Energizing the **Future** with **Composites**

جامعة الملك عبدالله للعلوم والتقنية
King Abdullah University of Science and Technology

Mechanics of Composites for Energy and Mobility

KAUST Research Conference
June 12-14, 2023
Building 19, Level 3, Hall 1-3
Organizers:
Prof. Gilles Lubineau,
Prof. Mani Sarathy.

Conference Agenda

12 June 2023

7:30	Networking Breakfast.
8:30	Opening Speech.
8:45	Executive Panel.
9:15	Coffee Break.
	SESSION 1: *"Integrity Management of Pipes."*
9:45	Andreas Echtemeyer: "*Integrity management of composite pipes*"
10:15	Chantz Denowh: *"Technology Advances for the Integrity Management of Spoolable Composite Pipelines"*
10:45	Chris Worrall: *"Making the next generation RTR pipe connections a reality"*
11:15	Shehab Ahmed: *"Sensing and ML Based Domain Inversion for Metallic and Non-Metallic Pipeline Inspection"*
11:45	Lunch, Campus Diner.
13:15	Enercomp Round Table.
14:00	Coffee Break.
	SESSION 2: *"Large Scale Composites."*
14:30	Peter Davies: *"Fibres and composites for marine renewable energy"*
15:00	Anna Pridmore: *"Composite Repair and Renewal of Large Diameter Pipelines: 10 Years of Increasing US Market Adoption"*
15:30	Imad Barsoum: *"Computational Modelling of the Installation Process of a Semi-flexible Kevlar Reinforced Composite Liner in Offshore Pipelines"*
16:00	Ahmed Wagih: *"Towards tough and reliable adhesive joints"*
16:30	MCEM Lab Tour & Networking time.
18:30	Dinner, Al Marsa Restaurant.

13 June 2023

7:30	Networking Breakfast.
8:30	Keynote Lecture Lars Schubert: *“Review of SHM Technology”*
9:15	Coffee Break.
	SESSION 3: *”Monitoring and Inspection.“*
9:45	Michele Meo: *“Non-linear Ultrasonic and Thermal wave imaging methods for SHM and NDT of primary composite structures”*
10:15	Theodoros Loutas: *“SHM of Composite Structures - Future trends in the Digital Era”*
10:45	Dimitrios Zarouchas: *“Cyber-Physical Structural Assets: The need for multi-sensing strategies in composite aerospace structures”*
11:15	Ferri Aliabadi: *“Structural health monitoring technologies for life management of composite fuselage”*
11:45	Lunch, Campus Diner.
	SESSION 4: *”Multifunctional Composites.”*
13:15	Pedro Camanho: *“Development of co-axial structural batteries”*
13:45	Gilles Lubineau: *“High-sensitivity RFID sensor for structural health monitoring”*
14:15	Khaled Salama: *“Climate Surveillance in the IoT Era: A Mobile, Modular, and Wirelessly Communicating Weather Station”*
14:45	Nicolas Calvet: *“Upcycling Industrial Solid Waste into Value-added Ceramic Composite Materials”*
15:15	Coffee Break & Poster Session.
16:15	SASCOM Panel.
17:00	MCEM Lab Tour & Networking time.
18:00	Dinner, Al Sayeed. Thuwal.

14 June 2023

7:30	Networking Breakfast.
8:30	Keynote Lecture Nikhil Verghese: *"Thermoplastic Composite Solutions for Opportunities in the Changing Energy Landscape"*
9:15	Coffee Break.
	SESSION 5: *"Composites for Hydrogen."*
9:45	Mani Sarathy: *"Composite Material Needs for the Hydrogen Economy"*
10:15	Abderrazak Traidia: *"Modelling hydrogen-induced rapid decompression damage in multilayer polymer liners"*
10:45	Fabienne Ellington: *"The Role of Thermoplastic Composite Pipelines in Offshore Hydrogen Transport"*
11:15	Closure Keynote Lecture Mohammad Al Tayyar: *"Advancing Sustainability: efficient applications for Hydrocarbon utilization"*
11:45	Lunch, Campus Diner.
13:15	Core Lab Visit.
16:00	Jeddah Historical Center.
	Closing Dinner in Jeddah.

Content

Content

Foreword

Composites have emerged as a key driver of innovation across industries, and Saudi Arabia is not far behind in recognizing their potential. With Vision 2030 in place, Saudi Arabia aims to further streamline its position as a major player in the production of composite materials. By leveraging its competitive advantage in high-volume industries such as energy, civil, and transportation, and high-technology markets such as aeronautics and space, Saudi Arabia seeks to fuel its economy with new opportunities. As such, it becomes necessary for academia, industry, and government institutes to come together and support this transformation. A scientific event that brings all parties under one roof will be beneficial for everyone involved. It will provide a platform to exchange ideas, share knowledge, and collaborate on new projects that can drive sustainable growth while enhancing Saudi Arabia's global competitiveness.

Drawing inspiration from the success of previous workshops (CEMAM in 2013, COMINT in 2015, FUTURECOMP in 2021), the Mechanics of Composites for Energy and Mobility Laboratory is organizing a research conference in the field of composite materials under the theme of "Energizing future with Composite". This conference will bring together distinguished academics, engineers, and industrial partners to discuss the latest advancements in relevant topics. These includes:

- Composites for Hydrogen
- Composites for Oil and Gas
- Composites for Wind and Solar
- Monitoring and inspection of composites structures

Organizers,

Prof. Gilles Lubineau (KAUST, Saudi Arabia)
Prof. Mani Sarathy (KAUST, Saudi Arabia)

Energizing the **Future** with **Composites**

The Composite Lab organized a KAUST Research Conference in the field of Composite Materials for Energy applications. The conference aims to attract a wider research community working in the areas of new technologies in the energy fields:

- Composites for Hydrogen
- Integrity Management of Pipes
- Large Scale Composites
- Monitoring and Inspection
- Multifunctional Composites
- Composites for Hydrogen

The topics of interest involve advanced concepts in experimental and numerical approaches for composites analysis, new inspection technologies for non-metallic structures, clean energy, sustainability of composite materials, and other new advances in composites of energy and mobility.

energizingcomposites.kaust.edu.sa

Organizers

Conference Organizers.

Prof. Gilles Lubineau
Prof. Mani Sarathy

Conference Scientific and Technical Committee

Abderrazak Traidia	Researcher in Saudi Aramco
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King's Vision

"In the name of God, Most Gracious, Most Merciful.

Based on Islam's eternal values, which urge us to seek knowledge and develop ourselves and our societies, and relying on God Almighty, we declare the establishment of King Abdullah University of Science and Technology, and hope it will be a source of knowledge and serve as a bridge between people and cultures.

We also hope that it delivers its humane and noble message in an ideal environment, with the help of God and the minds and the ideas of enlightened people, who will participate in this educational mission without discrimination.

In keeping with the traditions of the golded age of Arab Muslim civilization, we have established an endowment, from which we only wish God's blessings, so that this institution maybenefit the citizens of this beloved country, which is the cradle of Silam, and benefit all mankind.

I pray to God to make this University a "House of Wisdom", a forum for science and research, and a beacon of knowledge for future generations.

God bless you all."

King Abdullah bin Abdulaziz Al-Saud (1924 – 2015)

Vision 2030

A VIBRANT SOCIETY
With Strong Roots
With Fulfilling Lives
With Strong Foundations

A THRIVING ECONOMY
Rewarding Opportunities
Investing for the Long-term
Open for Business
Leveraging its Unique Position

AN AMBITIOUS NATION
Effectively Governed
Responsibly Enabled

جامعة الملك عبدالله
للعلوم والتقنية

King Abdullah University of
Science and Technology

Established in 2009, King Abdullah University of Science and Technology (KAUST) is a graduate research university devoted to finding solutions for some of the most pressing scientific and technological challenges in the world as well as Saudi Arabia in the areas of food and health, water, energy, environment and the digital domain. KAUST is a curiosity-driven, interdisciplinary problem-solving environment, with state-of-the-art labs, distinguished faculty and talented students.

KAUST brings together the best minds from around the world to advance research. More than 120 different nationalities live, work and study on campus. KAUST is also a catalyst for innovation, economic development and social prosperity, with research resulting in novel patents and products, enterprising startups, regional and global initiatives, and collaboration with other academic institutions, industries and Saudi agencies.

Vision

KAUST aspires to be a destination for scientific and technological education and research. By inspiring discoveries to address global challenges, we strive to serve as a beacon of knowledge that bridges people and cultures for the betterment of humanity.

Mission

KAUST advances science and technology through distinctive and collaborative research integrated with graduate education. We are a catalyst for innovation, economic development and social prosperity in Saudi Arabia and the world

We exist for the pursuit and advancement of scientific knowledge and its broad dissemination and benevolent application. We strive to enhance the welfare of society with a special focus on four areas of global significance – food, water, energy and the environment.

About

Mechanics of Composites for Energy and Mobility

The **Mechanics of Composites for Energy and Mobility Laboratory** (Composites Lab) is located at King Abdullah University of Science and Technology and is part of the Physical Science and Engineering Division. The Composites Lab started at KAUST in 2009 and is an integrated environment for composite science combining modeling and experimental expertise in a single working environment.

Our laboratory expertise incorporates three main areas:

- Developing advanced materials.
- Understanding and predicting the integrity of materials and structures.
- Advancing modeling and computational techniques.

A project at the Composites Lab is characterized by the amalgamation of experimental and computational/modeling mechanics and encompasses people with very different backgrounds to ensure we capture all aspects of these complex problems. In the Composites Lab you will find skills ranging from theoretical mechanics, applied mathematics, computer science to material science and chemical engineering. Our researchers are connected by their common passion for the fascinating potential of composite materials.

The Composites Lab develops and authenticates techniques to achieve better designs of composite material based structures. Much of this research is done in close cooperation with major industrial partners. This ensures a high level of applied research based on advanced theoretical concepts.

About

SAUDI ARABIAN SOCIETY FOR **COMPOSITE MATERIALS**

The Saudi Arabian Society for Composite Materials (SASCOM) aims to facilitate strong collaborations between scientists, engineers, educational and industrial partners interested in the study, manufacture and use of composite materials and structures.

