Mechanics of Composites for Energy and Mobility

جامعة الملك عبدالله للعلوم والتقنية

King Abdullah University of Science and Technology

KAUST Research Conference

FUTURE COMPOSITES

Shaping the Future with Composite Materials

MAY

24-27 2021

Virtual Conference

futurecomposite.kaust.edu.sa

cohmas.kaust.edu.sa

A 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 may benefit the citizens of this beloved country, which is the cradle of Islam, 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)


العلماء ورثة الأنبياء."
حديث شريف
"The learned are the heirs of the

Source: https://vision2030.gov.sa/

VISION رؤية 2030
المملكة العربية السعودية
KINGDOM OF SAUDI ARABIA

Pillars of Vision 2030

With strong roots
With fulfilling lives
With strong foundations

- Rewarding opportunities
- Investing for the long-term
- Open for business
- Leveraging its unique position

- Effectively governed
- Responsibly enabled

FOREWORD

Vision 2030 streamlines Saudi Arabia's role as one of the major players producing composite materials is necessary to exemplify Saudi's competitive advantage and to fuel the economy with high-volume (energy, civil, transportation) and high-technology markets (aeronautics and space). A scientific event that will bring together academia, industry and government institutes that support such transformation will be beneficial for all parties.

Encouraged by the success of our previous workshops (CEMAM in 2013, COMINT in 2015), Mechanics of Composites for Energy and Mobility Laboratory organizes a workshop in the field of composite materials with the theme of "Shaping the future with Composite Materials". This workshop provides a high-level forum to discuss the latest development of composite science and technology. A number of high-caliber professors, researchers, engineers and industry practitioners will share their knowledge, expertise and experience in their respective fields of expertise.

The workshop will be organized around following areas:

- Addressing the needs for Composite Industry 4.0
- Imagining new applications in energy and transportation sectors
- Improving composites through big data and artificial intelligence
- Inventing new concepts for composite assemblies and large structures
- Building a composite industry

This workshop marks for us two important events. First, the name of our lab, previously known as COHMAS, is now changing to "Mechanics of Composites for Energy and Mobility", highlighting our strong commitment to solving critical societal issues. Second, this is the inaugural event where we create Saudi Arabian Society for Composite Materials (SASCOM), establishing a new tool for federating composite-related knowledge and efforts in Saudi Arabia

Chairmen

Prof. Gilles Lubineau (KAUST)
Dr. Fahad Al-Khodairi (Corporate Fellow, SABIC)

Local organizing committee

Jassem ALYousef	MS Student
Wael Badeghaish	PhD Student
Nurlat Bekdullayev	PhD Student
Ragesh Chellattoan	PhD Candidate
Huiping Chen	Research Assistant
Lujain Fatta	MS Student
Mjed Hashem	MS Student
Ping Hu	PhD Candidate
Abraham Lagerweij	PhD Student
Xiaole Li	Postdoc Fellow
Ruslan Melentiev	Postdoc Fellow
Hussein Nesser	Postdoc Fellow
Muhammad Seraj	Research Technician
Mohammad Subah	MS Student
Ran Tao	Postdoc Fellow
Ahmed Wagih	Postdoc Fellow
Yangyang Xin	PhD Candidate

Editors

Arief Yudhanto, Gilles Lubineau

Graphic Designer

ENGRADA Creative Agency
Nada Alwafai
Istanbul, Turkey

Printing

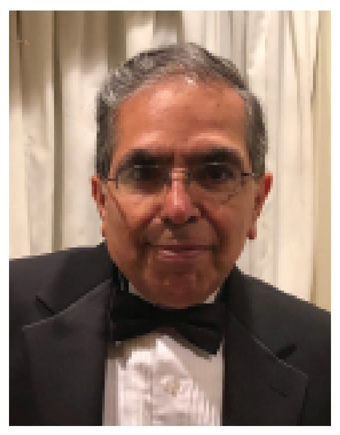
Sarawat, Jeddah

Workshop Speakers

List of speakers

Suresh Advani
Jamil Al-Bagawi
Fahad Al-Khodairi
Majed Alrefae
Muneer Bakhsh
John Botsis
Pedro Camanho
Wesley Cantwell
Pedro Da Costa
Martin Dunn
Gerard Fernando
Eric Feron
Enrique Garcia
Carlos González
Sadath Khan
Vassilis Kostopoulos
Shanmugam Kumar
Celine Largeau
Jinsong Leng
Gilles Lubineau
Véronique Michaud
Jerry Qi
Sanjay Rastogi
Tong-Earn Tay
Michael Wisnom
Recep Yaldiz

University of Delaware	USA
Saudi Aramco	Saudi Arabia
SABIC	Saudi Arabia
Yanbu Industrial College	Saudi Arabia
GDC Middle East	Saudi Arabia
Ecole Polytechnique Federale de Laussanne (EPFL)	Switzerland
University of Porto	Portugal
Khalifa University	UAE
KAUST (King Abdullah University of Science and Technology)	Saudi Arabia
University of Colorado Denver	USA
University of Birmingham	United Kingdom
KAUST (King Abdullah University of Science and Technology)	Saudi Arabia
National Composite Centre	United Kingdom
IMDEA Materials Institute	Spain
ISECC	Saudi Arabia
University of Patras	Greece
University of Glasgow	United Kingdom
IRT Jules Verne	France
Harbin Institute of Technology	China
KAUST (King Abdullah University of Science and Technology)	Saudi Arabia
Ecole Polytechnique Federale de Laussanne (EPFL)	Switzerland
Georgia Institute of Technology	USA
KAUST (King Abdullah University of Science and Technology)	Saudi Arabia
National University of Singapore	Singapore
Bristol University	United Kingdom
SABIC	The Netherlands



Suresh G. Advani

Suresh G. Advani is George W. Laird Professor of Mechanical Engineering and Associate Director, Center for Composite Materials at the University of Delaware. He received his Ph.D. from University of Illinois at Urbana-Champaign in 1987. His research interests are in rheology; fluid mechanics and heat transfer as applied to composite processing and alternate energy sources such as fuel cells and hydrogen storage. Advani has published over 350 journal papers and delivered over 200 invited lectures. He is the lead author of a text on Process Modeling in Composite Manufacturing Processes. Professor Advani is a Fellow of American Society of Mechanical Engineers and is the North American Editor for the journal Composites Part A: Applied Science and Manufacturing. Professor Advani recently received the Outstanding Researcher Award for 2015 from American Society of Composites and the Educator of the Year award from Society of Plastic Engineers. Professor Advani is also the creator of Liquid Mold Filling Software called LIMS which is used by many industries and academic institutions to advance the manufacturing science of composites.

Emerging role of process models and simulations in composites manufacturing

G.W. Laird Professor of Mechanical Engineering and Associate Director, Center for Composite Materials
University of Delaware, Newark, DE 19716, U.S.A.
E-mail: advani@udel.edu

ABSTRACT

This talk will highlight the ever increasing benefits of process modeling in Composite Manufacturing processes. First, the use of science base approach of materials processing, which integrates material parameters with transport phenomena at various scales during manufacturing to create multi-physics models will be discussed. Next the importance of implementing these models in fast and open architecture simulations that can be seamlessly interfaced with optimization, functional design and process control tools to improve the yield of the process despite the variability in the incoming materials and process parameters will be demonstrated. The use of such simulations in transportation, wind and energy storage applications will be presented. Automation can be introduced with tailored equipment designs that rely on sensors and simulations interfaced with actuators to address variability and disturbances in the process. Examples where this has been demonstrated on a laboratory scale will be presented for Liquid Molding processes such as Resin Transfer Molding, Vacuum Assisted Resin Transfer Molding and Compression Resin Transfer Molding. This approach naturally lends itself to Digital Twins and Industry 4.0 Manufacturing.

