sc. Christoph ***Vanselow***

Student Research Assistants

Hassan ***Ahmad***
Seray ***Baglar***
Mahesh ***Basavanahalli Senjeevamurthy***
Eunice Doret ***David Selvaraj***
Friedrich ***Eickmann***
Egor ***Maul***
Christian ***Pfaab***
Hendrik ***Rackl***
Umair ***Rehman***
Leonard ***Schröder***
Kevin ***Schünemann***
Shashank ***Vasuke***
Yousaf ***Zain***

Technical Assistants

Dipl.-Ing. Werner ***Behrendt***
Thomas ***Eilts***
Dipl.-Ing. Frank ***Horn***
Uwe ***Reinhard***

Alumni

Dipl.-Ing. Thomas ***Behrmann***
B. Sc. Marie ***Dethlefs***
Michael ***Essert***
B. Sc. Oskar ***Hoppe***
Dr.-Ing. Marc ***Lemmel***
B. Sc. Robin ***Lipinski***
Dr.-Ing. Stefan ***Patzelt***
Dr.-Ing. Helmut ***Prekel***
Dipl.-Ing. Jan ***Westerkamp***

Participation in scientific committees and associations

Member		Short Name	Scientific Committee / Association
	BIMAQ	AUKOM	AUKOM Ausbildung Koordinatenmesstechnik e. V.
	BIMAQ	FQS	Forschungsvereinigung Qualität
Andreas	**Fischer**	DGaO	Deutsche Gesellschaft für angewandte Optik
Andreas	**Fischer**	AHMT	Arbeitskreis der Hochschullehrer für Messtechnik e. V.
Andreas	**Fischer**	ForWind	ForWind – Zentrum für Windenergieforschung
Andreas	**Fischer**	MAPEX	Center for Materials and Processes
Andreas	**Fischer**	SPIE	The International Society for Optics and Photonic
Andreas	**Fischer**	EOS	European Optical Society
Andreas	**Fischer**	OSA	The Optical Society
Andreas	**Fischer**	IEEE	Institute of Electrical and Electronics Engineers
Andreas	**Fischer**	VDI	Verein Deutscher Ingenieure
Andreas	**Fischer**	GALA	Deutsche Gesellschaft für Laser-Anemometrie
Andreas	**Fischer**	DHV	Deutscher Hochschulverband
Andreas	**Fischer**		Regelungstechnisches Kolloquium in Boppard
Andreas	**Fischer**	SFB 747	Sonderforschungsbereich 747 Mikrokaltumformen
Andreas	**Fischer**	SFB TRR 136	Sonderforschungsbereich TRR 136 Prozesssignaturen
Andreas	**Fischer**	SFB 1232	Sonderforschungsbereich 1232 Farbige Zustände
Andreas	**Fischer**	BEST	Bremer Forschungszentrum für Energiesysteme
Gert	**Goch**	WGP	Wissenschaftliche Gesellschaft für Produktionstechnik
Volker	**Renken**		BMWI-Forschungsnetzwerke Energie: Systemanalyse, Stromnetze, Erneuerbare Energien
Michael	**Sorg**	DFMRS	Deutsche Forschungsvereinigung für Meß-, Regelungs- und Systemtechnik e. V.
Michael	**Sorg**		BMWi-Forschungsnetzwerke Energie: Systemanalyse, Stromnetze, Erneuerbare Energien
Dirk	**Stöbener**	MAPEX	Center for Materials and Processes
Dirk	**Stöbener**	SFB TRR 136	Sonderforschungsbereich TRR 136 Prozesssignaturen
Dirk	**Stöbener**	VDI	Verein Deutscher Ingenieure
Dirk	**Stöbener**	VDI FA 3.61	VDI Fachausschuss 3.61 Messen an Zahnrädern und Getrieben
Dirk	**Stöbener**	VDI FA 3.34	VDI Fachausschuss 3.34 Large Volume Metrology
Gerald	**Ströbel**	DFMRS	Deutsche Forschungsvereinigung für Meß-, Regelungs- und Systemtechnik e. V.
Gerald	**Ströbel**	VDI/VDE-GMA	VDI/VDE-Gesellschaft Mess- und Automatisierungstechnik
Axel	**von Freyberg**	FVA AK Messt.	Forschungsvereinigung Antriebstechnik e. V. - Arbeitskreis Messtechnik

Laboratories

Laboratory for dimensional metrology

BIMAQ's infrastructure features a variety of modern high-precision measurement systems. The equipment ranges from tactile coordinate, gearing and roughness measuring devices via optical systems like stripe pattern projection and laser triangulation through testers for non-destructive analysis with thermal, magnetic and acoustic probe systems and sensors. This equipment is used for the calibration and validation of newly developed measurement and sensor systems, e. g. for optical gear measurements, but it is also the basis for measurements within research projects and for the regional industry.

BIMAQ conducts form, size and location tests on very small to very large components by dimensions of a few millimetres up to 3 meters and offers standardized measurement and evaluation procedures as well as customer-specific solutions, such as the evaluation of advanced features or the digitization of a component.

Services

- Development of measurement and evaluation strategies
- Acquisition and analysis of dimensional deviations - tactile or optical
- Characterizing surface quality - tactile or optical
- Gear inspection
- Surface integrity analysis - non-destructive and non-contact
- Order/reference measurements

Contact: a.freyberg@bimaq.de

Tactile measurement of a 5-axis milled gear segment

LAB

Laboratory for large gears (in BIMAQ-Technikum)

To calibrate large gears currently no appropriate standards exist, that allow the traceability of the test processes to the SI unit "meter" with sufficient accuracy. In close cooperation with the National Metrology Institute of Germany (PTB), BIMAQ therefore is involved in developing large gear standards with a diameter of 2000 mm and more.

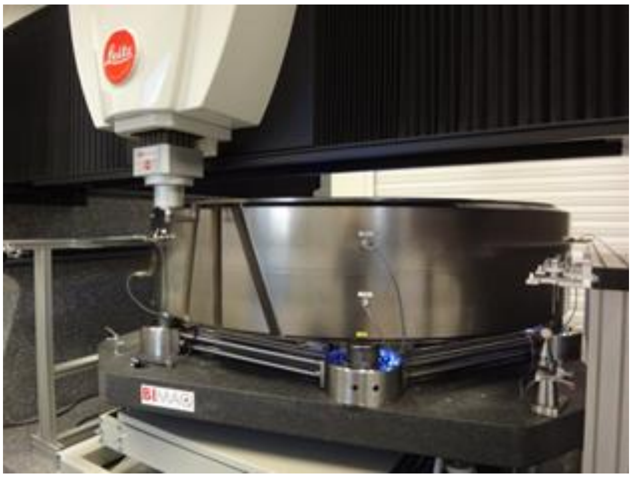
Furthermore, BIMAQ analyses the cause-effect relationships between gear manufacturing, geometric deviations and occurring gearbox damages. In the field of quality inspection of gears, algorithms are being developed in order to evaluate dimensional measurement data.

Technical specifications

Portal coordinate measuring machine Leitz PMM-F 30.20.7:

- Measuring volume:
  3.0 x 2.0 x 0.7 m^3
- Measuring uncertainty:
  $MPE_E = (1.3 + (L \text{ in mm})/400)\ \mu m$

Tactile measurement of large cylindrical gearing



Measuring a 2 m gear standard
on BIMAQ's large CMM

- Workpiece mass:
  max. 6,000 kg
- Rotary table:
  for rotation-symmetric components up to 3.0 m diameter
- Air conditioning:
  maximum temperature gradients
  0.4 K/h, 0.8 K/d, 0.2 K/m

Services

- Order/reference measurements
- Calibration of reference standards
- Analysis and evaluation of geometric deviations
- Development of measurement and evaluation strategies
- Software development

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Laboratories

Laboratory for optical metrology

The laboratory for optical metrology includes the two main fields of research:

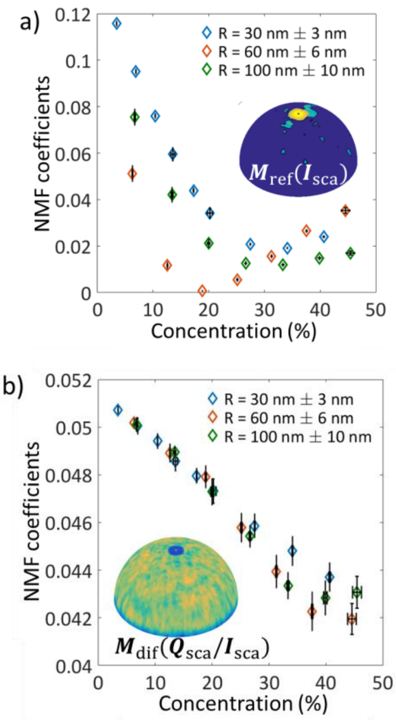
- In-process measuring methods and
- Surface integrity evaluation.

The focus "In-process measurement methods" concentrates on the surface assessment with scattered light and other optical methods as well as the determination of (primarily) mechanical workpiece loads during manufacture.

The used light scattering methods allow a quick, in-process determination of (statistical) surface characteristics, without detecting the actual topography of the component. The procedures can be applied to investigate fast moving component surfaces in the manufacturing process. In addition to assessing the mean roughness in the observed measurement spot, statements about structure heights and widths as well as individual defect classes of components are possible. This evaluation can be applied not only for structure areas with sizes above the optical wavelength, but also for structures in the nanometre range (below the optical wavelength) due to the use of the rigorous scattering theory based on Maxwell equations. The measurement methods are investigated with simulative and experimental approaches leading to results about measurement resolution and uncertainty for specific applications as well as general measurability limits.

Services

- Feasibility studies on the application of measurement principles, particularly in manufacturing and heat treatment processes,
- Development of measuring methods for industrial applications,
- Basic research for new measurement methods in the two fields of research,
- Simulation and measurement of light scattering on micro- and nano-structured workpieces to assess the structural quality,
- Non-destructive surface integrity/topography checking by comparison with reference samples.



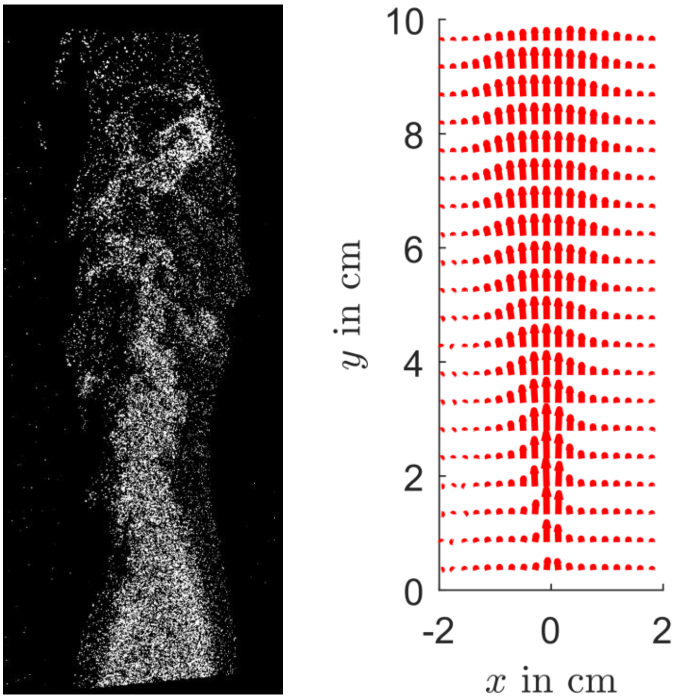
Simulation of scattered light evaluation for measuring the nanoparticle concentration (coverage) on surfaces

Contact: d.stoebener@bimaq.de

Laboratory for flow metrology

The three velocity components of a flow field can be determined in a measurement plane with a stereoscopic particle image velocimetry (PIV) system, which is the centrepiece of the laser-based flow metrology laboratory. The particle-based measurement technique is applied in challenging conditions, e. g., hot jet flows, flame flows or two-phase flows. The main research topic is to quantify the measurement uncertainty caused by the influence of inhomogeneous refractive index fields. These fields lead to varying image distortions and, thus, measurement deviations of the particle position. The uncertainty budget for the determined velocity fields are obtained from model-based error propagations of the simulative and experimentally investigated refractive index field. The analysis of the measurement uncertainty budget is a key topic to identify and finally overcome fundamental limits of measurability.

Stereoscopic PIV system



PIV raw image (left) and mean velocity field (right) of a flame flow

Technical data

Dual-head PIV-Laser (Quantel Evergreen):

- pulse energy: 2 × 200 mJ
- wavelength: 532 nm
- pulse rate: 15 Hz
- pulse length: <10 ns
- light guide arm: 2.1 m

2 × sCMOS cameras (Andor Zyla):

- resolution: 5.5 Mpixel
- pixel width: 6.5 µm
- dynamic: 16 bit

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Laboratories

LAB **Laboratory for thermography**

Boundary layer visualization on wind turbine rotor blades in operation

The boundary layer flow influences the temperature distribution on the surface of a rotor blade, which can be detected by a high speed thermographic imaging system. BIMAQ offers thermographic measurements of rotor blades on wind turbines in operation. Measurements are conducted in cooperation with the Deutsche WindGuard Engineering GmbH in Bremerhaven. Measurements can be performed from a distance between 60 m and 500 m.

Technical data

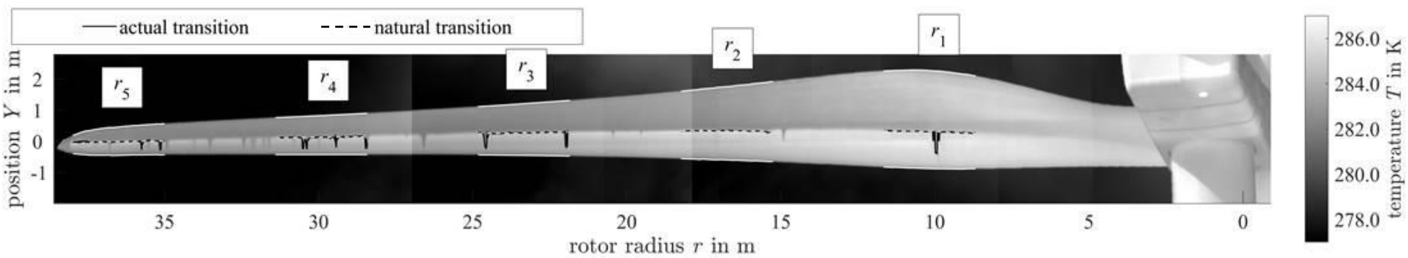
ImageIR thermographic imaging system:

- High speed IR imaging system
- Thermal resolution: 0.025 K
- Spectral range: 2 – 5 µm
- Detector format: 640 x 512 pixel
- Focal length incl. telephoto lens: 200 mm
- Integration times between 1 µs and 1600 µs

ImageIR thermographic imaging system

Services

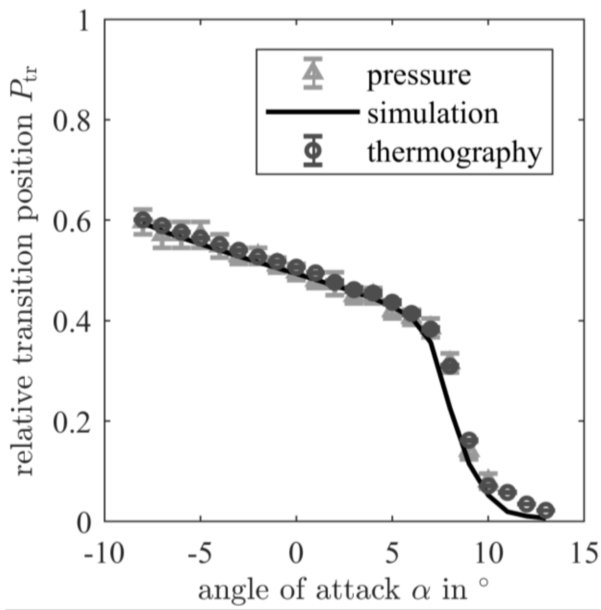
- Determination of the laminar/turbulent transition location
- Detection of early laminar-turbulent transition due to leading edge contamination, erosion, manufacturing irregularities or the effects of leading edge protection
- Analysis of impact of leading edge protection on the boundary layer flow
- Inspection of vortex generators, zig-zag tapes and other flow control devices
- Investigation of the feasibility of anti-icing and de-icing systems



Evaluated thermographic image of the rotor blade of an 1.5 MW wind turbine with a 77 m rotor diameter

Boundary layer visualization in wind tunnel experiments

In order to investigate the boundary layer flow phenomena on airfoils, thermographic measurement approaches are developed and applied. The research focus are new image evaluation techniques based on the flow dynamics. The flow experiments with two different IR imaging systems are performed at the Deutsche WindGuard's aeroacoustic wind tunnel in Bremerhaven, where laminar air flows at speeds of up to 360 km/h and chord-Reynolds numbers of up to 6 million can be generated.



