


36th Conference of the European Working Group on Acoustic Emission

18 – 20 September, Potsdam/Germany

EWGAE 2024

Programme & Abstracts

ewgae2024.com

dgzfp

THM
TECHNISCHE HOCHSCHULE MITTELHESSEN

Universität Augsburg University

CONTENTS

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WELCOME

It is our pleasure to invite you to the upcoming 36th Conference of the European Working Group on Acoustic Emission (EWGAE), which will be held from 18 – 20 September 2024 in Potsdam, Germany.

The EWGAE conference is a prestigious international forum for researchers, engineers, and practitioners who are interested in the field of acoustic emission. The conference aims to provide an opportunity for participants to exchange ideas and share the latest advances in the field of acoustic emission, including theoretical and experimental investigations, instrumentation, data analysis, and applications.

This conference will feature keynote lectures on AE applications for geothermal applications, concrete structure and bridge monitoring and explore its cale up to seismicity. Prof. Dr. Nathalie Godin is awarded the prestigious "Adrian Pollock Award" and will present her achievements in service life estimation of composite materials. Various technical sessions and panel discussions on Open Source AE and the future of AE in Europe will cover a broad range of hot topics in AE. The conference dinner in the Biosphere Potsdam will provide a vivid atmosphere and opportunities for networking and building new collaborations.

We are confident that your participation in the EWGAE conference will be a valuable experience for you, and we hope that you will join us for this exciting event.

We look forward to welcoming you to the EWGAE conference and to the vibrant city of Potsdam, Germany.

Prof. Dr. Markus Sause, University of Augsburg
Prof. Dr. Gerd Manthei, THM – University of Applied Sciences
Dr. Thomas Wenzel, German Society for Non-Destructive Testing

Conference Secretariat

Steffi Dehlau | German Society for Non-Destructive Testing (DGZfP e.V.)
Max-Planck-Str. 6, 12489 Berlin, Germany
Phone: +49 30 67807-128, E-mail: tagungen@dgzfp.de

Organising Committee

M. Sause, University of Augsburg
G. Manthei, THM
H. Trattnig, Vallen Systeme
S. Dehlau, DGZfP

Scientific Committee

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I. Baran (Poland)
A. Brunner (Switzerland)
A. Gallego (Spain)
N. Godin (France)
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E. Serris (France)
G. Manthei (Germany)
H. Trattnig (Germany)
T. Thenikl (Germany)
H. Vallen (Germany)
E. Verstrynge (Belgium)

Conference Website

The **ewgae2024.com** website has been prepared for the conference. The site includes organisational issues, the technical programme, social events, tours and information on the exhibition.

The DGZfP event app

In the DGZfP event app you will find all important information about the programme, the lectures, the exhibition and news about the conference.
To access the web app, please open this website **dgzfp.plazz.net**. Here you'll be asked for your user data (login). Please use the login data you entered when you registered for the EWGAE on the event website.
If you have not registered yourself and therefore do not have your own access data, you are welcome to register as a user via **ewgae2024.com**.
To use the DGZfP event app with app icon on your mobile device, add it via the browser menu as „Install app“ or „Add to home screen“.
If you have any questions, please do not hesitate to contact us.

Lectures

Lectures will be presented in 2 parallel sessions

Session A:	We.1.A – Fr.2.A	Room F2 + F3
Session B:	We.1.B – Fr.2.B	Room E1

Posters

Posters will be presented in the foyer during the entire conference.

Registration Fees

Professionals, on site registration 950 €; Students (PhD Students up to 30) 500 €

Breaks

Coffee and lunch breaks will be served in the exhibition and poster area (foyer).

Taxi

A taxi ride to Airport BER – Berlin-Brandenburg costs about 100 – 130 Euros.

AirportShuttle BER2 – Express bus to and from the airport

There will be a direct express bus line to the airport with comfortable coaches – the AirportShuttle BER2 from Potsdam. This line will be subject to a surcharge under the VBB pricing system. The bus offer greater comfort, have step-free access and provide plenty of space for luggage.
The BER2 bus line from the bus operator Anger travels between Potsdam Central station and the airport 16 times a day – timed so as not to clash with the RB22 trains. The full journey takes just under an hour. A single journey costs 10 €. More Information: **vbb.de**

General Liability

The conference organisation does not accept responsibility for personal accidents or for damage of private properties of the participants occurring during the conference period or arising due to conference participation. Participants are advised to provide their own insurance against any risk, as the consider necessary. In all matters related to the arranging of any accommodation, meeting, tour and service for persons attending the conference or their families and other accompanying persons, or for entertainment, local transportation or similar courtesies, the conference organisation acts as agent only, and the conference venues, tour agencies, carriers and other suppliers of services act as independent contractors.

WiFi

Free WiFi is avaibable during the conference.

NDT.net

The proceedings will be published by our media and publishing partner NDT.net – Open Access Archive in a special issue of the e-Journal of Nondestructive Testing.

NDT net

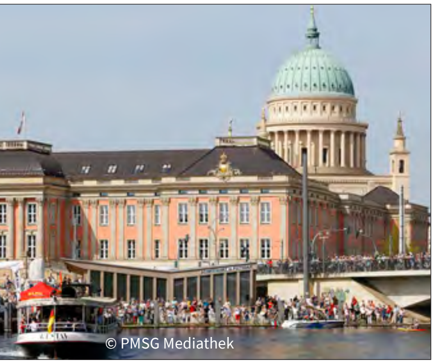
Media and Publishing Partner

THE STATE CAPITAL POTSDAM – A BRIEF PORTRAIT

Berlin‘s „beautiful sister“ was once said, and it holds true again today. Potsdam is not only a particularly impressive place with famous buildings, southern flair and a charming landscape, but also a very fateful place. Prussian, German and international history come together here in an almost magical way.

City of knowledge

Science and research have played and continue to play an outstanding role in the development of the city and are its most important potential for the future. Potsdam already has more scientists per capita than any other German city. The city‘s tradition in the field of science, which dates back to 1875, has been taken up and continued by the University of Potsdam, the University of Applied Sciences, the GeoResearchCenter and numerous other public and private institutions and companies. Today, more than 40 scientific institutions are active in Potsdam and its immediate surroundings.


© PMSG Mediathek

Potsdam is an attractive location for companies committed to innovative technologies. World-renowned companies such as Oracle and VW have established branches in the city. High-tech companies are already turning scientific findings into usable products. Potsdam‘s three universities – the University, the University of Applied Sciences and the University of Film and Television – embody Potsdam‘s future in a special way. Areas relevant to value creation such as natural sciences, computer science, the media industry and information technologies form the basis for the city‘s economic development.

Media city

The city‘s tradition as a media location goes back a long way. In the years after 1911, Babelsberg achieved world fame as the cradle of film in Germany. While Babelsberg was a production location for classic cinema films until 1990, today television productions and a flourishing multimedia industry are also an inseparable part of Babelsberg as a media city. Existing studios have been renovated and modernized, and new ones have been added. Excellent infrastructure, qualified specialists and the broad spectrum of film, television and multimedia offer innovative companies in the media industry excellent development opportunities and synergy effects.
Babelsberg is home to Rundfunk Berlin Brandenburg, Studio Babelsberg AG, the Ufa production group and numerous other media companies. The Konrad Wolf Academy of Film and Television, Potsdam‘s oldest film academy, offers space for 500 students. The site of the media city is also home to the German Broadcasting Archive, administrator of the program and press archive of GDR television and radio.

City of culture

The palaces and gardens created over the past centuries by ingenious master builders and garden architects form the core of Potsdam's UNESCO World Heritage Site and are the reason for the city's international reputation and appeal. They are the decisive magnet for Potsdam as a tourist destination and a key factor in Potsdam's tradition. They form the benchmark for the urban development of the state capital. The focus of its development is the recovery of the historic city center. Potsdam encompass a multitude of assets, would those be related to technology, history, culture or politics.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SOCIAL PROGRAMME

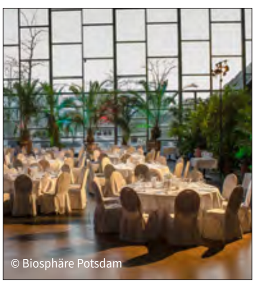

© Weiße Flotte Potsdam

Get together on boat

Wednesday, 18 September, 18:30 h

We invite you to a get together on board the "MS Schwielowsee". The boat trip will go around the Wannsee, past some interesting and historical places. Catering (fingerfood and drinks) is provided.

When: 18:30 h by **bus shuttle** from conference hotel, boat leaves at 19:00 h (End: 22:00 h bus shuttle back to the hotel)
Price per person: inclusive for registered participants and registered accompanying persons


© Biosphäre Potsdam

Conference dinner at Biosphäre Potsdam

Thursday, 19 September from approx. 19:00 h

We are pleased to invite you to a conference dinner in the exotic flair of the Biosphäre Potsdam. On the way to the Orangery you can enjoy a bird's eye view of the tropical garden. A varied programme with award ceremonies, music and dancing awaits you that evening.

Price per person: inclusive for registered participants and registered accompanying persons

Information on individual travel on the conference website.

Prof. Dr. Arno Zang | Wednesday, 9:15 – 10:00 h

Acoustic emission measurements in granitic rock for geothermal purposes: in-situ hydraulic testing at Äspö Hard Rock Laboratory, Sweden and laboratory cyclic fatigue experiments

For more than 30 years, I work at German Research Centre for Geosciences GFZ. In the beginning, I helped building a rock deformation laboratory including tri-axial testing of rock cores with acoustic emission measurements and post mortem fracture analysis. Last 15 years, I moved to design and perform underground experiments for efficient geothermal heat extraction. We use German, French and Swedish underground research facilities. I am teaching at Potsdam University as Professor of Geophysics and Rock Mechanics courses in Fracture Mechanics, Rock Physics and Stress Analysis.

Dr. Ernst Niederleithinger | Wednesday, 10:00 – 10:45 h

Breaking barriers, not just pencil mines: The route ahead for combining active and passive acoustic measurements for damage detection in concrete construction.

Ernst Niederleithinger is a geophysicist and currently head of Department 8.2 „Non-destructive testing methods for the construction industry“, an interdisciplinary group of around 30 scientists, engineers, technicians and students in BAM. He is a member of various bodies and committees that deal with standards and regulations for non-destructive testing in the construction industry. He has been working on active ultrasound monitoring and coda wave interferometry, among other things, since 2012.

Prize Winner:
Adrian Pollock Award

Prof. Dr. Nathalie Godin | Thursday, 8:30 – 9:15 h

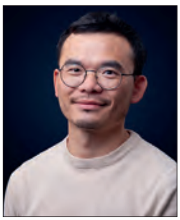
From damage diagnosis to service life estimation by acoustic emission: interests, limitations and contribution of modelling

Nathalie Godin is an Associate Professor at the National Institute of Applied Sciences in Lyon since 1996 and conducts research at MATEIS lab. She received her PhD degree from the University of Bordeaux in 1994 and her HDR, delivered by INSA of Lyon and the University Claude Bernard Lyon, in 2009. She has more than 25 years of experience in acoustic emission and its application for the analysis of damage in various classes of materials, in particular fiber-reinforced composites. The main topics of her research concern the durability of composite materials and the prediction of their fatigue lifetime under mechanical or thermomechanical tests with acoustic emission. She has co-authored over 80 articles, 5 book chapters and 2 books. She has supervised 35 MSc students and 28 PhD students.

Prof. Dr. Torsten Dahm | Friday, 9:00 – 09:45 h

Seismicity during Unrest: Exploring the Physical State and Geological Structures of the Earth

Torsten Dahm studied geophysics at the Technical University Karlsruhe and obtained his doctor's degree in geophysics in Karlsruhe in 1994. After holding an assistant lectureship in the group of Prof. Müller, University of Frankfurt, and after his habilitation in 2000, he became Professor in marine seismology at the University of Hamburg. Since 2012 he is Professor in Geophysics at the University of Potsdam and head of the GFZ section 2.1 "Physics of Earthquakes and Volcanoes".
Prof. Dahm has a broad background in seismology and volcano physics and is involved in different research initiatives in these fields. His main areas of interest cover earthquake source processes, physics of fluid-filled fractures, and theoretical and experimental seismology.



Dr.-Ing. Chongjie Kang | Friday, 9:45 – 10:30 h

Digital twin in bridge maintenance

Dresden University of Technology, Institute of Concrete Structures, Dresden, Germany

Dr. Kang is provisional research area leader at the Institute of Concrete Structures at Dresden University of Technology. His research focuses on bridges; his dissertation also dealt with the topic: Proof of track resistance taking into account the track-bridge interaction.
The keynote will present the concept and the main components of a digital twin. The potential of digital twins for the maintenance and extension of the service life of existing structures will be demonstrated.

19 Sept., 09:15 h | Room F2 + F3

OpenAE Initiative: A Contribution to the Open Source Acoustic Emission

The OpenAE initiative aims to promote collaboration and standardization in the field of AE by providing an open-source platform for researchers and industry professionals to share data, algorithms, and best practices.
In this panel discussion, experts from academia and industry will discuss the benefits of the OpenAE initiative, the importance of open-source standards in AE technology, and the potential impact on future research and applications. Join us as we explore the latest developments in AE testing and how open collaboration can drive innovation in this critical field. Moderated by Horst Trattnig, Vallen Systeme GmbH

Dr. Boris Muravin

Integrity Diagnostics Ltd., Netanya, Israel

Acoustic Emission, Structural Health Monitoring and Fracture Mechanics expert with 30 years of industrial experience. Author of ASTM Standard E2983-14 for Structural Health Monitoring by AE method. Author of ASTM Standard E3100-17 Guide for Acoustic Emission Examination of Concrete Structures1. CEO at Integrity Diagnostics Ltd.

- Chairman of Israeli Acoustic Emission Society
- Former Chairman of Non-Destructive Testing Brach of the Israeli Association of Engineers and Architects
- Chairman of Terminology Section in Acoustic Emission Committee of American Society of Testing and Materials
- Lecturer of Fracture Mechanics at Afeka Engineering Collage

Prof. Didem Ozevin

University of Illinois Chicago, USA

Dr. Ozevin is a professor of the Civil, Materials, and Environmental Engineering Department at the University of Illinois Chicago. Before her academic appointment, she worked at Physical Acoustics Corporation as a research scientist for over four years. Her research includes acoustic emission, ultrasonics, and integrating structural design and damage assessment methods for resilient infrastructures. Her research was supported by several federal agencies in the U.S., including National Science Foundation, the Department of Energy, the Department of Defense, and the Department of Transportation. She received the American Society of Nondestructive Testing Faculty Award in 2014 and the NSF CAREER Award in 2016. She has over a hundred publications in peer-reviewed journals and conference proceedings. She was selected as one of Crain's Notable Women in STEM in 2023. Dr. Ozevin received her Ph.D. from Lehigh University in 2005.

Prof. Dr. Markus Sause

University of Augsburg, Germany

Prof. Dr. Markus Sause is a Professor of Mechanical Engineering and Director of the AI Production Network at the University of Augsburg. His research includes hybrid fiber-reinforced composites, non-destructive testing methods, and data analysis. He uses multiscale and multiphysics models alongside experimental approaches. He focuses on condition monitoring, new sensor technologies, data fusion, and machine learning for data preprocessing, decision-making, and forecasting.

19 Sept., 13:30 h | Room F2 + F3

Reshaping the European Landscape of Acoustic Emissions Testing Today

Acoustic emissions testing has become increasingly important in various industries, including aerospace, automotive, and construction. In this panel discussion, experts will explore how advancements in technology, regulations, and industry standards are reshaping the European landscape of acoustic emissions testing. From the latest innovations in sensors and data analysis to the impact of sustainability and safety regulations, this discussion will provide valuable insights into the evolving field of acoustic emissions testing in Europe today. Join us as we delve into the challenges and opportunities that lie ahead in this dynamic and critical area of non-destructive testing. Moderated by Prof. Dr. Markus Sause, University of Augsburg

Eric Duffner

Federal Institute for Materials Research and Testing (BAM), Germany

He is graduated in mechanical engineering from the Berlin University of Applied Sciences in 2004 and started working at the Federal Institute for Materials Research and Testing (BAM) in Berlin in the same year.
Since then, he has been working in the field of hazardous goods transportation with a focus on pressure vessels for the high-pressure storage of gases. He has more than 20 years of experience in research, testing and approval of composite pressure vessels and their safe transportation. He is a member of several national and international standardization groups on the subject of pressure vessels and has gained a lot of experience in regulatory work for the transport of dangerous goods and gas transport in the automotive sector.
Eric Duffner has been working for more than 15 years in the field of non-destructive testing, in particular in acoustic emission testing for mainly composite pressure vessels and is a certified acoustic emission level 3 tester and member of the DGZfP Technical Committee for Acoustic Emission Test Procedures. As part of the competence center H2Safety@BAM.de, Mr. Duffner heads the TestCert-3 work package on „Online monitoring and structural health monitoring for hydrogen storage and transport technologies“. He is currently working in Department 3.5 „Safety of Gas Storage Systems“, where he is leading several national research projects on composite pressure vessels.