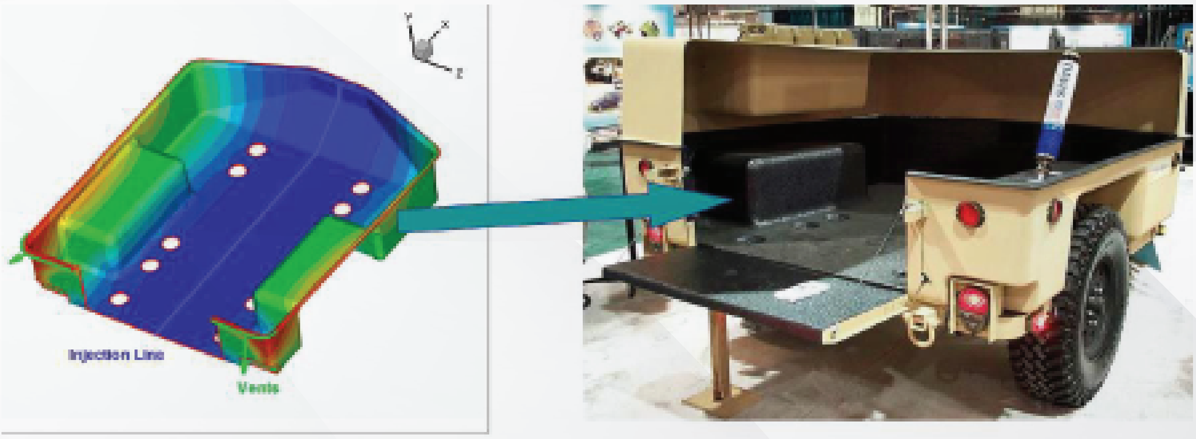


Figure 1: Mold Filling Simulation of a Tractor Trailer Bed through a center line gate injection with last regions to fill at the corners. Such simulations can be integrated in Digital Twin Designs in the Future for Industry 4.0 Manufacturing

Jamil Al-Bagawi

Jamil Al-Bagawi works as a Chief Engineer in Saudi Aramco. Al-Bagawi is responsible for all above surface engineering related functions, and major roles such as Specialist Development Program, Technology Program, Corporate Innovation, Knowledge Management and Patents. He serves as a chairman of Saudi Aramco Board of Engineers and Energy Management Steering committee. Al-Bagawi began his career at Saudi Aramco in 1995 as an engineer in the central engineering of Saudi Aramco. He held various positions in Consulting Services Department, Abqaiq Plants, and Ras Tanura Refinery. He held several positions in Aramco, including Manager of Consulting Services Department, Inspection Department, Research and Development Center, Shedgum Gas Plant, Coordinator of Professional Engineering Development Division, Supervisor of Energy Conservation Unit and other management positions. As part of Saudi Aramco Accelerated Transformation Program, Jamil successfully led, established and introduced Operational Excellence to Saudi Aramco which resulted in considerable savings and enhancements in the operational processes for all Saudi Aramco businesses. He successfully led the efforts to develop Saudi Aramco ngineering competency maps which became the standard approach to develop Saudi Aramco engineering workforce. Al-Bagawi holds a PhD in Mechanical Engineering, and has graduated from Harvard Business School (General Management Program). Prior to joining Saudi Aramco, Al-Bagawi was a lecturer at the Department of Mechanical Engineering, King Fahd University of Petroleum & Minerals (KFUPM) from 1991 to 1995. He was the Board Chairman of the Saud Council of Engineers and the President of Federation of Engineering Institutions of Islamic Countries (FEIIC).

Saudi Aramco's non-metallic program - Journey and ambition

Jamil J. Al-Bagawi
Chief Engineer, Saudi Aramco
Engineering Services, Dhahran 31311, Saudi Arabia
E-mail: jamil.bagawi@aramco.com

ABSTRACT

Non-metallic materials are playing an ever increasing role in our world. When we say nonmetallic materials, we are referring to industrial and consumer products that are produced using chemicals and polymers derived from the hydrocarbon value chain, which substitute products conventionally made from metals and other materials.

We at Saudi Aramco many years ago began exploring nonmetallic materials as a mean of corrosion mitigation in our facilities through selective pilot projects. Having experienced the benefits of this material in corrosion mitigation, faster installations and life cycle cost savings, the use of nonmetallic s in Saudi Aramco products grew exponentially in the past five years. Apart from the conventional non-metallic applications in water and low pressure services which started as early as 1970s, today we have successfully installed more than 9,000 km of pipes in diverse applications across our assets in more harsh services such as high pressure oil, gas and water. This space used to be fully occupied by steel.

Building on our success in the O&G sector, we expanded our non-metallic business strategy to cover four additional sectors which are Building & Construction, Automotive, packaging and Renewables due to their impact and synergy with Saudi Aramco's Business. Our non-metallic materials strategy has five key pillars, which are Research and Development, Deployment, Localization, investment and Advocacy.

In Line with Vision 2030, Saudi Aramco non-metallic material strategy aims to place Aramco and the Kingdom as a global leader in the non-metallic materials business with a key objective of maximizing the value of our resources across the hydrocarbon value chain, driving sustainability, localizing industry and reducing our carbon footprint. Indeed, our non-metallic business strategy is in line with our corporate approach to sustainability.

We at Saudi Aramco believe that Innovation and R&D are key enablers to advance the future of non-metallic across all industries. Through new ideas, collaborations and technological breakthroughs we can address the challenges of tomorrow.

Fahad Al-Khodairi

Fahad Al-Khodairi is a Corporate Fellow at SABIC global research and application development centers since 2016, leading polymers R&D activities in Riyadh, Saudi Arabia. At SABIC, he has worked as General Manager of Oil-to-Chemicals Technology (2013 – 2016), General Manager of Polymers SBU Technology Management (2009 – 2013), General Manager of R&D Polymers Research (2001 – 2009), PVC Technology Manager (1999 – 2001) and P&M Laboratories Manager (1997 – 1999). He has a strong experience and vast knowledge in petrochemical and chemical industry including strategy, research, acquisition, contracts and licensing management; managing research portfolio, setting tools and processes; value proposition and creation along with entire value chain needs. He chaired member of several affiliated boards and ex-member of GPCA. He is co-inventor of several patents, author and co-author of technical papers in reputable journals and a book chapter (The fatigue of hybrid composites) in Fatigue in Composites (Ed. Bryan Harris, CRC Press, 2003). He obtained MSc and PhD in Material Science from Brunel University London, UK (Fatigue of Unidirectional and Hybrid Composites).

SABIC's journey in composites applications and carbon fiber opportunities in the Kingdom of Saudi Arabia

Fahad Al-Khodairi
Corporate Fellow, SABIC, Technology and Innovation, PO BOX 5101, Riyadh 11422, Saudi Arabia
E-mail: khodairi@sabic.com

ABSTRACT

The Kingdom of Saudi Arabia is embarking on a journey to transform the country by 2030. The KSA Vision 2030 aims at decisively developing the Industrial landscape of the Kingdom via various programs. Efforts like the National Companies Promotion Program, Human Capital Development Program, Strategic Partnerships Program, National Industrial Development and Logistics Program, National Transformation Program are examples of this initiative.

One excellent opportunity for investors to capture in the Kingdom is to build downstream manufacturing capabilities for carbon fiber reinforced plastics, and to meet the expected growing needs in renewables (wind energy), automotive, oil and gas, building and construction, and other applications. Local suppliers of these materials will have the advantage of being able to supply essential intermediate products, like prepreg, pultrusion, and compounding.

To envision the expected consumption of carbon fibers, Saudi Arabia is undergoing a significant transition to low-carbon energy generation targeting an ambitious 16 GW of wind power installation by 2030, and localization of blades manufacturing. In addition, the KSA automotive 2030 vision aims to attract 3-4 OEMs across ICE and EV value chain enabled by the Saudi Auto City with a high quality automotive infrastructure.