Relative position P_{tr} of the laminar-turbulent transition on the chord as a function of the angle of attack α

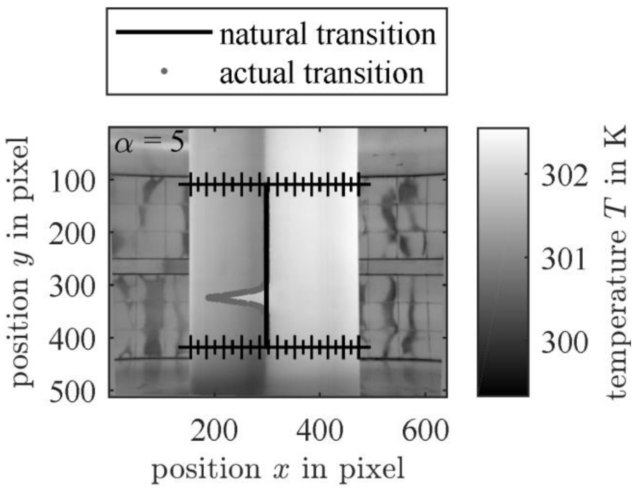
Technical data

VarioCam hr:

- Detector format: 640 x 480 pixel
- Thermal resolution: 0.030 K
- Spectral range: 7.5 - 14 µm
- Focal lengths: 12.5 mm and 30 mm

ImageIR:

- Detector format: 640 x 512 pixel
- Thermal resolution: 0.025 K
- Spectral range: 2 - 5 µm
- Focal lengths: 12 mm, 25 mm, 100 mm and 200 mm



Thermographic flow visualization on an airfoil in the wind tunnel

Services

- Localization of the laminar-turbulent transition with a measurement uncertainty < 0.5 % chord length
- Visualization of flow separations
- Automated evaluation of wind tunnel campaigns
- Comparison with reference measurements and simulation data

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Laboratories

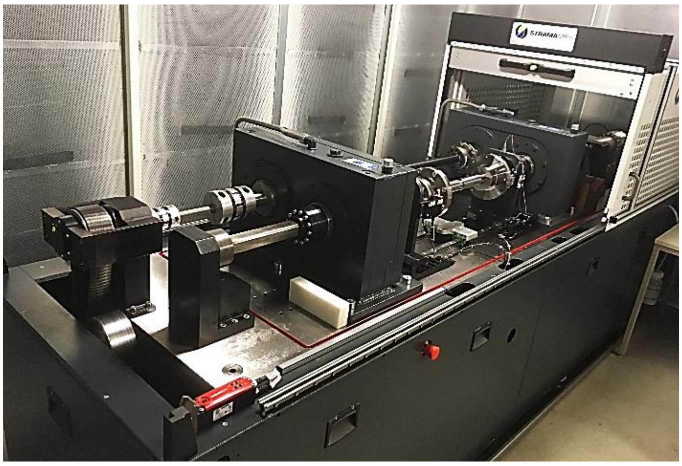
LAB

Laboratory for wind turbine sensors (in BIMAQ-Technikum)

Wind turbine generators (WTG) are dynamically highly stressed, which can lead to bearing and gear damages. For targeted improvements in design, production and choice of material meaningful metrics are missing. The individual transmission components (gears, bearings, shafts) are metrologically not accessible during operation, so far. A few states can be observed from the outside, e. g., temperature changes on the housing or noises or vibrations. But, the causes of problems are mostly inside the gear housing. These include mechanical stresses which may lead to undue distortion of the individual teeth and subsequently to wear of the tooth flanks.

Drivetrain inside the hub of a wind energy system

For testing new sensor concepts for WTG drivelines, the dynamic behaviour of WTG drivelines can be simulated experimentally in the BIMAQ-Technikum using a torque test rig. In addition, a WTG drive train and a 3.4 MW research WTG are available for sensor tests.



Torque test rig

Technical test rig specifications

- Torque: ± 1 000 Nm
- Speed: ± 3 000 min^{-1}
- Axial force: 0 - 10 000 N

Services

- Development of sensing prototypes
- Order and reference measurement
- Development of new measurement and evaluation strategies
- Software development

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Wind turbine drive train for sensor tests

LAB

BIMAQ-Technikum and Mechanical workshop

BIMAQ maintains a 400 m² Technikum to support the research work.

The Technikum contains the

- Laboratory for large gears
- Torque test rig
- Experimental field
- Mechanical workshop

Mechanical workshop

For the production of test rigs, test stands and prototypes, the mechanical workshop is equipped, for example, with a

- CNC milling machine
  Travel distance: 400 mm x 400 mm x 400 mm
- 3D printer
  Space: 203 mm x 203 mm x 152 mm
- Milling drill plotter
  Maximum material size:
  229 mm x 305 mm x 35 mm

Services

- Item and small-batch production
- Additive and cutting machining

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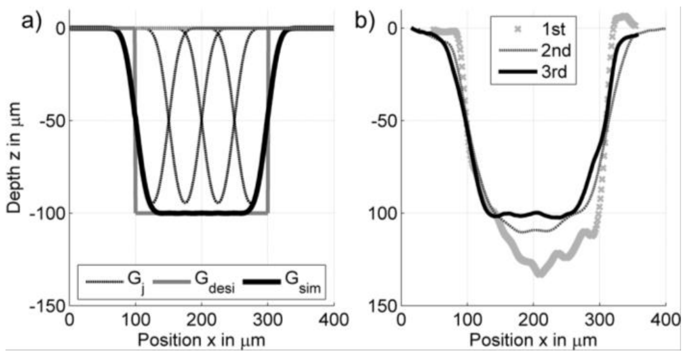
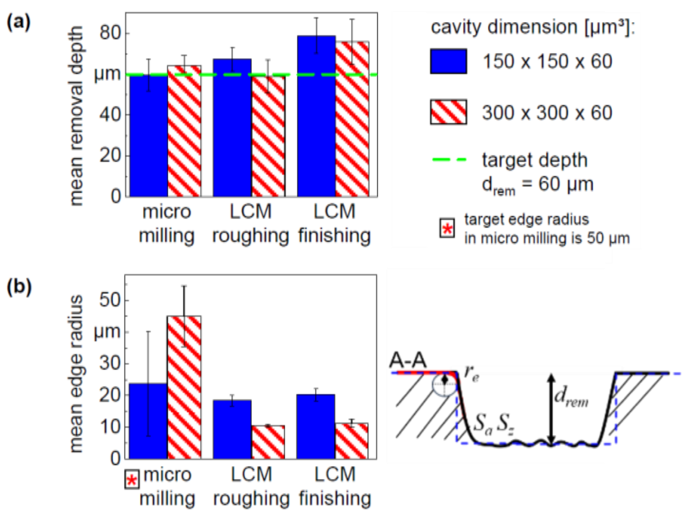
SFB 747 Micro Cold Forming - Subproject A5

Controlled scalable laser removal procedure for the manufacturing of contoured micro forming tools

Funding organization: DFG/SFB
Funding ID: SFB 747 Mikrokaltumformen
Duration: 1 Jan 2007 - 31 Dec 2018
Project scientist: Merlin Mikulewitsch

Laser chemical machining (LCM) is a novel procedure used to manufacture micro forming tools from hard metals with relatively low cost compared to competing micro-machining processes such as micro-milling or micro electrical discharge machining. The material is removed by an etchant that is chemically activated by heat from a focused laser beam, localized at the area of incidence, producing the desired geometry by moving the beam.





Top: Path plan (**a**) and cross section of a rectangular die after 3 control steps (**b**). *Bottom:* Cavity depth (**a**) and mean edge radii (**b**) of two micro dies manufactured with laser chemical machining (LCM) and micro milling.

The subproject A5 evaluated and improved the process capability of laser chemical machining in addition to reducing irregularities and dimensional deviations inherent in the etching process. A stable and reproducible production of micro forming tools without manual determination of the optimal process parameters was achieved using the developed adaptive control system. Integrating the control system in the LCM process reduced the flatness deviation of a rectangular micro die (top figure) from about 33 µm to less than 3 µm. The manufacture of non-passivated materials was also shown to be possible, albeit with overall increased surface roughness due to the constant background removal. The comparison with competing methods such as micro milling showed that LCM achieved much smaller and less dispersed edge radii (bottom figure).

[1] H. Messaoudi, F. Böhmermann, M. Mikulewitsch, A. von Freyberg, A. Fischer, O. Riemer, F. Vollertsen: Chances and limitations in the application of laser chemical machining for the manufacture of micro forming dies. 5th Int. Conf. on New Forming Technol. (ICNFT), Bremen, 09.2018. MATEC Web Conf. 190:15010 (8 pp.).
[2] P. Zhang, A. von Freyberg, A. Fischer: Closed-loop quality control system for laser chemical machining in metal micro-production, Int J Adv Manuf Technol (2017) 93:3693.

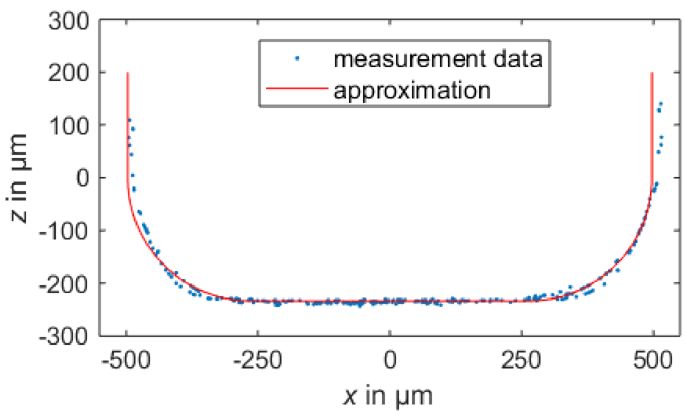
SFB 747 Micro Cold Forming - Subproject B5

Quality inspection and logistic quality control for micro production processes

Funding organization: DFG/SFB
Funding ID: SFB 747 Mikrokaltumformen
Duration: 1 Jan 2007 - 31 Dec 2018
Project scientists: Axel von Freyberg, Matthias Auerswald

Micro cold forming poses two challenges for the quality inspection process: On the one hand, the parts and geometrical features to be tested have sub-millimetre dimensions and request high dynamic ranges of the measuring systems; on the other hand, the forming processes produce parts in a high clock rate, which limits the time available for measuring and evaluating the individual parts. To cope with these conditions, the collaborating institute BIAS is developing a digital holographic measuring system within this project to acquire geometric date of the part's surface.

In contrast to conventional dimensional metrology, the optically acquired surface data represents a combination of geometric elements, which has to be separated into individual objects prior to the evaluation of geometric deviations and parameters. For this purpose, algorithms have been developed for an automated holistic approximation of the combined geometric elements, including the optimal decomposition of these elements (see figure). This new approach was adapted to combinations of higher order geometric elements (e. g. ellipse, parable etc.) to address the increase of complexity within the SFB 747.



Geometric decomposition and approximation

[1] A. von Freyberg, A. Fischer: Holistic approximation of combined surface data. Precision Engineering 54: 396-402, 2018.

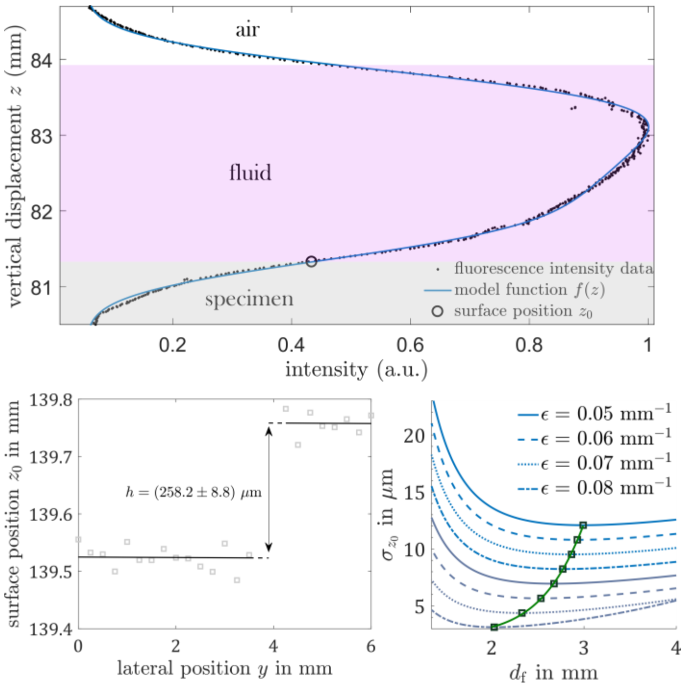
[2] M. Agour, C. Falldorf, B. Staar, A. von Freyberg, A. Fischer, M. Lütjen, R.B. Bergmann: Fast Quality Inspection of Micro Cold Formed Parts using Telecentric Digital Holographic Microscopy. 5th Int. Conference on New Forming Technology (ICNFT), Bremen, 18 - 21 Sep 2018. MATEC Web Conf., 2018, 190, 15008.

SFB 747 Micro Cold Forming - Subproject B9

In-situ geometry measurement using confocal fluorescence microscopy

Funding organization: DFG/SFB
Funding ID: SFB 747 Mikrokaltumformen
Duration: 1 Aug 2017 - 31 Dec 2018
Project scientist: Merlin Mikulewitsch

The in-situ geometry acquisition of micro-structures in manufacturing processes such as Laser Chemical Machining (LCM) places special demands on optical measuring systems, since the measured objects are surrounded by a fluid. Confocal fluorescence microscopy was previously used to reduce artifacts and improve the measurability of metallic surfaces. By detecting the strongly scattering fluorescence of a fluorophore coating (e. g. a thin layer < 100 µm), a signal drop at the boundary between the measuring object and air is observed, allowing the determination of the surface position. This provides an advantage over conventional confocal microscopy at sharp edges. The measurement in thicker layers (such as fluorescent fluids > 1 mm), as needed for in-situ application in the LCM process, shows strong dependencies on the fluorophore concentration and fluid depth, unlike in thinner layers. The evaluation therefore requires a modeling of the fluorescence signal (top figure).



Top: Measured fluorescence intensity signal (black) with fitted model function (blue).
Bottom: Surface positions z_0 of a step-geometry with the step height measurement result (left) and the minimal position uncertainty σ_{z_0} (squares) for various concentrations ($\propto \epsilon^{-1}$) and fluid depths d_f (right).