Prof. Dr. Nathalie Godin

INSA Lyon, France

Professor Godin is the winner of the Adrian Pollock Award 2024 of the EWGAE and will also be giving a keynote speech on this occasion on Thursday, 19 September. Information about Natalie Godin can be found on page 6.

Horst Trattnig

Vallen Systeme GmbH

Since 04/2015 Vallen Systeme GmbH Munich, Germany Managing Director – Details of position:

- Head of the development and production team
- Responsible for new AE Products and Solutions
- Ramp up of new products in the production line
- Responsible for the conformity of intrinsically safe products

ACOUSTIC EMISSION INDUSTRY
Since 2018: Delegate of DIN (Germany) in CEN TC138/WG7 &
ISO TC135/SC9, Convenor of ISO TC135/SC9/WG11
Since 2015: Member of Acoustic Emission Working Group (AEWG) USA
Since 2022: Member of European Working Group of Acoustic Emission (EWGAE)

Dr. Els Verstrynge

KU Leuven University, Belgium

Dr. Els Verstrynge is Associate Professor at the KU Leuven University in Belgium and an expert in the development of acoustic emission methods in Civil Engineering applications. She has a dual background in structural and architectural engineering. Her research aims at multi-scale condition assessment of existing materials and structures in view of degradation analysis, retrofitting, renovation and reuse, with a focus on reinforced concrete structures and historical masonry.
In the past fifteen years, she has spent research stays at the Technical University of Delft, the University of Minho in Portugal, Stanford University and the University of Edinburgh. In 2020, she won the EWGAE young researcher award and gave a keynote lecture at the Ljubljana conference in 2022 on "Acoustic emission for multi-scale assessment of degradation in existing structures."

The EWGAE awards: Adrian Pollock Award, the EWGAE Young Researcher Award, and EWGAE Student Paper Award are designed to recognise outstanding contributions to the field of acoustic emission.

The **Adrian Pollock Award** is open to researchers who have made significant contributions to the field of acoustic emission throughout their careers.

The **EWGAE Young Researcher Award** is aimed at recognizing outstanding contributions made by researchers who are in the early stages of their careers.

The **EWGAE Student Paper Award** is open to undergraduate and graduate students who have demonstrated excellence in acoustic emission and participate in the conference.

The recipients of these awards will be selected by a panel of experts in the field and will be announced during the conference. The awards ceremony will be held during the gala dinner, and recipients will be presented with a certificate of recognition, a free conference participation and a cash prize of 300 € for the Student Award winners.

Beijing Softland Times Technology Co., Ltd

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Beijing Softland Times Technology Co., Ltd. specializes in the development, production, and sales of advanced acoustic emission systems. With more than a decade of experience in the industry, the company provides high-performance systems tailored for scientific research and industrial diagnostics. Our products and services have been extensively used across numerous sectors, including research universities, research institutions, aerospace, and railway industries.

MISTRAS Group

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Website: mistrasgroup.com

MISTRAS Group (NYSE: MG) has served as a global leader in non-destructive testing (NDT) inspection techniques and applications for decades, particularly in acoustic emission (AE) and ultrasonic testing (UT). Speak to our team about our innovative technologies used for research, field, and laboratory applications, all developed in house by our team of dedicated experts.

POLYTEC GmbH

Contact: Samy Monsched
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The innovative high-tech company Polytec has been developing and producing optical measurement technology solutions for research and industry for more than 50 years. This includes systems for vibration measurement, surface characterization, length and speed measurement, process analytics and optical systems. Polytec has subsidiaries in Europe, North America and Asia and offers a worldwide service network.
As the world market leader in laser vibration measurement, Polytec defines the global standard in research, product development and quality control. Polytec customers use a comprehensive range of solutions for almost every vibration-related problem in research, development, production and condition monitoring. Laser Doppler vibrometers are used to examine objects of very different sizes – from entire car bodies, large aerospace parts, engines and actuators to micro components such as MEMS or biomedical samples and components in the micrometer range.

Qawrums Ltd.

Contact: Liu Yang
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Qawrums Ltd. (previous name: “QingCheng Ltd.”) is an enterprise specializing in the research and development, production and technical application services of acoustic wave (acoustic emission) testing equipment and systems including convectional bench-top AE testing systems and wireless remote IoT-AE monitoring systems. In addition, we also develop and manufacture vibration testing system, handheld ultrasonic gauges, other testing and inspection systems, and condition monitoring systems.
We have been committed to acoustic emission testing equipment and monitoring systems for more than 20 years and have offices in Guangzhou (headquarter) and Beijing (branch).
Our mission is to provide high quality and reliable IIoT online unattended condition monitoring solutions for predictive maintenance of valuable industrial assets in the world.

Vallen Systeme GmbH

Contact: Horst Trattnig
Phone: +49 8171 38391-0
E-mail: info@vallen.de
Website: vallen.de

Vallen Systeme – that is the fascination of an internationally successful Acoustic Emission (AE) system provider and technology leader, connected with the culture and tradition of a German-based company.
Our commitment is to deliver innovative technology that makes a real difference to the safety of human life, preservation of the
environment and true asset management. This commitment sets us apart and makes us Vallen Systeme – The Acoustic Emission Company.

CONFERENCE VENUE
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PROGRAMME OVERVIEW

Wednesday, 18 September

	SESSION A – Room F2 + F3	SESSION B – Room E1
09:00	**Opening**	
09:15	**Keynotes**	
10:45	Coffee Break	
11:15	**We.1.A Condition Monitoring 1**	**We.1.B Vessels and Storage Tanks**
12:55	Lunch Break	
14:00	**We.2.A Condition Monitoring 2**	**We.2.B Signal detection**
15:40	Coffee Break	
16:10	**We.3.A Condition Monitoring 3**	**We.3.B Material behaviour 1**

18:30 – 22:30 **Get together on boat**

Breaks located in the foyer

Thursday, 19 September

	SESSION A – Room F2 + F3	SESSION B – Room E1
08:30	**Keynote** Prize Winner Adrian Pollock Award	
09:15	**Panel discussion:** OpenAE Initiative	
10:15	Coffee Break	
10:45	**Th.1.A Equipment**	**Th.1.B Material behaviour 2**
12:25	Lunch Break	
13:30	**Panel discussion:** Reshaping the European Landscape of Acoustic Emissions Testing Today	
14:30	Coffee Break	
15:00	**Th.2.A Localisation of Defects**	**Th.2.B Material behaviour 3**

16:30 – 17:30 **EWGAE Business Meeting** Room F2 + F3

19:00 – 24:00 **Conference dinner at the Biosphäre Potsdam**

Friday, 20 September

	SESSION A – Room F2 + F3	SESSION B – Room E1
09:00	**Keynotes**	
10:30	Coffee Break	
11:00	**Fr.1.A Civil engineering 1**	**Fr.1.B Material behaviour 4**
12:40	Lunch Break	
13:40	**Fr.2.A Civil engineering 2**	**Fr.2.B Condition Monitoring 4**

14:45 **Closing**

09:00 **Opening** Conference organisers and representatives of charter groups

Keynotes *Room F2 + F3*
Gerd Manthei

09:15 **Keynote:** Acoustic emission measurements in granitic rock for geothermal purposes: in-situ hydraulic testing at Äspö Hard Rock Laboratory, Sweden and laboratory cyclic fatigue experiments
Arno Zang, Helmholtz Centre Potsdam, Germany

10:00 **Keynote:** Breaking barriers, not just pencil mines: The route ahead for combining active and passive acoustic measurements for damage detection in concrete constructions
Ernst Niederleithinger, Bundesanstalt für Materialforschung und -prüfung (BAM), Berlin, Germany

10:45 Coffee Break

	SESSION A – Room F2 + F3	SESSION B – Room E1
	We.1.A Condition Monitoring 1 Stéphanie Deschanel	**We.1.B Vessels and Storage Tanks** Marvin Hamstad, Boris Muravin
11:15	1092 Monitoring of drill breakages on the spindle of a machine tool using acoustic emission Tobias Gaul, Fraunhofer IKTS, Dresden, Germany	1058 Research on the Application of AI in Acoustic Emission Waveform Data Pattern Recognition Yang Liu, QAWRUMS Ltd., Guangzhou, China
11:35	1051 The capability of Acoustic Emission features to monitor diamond-coated burr grinding wear and effectiveness. Tom Jessel, Cardiff University, Cardiff, United Kongdom	1099 Monitoring of GFRP pipelines in Power Plants using acoustic emission testing Lars Schubert, Fraunhofer IKTS, Dresden, Germany
11:55	1056 Experience in Monitoring Brazed Aluminum Heat Exchanger, after Major Repairs Alessandro Santana Cruz, Luiz Tiago Balbi Finkel, Petrobras, Brazil	1096 Damage-tolerance design for composite high-pressure hydrogen vessels when AE testing is applied Yoshihiro Mizutani, Tokyo Institute of Technology, Ookayama, Meguro-ku, Tokyo, Japan

SESSION A – Room F2 + F3

12:15
1102
Monitoring of a fatigue test on a full-size railway steel bridge with acoustic emission
Gerald Lackner, TÜV AUSTRIA GMBH, Wien, Austria

12:35
1218
Recent Advances in Wind Turbine Rotor Blades Using Acoustic Emission
Valery Godinez Azcuaga, Mistras Group, Inc, Princeton Junction, NJ, United States

12:55
Lunch Break

We.2.A Condition Monitoring 2

Anne Jüngert, Lars Schubert

14:00
1027
Monitoring of ultrasonic fatigue testing with acoustic emission
Mikhail Seleznev, Technische Universität Bergakademie Freiberg, Germany

14:20
1040
Streamlined method for constructing acoustic vulnerability curves in trees
Kaat De Boeck, Ghent University, Aalst, Belgium

14:40
1041
Optimising Sensor Placement for Tool Condition Monitoring: A Comparative Analysis of Acoustic Emission Data
Christina Baumeister, University of Augsburg, Germany

SESSION B – Room E1

12:15
1104
Failure monitoring and classification from acoustic emission tests on impact-damaged hydrogen composite pressure vessels
Emanuel Kästle, BAM, Berlin, Germany

12:35
1031
Method of Assessing the Level and Quantity of Sludge in Crude Oil Storage Tanks
Ireneusz Baran, Office of Technical Inspection (UDT), Kraków, Poland

We.2.B Signal detection

Els Verstrynge

14:00
1023
Experimental and numerical investigation of the sensor effect on the acoustic emission during Pencil-lead Break tests on PMMA plates
Xi Chen, MATEIS, INSA LYON, Villeurbanne, France

14:20
1048
Automatized determination of the end of a wave mode in acoustic emission signals
Ruben Büch, KU Leuven & METALogic, member of the TÜV Austria Group, Rotselaar, Belgium

14:40
1065
Continuous acoustic data mining from a scattering network
Théotime de la Selle, ISTerre – Université Grenoble Alpes, Grenoble, France

	SESSION A – Room F2 + F3	SESSION B – Room E1
15:00	1057 Monitoring a batch crystallization process by acoustic emission Eric Serris, Mines Saint-Etienne, Saint-Etienne, France	1117 Classification of Source Coordinates through Wavelet - Analysis and Neural Network: Analysis of Data Preparation and Network Structure Ivan Sirbu, THM, Giessen, Germany
15:20	1069 Damage evaluation results of a hybrid pinned single-lap-shear joint by acoustic methods using a multi-method SHM system Christoph Kralovec, JKU Linz, Austria	1105 Simulation of elastic wave propagation with lattice model Yubao ZHOU, Delft University of Technology (TU Delft), Netherlands
15:40	Coffee Break	
	We.3.A Condition Monitoring 3 Gerald Lackner	**We.3.B Material behaviour 1** Natalie Godin
16:10	1108 Acoustic emission monitoring of a laser powder bed fusion process Anne Jüngert, Materialprüfungsanstalt (MPA) Universität Stuttgart, Germany	1091 Acoustic Emission based determination of delamination initiation in GFRP laminates Andreas J. Brunner, retired from Empa, Dübendorf, Switzerland
16:30	1036 Speech recognition inspired features for acoustic emission Quy Raven Luong, Universität Augsburg - MRM, Augsburg, Germany	1098 Assurance of integrity of composite pressure vessels by AE testing using remaining life indicator Masaaki Samejima, Tokyo Institute of Technology, Tokyo, Japan
16:50	908 Acoustic Emission during Fatigue testing of Wind Turbine Blades with digitalized damage monitoring Malcolm McGugan, Technical University of Denmark, Roskilde, Denmark	1043 AE based crack size estimates from delamination propagation in fiber reinforced thermoset composites Maria Gfrerrer, Montanuniversität Leoben, Austria

	SESSION A – Room F2 + F3	SESSION B – Room E1
17:10	1050 Corrosion source location on a plate-like structure made of the Mg alloy WZ73 Marcel Mandel, TU Bergakademie Freiberg, Germany	1049 Study of the Martensitic Transformation of Steel During the Induction Hardening Process by means of Acoustic Emissions Erlantz Sola, Barañain, Spain
17:30	1081 Process and Wear Monitoring in Plastic Injection Molding using Ultra Low Cost AE Equipment Peter-Christian Zinn, Industrial Analytics Lab GmbH, Bochum, Germany	1022 Acoustic Emission simulation: assessing the influence of AE source modeling and addressing the issue of dimensionality in the propagation medium Aurélien Doitrand, MATEIS, INSA LYON, Villeurbanne, France

18:30 – 22:30 **Get together on boat** (details on page 5)

Keynote – Prize Winner Adrian Pollock Award *Room F2 + F3*
Horst Trattnig

08:30 From damage diagnosis to service life estimation by acoustic emission: interests, limitations and contribution of modelling.
Nathalie Godin, INSA de Lyon, laboratoire MATEIS, Villeurbanne cedex, France

	SESSION A – Room F2 + F3	SESSION B – Room E1
09:15	**Panel discussion:** **OpenAE Initiative:** A Contribution to the Open Source Acoustic Emission Horst Trattnig	
10:15	Coffee Break	
	Th.1.A Equipment Horst Trattnig	**Th.1.B Material behaviour 2** Tomaž Kek
10:45	1045 Studies on a Mobile Acoustic Emission Sensor Verification Device Adelmo Fernandes de Oliveira Junior, Universität Augsburg, Germany	1026 Estimation of the remaining useful lifetime during fatigue tests based on AE indicators. Nathalie Godin, INSA of Lyon, laboratory MATEIS, Villeurbanne cedex, France
11:05	1055 Optical fiber sensors for acoustic emission monitoring Antoine Gallet, Université Paris-Saclay, CEA LIST, Gif-sur-Yvette, France	1035 Experimental investigation into bond characteristics of quartz sand modified enamel coated steel bar in concrete based on AE data Fujian Tang, Dalian University of Techno-logy, Dalian, China
11:25	1064 The Influence of Coupling-Specific Parameters and Structural Parameters on the Electromechanical Impedance of Acoustic Emission Sensors Christopher Reinhardt, Hochschule Bochum, Germany	1062 Investigation of the emission mechanisms of acoustic multiplets associated with fatigue cracking Stéphanie Deschanel, INSA Lyon, MATEIS laboratory, Villeurbanne cedex, France

	SESSION A – Room F2 + F3	SESSION B – Room E1
11:45	1097 ISO 24543 for AE sensor sensitivity verification – support packages help to implement software scripts Hartmut Vallen, Vallen Systeme GmbH, Wolfratshausen, Germany	1197 Acoustic emission during the freezing of water or the melting of ice in aircraft Helge Pfeiffer, KU Leuven, Belgium
12:05	1116 Explainable AI based Predictions for Workpiece Quality Timm Straub, THM, Friedberg, Germany	1080 Acoustic Emission Energy Release Rate Model for Classification of Damage Development in Large Fiber Reinforced Plastic Composite Structures Boris Muravin, Integrity Diagnostics Ltd., Netanya, Israel
12:25	Lunch Break	
13:30	**Panel discussion:** Reshaping the european landscape of acoustic emissions testing today Markus Sause	
14:30	Coffee Break	
	Th.2.A Localisation of Defects Yoshihiro Mizutani	**Th.2.B Material behaviour 3** Andreas J. Brunner
15:00	1061 Identification of corrosion nature using acoustic emission in representative scale samples Maël Pénicaud, Université Paris-Saclay, CEA LIST, GIF-SUR-YVETTE Cedex, France	1066 Combined Acoustic Emission and Ultrasonic Measurements in Cross Laminated Timber-Steel Composite Beam Gerd Manthei, THM, Giessen, Germany
15:20	1118 Research of Acoustic Emission Characteristics and Applicability of Artificial Intelligence for Source Localization Erbil Batur Bulut, THM, Giessen, Germany	1068 Quantifying tactile perception of fabrics using both frictional and acoustic methods Daniel Hefft, University of Birmingham, United Kingdom