Vision
SASCOM aspires to be the independent facilitator for empowering collaborative activities in the field of composite science and technology among scientists and engineers in the academia and industry of the Kingdom of Saudi Arabia. We strive to provide a dynamic and high-level network of experts who can disseminate knowledge about composite materials that provide societal and economic impact in Saudi Arabia.

Mission
SASCOM encourages the knowledge exchange, collaborations, educational offer about composite science and technology in both national and international landscapes by connecting scholars, professionals, and experts from all over the world. We also support our partners either by directly providing experts on composite materials or by indirectly advising where to find the best experts.

@SaudiComposites @saudi.sascom548 sascom.org

About

ENERCOMP

Technology Consortium for Composites Performance in Energy Applications.

Performance and integrity management are the key challenge in Composites Deployment across the Energy value chain: Production, transportation, storage and use.

Vision
To increase confidence and enable further penetration of composites materials in the Energy sector by availing new technologies for for enhancing composite performance and integrity management.

Mision
To develop innovative integrity management solutions through collaborations with industry and academia by translating fundamental research into deployable technologies.

Fully aligned with RDIs, Sustainable Environment and Supply of Essential Needs, Energy and Industrial Leadership, Economies of the Future.

FOCUS AREAS

- **Inspection (NDT):** Development/adaptation of NDT solutions for damage detection in in-service composite pipes and vessels.
- **Sensing & monitoring (SHM):** Development and validation of multifunctional wireless sensors; Integration into composite structures (retrofitting and/or newly manufactured); Development of interrogation devices and data interpretation guidelines
- **Performance:** Development and validation of innovative toughening and strengthening technologies for composite structures. Integration of composites in energy applications at harsh environment and sustainable energy fields.
- **Digital Solutions:** Development and validation of numerical models to predict composite structure behaviour in O&G service. Digital solutions to use NDT/SHM data for decision-making.

Speakers

Andreas Echtermeyer

Professor in the Dept. of Mechanical and Industrial Engineering, Norwegian University of Science and Technology

Andreas Echtermeyer is Professor for composites and polymers in the Department of Mechanical and Industrial Engineering at the Norwegian University of Science and Technology (NTNU) Trondheim. He joined the university full time in 2008 after having been an adjunct professor since 2003. Previously he worked for Det Norske Veritas (DNV) as senior principal engineer in the section "Structural Integrity and Laboratories" and was responsible for composites and polymers in offshore applications. He continues to be a consultant for DNV. He received his PhD in Materials Engineering from the Massachusetts Institute of Technology and his Diploma in Physics from the Technical University of Munich.

He is author or co-author of more than 100 articles and more than 200 technical reports. He was the main contributor and responsible for the development of several of DNV's standards for composites. He has been project manager or responsible of many national and international research projects as well as industrial development projects.

Integrity management of composite pipes

Abstract

Composite materials are frequently used for pipes and pressure vessels onshore, offshore and downhole. They transport water, hydrocarbons, chemicals and hydrogen. Design standards exist and are being developed for new applications. A brief overview of standards for composite pipes will be given. However, good integrity management procedures, as known for metals, are still missing. This issue is addressed by the DNV led C-PIMS (Composite Pipeline Integrity Management) project.

This presentation gives an overview of recent work on Non Destructive Testing (NDT) combined with methods to evaluate the severity of the detected damage. Inspecting thick walled multi component composite structures is still a challenge and some promising results to solve this challenge are shown. Once damage is detected its influence on the strength and remaining lifetime needs to be evaluated. A finite element method based on fatigue progressive failure analysis will be shown. The results shall eventually be input for a digital twin of the components. While this work concentrates on offshore applications the results are general and can be applied for all structures.

Co- Authors: F Victor Maneval, Mohd Fadzil Bin Mohd Tahir and Philippe Noury

Chantz Denowh

Director of Destructive Testing at
ADV Integrity

Chantz has spent the last eight years conducting full-scale testing and analysis to develop and validate integrity assessments and remediation methods for the midstream oil and gas industry. At ADV Integrity, Chantz is the Director of the Destructive Testing Group and specializes in full-scale test design. Chantz also has expertise in the integrity assessment, inspection, and testing of composite pipe products and has led multiple joint industry projects in these areas. He is an active member of the American Petroleum Institute committees for the manufacture and integrity management spoolable reinforced plastic line pipe. Chantz received his B.S., M.S., and Ph.D. degrees in Mechanical engineering from Montana State University and is a licensed professional engineer.

Technology Advances for the Integrity Management of Spoolable Composite Pipelines

Abstract

Today's pipeline industry is facing new and growing challenges to keep aging infrastructure operational and transition to emerging fuels such as hydrogen and carbon dioxide. Existing carbon steel pipelines, often in use past their intended service lives, are not ideal for transporting these emerging fuels due to their susceptibility to hydrogen embrittlement and corrosion. The use of spoolable composite pipelines as either free-standing pipelines or in repurposing existing steel pipelines as pull-through liners will be an integral part of this transition. A current gap in the use of spoolable composite pipelines are commercially available non-destructive examination technologies and monitoring methods. This work begins to bridge this gap by reviewing current and future integrity management practices for composite pipelines. This includes considerations over the entire pipe life cycle from design and qualification testing, installation, and operation. Results from an inspection and monitoring test program are presented for microwave, fiberoptic, and acoustic emissions technologies. The feasibility of implementing these technologies is also discussed. The end goal of this research is to promote the growth of composite pipelines through improved integrity management practices.

Chris Worrall

Consultant at TWI

Chris is responsible for helping solve some of the problems TWI's Industrial Members face with exploiting the benefits of composite materials, using his experience and expertise to deliver composites joining, manufacture, processing and testing projects. Since the inauguration of the Non-metallic Innovation Centre (NIC) in 2019, Chris has been instrumental in providing non-metallic solutions for the oil and gas industry, and has played a key role in understanding the mechanical performance of non-metallic pipes, and developing innovative joining methods.

Chris holds a PhD in the field of impact of composite sandwich structures in addition to a BSc in metallurgy and materials science, and was a researcher in the Marinetech NW consortium, developing cost-effective composites for the oil and gas industry.

Making the next generation RTR pipe connections a reality

Abstract

In the Oil and Gas industry, there is a huge opportunity for replacing traditional metallic pipes with non-metallic alternatives, such as reinforced thermosetting resin (RTR) composite pipes, with the promise of significant cost savings achieved by eliminating corrosion. The NIC Foresight Review1 concluded that one of the medium-term gaps in the industry is the development of new connections and sealing systems for large diameter (>16") high-pressure (>1500 psi) applications.

The Non-Metallic Innovation Centre (NIC) is developing an innovative method for joining reinforced RTR composite pipes that has the potential to replace an adhesive joint and a sealing gasket, contributing to a more reliable joining solution for the oil and gas industry. The proposed solution is to replace the adhesive with a welded solution. Thermoset composites themselves cannot be welded in the same way their thermoplastic counterparts can, but a thermoplastic interlayer can act as both a joining element and a seal, if the right materials are selected and the welding process is process is carried out correctly. Welding thermoset composites is, however, not straightforward. Depositing the thermoplastic layer on the surface of the thermoset has to be carried out in a way that not only provides sufficient adhesion strength, but is also compatible with 16-inch pipe diameters. The approach adopted by the NIC is first to deposit a layer of thermoplastic onto both surfaces of the GRE components using a friction process. After trimming, the pipes and coupler can be joined in the field, again using a friction process or another welding process, such as induction welding. The process under development has already successfully joined RTR composite pipes of up to 200mm (8-inch) in diameter, and plans to extend the capability to accommodate 16-inch pipes.

Beyond the novelty of the approach that makes the welding of RTR pipes possible, the method under development can easily be automated, is less reliant on manpower expertise, and should therefore translate into more reliable connections over time. This paper aims to present some conceptual aspects of the technology, and share several attractive prospects for an increased productivity during the deployment phase and an improved reliability of the connection over its life cycle.

References

1. NIC, 2019: 'Foresight Review – Applications of Non-metallics in the Oil and Gas Industry'.

Shehab Ahmed

Professor and Chair of the Electrical & Computer Engineering, KAUST

Shehab Ahmed is Professor and Chair of the Electrical & Computer Engineering. He also holds a joint appointment as Professor of Energy Resources and Petroleum Engineering and is a member of the Ali I. Al-Naimi Petroleum Engineering Research Center (ANPERC).

His 24 year career is a mix of academic and industry appointments, the latter solely in the oilfield. Before joining KAUST in August 2018 he held appointments at Texas A&M University, Schlumberger Technology Corporation, Texas A&M University at Qatar and Oman Drilling Systems. He leverages his core expertise in electromechanics, energy conversion and applied control to address challenges across the energy domain.

Sensing and ML Based Domain Inversion for Metallic and Non-Metallic Pipeline Inspection

Abstract

Ferromagnetic pipelines are crucial for transporting fluids such as oil and gas. Nevertheless, they are prone to defects such as cracks and corrosion, which can jeopardize their integrity and lead to operational failures. To ensure safe and efficient operation, pipelines require regular inspection and maintenance. However, many of the existing inspection techniques have limitations. To address these challenges, we propose novel approaches that employ electromagnetic resonance coupling (Fig. 1) and inductive sensing (Fig. 2) for inspection and monitoring of pipeline defects. Inductive sensing has the additional advantage of eliminating the need for an excitation source and is unaffected by permanent magnet fields.

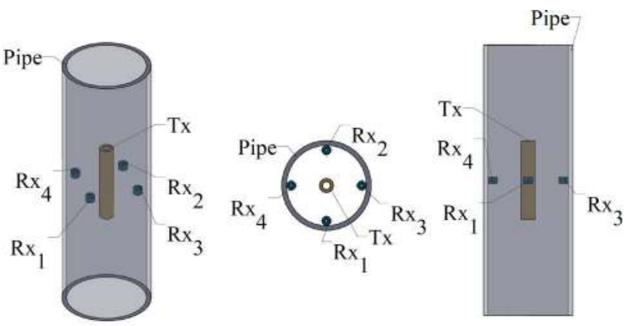

Figure 1: Pipeline inspection concept utilizing electromagnetic resonance coupling.