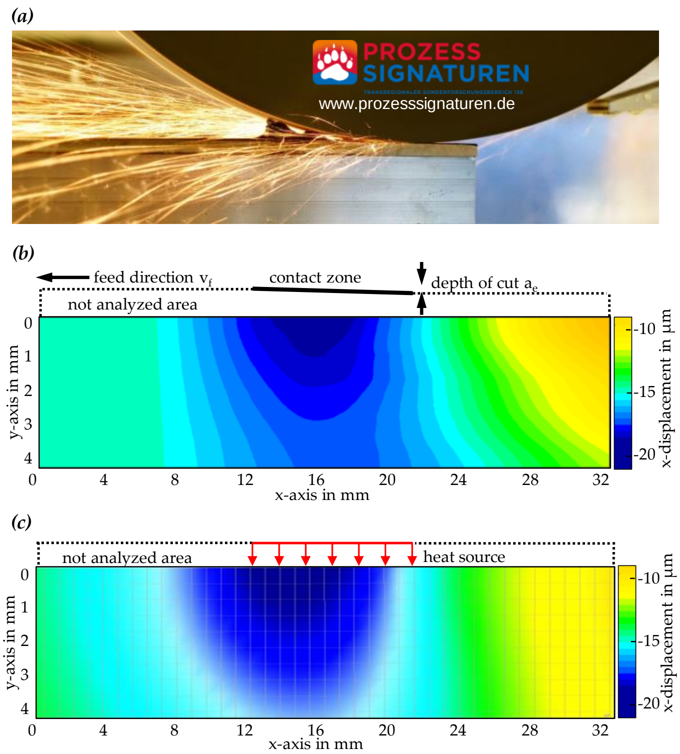
The project results demonstrated the suitability and potential of fluorescence microscopy for in-situ measurement of geometry parameters (such as the step height of a submerged step, see bottom figure). Additionally, fundamental uncertainty limits were theoretically calculated and associated with the parameters fluid depth d_f and concentration dependent attenuation ϵ, revealing a minimum uncertainty σ_{z0} for each parameter respectively. The resulting theoretically achievable uncertainty limit of 0.1 µm demonstrates a potential for a future decrease of the experimental measurement uncertainty.

[1] M. Mikulewitsch, M. Auerswald, A. von Freyberg, A. Fischer: Geometry measurement of submerged metallic micro-parts using confocal fluorescence microscopy. Nanomanufacturing and Metrology 1(3):171-179, 2018.
[2] M. Mikulewitsch, A. von Freyberg, A. Fischer: Confocal fluorescence microscopy for geometry parameter measurements of submerged micro-structures. Optics Letters 44(5):1237-1240, 2019.

Surface-based optical measurements of mechanical material stresses

Funding organization: DFG/SFB
Funding ID: SFB Transregio 136
Duration: 1 Jan 2018 - 31 Dec 2021
Project scientist: Andreas Tausendfreund

In the first phase of the SFB, the suitability of Speckle photography for in-process measurements in highly dynamic manufacturing processes was demonstrated. Specially adapted evaluation algorithms and measuring systems were developed for this purpose, so that the use of speckle photography could also be realized on fast-rotating systems such as single-tooth peripheral milling or grinding under strong flying sparks [1, 2, 3].



(a) Dry grinding process with strong flying sparks,
(b) measured loads in form of deformations and
(c) finite element simulation with model assumption of a moving heat source [2].

Three-dimensional deformations of the measured surface cannot be measured yet. This problem is to be solved by a novel approach for in-process measurements based on an analysis of the shape-modified speckle correlation functions. In addition to this three-dimensional reconstruction of the deformation fields, a central aim of the project is to determine parameters for establishing process signatures from the time-resolved stress fields measured in highly dynamic manufacturing processes. In this connection a quantification of the measurement uncertainty budget and a reduction of measurement uncertainty contributions are planned. In addition, data analysis is to be accelerated, for example by parallelization approaches. This reduces long evaluation times, enabling in-process control in the future.

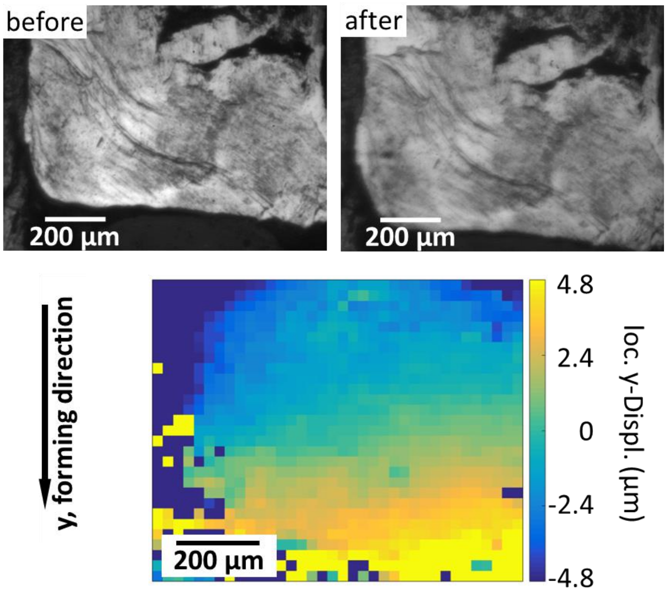
[1] A. Tausendfreund, D. Stöbener, A. Fischer: Precise In-Process Strain Measurements for the Investigation of Surface Modification Mechanisms. Journal of Manufacturing and Materials Processing 2(9):1-11, 2018.
[2] A. Tausendfreund, F. Borchers, E. Kohls, S. Kuschel, D. Stöbener, C. Heinzel, A. Fischer: Investigations on material loads during grinding by speckle photography. Journal of Manufacturing and Materials Processing 2(4):71 (12 pp.), 2018.
[3] A. Tausendfreund, D. Stöbener, G. Ströbel: In-process measurements of strain fields during grinding. In: euspen 2016, Nottingham/UK, 30 May - 3 Jun 2016, pp. 85-86.

SFB 1232 Coloured states – Subproject D04

Characterization of coloured states by measuring the deformation history during forming

Funding organization: DFG/SFB
Funding ID: SFB 1232/1 - 2018
Duration: 1 Apr 2018 - 30 Jun 2020
Project scientist: Gabriela Alexe

The SFB initiative "From coloured states to evolutionary structural materials" is developing a new experimental method of material design. The overall goal is to find efficient and targeted compositions and process chains for new metallic construction materials that meet a specific requirement profile. This novel high-throughput approach is based on new methods for the original forming, colouring and characterization of microscopic material samples, sample logistics



In-situ measurements before and after a forming step with a global shift of ≈ 67 µm: images and the calculated local dislocations resulting in a ≈ 1.5% positive strain in the forming direction (*y*-direction) .

and mathematical and computer methods for the analysis of large amounts of data. Microscopic, easy-to-manufacture samples are examined for so-called descriptors using adapted short-term characterization methods. The transfer of the determined descriptors to the macroscopic material properties of the requirement profile is carried out by a heuristic predictor function, which only requires a few macro samples.

The classical tensile test is a standard method of material characterization and provides properties such as yield strength and strain hardening. The aim of this subproject is to investigate a comparable method for micro samples. Compressive stresses can be introduced into the sample by means of electro-hydraulic forming. These should lead to approximately uniaxial, homogeneous tensile stresses through a targeted deflection of the material flow in local areas. The strains resulting from the tensile stresses are recorded in situ through an optical access in the tool using the high resolution speckle photography method. From the strain data, supplemented by the applied force or energy and comparative material data from simulations, meaningful descriptors for use in predictor functions are formed.

[1] L. Langstädtler, H. Pegel, M. Herrmann, C. Schenck, D. Stöbener, J. F. Westerkamp, A. Fischer, B. Kuhfuß: Electrohydraulic extrusion of spherical bronze (CuSn6) micro samples. 8th International Conference on High Speed Forming, Columbus, Ohio/USA, 13 - 16 May 2018. (10 pp.)
[2] A. Fischer: Limiting uncertainty relations in laser-based measurements of position and velocity due to quantum shot noise. Entropy 21(3):264 (19 pp.), 2019.

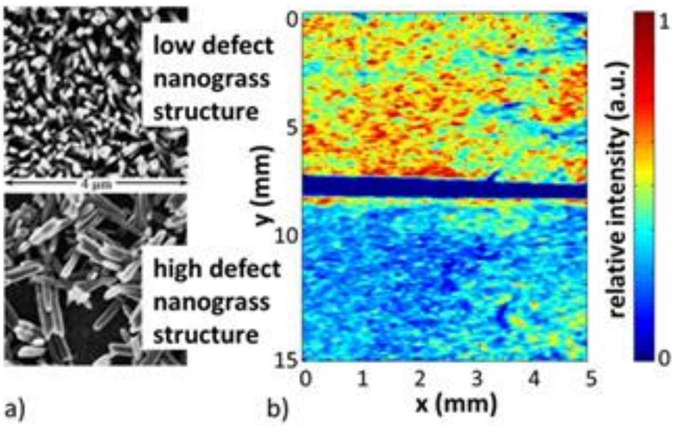
Method development for measuring procedures for the in-process-characterization of sub-100-nm-structures

Funding organization: DFG
Funding ID: GO 554/35-1
Duration: 1 Apr 2015 - 28 Feb 2019
Project scientist: Gabriela Alexe

More and more applications from nanotechnology are finding their way into mass production. One of the biggest challenges is the adequate process management, resulting in an increasing need for suitable in-process measuring methods for rapid quality testing and process control. Theoretical considerations show that scattered light distributions of illuminated surfaces also contain information about existing nanostructures. Due to their fast, integral and non-contact data acquisition, scattered light measurement methods are predestined for in-process measurements on nanostructured systems.

The aim of this project was the realization of a simulation-assisted methodology for the design of in-process scattered light measuring methods for nanostructured surfaces with sub-wavelength dimensionality, developed for several specific applications. Light scattering distributions for intact and defective surfaces were rigorously calculated and the scattering features connected to specific defects were determined with statistical relevance. Machine learning approaches (non-negative matrix approximation) supported the feature extraction. Whether for stochastic or periodical structures, fast measuring methods to unambiguously distinguish the defective surfaces can be this way configured without a comprehensive experimental effort (see figure).

For the case of subwavelength sinusoidal gratings formed in a roll-to-roll procedure, an evaluation algorithm for the grating height was developed, able for inline application. Offline measurements resulted in measurement uncertainties for the grating height of ≤ 12 nm, with a potential for < 4 nm.



a) Examplary SEM images of intact and defective nanograss-structured surfaces.
b) Measured scattered intensities during a large area simultaneous scan over an intact and a defective nanograss structure.

[1] G. Alexe, A. Tausendfreund, D. Stöbener, A. Fischer: Model-assisted measuring method for periodical subwavelength nanostructures. Applied Optics 57:92-101, 2018.
[2] D. Stöbener, G. Alexe, A. Tausendfreund, A. Fischer: Methode zur Erfassung periodischer Sub-Wellenlängen-Nanostrukturen für den In-Prozess-Einsatz. tm - Technisches Messen 85(2): 88–96, 2018.

MultiSenseo

Multisensory measurement of the geometry of large gears

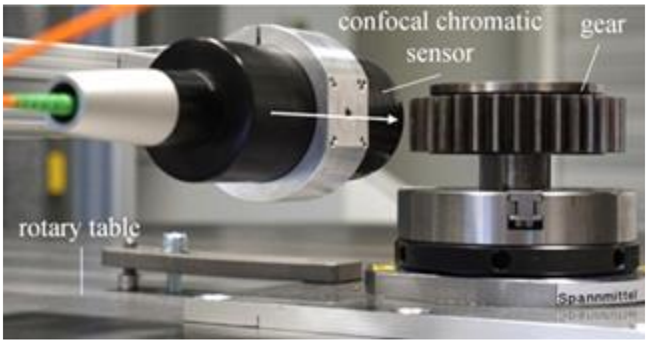
Funding organization: DFG
Funding ID: FI 1989/2-1
Duration: 1 Mar 2018 - 28 Feb 2021
Project scientist: Marc Pillarz

The quality inspection of gears (d > 1 m) is a major challenge. With increasing gear dimensions, the required dynamic range of the measuring system is constantly rising. While the tolerances increase with increasing diameter and modulus of a gear, the ratio of the required measuring uncertainty to the measuring volume decreases. Measurements of the geometry of large gears with an uncertainty < 5 µm are therefore necessary.

Coordinate and gear measuring machines are the standard measuring systems for gears. However, they reach their limits with large gears. The serial data acquisition of the probed points leads to long measuring times. Further, they consist of stable and heavy materials and the measuring volume cannot be scaled up. Thus, the geometry measurement of large gears is associated with a high logistical effort with regard to the transport of the measured object to the measuring system. Alternative measurement approaches, however, do not yet achieve the required measurement uncertainty.

For this reason, the aim of the research project is to determine geometric features like the base circle radius r_b of large gears using a novel, model-based measuring approach in combination with a multi-sensor system of optical distance sensors. The measuring system can be scaled to the required measuring volume by a modular design. The multisensory setup enables also a parallel and fast data acquisition.

By means of simulations, the theoretically achievable uncertainty of the base circle radius of large gears depending on the sensor uncertainty is estimated to less than 5 µm. A validation of the model-based multisensory approach is firstly shown for a gear with a diameter of d = 0.105 m. Measurement uncertainties of the base circle radius of less than 4.5 µm are achieved. Hence, the experimental and theoretical results prove the principle applicability of the multisensory approach for a precise inspection of gears.



Experimental setup of a single sensor measurement for emulation and validation of the multisensory measurement approach

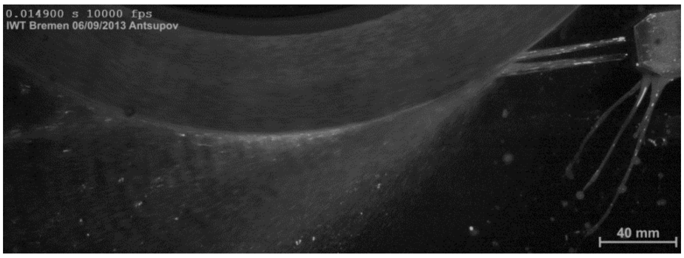
[1] A. Fischer: Angular dependent radius measurements at rotating objects using underdetermined sensor systems. IEEE Transactions on Instrumentation and Measurement 67(2):425-430, 2018.

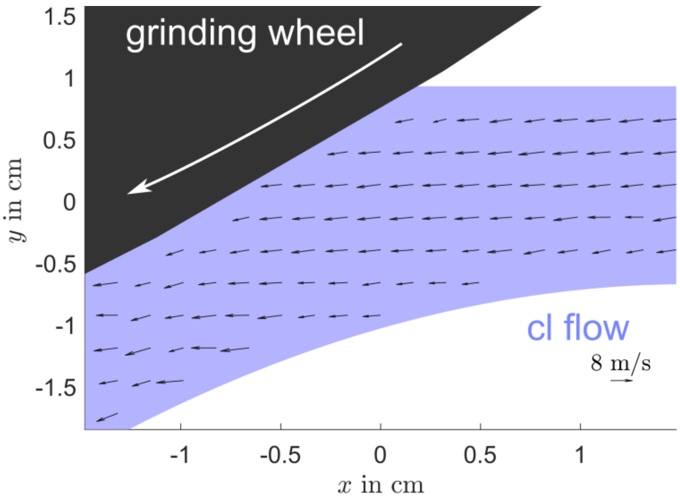
ProstKühl

Near process flow measurements of the cooling lubricant supply in grinding processes

Funding organization: DFG
Funding ID: 415003387
Duration: 36 months
Project scientist: n.n./Christoph Vanselow

Grinding is an essential manufacturing process for the production for e. g. metallic or optical components. High process speed requires an efficient cooling in order to avoid grinding belt. However, flow mechanisms for an efficient cooling lubricant (cl) supply are not yet known. Only heuristic optimization of the supplying cl jet flow was performed so far. In process flow field measurements of the cl flow could provide information to understand the flow mechanisms responsible for an efficient cooling of the grinding process.





Mean incident cl flow velocity field on the grinding wheel

The optical flow measurement technique particle image velocimetry (PIV) shall be used in order to determine the flow field of the two phase flow of cl and air. However, a big challenge is to achieve valid flow field measurements due to the fluctuating refractive index field of the two phase flow, which causes disturbing light refraction. In order to achieve valid flow field measurements, the mean flow field is determined by statistical evaluation of the PIV measurements. Further, systematic and random measurement deviations due to light refraction are determined by a novel measurement technique which measures resulting light deflections inside the flow.