SABIC, a global leader in the chemical industry, will play a key role in supplying resins to investors in KSA which are suitable for applications in commercial aircrafts, auto, pipe and other segments.

Recently, SABIC introduced the newest addition to its expanding portfolio of thermoplastic materials. UDMAX™ unidirectional fiber reinforced thermoplastic composite tape products complement its legacy portfolio of filled injection moldable compounds, e.g. STAMAX™. The new continuous glass fiber reinforced polyolefin tape is designed for reinforcing industrial applications, such as pipes and pressure vessels, offering unmatched tensile strength. This novel product has one of the highest glass contents available in the industry combined with an optimal fiber distribution and resin impregnation.

Majed A. Alrefae

Majed A. Alrefae is an Assistant Professor at Yanbu Industrial College, Royal Commission Yanbu Colleges and Institutes. 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. His research focus is on developing plasma processes to produce carbon nanostructures for energy and water desalination applications.

The future of composites with graphene nanopetals: Scalable deposition of graphene nanopetals on carbon fiber

Majed A. Alrefae
Royal Commission of Yanbu, Yanbu Industrial College, Department of Mechanical Engineering
Yanbu Industrial City 41912, Saudi Arabia
E-mail: refaem@rcyci.edu.sa

ABSTRACT

Graphene nanopetals are vertically-aligned carbon nanostructures materials that can be deposited on carbon fiber. Several studies showed that graphene nanopetals decrease the interfacial thermal and electrical resistances of composites, improve the interfacial strength of composites, and enhance the sensitivity and selectivity of biosensors. Here, a large-scale roll-to-roll plasma chemical vapor deposition (CVD) system was implemented to mass-produce graphene nanopetals on carbon fiber [1]. Microscale and macroscale characterization techniques were used to optimize the growth process using a sequential design of experiment model. Results show the improved density of the carbon nanostructures with increased production time. Furthermore, a heat transfer model was developed to quantify the influence of temperature distribution of carbon fiber in the roll-to-roll graphene deposition. The model was validated with in situ temperature measurements of carbon fiber in the plasma region using optical emission spectroscopy. This work aims to expand the production of graphene-coated carbon fiber for future applications of composites in energy, transportation, and sensing.

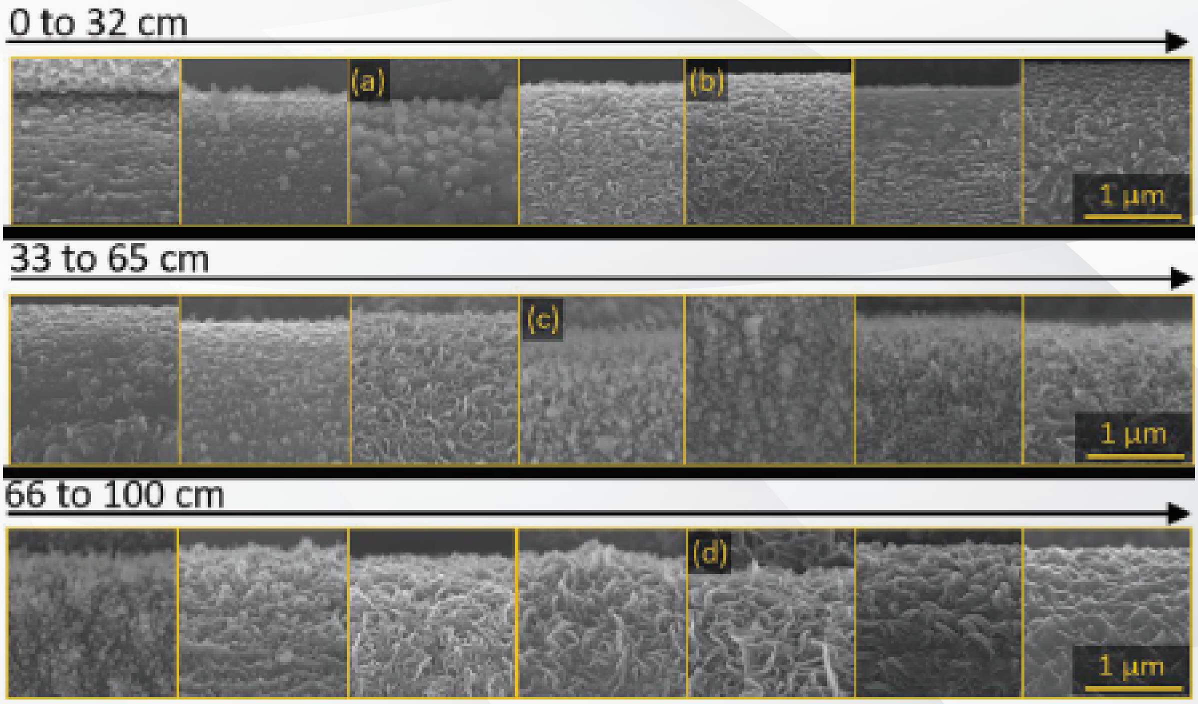


Figure 1: SEM images of graphitic petals along the 1-m long carbon fiber tow. Different morphologies exist depending on the production time, including a) separate graphene nanopetals, b) small-area growth of graphene nanopetals, c) unstructured graphene nanopetals, and d) extensive deposition of graphene nanopetals. The figure is extracted from [1].

REFERENCES

[1] K.R. Saviers, M.A. Alrefae, and T.S. Fisher, Roll-to-Roll Production of Graphitic Petals on Carbon Fiber Tow, Advanced Engineering Materials, 20(8), 1800004 (2018).

Muneer Bakhsh

Muneer Bakhsh has a large experience, around 30 years, in aircraft industry. He was born in Al-Madina, Kingdom of Saudi Arabia. In 1999, he obtained his bachelor and master degrees from Embry-Riddle Aeronautical University, Florida, USA in the field of engineering and design of aircraft. His excellence in the field of design of aircraft bodies from composite materials enabled spending 27 years working in USA for several leading aircraft companies. Eng. Muneer has several leading positions in several companies. In last quarter of 2019, he was appointed by the public investment fund organization as the deputy-chairman and Chief Executive Officer (CEO) of Saudi aircraft preparation and maintenance company (GDC Middle East), which is one of the public investment fund companies that was established to transfer aircraft industry to Kingdom of Saudi Arabia. Also, he was appointed as deputy-chairman for Middle East Propulsion Company (MEPC), one of the economic balance program companies. He was appointed in USA by Boeing to design horizontal stabilizers for the aircraft (Boeing 787), Honda to design fuselage of Honda jet and Gulfstream for aircrafts to design winglet for aircraft (Gulfstream-G500/600). Among his biography in the field of designing aircrafts, he established two companies in USA to design aircraft and he also present a patent in the field. Upon his arrival to Kingdom of Saudi Arabia in 2016, he was appointed at the Saudi Technology Development and Investment Company (TAQNIA), at which he established a factory for aircraft bodies at King Khaled international airport. Then, he moved to Saudi Arabia Military Industries (SAMI) Company to work as general director of air systems.

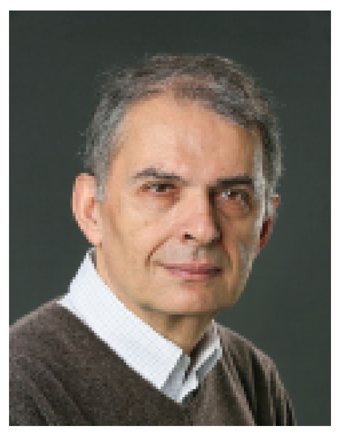
Carbon fiber in the aerospace industry

Muneer Bakhsh
GDC Middle East, Saudi Arabia
E-mail: mbakhsh@gdcme.com

ABSTRACT

The future of composite material is increasing tremendously. The need for such material is from all kind of industries, especially Aerospace, due to its characteristics like the strength of the material and light weight. Yet, the cost and manufacturing technics need to improve to make this material more available to all industries such as constructions and machineries. There are many institutions in the Kingdom working on developing composite materials such as KAUST, KACST, SABIC, and many others. As a former composite design engineer, with experience designing the horizontal stabilizer for the Boeing 787 Dream-Liner, and Winglets of the Gulfstream G500 and G600 as well as the all composite fuselage of the HondaJet and many other components, I have extensive experience with Carbon fiber materials.