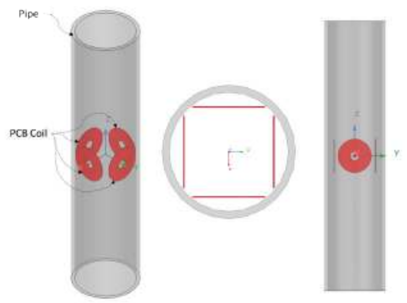

Figure 2: Pipeline inspection concept utilizing inductive sensing.

The interpretation of sensor measurements is difficult due to their intrinsic nonlinearity with respect to defect characteristics. We have developed various physics-based machine learning frameworks to carry out full domain inversion with very low latency, resulting in cross-sectional images as the sensing assembly progresses in the pipeline1-3. These images are then used to reconstruct the pipeline geometry. This physics-informed data driven approach helps identify patterns in complex data that may not be apparent to human operators. Extension of the methodology to non-metallic applications is a natural extension of this work.

References

1. G. Ooi, et al, SPE-211807-MS, ADIPEC 2022.
2. G. Ooi, et al, SPE-211805-MS, ADIPEC 2022.
3. G. Ooi, et al, SPE Annual Technical Conference and Exhibition, 2022.

Co- Authors: Tarek M. Mostafa, and Moutazbellah Khater, Hakan Bagci and Shehab Ahmed.

Peter Davies

Researcher at IFREMER

Peter Davies, FIMMM, is a researcher at IFREMER, the French Ocean Research Institute, and head of the Materials Laboratory. His research interests are centred on the durability of marine composites, fibre ropes, adhesives and elastomers.

Fibres and composites for marine renewable energy

Abstract

Fibres and composites are an essential part of developments to commercialize marine renewable energy.
Intervention at sea for maintenance or repair is expensive and high-risk; so long term reliability is a priority.
Polymer and composite components for marine energy recovery systems are numerous, and include mooring lines, dynamic cables, turbine blades (for tidal and floating wind) and various protection elements.
Work at IFREMER in recent years has focussed on the long term behaviour of these materials and this presentation will discuss two examples: synthetic fibre mooring lines and composite tidal turbine blades.

Fibre ropes can be considered as composites without the matrix, but in most marine applications the coatings applied to fibre yarns are critical to guarantee long term durability[1].For floating wind either HMPE (high modulus polyethylene) or nylon fibre ropes are employed, according to the type of floater, and both show a particular response under tensile loading. Their behaviour results from a combination of fibre properties, rope construction and loading history. These structures have received little academic attention but a thorough understanding of their properties is essential in order to design a reliable floating wind turbine.

The second example will discuss composite tidal turbine blades. A recent study funded by the EU Horizon programme, RealTide[2], provided us with the opportunity to perform tests on full size carbon fibre reinforced blades. This required design and manufacture of a specific test set-up, instrumentation of the blades (over 100 measuring points) and testing to failure. Results from tests and numerical modelling will be presented and alternative materials options will be discussed.

References

1. Y. Chevillotte et al. *Ocean Engineering*, 199, 107011 (2020)
2. P. Davies et al. *International Marine Energy Journal*, vol.5, 1, (2022)

Anna Pridmore

VP of Pipeline & Water Infrastructure
at Structural Technologies

Dr. Anna Pridmore is the Senior Vice President of Pipeline Infrastructure for Structural Technologies. She has 20 years of interdisciplinary experience working with advanced composites with a specialty in pipeline and civil infrastructure repair and renewal. Anna's passion is working with clients to add value to their asset management programs sharing her expertise in condition assessment, options analysis, technical support, engineering, specifications, and project oversight.

Anna has a doctorate in structural engineering from the University of California, San Diego, and is a Professional Engineer in California. She volunteers a lot of her time for the betterment of the profession, serving in leadership for American Society of Civil Engineers (ASCE) and on committees for American Society of Mechanical Engineers (ASME), American Water Works Association (AWWA), and Design-Build Institute of American (DBIA).

Composite Repair and Renewal of Large Diameter Pipelines: 10 Years of Increasing US Market Adoption

Abstract

The use of carbon fiber-reinforced polymer (CFRP) for repair and renewal of large-diameter pipelines in the United States has grown significantly over the past decade. This growth is nearly all connected to the benefits of composites, including long-term durability and trenchless construction process.

In the scenario where specific pipeline segments or overall pipelines are distressed, CFRP offers an elegant solution to deliver a fully structural 50-year service life extension with minimal construction disruption. The main drivers for its utilization are CFRP's trenchless installation method and that it has little to no impact on hydraulic performance. CFRP is chosen mainly to meet needs in areas of high congestion, either urban or within complex industrial and power plant environments.

Over the past decade significant advancements have also been made in market acceptance and adoption of composite repairs of large-diameter pipelines. In 2018 American Water Works Association (AWWA) published C305-18, a new standard for CFRP Renewal and Strengthening of Prestressed Concrete Cylinder Pipe (PCCP), which took nine years to develop. Along with the AWWA C305 standard, American Society of Mechanical Engineers (ASME) also has a code case in development for Internal Repair of Class 2 & 3 Buried Piping Using Carbon Fiber Composite Materials. The code case has been preceded by multiple US Nuclear Regulatory approvals of the use of CFRP for large-diameter pipeline renewal on an exemption basis, which have helped to drive increased adoption within the nuclear industry.

I will discuss the development of industry standards for composite repairs of large-diameter pipelines and how extensive research and development, full-scale testing, and field installations played a role. This includes materials, durability, and full-scale pressure testing. I will also focus on how composite repairs of large-diameter pipelines have impacted the longevity and reliability of critical infrastructure for large diameter pipeline owners, with multiple case histories highlighted. Workshop participants will learn about the options analysis process – both how and why CFRP is selected – and how the use of composites is continuing to grow for pipeline applications.

Imad Barsoum

Associate Professor, Mechanical Engineering, Khalifa University

Dr. Imad Barsoum is an Associate Professor in Mechanical Engineering and deputy director of the Advanced Digital and Additive Manufacturing (ADAM) research centre at Khalifa University, Abu Dhabi, UAE. He received his M.Sc. degree 2002 in Metallurgical Engineering from the University of Utah (USA) and his Ph.D. degree 2008 in Solid Mechanics from the Royal Institute of Technology (KTH) in Sweden. He has worked extensively with computational modelling and finite element analysis (FEA) in several industries and for various applications. He is author of many scientific journal and conference papers related to the subject and is frequently consulted by several industries for his expertise in FEA.

Computational Modelling of the Installation Process of a Semi-flexible Kevlar Reinforced Composite Liner in Offshore Pipelines

Abstract

Internal corrosion in pipelines is a persistent problem in the oil and gas industry. Available conventional rehabilitation techniques to prolong the life of the pipeline use an internal lining system to isolate the corrosive medium from the host pipe's inner surface. To overcome many of the shortcomings associated with conventional lining technologies, a Kevlar-reinforced flexible polymer composite liner (IFL) has been recently developed. This flexible liner was installed in several stages and is of interest in understanding the mechanisms behind the installation process and, more specifically, determining the forces and stresses at each stage of the installation process. In the current study1,2 a nonlinear finite element modelling framework is presented, as shown in Fig. 1, to simulate the full installation process of the IFL. The FE model is further validated using physical tests, making it a reliable tool for simulating the entire installation process composite liners and RTPs.

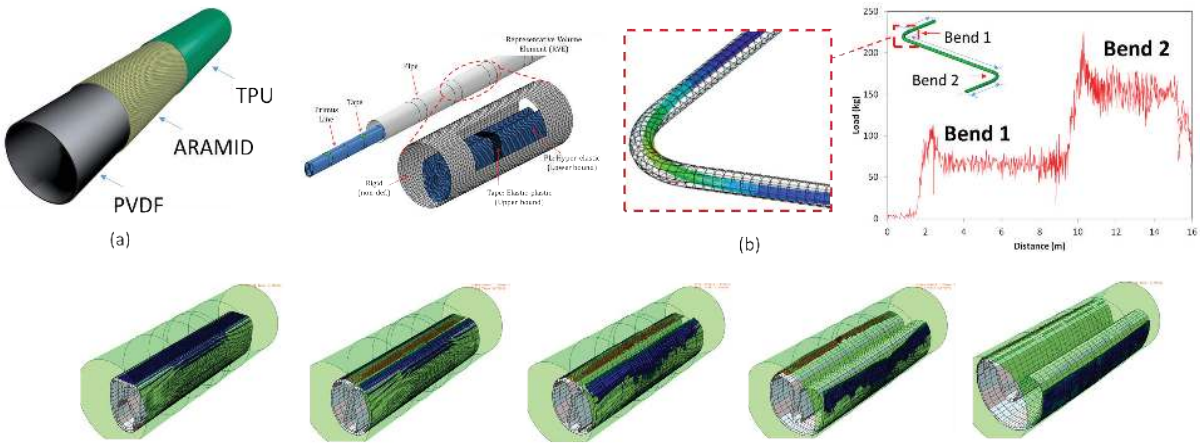

Fig.1: (a) The In-Field Liner (IFL), (b) pull-in of the tape wrapped IFL through a steel host pipe, and (c) inflation of the IFL inside the steel host pipe1.

References

1. Barsoum, I. et al. *J. Pipeline Syst. Eng. Pract.*, Vol. 9, Issue 4, (2018).
2. Fahed, M., et al. J. *Press. Vessel Technol.*, vol. 142, issue. 4, (2020).

Ahmed Wagih

Research Scientist at King Abdullah University of Science and Technology

Dr. Ahmed Wagih Abdel Hady a senior research scientist at the Mechanics of Composites for Energy and Mobility (MCEM) lab. at King Abdullah University for Science and Technology (KAUST). He obtained his Ph.D degree from Girona University, Spain in 2018. He was a postdoc fellow at Chalmers University of Technology until 2019. Finally, he joined KAUST as a postdoctoral fellow until 2022.