The resulting systematic measurement deviation is corrected and the random measurement deviations are used for an uncertainty estimation of single-shot PIV measurements. Based on these results the feasibility of high-speed and stereoscopic PIV measurements is checked.

[1] C. Vanselow, A. Fischer: Influence of inhomogeneous refractive index fields on particle image velocimetry. Optics and Lasers in Engineering 107:221-230, 2018.
[2] C. Vanselow, A. Fischer: Messunsicherheit von PIV-Messungen durch Brechungsindexfelder in Flammen. 26th GALA-Fachtagung "Experimentelle Strömungsmechanik", Rostock, 4 - 6 Sep 2018, No. 12 (8 pp.).

ThermoStall

Contactless in-process measurement of separated flow on non-scaled rotor blades of wind turbines

Funding organization: DFG
Funding ID: 420278089
Duration: 36 months
Project scientist: n.n./Daniel Gleichauf

Because of the efficiency lowering effect, boundary layer flow separation is an unwanted phenomenon on rotor blades of wind turbines. The separated flow also induced unsteady loads, reducing the lifespan of the structural material and causing sound emission.

To achieve a better understanding of the acting boundary separation flow, a cheap, fast, non-invasive and contactless method for flow visualization is demanded to be capable of coping with the difficult requirements of in-process measurements.

The aim of this project is to advance the existing thermographic flow visualization metrology for flow separation detection on wind turbines in operation. Compared to state-of-the-art methods, using an invasive preparation of the blade surface, the thermographic flow visualization uses the effect of different surface temperatures due to different heat transfer coefficients in the boundary layer to differentiate between flow regimes contactless [1].

Thermographic flow visualization on wind turbine in operation with an infrared camera

While the potential of this method for detecting flow separation was already verified in wind tunnel application through evaluating flow fluctuations [2], the application to in-process measurements has yet to be made. Difficulties to overcome are the infeasibility of increasing the flow regime thermal contrast in field measurements or recording image series for flow fluctuation investigation despite the rotational movement of the rotor. Additional factors to consider are a low spatial resolution due to high measuring distances and the overall non-consistent, non-laboratory environmental circumstances. Furthermore different spatio-temporal image processing methods should be implemented to increase the contrast between the flow separation and other flow states to further improve the in-process flow visualization on wind turbines in operation.

[1] C. Dollinger, N. Balaresque, M. Sorg: Thermographic boundary layer visualization of wind turbine rotorblades in operation. EWEA 2014, Barcelona, Spain, 10 - 13 Mar 2014, No. 9. (Poster)

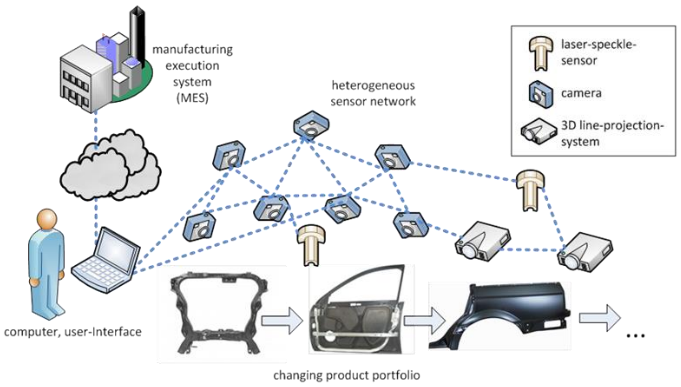
[2] C. Dollinger, N. Balaresque, M. Sorg, A. Fischer: IR thermographic visualization of flow separation in applications with low thermal contrast, Infrared Physics & Technology 88:254-264, 2018.

IQZeProd

Inline quality control for zero-error-products

Funding organization: AiF
Funding ID: 232 EGB
Duration: 1 Oct 2018 - 30 Sep 2020
Project scientist: Johannes Stempin

Quality control in manufacturing is usually realized at the end of the process chain. At this point, considerable costs and energy have already been invested into the components throughout the previous manufacturing steps. According to the state of the art, significant potentials of productivity and quality cannot be realized due to the late or unreliable detection of failures. In order to make the manufacturing process more robust and sustainable, the project IQZeProd will develop and implement new inline monitoring solutions for the realization of a zero defect strategy in the field of industrial manufacturing, including those in automotive, aerospace, electronics and consumer industries.



Exemplary topology of a heterogeneous sensor network with decentralized data pre-processing for quality monitoring of a variable component spectrum

Up to now some research institutes have individually tried to improve specific sensor technologies or to introduce new sensors to a process. This project will try to tackle zero defect manufacturing by setting up a scalable multi-sensor monitoring approach, which can be applied to most manufacturing technologies. The aim is to guarantee a failure-free final product at the end of the production chain by detecting any failure or misalignment of production parameters as early as possible.

Accordingly, technological case studies in four important manufacturing processes – sheet metal forming of automotive parts, wood processing, additive manufacturing/3D printing, coating of solid 3D parts - will be set up to determine the possible monitoring solutions on the production process level. Nevertheless, monitoring the manufacturing process is only seen as a first step to reduce rejection rates effectively. By this means failures cannot only be identified during production, but prevented with foresight.

[1] S. Patzelt, C. Stehno, D. Stöbener, G. Ströbel, A. Fischer: In-Prozess-Charakterisierung spiegelnder Oberflächen mit Laserstreulicht und leistungsfähiger Hardware. tm – Technisches Messen 84(9):557-567, 2017.

[2] S. Patzelt, D. Stöbener, G. Ströbel, A. Fischer: Uncertainty of scattered light roughness measurements based on speckle correlation methods. SPIE Optical Metrology, München, 25 - 29 Jun 2017, Vol. 10329, No. 103291P (11 pp.).

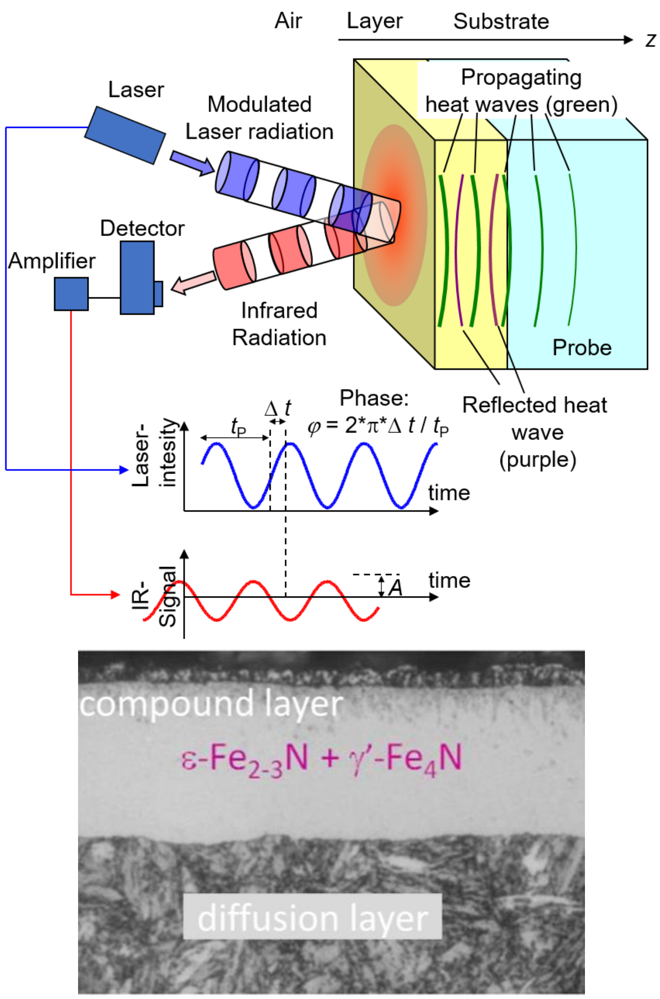
PhoMeNi

Photothermal measurement technique for non-contact in-process detection of nitriding layer formation during gas nitriding for industrial nitriding furnaces

Funding organization: AiF
Funding ID: 20501 N
Duration: 1 Feb 2019 - 31 Jul 2021
Project scientist: Merlin Mikulewitsch

For many decades, gas nitriding has been one of the most important thermochemical surface layer treatment processes for steels in order to improve surface hardness and wear resistance. The resulting nitriding layer consists of the outer compound layer and the underlying diffusion layer. Gas nitriding can often lead to incorrect nitriding results such as soft spots, a nitriding layer that is too thin or highly porous. Presently, the nitriding process lacks a direct measuring method to observe the boundary layer development in process, i.e. in an industrial nitriding furnace. While X-ray diffractometry enables an in-situ characterization of the nitride phase formation, it can also not be used in industrial nitriding furnaces. The project PhoMeNi aims to employ photothermal radiometry, an alternative measurement technique that will allow in-process, contact-free and non-destructive boundary layer examination.

Since photothermal signals depend on the thermal properties of the surface, modifications to the boundary layer such as the diffusion and compound layer or near-surface porous zones can be observed during their formation and growth in process. PhoMeNi aims to develop a concept for the implementation of a photothermal sensor in industrial furnaces, as well as to elaborate new findings on the kinetics of nitriding layer formation.



Top: Measurement principle of photothermal radiometry. *Bottom:* Nitriding layer cross-section.

[1] J. Dong, H. Prekel, M. Dethlefs, J. Epp, A. Fischer: In-situ-Untersuchung von Randschichten während des Gasnitrierens mittels Röntgendiffraktometrie und photothermischer Radiometrie. HTM Journal of Heat Treatment and Materials 72(3):154-167, 2017.

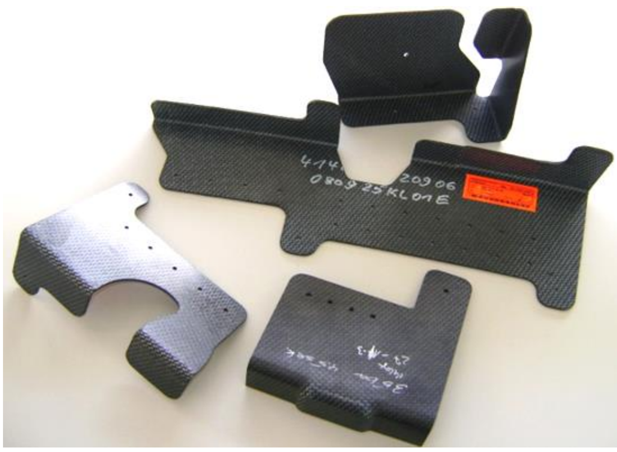
MoQua

Model-based quality control for zero-defect production in a thermo-forming process

Funding organization: AiF
Funding ID: 19336 N
Duration: 1 Feb 2017 - 31 Jan 2019
Project scientist: Johannes Stempin

The objective of this project is the development of a three level quality control with adaptive modules. In combination with suitable sensors and empirical values stored in databases, this quality control will enable a zero-defect thermo-forming production.

The innovation is to consider the workpiece quality as control variable. Thereby, the inner quality of the workpiece as well as its geometry is being controlled in-situ. The required technologies, in particular a deep understanding about the influences of workpiece heating, the press power and workpiece positioning, will be developed and implemented. Within this system, the quality control compensates quality deviations, which occur within the first production steps, by parameter adaptions in the subsequent sub-processes. Thus, the quality features of the workpieces finally meet the tolerances.



Fiber composite clips of aerospace industry
(source: Faserinstitut Bremen e. V.)

Sensors will acquire the process parameters and environmental effects in-process, and this data is being analysed in parallel to realize a closed-loop control. This control system leads to a reproducible and high workpiece quality, and, at the same time, reduces the reject rate while adapting the process to new workpieces or geometry variations. The functionality of the quality controller is the capability to predict how the process parameters affect the workpiece quality and to automatically adapt these parameters in case of imminent exceeding tolerances.

The implementation and demonstration of the project results are carried out in the frame of a thermo-forming process for the production of thermoplastic fibre composite workpieces, as their material behaviour requests a strict compliance of the process parameters.

[1] J. Stempin, A. Fischer: Regelungsstrategien für einen Thermoformprozess. 52. Regelungstechnisches Kolloquium, Boppard, 21 - 23 Feb 2018, pp. 13-14.
[2] J. Stempin, R. Vocke, F. Jansen, A. von Freyberg, A. S. Herrmann, A. Fischer: Development of a model-based quality control system for “zero-error” production of flexible batch sizes in the thermoforming process. MAPEX Symposium 2018 Process Monitoring", Bremen, 18 - 19 Jun 2018. (Poster)

SelTon-X

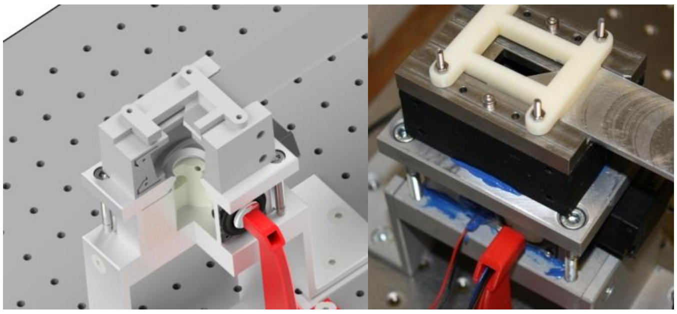
Analysis of the leak tightness of the SelTon self-tonometer and its influence on the measurement uncertainty

Funding organization: BMWi
Funding ID: 03THW04H02
Duration: 1 Sep 2018 - 29 Feb 2020
Project scientist: Jan Osmers

Glaucoma is currently the most common cause of irreversible blindness worldwide. An increased intraocular pressure (IOP) is a major risk factor and its reduction describes the only therapeutical approach. A gentle tonometer that can be operated by the patient himself to determine the fluctuations of daily pressure would be desirable for optimal therapy monitoring. For this reason, BIMAQ has developed a concept for a self-tonometer in which the IOP is determined contactlessly from the oscillation characteristics of the eye. In the SelTon project (BMBF Funding ID.: 13GW0054), the measuring principle was tested on humans. In addition to promising results, a significant cross-sensitivity of the device was also determined. If there are leaks when setting up the tonometer, the measured value changes and may lead to large deviations. The main goal of the WIPANO project is to investigate this cross sensitivity and to compensate it with a mathematical model.

The overall project is divided into six work packages (WP), which are completely handled by BIMAQ. Starting with the creation of a list of requirements, a design and construction of a leakage test rig will be implemented on the basis of this, with which a series of measurements being carried out with a varying degree of leakage. In addition, the measurement data of the clinical test series from the SelTon project will be investigated with regard to the cross-sensitivities by biometric properties of the measured eyes. Finally, a mathematical relationship between leakage and change in system behaviour is to be determined with which the cross-sensitivity can be eliminated.

In the case of successful compensation of the cross-sensitivities of SelTon, the economic exploitation, further development of the device and medical approval will be sought immediately after the project.