GDC Middle East is a Public Investment Fun (PIF) company specializing in Aerospace Engineering, Aircraft Upgrades, Modification, and MRO in addition to Airworthiness, Certifications and Qualifications. Currently, GDC has 250 employees, and 80 percent of our work force is Saudis. Our current customers are RSAF, and other government entities. I believe it's an exciting time to be in the Kingdom and see the development of such technologies, specially being involved in it and be part of it.



John Botsis

John Botsis obtained his diplôme in Civil Engineering from the University of Patras, Greece, in 1979. He continued his education at the Case Institute of Technology, Cleveland, Ohio, USA, where he received his MS and Ph.D. in 1984. After two years working at the Research Centre for the National Defence in Athens, he returned to the U.S., and was appointed as an Assistant Professor at the University of Illinois in Chicago, Associate Professor in 1991 and Full Professor in 1995. In 1996, he was appointed as a Professor of Solids and Structural Mechanics at the EPFL, Switzerland. His activities cover experimental mechanics, fracture and fatigue of advanced materials including composites and biomaterials using novel experimental techniques, numerical methods and micromechanics. He has co-authored more than 150 journal papers, several book chapters and two textbooks. His research has been funded from the Swiss National Science Foundation, State Secretariat for Education and Research, Swiss Commission for Technology and Innovation, EU and Swiss industries.

Experiments and analysis of delamination of carbon epoxy composites

John Botsis
Ecole Polytechnique Fédérale de Lausanne (EPFL), LMAF STI, Lausanne, CH-1015 Switzerland
E-mail: john.botsis@epfl.ch

ABSTRACT

It is well known that a large scale bridging (LSB) in the fracture of laminated composites is one of the most important toughening mechanisms. The resulting resistance to fracture, however, is dependent upon loading, specimen geometry, lay-out and microstructure, rendering its modeling very challenging. In this presentation, experimental results and modeling of fracture in CFRP are presented. The experimental part consists of monotonic tests of interlaminar and intralaminar fractures of unidirectional specimens, as well as load-controlled fatigue of interlaminar specimens. The modeling part involves an iterative scheme to calculate the traction-separation relations due to LSB using strains that are obtained from the embedded sensors, parametric finite element simulations and optimization.

The results demonstrate an important effect of specimen thickness in the fracture response of composites under monotonic and fatigue loads, and allow to deduce scaling relationships due to LSB. The obtained traction-separation relations are employed in the cohesive zone simulations to predict very well the corresponding load-displacement and fracture resistance curves (R-curves) for specimens of various thicknesses. Micromechanical observations and analysis show that when the separation-dictated cohesive response is present (i.e., adhesive joints), no effects of specimen's stiffness is expected. When fiber bundles are involved in the formation of closing tractions, i.e. LSB in carbon fiber-reinforced polymer (CFRP), an important variation should be expected, both in R-curve behavior and traction-separation relations. The latter effect is attributed to the fibers bundles (in the bridging zone) that are loaded in traction and bending, which vary according to the loading type and specimen's stiffness.

To elucidate further these observations, computational micromechanics models are developed to predict the effect of specimen's thickness on the bridging. Data reduction and analysis shows that if the traction-separation relation is enriched with the local crack opening angle, the observed experimental response can be easily reproduced, suggesting that the cohesive relation with two-kinematic parameters is a physically sound model. The results of these works concludes that the traction-separation-angle relationship is a structural property.

Pedro Camanho

Pedro Camanho has been a Full Professor at the Department of Mechanical Engineering of the University of Porto (UPorto), Portugal, since 2014. He is also currently the President of the Associated Laboratory in Energy, Transportation and Aeronautics (LAETA), and the Vice-President of INEGI. He received MSc in Mechanical Engineering from UPorto in 1995, and PhD in Composite Materials from the Department of Aeronautics, Imperial College London, UK, in 1999. He was a Visiting Scientist at the U.S. Air Force Research Laboratory (1999), and NASA-Langley Research Center (2000-2011). He was a Royal Society Visiting Professor at Imperial College London (2005) and a Visiting Professor at the Laboratoire de Mécanique et Technologie, Ecole Normale Supérieure de Cachan - Université Paris-Saclay (2014). He received NASA H.J.E. Reid Award for Outstanding Scientific Paper (2006), Young Researcher in Applied and Computational Mechanics Award from the Portuguese Association of Theoretical, Applied and Computational Mechanics (2005), Engineering Fracture Mechanics Most Cited Articles Award (2005-2009), Mechanics of Materials Highly Cited Research Award (2016), and Excellence in Research Award of the University of Porto (2020). He was elected Fellow of the Royal Aeronautical Society in 2020. He is member of the Editorial Board of the International Journal of Solids and Structures (Elsevier), Composites Part A (Elsevier), European Journal of Computational Mechanics (Taylor & Francis), and Computers, Materials and Continua (Tech Science Press). He has published over 140 papers in international peer reviewed journals. His work has been successfully transferred to the industry and services: ABAQUS (Dassault Systèmes), LS-DYNA, MSC-NASTRAN (Digimat), HYPERSIZER, ESACOMP and ANSYS. His main research interests 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, energy-storage and ultra-thin composites.

Generation of statistical design allowables of composite laminates using machine learning

Pedro P. Camanho[1], Carolina Furtado[2], Albertino Arteiro[1]
[1]DEMec, Faculdade de Engenharia, Universidade do Porto
[2]Department of Aeronautics and Astronautics, Massachusetts Institute of Technology
E-mails: pcamanho@fe.up.pt, cfurtado@mit.edu, aarteiro@fe.up.pt

ABSTRACT

This work represents the first study towards the application of machine learning techniques in the prediction of statistical design allowables of composite laminates. Building on data generated analytically [1], four machine learning algorithms are used to predict the notched strength of composite laminates and their statistical distribution, associated to material and geometrical variability.

Very good representations of the design space (relative errors of around ±10%) and very accurate representations of the distributions of notched strengths and corresponding B basis allowables are obtained. The Gaussian Processes models proved to be the most reliable, considering their continuous nature and fast training process. This work serves as basis for the prediction of first ply failure, ultimate strength and failure mode of composite specimens based on non-linear finite element simulations, providing further reduction of the computational time required to virtually obtain the design allowables for composite laminates.

REFERENCES

[1] C. Furtado, A. Arteiro, M.A. Bessa, B.L. Wardle, P.P. Camanho. Prediction of size effects in open hole laminates using only the Young's modulus, the strength, and the R-curve of the 0° ply, Composites Part A, 101, pp. 306-317, 2017.

Wesley Cantwell

Wesley Cantwell is a Professor of Aerospace Engineering and the Director of the Aerospace Research and Innovation Center at Khalifa University, United Arab Emirates. He was awarded his MSc (1982) and PhD (1985) degrees in Aeronautical Engineering from Imperial College, London. Following his graduate studies, he joined the Ecole Polytechnique Federal de Lausanne (EPFL) Switzerland where he worked for nine years as a research scientist. He then joined the University of Liverpool where he worked as a Lecturer, Reader and Professor until joining Khalifa University in 2012. During this time he directed a research group focusing on the mechanical properties of lightweight materials and structures. He has published 230 journal papers on composites, fracture, manufacturing technologies and non-destructive testing. He is a member of the editorial board of a number of international journals, including Composites Science and Technology and the International Journal of Impact Engineering.