His research interest includes experimental investigation and analytical and numerical simulation of failure/fracture in composite materials/structures. During his career, he published more than 75 papers in highly-ranked journals, 3 US patents, and communicated more than 10 conference presentation.

Towards tough and reliable adhesive joints by microstructuring the adhesive layer

Abstract

With the increase of composite deployment in many applications such as aerospace, automotive, and pipelines (to build a pipeline and to be wrapped around corroded steel pipelines to ensure their mechanical integrity), the demand for reliable high-performance composite repair increases. In most cases, composite repairs are applied using adhesives, where an adhesive joint between the structure and the repair is formed. This technique is applied today, but as a temporary solution and for secondary structures. A major concern about adhesive joints is the low confidence of the joint due to low toughness and failure instability, which leads to catastrophic failure (once a crack initiated in the joint is propagated in an uncontrolled manner). **Our objective is here to introduce a new strategy to enhance the toughness and failure stability of adhesive joints by creating crack arrest features during crack propagation.**

Our strategy for enhancing the toughness was inspired by the biological adhesion adhesive system, the *Mytilus californianus* (one of the sea livings), where it exhibits excellent bonding with high adhesion strength and toughness in the deep water due to the presence of wisely distributed voids in the protein bonding layer. Therefore, we mimicked the microstructure of this biological adhesion system, where we embed sacrificial cracks inside the adhesive layer that allows the generation of nonlocal dissipative mechanisms, which increases the fracture energy of the interface. We demonstrated the toughening effects and controlled crack propagation of this bio-inspired adhesive system for the fundamental fracture toughness modes in static and fatigue, mode I [1] and II [2], and semi-structure, T-joint [3]. Moreover, we extended this toughening strategy to toughen thermoplastic adhesive tapes, where we achieved a large enhancement in the shear strength and toughness of the tapes with three times longer fatigue life.

References

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Lars Schubert

Department Head of Condition Monitoring and Test Services
Fraunhofer IKTS

As part of Dr. Schubert's scientific research, he worked on the theoretical basis for the interaction of guided waves with damage in fiber composite structures. Since 2005, he has been working with the Fraunhofer Institute for Ceramic Technologies and Systems IKTS, Dresden, where he currently heads the Department of Condition Monitoring and Test Services. Since 2012, he has also been the Chairman of the Condition Monitoring Technical Committee of the German Society of Non-destructive Testing.

Recent developments for monitoring and non-destructive testing of composites for energy and mobility applications

Abstract

The use of composite materials in energy and mobility applications has grown significantly in recent years due to their high strength-to-weight ratio and ability to withstand harsh environments. However, these materials can also be prone to damage, making regular testing and monitoring essential for ensuring safety and performance.

Typical damages in composites can include delamination, cracking, and matrix cracking. These types of damage can lead to a loss of strength and stiffness, making it important to detect them early on.

One of the most effective ways to detect damage in composites is to use non-destructive testing (NDT) and structural health monitoring (SHM) methods such as guided waves, acoustic emission, ultrasound and eddy current. Guided waves, for example, can be used to detect delamination within a composite structure, while acoustic emission can be used to detect damage that occurs during service. Ultrasound and high frequency eddy current are also commonly used NDT methods for composite materials.

The talk will introduce different methods for SHM and NDT used at Fraunhofer IKTS. Examples of energy applications where composite materials are used include storage tanks, composite vessels and composite materials for wind turbine blades will be shown. Examples of mobility applications include the use of composite materials in train boogies as well as parts of automotive applications. These applications require regular testing to ensure the integrity of the materials and to detect any damage that may have occurred during operation.

To successfully integrate sensors for SHM it is important to consider factors such as environmental influences and operational conditions of structure as well as sensor type, location and data analysis methods. This can be done through a procedure for development of customized monitoring systems, which considers the specific needs of the application. Some examples of integration of sensors will be shown during presentation.

In the future, collaboration between industry and research institutions will be crucial for the development of new and improved NDT methods for composite materials. This will include the development of sensors, data analysis methods, and integration of NDT into manufacturing processes.

Michele Meo

Professor, Department of Aerospace Engineering, University of Southampton

Dr. Michele Meo is a Professor of Aerospace Smart Materials and Structures in the Department of Aerospace Engineering at the University of Southampton. His research interests include the development of nonlinear ultrasonic based Non-Destructive and Structural Health Monitoring, impact detection system and smart multifunctional materials and their application in different engineering fields, such as aerospace vehicles, wind and civil structures. He has published over 300 journal and conference papers and is editor of various books on composite materials.

Non-linear Ultrasonic and Thermal wave imaging methods for SHM and NDT of primary composite structures

Abstract

Accurate monitoring and inspection of large aircraft composite materials is a complex on-going challenge. This keynote lecture will give an overview of the state of the art of ultrasonic and thermal wave imaging in NDT[1–3] and SHM[4–6] of aircraft composite structures in the research field and in industrial application. This will be accompanied by our latest developments of an impact detection system applied to a large commercial aircraft wing, and of nonlinear acoustic-ultrasonic based non-destructive and structural health monitoring systems for the detection and imaging of barely visible impact damage[7], creep, cracks and manufacturing defects in laminated materials[8].

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Theodoros Loutas

Associate Professor, Department of
Mechanical & Aeronautical Engineering,
University of Patras

Dr. Theodoros Loutas is an Associate Professor with the Department of Mechanical & Aeronautical Engineering of the University of Patras, Greece. He obtained his PhD in 2007 from the same department. His research interests lie in the areas of Structural Health Monitoring of Materials and Structures, Fracture Mechanics of composites etc. Lately, he has developed significant research work on the fracture behavior of composite materials and bonded joints and has pioneered some early works in the Remaining Useful Life prognostics of (composite) structures developing novel probabilistic Machine Learning algorithms. He has authored 75 papers in high-impact international peer-reviewed journals, 4 chapters in books and more than 90 papers in international conferences. His research has attracted significant funding from European (Horizon 2020, Clean Sky II, European Space Agency) as well as National programs. He reviews frequently for all major journals in the Composites and Structural Health Monitoring fields, and he is part of the prestigious Stanford list of the global top 2% most cited researchers in his field.

SHM of Composite Structures - Future trends in the Digital Era

Abstract

Prognostics Health Management (PHM) is an emerging field of engineering that aims to provide real-time monitoring and diagnosis of the health of engineering structures, such as bridges, airplanes, and wind turbines. The goal of PHM is to predict the remaining useful life of these structures and detect any potential faults or defects before they become critical. This is achieved by collecting data from sensors embedded within the structure and using machine learning algorithms to analyse the data and make predictions about future performance. PHM has the potential to significantly reduce maintenance costs, improve safety, and extend the lifespan of engineering structures. Towards PHM of modern structures and engineering assets Structural Health Monitoring (SHM) is a vital technology which provides a mature solution for the real-time monitoring of structures. Up to date though, SHM has almost exclusively involved damage diagnostics. Recenlty, we started researching on the feasibility of reaching the ultimate level of SHM i.e. the Remaining Useful Life prognostics, where we attempt to provide probabilistic estimates of the time to failure, based on SHM data [1,2]. Highlights of this research are the focus of this presentation.

A methodology that leverages SHM data from different sensing technologies relies in several parallel activities from damage detection and localization to damage identification and severity assessment, sensitive-to-damage feature extraction processes, training methodologies, data fusion and remaining useful life predictions utilizing simple or sophisticated algorithms.

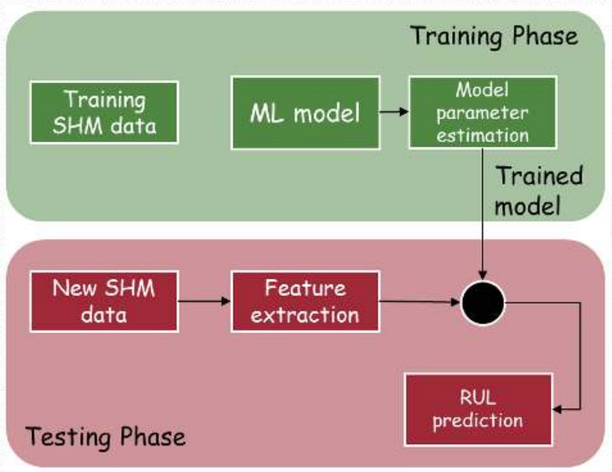

Figure 1: Methodology overview of SHM data-driven prognostics.

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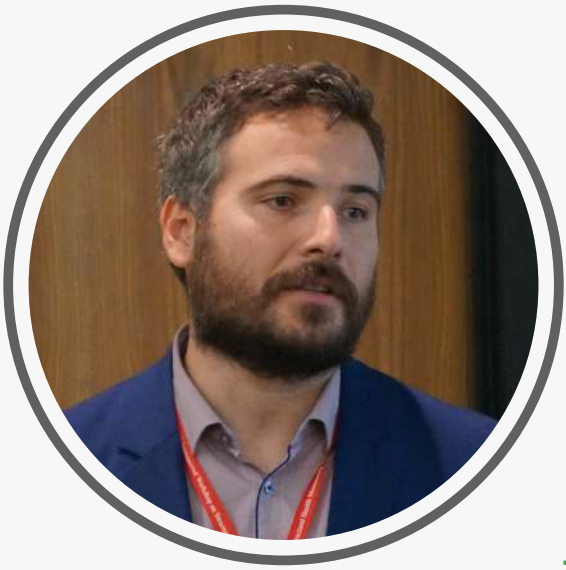

Dimitrios Zarouchas

Associate Professor and Director of the Center of Excellence in AI for Structures, Delft University of Technology

Dr. Dimitrios Zarouchas is Associate Professor and Director of the Center of Excellence in Artificial Intelligence for Structures at the Aerospace Engineering Faculty of Delft University of Technology, the Netherlands. His research interests focus on damage mechanics and fatigue analysis of composite structures, AI-based structural health monitoring and health management, structural reliability and stochastic finite element analysis. His main goal is the development and deployment of intelligent cyber-physical structural systems with state awareness capabilities for enabling real-time diagnostics and prognostics.
Dimitrios has published more than 80 journal publications and has been leading multi-million research and innovation projects, funded by EU and National schemes.