	SESSION A – Room F2 + F3	SESSION B – Room E1
15:40	1063 **Impact of Model Knowledge on Acoustic Emission Source Localization Accuracy** Thomas Erlinger, Johannes Kepler University Linz, Austria	1085 **Influence of loading conditions on acquired AE signals in biocomposites** Tomaž Kek, University in Ljubljana, Faculty of Mechanical Engineering, Ljubljana, Slovenia
16:00	1034 **An Approach to Calculate Source Locations for Thicker Plates when Acoustic Emission Signals are Dominated by Trailing Waves** Marvin Hamstad, University of Denver, United States	1088 **Detection and characterisation of galling wear by acoustic emission during friction tests using artificial intelligence** Florian Razafintsalama, Cetim, Nantes, France

16:30 – 17:30 **EWGAE Business Meeting** Room F2 + F3

19:00 – 24:00 **Conference dinner at the Biosphäre Potsdam** (more information on page 5)

Keynotes *Room F2 + F3*
Markus Sause

09:00 **Keynote:** Seismicity during Unrest: Exploring the Physical State and Geological Structures of the Earth
Torsten Dahm, Helmholtz Centre Potsdam, Germany

09:45 **Keynote:** Digital twin in bridge maintenance
Chongjie Kang, Institut für Massivbau, Technische Universität Dresden, Germany

10:30 Coffee Break

	SESSION A – Room F2 + F3	SESSION B – Room E1
	Fr.1.A Civil engineering 1 Alain Proust, Stefan Pirskawetz	**Fr.1.B Material behaviour 4** Markus Sause
11:00	1039 Acoustic Emission Measurements During a Four-Point Bending Test on a Reinforced Concrete Specimen Gerd Manthei, THM, Giessen, Germany	1107 Mechanical Robustness Analysis of Semiconductors with a Single Needle Probe Card Using Acoustic Emissions Florian Tremmel, Infineon Technologies AG, Neubiberg, Germany
11:20	1046 Acoustic emission monitoring of a large-scale 50-year-old prestressed concrete bridge girder during an eccentric three-point bending test Charlotte Van Steen, KU Leuven, Belgium	1123 Monitoring Cultural Heritage: Acoustic Emission Testing in Museum Galleries Ashley A. Freeman, Getty Conservation Institute, Los Angeles, Ca, United States
11:40	1033 Acoustic Emission in Wind Energy: An Applications for Monitoring Hybrid Tower Tendons Max Käding, MKP GmbH, Weimar, Germany	1028 Performance Evaluation of Low-Cost Packaging for Multifrequency MEMS AE Sensors Didem Ozevin, University of Illinois Chicago, United States
12:00	1052 Development of a Semi-Autonomous Pulse and Receive Concrete Inspection System Tim Atkinson, School of Engineering, Cardiff University, Cardiff, United Kingdom	1264 Structure Reliability Evaluation based Acoustic Emission: Case 2 Studies Wael A. Megid, TISEC Inc., Morin Heights, Canada

	SESSION A – Room F2 + F3	SESSION B – Room E1
12:20	1087 Supporting the infrastructure operators with customer specific AE-monitoring solutions Gerald Lackner, TÜV Austria GmbH, Wien, Austria	
12:40	Lunch Break	
	Fr.2.A Civil engineering 2 Didem Ozevin, Tomoki Shiotani	**Fr. 2.B Condition Monitoring 4** Gerd Manthei
13:40	1089 Application of Acoustic Emission on fatigue Damage of steel Bridges Vaclav Svoboda, Preditest, s.r.o. , Prague, Czech Republic	1120 Acoustic emission for monitoring of fatigue damage in concrete elements of wind turbine towers Stephan Pirskawetz, BAM, Berlin, Germany
14:00	1094 Two-Step AE Source location for Detecting Tendon Rupture inside PC Box-Girder in-Service Nobuhiro Okude, Kyoto University, Kyoto, Japan	1110 Detection of Active Infestation by Wood-Boring Insects via Acoustic Emission Using the IADS (Insect Activity Detection System) Lisa Anna Limmer, HAWK Hildesheim, Germany
14:20	1100 Evaluation of Concrete Fatigue Damage with Elastic Wave-based Measurement Techniques Els Verstrynge, Ku Leuven University, Leuven, Belgium	1146 Continuous health monitoring of reinforced concrete bridge deck based on traffic load-induced acoustic emission Takashi Usui, Toshiba corporation, Saiwai-ku, Kawasaki, Kanagawa, Japan
14:45	**Closing**	

P1 924 **Application of the Acousto-ultrasonics technique to bridge cables in their anchorages.**
Raphaël Johannes, Univ. Gustave Eiffel, SMC, France

P2 1030 **Influence of velocity changes on acoustic emission monitoring of masonry walls under diagonal compression load**
Anna Maria Sktodowska, BAM, Berlin, Germany

P3 1236 **Ultra High Preformance Concrete Mechanical Behavior and Failure Mechanisms Monitored by Acoustic Emission**
Tal Yadlin, Civil Engineering Department, Shamoon College of Engineering Omer, Israel

Measurement Equipment and Customized Solutions for Acoustic Emission Testing

We develop and produce innovative technology that makes a true difference for the safety of humans, the environment and the preservation of infrastructure. This commitment differentiates us from other suppliers and defines who we are: Vallen Systeme – The Acoustic Emission Company

AMSY-6 System

The AMSY-6 System is a fully featured, multi-channel Acoustic Emission measurement system. It forms a flexible basis that can be customized, extended and configured to the needs of an application.

The field of applications ranges from various inspection tasks such as pressure vessel testing, leakage testing to research and structural health monitoring of large objects

spotWave Device

The spotWave device is a portable single channel AE-measurement unit that can be controlled by a Laptop, Tablet PC, Smartphone or IoT device. It is a fully featured AE measurement device. The software supports the Vallen pridb and tradb data file format.

Typical applications are leakage detection, hot spot monitoring, AE research, etc.

Acoustic Emission Sensors

A wide range of sensors is offered covering any AE testing application.

Sensors are available for standard environments, explosion hazardous areas, for underwater applications, high temperature surfaces and harsh environments.

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Vallen AE Suite Software

Unmatched flexibility and transparency at all times makes the Vallen AE Suite Software the preferred tool of choice for all acoustic emission applications.

Its modular architecture can be configured and extended to match any requirement of an application.

It offers everything from simple data visualization over complex analysis and pattern recognition to automation and web-based dashboards.

Measurement data is written to a database structure that complies with SQLite3 standard. It can be accessed from any application supporting SQLite3 which includes Matlab, Python and many more fast development environments.

Acoustic emission measurements in granitic rock for geothermal purposes: in-situ hydraulic testing at Äspö Hard Rock Laboratory, Sweden and laboratory cyclic fatigue experiments

A. Zang [1], P. Niem[1], G. Zimmermann [1], L. Zhuang [1], H. Hofmann [1]
[1] Helmholtz Centre Potsdam, Germany

Enhanced Geothermal Systems (EGS) offer potential as a renewable energy resource. However, there are technological challenges to be addressed. How to stimulate fractures in crystalline rock effectively under various in situ stress conditions? How to capture the permeability enhancement process? How to minimize environmental impacts like injection-induced seismic events? As field tests in deep wells are costly, we see controlled experiments in underground research facilities combined with laboratory tests as a valuable alternative for optimizing energy extraction methods with advanced fluid-injection schemes. We report on underground in situ tests performed at the Äspö Hard Rock Laboratory, Sweden, with different water injection schemes and acoustic emission measurements to quantify the seismically radiated and hydraulic energy budget.
An array of eleven 70 kHz acoustic emission sensors, four accelerometers and two broadband seismometers is used to quantify the extension of six hydraulic fractures propagated from intact sections of a 28 m long horizontal borehole at 410 m depth drilled from an existing tunnel in the direction of minimum horizontal compressive stress. Additionally, the evolution of fractures is mapped with impression packers at the borehole wall. The stimulated rock volume 20 x 20 x 20 meters in size consists of granodiorites, diorite gabbro and granites. Injection protocols include conventional monotonic, innovative cyclic progressive and pulsed hydraulic stimulations to increase fracture complexity and permeability for heat extraction.
Hydraulic tests in naturally fractured granite with a maximum of 30 litres of water injected generate small scale hydraulic fractures up to 40 square meters in size. The seismic response of the hydraulic fracture strongly depends on injection style and rock type. In the same rock type, the cyclic injection produces larger seismic b-values as compared with the monotonic injection. This indicates a safer treatment. The fracture pattern inferred from impression packer results and acoustic emission hypocentre solutions turn out to be more complex when replacing conventional by fatigue hydraulic testing. In laboratory tests, we could confirm lower breakdown pressures, a shift to smaller AE amplitudes and a more branching fracture pattern as a function of fatigue cycles.
We interpret the larger fracture process zone evolving during cyclic hydraulic fracturing as a result of depressurization phases and stress relaxation at the fracture tip. Evidence for this comes from natural proppants (debris material) observed in granite fracture walls in the laboratory, reactivation of natural fractures, and from larger seismic b-values indicating a replacement of larger amplitude AE events by a cloud of smaller events in the laboratory and underground fatigue tests. We admit that full-scale field tests are required once the tailor-made fatigue concept of the target rock has been determined.

Breaking barriers, not just pencil mines: The route ahead for combining active and passive acoustic measurements for damage detection in concrete constructions

E. Niederleithinger [1]
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The last few years have seen a tremendous increase in practical applications of acoustic emission monitoring of prestressed concrete bridges in Germany. It was shown that AE can reliably detect tendon wire failures (which potentially leads to structural failure) and due to its unmatched temporal resolution, raise an alarm in due time. Due to the increasing age and increasing loads on most bridges, the demand for such system is expected to grow further. However, AE is not able to give quantified values for the effect of tendon wire breaks or other events on the load capacity or other engineering parameters. For this reason, it has to be combined with other sensors, such as strain gauges or deformation/inclination sensors. Depending on the setup, they offer information which can directly be used in capacity and condition assessment, but area of influence might be limited as well as sensitivity. Is there something to fill the gap?
Recently there have been several studies on how to use active ultrasonic measurements for monitoring concrete constructions. Many factors include elastic parameters, stress, cracking, or general material decay influence the propagation of ultrasonic signals in concrete. Scientist have learned to use very sensible algorithms from seismology to detect even very small changes (e. g. relative velocity changes of 10-6) . These changes can be converted e. g. to stress changes of damage indicators by calibration. Fortunately, it has turned out, that the same sensors can be used both for active (ultrasonic) and passive (AE) data acquisition.
The concept has meanwhile been tested in various laboratory studies on several scales and is currently evaluated on a bridge in southern Germany. The current state of the project will be presented.

Monitoring of drill breakages on the spindle of a machine tool using acoustic emission

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[1] Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, Germany;
[2] OTT-JAKOB Spanntechnik GmbH, Lengenwang, Germany

Numerous sensors are integrated into modern machine tools to detect and control the forces acting on the tool or workpiece, or to monitor mechanical components such as ball bearings. In addition to the machine itself, the tool is also a sensitive component. In extreme cases, spontaneous failure of the tool can lead to a collision with the clamped workpiece and cause irreparable damage. This results in subsequent costs due to material loss, repair, or production downtime, which can be considerable high. It is therefore important to detect possible wear or failure of tools during the production process. Tool monitoring is particularly useful for flexible production systems which, due to their dynamic application situation, do not allow an estimation of tool life and therefore no fixed tool maintenance intervals. Consequently, the integration of sensors into the machine tool is intended to detect wear at an early stage and minimize tool failure.
The integration of a sensor system was carried out in collaboration with Ott Jacob Spanntechnik during a joint research project. The purely mechanical component of the rotary union of a motor spindle was expanded to include an integrated acoustic emission sensor. The focus was on the development of inexpensive sensors for integration into the machine and an evaluation procedure for detecting tool breakage.
This paper presents the evaluation principles used and examines their applicability in a manufacturing process. At first, acoustic emission signals from tool breakages were generated in laboratory on a simplified cooling channel setup. The measurement data were used to detect breakage events using different acoustic emission parameters and machine learning methods. It was shown that both methods can identify drill break in the signal, regardless of the diameter. The measurements were then repeated on a machine tool under realistic operating conditions and extended to include wear detection.

The capability of Acoustic Emission features to monitor diamond-coated burr grinding wear and effectiveness.

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[1] Cardiff University, Cardiff, United Kingdom

Within manufacturing there is a growing need for autonomous Tool Condition Monitoring (TCM) systems, with the ability to predict tool wear and failure. This need is increased, when using specialised tools such as Diamond-Coated Burrs (DCBs) for grinding high strength ceramics or glass, in which the random nature of the tool, inconsistent manufacturing methods and high wear rates create large variance in tool life. This unpredictable nature leads to a significant fraction of a DCB tool's life being underutilised due to premature replacement. Workpiece surface damage, increased grinding forces and large-scale diamond grain pullout could all be the result of high levels of runout and in-circularity common within electroplated DCBs. As such it is important to not only monitor the overall tool wear but also tool condition. Acoustic Emission (AE) presents as an indirect on-machine sensing method highly suited to grinding applications. The high frequency range of AE, >20 kHz, prevents machine noise from dominating the acquired signals, isolating the micro-scale machining processes within noises machine environments. AE resulting from the grinding process has the potential to monitor not only tool wear but also runout and circularity. A series of DCB wear tests have been conducted, each consisting of the continuous acquisition of AE during grinding and frequent tool surface measurements. Preliminary results demonstrate AE kurtosis can be seen as an indicator of each tool's runout, representing the fraction of time the tool and workpiece are in contact during a revolution. As a result, an indirect monitoring system capable of monitoring wear and tool state with AE could be utilised within the manufacturing sector.

Experience in Monitoring Brazed Aluminum Heat Exchanger, after Major Repairs

A. Santana Cruz [1], L. Balbi Finkel [2], C. Bittencourt [1], N. de Moura [3], R. Sant‘anna do Nascimento [2], A. Cardoso Gomes da Silva [1], J. Zocolotti de Aquino [4]
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Online monitoring through the acoustic emission technique (AE) has been conducted to assess the structural integrity and tightness of brazed aluminum plate exchangers (BAHX) in a natural gas processing plant. This includes the installation of sensors and instrumentation for constant operational monitoring. The main objectives are to evaluate structural integrity, observe structural behavior during different operational stages, avoid potential failures due to critical crack propagation, identify signs of leaks, and contribute to the safe operation until equipment replacement becomes feasible.
The BAHX has unique design, specifically tailored for the gas processing unit. Without him, the unit become inoperative. Failures were not expected, given the good operational history. There is limited literature and consolidated knowledge in the Brazilian market for the maintenance and operation of these equipments, with few specialized manufacturers around the world, whose design data are protected by patents, limiting owner´s access to construction details. As integrity inspection tools, consulted manufacturers recommend only periodic shutdowns for liquid penetrant testing examination and leak tightness testing, within a user-defined timeframe.
The context of failures was challenging, with the August 2022 coinciding with high external gas demand due to the Russo-Ukrainian war. The June 2021 failure occurred during an inflated external market due to project delays (Nord Stream II) and maintenance shutdowns of LNG terminals. Internally, Brazil faced its worst historical drought, with thermoelectric plants needing to supplement the national electrical system. Additionally, there was an acceleration in COVID-19 deaths due to the economy reopening with little population immunization coverage.
The online monitoring not only ensures operational safety but also led to discoveries of operational systems and routine maneuvers that triggered damage mechanisms on the equipment. This allowed for the implementation of adjustments to mitigate the propagating effects of damage, thereby increasing the equipment‘s lifespan.

Monitoring of a fatigue test on a full-size railway steel bridge with acoustic emission

G. Lackner [1], H. Marihart [2], M. Prokofyev [1]
[1] TÜV AUSTRIA GMBH, Wien, Austria

Within the frame of the Rail4Future project (https://www.rail4future.com) co-funded by the Austrian Research Promotion Agency, a railway steel bridge was removed from the track and transported to a site for constructional steelwork in one piece. Artificial defects were introduced at different sections of the bridge structure as per advice of the scientific project partners in order to initiate fatigue cracks in the course of the subsequent fatigue test. One objective of the fatigue test was to identify suitable measurement and testing techniques for monitoring of fatigue crack growth. Among other techniques utilised by different project partners, acoustic emission testing was applied by TÜV AUSTRIA.
This contribution describes the preparation of the acoustic emission monitoring and the results obtained. It is shown that this non-destructive testing technique is suitable for fatigue crack monitoring of railway steel bridge components.