The Aerospace Research and Innovation Center (ARIC) – A model for industry-university collaboration in the UAE

Wesley Cantwell
Khalifa University of Science and Technology (KUST), Aerospace Research and Innovation Center
Abu Dhabi, United Arab Emirates
E-mail: wesley.cantwell@ku.ac.ae

ABSTRACT
This talk will discuss the establishment of an industry-backed composites research center in Abu Dhabi, UAE. The agreement to establish the center was signed at the Dubai Airshow in November 2013 and the laboratory was finally completed and opened in late 2016, Figure 1a. ARIC is funded through a partnership between Mubadala (an investment arm of the Abu Dhabi Government) and Khalifa University and was established to support the manufacturing operations of Strata, a composite aerostructures company based in the Emirate of Abu Dhabi. Strata has established partnerships with Boeing and Airbus as well as tier one suppliers such as FACC, SABCA and SAAB. ARIC provides research support for Strata, with its engineers spending extended periods in the research laboratory and ARIC personnel being based part-time in the company. Phase I of ARIC was completed in December 2018 and focused on composites manufacturing and automation in component assembly. Phase II of the center involves extending these topics as well as focusing on AI and additive manufacturing initiatives. Research in ARIC is underpinned by an array of equipment that includes an autoclave, RTM press, an industrially-sized metal printer, an X-ray computed tomography system as well as robotic arms for automated drilling and assembly. The talk will also present the findings of on-going research projects, such as activities to investigate scaling effects in the manufacture and testing of resin-infused composite structures.

(a) (b)

Figure 1: (a) Photograph of the ARIC laboratory and (b) the EOS 400-4 additive manufacturing machine.

REFERENCES
A. Alantali, R.A. Alia, R. Umer, W.J. Cantwell (2018). Scaling effects in the manufacture and testing of grid-stiffened composite structures, Journal of Composite Materials, 52(17), 2351-2363 (2018).

Pedro M. F. J. Costa

Pedro M. F. J. Costa is an Assistant Professor of the Materials Science and Engineering Program at the King Abdullah University of Science and Technology (KAUST) and Principal Investigator of the Laboratory for Carbon Nanostructures (KAUST). Previously, he held an Adjunct Assistant Professor position at the University of Aveiro (UA), Portugal, and co-founded a start-up, Graphene Crystal, Saudi Arabia. Before that, he was a Junior Research Group Leader at UA while also collaborating has an Alexander von Humboldt Fellow with the IFW-Dresden, Germany. Dr. Costa worked as a post-doctoral research associate at the National Institute for Materials Science (NIMS), Japan, and at the Department of Materials Science and Metallurgy of the University of Cambridge, United Kingdom (UK). His graduate studies were carried out under the supervision of Prof. Malcolm L. H. Green FRS, at the Inorganic Chemistry Laboratory, University of Oxford, UK. He is a member of various acknowledged scientific societies such as the Royal Society of Chemistry (RSC), the Royal Microscopical Society and the Materials Research Society. He is an active committee member of the RSC Interest Group - Chemical Nanoscience and Nanotechnology. Dr. Costa has co-authored numerous scientific papers and communications and he is a regular reviewer for major scientific journals in matters related to electron microscopy and carbon nanostructures. He has received several awards such as the Japan Carbon Award for Young Researchers and an Alexander von Humboldt Fellowship for Experienced Researchers. Presently, Dr. Costa's research interests focus on carbon nanostructures, from synthesis to applications, and electron microscopy. He is engaged in understanding how to optimise the use of carbon-based materials in the fields of energy storage/conversion, gas uptake and civil engineering. Besides this, he also investigates metrology of carbon materials.

Thin films of graphite grown on Ni foils by chemical vapor deposition

Geetanjali Deokar[1], Alessandro Genovese[2], Pedro M. F. J. Costa[1]
[1]King Abdullah University of Science and Technology, Physical Science and Engineering Division, Laboratory for Carbon Nanostructures, Thuwal 23955-6900, Saudi Arabia
[2]King Abdullah University of Science and Technology, Core Labs, Thuwal 23955-6900, Saudi Arabia
E-mail: pedro.dacosta@kaust.edu.sa

ABSTRACT

Graphite thin films (GTF) are used as heat-sinks in electronic devices such as mobile phones. Generally, the thickness of these films is in the order of tens of micrometers due to production methods being based on the pyrolysis and graphitization of polymers [1]. As devices scale down, it is important to ensure that thermal management solutions continue to be available which, furthermore, conform to market regulations. Thus, over the past decade, there has been renewed interest in the use of chemical vapor deposition (CVD) to grow sub-micrometer GTF with high structural quality and low surface roughness.

Since the CVD process relies on the thermal dissociation of hydrocarbons onto transition metal substrates, it is important to tailor the catalytic foil to the type of graphite aimed. Due to the relatively high solubility and diffusivity of C into Ni, this metal is commonly preferred for the growth of GTF (as opposed to Cu, the most popular substrate for the growth of single-layer graphene by CVD). To present, there is still little understanding of how to control the production of GTF from Ni foils and if it is possible to achieve wafer-scaled films with less than 100 nm that can be handled without cracking.

In this communication, we will show our recent efforts to produce wafer-scale high-quality GTF with thickness below 100 nm (Fig. 1). Detailed structural analysis of the catalyst-graphite interface and the study of the reactor's parameters permitted valuable insight to the mechanism of GTF formation. Remarkably, regions with just a few layers of graphene were identified (Fig. 1c). Despite this, these films were robust and could be dissociated from the metal foil without the use of a polymer support. After transfer, they retained the expected properties of GTF, added to visible light transparency.

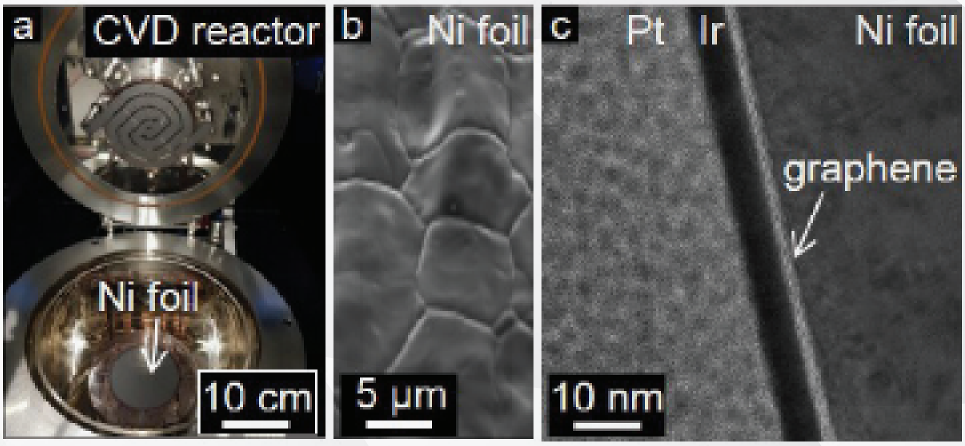


Figure 1: Thermal CVD growth of GTF on Ni foils. (a) Photo of the CVD reactor chamber with a 4" Si wafer where a Ni metal foil was placed; (b) Scanning electron micrograph of the Ni surface with µm-sized grains; (c) Transmission electron micrograph of a post-growth Ni foil, seen in cross-section, where regions with a very thin layer of graphite (graphene) are present. The Pt and Ir originate from the microscopical lamella preparation (by focused ion beam).

REFERENCES

[1] M. Murakami, K. Watanabe, S. Yoshimura, High-quality pyrographite films, Appl. Phys. Lett., 48 (23), 1594-1596 (1986).