Cyber-Physical Structural Assets: The need for multi-sensing strategies in composite aerospace structures

Abstract

The core of a cyber-physical structural asset design is to ensure the availability of real-time information which will allow the performance of diagnostic tasks and future state predictions, enabling optimum operational decisions. The stream of real-time information can be achieved by the utilization of sensing technologies, in the form of permanently installed sensors - structural health monitoring (SHM). However, applying SHM in the aerospace industry has not yet fully matured1 and especially its application to composite structures is challenging. For a realistic aircraft maintenance scenario, one must consider the needs of the maintenance engineer at the final application: what type of health management information is required to make further maintenance decisions for an aircraft? This requires a full consideration of all four SHM levels; 1) damage detection, 2) its location, 3) damage type identification and 4) its effect on the structural integrity and even to expand damage prognostics. It is apparent that for composite structures, that exhibit complex failure mechanics, a multi-sensing strategy should be employed to fulfil this 4-step procedure[2]. Furthermore, in an in-service scenario, large complex composite aircraft structures will be monitored under realistic loading conditions, which requires reliable, probabilistic, and upscalable algorithms[3].

This paper explores the concept of multi-sensing strategy, its opportunities, advantages, and limitations and it demonstrates the first indications of how multiple SHM techniques and data fusion concepts can be incorporated by presenting a high-level design of a conceptual SHM system for a complex multi-stiffener composite aircraft wing structural component.

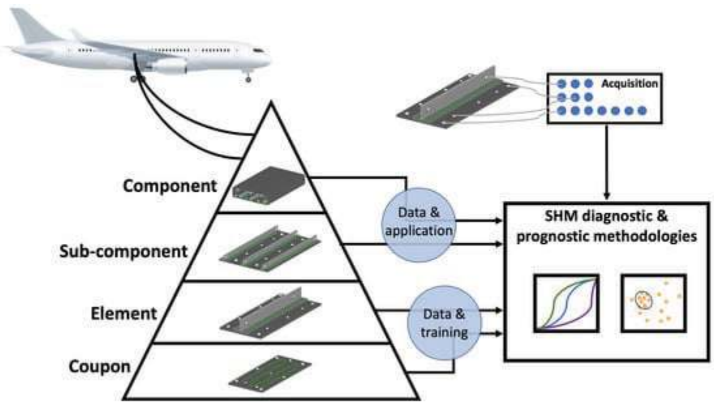

Figure 1: Structural health monitoring (SHM) pyramid approach for upscaling composite aircraft structures based on the building-block approach for structural testing[1].

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Ferri Aliabadi

Professor at Imperial College London

Ferri serves as a chair in aerostructures, Department of Aeronautics, Faculty of Engineering, Imperial College London. He joined the Imperial College in 2005 where he became the head of Department of Aeronautics (2009-2017). Prior to joining Imperial College in 2005, he was Professor of Computational Mechanics, Director of Research and the Director of Aerospace Engineering at Queen Mary, University of London (1997-2004) and Reader and Head of Damage Tolerance Division at WIT, Southampton (1987-1996), Ben Franklin Scholar, PA, USA (1986), Research Fellow, Aero and Astro, Southampton University (1984-86). In the last decade, he pursued research and development in Structural Health Monitoring (SHM) for composite airframe, collaborating with Airbus and Leonardo and funded by EU. He was a principal investigator of Clean Sky projects (SMASH and SCOPE), and a project coordinator of SHM platform in the wing structure of SARISTU. He was also a principal investigator of Clean Sky 2 projects (core partnership with SHERLOC) to develop the next generation of smart (highly-sensorised) composite airframe. He has published 450 papers in leading international journals and 62 books related to experimental and computational methods in solids and structures. He was the Editor in Chief of 6 international journals, currently the Editor in Chief of International Journal of Multiscale Modelling, book series of Experimental and Computational Methods in Solids and Structures, and an editorial board member of 8 international journals. He is a recipient of several awards, including Distinguished Achievement Medal.

Structural health monitoring technologies for life management of composite fuselage

Abstract

The presentation will present a combine approach to advanced Structural Health Monitoring (SHM) and smart repair technologies with a probabilistic design philosophy, and hence to develop new maintenance concepts to reduce the direct operative costs without lowering the operational safety of a composite fuselage[1-7].

The main four parts of the presentation include:

- The design, manufacture and test of composite structures with dedicated SHM sensors giving reliable information on the health of the structure.
- The development of advanced technical capabilities for making the integration of sensors in modern composite structures practical and efficient so as to facilitate industrialization.
- The development of a methodology that comprises of advanced large scale modelling tools, validated by structural testing, which use/process the sensor signals to predict the residual strength of a damaged structure.
- The development and experimental validation of a probabilistic method that leads to reduction of maintenance costs during service life.

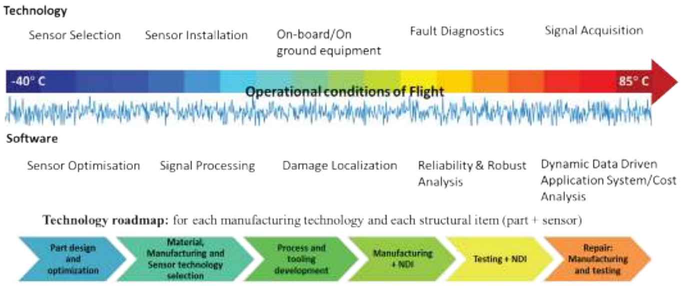

Figure 1: SHM Road Map1.

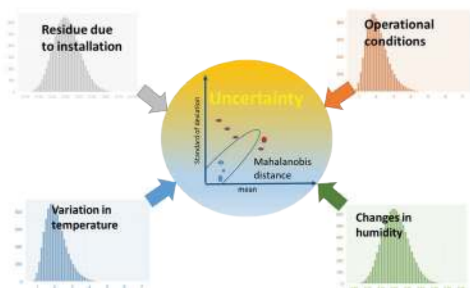

Figure 2: Uncertainty quantification for SHM Damage Detection.

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Pedro Camanho

Professor at the University of Porto

Pedro Camanho (FRAeS) received his PhD in Composite Materials from the Department of Aeronautics, Imperial College London, UK, in 1999. In the same year he joined the Institute of Mechanical Engineering and Industrial Management as Director of the Structural Integrity Unit and the Department of Mechanical Engineering of the University of Porto as Assistant Professor. Since 2014 he has been Full Professor at the Department of Mechanical Engineering of the University of Porto. Pedro Camanho is the President of the Associated Laboratory in Energy, Transportation and Aeronautics, and member of the Editorial Board of multiple international journals. The main research interests of Pedro Camanho are the mechanics of deformation and fracture of advanced polymer composite materials, and new concepts for lightweight composite materials and structures for aerospace applications such as hybrid, nano-structured, multi-functional, variable-stiffness, morphing, energy-storage and ultra-thin composites. Pedro Camanho was Visiting Scientist at NASA-Langley Research Center, and at the U.S. Air Force Research Laboratory. He was Visiting Professor at Imperial College London, École Normale Supérieure de Cachan, Cambridge University, and Brown University. Pedro Camanho is the recipient of the 2006 NASA - H.J.E. Reid Award for Outstanding Scientific Paper. He also received the 2020 Excellence in Research Award of the University of Porto, and the Career Award from the Portuguese Society of Fatigue and Structural Integrity.

Development of co-axial structural batteries

Abstract

A new all-solid-state structural energy storage device, which integrates a Na^{+}-based ferroelectric glass electrolyte with metallic electrodes and current collectors and thin-ply carbon-fiber laminates [1] to create a coaxial multifunctional beam, is proposed. This new design optimizes beam-type structures of general cross-sections by incorporating an electrochemical system capable of storing electrical energy, while also acting as a load-carrying element with appropriate mechanical performance. Electrochemical testing has demonstrated its ability to perform three-minute charges to one-day discharges (70 cycles), as well as long-lasting discharges (>40 days at 1 mA), with an energy density of 56.2 $Wh.L^{-1}$ and a specific energy of 38.0 $Wh.kg^{-1}$, taking into account the total volume and weight of the structural cell [2]. Mechanical tests have also shown that the coaxial structural battery can withstand severe inelastic deformation without affecting its functionalities, see figure 1. Additionally, the absence of alkali metals and liquid electrolytes make this coaxial structural battery a safe and viable alternative for energy storage in applications where traditional lithium-ion batteries may not be suitable. However, micro-CT scan, see figure 2, performed on mechanically tested coaxial structural batteries revealed some drawbacks of this innovative configuration: i) the granular nature of the proposed electrolyte does not guarantee any mechanical contribution to axial tensile loads, and ii) the metal-carbon interface was observed to be the bottleneck for the structural integrity of the beam-type battery. These results motivate two parallel research lines: the evaluation of the mechanical and electrochemical properties of Li-free all-solid-state electrolytes identifying the Nasicon as the most suitable candidate, and the mechanical characterization and functionalization of metal-carbon interfaces.

Figure 1: Beam-type structural battery loaded in three-point bending.

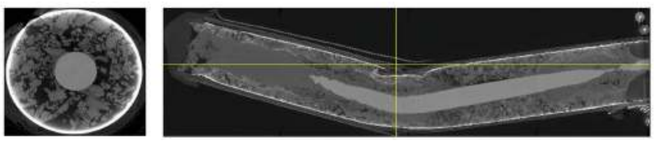

Figure 2. µCT scan: (a) Transverse section, (b) axial scan of mechanically tested structural battery.

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Co- Authors: Federico Danzi[b], Maryam Niazi[b]

Gilles Lubineau

Professor at King Abdullah University
of Science and Technology

Prof. Gilles Lubineau is Professor of Mechanical Engineering at the PSE Division at KAUST. He is the Director of the Mechanics of Composites for Energy and Mobility laboratory, an integrated environment for composite engineering that he created in 2009 when joining KAUST.

Current research interests include: integrity at short and/or long-term of composite materials and structures, inverse problems for the identification of constitutive parameters, multi-scale coupling technique, multifunctional materials and modeling, nano and multifunctional materials and devices. He collaborates with many industries from a variety of sectors including the Energy sector, the Transportation sector or the Consumer electronics sector.