Recent Advances in Wind Turbine Rotor Blades Using Acoustic Emission

V. Godinez Azcuaga [1], O. Ley [1], E. Lowenhar [1], P. Banakiewicz [1], B. Newlin [1], K. Respet [1], S. Kattis [2]
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Since the early 1990's, Acoustic Emission has been considered as the most appropriate NDE method for continuous monitoring of industrial assets during operation. Pressure vessels, process piping, bridges, tunnels, and steam boilers are a few examples. In the wind industry, AE has been used to monitor rotor blades during accelerated fatigue tests. However, long term continuous monitoring during operation has been elusive because several factors such as size of data acquisition units, need for multiple sensors, limitation on data transmission, and algorithms for data reduction to actionable information useful to the customer. Nevertheless, in the last decade, we have seen a dramatic advance in electronics miniaturization, availability of high-density computer power, development of modern data analytics algorithms, availability of relatively inexpensive data storage, and ubiquitous internet connectivity, which has created the necessary environment to overcome most of the obstacles to commercial deployment of acoustic emission technology for continuous monitoring of wind turbine blades at a reasonable price. Additionally, the projected growth in the installed capacity of offshore wind power, the increase in the size of wind turbines, and the financial pressure to maximize asset up-time, together with an increasing demand to maintain assets operating beyond their original life expectancy have increase the need for continuous monitoring.
This paper discusses the evolution of traditional AE technology from testing blades in the laboratory to the commercial deployment of an AE technology package for monitoring onshore wind turbines, which includes specifically designed data acquisition unit, sensors, real-time edge alarms, communications and algorithms to reduce data to actionable information, and a cloud-based dashboard. Current challenges and opportunities to deploy the technology in offshore wind turbines will also be discussed.

Research on the Application of AI in Acoustic Emission Waveform Data Pattern Recognition

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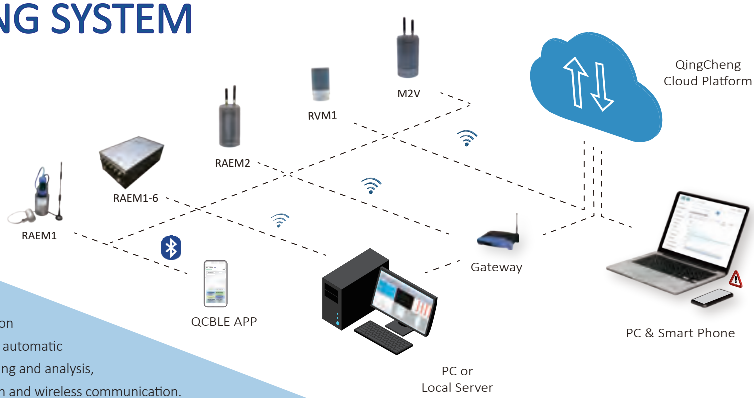
This paper investigates the method of using the deep learning model ECAPA-TDNN for pattern recognition in acoustic emission (AE) waveform data. Acoustic emission technology is a crucial non-destructive testing method. Traditional analysis methods mainly rely on parameter data, while waveform data contain more information, which can significantly enhance recognition accuracy. The ECAPA-TDNN model, by incorporating SE-Res2Block modules, multi-layer feature aggregation and summation, and an attention pooling mechanism, can effectively capture complex temporal features, enabling accurate classification of AE events such as lead break, friction, impact, and steel ball drop. The experiments, accelerated by GPU, combined with data preprocessing and data augmentation techniques, significantly improved training efficiency and recognition accuracy. The results show that the overall recognition accuracy on the test set reached 93.7%, validating the effectiveness and superiority of this method in AE waveform data analysis. This research provides new insights and tools for the development of non-destructive testing technology, and also lays a foundation for future model optimization and application expansion.

ACOUSTIC WAVE (ACOUSTIC EMISSION)

IIoT WIRELESS ONLINE

MONITORING SYSTEM



RAEM

is an industrial IoT acoustic emission monitoring system that integrates automatic control signal acquisition, processing and analysis, data storage, clock synchronization and wireless communication.

RAEM is a stand-alone AE instrument, which can not only be used as a benchtop AE testing equipment but also be used as a remote unattended online monitoring system.

Leakage monitoring of valves and pipelines

Condition monitoring of wind turbines

Wire breaks monitoring of bridges

Corrosion detection of storage tanks

AUTOMATIC

Automatic acquisition, processing and transmission once powering up, no need for manual operation and control.

STAND-ALONE

Independent of laptops, smartphones or other control systems. Standalone complete system for remote unattended monitoring applications.

WIRELESS

Wireless data transmissions, like 4G, WiFi, LoRa, Bluetooth and more. AE sensors and battery pack can be built-in to reduce wiring connections.

AI PATTERN RECOGNITION

Pattern recognition and location at RAEM1 & other smart sensors, gateway, cloud server, and client terminals, by voiceprint technology of big data, machine learning and artificial intelligence.

ALARMING

Automatically analyse data and send out alarm notifications when abnormal events happen via SMS or emails.

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Monitoring of GFRP pipelines in Power Plants using acoustic emission testing

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[1] Fraunhofer IKTS, Dresden, Germany; [2] RWE Power AG, Bergheim, Grevenbroich, Germany

In coal-fired power plants, the flue gas is transported through fibreglass-reinforced pipelines to cooling towers during the combustion of the respective raw material, which often serve as a marker for a power plant in the landscape. These glass-fibre reinforced pipelines are located at great heights (~40m) and can have very large diameters (5-7m). Up to now, testing has been carried out as part of inspections during planned shutdowns and is associated with corresponding costs. The article discusses the use of acoustic measurement methods based on a 4-month installation at the Niederaussem power plant. Measurement results based on the acoustic emission analysis and active guided wave measurement were shown. For the acoustic emission measurements, a repaired site was instrumented and different parameters like hit/event rates, acoustic energies as well as weighted peak frequencies of the acoustic signals were recorded over the monitoring period of 4 months.
The active measurement method based on evaluation of guided waves was used in order to investigate the relationship between material characteristics of the aged laminates and sound velocities. For this purpose, various sample panels were taken from the clean gas channels and material parameters were determined. These material parameters were then compared with experimentally determined sound velocities of different wave modes, which were excited using the measurement method based on guided waves and recorded using a laser vibrometer.

Damage-tolerance design for composite high-pressure hydrogen vessels when AE testing is applied

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An approach was proposed to design high-pressure composite hydrogen vessels for fuel cell vehicles with damage tolerance. In addition, a stacking-sequence optimization method was developed, which was built upon the damage tolerance design. A no-growth approach, damage categorization, and residual strength requirements were proposed for the damage-tolerance design method for high-pressure hydrogen vessels, which were implemented in the damage-tolerance design method for composite aircrafts. The initial burst pressure was set at 180% of normal working pressure (NWP) assuming that the structural health monitoring (SHM) system with acoustic emission (AE) testing would immediately detect the occurrence of fiber failure. Stacking-sequence optimization was then conducted to minimize vessel thickness and meet the residual strength requirements. As a result of the optimization, the calculations confirmed that the vessel thickness could be reduced by approximately 52% of the existing vessel stacking sequence. The results show that the thickness of the vessel can be reduced by introducing a damage-tolerant design. Moreover, the proposed method for an optimal design based on the damage-tolerance design method is effective.

Failure monitoring and classification from acoustic emission tests on impact-damaged hydrogen composite pressure vessels

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Composite overwrapped pressure vessels (COPV) for hydrogen will play an important role in emission free mobility and energy storage. The DELFIN project (2018 – 2022) was set up with the goal of developing improved COPVs that are lighter, cheaper and more durable. A key aspect of this project was to conduct full-scale impact tests with different gas pressure levels that were used to evaluate the vessels' crash performance and to verify numerical impact simulations. These tests were followed by controlled pressure experiments until the burst pressure was reached. The procedure was monitored with acoustic emission testing (AT) and subsequent computer tomography (CT). The residual COPV stability and the AT results are compared to different scenarios regarding the impact energies and impact angles. The event localization from AT shows a clear correlation of the emitted energy with the damaged areas. We classify the recorded signals into groups that can be related to the failure mechanism and compare those to the pressure evolution before failure of the COPV. All tests indicate that large impact energies lead to a significant reduction of the burst pressure of COPVs, whereas a higher internal pressure can have a stabilizing effect that reduces the damaging effect.

Method of Assessing the Level and Quantity of Sludge in Crude Oil Storage Tanks

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When crude oil is stored in large tanks, invariably high-molecular-weight organic sediments (paraffin) are deposited but the resulting sediments contains also solid particles (sand, silt, corrosion products, etc.) and also water. After some period of in-service of tank, these deposits build up to form a sludge, which causes a reduction in the storage capacity. These high in hydrocarbons a valuable raw material could be proper recovered and recycled back to the refining process. Therefore, it is significant to know the sludge characteristics shape and volume to define the best form of treatment (maintenance of tank for control of level of sludge) and removal method (in case of out of service and opening of tank). The knowledge about volume and shape of such sludge inside tanks is important for user of tank farm due to a reasons such as e.g. maintenance of storage tanks and control of level of sludge inside them, when conventional treatments are used to remove crude oil sludge, there is a potential for high environmental impact, the choose of the method of cleaning is very essential. In this paper will be presented AE technique and thermography for assess of level, volume and shape of sludge inside storage tank. In 2017, the Office of Technical Inspection launched a project to develop a system for assessing the level and quantity of sludge in crude oil storage tanks, using the AE technique and thermography. As part of the project implementation, UDT started cooperation with companies, that are the leader in oil and fuel logistics in Poland. In the following years, a complete methodology and procedure for assessing the level, volume and shape of sediments was developed, as well as a process of verifying the results. A description of the invention was prepared and submitted to the Patent Office.

Monitoring of ultrasonic fatigue testing with acoustic emission

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Ultrasonic fatigue testing (USFT) is an effective method for rapid determination of the fatigue limit of metallic materials under high and very high cycle fatigue (VHCF) loading. Commonly used methods of USFT monitoring can detect fatigue cracks only close to the end of the fatigue life, whereas the crack initiation time and accumulation of fatigue damage remain unclear. Among others, the method of acoustic emission (AE) is one of the most promising techniques for monitoring due to its exceptional sensitivity to localized processes in materials. Yet, the application of AE to USFT is greatly hindered by the inherent severe noisiness of the registered data stream. The aim of present work was to develop a signal processing method, capable of detecting damage-related AE activity during USFT by noise suppression.
Based on a thorough AE analysis, the processing algorithm was developed in a MATLAB environment and contained further main steps: USFT cropping, spectrogram calculation by short time Fourier transformation (STFT), resonance noise peaks detection and removal, calculation of filtered signal power and related AE activity. The proposed algorithm was applied to USFT of aluminium alloy AlSi9Cu3 and 42CrMo4 steel. Both alloys were tested under asymmetric cyclic loading (R = 0.1) at a resonant frequency of 19.5 kHz up to 109 cycles using a machine by BOKU, Austria. Samples with no fatigue failure were considered as runouts. AE was continuously recorded at 2 MHz sampling frequency using a broadband PICO sensor, a 40 dB preamplifier and a 18-bit PCI-board by PAC, USA.
The designed signal processing method revealed high AE activity during USFT of samples with fatigue cracks, whereas the reference samples (runouts) showed non or very low AE activity. Monitoring of USFT with AE was found to be a promising method for detection of fatigue damage on early stages of fatigue life.

Streamlined method for constructing acoustic vulnerability curves in trees

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When a tree is exposed drought stress, the water columns inside the xylem are subjected to an increasing tension. If this tension exceeds a certain threshold, the water column will break. This process is called embolism formation, and it leads to reduced water transport and ultimately to tree mortality. To assess a tree's susceptibility to drought, a vulnerability curve is typically developed by plotting the decline in hydraulic conductivity against increasing tension within the xylem. This curve is established by performing a bench dehydration experiment during which the tension in an excised stem is measured. As a proxy of loss of hydraulic conductivity, the formation of emboli is monitored with acoustic emission sensors (broadband point-contact sensors). However, during dehydration, acoustic signals may originate from processes unrelated to embolism formation, potentially leading to an overestimation of a tree's drought tolerance. To address this issue, we used an automated clustering algorithm to identify acoustic emission clusters with frequency features related to embolism formation and one cluster unrelated to this process. The acoustic emission activity of the embolism-related clusters seldomly decreased to zero, which complicates determination of the endpoint where the xylem is assumed to be fully embolized, and thus 100% loss of conductivity is reached. Therefore, we developed a method to determine the dehydration endpoint based on clustered acoustic emission data. This method was streamlined and tested using the data from four tree species (Fagus sylvatica, Quercus robur, Platanus x acerifolia and Betula pendula; n=3). Despite the increased complexity of data processing introduced by clustering acoustic data, we recommend incorporating frequency information from these signals for constructing accurate and reliable acoustic vulnerability curves.

Optimising Sensor Placement for Tool Condition Monitoring: A Comparative Analysis of Acoustic Emission Data

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For monitoring machining processes, the position of acoustic emission sensors affects the quality of the resulting information. This drives this comparative study which presents a comparison of acoustic emission data recorded simultaneously by a sensor under the milling table and another sensor near the spindle during milling and drilling tests on a CNC milling machine. The signal information is clearly influenced by the different positions. While the signals near the spindle are dominated by vibrations of the spindle motor during machining, these strong contributions do not occur in the recorded data of the machining process detected by the sensor under the table. However, the position of the sensor on the spindle has the advantage of maintaining a constant distance from the acoustic emission source, as the sensor moves with the tool. In contrast, the sensor under the machine table suffers from the fact that the distance to the milling or drilling movement is constantly changing. This results in different dominant frequencies, which are analysed in this study. Furthermore, the recorded signals were used to calculate characteristic features for assessing the machining process. These features can be used to train a machine learning model to predict the state of the tool, focusing on the state of wear. The efficiency of the wear prediction is analysed and the results are compared.

Monitoring a batch crystallization process by acoustic emission

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Crystallization is regarded as an important unit operation for separation and purification, as well as the production of solid particles with specified end-use properties. However, it is still difficult to control or to optimize the crystallization process due to the complexity of the coupled phenomena taking place simultaneously in the liquid and solid phases. In order to overcome such drawback, different analytical technologies have been implemented in the literature for monitoring (in situ, at best) the key crystallization parameters, e. g. solute concentration and crystal size distribution, which in turn enhances the comprehension about this operation. In our work, a multi-probe monitoring system composed of acoustic emission, ATR-FTIR and imaging probes was applied to the crystallization of a model system (an aqueous solution of adipic acid) in a semi-batch crystallizer. The crystallization was carried out under two different feed rates and under vacuum or atmospheric pressure. The goal was to demonstrate the usefulness of the multi-probe system for monitoring the crystallization process and to study the influence of the process (stirring rotation speed, cooling speed, etc.) on the acoustic emission. As a matter of fact, the multi-probe system tracked information about the dissolved adipic acid in the liquid phase with the ATR-FTIR spectrometry, while the crystal size, shape and number were monitored with the help of the imaging probe (with image treatment methods). The acoustic emission probes were used to detect the beginning of crystallization and the phenomena of crystal growth and agglomeration

Damage evaluation results of a hybrid pinned single-lap-shear joint by acoustic methods using a multi-method SHM system

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Large civil aircraft structures must adhere to stringent design criteria, including damage tolerance, for flight safety. Despite the potential of adhesive bonding for joining components, confidence remains limited, leading to the prevalent use of rivets and bolts in the aviation industry. This persists despite advancements in material combinations and the weight penalties associated with conventional joining techniques. To tackle the challenges of classical structural bonding, metallic pins produced through additive manufacturing can be used to reinforce adhesive joints between metal and fiber-reinforced polymers (FRP), creating pinned hybrid joints. These pins improve strength and damage tolerance while also reducing weight compared to mechanical fastening. However, uncertainties remain due to factors such as material properties and manufacturing processes. Structural health monitoring (SHM) can help reduce uncertainties and ensure the integrity of pinned hybrid joints.
The present paper presents results of a new multi-method SHM concept for pinned hybrid joints that uses piezoelectric wafer active sensors (PWAS) for the application of several acoustic methods and electric contacting of the joint for the application of resistance-based methods. The acoustic methods, namely the electromechanical impedance method, the guided waves method, and the acoustic emission method are realized in a laboratory SHM system by the same PWAS using a self-made Arduino-based switching unit. Consequently, the cabling and the measurement equipment effort is small and measurements can be used to verify each other, thus, increasing the reliability of damage evaluation results. Furthermore, different self-sensing methods could be implemented to ensure the reliability of the measurement system. The latest acoustic-based results of the multi-method SHM system applied to an extremely low-cycle tension-tension test (31 loadings until rupture) are presented, discussed, and validated with the results of a digital image correlation system. Advantages and disadvantages of the different acoustic methods are discussed and conclusions for future work are presented.