Martin Dunn

Martin Dunn is a Professor and Dean of the College of Engineering, Design and Computing at the University of Colorado Denver. He joined CU Denver in 2018 after serving as Professor and Founding Associate Provost for Research at the Singapore University of Technology and Design (SUTD) where he oversaw the design and operation of the research and innovation enterprise. Prior to joining SUTD, he served as a Program Director in the Civil, Mechanical and Manufacturing Innovation Division at the US National Science Foundation. He served the NSF while on leave from the University of Colorado, Boulder where he held the Victor Schelke Endowed Chair. Dunn's research focuses on understanding the mechanics and physics of complex heterogeneous materials through a combination of theory and experiment, and using this understanding to create methods and tools to design and manufacture new materials and components. He has received international recognition and awards for his research accomplishments as well as awards for products designed with the methods and tools developed from his research.

Design and additive manufacture of composite materials and structures

Martin Dunn
University of Colorado Denver, College of Engineering, Design and Computing, Denver, Colorado 80204
E-mail: martin.dunn@ucdenver.edu

ABSTRACT

I describe our recent developments of a multiscale digital design and manufacturing workflow that simultaneously determines the macroscopic topology and the spatially-variable microstructure of 3D composite components based on a combination of data-driven statistical homogenization, finite element simulation, and multiscale topology optimization [1, 2]. Our approach results in a 3D map of anisotropic composite stiffness, parameterized by microstructure descriptors that depend on the specific additive manufacturing technology used to realize the component. We apply our approach to 3D solid and multilayer plate composite components performing in static and dynamic settings - realizing them by additive manufacturing (both voxel-based photopolymer jetting and direct write technologies), and experimentally validating their performance. I will describe the most recent extensions of our approach to continuous fiber composite structures where a computer graphics approach is used to translate the abstract design representation in terms of the spatially-variable anisotropic stiffness to physically realizable continuous fiber layouts in two and three dimensions. Figures 1 shows an example of a components recently designed and fabricated with our digital workflow [1].

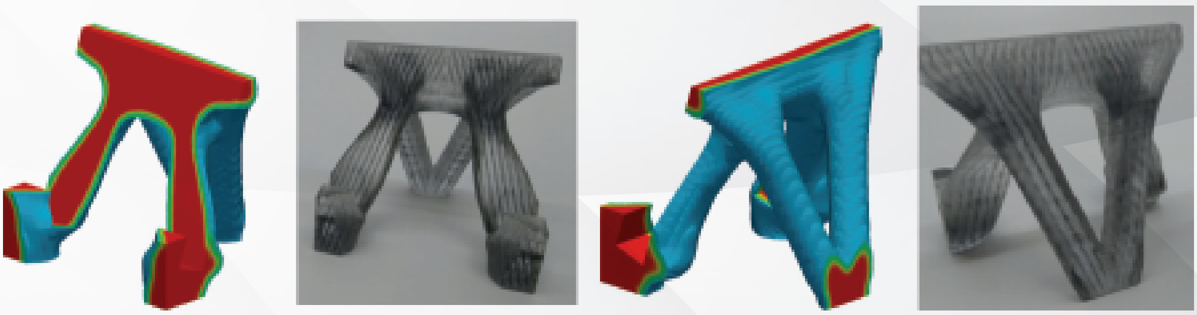


Figure 1: Optimal design and additive manufacture of the microstructure and macroscale topology of a composite structure – an iPad holder.

REFERENCES

[1] N. Boddeti, Z. Ding, S. Kaijima, K. Maute, and M. L. Dunn, M. L., 2018, Simultaneous digital design and additive manufacture of structures and materials, Scientific Reports 8(1):15560 (2018)

[2] I. F. Ituarte, N. Boddeti, V. Hassani, M. L. Dunn, and D. W. Rosen, Design and Additive Manufacture of Functionally Graded Structures Based on Digital Materials, Additive Manufacturing, 30, Article 100839 (2019)

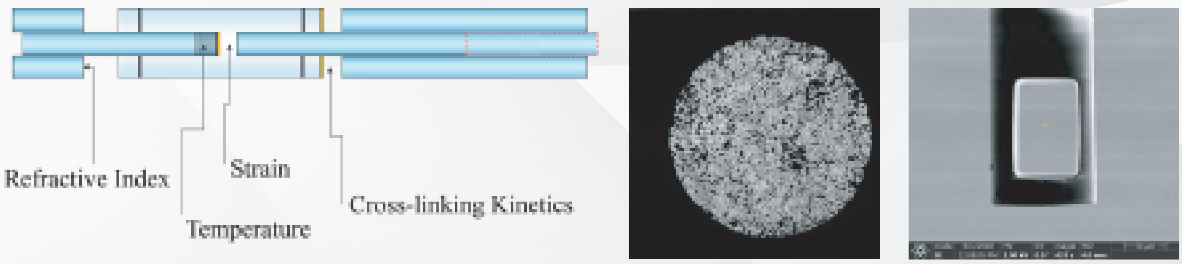
Gerard Fernando

Gerard Fernando is a Professor of Polymer Engineering and Head of Sensors and Composites Group at the School of Metallurgy and Materials, University of Birmingham, UK. He was appointed to the Chair of Polymer Engineering in 2005. Prior to this, he was a Reader and Lecturer at the Royal Military College of Science, Shrivenham, UK and Brunel University, London, UK, respectively. His primary research interest is in the design and deployment of optical fibre-based sensor systems for: (i) chemical process monitoring; and (ii) structural integrity assessment of fibre reinforced composites. In addition to developing a unique multi-measurand optical fibre sensor for engineering materials, he has developed the following techniques for fibre reinforced composites (patents secured or applied): (i) clean filament winding and environmentally friendly pultrusion; (ii) fibre spreading; (iii) production of vertically-aligned short-fibre core material for sandwich composites; and (iv) the production of highly-aligned organic fibres as a continuous process via electro-spinning – which includes the production of aligned lignin fibres.

Chemical process monitoring and structural integrity assessment using optical fibre sensors

D. King, A. Nair, B. Degamber, O. Dumitrescu, S. Malik, D. Harris, R. Mahendran, R. Badcock, S. Krishnamurthy, L. Wang, F. Nevis, T. Ma, J. Willberry, M. Uddin, Z. Sun, S.D. Pandita, G. Kister, R. Chen, V. Machavaram, J.D.R. Talbot and G.F. Fernando
School of Metallurgy and Materials, University of Birmingham, Edgbaston, Birmingham. B15 2TT. UK.
E-mail: g.fernando@bham.ac.uk

ABSTRACT
Significant advances have been made in recent years, on the design and deployment of optical fibre sensors for chemical processes monitoring and structural integrity assessment of engineering materials. However, the majority of these devices tend to impart information on one measurand. It is proposed that in order to assess the chemical, thermal and mechanical integrity of materials, information on two or more parameters is required. In this presentation, two case studies are considered. The first case study describes the design and demonstration of a multi-measurand fibre optic sensor system that is capable of imparting information on strain, temperature, cross-linking kinetics and refractive index. A schematic illustration of the multi-measurand sensor for use with thermosetting resins is shown in Figure 1a. Recent developments on cure monitoring and damage detection using the reinforcing E-glass fibres and small-diameter optical fibres will be considered (Figure 1b). Techniques for the production of intrinsic Fabry-Perot cavities in conventional optical fibres (Figure 1c), for sensing applications, will be presented. The second case study discusses the integration of optical fibre sensors into a differential scanning calorimeter. Here, data are acquired simultaneously on the thermal, spectral and refractive index during the processing of a thermosetting resin. It will be demonstrated that establishing correlation between the various analytical techniques can facilitate the development of low-cost optical fibre sensors for thermosetting/thermoplastic resins and composites.



(a) (b) (c)

Figure 1: (a) Schematic illustration of the multi-measurand sensor [1]; (b) self-sensing composite using small-diameter optical fibres [2, 3]; (c) intrinsic Fabry-Perot cavity in a conventional optical fibre.