Before joining KAUST, Prof. Lubineau was a faculty member at the École Normale Supérieure of Cachan, and a non-resident faculty member at the École Polytechnique, France. He also served as a visiting researcher at UC-Berkeley. Following his "aggregation" in theoretical mechanics, Prof. Lubineau earned a PhD degree in Mechanical Engineering and an HDR from École Normale Supérieure de Cachan (ENS-Cachan).

He has authored over 200 journal and conference papers. His work covers a very wide expertise from Material Science to Composite Engineering and Computational Mechanics. Prof. Lubineau is an elected Member of the European Academy of Sciences and Arts.

High-sensitivity RFID sensor for structural health monitoring

Abstract

Embedded sensors are one of the most effective and accurate methods for monitoring large structures. Composite structures such as pipelines, tanks, aircraft, ships, and ground vehicles confront some challenges with embedding strain sensing systems incorporating strain gauges or optical fibers that can introduce delamination, cracking and structural failure of the host in addition to the need for dedicated and expensive equipment

We present an RFID sensing technology that allows wireless transmitting of data and power while addressing issues associated with host/composite material integrity, combined with high sensing sensitivity. We develop a flexible and thin sensor based on LC circuit where the capacitance is considered a sensing unit4-5. We introduce a controlled network of cracks in the parallel electrodes and benefit from the way these cracks modify the electromagnetic wave penetration inside the parallel plate capacitor1-2. The tailored network of cracks creates a piezoresistive effect that leads to a transmission line behavior of the capacitance resulting in a tremendous increase in sensitivity3. This unconventional change in capacitance of the LC oscillator allows a large shifting in resonance frequency of the flexible circuit, producing a sensitive wireless strain sensor with a Gauge factor of 50 for less than 1% strain.

A few centimeters away from the sensor, the frequency shift of the sensor under strain is read passively through an external read-out system (antenna) by simple frequency sweeping. Eliminating wires, power source, and electronic chip from the sensor body allow the sensor to be integrated easily inside the composites materials while maintaining the materials' mechanical performance. The experimental results show the ability of our cracked wireless strain sensor to detect small strain signals through the composites structure with high accuracy. The developed sensor is intended to be a part of a wireless sensor network (WSN) for monitoring large composites structures.

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Khaled Salama

Professor at King Abdullah University of Science and Technology

Dr. Salama, a Senior Member of IEEE, is a proficient electrical engineer with degrees from Cairo University, Egypt (B.S., 1997) and Stanford University, USA (M.S., 2000; Ph.D., 2005). Since 2009, he's been at King Abdullah University of Science and Technology (KAUST), Saudi Arabia, where he initially served as Founding Program Chair, associate dean of students and director of KAUST sensors initiative. He published 350 articles and 45 U.S. patents, primarily focusing on low-power mixed-signal circuits for intelligent fully integrated sensors and neuromorphic circuits.

Climate Surveillance in the IoT Era: A Mobile, Modular, and Wirelessly Communicating Weather Station

Abstract

The increasing need for effective climate monitoring necessitates innovative and robust solutions. This paper proposes a self-powered, solar-operated weather station that integrates Internet of Things (IoT) sensor devices and a programmable system-on-chip (PSoC) to overcome the limitations of traditional environmental monitoring stations. The system is designed around three core principles: mobility, modularity, and wireless communication. It features a weatherproof design and a broad array of sensors for comprehensive data collection, including temperature, humidity, atmospheric pressure, dust concentration, wind speed, and specific gas concentrations. The station's modularity is highlighted by its design that allows for straightforward sensor swapping. Experimental trials attest to the system's operational autonomy, resilience, adaptability, ease of assembly, and cost-effectiveness, proving its potential for wide-scale application in combating climate change.

Nicolas Calvet

Assistant Professor at Khalifa University

Dr. Nicolas Calvet is an assistant professor in the Mechanical Engineering Department at the Masdar Institute, Khalifa University in Abu Dhabi, United Arab Emirates (UAE) since 2013. He is the founder and chair of the Masdar Institute Solar Platform (MISP), the first facility in the UAE dedicated to concentrated solar power (CSP), thermal energy storage (TES), and atmospheric water generation (AWG) Research Development & Demonstration. In parallel, he is the co-founder and CEO of Seramic Materials Limited, a UAE-based startup company, pioneer in recycled ceramics. Finally, he is representing the UAE at the SolarPACES Executive Committee, a technology collaboration program from the International Energy Agency (IEA).

Dr. Calvet has a BS in Physics and an M.S. in Sciences & Technologies (Solar Energy) from the University of Perpignan Via Domitia (UPVD) in France. Then he obtained his Ph.D. in Engineering Sciences (Energy and Environment) in 2010 at the PROMES CNRS Laboratory in France. In 2011, he joined the National Renewable Energy Laboratory (NREL) in the USA working as a postdoctoral researcher in the CSP group. In 2012, he worked at the CIC Energigune Energy Cooperative Research Centre in Spain in the TES group before moving to Abu Dhabi.

Upcycling Industrial Solid Waste into Value-added Ceramic Composite Materials

Abstract

Every year, more than 1 billion tons of industrial solid waste are generated worldwide leading to waste management and environmental issues as well as significant cost of disposal supported by industry. During his Ph.D., Dr. Calvet explored the opportunity to reuse industrial solid waste as a source of secondary materials to develop composite ceramic materials. Ten years later, he created Seramic Materials Limited[1], a UAE-based Start-up Company that develops circular economy solution to upcycle industrial solid waste into value added ceramic products.

Fig 1: Pictures of (a) ReThink Seramic Flora, the world's first 100% recycled material for high temperature thermal energy storage applications commercialized by Seramic Materials Ltd., and (b) 25 tons of Flora tested in StorEnergy's pilot located in Plataforma Solar de Almeria (PSA) in Spain

Different industrial solid waste are mixed together to obtain the desired properties depending on the final application in the technical ceramic and construction materials markets. ReThink Seramic – Flora is the first commercial product of Seramic Material[2], which was developed for high temperature thermal energy storage (TES) up to 1250˚C in renewable energy such as solar PV, wind, or concentrated solar power but also for waste heat recovery in industry and excess grid electricity thermal energy storage (ETES). This composite material was successfully tested in real conditions in a prototype in Plataforma Solar de Almeria in Spain by StorEnergy Doo (Serbia).

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2. Masdar News Website on February 2023.

Nikhil Verghese

Corporate Fellow at SABIC, T&I

Dr. Nikhil is a Corporate Fellow in SABIC Corporate Technology and Innovation (T&I), located in KSA. He report to SABIC's Executive Vice President of T&I and is responsible for the polymer-related activities that include incubating new platforms and products, assessing key industrial partnerships and potential acquisitions, establishing relationships with universities (especially in Saudi Arabia), mentoring and championing T&I talents. He joined SABIC in 2012 after spending 12 years at The Dow Chemical Company, creating and launching FORTEGRA™ (rubber-toughened epoxy and epoxy vinylester) and VORAFORCE™ (epoxy and polyurethane) for composite manufacturers. At SABIC, he helped to establish Advanced Composites Center of Excellence in Geelen, The Netherlands (2015-2018), and to develop continuous fiber-reinforced thermoplastic (UDMAX™). He received his M.S. and Ph.D. degrees in Material Science and Engineering from Virginia Tech in 1999 specializing in carbon fiber composites.

He has published 48 journal papers, co-authored some 90 conference presentations, chapters in 4 books, and contributed to 50 patents (filed and granted). He is currently serving as an adjunct professor at Rice University's Department of Material Science and NanoEngineering since 2020 and is a member of the technical Industry Advisory Board in Macromolecules Innovation Institute of Virginia Tech and Department of Material Science and NanoEngineering of Rice University.

Thermoplastic Composite Solutions for Opportunities in the Changing Energy Landscape

Abstract

Thermoplastic composites are increasingly being considered for large volume applications that involve replacing incumbent materials such as metals. Recent global and national goals around carbon neutrality and circularity, are creating transformational opportunities in market segments like Automotive where new energy powertrains such as hybrid or full electric eVs are quickly replacing the internal combustion engine. The Oil and Gas segment is also undergoing changes with clean energy sources such as natural gas and hydrogen requiring transportation and storage. These changes present exciting opportunities for fiber-reinforced thermoplastic composites (discontinuous, continuous fiber and hybrid systems) as they help drive light weighting, withstand aggressive exposure conditions that help reduce lifetime maintenance costs and last but not least, help reduce part assembly costs. Finally, the need to reduce secondary operations and the ever increasing pressure on sustainability, creates the perfect opportunity to explore the use of hybrid thermoplastic matrix composites for these applications.

This talk will therefore focus on how best to look at mass adoption of hybrid, structural thermoplastic composite systems that fundamentally combine geometric and processing flexibility of virgin or short/long fiber reinforced injection molded compounds together with strategic placement of continuous fiber tape or laminate based products to deliver the right cost-performance balance. Examples from Automotive and Oil and Gas & Hydrogen will be described with the ultimate goal of delivering part consistency at large production build volumes whilst having the flexibility to accommodate changes that the industry demands.

Mani Sarathy

Professor at King Abdullah University of Science and Technology

S. Mani Sarathy is a Professor of Chemical Engineering and Associate Director of the Clean Combustion Research Center (CCRC) at King Abdullah University of Science and Technology (KAUST). He has affiliations with the Mechanical Engineering and Environmental Science and Engineering programs at KAUST. He was also appointed as Senior Manager of Technology and Innovation at ENOWA Hydrogen in Neom from 2020-2022.

Dr. Sarathy was previously a Postdoctoral Researcher in the Combustion Chemistry group at the U.S. Department of Energy Lawrence Livermore National Laboratory.

He received his PhD and M.A.Sc. degrees in Environmental and Chemical Engineering at the University of Toronto and his B.A.Sc. in Environmental Engineering Chemical Specialization from the University of Waterloo. Mani Sarathy has been named a Clarivate Analytics Highly Cited Researcher three times.

His research interest is in developing sustainable energy technologies with decreased net environmental impact. A major thrust of his research is using chemical kinetic simulations to design fuels, engines, and reactors.