Experimental and numerical investigation of the sensor effect on the acoustic emission during Pencil-lead Break tests on PMMA plates

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Pencil leads are broken on PMMA plates at various source-sensor distances to evaluate the influence of the propagation distance and the sensor type on AE signals. The resulting waves are detected using a broadband or a resonant sensor. The ability of five transducers, PKBBI sensor, MICRO80 sensor, MICRO200HF sensor, Nano30 sensor, and WD sensor, to recreate the characteristic forms of plate waves is evaluated. Because of the response spanning between 300 to 400 kHz frequency range, Nano30 and MICRO80 sensors have a bigger magnitude in the S0 mode than in the A0 mode, especially for small sensor-source distances. Their different responses demonstrate why similar test specimens and test settings can provide diverse findings due to the sensor effect, which is significant for the use of AE data in the classification of AE sources. Then, based on the normalization method, we suggest a procedure to acquire equivalent values for the selected descriptors using Laplacian Score and Principle Component Analysis. In order to gain a thorough understanding of the sensor effect through 3D finite element simulation, a comparative analysis is conducted between the perfect contact sensor and the resonant sensor with sensor effect. The sensor effect arises from the convolution of the Fourier Transform of the signal with the sensitivity curve in the frequency domain. By comparing the waveforms in the time and frequency domain, it is useful to determine how the different sensors differ from the AE signals.

Automatized determination of the end of a wave mode in acoustic emission signals

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Acoustic emission signals can be composed of multiple wave modes with different characteristics. The various wave modes contain information about their source, as it is related to the orientation of a source, the type of source and its depth in a plate-like structure. Furthermore, in structures with multiple possible wave modes, inversion of a wave can be impossible without mode recognition. Manual wave mode recognition is possible but tedious for a large number of signals. In previous work, the author tested a method for automating wave mode recognition. A shortcoming of this method is that it recognizes only the arrival of the wave modes. Subsequently, all samples from the start of a specific mode are attributed to this specific mode until the start of the next mode or until the end of the signal. This article presents an improved method for determining the end of a wave mode. As is already required for determining the starting moments of a wave mode, cross-correlations are calculated with a reference wavelet representing this wave mode. To determine the end of a mode, the next cross-correlation peak that follows the peak indicating the start of the mode is considered. This cross-correlation peak indicates either a repetition of the same wave mode, or the arrival of a high amplitude wave component belonging to a different wave mode. Hence, it is meaningful to consider such a cross-correlation peak as an indication of the end of the wave mode in the signal.

Continuous acoustic data mining from a scattering network

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Continuous analysis of seismograms data is widespread due to the variety of signals at various time and frequency scales. Advances in machine learning have opened the way to exploring the internal structure of seismic data generated by long-term recordings, leading to the classification of signals according to their sources. Initially only supervised, investigative methods based on clustering (unsupervised), which require minimal human expertise in signal identification and do not rely on pre-known datasets, now offer new perspectives. The objective of this work is to adapt a continuous seismic data mining method to damage monitoring through acoustic emission, where the acoustic signatures of physical mechanisms contained in continuous acoustic background are far less taken into account.

To meet the challenge of exploring AE long recordings, e. g. from fatigue testing, and recognizing sources based on both statistics and physics, a relevant tool for representing time series, known as a deep scattering network, has been developed. This consists in a deep convolutional neural network that implements a cascade of convolutions with wavelet filters, a modulus function, and pooling operations. The output of such a network at each layer enables the construction of the scattering spectrogram representation. The advantage of unsupervised classification of time series is that scattering spectrograms are locally invariant to translation and preserve transient phenomena such as attack and amplitude modulation.

We show that a scattering network adapted to AE, combined with a reduction model and a clustering algorithm, is an effective tool for performing an unsupervised investigation of continuous acoustic data by applying our method on AE streaming recorded during fatigue tests: low-amplitude acoustic multiplets non recorded by the classical AE procedure were successfully clustered, and the content of the continuous acoustic background can be automatically grouped into classes of similar physical mechanisms, e. g. frictions, plasticity or electronic/mechanical noise.

Classification of Source Coordinates through Wavelet – Analysis and Neural Network: Analysis of Data Preparation and Network Structure

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For the two-dimensional localization of acoustic emission events (AE), artificial intelligence (AI) was applied. AE events were generated by breaking pencil leads on a granite plate measuring with dimensions of 50 cm × 50 cm × 6 cm. A total of 128 measurements were carried out at each of the 81 positions on the top surface of the granite plate. The recorded signals with 16 channels were processed using continuous wavelet transformation (CWT). The resulting RGB images served as input data for a convolutional neural network (CNN). The transformed images of the measured AE signals were converted into a four-dimensional input by considering them as deeper input, allowing for improved data capture. The result was analysed using a binary classifier according to the one-versus-all method.
However, due to limited computational capacity, processing the four-dimensional data posed a challenge, resulting in significant programming effort. The results of this investigation provide insights into the potential of using AI for the localization of AE events.

Simulation of elastic wave propagation with lattice model

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Acoustic emission (AE) occurring in concrete fracture process is a combination of concrete fracture at local material level and the propagation of induced elastic waves at structural level. Simulation of the fracture-induced AE in concrete needs a model that is able to address the fracture behavior and the wave propagation at the same time. However, to date, no available modelling tools can simulate the whole fracture-induced AE process.
Among others, the lattice models have the potential to achieve the simulation of the whole fracture-induced AE process. However, the lattice models are currently restricted to statistical analysis of AE events in fracture process. This paper investigates the feasibility and limitation of lattice model for the simulation of elastic wave propagation process. Several simulation cases are performed considering the propagation of both plane waves and point-source waves. The simulation results, in terms of wave velocity and geometric spreading loss of wave amplitudes, agree well with the analytical solutions. This study represents the first step for the simulation of complete fracture-induced AE waves in concrete.

Acoustic emission monitoring of a laser powder bed fusion process

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Additive manufacturing (AM) metal parts offers opportunities for various industrial applications. From individual production of spare parts for unique mechanical components to prototyping of complex structures, the possibilities of production using the additive manufacturing process are manifold. One common AM technique is the Laser Powder Bed Fusion (PBF-LB/M) process, where a laser is used to selectively melt metal powder and create the parts layer wise as designed in a model. During manufacturing certain defects like pores, cracks and lack of fusion may be created in the built parts. As AM parts often have complex geometries, a post-process non-destructive testing is difficult or even not possible. Thus, different optical monitoring techniques are applied to detect flaws during the build process with the aim to detect and repair defects right away during the manufacturing process. However, optical monitoring system require a clear view of the melt pool and quite expensive equipment. Acoustic monitoring by AE sensors attached to the built plate would be a cheaper alternative which also can be used without visual contact to the building chamber. This paper shows a first approach of an AE based process monitoring. The build plate of a PBF-LB/M machine therefore was adapted to hold four AE sensors that are then used to monitor the process. The build process itself creates AE signals caused by the melting and cooling and the mechanical application of powder. The formation of pores and cracks is expected to create additional acoustic emissions that will be distinct from the AE pattern from the printing process. This AE signals can be linked to the different layers of the printed part or in the long run to the laser position. Results from the first tests in a customized LPBF machine will be shown.

Speech recognition inspired features for acoustic emission

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For the application of acoustic emission methods in the field of condition monitoring, extracting meaningful information out of signals is an essential step in signal processing and mandatory for machine learning. However, when dealing with acoustic emission signals, the computational intensity of extracting features is becoming more important due to its large amount of data. The methodology in this study, hence, investigates established methods from descriptive statistics as typically used in acoustic emission and techniques commonly employed in speech recognition. Thereby, the objective is to improve the feature extraction of acoustic emission signals, emphasizing the synergies between the methods of both approaches. Extracting traditional acoustic emission features based on descriptive statistics alone usually yields robust features capturing the significant patterns within the time and frequency domain. However, traditional acoustic emission features may neglect more detailed information present in the signals due to averaging or mere evaluation of extreme values. To address this limitation, the methodology is extended by incorporating techniques from the field of speech recognition, such as applying window functions and digital filter banks to calculate the so-called cepstral coefficients. When comparing machine learning models that incorporate these cepstral coefficients alongside those that do not, this approach demonstrates that speech recognition techniques can result in more effective models. Here, the basic concept for speech recognition-based feature extraction and its implementation are presented, and necessary considerations and techniques are discussed, which are crucial for performant signal processing, particularly for real-time monitoring applications. The methodology is demonstrated, using acoustic emission signals derived from industrial-scale processes , such as e. g. milling, drilling or friction stir welding.

Acoustic Emission during Fatigue testing of Wind Turbine Blades with digitalized damage monitoring

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A vision of smart, reliable wind turbine blades with damage mechanism based structural health monitoring is presented. An overview is given of recent structural test campaign results that develop and demonstrate the damage detection approach. Examples from the test program of localization and characterization of progressive damage show how sensing and monitoring technology is combined to provide input to update blade digital twins and prognostic models. Success in developing new hardware and procedures for monitoring damage during blade tests has opened the way for current work to demonstrate the approach on operating turbines with a combination of embedded sensors and scans performed by drones and blade-crawling robots. The information thus generated is handled automatically within a digital infrastructure and presented by specially developed assisted intelligence software.
Acoustic emission topics: Structural testing, damage detection and characterization, digitalization and data visualization

Corrosion source location on a plate-like structure made of the Mg alloy WZ73

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Laser vibrometry offers several advantages, including non-contact measurement, real-time data acquisition with a broad vibration bandwidth, high lateral and vibration resolution, and the capability for both single-point and full-field measurements.
While the technology has proven effective, one persistent challenge has been the presence of noisy signals caused by dark laser speckles, particularly on rough surfaces. The introduction of innovative multi-path interferometry with diversity reception has addressed this issue. This approach balances information from the highest signal level of each path using patented algorithms (QTec®), resulting in a consistently stable signal. The advancements brought about by QTec have expanded the applications of laser vibrometry, notably in the field of acoustic emissions.
The QTec single-point vibrometer is employed to record vibrations across a broad frequency range directly on fused silica components during the CNC grinding process. Two settings were chosen for processing: Setting 1 with high-speed RPM and low feed rate to minimize SSDs (subsurface damages – SSD), and Setting 2 with low-speed RPM, high feed rate, and large infeed depth to intentionally induce numerous SSDs.
The measurements in the scenario where many SSDs were expected revealed significant acoustic emissions in the velocity-time signal of the vibrometer. These emissions manifested as stochastically distributed velocity peaks with frequencies around 300kHz. Conversely, the measurements in which very few SSDs were anticipated showed minimal acoustic emissions, with vibrations primarily occurring at multiples of the speed RPM.
Additionally, the new QTec Scanning Vibrometer is employed to analyze wave propagation resulting from corrosion. At a distance of d = 1.66 m, Lamb wave characteristics were recorded using an AE sensor and compared to a simulated corrosion event signal. The vibrometer‘s signal correlation enabled wave path reconstruction, ultimately facilitating the localization of the corrosion source by considering reflections and constructive interference effects in the AE sensor time signal.

Process and Wear Monitoring in Plastic Injection Molding using Ultra Low Cost AE Equipment

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Acoustic Emission has proven to be a powerful yet costly tool when it comes to monitoring various industrial processes, foremost in manufacturing. This is mostly due to either (i) the costs of AE monitoring equipment itself or (ii) the costs for implementation of the off-the shelf-equipment and fine-tuning of data AE analysis. Hence, AE monitoring is currently lacking striking industrial use cases not because of particular technological disadvantages but because these use cases do simply not pay off.
To tackle this issue of commercial potential of AE monitoring, we present an exemplary use case of wear monitoring – which is a well-known application for AE for many years – in a plastic injection molding process using ultra-low cost (about an order of magnitude cheaper than current commercially available systems) AE monitoring equipment. We show that the wear status of a mold can be computed from AE data ranging between 20 kHz and 80 kHz, a relatively low frequency range which is a key reason for the equipment being that cost efficient. In particular, no dedicated hardware for inline frequency analysis using Fast Fourier Transformations such as Field Programmable Gate Arrays (FPGA) is necessary. In addition, we also show that process monitoring in terms of catastrophic events, e. g. a crash of the mold, is equally possible to detect.
To highlight the commercial aspect of this exemplary use case, we calculate typical costs of spontaneous failures resulting from wear and compute return on invest (ROI) timelines from this. We finally present a variety of similarly cost-efficient use cases that might be tackled in the future utilizing ultra-low cost AE monitoring equipment.

Acoustic Emission based determination of delamination initiation in GFRP laminates

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Acoustic Emission (AE) has the potential to identify delamination initiation in quasi-static Mode I fracture tests. The investigation in [1] showed that a combined AE activity and intensity criterion yields GIC values for an AS4/PEEK carbon fiber thermoplastic composite that are comparable to those from standard data analysis (ASTM D5528). Another study [2] of delamination initiation under Mode I and Mode II loading of carbon fiber reinforced thermoplastic and thermoset composites compared AE activity and historic index for initiation detection. In the present study, AE is explored for analysis of initiation under Mode I, Mode II and Mixed Mode I/II loading of glass fiber reinforced epoxy laminates. AE signal energy is explored as additional initiation criterion. Two different test set-ups have been used, i. e., ENF and C-ELS for Mode II and MMB and FRMM for Mixed Mode I/II. The data indicate that for some test configuration noise signals make unambiguous initiation detection difficult. In all tests however, crack initiation determined by means of AE yields more conservative values of GC compared to the criteria defined according to the standards.

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Assurance of integrity of composite pressure vessels by AE testing using remaining life indicator

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Composite overpressure vessels (COPVs) are utilized in fuel cell vehicles (FCVs). The remaining life of COPVs decreases with repeated fillings. To indicate this decrease in remaining life, a remaining life indicator is premixed within the vessels. When the remaining life decreases, the indicator fractures before the structural components do. This allows for early detection, signaling that the remaining life of the vessel is nearing its end. Specifically, the indicator is designed to fracture before the carbon fiber, which ensures the vessel‘s strength. This fracture is then detected by AE (Acoustic Emission) testing, enabling determination of the vessel‘s remaining life. In this study, we embedded the indicator in coupon specimens and conducted a basic study to assess the feasibility of our proposed method. As the indicator, we used a carbon fiber with a slightly smaller fracture strain than that of the carbon fiber comprising the vessels. Three types of coupon specimens with different amounts of indicator were prepared, and tensile tests were conducted. As a result, it was confirmed that the longitudinal modulus of elasticity was not affected by the incorporation of the indicator, the fracture strain remained unchanged, and the indicator‘s failure did not induce the fracture of the original CFRP (Carbon Fiber Reinforced Plastic). These results indicate that the integrity of COPVs can be ensured by incorporating the indicator into them and monitoring the fracture of these materials using AE testing.

AE based crack size estimates from delamination propagation in fiber reinforced thermoset composites

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Interlaminar delamination propagation in fiber-reinforced polymer-matrix composites has been investi-gated by in-situ AE and video recording of projection radiography images [1]. This showed that delamination results from micro- and meso-scale matrix cracks. For carbon fiber reinforced thermoplastic PEEK under quasi-static tensile opening (so-called mode I) loads, rough size estimates ranged between a few tens to a few hundred micrometers in diameter. This range is consistent with damage increments observed by radiography with a contrast agent at 25 Hz video sampling rate. A similar approach applied to mode I interlaminar delamination in a glass and a carbon fiber reinforced thermoset epoxy composite utilizes optical microscopy for fracture surface area estimates instead of radiography. Both laminates are manufactured with the same epoxy matrix. Hence, the data allow for identifying potential effects due to different fiber type (glass and carbon) or fiber-matrix adhesion in thermoset composites as well as a comparison between carbon fiber thermoset (epoxy) and thermoplastic (PEEK) composites. AE analysis investigates various parameters, e.g., amplitude or energy as well as different signal filtering for this approach.

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Study of the Martensitic Transformation of Steel During the Induction Hardening Process by means of Acoustic Emissions

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Non-Destructive Testing (NDT) technology known as Acoustic Emission (AE) has been used to investigate the phase transformation of 42CrMo4 steel in a cylinder during an induction hardening process. The objective of this study is to characterize the martensitic transformation of the material using the data obtained by the AE sensor during the process. The heating process of the cylinder is carried out statically, focusing the heat on the area to be treated and then analyzing it. After quenching, destructive tests are carried out to determine the hardness and three-dimensional geometry of the steel microstructure after the process (hardness and X-ray diffraction tests). Once the microstructure of the material is known, it is possible to relate the results with the signals obtained by AE, making possible in future induction hardening processes the estimation of martensite by non-destructive techniques.