Leakage test rig

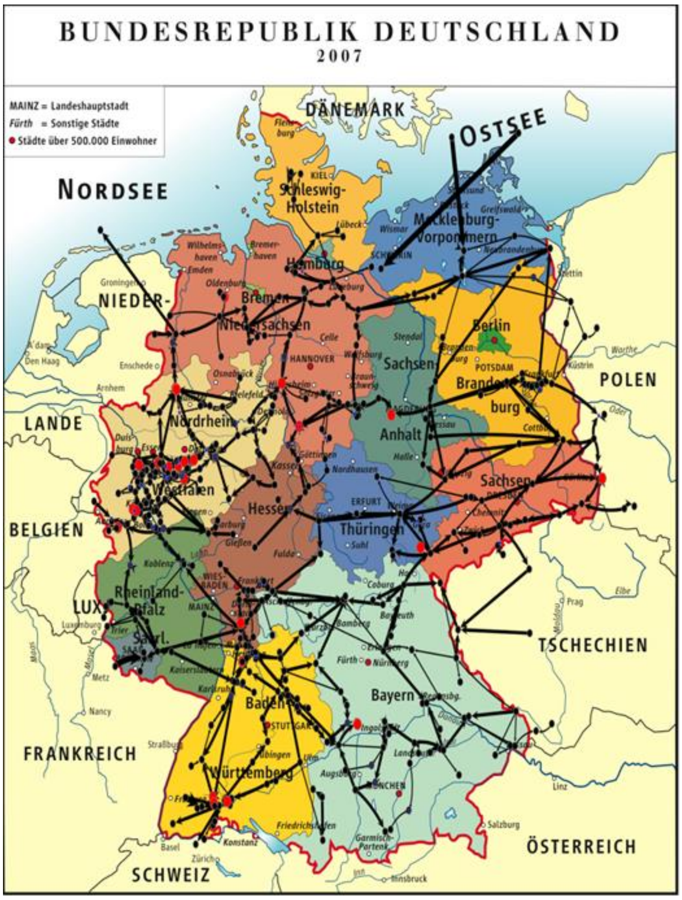
[1] J. Osmers, M. Sorg, A. Fischer: Optical measurement of the corneal oscillation for the determination of the intraocular pressure. Biomedical Engineering/Biomedizinische Technik, 2019. (accepted for publication)
[2] J. Osmers, M. Sorg, A. Fischer: Die Biometrie des Auges als Ursache für systematische Messabweichungen bei der akustischen Tonometrie. tm - Technisches Messen 86(4):237-246, 2019.

GEOWISOL2

Analysis and comprehension of the powerline infrastructure in Germany

Funding organization: BMBF
Funding ID: 40401065
Duration: 1 Jan 2019 - 31 Dec 2021
Project scientist: Yannik Schädler

The importance of renewable energies for an alternative energy system is one of the main goals for energy system transformation and for the reduction of climate-damaging greenhouse gases. Due to the fluctuation of wind and solar power, the challenges for the German power grid, which is subject to greater dynamic demands than in the past, are increasing with its share in power generation. In order to optimally cover the increasing demand for energy transfer, it is necessary to have a precise knowledge of the feed-in and demand quantities, resolved in terms of time and place. Such a comprehensive database is currently only available for parts of the electricity grid or with limited time and location resolution.



For this reason, a database was developed within the GEOWISOL project which provides feed-in quantities for wind and solar energy as well as load time series as 15-minute average values and with a local resolution in the 2-digit postcode range based on real measurement data. Based on this, the proposed research project aims to extend the existing data base for the German electricity grid by feed-in data of further energy sources (e. g. conventional power plants, biomass, hydropower) and to map the determined geographical distribution to the real power lines existing in the grid. On this basis, the transmission volumes in the current expansion state and for future expansion scenarios are to be analysed and evaluated over time. In particular, the integration of offshore wind energy, which is becoming increasingly important, is to be taken into account. This will result in a tool that can evaluate future energy infrastructure projects (e. g. grid expansion, energy storage).

[1] V. Renken et al.: Geographical comparison between wind power, solar power and demand for the German regions and data filling concepts. Renewable energy 126:475-484, 2018.

BiSWind

Component integrated sensor system for wind energy systems

Funding organization: Federal Ministry BMWi
Funding ID: 0325891D
Duration: 1 Dec 2015 - 31 Jul 2019
Project scientist: Michael Sorg

Drive trains of wind energy systems experience a broad range of dynamic loads. Transient torque reversals originate in power loss and emergency stops, start cycles and in sheer winds and turbulence. The subsequent failure of bearings and gearboxes result in over 50 % of wind energy. To improve the design of drive train components

Research wind energy system of the University of Bremen

with precise load cycles, precise and long-term measurements are required.

Torque sensors are currently used only sporadically and not in volume production. Direct measurements of loads are not available for most parts of the drive train, especially from the inside of the gearbox. Data over the lifetime are scarce and correlations to failure events are thus limited to a few cases.

The co-operative research project develops a component-integrated measuring system. The key design aspects are measurement of torque, temperature, vibration and rotational speed with a sensor that is resistant to aging and aggressive media, and is self-sufficient.

The scientific and technical objectives cover a broad range beginning with the process development for direct coating and structuring of resistance structures and electrodes directly on shafts for the durable sensor itself. To be self-sufficient newly developed AIN and AIScN based piezoelectric structures have to provide the energy for the sensor module which in turn will be assembled on a cylindrical low temperature co-fired ceramics. This sub-project investigates both the suitability and the performance of the measuring system for application in wind turbines.

[1] K. Tracht, G. Goch, P. Schuh, M. Sorg, J. F. Westerkamp: Failure probability prediction based on condition monitoring data of wind energy systems for spare parts supply. CIRP Annals 62(1):127-130, 2013.

InSensa

In-process sensors and adaptive control systems for additive manufacturing

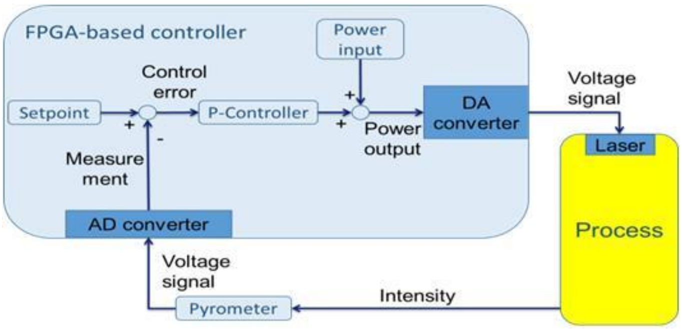
Funding organization: Federal Ministry BMBF
Funding ID: 02P15B076
Duration: 1 May 2017 - 30 Apr 2020
Project scientists: Volker Renken, Daniel Gleichauf

Selective laser melting (SLM) becomes an important factor for the manufacturing of different construction parts. The technology offers variances and functionalities going beyond conventional possibilities.

However, the SLM machines possess seldom sensors to detect actual process states and have limited reaction on disturbances. That leads either to part errors and unnecessary follow-up costs or to a not optimised manufacturing procedure regarding resources and efficiency.

Aim of the project is the integration of additional sensor and control technology into the machines. Different sensors measuring intensity in visible (RGB) and infrared range (IR) as well as topography (in-process depth meter - IDM) shall be included. Therefore, the process parameters as melt pool size and temperature will be reasoned and controlled by adaptive model-based control strategies within a cascaded control structure [1]. For that purpose, techniques from machine learning are included in the control hardware. The process speed is a high challenge for the control hardware and software. In order to be able to react on measurable changes fast models and fast hardware are needed. First results show control times of below 50 µs [2].

Principal control ability has been shown for a proof-of-concept experiment by scanning with low scan speed over a bridge structure. Thus, a closed-loop P-controller approach leads to a reduction of temperature deviation of up to 70 % compared to open-loop control (see Figure).



Control structure within closed-loop of manipulating the laser power by pyrometer measurement

The standard deviation of pyrometer measurement signal is reduced by 25 % in closed loop control approach by build jobs of cubes and triangle geometries. The results are promising to reduce error rates significantly for complex part geometries.

[1] V. Renken, S. Albinger, G. Goch, A. Neef, C. Emmelmann: Development of an adaptive, self-learning control concept for an additive manufacturing process. CIRP Journal of Manufacturing Science and Technology 19:57-61, 2017.

[2] V. Renken, L. Lübbert, H. Blom, A. von Freyberg, A. Fischer: Model assisted closed-loop control strategy for selective laser melting. LANE 2018 10th CIRP Conference on Photonic Technologies, Fürth, 3 - 6 Sep 2018, Procedia CIRP 74:659–663, 2018.

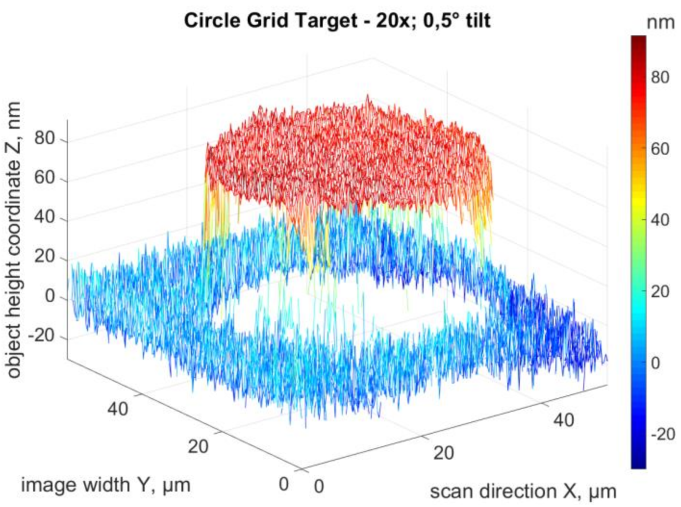
SiToH

Fast, interferometric, in-process topography measurement of moving surfaces applying high-performance hardware

Funding organization: BMBF
Funding ID: 100363507
Duration: 1 Aug 2018 - 31 Jul 2021
Project scientist: Gert Behrends

Rising demands regarding the quality of optically smooth surfaces of consumer goods and intermediate products necessitate metrology systems, which are able to quantify the topography of these surfaces in a quick and accurate manner.

One suitable measurement technique is vertical scanning white light interferometry (VSWLI), as specified in DIN EN ISO 25178. State of the art VSWLI is able to accurately record surface topographies with a height resolution < 1 nm. Drawbacks of this method are its limitation to stationary surfaces and extensive post-processing when measuring large areas. SiToH overcomes these limitations by applying lateral scanning white light interferometry (LSWLI), as first described by Olszak [1]. LSWLI combines vertical and horizontal scanning into a single motion, enabling continuous measurements of moving surfaces.



Topography of a pillar shaped calibration target, recorded with LSWLI.
Note missing data points on the pillar's steep sidewall.

As one of the principal innovations of this project is to use LSWLI on cylindrical rollers, it is imperative to investigate the behaviour of the LSWLI signal on curved surfaces.

On plain surfaces the signals' vertical measurement support points are evenly spaced and dependent on the tilt angle.

Experiments on plain samples show angles between 0.5° and 2° to yield the best results. Ambiguities in the recorded correlograms adversely affect the height evaluation at smaller angles. Shadows of tall surface features are a source of error at steeper angles.

On circular objects, on the other hand, the axial support point grid is densest, where it is closest to the sensor, becoming increasingly spread out nearing the edge of the field of view. This non-linear spread of support points and the resulting laterally distributed object height uncertainty is a subject of current research.

[1] A. Olszak: Lateral scanning white-light interferometer, Applied Optics, 39:6-13, 2000.
[2] G. Behrends, D. Stöbener, A. Fischer: Topografiemessung gekrümmter Oberflächen mittels lateral scannender Weißlichtinterferometrie, 120. Jahrestagung der DGaO, Darmstadt, 11 - 15 Jun 2019.

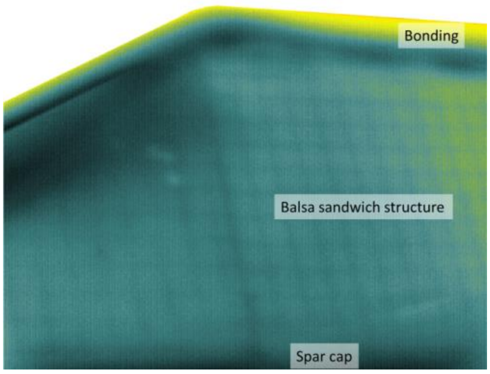
ThermoFlight

Concept for the development of an optimized maintenance and inspection method for offshore wind turbines using thermography and SHM as non-destructive testing technologies in combination with unmanned aerial vehicles

Funding organization: BIS
Funding ID: 59203/4
Duration: 1 Jan 2017 - 31 Dec 2018
Project scientist: Christoph Dollinger

The planned expansion of offshore wind energy in Germany requires the maintenance and operation to be efficiently organized both economically and ecologically for at least 25 years for a growing number of wind energy turbines. The maintenance and testing teams are confronted with new challenges offshore. This is due to short time windows as a result of difficult weather conditions as well as high safety requirements and regulations.

Especially the rotor blade tests by industrial climbers are difficult to plan under these harsh conditions. With the objective of minimizing the use of personnel for inspections and the resulting downtimes of the offshore wind turbines, the use of non-destructive testing methods and structural health monitoring is investigated. Especially in combination with unmanned aerial vehicles, these technologies can contribute to an efficient, safe, energy and material-optimized rotor blade inspection process.



Thermographic image of the inner structure of a rotor blade

For the non-destructive testing of the inner structure of offshore wind turbine rotor blades the potential of thermographic images taken from unmanned aerial vehicles is investigated. The resulting requirements in terms of weight and power supply limit the variety of suitable thermographic cameras and due to that affect the available spatial and thermal resolution.

In order to characterize the method, thermographic measurements, both with high-end and light-weight thermographic systems, in standstill for deep structural (see figure) and on the running wind turbine for surface near defects are performed [1]. The objective is to compensate the observed technical limitations by the use of image processing in terms of a contrast enhancement [2].

[1] C. Dollinger, M. Sorg, N. Balaresque, A. Fischer: Measurement uncertainty of IR thermographic flow visualization measurements for transition detection on wind turbines in operation. Experimental Thermal and Fluid Science 97:279-289, 2018.
[2] C. Dollinger, N. Balaresque, M. Sorg, A. Fischer: IR thermographic visualization of flow separation in applications with low thermal contrast. Infrared Physics & Technology 88:254-264, 2018.

Cooperations with industry and measurement services

Cooperation partners

A
- Aconity3D GmbH, ***Herzogenrath***
- *Alfavision*, ***Hutthurm***
- ASENTEC GmbH, ***Heilbronn***
- AUKOM e. V., ***Braunschweig***

B
- BIAS Bremer Institut für angewandte Strahltechnik, ***Bremen***
- BIBA Bremer Institut für Produktion und Logistik, ***Bremen***
- BIME Bremer Institut für Strukturmechanik und Produktionsanlagen, ***Bremen***

C
- C.F.K. CNC-Fertigungstechnik Kriftel GmbH, ***Kriftel***
- CoSynth GmbH & Co. KG, ***Oldenburg***

D
- Deutsche Wind Guard GmbH, ***Varel***
- Deutsche WindGuard Engineering GmbH, ***Bremerhaven***
- Deutsche WindGuard Systems, ***Berlin***
- DFMRS Deutsche Forschungsvereinigung für Meß-, Regelungs- und Systemtechnik e. V., ***Bremen***

E
- energy & meteo systems GmbH, ***Oldenburg***

F
- Faserinstitut Bremen e. V. FIBRE, ***Bremen***
- Fraunhofer-Einrichtung für Additive Produktionstechnologien IAPT, ***Hamburg-Bergedorf***
- Formtech GmbH, ***Weyhe***
- Fraunhofer Institut für Windenergie und Energiesystemtechnik IWES, ***Bremerhaven***
- Fraunhofer-Institut für Keramische Technologien und Systeme IKTS, ***Dresden***
- Fraunhofer-Institut für Organische Elektronik, Elektronenstrahl- und Plasmatechnik FEP, ***Dresden***
- FRT GmbH, ***Bergisch Gladbach***
- FWBI Friedrich Wilhelm Bessel Institut Forschungsgesellschaft mbH, ***Bremen***
- Gottwald Hydraulik, ***Bremen***

G
- Gesellschaft für Bild- und Signalverarbeitung (GBS) GmbH, ***Ilmenau***

H
- Hansgrohe SE, ***Schiltach***
- Helmholtz-Zentrum, Institut für Fluiddynamik, ***Dresden***
- Hexagon Manufacturing Intelligence, ***Wetzlar***

I
- IMSAS Institut für Mikrosensoren, -aktoren und -systeme, Universität ***Bremen***
- InfraTec GmbH Infrarotsensorik und Messtechnik, ***Dresden***
- *in-situ GmbH*, ***Sauerlach***
- ISRA VISION AG, ***Darmstadt***