Composite Material Needs for the Hydrogen Economy

Abstract

Abundant and low cost renewable energy available in Saudi Arabia can be used to produce green hydrogen. Other forms of low-carbon hydrogen are also being envisioned from hydrocarbon and unconventional sources. To advance the hydrogen economy, a number of innovations are needed in H2 production and storage. Hydrogen production requires significant focus on electrolyzer manufacturing and materials to lower levelized cost of H2 produced. Storage and transport of hydrogen is required to lower the cost of hydrogen delivery.

This talk will highlight needs for composite materials in electrolyzers and storage facilities and how these may reduce overall levelized cost of hydrogen. The utilization of carbon materials derived from hydrocarbon pyrolysis and hydrogen will also be discussed.

Abderrazak Traidia

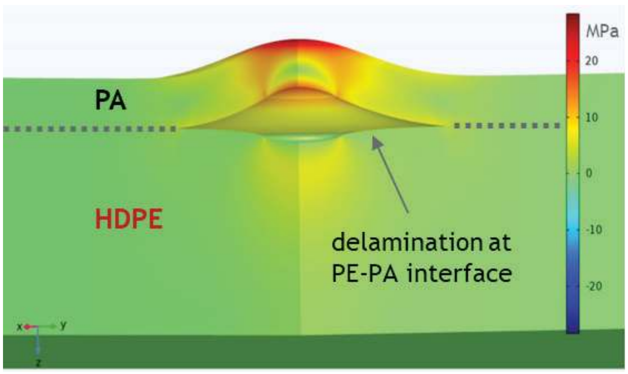
Science Specialist - Aramco R&D Center
R&D Program Lead – Composites for Energy

Abderrazak Traidia is an R&D Specialist at Saudi Aramco with expertise in mechanics of materials. He joined Saudi Aramco in 2012 and has actively contributed to establishing and leading multiple teams and R&D programs in the general field of asset integrity management with particular focus on hydrogen embrittlement of metals and polymer degradation in hydrocarbon service. He co-led the establishment of Saudi Aramco's Nonmetallic Innovation Center (NIC) in Cambridge (UK) in 2018 and is currently assigned to the Aramco Overseas Company in London (UK) managing partnership R&D projects in Europe in the field of polymer composites for energy applications. Abderrazak holds a PhD in Mechanical Engineering from Ecole Polytechnique (France). He represents Saudi Aramco in various RTO research boards and JIP/standards technical committees. He co-authored over 17 peer-reviewed publications and 25 conference proceedings. He is also a co-inventor for 13 Saudi Aramco granted patents.

Modelling hydrogen-induced rapid decompression damage in multilayer polymer liners

Abstract

Polymers and continuous-fiber composites are likely to play an important role in the development of a reliable infrastructure for hydrogen production, distribution, storage and use. Reducing gas permeation through thermoplastic liners is currently a hot research topic, particularly in pipe applications where multi-layer liners are being adopted as cost-effective permeation barrier solution in high pressure service. The rapid depressurization of a high pressure H2 equipment (pipes and pressure vessels) made of polymer composites, also known as rapid gas decompression (RGD), can lead to different types of damage such as cavitation, blistering, delamination or ultimately liner collapse. These damage mechanisms are mainly controlled by hydrogen desorption kinetics during decompression as well as the mechanical properties of the polymer/composite and interface strength. In an effort to progressively reduce cumbersome and costly RGD tests1 by reliable prediction models, the present work proposes a simple continuum diffusion-deformation-damage model applicable to rapid hydrogen decompression in multilayer polymer liners used in thermoplastic composite pipes and hydrogen tanks. Some initial comparisons with experimental work are also presented and the limitations of the current approach are highlighted with suggested routes for future developments.



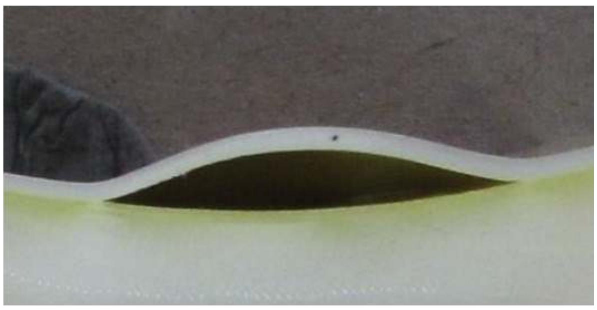


Fig. 1: Blistering damage in a multilayer PA-PE liner following rapid hydrogen gas decompression at 30 bar/min

References

1. API SPEC 15S, 3rd Edition, April 2022 - Spoolable Reinforced Plastic Line Pipe.

Co- Authors: Abdullah Shahrani

Fabienne Ellington

VP Middle East & Asia-Pacific at Strohm

With master's degrees in Fluid Mechanics and Hydrodynamics, Fabienne has over 25 years of experience in the Oil & Gas industry. Her roles have ranged from engineering and project management, commercial and regional management, specialising in SURF projects with EPCI type contractors. For the last 4 years, Fabienne has been overseeing the Asia-Pacific and Middle East region for Composite Pipe developer and manufacturer Strohm, as the new technology product turns the corner from development to commercialisation in Conventional and Renewable Energy markets.

The Role of Thermoplastic Composite Pipelines in Offshore Hydrogen Transport

Abstract

Adding to the ecological and geopolitical drivers that steer the energy transition away from oil and gas, three main drivers that promote the development of offshore hydrogen production include producing green hydrogen from solar and wind, taking the electrolysis offshore, and cost-effective offshore electrolysis. Green hydrogen is enabled by the continuous cost reduction of renewable power, improved efficiency, and reduced cost of electrolysis. Taking the electrolysis offshore can solve issues related to grid integration of offshore-produced electrical power, and new shore landings and onshore infrastructure (substations). Offshore electrolysis has less conversion loss, lower hydrogen transportation loss, lower capex (transporting energy by pipelines is cheaper than that by electrical cable; note that pipeline is cost effective, and can transport up to 10 times power than a high voltage electrical cable of similar size; high cost offshore electrical converter stations or substations are not needed).

Offshore green hydrogen will be developed via three concepts: (1) utilizing existing offshore infrastructure and retrofitting electrolysers to pilot new technologies, (2) new developments with centralized electrolysers located on stand-alone platforms, (3) new, large developments with decentralized electrolysers integrated in the wind turbine. Ultimately, the third concept will lead to the lowest cost of hydrogen production. This concept will be the basis for the industrialization of offshore hydrogen production with a standard 'island-mode' wind-turbine and integrated electrolyser that is connected with a hydrogen pipeline to an export pipeline to shore.

Fully-bonded Thermoplastic Pipe (TCP) technology is the ideal solution to connect the wind turbines, effectively replacing today's electrical array cables. TCP is a field proven and robust pipe construction and is insensitive to corrosion and hydrogen embrittlement. It has low permeation rate for hydrogen, long service life without maintenance, can be installed with simple, cost-effective and proven methods, and has a low total cost of ownership. My presentation will further expand upon the technical differentiators of TCP relative to other forms of pipeline. I will also explain about the advantages of decentralized offshore wind power generation and the role TCP can play in the infield transportation of hydrogen in such a scenario.

Mohammad Al-Tayyar

Program Director of the Oil Sustainability Program

Mohammad Al-Tayyar's career spans more than 20 years in the energy field. He held multiple technical and leadership roles within Saudi Aramco focused on process engineering, technology development and commercialization, new business development, strategy and joint venture management.

Mohammad is currently the Program Director of the Oil Sustainability Program. A program designed to create new and innovative applications for oil. He is a member of multiple committees within the Ministry of Energy ecosystem and has been focused on the program's implementation targets.

Mohammad holds a Bachelor of Engineering degree in chemical engineering from Vanderbilt University, and a master's degree in engineering & management from the Massachusetts Institute of Technology school of engineering and Sloan school of Management. He is an Eisenhower Fellow.

Advancing Sustainability: efficient applications for Hydrocarbon utilization

Abstract

Mohammed Al-Tayyar will highlight the importance of collaboration in advancing efficient technologies for energy access and use. In his presentation, Eng. Al-Tayyar will shed light on the Oil Sustainability Program (OSP) and its objective to develop, innovate, and sustain the role of hydrocarbons through showcasing the Program's different sectors (materials, transportation, and utilities) and enablers (policy and awareness, innovation, funds, and standards) who help support the Program's mandate.

Most importantly, Eng. Al-Tayyar will emphasize the critical role collaboration plays in advancing innovation of applications and efficiency of technology for the betterment of both local and global communities. An extension of this collaboration, is the ongoing efforts created between OSP and KAUST on multiple fronts ranging from technological advancements for a better mobility sector, to a composite consortium.

Panels

Opening Panel

The opening panel of the conference brings the academy together with the leaders from governmental institutions and energy companies. Today, there is an emerging need for non-metallic transition in oil and gas industry. Panellists will describe why this transition is required and their achievements with composites in the oil and gas industry. Their expectations from the research institutes and industrial partners will be discussed, to overcome the challenges and to fill the gaps they have experienced during the implementation of non-metallic solutions will be discussed.

- Abdulaziz Asiri
- Fahad Al-Dosari
- Abdallah Al Tamimi
- Abderrazak Traidia

SASCOM Panel

The Saudi Arabian Society for Composite Materials (SASCOM) aims to facilitate strong collaborations between scientists, engineers, educational and industrial partners interested in the study, manufacture, and use of composite materials and structures. The SASCOM panel of the conference brings the Academy and the industry together to discuss the role of the society in developing the composites field in Saudi. The panellists will discuss their expectations of what SASCOM will provide, and how to develop the landscape for the composites field in Saudi.