Acoustic Emission simulation: assessing the influence of AE source modeling and addressing the issue of dimensionality in the propagation medium

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A thorough understanding of simulating Acoustic Emission (AE) requires the source modeling and propagation medium to be considered respectively. Crack initiation and propagation simulation as an AE source can be performed by the Successive Node Release (SNR) method and the Direct Node Release (DNR) method. Both are compared to show how the source model affects the AE signals. The SNR method is commonly used to simulate the crack initiation and propagation. It is necessary to consider the influence of the crack velocity profile on the crack initiation [1]. However, for the DNR method, all nodes are instantaneously released once the critical crack length is attained. Hence, it is not necessary to consider the velocity profile. Instead, it is sufficient to define the average crack velocity. However, the kinetic energy varies when employing different methods, leading to a variance in the source energy. We thus assess the suitable conditions to apply the DNR method to represent crack initiation and investigate the influence of the node release methods on the AE signals. Secondly, a comparative assessment of the Pencil-lead Break test on PMMA plates is conducted using both two-dimensional (2D) and three-dimensional (3D) finite element simulations. This analysis is valuable for understanding the deficiencies and constraints of the 2D simulation. However, there is a significant difference in the AE signals between 2D and 3D simulations, suggesting that the 2D simulation is unable to capture the AE information during wave propagation, in spite of its lower computational cost. Therefore, to obtain extensive and precise information from the PLB test, it is crucial to have an extensive understanding of the limits of the 2D simulation. This understanding should take into account factors such as the distance between the sensor and the source, as well as the descriptors chosen to characterize the AE.

From damage diagnosis to service life estimation by acoustic emission: interests, limitations and contribution of modelling

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Most materials applications require a long lifetime under service conditions. It is therefore essential to better understand the mechanisms and kinetics of damage in order to perform a reliable lifetime estimation. The diagnostic phase consists in detecting and identifying the various damage mechanisms. These methods exploit data measured by a network of AE sensors to determine the damage state, and then prognostics strategies can predict the remaining useful lifetime (RUL) of the structure. This approach based on AE data includes several steps:

1) Identification of the acoustic signature of damage mechanisms using acoustic emission and machine learning: diagnosis of health state. This provides an approach for identifying critical damage during service, with a view to controlling component lifetime.
2) Prediction of lifetime during fatigue tests in a PHM (Prognostic Health Management) approach. This approach is based on determining the energy released and identifying critical times in the energy release during mechanical tests. Thus, beyond this characteristic point, criticality can be modelled by a power-law to evaluate the time to failure.
3) Modelling of the acoustic emission from the physical mechanism to the AE signal: towards a quantitative analysis. In addition, modelling AE signals allows to expand the training database while avoiding the high costs involved in large-scale experimental campaigns.

These approaches will be presented, highlighting their advantages and limitations. The presentation will also attempt to discuss the scientific issues that need to be resolved to improve robustness and reliability.

Studies on a Mobile Acoustic Emission Sensor Verification Device

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Despite the fact that there are two ASTM standards, ASTM 1106 for primary calibration and ASTM E 1781 for secondary calibration of acoustic emission sensors, there is no company or institution currently offering calibration services based on these standards due to lack of availability or practical aspects. Another option is CEN ISO/TR 13115, which needs a large volumetric propagation medium leading to similar practical limitations as for the ASTM standards. Many acoustic emission users try to fill the gap of calibration services by using simplified verification standards. However, there is currently no verification standard suitable for using in the field. In that sense, one ambition of the project CalibrAEte is to establish a new standard for primary and secondary calibration that can be implemented in laboratories without a huge invest. Another objective of the project is to establish a verification procedure using a device to verify acoustic emission sensors by a wave-based approach in the field. The proposed approach uses a durable propagation medium that carries the elastic waves from a repeatable source to the sensor under test. This research focuses on such a mobile verification device in the sense that an optimal configuration is proposed. This contribution will present the major aspects and details of an acoustic emission sensor verification setup that can be used not just in the laboratory environment but also in harsh field conditions. It will be shown the performance of the reference sensor developed for this purpose along with the setup itself, which was partially developed by aid of numerical methods. Also, experimental results in different temperature conditions, will be presented to assess the robustness of the setup. It also be presented a sensitivity analysis of the setup using different sensors in different stages of degradation.

Optical fiber sensors for acoustic emission monitoring

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Different kinds of sensors exist for acoustic emission, most of the time based on piezoelectric materials. However, the intrusivity of such sensors and their inadequation with severe environmental conditions may be an hindrance for some applications, limiting the number of sensors that can be used or totally preventing acoustic emission monitoring.

On the other hand, optical fiber sensors have been used for several years in fields such as civil engineering thanks to their low intrusivity, good embedding capabilities. Optical fiber sensors can indeed withstand extreme temperatures, ionizing environments, be used in explosive atmospheres… However, the sensors and associated optoelectronic system are in general designed to measure high amplitude of variations of physical quantities, or quantities varying slowly, such as temperature or strain. The measurements of ultrasonic mechanical waves in acoustic emission requires the design of a specific system.

We present here a system based on Fiber Bragg Gratings (FBGs) in optical fibers for acoustic emission monitoring. The sensors are interrogated using the so-called edge filtering technique, enabling the acquisition of ultrasonic waves. The system is designed to enable the simultaneous interrogation of several FBGs in the same optical fiber, reducing even further the intrusivity of the system. A specific care is also taken to enable the measurement under varying environmental and operational conditions, making the system suited for real applications.

After explaining the principle of the system, this talk will show validation tests of its sensitivity in representative laboratory applications.

The Influence of Coupling-Specific Parameters and Structural Parameters on the Electromechanical Impedance of Acoustic Emission Sensors

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Acoustic emission (AE) sensors are widely used for testing and monitoring purposes, necessitating effective field-testing methods to assess their functionality during use, ideally resulting in a method for self-diagnostic. A novel approach for field-testing is to measure the electromechanical impedance (EMI) of the AE sensor.
This method requires minimal additional equipment and eliminates human interaction, which is needed for current field-tests like pencil-lead break tests.
However, the EMI includes the mechanical impedances of the sensor, the coupling layer, and the structure. Therefore, the measurements contain information about all three and influences of the structure and the coupling layer need to be investigated to be able to establish a method for self-diagnosis in field. Additionally, the piezoelectric effect is temperature-dependent, which affects the measured EMI spectra and may result in erroneous assessments of the sensor‘s condition if not accounted for.
This work presents experimental studies on the influence of measuring equipment, environmental temperature, coupling-specific parameters and structural parameters on the EMI of AE sensors. Moreover, numerical simulations have been conducted to provide additional support and to extend the experimental studies of the latter two. To ensure reproducible sensor coupling to a structure, a setup was constructed to couple the sensor to the structure at the same position and with the same force. The thickness of the coupling layer is determined by a small amount of silicon carbide particles with a specific diameter. This setup is also used to examine the effect of structural parameters.

ISO 24543 for AE sensor sensitivity verification – support packages help to implement software scripts

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This paper presents an overview over ISO 24543, the new ISO Standard for acoustic emission (AE) sensor sensitivity verification, published in Sept 2022.
ISO 24543 is based on the face-to-face setup, where a piezoelectric transmitter generates a known particle motion pulse, stimulating a directly coupled AE sensor.
ISO 24543 gives two procedures, one for the determination of a transmitter's transmitting sensitivity spectrum, referring to absolute units of nm/V, and one for the determination of the AE sensor's receiving sensitivity spectrum, referring to absolute units of V/nm. ISO 24543 has been developed to replace the face-to-face method that delivers sensitivity spectra referring to units of V/µbar, whereby the units of µbar used for the stimulation of the SUT are neither proven nor reproducible.
This paper introduces two support packages, containing descriptions and examples of software scripts that shall help experts getting their sensor verification setup quickly running.
This presentation also discusses the influence of the sensor's load on the particle motion at the transmitter's output.

Explainable AI based Predictions for Workpiece Quality

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It is well known that sound emissions of drilling and milling machines can be used to predict process and work piece quality. Deep Learning models have successfully been applied for that task. However, artificial neural networks are perceived as black boxes as the inference mechanisms of the network are not transparent.
In this paper we present a Convolutional Neural Network trained on audio data with which process and product quality of a milling process can be controlled. The model was trained on 10-second audio snippets recorded from a milling machine that were converted into spectrograms. The trained model classifies the drilling process and predicts the expected workpiece quality. Additionally, rough estimates of the center rough and average roughness depth values are predicted. Moreover, we apply the Explainable AI methods that produce explanations by highlighting sections of the spectrogram that were relevant for the prediction. The spectrograms enriched with the explanations provide insights into the decision making process of the deep learning model in a human interpretable form. Patterns of how and why of a prediction become visible. Areas considered relevant by the model can be compared to the expectations of the human user. Through this explanation component, the model is not only able to make predictions but also to increase trust in the system which is an important aspect of acceptance of AI based quality assurance.

Estimation of the remaining useful lifetime during fatigue tests based on AE indicators.

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A main purpose of this work is to consider the possibility of estimating the rupture time of several kinds of materials from damage evolution recorded by AE technique. This approach is based mainly on acoustic energy in order to identify a critical time, indeed beyond this characteristic time, the AE energy can be modeled with a power-law, indicating the beginning of the critical damage phase. This analysis is conducted on composites materials CMC and on 7075-T6 aluminium alloys covered with different coating combinations, during fatigue tests. Some indicators are based on the distinction of the acoustic activity acquired during the loading and unloading phases of the cycles. Several indicators denoted RAE, RLU, RH are defined and allow identifying a characteristic time in both cases.
As an example, the joint analysis of these indicators on anodized samples allows to highlight characteristic times ranging from 15% to 70% of the specimen's lifetime. The early time at 15% is related to the saturation of oxide layer cracking during the first cycles of fatigue tests. By 70% of failure life, the AE activity correlates with the propagation of the main crack in the substrate, assisted by brittle fracture of the surrounding oxide layer. On composite, the same analysis allows identifying a characteristic time around 55% of the rupture time attributed to the avalanche fibres ruptures, controlled by the oxidation of fibres and by the recession of interfaces. In both cases, the liberated energy recorded after these critical times can be modelled by a power law. These specific times provide information on the Remaining Useful Lifetime (RUL) of the material and could be used to anticipate future failure.

Experimental investigation into bond characteristics of quartz sand modified enamel coated steel bar in concrete based on AE data

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Acoustic emission (AE) is widely used in industries such as aerospace, petroleum, and construction. In civil engineering, especially for concrete structures, AE has been successfully utilized to detect concrete cracking, rebar corrosion, and bond characteristics between steel rebars and concrete. Recently, a quartz sand modified enamel (QSME) coating has been proposed to enhance the corrosion resistance and bond strength of steel rebars in concrete structures. This study focuses on the bond characteristics of QSME-coated steel rebars in concrete based on AE data collected during the tests. Concrete block specimens with steel bars coated with QSME embedded in the center were fabricated in the laboratory. Pull-out tests were conducted under both reversed cyclic and monotonic loadings. AE sensors were attached to the concrete surface to capture the energy released during the debonding process. For comparison, specimens with uncoated, enamel-coated, and epoxy-coated steel bars were also prepared and tested. Analysis of acoustic emissions captured during the pull-out tests allowed to visualize the bond damage development during the tests and to differentiate between the behavior of the various rebar coating types. Results show that three stages are observed in the bond-slip curves. The AE energy released by QSME-coated rebar specimens was higher than that of uncoated, epoxy-coated, and enamel-coated specimens. This can be attributed to the enhanced chemical adhesion and interfacial friction between QSME-coated steel rebars and concrete.

Investigation of the emission mechanisms of acoustic multiplets associated with fatigue cracking

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Since the discovery of fatigue phenomena, scientific research has constantly sought to understand and predict the failure of materials caused by crack initiation and propaga-tion under variable loads. These processes have been - and still are - the cause of unfore-seen accidents and malfunctions in many technical fields.
Numerous studies using acoustic emission (AE) – a key method in non-destructive testing - have shown a correlation between acoustic activity and damage. However, these measurements suffer from the non-specific nature of AE signals, which may be due to nu-merous different physical sources.
To investigate further the mechanisms of AE emission associated with fatigue, we study here, as part of the ANR e-WARNINGS project, the groups of acoustic signals gen-erated specifically by fatigue cracking in metals. Signatures of a single source, these sets of similar signals are called acoustic „multiplets“, after the analogous seismic phenomenon [1]. These so-called acoustic multiplets are characterized by highly correlated waveforms, are repeatedly triggered over many successive loading cycles at nearby stress levels and origi-nate from a single location. Produced during the propagation of fatigue cracks in various alloys, these signals, emitted in noisy environments, are automatically detected by a dedi-cated algorithm [2], grouped into multiplets and analyzed to understand the physical mechanisms from which they originate. By synchronizing their detection with digital image correlation measurements of fracture mechanics quantities, the investigation of this acous-tic emission phenomenon shows that two mechanisms are at the origin of the multiplets: repeated local friction of fracture surfaces and incremental crack propagation in the Paris regime, probably due to the reactivation of crack tip plasticity at each cycle.

[1] S. Deschanel et al. Scientific Reports, vol.7, no1, p.13680, 2017.
[2] T. de la Selle, SSRN, Mechanical Systems and Signal Processing, https://ssrn.com/abstract=4405532

Acoustic emission during the freezing of water or the melting of ice in aircraft

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It is a frequently overlooked phenomenon that matter can produce sound emissions when undergoing a phase transition. The exact cause of this sound is until now not modeled and understood in depth, but it appears certain that sudden volume changes, cracks, friction, and other sources that occur during e.g. crystal decay/growth in melting/freezing processes must be considered. However, a generally accepted theory of the „sound of phase transitions“ is lacking. In this paper we present a general introduction in this field.
Besides the more fundamental aspects, the AE generation during the melting of ice can be used to detect the presence of this respective substance in technical structures. An interesting application is to detect the melting ice in aircraft. Adverse water accumulation, resulting from contamination and condensation, is regularly found in fuel tanks, and scheduled drainage procedures of this water after the melting of the ice are important to ensure the safety of systems and structures.
A practical problem for drainage after flight is determining the right time to start the process. Beginning too early would mean that the remaining ice cannot be removed, and waiting too long presents an economic problem as it increases the aircraft‘s downtime. There is currently no technology that reports when all water has melted. To realize this goal acoustic sensors were attached to the skin of the tank walls, and the acoustic signals were intense enough to propagate through the aluminum sheets and coating and further analyzed. In this way, the completion of the melting of ice was determined by the time at which the acoustic emission stopped. We present measurements on a laboratory scale, the results from a climate chamber on relevant replica’s, and the outcome of a first campaign on an operational aircraft (Airbus A330).

Acoustic Emission Energy Release Rate Model for Classification of Damage Development in Large Fiber Reinforced Plastic Composite Structures

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Acoustic emission identification of fracture mechanisms in composite materials is of great importance for the practical assessment of the serviceability of aerospace structures, such as unmanned aerial vehicles, rocket motors, and others. Many scientific research studies conducted in recent decades have demonstrated the unique capabilities of the Acoustic Emission (AE) method to detect and identify different failure mechanisms, including fiber breakage, matrix cracking, and delaminations in fracture tests of composite specimens. However, testing large composite structures, in many cases, can be accompanied by multiple time-overlapped fracture events activated simultaneously, resulting in considerable difficulties in the classification and assessment of combined prolonged AE signals.
In this work, we propose the Energy Release Rate (ERR) model for the classification of AE activity related to fiber-reinforced plastic (FRP) composite fracture. The model identifies accurately both micro-scopic and macro-scopic fracture mechanisms in large aerospace structures and composite vessels having complex composition of materials. The model is practically applied using several machine learning methods and provides a simple means to identify and discriminate typical fracture mechanisms and their combinations. Specifically, we describe ERR model, choice of most informative AE parameters, the choice of suitable machine learning classification methods, their training and testing on several hundreds of FRP specimens, and model validation during practical tests of large full-size FRP composite structures.