K
- K & R enatec GmbH, ***Schwanewede***
  Klingelnberg GmbH, ***Hückeswagen***

L
- Labor für Mikrozerspanung, ***Bremen***
- Leibniz-Institut für werkstofforientierte Technologien - IWT, ***Bremen***
- Lloyd Dynamo Werke GmbH, ***Bremen***

Cooperation partners

M

- Materialise GmbH, ***Bremen***
- Meridian Lightweight Technologies United Kingdom (MLTUK), Sutton-In-Ashfield, ***Nottingham/UK***
- *Mevisco Gmbh & Co. KG,* ***Bremen***
- Micro Systems Engineering GmbH, ***Berg***

O

- OptoPrecision GmbH, ***Bremen***
- Optris GmbH, ***Berlin***

P

- Physikalisch-Technische Bundesanstalt PTB, ***Braunschweig***
- Pöppelmann GmbH & Co. KG, ***Lohne***
- Precitec GmbH & Co. KG, ***Gaggenau***

R

- Roland Klinik Bremen gGmbH, ***Bremen***

S

- Sachverständigenbüro Otto Lutz, ***Bundorf***
- Schaeffler Technologies AG & Co. KG, ***Herzogenaurach***
- Siegert Thinfilm Technology GmbH, ***Hermsdorf***
- Siemens AG, ***Bremen***
- SINUS Messtechnik GmbH, ***Leipzig***
- *Stiftung OFFSHORE-WINDENERGIE,* ***Varel***

T

- Tata Steel Plating, Hille & Müller GmbH, ***Düsseldorf***
- Technische Universität Dresden, Institut für Festkörperelektronik, ***Dresden***
- Temicon GmbH, ***Dortmund***
- Tomey GmbH, ***Nürnberg***
- Technische Universität Ilmenau, Fachgebiet Elektroniktechnologie, ***Ilmenau***
- Technische Universität Ilmenau, Fachgebiet Mikromechanische Systeme, ***Ilmenau***
- Toho Tenax Europe GmbH, ***Wuppertal***
- Trecolan GmbH, ***Bremen***

U

- Universitätsklinikum, Augenklinik, ***Würzburg***

V

- VEW Vereinigte Elektronikwerstätten GmbH, ***Bremen***
- VTD Vakuumtechnik Dresden GmbH, ***Dresden***

W

- Weiss Medizintechnik GmbH, ***Rednitzhembach***
- Weiss Umformwerkzeuge GmbH, ***Rednitzhembach***
- wenglor sensoric GmbH, ***Tettnang***
- WindMW Service GmbH, ***Bremerhaven***

Cooperations with industry and measurement services

Measurement services

Dimensional measurements

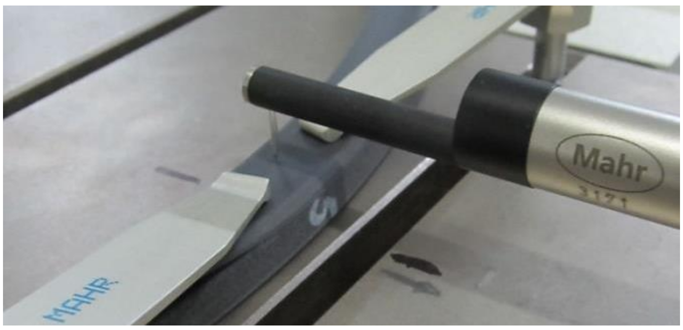
Duration: continuously

Contact: a.freyberg@bimaq.de

With its extensive measurement equipment, BIMAQ offers measurement services for the local industry.

The measurement tasks range from dimensional measurements on metallic and fibre composite materials for the automotive, energy, aerospace and space industry to roughness measurements on flexible sealing elements. Depending on the application, geometrical features are acquired on coordinate measuring machines with tactile or optical probes and dimensional, shape and position deviations are evaluated. Other applications require the optical acquisition of free-form surfaces by means of stripe pattern projection systems.

Roughness measurements are performed either with a stationary measuring device or with a mobile device, e. g. on bearing rings with diameters up to 2 m.



Roughness measurement on a flexible sealing element

Thermographic flow visualization

Duration: continuously

Contact: d.gleichauf@bimaq.de

In a close cooperation with Deutsche WindGuard Engineering GmbH, thermographic measurements for flow visualization in wind tunnel experiments and on the rotor blades of wind turbines in operation are performed. The thermographic method for flow visualization is non-invasive and provides the location of different flow regions including the laminar-turbulent transition. The flow regions can be distinguished by differences in heat flux and temperature fluctuations in time. In wind tunnel experiments, the acquisition, the automated processing and the evaluation of the results are part of the offered services.

Combined with a telephoto lens, the high-performance IR-camera is capable to detect small temperature differences on the rotor blade surface for a visualization of the flow conditions on wind turbines in operation. The information can be determined without the expensive instrumentation of conventional methods for flow visualization. The measurements are carried out at a distance of several hundred meters and enable an overall evaluation of the flow conditions at the rotor blade as well as the study of influences by contamination and erosion of the rotor blade on the flow.

Teaching activities, student projects, graduation works

Teaching activities

Lecture	PT	SE	Wing	BB	Sem. BSc	Sem. MSc	CP	Students WiSe 17/18 and SoSe 2018
Messtechnik	●	●	○	○	3^{rd}		3	144
Übung Messtechnik	●		○	○	3^{rd}		1	134
Labor Messtechnik	●		○	○	3^{rd}		1	54
Regelungstechnik	●		○		5^{th}		3	80
Übung Regelungstechnik	●		○		5^{th}		1	76
Labor Regelungstechnik	●		○		5^{th}		1	56
Grundlagen der Qualitätswissenschaft	●	●	●		5^{th}	1^{st}	3	158
Regenerative Energien	●	○	○	○	4^{th} 6^{th}	1^{st}	3	39
Prozessnahe und In-Prozess-Messtechnik	●	●	●		4^{th} 6^{th}	1^{st} 2^{nd} 3^{rd}	3	12
Geometrische Messtechnik mit Labor* AUKOM	●	●	○		5^{th}	1^{st}	3	39
Methoden der Messtechnik - Signal- und Bildverarbeitung	●	●	●		5^{th}	1^{st} 2^{nd}	3	13
Einführung in die Automatisierungstechnik mit Labor	●	●	○		5^{th}	1^{st} 2^{nd}	3	27
Produktion von Verzahnungen (held by several chairs)	●	○				1^{st} 2^{nd}	6	7
Labor Produktion von Verzahnungen (held by several chairs)	●	○				1^{st} 2^{nd}	3	3
Grundlagenlabor Produktionstechnik		●			4^{th}		2	35
Messtechnisches Seminar	●	●	●		4^{th}	1^{st} 2^{nd}	3	18*

**started in summer term 2019*

Legend:

● - Pflicht-/Wahlpflicht-/Wahlfach, ○ - fakultativ

PT - Produktionstechnik, **SE** - Systems Engineering, **Wing** - Wirtschaftsingenieurwesen Produktionstechnik, **BB** - Berufliche Bildung

* - AUKOM Certificate: AUKOM is a manufacturer-independent association for training in the field of geometric measurement technology. AUKOM offers the students to earn the level 1 basic certificate at cost (in total, there are 3 levels of training: 1 basic, 2 advanced, 3 expert).

Teaching

Teaching activities, student projects, graduation works

Student projects

Kind of project	Title	Semester	Course of studies*
Informatikprojekt Informatikprojekt	Aufbau eines 3D-Laserscanners mit Signalauswertung und Geräteansteuerung unter MATLAB	SoSe 2019	BSc PT BSc WING

*SE - Systems Engineering, PT - Produktionstechnik, WING - Wirtschaftsingenieurwesen - Produktionstechnik

Graduation works

Bachelor theses

- Aala Eldien ***Hassan***:
  Quantifizierung von Messabweichungen für PIV-Messungen in Flammen.
  Colloquium: 2 Nov 2018
- Eva-Maria ***Lammers***:
  Untersuchung der Wärmeentwicklung beim medizinischen Bohren von Knochen.
  Colloquium: 20 Dec 2018
- Nils ***Poeck***:
  Kontraststeigerung in Messungen zur thermografischen Strömungsvisualisierung durch Merkmalextraktion von Bild-informationen.
  Colloquium: 22 Jan 2019

Master theses

- Justin ***Man-Igri***:
  Einfluss von inhomogenen Brechungs-indexfeldern bei der stereoskopischen Particle-Image-Velocimetry in Flammen.
  Colloquium: 18 Dec 2018

Publications and qualification of young academics

Publications

Books

- C. ***Dollinger***:
  Thermografische Strömungsvisualisierung an Rotorblättern von Windenergieanlagen.
  In: Forschungsberichte des Bremer Instituts für Messtechnik, Automatisierung und Qualitätswissenschaft (Hrsg.: A. Fischer, G. Goch), Vol. 2, Shaker, Aachen, 2018.
- K. ***Ni***, Y. Peng, D. Stöbener, G. Goch:
  Cylindrical gear metrology.
  In: Metrology (Hrsg.: Wei Gao), Springer, Singapur, 2019, pp. 1-29.
- A. ***Tausendfreund***:
  Laser-optische Messverfahren zur Charakterisierung von Oberflächendefekten im Nanometerbereich.
  In: Forschungsberichte über Messtechnik, Automatisierung, Qualitätswissenschaft und Energiesysteme (Hrsg.: G. Goch, A. Fischer), Vol. 7, Verlag Mainz, Aachen, 2019.
- P. ***Zhang***:
  Qualitätsregelungssystem eines laser-chemischen Ätzprozesses für die metallische Mikroproduktion.
  In: Forschungsberichte des Bremer Instituts für Messtechnik, Automatisierung und Qualitätswissenschaft (Hrsg.: A. Fischer, G. Goch), Vol. 1, Shaker, Aachen, 2018.

Journals

- G. ***Alexe***, A. Tausendfreund, D. Stöbener, A. Fischer:
  Model-assisted measuring method for periodical sub-wavelength nanostructures.
  Applied Optics 57:92-101, 2018.
- M. ***Auerswald***, A. von Freyberg, A. Fischer:
  Laser line triangulation for fast 3D measurements on large gears.
  International Journal of Advanced Manufacturing Technology 100(9-12):2423-2433, 2019.
- C. ***Dollinger***, N. Balaresque, N. Gaudern, D. Gleichauf, M. Sorg, A. Fischer:
  IR thermographic flow visualization for the quantification of boundary layer flow disturbances due to the leading edge condition.
  Renewable Energy 138:709-721, 2019.
- C. ***Dollinger***, N. Balaresque, M. Sorg, A. Fischer:
  IR thermographic visualization of flow separation in applications with low thermal contrast.
  Infrared Physics & Technology 88:254-264, 2018.
- C. ***Dollinger***, M. Sorg, N. Balaresque, A. Fischer:
  Measurement uncertainty of IR thermographic flow visualization measurements for transition detection on wind turbines in operation.

Experimental Thermal and Fluid Science 97:279-289, 2018.

- J. ***Dong***, J. Epp, R. Lipinski, M. Sorg, H.-W. Zoch, A. Fischer: *Combined X-ray diffraction and photo-thermal radiometry methods for in situ analysis of nitriding treatment.* Metallurgical Research & Technology 115(4):408 (8 pp.), 2018.
- A. ***Fischer***: *Angular-Dependent Radius Measurements at Rotating Objects Using Underdetermined Sensor Systems.* IEEE Transactions on Instrumentation and Measurement 67(2):425-430, 2018.
- A. ***Fischer***: *Fisher information and Cramér-Rao bound for unknown systematic errors.* Measurement 113:131-136, 2018.
- A. ***Fischer***: *Limiting uncertainty relations in laser-based measurements of position and velocity due to quantum shot noise.* Entropy 21(3):264 (19 pp.), 2019.
- F. ***Greiffenhagen***, J. Peterleithner, J. Woisetschläger, A. Fischer, J. Gürtler, J. Czarske: *Discussion of laser interferometric vibrometry for the determination of heat release fluctuat-ions in an unconfined swirl-stabilized flame.* Combustian and Flame 201:315-327, 2019.
- M. ***Mikulewitsch***, M. Auerswald, A. von Freyberg, A. Fischer: *Geometry measurement of submerged me-tallic micro-parts using confocal fluorescence microscopy.* Nanomanufacturing and Metrology 1(3):171-179, 2018.
- M. ***Mikulewitsch***, A. von Freyberg, A. Fischer: *Confocal fluorescence microscopy for geometry parameter measurements of submerged micro-structures.* Optics Letters 44(5):1237-1240, 2019.
- J. ***Osmers***, Á. Patzkó, O. Hoppe, M. Sorg, A. von Freyberg, A. Fischer: *The influence of intraocular pressure on the damping of a coupled speaker–air–eye system.* Journal of Sensors and Sensor Systems 7:123–130, 2018.
- J. ***Osmers***, M. Sorg, A. Fischer: *Die Biometrie des Auges als Ursache für systematische Messabweichungen bei der akustischen Tonometrie.* tm - Technisches Messen 86(4):237-246, 2019.
- T. ***Reichstein***, A. P. Schaffarczyk, C. Dollinger, N. Balaresque, E. Schülein, C. Jauch, A. Fischer: *Investigation of laminar-turbulent transition on a rotating wind-turbine blade of multimegawatt class with thermography and microphone array*. Energies 12(11):2102 (21 pp.), 2019.

Publications and qualification of young academics

Publications

- V. ***Renken***, M. Sorg, V. Marschner, L. Gerdes, G. Gerdes, A. Fischer:
  Geographical comparison between wind power, solar power and demand for the German regions and data filling concepts.
  Renewable Energy 126:475-484, 2018.
- D. ***Stöbener***, G. Alexe, A. Tausendfreund, A. Fischer:
  Methode zur Erfassung periodischer Sub-Wellenlängen-Nanostrukturen für den In-Prozess-Einsatz.
  tm - Technisches Messen 85(2):88–96, 2018.
- A. ***Tausendfreund***, D. Stöbener, A. Fischer:
  Induction of highly dynamic shock waves in machining processes with multiple loads and short tool impacts.
  Applied Sciences 9(11):2293 (13 pp.), 2019.
- A. ***Tausendfreund***, F. Borchers, E. Kohls, S. Kuschel, D. Stöbener, C. Heinzel, A. Fischer:
  Investigations on material loads during grinding by speckle photography.
  Journal of Manufacturing and Materials Processing 2(4):71 (12 pp.), 2018.
- A. ***Tausendfreund***, D. Stöbener, A. Fischer:
  Precise in-process strain measurements for the investigation of surface modification mechanisms.
  Journal of Manufacturing and Materials Processing 2(1):9 (11 pp.), 2018.
- C. ***Vanselow***, A. Fischer:
  Influence of inhomogeneous refractive index fields on particle image velocimetry.
  Optics and Lasers in Engineering 107:221-230, 2018.
- A. ***von Freyberg***, A. Fischer:
  Holistic approximation of combined surface data.
  Precision Engineering 54:396-402, 2018.
- Q. ***Wang***, J. Miller, A. von Freyberg, N. Steffens, A. Fischer, G. Goch:
  Error mapping of rotary tables in 4-axis measuring devices using a ball plate artifact.
  CIRP Annals - Manufacturing Technology 67(1):559-562, 2018.
- C. ***Wolf***, C. Mertens, A. Gardner, C. Dollinger, A. Fischer:
  Optimization of differential infrared thermo-graphy for unsteady boundary layer transition measurement.
  Experiments in Fluids 60:19 (13 pp.), 2019.

Conference contributions

- M. ***Agour***, C. Falldorf, B. Staar, A. von Freyberg, A. Fischer, M. Lütjen, R. B. Bergmann:
  Fast quality inspection of micro cold formed parts using telecentric digital holographic microscopy.
  5th Int. Conference on New Forming Techno-logy (ICNFT), Bremen, 18 - 21 Sep 2018.
  MATEC Web Conf. 190:15008 (8 pp.).