- Abduljabar Alsayoud
- Ammar Melaibari
- Majed Alrefae
- Nikhil Verghese

Abdulaziz Asiri

Engineering Consultant at ARAMCO

Abdulaziz Asiri holds a MSc Degree in Polymer Engineering from the University of Akron in Ohio on 2003 where his research thesis was focused on utilizing carbon fiber in sandwiched carbon composite panels for enhancing the impact resistance. Mr. Asiri has 25 years of industrial experience in Saudi Aramco where 19 years of them specialized on nonmetallic materials. During his work Mr. Asiri introduced new nonmetallic technologies to Saudi Aramco such as fire-retardant composite pipes in aboveground firewater application, composite pipe in aboveground hydrocarbon service, large diameter HDPE pipe replacing concrete flume, and composite lined carbon steel production tubing in downhole application. He developed internal materials specification standards, conducted failure analysis and materials selection of non-metallic materials in particular composite pipes, elastomer lining, subea flexible pipes, thermoplastic piping. Member of several international standardization committees API and ISO. Abdulaziz authored and coauthored over 20 technical papers in journals and conferences.

Fahad Al-Dosari

Head of Innovation & Technology Management at Oil Sustainability Program

Fahad has been the head of Innovation & Technology Management at the Oil Sustainability Program (OSP) since July 2021. In his critical role, Fahad is responsible for identifying OSP's development needs for the most in oil-demand applications across material, transportation, and utility sectors that align with the future sustainability approach. He builds the necessary capacity in emerging innovation by connecting with relevant entities and bridging the gap between academia and industry players to accelerate the adoption of innovative solutions. He is an active member of various committees and professional organizations within the energy ecosystem.

Fahad holds a Bachelor's degree in chemical engineering from KSU with over 12 years of enrich experience in oil and gas field. He began his career at SABIC Technology & Innovation in 2011 and held several technical and leadership roles during his tenure. His comprehensive professional background and technical expertise make him a valuable asset to the energy ecosystem.

Abdallah Al Tamimi

Manager Experimental R&D Technology & Innovation at ADNOC

Dr. Abdallah is the Experimental R&D manager in Abu Dhabi National Oil Company (ADNOC) who is also leading the ADNOC Research and Innovation Center (ADRIC).

Before being named the leader of ADRIC in 2023, Dr. Abdallah was responsible for a diverse portfolio of Technology projects addressing different challenges in the Upstream & Downstream operations. Thus, designed diverse R&D and technology strategies to achieve optimum operational efficiency and minimum emissions.

His primary area of expertise is assets integrity and non-metallics and is recognized as an active member in international communities on these subjects.

Dr. Abdallah graduated from the Petroleum Institute, Abu Dhabi, UAE, in Mechanical Engineering and received his MSc and PhD in Reliability Engineering from the University of Maryland, College Park, USA.

Abduljabar Alsayoud

Assistant Professor at KFUPM.

Dr. Abduljabar Alsayoud is an Assistant Professor at the Materials Science and Engineering Department at King Fahd University of Petroleum and Minerals (KFUPM). He received a Ph.D. in Materials Science and Engineering from The University of Arizona in 2017.

His expertise includes computational methods in materials science (DFT, Molecular Dynamics, KMC, CALPHAD), and design of advanced materials. He is also affiliated with the Interdisciplinary Research Center for Advanced Materials at KFUPM, focusing on polymer composites for energy transition. Abduljabar has led multiple research projects, including the design of palladium alloy membrane for hydrogen separation. Abduljabar is currently investigating the behavior of fiber-matrix interface at an atomic level for enhancing the performance and durability of composites applied in various industries. He has played a key role in establishing Materials Science and Engineering Department at KFUPM. He also served as the Director of Office of Cooperation with KAUST for two years, facilitating collaborations between institutions.

Ammar Melaibari

Professor at King AbdulAziz University

Dr. Ammar Abdulghani Melaibari is currently the Deputy Director for the Center of Nanotechnology & the Chairman of Mechanical Engineering Department at the College of Engineering, King AbdulAziz University.

His research interests are Material design and manufacturing processes with focus on nanotechnology; mimicking microstructure of biomaterial; modification of mechanical, chemical, and thermal properties of materials; development of manufacturing processes. His publications in several scientific journals in the fields of physics, material science, and engineering. He also has multiple US patent on new Composites materials. Dr. Ammar received Research Excellence Awards from Sigma Xi & Iowa State University, and King AbdulAziz University.

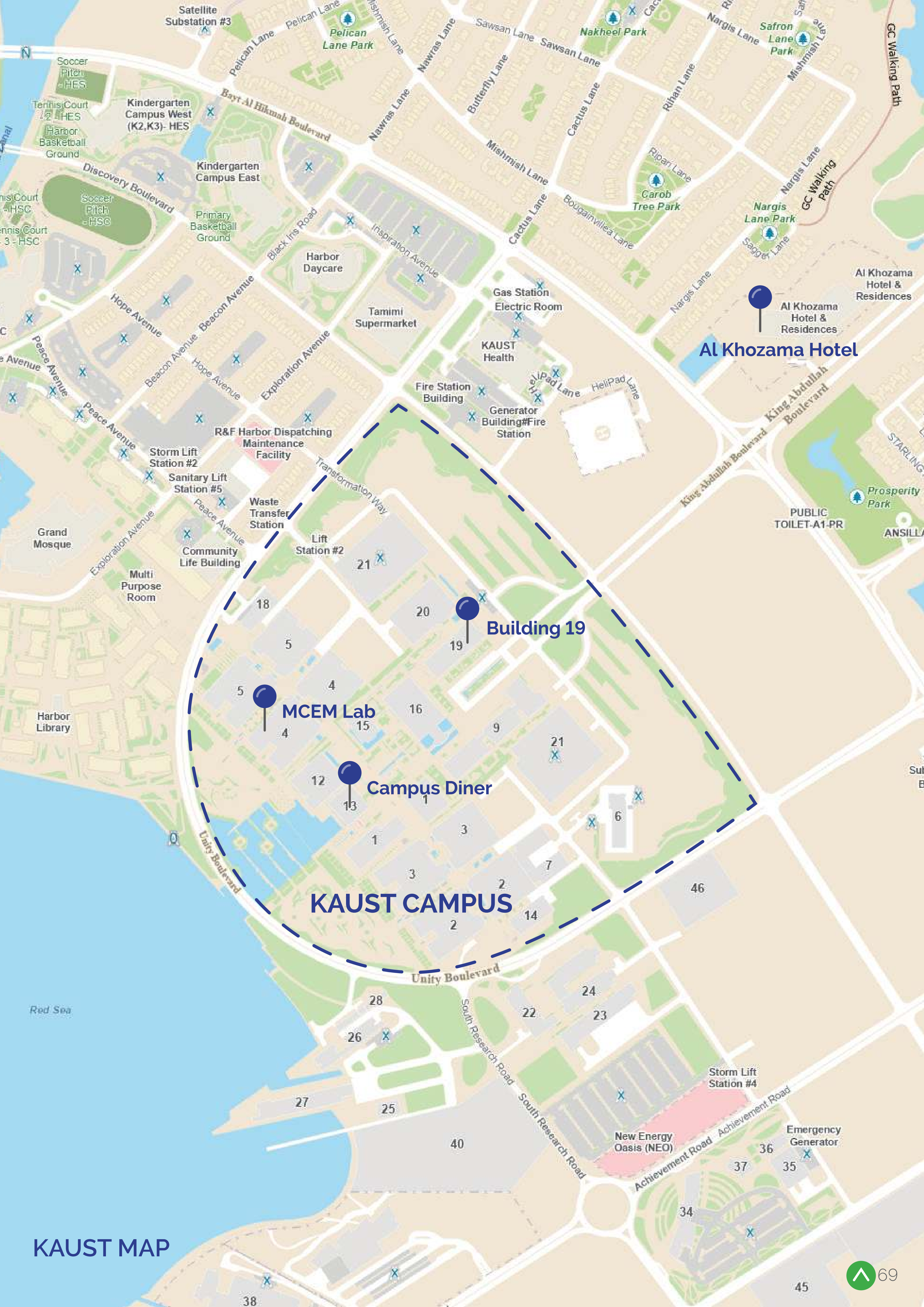
Majed Alrefae

Professor at Yanbu Industrial College

Majed A. Alrefae is an Assistant Professor at Yanbu Industrial College, Royal Commission for Jubail and Yanbu. He received his Ph.D. from Purdue University in 2018, MS from KAUST in 2013, and BS from KFUPM in 2008.

He worked as a project engineer at SABIC from 2008 to 2010. At Purdue University, Majed optimized and characterized a custom-built scalable roll-to-roll plasma CVD system to deposit carbon nanostructures on various flexible substrates, including Cu foil and carbon fiber. Majed won the KAUST Seed Fund in 2012 and was the most improved Entrepreneurial Lead in the I-Corps Program in 2017 for commercializing carbon nanostructures.

KAUST MAP



KAUST CAMPUS
Building 19
MCEM Lab
Campus Diner
Al Khozama Hotel
Al Khozama Hotel & Residences
Satellite Substation #3
Pelican Lane Park
Nakheel Park
Safron Lane Park
Soccer Pitch - HES
Tennis Court 1, 2 - HES
Harbor Basketball Ground
Kindergarten Campus West (K2,K3)- HES
Kindergarten Campus East
Soccer Pitch - HSC
Primary Basketball Ground
Harbor Daycare
Tamimi Supermarket
Gas Station
Electric Room
KAUST Health
Fire Station Building
Generator Building#Fire Station
Carob Tree Park
Nargis Lane Park
R&F Harbor Dispatching Maintenance Facility
Storm Lift Station #2
Sanitary Lift Station #5
Waste Transfer Station
Lift Station #2
Grand Mosque
Community Life Building
Multi Purpose Room
Harbor Library
Prosperity Park
PUBLIC TOILET-A1-PR
Red Sea
Storm Lift Station #4
New Energy Oasis (NEO)
Emergency Generator
Bayt Al Hikmah Boulevard
Discovery Boulevard
King Abdullah Boulevard
Unity Boulevard
South Research Road
Achievement Road
Transformation Way
Inspiration Avenue
Exploration Avenue
Beacon Avenue
Hope Avenue
Peace Avenue
Black Iris Road
Mishmish Lane
Sawsan Lane
Nargis Lane
Cactus Lane
Bougainvillea Lane
HeliPad Lane
GC Walking Path

Mechanics of Composites for Energy and Mobility

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ENERGIZING COMPOSITES