Identification of corrosion nature using acoustic emission in representative scale samples

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Corrosion monitoring is of utmost importance for many applications, as corrosion occurs in many industrial sectors such as energy production, transport or civil engineering. However, depending on the application, identifying the type of corrosion may enable a more relevant diagnostic: for example, detecting pitting corrosion may help preventing leakages in oil and gas applications, with significant economical, ecological and safety benefits.
In particular, as acoustic emission detects the signature of the evolving defects, it should be possible to identify the nature of the source if the characteristics of the signals are differing. However, several potential sources of acoustic events exist during a corrosion process, among which the depassivation of the surface, the tearing of metal, but also bubble formation and explosion (and industrial background noise). Moreover, the various acquired signals will be impacted by the propagation between the source and the sensor in realistic configurations.
This talk will first present experiments designed to acquire controled data corresponding to different corrosion natures, depending on the nature of the corroding fluid and the exposure of the metal, to enable the proper evaluation of a clustering strategy. A clustering methodology will then be explained, which relies on several steps: first, the events location is retrieved. This information is used to compensate the propagation from the source to the sensors before extracting characteristics on the signals on which the clustering will be indeed performed. This methodology will then be applied to the data obtained from the controled experiments.

Research of Acoustic Emission Characteristics and Applicability of Artificial Intelligence for Source Localization

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Within this research, the deployment of artificial intelligence for the localization of acoustic emissions (AE) is being investigated. In detail, series of experiments were conducted on a plate of granite with homogeneous and isotropic material behavior. Acoustic emissions could be generated by the breaking of pencil leads, as well as the impact of rice grains and steel balls on 81 specific positions with a distance of 50 mm in both horizontal axes to each other. The response of the system was recorded using 16 acoustic emission sensors, of which 8 sensors were positioned on each surface side of the plate. In further steps the data could be processed, so that the resulting characteristic signal features could be translated into spec-trograms and furthermore being used as input for the artificial intelligence. Additionally, the corresponding source locations appeared as labels. Both, the signal features as well as the labels, could be implemented in the process of supervised learning using a convolutional neural network (CNN). The results of this network indicated a validation accuracy of over 99% as well as a low loss value by classifying the inserted features to the right labels. Thus demonstrates the excellent applicability of artificial intelligence for the source localization of acoustic emission (AE).

Impact of Model Knowledge on Acoustic Emission Source Localization Accuracy

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Reliable and precise damage localization in mechanical structures is of high importance in the context of structural health monitoring (SHM). The acoustic emission (AE) method has already shown its excellent suitability for damage localization. However low signal-to-noise ratios (SNRs) are often prevalent in SHM, thus an increase in localization accuracy and robustness is still in demand. The present study faces this task through the integration of various model knowledge for AE source localization. The basis of the presented algorithm is the consideration of the dispersive behavior of elastic waves in thin-walled structures. The continuous wavelet transform (CWT) is used to obtain time-frequency representations of the signals, where frequency-dependent values for time-of-arrival (TOA) are extracted. Furthermore, the algorithm incorporates the knowledge that all sensors receive signals with the same time and location of origin, as well as the slightly different sensitivity of the theoretically equal sensors. The final localization results are achieved by a two-way grid search optimization. The algorithm is experimentally tested on a large aluminum plate with four piezoelectric wafer active sensors (PWASs) arranged in an array of 100 mm x 100 mm. The mean localization error of pencil lead breaks at ten different positions within the sensor array is used as an accuracy measure. It is shown that as more of the described model knowledge is incorporated into the localization, the accuracy increases. With the final algorithm, the mean localization error is more than halved compared to AE localization based on classical TOA estimation. Although the experiment described is conducted under laboratory conditions, the remarkable increase in accuracy suggests that AE source localization may be successful even at low SNR as typical for operational conditions.

An Approach to Calculate Source Locations for Thicker Plates when Acoustic Emission Signals are Dominated by Trailing Waves

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In many acoustic emission (AE) applications, signal arrival times from an array of sensors are coupled with an appropriate velocity to calculate the source location of AE events. To date, the AE signals present in these applications are Lamb and/or Rayleigh waves. In a previous publication [1], finite element modeled (FEM) AE signals in thicker plates were dominated by trailing wave (TW) packets, when no Rayleigh wave was present. The typical character of the TW dominated signals was described as a spaced-in-time train of short-in-time wave packets. Further, it was pointed out, that when TW dominate the signals, it is not clear how arrival times for source location calculations might be obtained along with an appropriate propagation velocity.
The goal of this work is to develop a source location approach for cases of dominant TWs in the AE signals in thicker plates. The FEM-signal database from the previous publication was used for this study. The database consisted of in-plane dipole sources at five different depths and four different steel plate thicknesses (50, 75, 100 and 125 mm). Bottom-surface out-of-plane displacement signals versus time for propagation distances from 250 to 1500 mm were examined. The FEM signals were frequency filtered to examine a broadband case of 80 to 500 kHz and a narrowband case of 100 to 300 kHz. To study the potential source location accuracy, a total of seven four-sensor arrays were employed. The study results describe a process to select appropriate arrival times and obtain a propagation "velocity." This information was used to calculate source locations for the sensor arrays. The location errors were shown to be less than the plate thickness.

[1] Hamstad, Marvin, Sause, Markus G.R. (2022). On trailing waves rather than Lamb waves being generated by buried in-plane dipoles in thick plates. EWGAE35 & ICAE10

Combined Acoustic Emission and Ultrasonic Measurements in Cross Laminated Timber-Steel Composite Beam

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Combined acoustic emission and ultrasonic measurements were carried out before and during a four-point bending test on a composite floor beam made of cross-laminated timber with length of 11.6 m, width of 1.5 m, and thickness of 0.28 m. One key aspect of the composite design is the formation of the shear-resistant connection between the panel and steel girder. For the measurements a 16-channel system with combined acoustic emission and transmission measurements was used. The signals were digitized with a very high frequency of 10 MHz with amplitude resolution of 16 bits. To monitor acoustic emission activity a network of 16 AE sensors were attached to the surface of the specimen in the central part of the specimen where the highest deflection and load were expected. For this purpose, broadband AE sensors with measurement frequency of up to 200 kHz were used. The ultimate failure of the specimen occurred at a maximum test load of approximately 200 kN. The deflection at this force was about 200 mm. During the tests which lasted about 50 minutes approximately 8,500 AE events were detected. More than 2,600 events were recorded by at least six channels which makes them well suited for three-dimensional localization. Because of the inhomogeneous cross-laminated timber conventional localization using an unique velocity model are not possible. Therefore, a velocity model was experimentally determined by measure the velocity of the elastic waves in all directions. The greatest value was measured in the longitudinal direction along the beam axis. The average value is approximately 4000 m/s. While in the transverse direction the velocity drops down to approximately 2800 m/s. The lowest value was measured in thickness direction of about 1800 m/s.

Quantifying tactile perception of fabrics using both frictional and acoustic methods

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Unlike most of the tribological phenomena that involve inanimate materials, skin friction is a complex biotribological action that is heaving influenced by the state of the biological item, human skin, the characteristics of the counter substrate, and the interface. It is the physical process that underpins tactile perception, in conjunction with the psychological process of human being. For decades, the tribological community has been fascinated by skin friction, and developed various methods to quantify skin friction, most of which are based on a mechanical device to quantitatively measure friction force and vibration generated at the articulating interface.

To advance the knowledge in skin tribology, in particularly when it comes to porous and deformable substrates, we have developed a new method that incorporates a conventional friction plate with a passive acoustic emission sensor for quantifying finger friction. We found that frictional forces (expressed as Coefficient of Friction) acquired were distinctive enough between solid substrate and fabrics, but not such much between fabrics. However, acoustic emission was able to further differentiate the subtle difference between the fabrics. We were able to correlate the acoustic emission data with human perception descriptors such as soft, slippery, greasy. Using acoustic emission method to directly capture finger (or skin) friction has a great potential as a new strategy for tribological measurement when carrying out experiment on a bench is not possible. It could also work as a tribo-sensing system in biomedical applications. We strongly believe that the advancement made in this present work could be of great interest to the broad tribology and acoustic emission communities.

Influence of loading conditions on acquired AE signals in biocomposites

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Composite materials are increasingly used in lightweight transportation systems and civil engineering due to increasing weight constraints and installation costs. In the case of transportation systems such as in the aerospace and automobile industries, the use of composite materials reduces the weight, which is reflected in increasing the transportable load and reducing fuel consumption, and therefore the mechanical performance of the material is a very important and desired attribute. Biocomposites reinforced with natural fibers, such as flax, are gaining attention in engineering applications due to their sustainable and mechanical properties.
This paper‘s research was designed to investigate the AE signals at different loading conditions of V-notched biocomposite specimens. Applying different loading cases, ranging from pure tension to pure shear, provided an understanding of the material‘s response under diverse stress states. The multi-axial strength and failure characteristics of biocomposites are evaluated. Digital image correlation technique provided measurement of strain fields complemented with AE data. AE signals have proven effective in capturing the onset and progression of different failure sources in composite material.

Detection and characterisation of galling wear by acoustic emission during friction tests using artificial intelligence

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On-line monitoring, using non-destructive testing, of surface defects such as work hardening or galling wear in components or structures in service, has been attracting increasing interest from manufacturers in recent years as a means of ensuring the quality and safety of their systems.
This study aims to evaluate the ability of the acoustic emission method to detect and further characterise surface damage, so that it can be used as an SHM system to monitor components or structures in service.
This method was developed on a friction test rig. Galling wear tests were then carried out according to the new ASTM G196 standard, and a raw database of more than 75 tests with different levels of adhesion and galling wear was collected by acoustic emission. The processing of raw data enabled new indicators to be calculated, such as kurtosis or RMS per frequency band, in addition to those commonly used in acoustic emission.
These indicators were then evaluated using a neural network based AI anomaly detection algorithm, trained on the healthy part of the previously created database. The methodology used in study was carried out in several iterations in order to find the most relevant indicator to detect and characterise the different levels of galling wear. Thus, this approach made it possible both to assess the sensitivity of these indicators for galling wear detection and to seek a model for predicting the onset of galling wear.

Seismicity during Unrest: Exploring the Physical State and Geological Structures of the Earth

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The study of strong earthquakes is one of the fundamental questions in seismology, particularly in order to better understand the seismic hazard and the effects on humans. However, the study of weak earthquakes, which occur almost constantly and are often referred to as seismicity, addresses completely different questions and can be used to study the physical state and geological structures of the Earth's crust. The difficulty in reaching this conclusion stems from the fact that seismicity is dependent on a multitude of variables, and a comprehensive understanding of the processes that lead to earthquakes is essential.
In recent years, research in this field has made significant strides, resulting in the development of seismicity models that suggest the possibility of utilizing micro-earthquakes as a „sensor" in the Earth. The presentation will illustrate various methods of recording seismicity and their applications in studying the subsurface. The applications of seismicity are diverse, encompassing both kilometer-sized strong earthquakes and natural or man-made injection experiments of a few meters in size. The methods of earthquake seismology and seismicity offer potential applications in the field of acoustic emission research.

Digital twin in bridge maintenance

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Bridges are essential components of infrastructure, responsible for continuous transportation and ensuring safety. However, the deterioration of bridges is rapidly increasing worldwide, resulting in various maintenance concerns. In Germany, more than 50% of the bridges area on the Federal Highways were older than 30 years, and more than 30% of all bridges area were not in good structural condition, according to statistic of Federal Highway Research Institute in 2024. The need for bridge maintenance is expected to increase significantly, especially in terms of extending the life of bridge structures to save material and other resources. To achieve this, significantly more information is required at a much earlier stage than is usual today. All the necessary but heterogeneous information should be ideally systematically handled, linked, and centrally presented. To address this, digital methods, particularly the entire concept of digital twins, are increasingly investigated and implemented within the civil engineering sector. They exhibit significant potential in maintaining and extending the service life of existing constructions. In this contribution, the concept and the essential components a bridge digital twin are firstly introduced. Subsequently, some pilot projects, including the SmartBridge Hamburg, the Nibelungen Bridge in Worms, and the OpenLAB – IDA-KI Research Bridge in Bautzen, will be extensively elaborated upon. The objectives and functionalities of the bridge digital twins, the related data monitoring systems, the data processing methods, and visualization strategies are explained in detail. Finally, the major knowledge and future challenges are concluded.

Acoustic Emission Measurements During a Four-Point Bending Test on a Reinforced Concrete Specimen

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Acoustic emission (AE) measurements were carried out during a four-point bending test to investigate the influence of the shear load-bearing capacity of reinforced concrete beams (so-called Leonhardt beam) with shear reinforcement. The results of AE measurements show that the AE activity begins immediately after starting loading. During the test approximately 3.500 AE events could be automatically located using longitudinal and transverse wave arrival times. Most AE events are in the central region of the specimen within the sensor network. Therefore, only the flexural tensile cracks are represented through AE locations. The transverse shear crack that occurred during the ultimate failure of the specimen is outside the sensor arrangement and has not been detected. Due to the localization error, the AE events are distributed in a cloud-like manner, and as a result, they do not sharply depict the macroscopic flexural tensile cracks. Ra-ther, acoustic emission indicates that a crack network of many small microscopic cracks formed in the tensile area, resulting in a very rough and fragmented crack morphology. Additional to the conventional source location, we applied the so-called collapsing method to highlight structures already inherent within the unfocused AE events clouds.

Acoustic emission monitoring of a large-scale 50-year-old prestressed concrete bridge girder during an eccentric three-point bending test

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Deterioration of reinforced and prestressed concrete structures is one of the main challenges in structural engineering. As the majority of our infrastructure is built around 1960-1980, most structures have reached or will soon reach their design lifetime, giving rise to more structural problems and costs in the coming decades. It is therefore important to develop efficient assessment schemes allowing to assure the safety and reliability of these existing structures and to estimate their residual lifetime. Within the framework of the Bridge|50 research project, a 50-year-old prestressed concrete bridge showing signs of corrosion damage was decommissioned. The bridge girders were recovered and have been subjected to large-scale load tests with varying loading patterns. This paper presents the results acquired during acoustic emission (AE) monitoring of one of the I-shaped girders during a monotonic three-point bending test with an eccentric point load. The results show that the failure mode and location could be detected based on AE activity and zonal AE localization. The onset of concrete cracking was observed by a decrease in peak frequency of the AE signals. Average frequency (AF) and rise angle (RA) value analysis was used to characterize the crack mode, which shifted from tensile to shear mode during bending.

Acoustic Emission in Wind Energy: An Applications for Monitoring Hybrid Tower Tendons

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The growing significance of wind energy in supplying renewable electricity underlines the increasing importance of wind turbine efficiency. Hybrid towers, integrating steel and prestressed concrete in a stacked structure, address traditional limitations in nacelle height but face new vulnerabilities, exemplified by a collapse in September 2021. This highlights the crucial need for continuous monitoring, particularly of the tower structure‘s tendons.
This study introduces acoustic emission monitoring as a novel approach for the early detection of wire-breaks within the highly stressed tendons of hybrid towers. The investigations described focus on evaluating the suitability of this method for the specific use case and developing a generalized monitoring approach. Accordingly, background noise in an operating wind turbine tower was recorded and analyzed over a year-long operational period. Correlation analyses of this data unveiled intricate relationships between operational parameters and noise levels, with wind speed, rotor speed, and blade pitch angle exerting influence. Laboratory experiments were conducted on a full-scale specimen, and wire-breaks were artificially provoked to characterise the damage signal and assess its attenuation in relevant structural components.
The experimental results were integrated into a stochastic model to determine feasible sensor distances, aiming for a 90% probability of detection at a 95% confidence level. Low attenuation along the tendon was identified, enabling reliable detection over significant distances. Nevertheless, practical considerations suggest a focus on tendon anchorages, with the potential for grouped monitoring in specific areas to optimize sensor deployment. The study proposes a sensor network configuration to enhance the safety and reliability of wind turbine structures.

Development of a Semi-Autonomous Pulse and Receive Concrete Inspection System

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Concrete structures are being subjected to increasing loads and used beyond their intended lifespan. When combined with operators shrinking maintenance budgets it is imperative structures are monitored for damage. Acoustic Emission (AE) and AE Tomography offer a method for damage detection and characterisation.
However, they are encumbered by their equipment and setup requirements, and best used on areas where damage is already known to have occurred. An autonomous pulse catch system could be used to identify these areas. To explore the potential of such a system, seven concrete beams differentiated by their aggregate size were tested using an automated pulse and receive system. The effect of aggregate size, and pulse frequency on attenuation and wavespeed are investigated. The pulse regime consisted of narrowband pulses ranging from 30 kHz to 500 kHz. The results show that high frequency pulses experienced greater attenuation than low frequency pulses. Whilst a link appears between the size of the aggregate and the rate of attenuation of high frequency signals. A strong negative correlation between amplitude loss and pulse frequency was observed. For the specimen containing coarse aggregate, pulse velocity was constant between 100 kHz and 500 kHz, whereas specimens containing coarse aggregate experienced frequency dependant attenuation. This testing shows the significant potential for an automated pulse and receive system, which could lead to the development of an autonomous health monitoring system. In addition, the approach can be instrumental in developing large data sets, that can be used in Machine Learning processes, to develop a deeper understanding of AE signal propagation in concrete materials.