- G. ***Alexe***, A. Tausendfreund, D. Stöbener, A. Fischer:
  Feasibility study for coverage measurements of Au-nanospheres deposited surfaces based on light scattering.
  European Optical Society Biennial Meeting (EOSAM) 2018, Delft, Netherlands, 8 - 12 Oct 2018, pp. 298-299.
- N. ***Balaresque***, C. Dollinger, A. Fischer, H. Huhn, S. Krause, O. Lutz, J. Scheel, M. Sorg, C. von Zengen:
  Inspection of offshore wind turbine rotor blades by thermography and acoustic monitoring.
  WindEurope – Conference & Exhibition, Hamburg, 25 - 28 Sep 2018. (Poster)
- C. ***Dollinger***, D. Gleichauf, N. Balaresque, A. Fischer:
  Messung des strömungsbeeinflussenden *Kontaminationsgrads von Rotorblättern mittels thermografischer Strömungs-visualisierung.*
  XXXII. Messtechnisches Symposium des AHMT, Bremen, 20 - 21 Sep 2018.
  tm - Technisches Messen 85(S1):129-135, 2018.
- H. ***Messaoudi***, F. Böhmermann, M. Mikulewitsch, A. von Freyberg, A. Fischer, O. Riemer, F. Vollertsen:
  Chances and limitations in the application of laser chemical machining for the manufacture of micro forming dies.
  5th Int. Conference on New Forming Technology (ICNF), Bremen, 18 - 21 Sep 2018.
  MATEC Web Conf. 190:15010 (8 pp.).
- J. ***Osmers***, M. Sorg, A. Fischer:
  Einfluss der Biometrie des Auges auf die Messunsicherheit eines akustischen Tonometers.
  XXXII. Messtechnisches Symposium des AHMT, Bremen, 20 - 21 Sep 2018.
  tm - Technisches Messen 85 (S1):66-72, 2018.
- V. ***Renken***, L. Lübbert, H. Blom, A. von Freyberg, A. Fischer:
  Model assisted closed-loop control strategy for selective laser melting.
  10th CIRP Conference on Photonic Technologies (LANE 2018), Fürth, 3 -6 Sep 2018.
  Procedia CIRP 74:659–663, 2018.
- Y. ***Schädler***, M. Sorg, V. Renken, A. Fischer:
  Untersuchung der geographischen Verteilung und zeitlichen Korrelation von Wind- und Solar-Einspeisung auf Basis von Messdaten.
  DFMRS Windenergietagung 2019, Bremen, 28 Mar 2019.
- M. ***Sorg***, C. Dollinger, A. Fischer:
  Quantitative Bestimmung des Kontaminati-onsgrades von Rotorblattvorderkanten (LEC) mittels Thermografie.
  DFMRS Windenergietagung 2019, Bremen, 28 Mar 2019.
- D. ***Stöbener***, G. Alexe, L. Langstädtler, C. Schenck, B. Kuhfuss, A. Fischer:

Publications and qualification of young academics

Publications

Speckle photography based method for the characterization of material properties.
68th CIRP General Assembly, Tokyo, Japan, 19 - 25 Aug 2018.

- A. ***Tausendfreund***, G. Alexe, D. Stöbener, A. Fischer:
  Application limits of digital speckle photo graphy for in-process measurements in manufacturing processes.
  European Optical Society Biennial Meeting (EOSAM) 2018, Delft, Netherlands, 8 - 12 Oct 2018, pp. 255-256.
- C. ***Vanselow***, A. Fischer:
  Messunsicherheit von PIV-Messungen durch Brechungsindexfelder in Flammen.
  26. GALA-Fachtagung "Experimentelle Strömungsmechanik", Rostock, 4 - 6 Sep 2018, No. 12 (8 pp.).
- Q. ***Wang***, G. Goch, A. von Freyberg, F. Horn, N. Steffens, A. Fischer:
  Performance investigation of a large-scale rotary table under loads.
  33rd ASPE Annual Meeting, Las Vegas, USA, 4 - 9 Nov 2018, pp. 496-500.
- C. ***Wolf***, C. Mertens, A. D. Gardner, C. Dollinger, A. Fischer:
  Optimization of differential infrared thermography for unsteady boundary layer transition measurement.
  44th European Rotorcraft Forum, Delft, Niederlande, 18 - 21 Sep 2018 (14 pp.).

Other contributions

- R. B. ***Bergmann***, C. Falldorf, A. Dekorsy, C. Bockelmann, M. Beetz, A. Fischer:
  Ganzheitliche optische Messtechnik.
  Physik Journal 18(2):34-39, 2019.
- N. ***Balaresque***, C. Dollinger:
  Thermographic On-Site Measurements of De-Icing Systems of Wind Turbines in Operation.
  Wind Turbine Icing & Ice Prevention Forum, Berlin, 6 Oct 2017.
- C. ***Dollinger***:
  Thermografische Strömungsvisualsierung an Rotorblättern von Windenergieanlagen.
  ForWind Seminar, Oldenburg, 7 Jun 2018.
  (talk invited by Prof. M. Kühn)
- A. ***Fischer***:
  XXXII. Messtechnisches Symposium.
  tm - Technisches Messen 85(S1):S1, 2018.
  (Editorial)
- A. ***Fischer***:
  XXXII. Messtechnisches Symposium des AHMT in Bremen.
  tm - Technisches Messen 86(4):185-186, 2019. (Editorial)
- A. ***Fischer***, D. Stöbener:
  Speckle-based in-process measurements.
  MAPEX Symposium 2018 "Process Monitoring", Bremen, 18 - 19 Jun 2018.
- A. ***Fischer***:
  Beating the limits of measurements.

7th MAPEX Early Career Researcher Workshop, Bremen, 25 Oct 2018. (plenary talk invited by Prof. L. Colombi Ciacchi)

- *V. **Renken**, A. Fischer:*
Fehlerreduktion in der additiven Fertigung durch Sensorintegration und eine adaptive Regelungsstrategie.
Workshop "Qualitätssicherung und Messtechnik in der Additiven Fertigung", Jena, 8 Mar 2018.
- J. ***Stempin***, R. Vocke, F. Jansen, A. von Freyberg, A. S. Herrmann, A. Fischer:
Development of a model-based quality control system for "zero-error" production of flexible batch sizes in the thermoforming process.
MAPEX Symposium 2018 "Process Monitoring", Bremen, 18 - 19 Jun 2018. (Poster)
- C. ***Vanselow***, C. Dollinger, A. Fischer:
Flow field measurements under challenging in-process conditions.
MAPEX Symposium 2018 "Process Monitoring", Bremen, 18 - 19 Jun 2018. (Poster)

Publications and qualification of young academics

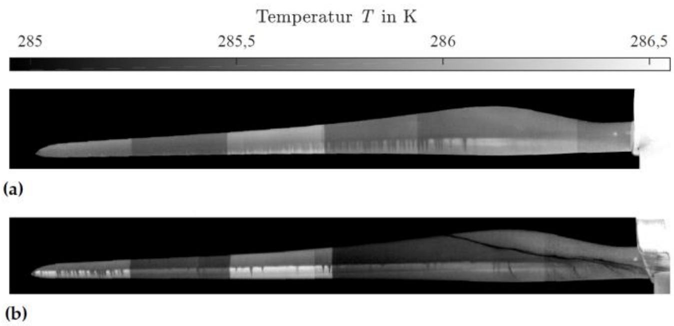
PhD theses

Thermografische Strömungsvisualiserung an Rotorblättern von Windenergieanlagen
Dr.-Ing. Christoph Dollinger
Date of thesis defense: 27 Jul 2018
Supervisor: Prof. Dr.-Ing. habil. Andreas Fischer

For the development of new and the improvement of existing rotorblades for wind turbines (wind energy converters, WECs), the knowledge of the boundary layer flow conditions on the rotorblade in operation is essential. The boundary layer flow influences the lift and, in particular, the performance-limiting drag and thus has a direct influence on both the performance and the acoustic emissions of the WEC.

Current methods used to measure or visualize the boundary layer flow at WECs require a time-consuming and cost-intensive preparation of the rotorblades and influence the flow itself. A suitable method for the non-invasive measurement of the flow conditions is the thermographic flow visualization. The thermographic flow visualization allows the identification of present flow regions based on different surface temperatures. In wind tunnel experiments, the method has proven to be a valuable instrument for boundary layer visualization.

However, up to now an application for measurements on WECs in operation with a long working distance and low thermal contrast has only been carried out in a qualitative form. Therefore, the aim of this thesis consists of an initial characterization of the measurability limits as well as the development of new signal processing methods. For the first time, this allows an identification and localization of different flow regions on the rotorblades of WECs in operation.



Thermografieaufnahmen eines Rotorblattes einer GE 1.5 sl WEA, wobei vor der Aufnahme von Teilbild (a) längere Zeit kein Niederschlag gefallen ist und Teilbild (b) direkt nach einem starken Regenschauer aufgenommen wurde.

[1] C. Dollinger, N. Balaresque, N. Gaudern, D. Gleichauf, M. Sorg, A. Fischer: IR thermographic flow visualization for the quantification of boundary layer flow disturbances due to the leading edge condition. Renewable Energy 138:709-721, 2019.

[2] C. Dollinger, N. Balaresque, M. Sorg, A. Fischer: IR thermographic visualization of flow separation in applications with low thermal contrast. Infrared Physics & Technology 88:254-264, 2018.

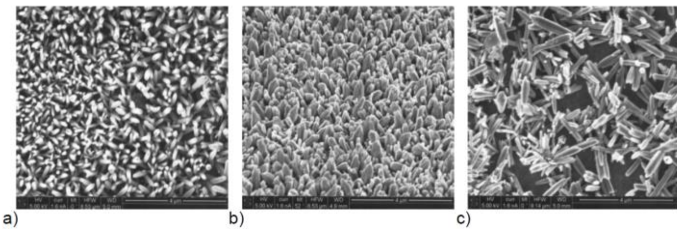
[3] C. Dollinger, M. Sorg, N. Balaresque, A. Fischer: Measurement uncertainty of IR thermographic flow visualization measurements for transition detection on wind turbines in operation. Experimental Thermal and Fluid Science 97:279-289, 2018.

Laser-optische Messverfahren zur Charakterisierung von Oberflächendefekten im Nanometerbereich

Dr.-Ing. Andreas Tausendfreund
Date of thesis defense: 23 Nov 2018
Supervisor: Prof. Dr.-Ing. Gert Goch

In the last decade, nanotechnology has found broad technical application beyond the laboratory scale. The generation of nanostructured, functionalized surfaces is accompanied by the growing need to be able to characterize surface defects already during the ongoing manufacturing process. Only a fast measuring technique prevents the often expensive further processing of defective components in a process chain and guarantees the quality of the end product.

Currently, there are no in-process measuring methods that are suitable for defect detection of stochastically structured surfaces in the nanometre range. According to the current state of the art, only optical measurement methods can be considered for this purpose. In this respect, angle-resolved laser-optical measurement methods with an analysis of the specific scattered light distributions prove to be particularly predestined.



Occurrence of different defect classes in the electrochemical fabrication of ZnO nanograss surfaces: a) intact structure; b) unstable column growth; c) clustering of the columns; sources: Institute for Solid State Physics (IFP), University

The aim of the present work is to improve the in-process capability of these scattered light measurement method related to characterization of nanostructures.

The challenge is that the influences of aperiodic nanostructures or their defects on the scattered light pattern are usually unknown. In a large number of simulated field distributions, however, specific defect characteristics can be identified with the help of which a characterization of the observed structures is possible. The development of such a measurement method requires a very large number of strictly calculated scattering patterns for the light scattering at different defective and intact structures.

[1] A. Tausendfreund, S. Patzelt, G. Goch: Parallelisierung rigoroser Streulicht-Simulationsalgorithmen für nanostrukturierte Oberflächen. tm - Technisches Messen, 77 (4), 2010, pp. 215-220.
[2] A. Tausendfreund, G. Goch: Parallelisation of rigorous light scattering simulation algorithms for nanostructured surfaces. CIRP Annals - Manufacturing Technology, 59 (1), 2010, pp. 581-584.

Publications and qualification of young academics

PhD theses

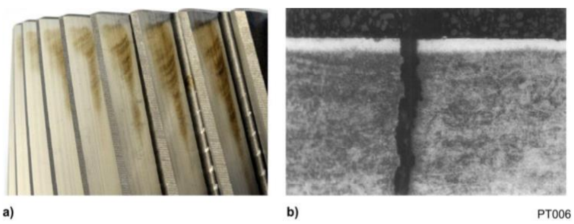
In- und Post-Prozess-Messverfahren für die Erfassung von thermo-mechanischen Schädigungen

Dr.-Ing. Philipp Thiemann
Date of thesis defense: 23 Nov 2018
Supervisor: Prof. Dr.-Ing. Gert Goch

In order to ensure the competitiveness of production technology in Germany, the continuous further development of manufacturing processes is essential in the context of globalization. However, tapping the technological potential of grinding processes also increases the risk of thermo-mechanical damage to the machined component. For this reason, there is a demand for a 100% inspection of hard-finish-machined functional surfaces. For this purpose, it is necessary to develop a metrological solution based on a non-destructive test method.

In grinding tests, various damage conditions could be generated on the case-hardened material 18CrNiMo7-6. The comprehensive characterization of these damages confirmed that, contrary to today's practice, the inherent stress displacement should be used as a target variable for the metrological recording of so-called grinding burns. For random, destructive testing, the radiographic internal stress analysis becomes more important, since alternative conventional methods can only evaluate the microstructure condition. Since only correlations between boundary zone and process states can be established on the basis of in-process methods, non-destructive post-process or in-situ testing methods are required for the evaluation of ground component surfaces.

Photothermal radiometry was excluded as a solution after the preliminary investigations, as significant microstructure-sensitive detection behaviour was determined. In contrast to this, the micro-magnetic method of the Barkhausen roughness analysis shows a microstructure or residual stress sensitive behaviour depending on the measured variable under consideration. Based on the results of the investigation, a two-parameter approach was developed for the reliable characterization of grinding burn. Here, the intrinsic stress-sensitive effective value of the bark-housing noise is combined with the microstructure-sensitive parameter Peak Position.



Characteristics of grinding burn a) Thermo-mechanically damaged gear wheel with burn marks b) Micrograph of a newly hardened microstructure with grinding crack (Rowe, W. B. (Hrsg.): Principles of modern grinding technology, Boston, 2009.)

[1] P. Thiemann, G. Ströbel, G. Goch: Mikromagnetische und photothermische Charakterisierung thermo-mechanischer Schädigungen. tm - Technisches Messen 80 (6), 2013, pp. 206-212.
[2] P. Thiemann, C. Dollinger, G. Goch: Untersuchungen zum Phänomen Schleifbrand. HTM Journal of Heat Treatment and Materials 69 (3), 2014

Awards

Bremer Ingenieurspreis 2018 (VDI)

On 22 Nov 2018, the Bremen VDI-regional-association awarded the annual Bremen Engineering Prize for outstanding bachelor's and master's theses by graduates from engineering courses of study.

Linda Wings and Daniel Gleichauf are the
2018 winners of the
Bremen Engineering Award (VDI)
Photo: ©Walter Müller/VDI

Daniel F. Gleichauf received this award for his master thesis supervised by BIMAQ, titled "Geometric assignment of thermographic measurements for flow visualization on rotor blades of wind turbines". His master thesis dealt with how measurement errors of conventional methods can be corrected in order to finally increase the efficiency of wind turbines.

Deutsche WindGuard Nachwuchs-Förderpreis 2018

The second time, Deutsche WindGuard GmbH and BIMAQ awarded the Young Talent Award for outstanding student works.

In awarding the prize, particular emphasis was placed on progress in science, understanding of measurement systems and the relevance of research results for practical measurement tasks.