REFERENCES
[1] A.K. Nair, V.R. Machavaram, R.S. Mahendran, S.D. Pandita, C. Paget, C. Barrow and G.F. Fernando, Process monitoring of fibre reinforced composites using a multi-measurand fibre-optic sensor, Sensors and Actuators B: Chemical, 212:93-106 (2015).
[2] L. Wang, A. Tomlin, S.D. Pandita, B.D. Gupta, S.A. Malik, M. Hudson, P.T. Curtis and G.F. Fernando, In-situ monitoring of cross-linking reactions using E-glass fibres and evanescent wave spectroscopy, Sensors and Actuators B: Chemical 236:358-366 (2016)
[3] S.A. Malik, L. Wang, P.T. Curtis, G.F. Fernando, Self-sensing composites: In-situ detection of fibre fracture, Sensors 16(5):615 (2016)

Eric M. Feron

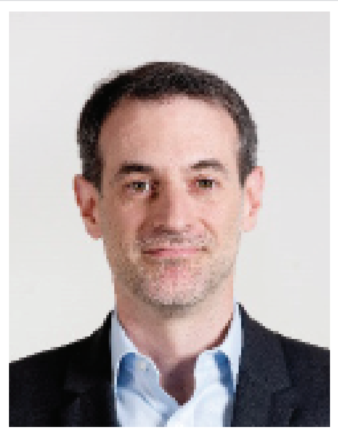
Eric M. Feron is currently a Professor of Electrical Engineering at King Abdullah University of Science and Technology. Following 12 years on the faculty of MIT, Eric Feron has been a professor of Aerospace Engineering at Georgia Tech for 14 years. His interests span the use and development of methods in Optimization, Control, and Computer Science to address relevant problems in Aerospace Engineering and closely related fields. Over time, systems of interest have included air transportation, aircraft, ground vehicles, propulsion, and spacecraft. Feron is a licensed aircraft pilot and ship operator

Artisan engineering re-invented: 3D printing with structural requirements

Eric M. Feron
King Abdullah University of Science and Technology, Computer, Electrical and Mathematical Science and Engineering (CEMSE) Division, Electrical Engineering Program, Thuwal 23955-6900, Saudi Arabia
E-mail: eric.feron@kaust.edu.sa

ABSTRACT

Additive manufacturing delivers much needed freedom to manufacturing and engineering design, allowing previously unavailable items to be produced quickly. Even small batches of items can be produced, provided they can meet precise engineering requirements from the get go. We validate feedback control with in situ measurements during the manufacturing process as a viable method to produce parts that meet specific macroscopic structural requirements. The validation is performed by printing a cantilever beam whose stiffness is required to reach a pre-defined value with a suitably instrumented entry-level FDM printer. Feedback control allows such a goal to be met with much higher accuracy than open-loop approaches. The approach can be extended to the production of items that must meet more complex requirements.



Enrique Garcia

Enrique Garcia has been the Chief Technical Officer at the National Composites Centre in Bristol, a centre of excellence in composites technology development since spring 2015. He has extensive experience in R&D and product development in diverse industries (renewable energy, aerospace, automotive, railways), and held senior manager positions in all of these sectors. He has focused on polymer-based products working from the nanoscale to the largest composite structures using a wide variety of manufacturing technologies with a special emphasis in design for manufacturing. He has developed successful strategies to lead innovation teams while adding value by guaranteeing schedules and quality and minimizing costs. Enrique's passion is to tackle big challenges and to share his vision with others by innovating, creating and developing. Enrique is particularly interested in working closely with academia, government and industry to develop capability and technology at the NCC that bridges the so-called "Valley of Death", transforming bright ideas into successful composite products. He has an Executive MBA from one of the top-five worldwide business schools, engineering degrees (BEng, MSc and PhD), speaks fluent English, Italian, and Spanish, and can hold a conversation in French.

D4C: Digital for composites

Enrique Garcia
National Composites Centre, Bristol, United Kingdom
E-mail: enrique.garcia@nccuk.com

ABSTRACT

The NCC has developed a framework for the adaptation and implementation of Digital Technologies into composites design and manufacturing: Digital for Composites (D4CTM).

The objective of the framework is to accelerate the process and to rapidly identify the value added (if any) by the introduction of digital into the technology development cycle. The presentation will cover the development of the D4C framework and several examples of how Digital Technologies are already impacting the development of new manufacturing technologies, including the Right-Every-Time methodology, as shown in Fig. 1. This development enables to move from the more traditional quality control of finished parts to in-process closed-loop control. This significantly increases the reliability of the different manufacturing processes and when fully developed could completely negate the need for the final inspection.

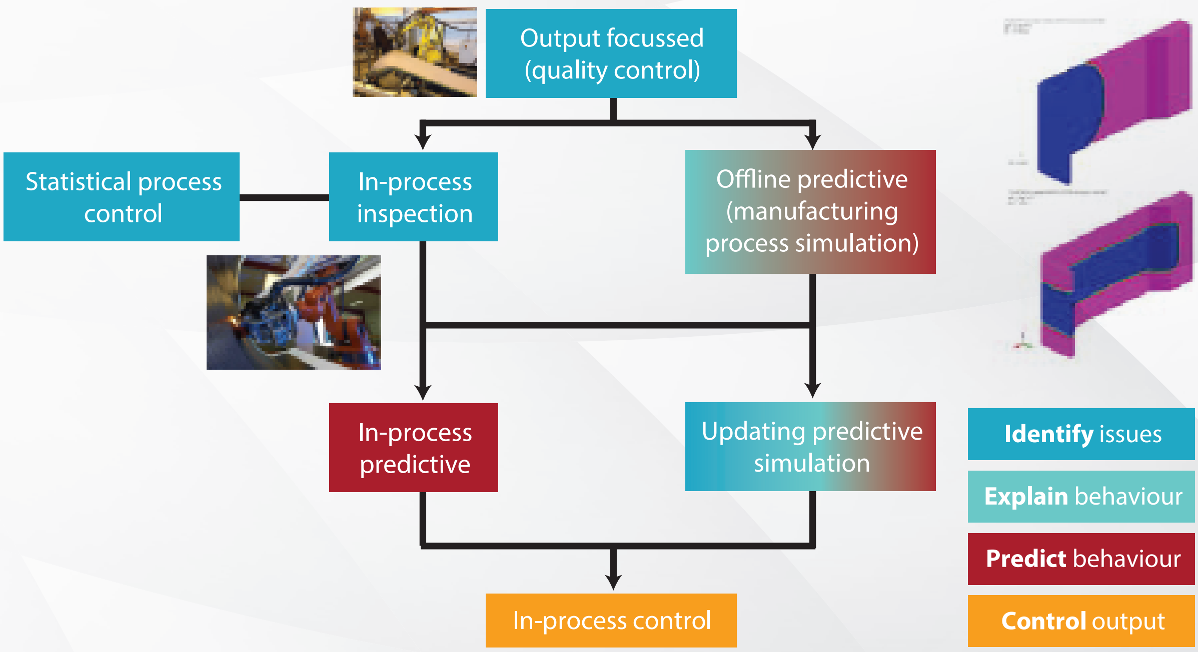


Figure 1 : D4C Right-Every-Time Framework for the implementation I4.0 into composites manufacturing

Carlos González

Carlos González is Senior Researcher and leader of the Structural Composites group at IMDEA Materials Institute and Associate Professor in the Department of Materials Science of the Polytechnic University of Madrid, Spain. His research activities focused on the analysis of the relation between microstructure and physical properties of structural composites. These technologies allow the development of virtual tests with a high level of reliability, which are starting to be used to reduce the number of mechanical tests for material certification. During the last years, his research was also focused on manufacturing techniques for fiber reinforced polymers, with special emphasis on out-of-autoclave techniques. Theses research activities have been carried out within the framework of more than 20 research projects funded by regional, national and international R&D programs and through contracts with companies (Airbus Operations, Airbus Defence & Space, etc).