Supporting the infrastructure operators with customer specific AE-monitoring solutions

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Cost-effective and efficient monitoring of infrastructure is crucial for planning maintenance and repairs while ensuring the safety of the structure. Acoustic emission is a method particularly suitable for long-term monitoring. However, the necessary extended monitoring period incurs high costs for the operator, primarily due to the exceptionally high costs of measuring equipment. The need for a tailored monitoring system for infrastructure applications is evident. TÜV AUSTRIA is developing a monitoring system called RISE, which represents a customized solution for steel bridge monitoring. The innovative online monitoring solution RISE assists experts with structural monitoring. Due to its compact design, low power consumption, and easy installation, the measuring system is specifically designed for continuous monitoring. Specifically, RISE is introduced for the hotspot monitoring of railway steel bridges. The passage of trains triggers a material response that can be recorded by the measuring system. This is used to perform crack monitoring on bridges and to have a tool for assessing crack activity and the degree of damage. This enables targeted planning of repairs and maintenance activities. Reducing the operating costs of the structure and ensures its save operation. The system is being developed to function robustly and provide a high level of automation.

Mechanical Robustness Analysis of Semiconductors with a Single Needle Probe Card Using Acoustic Emissions

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The combination of indentation testing and acoustic emission (AE) is widely used to analyze the fracture toughness of test substrates. In the manufacturing of semiconductor devices this material parameter also plays an important role. During the so-called wafer testing inside a wafer prober small probe tips are pressed onto the chip surface to check its performance. To prevent damaging the chip by that, the fracture toughness and load limit of it has to be defined in a prequalification step. This paper presents a test system that imitates the wafer testing process as close as possible and uses acoustic emission to detect appearing cracks and thereby also the load limit. The frontend of the test setup consists of a modular single needle probe card which can be placed in a wafer prober. Also, the indenter properties (tip diameter, stiffness, etc.) can be adjusted to the probe used later on during productive wafer testing to ensure realistic probing conditions. A piezoelectric sensor and a full strain gauge Wheatstone bridge are implemented close to the single indenter to measure the AEs and the applied contact force respectively. The signal-to-noise-ratios (SNRs) of both sensors are improved with an own analog amplifier module before recording them with an USB oscilloscope. A developed measurement software (LabVIEW) is used to adjust measurement parameters (trigger limit, record length, conversion factors, etc.) and automatically store and separate measurement data from different acoustic events and imprints. To evaluate the result files a second software tool (MATLAB) reads the files out and clusters the recorded events to separate crack signals from electrical and mechanical disturbances. With a prototype first test results are generated and the functionality and accuracy of the measurement concept is proven.

Monitoring Cultural Heritage: Acoustic Emission Testing in Museum Galleries

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In the dynamic landscape of cultural heritage, museums are actively adapting to address the challenges posed by climate change. Recognizing their role as stewards of invaluable artifacts and the need to minimize their environmental footprint, museums worldwide are implementing an array of innovative strategies. One prevalent approach involves reevaluating traditional climate control parameters within museum spaces. However, broadening the environmental conditions requires an evidence-based decision-making framework. This is crucial because fluctuations in temperature and humidity can generate internal stresses in objects, eventually leading to cracking in the materials comprising the artwork. Some cultural heritage practitioners are tackling this issue by directly monitoring the physical response of artifacts using non-destructive techniques, such as Acoustic Emission (AE). When performing such analysis in a museum gallery or historic site, considerations emerge, including how to optimize tests that are expected to yield low AE signals compared to environmental noise. Consequently, effective filtering of signals resulting from processes other than material fracture must be undertaken. The following discussion will explore some outcomes and considerations when deploying AMSY-6 systems to monitor historic wooden artifacts at the National Gallery of Victoria (NGV) in Melbourne, Australia, and the Victoria and Albert Museum (V&A) in London, UK.

Performance Evaluation of Low-Cost Packaging for Multifrequency MEMS AE Sensors

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This study explores cost-effective and highly efficient packaging solutions, focusing on the performance evaluation of a micro-electrical mechanical systems (MEMS) acoustic emission (AE) sensor compared to commercially available sensors. The MEMS AE sensor comprises sixteen individual resonators, each vibrating within the 90 kHz to 550 kHz frequency range. To simplify wiring complexities associated with the connection between the data acquisition system and the resonators, all resonators are electrically connected in parallel at the die level. A purpose-designed printed circuit board (PCB) is employed to mount the MEMS die and facilitate the wire bonding of the top and bottom electrodes to the output electronics. This connection is achieved using a shielded cable soldered onto the PCB. This PCB package is enclosed by a structured 3D-printed lid that seals the cable using a non-conductive epoxy. The acoustic performance of the packaging solution is evaluated through face-to-face calibration and simulations involving pencil lead break simulation on composite and metal structures. Our results demonstrate that when compared with traditional packaged sensors, our new packaging approach significantly eliminates electronic noise and increases the MEMS sensor‘s sensitivity to better and comparable levels with bulkier AE sensors. This package also intuitively has a substantially smaller thickness, making it more useful for applications with limited space. This research showcases the potential of this packaging solution in enhancing the overall performance of MEMS AE sensors.

Structure Reliability Evaluation based Acoustic Emission: Case 2 Studies

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A cost-effective inspection procedure was conducted using Acoustic Emission (AE) monitoring to detect fatigue crack initiation and/or growth and to assess the crack activity in eyebars of a steel bridge. Multiple AE sensors were installed on critical eyebars of a bridge. The AE characteristics and source localization were dynamically monitored and recorded on-site in real-time under the impact of normal traffic operation and controlled loading test. In the loading test, a loading truck ran at different speeds and stopped at critical floor beams. The parameters of AE signal were analyzed and the results showed that AE is a very reliable technology for confirm or denying the fatigue cracks initiation and assessing the condition of existing cracks and is a cost effective component in Structure Health Monitoring (SHM). The same approach was conducted for welded joints of steel pressure vessel during normal operation in refinery environment. Possible noise sources were identified and related signals were filtered. AE data generated from flawless and defective welded joints showed AE energy is reliable feature to confirm crack activity in high noise environment. Crack growth rate can be evaluated by determining changing rates in AE parameters which were in agreement with ultrasonic measurements. Sensors placement and experimental equation for crack growth evaluation is proposed and 7 times vessel wall thickness is recommended as optimal spacing between sensors.

Application of Acoustic – Emission on fatigue Damage of steel Bridges

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Acoustic emission technigue was used during static load of steel part of bridge containing fatigue cracks.
Next step of research program was monitoring of fatigue cracks on real steel bridge during loading by heavy trucks.
Paralell to this experimental investigation the acoustic emission was used to monitor steel rayilway bridge.
This bridge is over 150 years old and basic constructio was done by riveting.
Results of AE measurements have shown very good results documented damage processes with crack behaviour during cyclic loading.
The obtained acoustic emission results were confirmed by other NDT methods used also for this experiments.

Two-Step AE Source location for Detecting Tendon Rupture inside PC Box-Girder in-Service

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In order to identify tendon rupture inside a prestressed concrete (PC) girder, a new acoustic emission (AE) location system is necessary to be practically applied. In a PC girder of an in-service highway, PZT sensors are installed at a web and a deck of the PC girder, and elastic waves generated by tendon rupture are simulated by steel ball impact. AE source location assuming the homogeneous velocity distribution is applied in a development view of the box-girder. Then to verify the accuracy of the location results, the effect of elastic-wave propagation at a joined corner between the web and the deck is simulated by FDM. As a result, the attenuation of first-arrival P waves was observed at the joined corner. It implies that wave energy is so attenuated that apparent velocity decreases. Finally, AE locations lead to erroneous solutions in the development view solved with a constant velocity. To solve the problem, a two-step location system is developed. In the first step, the two-dimensional plane, where the tendon rupture is to be identified, is selected from the 1st and 2nd arrivals of AE Hits. Then, in the 2nd step, AE locations are determined from remaining AE sensors located on this plane. By applying this system, the location errors are within 5% at both the web and deck in a 15 m long PC box-girder.

Evaluation of Concrete Fatigue Damage with Elastic Wave-based Measurement Techniques

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Fatigue damage is a progressive and permanent change in the internal material structure due to cyclic loading. The cyclic loads can be due to wind, waves, temperature variation, and traffic loads. Each cyclic load application introduces micro-damages that accumulate to induce failure. Detecting these micro-damages requires sensitive measuring techniques. Hence this research compares the sensitivity of different measuring techniques applied to fatigue experiments of concrete. The applied NDT are the passive acoustic emission technique (AET) and active ultrasonic measurements. In addition, linear variable differential transformers (LVDTs) are applied as a reference measurement.
Accordingly in this research, cylindrical concrete samples are subjected to monotonic and cyclic Brazilian splitting tests. The cylinders are 100 mm in diameter and 150 mm in length. The cyclic load is applied to these samples with a loading frequency of 5 Hz. During the tests, the damage evolution is monitored with AET, ultrasonic measurements and LVDTs. There are eight AE sensors attached to the sample. The two LVDTs are positioned at the center of the sample's front and back side. Besides passively monitoring the acoustic emissions, the AET sensors are also used to do active ultrasonic measurements. The research reports the comparison conducted on the deformations and cracks measured with the LVDTs, the damage growth identified with the AET, and the change in the ultrasonic pulse velocity measurements. In addition, the study also presents the damage analysis capacity of the methods across different types of loading: monotonic, constant amplitude, and stepped fatigue loading. The comparison shows that combination of AET and ultrasonic velocity measurement is a sensitive indicator for damage growth.

Acoustic emission for monitoring of fatigue damage in concrete elements of wind turbine towers

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Wind energy has become an important player in the energy transition in Germany. Towers of onshore wind turbines are often designed as hybrid structures: the lower part is made of prestressed concrete whereas the upper part is made of steel tubes. The tall structures are permanently subjected to dynamic loads. A research project of BAM as part of the joint project WinConFat-Structure focusses on the development of techniques to monitor fatigue damage evolution in the concrete part. Results of a previous project show that a combination of ultrasonic and acoustic emission testing can give an indication for critical conditions near the end of the fatigue life of the concrete. In the ongoing project acoustic emission sensors have been installed at the base and at the transition piece between concrete and steel of a hybrid wind turbine tower. Beside of acoustic emission measurement the sensor spacing allows for measuring the concrete ultrasonic velocity along the circumference in both levels. Additional measurements like strain, temperature, inclination, or acceleration allow for comparison of environmental loads and change of acoustic properties of the concrete. The paper focusses on first acoustic measurements recorded since December 2023 in comparison to operating data of the wind turbine.

Detection of Active Infestation by Wood-Boring Insects via Acoustic Emission Using the IADS (Insect Activity Detection System)

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The preservation of wooden art and cultural artifacts is severely threatened by the infestation of wood-boring insects. Distinguishing between active and inactive infestations in practice poses a significant challenge, often leading to unnecessary treatments or delayed actions. This article focuses on the examination of the Insect Activity Detection System (IADS), an innovative AE measurement device for the detection of feeding noises of wood-boring larvae. Starting with an overview of the theoretical framework, the results of practical experiments are shown. Finally, we will present some possible applications of IADS in the conservation of art and cultural heritage.

Continuous health monitoring of reinforced concrete bridge deck based on traffic load-induced acoustic emission

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This paper presents continuous bridge deck monitoring based on b-value obtained from traffic load-induced acoustic emission (AE) signals. Using the self-powered AE system that we developed, we have observed traffic load-induced AE on an actual bridge for five years. The developed self-powered AE system demonstrated that long-term traffic load-induced AE measurements over five years could be performed without an external power source. Traffic load-induced AEs measured irregularly by event-driven measurement were accumulated, and b-values were calculated. We used an additive regression model that accounts for piecewise linear trends and seasonality to extract long-term trends accurately. Over the past five years, the bridge has deteriorated. In addition, repairs were made during the period. As a result of this monitoring, we determined the relationship between the damage condition of the bridge and the b-value trend obtained from the traffic load-induced AEs. The results confirmed that the b-value based on traffic load-induced AE corresponds well with the damage conditions on the underside of the deck slab or in a shallow area inside it. We consider that these results demonstrate the feasibility of continuous monitoring of reinforced concrete bridge deck slabs and can contribute to future maintenance and management efficiency. This work was partly supported by the New Energy and Industrial Technology Development Organization (NEDO) of Japan.

Application of the Acousto-ultrasonics technique to bridge cables in their anchorages

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The objective of this research is to evaluate the state of health of civil engineering cable structures using the acousto-ultrasonics method. More specifically, the element to be examined is the cable in its non-accessible part inside the anchor base. Cables in anchor caps are sensitive areas subject to various types of damage, such as water infiltration, which causes corrosion inside the anchor, or fretting fatigue. Such degradation cannot currently be assessed using NDT techniques.
A number of challenges need to be overcome, including the complex geometry of the anchors, which limits the installation of sensors, the diversity of damage that may be present, the sensitivity to the defects being sought and the reproducibility of the measurements.
Once the acoustic signals have been acquired, data analysis is crucial, requiring the use of unsupervised or supervised techniques such as principal component analysis, or more advanced techniques such as decision tree forests. These approaches aim to determine the state of health of anchor caps from the analysis of acoustic signals, providing a reliable diagnostic for the assessment of these parts of engineering structures.
This development could have major implications for the preventive maintenance and sustainability of cable infrastructures, by giving us a reliable and accurate method for assessing cable state.

Influence of velocity changes on acoustic emission monitoring of masonry walls under diagonal compression load

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Due to the non-destructive character and high sensitivity of the method, acoustic emission (AE) has great potential in damage detection and assessment in masonry structures exposed to, e. g., seismic loads. However, the highly heterogenic nature of the masonry structures and the low density cause high attenuation and distortion of the signal. Additionally, localization of the AE events is challenging because the AE wave propagates through various masonry constituents (bricks and mortar joints) with different velocities.

In this study, we present the preliminary results of the AE analysis collected during a diagonal compression test of a 1.19 x 1.23 m2 masonry wall. Before the loading, we installed a dense array of sensors in three different setup configurations to evaluate the velocity profiles in different directions (vertical, horizontal) and with different numbers of brick-joint-brick interfaces (three to five). Based on the ultrasonic pulse velocity measurements and estimated attenuation profiles, we chose the instrumental setup for the loading part of the experiment.

During loading, a brick failure occurred, resulting in damage accumulation near the top of the wall and deviating from the anticipated shear failure mode. AE sensors detected this damage accumulation before the brick failure became visible. In this contribution, we present the attempt to locate the AE events recorded during the diagonal compression loading and the analysis of the influence of different velocities on the accuracy of damage localization of the acoustic events.

Ultra High Preformance Concrete Mechanical Behavior and Failure Mechanisms Monitored by Acoustic Emission

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Acoustic Emission (AE) monitoring is widely recognized as an effective method for analyzing the mechanical behavior of concrete structural elements. It offers valuable insights into cracking and failure mechanisms, capturing details of both visible and internal cracks. The failure process of concrete involves crack nucleation and propagation, driven by various mechanisms. Understanding the mechanical performance of Ultra-High-Performance Concrete (UHPC) and Ultra-High-Performance Fiber-Reinforced Concrete (UHPFRC), particularly the role of fibers, necessitates a thorough investigation of their cracking behavior and failure mechanisms using AE monitoring.
AE monitoring offers the advantage of assessing damage before it becomes visible. This damage may occur in the concrete matrix, the steel fibers, or at the interface between these components. By characterizing the AE activity of the concrete matrix and fibers separately, these signatures can be identified within the composite's AE signals. The remaining AE events can then be attributed to interactions between the composite's constituents. For this study, the parameters most crucial for classifying failure mechanisms were counts, duration, rise time, and count to peak (PCNTS). Initially, the AE signatures of two primary failure mechanisms—the concrete matrix and the fibers—were established. Subsequently, the AE signatures of fiber debonding and pullout were indirectly determined by monitoring AE from the composite materials (UHPFRC). The results of simultaneous AE monitoring used to estimate damage evolution during flexure tests, were analyzed and compared across UHPC systems incorporating two types of steel fibers:
straight fibers and microfibers, as well as plain concrete. AE monitoring successfully identified active mechanisms behind each AE event, including matrix fracture, fiber fracture, and fiber pullout. These mechanisms were confirmed through statistical analysis of AE data and direct fractographic observations. This approach demonstrates the effectiveness of AE monitoring in distinguishing and understanding failure mechanisms in UHPC and UHPFRC systems, providing critical insights into their mechanical behavior.

EXHIBITORS