The awards were presented to

- Dennis ***Jacob*** for his bachelor thesis "Parallelization approaches for evaluation algorithms of digital speckle photography" and to
- Daniel ***Gleichauf*** for his master thesis: "Assignment of thermographic measurements for flow visualization on rotor blades of wind turbines".

Prof. Dr.-Ing. habil. Andreas Fischer presented the certificates and the donated prize money at the annual closing ceremony of the institute.

From the left: Prof. Andreas Fischer,
Daniel Gleichauf, Dennis Jacob

Publications and qualification of young academics

Awards

OLB Wissenschaftspreis

On 3 Apr 2019 Dr.-Ing. Christoph Dollinger has received the second prize of the Science Award 2019 awarded by the OLB Foundation for his outstanding PhD thesis with the topic "Thermographic flow visualization of rotor blades of wind turbines" in the category doctoral theses.

Photo: ©OLB/Hibbeler

His scientific progress in the field of thermographic flow measurement technology for application in wind turbines under real operating conditions was recognized as well as the successful transfer of his findings into industrial practice. The award winners were selected from a total of more than 80 nominations, whereby the jury assessed both the (technical) scientific level of the work and the social significance, the courage in choosing the approach and the ability to develop and convincingly present topics.

Events

Participation at events and conferences

Date	Event / Conference	Location	Participant(s)	
7 Jun 2018	ForWind Seminar	Oldenburg	C. Dollinger	talk invited by Prof. M. Kühn
18 - 19.Jun 2018	MAPEX Symposium "Process Monitoring" 2018	Bremen	A. Fischer J. Stempin C. Vanselow	oral presentation poster presentation poster presentation
19 - 25 Aug 2018	68th CIRP General Assembly	Tokyo, Japan	D. Stöbener	technical presentation
3 -6 Sep 2018	10th CIRP Conference on Photonic Technologies (LANE 2018)	Fürth	V. Renken	oral presentation
4 - 6 Sep 2018	26. GALA-Fachtagung "Experimentelle Strömungsmechanik"	Rostock	C. Vanselow	oral presentation
20 - 21 Sep 2018	XXXII. Messtechnisches Symposium des AHMT	Bremen	D. Gleichauf J. Osmers A. Fischer	poster presentation oral presentation local organizer of the conference
8 - 12 Oct 2018	European Optical Society Biennial Meeting (EOSAM)	Delft, The Netherlands	G. Alexe A. Tausendfreund	oral presentation oral presentation
25 Oct 2018	7th MAPEX Early Career Researcher Workshop	Bremen	A. Fischer	plenary talk invited by Prof. L. Colombi Ciacchi
13 - 14 Nov 2018	SFB/TRR 136 International Symposium on Process Signatures	Bremen	A. Fischer D. Stöbener A. Tausendfreund	participants
5 Mar 2019	Jugend forscht - Schüler experimentieren. Regional-wettbewerb Bremen-Mitte	Bremen	A. von Freyberg	Jury-Mitglied
28 Mar 2019	DFMRS Windenergietagung 2019	Bremen	Y. Schädler M. Sorg	oral presentation oral presentation
11 - 15 Jun 2019	DGaO 120th Annual Meeting 2019	Darmstadt	G. Behrends A. Fischer	oral presentation participant
16 - 20 Jun 2019	Windenergy Science	Cork, Irland	D. Gleichauf	oral presentation
24 - 27 Jun 2019	LiM	München	V. Renken	oral presentation
24 - 27 Jun 2019	SPIE Optical Metrology	München	M. Mikulewitsch A. Fischer	oral presentation participant
25 - 26 Jun 2019	Sensoren u. Messsysteme	Nürnberg	A. Tausendfreund A. Fischer	oral presentation participant

Events

Events @ BIMAQ

Event	Date	Organizing institution
XXXII. Messtechnisches Symposium des Arbeitskreises der Hochschullehrer für Messtechnik e. V.	20 and 21 Sep 2018	BIMAQ and AHMT
BIMAQ meets ZEISS	4 Oct 2018	MAPEX
Verleihung Bremer Ingenieurspreis 2018	22 Nov 2018	VDI
Deutsche WindGuard Nachwuchs-Förderpreis 2018	13 Dec 2018	Deutsche WindGuard GmbH
GEOWISOL2 Kick-off Meeting	18 Feb 2019	BIMAQ
SiToH Arbeitstreffen Bremen	20 Mar 2019	BIMAQ
Girl's Day 2019 - Workshop: Exploring the world with electronic sense	28 Mar 2019	University of Bremen / Workshop at BIMAQ
ERASMUS+ Project MESI 4.0 as guest at BIMAQ: Focus on wind energy	28 Mar 2019	BIMAQ
DFMRS-Windenergietagung 2019	28 Mar 2019	DFMRS
OLB-Wissenschaftspreis	2 Apr 2019	OLB Oldenburg
Offshore measurement	30 Mar 2019	BIMAQ
Hand-over of the "Transition Finder" software to Deutsche Windguard GmbH	18 Apr 2019	BIMAQ/Deutsche WindGuard

- XXXII. Messtechnisches Symposium des Arbeitskreises der Hochschullehrer für Messtechnik e. V. (AHMT)

  On Sep 20 and 21, 2018, the 32nd Measurement Symposium of the AHMT (Arbeitskreis der Hochschullehrer für Messtechnik e. V.) in Bremen took place and was co-organized by the Bremer Institut für Messtechnik, Automatisierung und Qualitätswissenschaft (BIMAQ). Young researchers reported about current metrological research topics. There were 13 lectures on the topics "3D measuring systems", "Measuring systems for production engineering", "Sensor systems for material characterization", "Geometric measuring technology" and "Fibre sensor systems and interferometry", which were

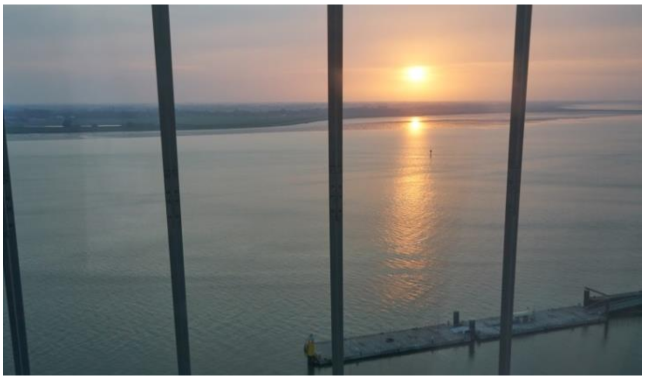
supplemented by inspiring discussions in the seven poster contributions.

Prof. Lutz Mädler from the Leibniz Institute for Material-Oriented Technologies gave a lecture on "Descriptors and Predictor Functions in the Method of Coloured States", which deals with the fast, experimentally based investigation of material properties using micro samples in high throughput. This provided fascinating insights into the diverse and lively world of metrology.

Dr.-Ing. Sebastian Bernd Bauer was awarded the Measurement Technology Prize. From the left: Prof. Dr. Scholl, Dr. Bauer, Prof. Dr. Puente León, Prof. Fröhlich, Prof. Dr. Henning

The lecture "Hyperspectral Image Unmixing Incorporating Adjacency Information", presented by Dr.-Ing. Sebastian Bernd Bauer should also be emphasized. For his PhD thesis, he was awarded the Measurement Technology Prize donated by the AHMT for his outstanding scientific achievements.

Last but not least, the visit to the Auswandererhaus and the conference dinner in Bremerhaven left an unforgettable impression.



Events

Events @ BIMAQ

- BIMAQ meets ZEISS

Dr. Marcin B. Bauza, Zeiss, Maple Grove/USA is responsible for New Technology and Innovation of the Carl Zeiss Industrial Metrology Business. On 4 Oct 2018 he contacted BIME and BIMAQ to learn more about MAPEX, whose members are affiliated to five different university faculties and four external research institutes on the university campus of Bremen. Prof. Fischer as a member of MAPEX had the opportunity to introduce him and the institute, as well as to inform Dr. Bauza about MAPEX's goals.

MAPEX Bremen
Material. Process. Excellence.

- GEOWISOL2 Kick-off-Meeting

All project partners, namely Stiftung Offshore Windenergie, energy & meteo systems GmbH, Deutsche WindGuard GmbH and Deutsche WindGuard Systems GmbH, as well as the project executive from Jülich were invited to the first meeting, which took place on 18 Feb 2019.

The goal of the project is the implementation of a database infrastructure for energy input in the network of power lines and the continuous analysis to find optimal expansion scenarios for high fractions of fluctuating inputs.

The morning meeting served to introduce each other and to present the contribution of the project partners to the project. The common lunch offered the opportunities to deepen the social contacts.

In the second session, next steps were discussed, such as which data are accessible and useful for the project, to prepare all partners to work efficiently on their next tasks.

- SiToH Arbeitstreffen Bremen

During a working meeting on March 20, 2019, the contact persons of the project partners GBS and CoSynth were shown the laboratories of the BIMAQ and the test setup for laterally scanning white light interferometry located therein. The kick-off meeting of this new project was at hansgrohe in Schiltach at 18 Sep 2018.

- Girl's Day 2019 - Workshop: Exploring the world with electronic sense

On 28 Mar 2019 four young girls participated the morning workshop "Exploring the world with electronic senses", which dealt with electricity that we cannot see but which obeys natural laws and can make the invisible visible. Things like even heat in the home, lights that turn on automatically, doors that close automatically and can detect obstacles are a matter of course nowadays, but not possible without electricity.

- ERASMUS+ Project MESI 4.0 as guest at BIMAQ: Focus on wind energy

Czech, Lithuanian, Spanish and German pupils from the school centre Geschwister Scholl (Gymnasiale Oberstufe) in Bremerhaven visited BIMAQ on 18 Mar 2019. As part of a two-year school partnership, they are supported by the ERASMUS+ project Modern Education in Science for Industry (MESI) 4.0. The students, who deal with regenerative and other future-oriented technologies, were able to learn a lot about wind energy. After an introductory lecture on topics such as floatation, thermography and energy fluctuations, there was an opportunity to learn about experiments in various laboratories:

Station 1: Analysis of the geographical distribution and time correlation of wind- and solar-input on the basis of real data

Station 2: Laboratory for dimensional metrology, Laboratory for large gears at BIMAQ Technikum plant

Station 3: Wind tunnel with thermographic flow measurement

Station 4: Fringe projection for geometry measurement

- DFMRS-Windenergietagung 2019

On 28 March 2019, the fourth DFMRS Wind Energy Conference took place at Haus Schütting in Bremen.

Lectures on all aspects of wind energy were compiled for the conference programme in the fields of measurement, control and system technology. The topics ranged from the current status of the expansion of offshore wind energy to multi-sensor systems for monitoring turbine operation and model-based control of wind turbines. BIMAQ's contribution to the conference programme were the two lectures "Investigation of the geographical distribution and temporal correlation of wind and solar feed-in on the basis of measured data" and "Quantitative determination of the contamination level of rotor blade leading edges (LEC) by means of thermography".

Events @ BIMAQ

- Offshore measurement

On Saturday, 30 Mar 2019, offshore measurements on wind turbines were carried out for the first time using thermography. The aim was to examine the feasibility of the measurement methods developed in the ThermoFlight project for defects and structural damage. Measurements were taken in cooperation with Stiftung Offshore, Deutsche WindGuard and BIMAQ at the Meerwind Süd | Ost wind farm of the project partner WindMW. The Meerwind project consists of the two offshore wind farms Meerwind Süd and Meerwind Ost, which were planned and constructed 23 km north of the island of Helgoland in the North Sea and are maintained from Helgoland. The wind farm consists of a total of 80 wind turbines with a capacity of 3.6 megawatts each. The output of up to 288 MW is fed into the grid via a transformer platform.

From the left: Dr. Holger Huhn (WindMW),
Dr. Dennis Kruse (Stiftung Offshore-Windenergie),
Nicholas Balaresque (Deutsche WindGuard) and
Michael Sorg (BIMAQ) in front of the service ship

Thermography system during the measurement carried out on the ship's deck

The measurements on Saturday could be classified as successful, but had to be stopped on Sunday due to bad weather.

- Hand-over of the "Transition Finder" software to Deutsche Windguard GmbH

The "Transition Finder" software is the result of ten years of cooperation between BIMAQ and Deutsche Windguard Gmbh in Varel. This laid the foundation for the development of image processing algorithms for thermographic imaging in order to visualize the flow around the rotor blades - an essential contribution to the optimization of the aerodynamics of rotor blades. Valuable experience gained from numerous joint measurement campaigns in the large wind tunnel in Varel, which is operated by Deutsche WindGuard, and in the open field of running wind turbines of well-known manufacturers worldwide was incorporated into the development of the software.

Professor Andreas Fischer hands over the "Transition Finder" to the Managing Director of Deutsche WindGuard Engineering GmbH, Nicholas Balaresque
From the left: Nicholas Balaresque, Prof. Andreas Fischer, Dr. Christoph Dollinger
(Photo: Deutsche WindGuard)

As a contribution to strengthening the regional economy, Professor Fischer handed over the Transition Finder algorithms to Deutsche WindGuard as an important milestone in thermography-based cooperation.

The programmable software enables the partner from Varel to further develop and continuously adapt to the requirements of the industry. Transition Finder is already being used for industrial measurement services on wind turbines in several countries as well as in wind tunnels at Delft Technical University in the Netherlands and at the German Aerospace Center in Göttingen.

DEUTSCHE
WINDGUARD

Press

WEYHE SYKE BASSUM

Doktorarbeit gewürdigt

Ehemaliger Syker Abiturient erhält Wissenschaftspreis

SYKE 2006 machte er sein Abitur am Gymnasium Syke, jetzt zeichnete die OLB-Stiftung Christoph Dollinger mit dem Wissenschaftspreis aus. Er erhielt den zweiten Preis in der Kategorie Doktorarbeiten für seine Promotion zum Thema „Thermografische Strömungsvisualisierung an Rotorblättern von Windenergieanlagen", die er an der Universität Bremen verfasste.

Insgesamt wurden acht Nachwuchstalente von Universitäten und Hochschulen in Bremen, Oldenburg und Osnabrück ausgezeichnet. Die OLB-Stiftung prämierte sechs herausragende Arbeiten mit insgesamt 22.000 Euro sowie aus Anlass der zehnten Ausschreibung seit dem Jahre 2000 zwei zusätzliche Arbeiten mit einem Sonderpreis Digitalisierung in Höhe von insgesamt 10.000 Euro.

Die Preise wurden von Karin Katerbau (Vorsitzende des Vorstands der OLB-Stiftung) und dem Vorsitzenden der Jury, Jürgen Mittelstraß (Konstanzer Wissenschaftsforum, Universität Konstanz), im Ehemaligen Landtagsgebäude in Oldenburg übergeben. Mittelstraß lobte in seiner Begrüßung die Qualität der eingereichten Arbeiten. Es sei sehr spannend gewesen, sich mit ihnen zu beschäftigen. Sie ließen erkennen, dass das universitäre Ideal der Einheit von Forschung und Lehre lebt, die Lernenden in die Forschung hineingezogen werden. Das gebe Hoffnung für die künftige Entwicklung der Universität und der Forschung in Deutschland.

Einer der zweiten Preise des Wissenschaftspreises der OLB-Stiftung ging an Dr.-Ing. Christoph Dollinger, der sein Abitur in Syke machte. Foto: OLB

„Mit dem OLB-Wissenschaftspreis wollen wir die Brücke schlagen zwischen Wissenschaft und Wirtschaft", betonte Karin Katerbau, „Wir wollen auch zukünftig viele kreative Geister, die wir hier in der Region haben, zur Entfaltung bringen. Nur so bringen wir den Nordwesten voran. Nur so können wir dafür sorgen, dass hoffnungsvolle Nachwuchswissenschaftler auch nach ihrer Ausbildung eine entsprechende Wirkungsstätte finden." (WR)

Weser Report - Weyhe, Syke, Bassum 7 Apr 2019

Impressum

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June 2019

Universität Bremen

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