Machine learning methods to detect flow disturbances in liquid moulding of composites

Carlos González[1,2], J. Fernández-León[1,3]
[1]IMDEA Materials, C/Eric Kandel 2, 28906 - Getafe, Madrid, Spain
[2]Departamento de Ciencia de Materiales, Universidad Politécnica de Madrid, E.T.S. de Ingenieros de Caminos, 28040 Madrid, Spain
E-mail: carlosdaniel.gonzalez@imdea.org
[3]Faculty of Computer Science, Multimedia and Telecommunications, Universitat Oberta de Catalunya, 08018, Barcelona, Spain
E-mail: joaquin.fernandez@imdea.org

ABSTRACT

In this work, a supervised machine learning (ML) model was developed to detect flow disturbances caused by the presence of a dissimilar material region in liquid moulding manufacturing of composites. The machine learning model was designed to predict the position, size and relative permeability of an embedded rectangular dissimilar material region through use of only the signals corresponding to an array of pressure sensors evenly distributed on the mould surface. A regression model based on the use of convolutional neural networks (CNN) was developed and trained with data generated from mould filling simulations carried out through use of OpenFoam as numerical solver. The evolution of the pressure sensors through the filling time was stored and used as grey-level images containing information regarding the pressure, the sensor location within the mould and filling time. The trained CNN model was able to recognize the presence of a dissimilar material region from the data used as inputs, yielding reasonable accuracy in terms of detection. Accuracy and model robustness were also addressed in the paper. The ability of ML models to examine and overcome complex physical and engineering problems such as defects produced during manufacturing of materials and parts is particularly innovative and highly aligned with Industry 4.0 concepts [1,2].

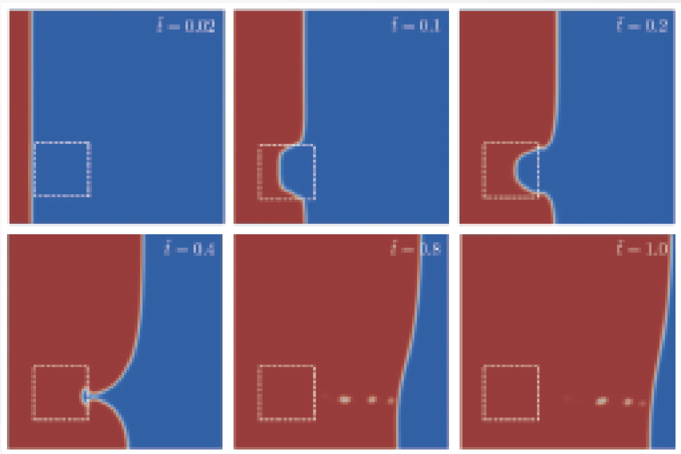


Figure 1: Snapshots of the flow progress through a squared RTM mould containing a square region with relative permeability of $\delta\Omega = 0.1$.

REFERENCES

[1] C. González, J.J. Vilatela, J.M. Molina-Aldareguía, C.S. Lopes, and J. LLorca. Structural composites for multifunctional applications: Current challenges and future trends. Progress in Materials Science, 89:194, 251 (2017)

[2] Nihad A. Siddig, Christophe Binetruy, Elena Syerko, Pavel Simacek, and Suresh Advani. A new methodology for race-tracking detection and criticality in resin transfer molding process using pressure sensors. Journal of Composite Materials, 52(29):4087-4103 (2018)

Sadath A. Khan C.N.

Sadath A. Khan C.N. is an Engineering Director of ISECC (Infra-Structure Engineering and Construction Company), a subsidiary of Saudi Arabian Amiantit Company, dealing with composite piping and fitting. He started his career at ISECC in 1993 as a Design Engineer. He then served ISECC in various positions, namely QC and Field Engineer, Engineering Manager, Installation Manager, and currently Engineering Director. He accumulates 26-year of experience in non-metallic design and research, particularly for piping and tank, and project management. He also serves as a committee member for various standards in American Water Works Association (AWWA), including AWWA C-950 and M45 (Fiberglass Pipe Design), AWWA D-120 (Tanks Design Committee), AWWA D-121 (Panels Tanks Committee). He received MS degree in Civil Engineering (Structural Engineering) from King Fahd University of Petroleum and Minerals (KFUPM), Dammam, Saudi Arabia, and BS degree (First Class) in Civil Engineering from Osmania University, India.

Forty-two years of GRP usage in oil, gas, water and petrochemicals in the Middle East

Sadath A. Khan
Infra-Structure Engineering and Construction Company (ISECC), a subsidiary of Saudi Arabian Amiantit Company, Dammam, 31421, Saudi Arabia
E-mail: sadathcn@amiantit.com, grpexpert@gmail.com

ABSTRACT

Necessity is mother of invention; the saying goes on. Middle East is well known for its arid regions, and poses challenging climatic conditions coupled with varying nature of geological features. In general, the Middle East is surrounded by Red Sea and Arabian Gulf. The soils of these arid regions are laden with salts and fossil fuels. The deserted area of Middle East contains a chlorine on the air, and salts in the underground, leading to expansive soils called "Sabkhas", which are very sensitive to fluctuating water tables due to vicinities of two gulfs. All these concomitant conditions pose harsh environments for traditional piping materials. This situation has been aggravated with fluctuating humidity, temperatures coupled with arid environment poses high amount of risk for traditional construction materials. The mitigation of this risk was found in the hard plastics called as Glass Reinforced Plastics, commonly known by various standards, as Fiber Reinforced Plastics (FRP), GRP, Glass Fiber Reinforced Plastic (GFRP), Reinforced Plastic Mortar (RPM) or Reinforced Thermoset Resin Plastic (RTRP) is an amalgamation of resin, glass fiber, manufactured using appropriate additives and treatment methods. It is a engineering composite material uniquely capable of meeting a wide variety of specific processes and end-product requirements of various applications in fluid transportation requirements. It has a combinations of properties generally not found in any other traditional or conventional material. These include exceptionally high strength-to-weight ratio (with thin structures and superior mechanical properties that can withstand high pressure), superior corrosion resistance (no scaling and no build-up), maintenance free, higher hydraulic efficiency (smaller sizes), light weight (lower transportation and installation costs), higher resistance to a pressure surge (safer under worst conditions due to its low modulus of elasticity), best joining systems, excellent workability and design flexibility.

This paper discusses various stages of the GRP piping system in various fields of oil, gas, water and petrochemical industries in various areas of Saudi Arabia and Middle East in general, which was started in 1977. This paper provides an overview of the longest serving case history of the GRP piping system. The GRP piping system utilizing 25-mm to 4000-mm diameter pipes has been used in underground, on the ground, undersea with the gravity level producing 250 bar pressure on the pipes. In addition, this paper enumerates the challenges faced by the implementation of GRP piping system. Also, there is a need for the industry and university to work together, and pave a way for studying the methods for extending the service life of GRP piping systems.

REFERENCES

[1] Abdullah Al-Mhaidib, Sabkha Soil in the Kingdom of Saudi Arabia: Characteristics and treatment, Journal of King Abdulaziz University: Engineering Sciences, ISSN 1319-1047
[2] Kleovous G. Leondaris, Field Experience with Fiberglass Pipe in the Middle East, Buried Plastic Pipe Technology, Editors: George S. Buczala and Michael J. Cassady, ASTM - STP 1093
[3] Lee E. Pearson, Fiberglass pipe product standards - An update on performance, Buried Plastic Pipe Technology, Editors: George S. Buczala and Michael J. Cassady, ASTM - STP 1093
[4] AWWA-Manual M-45 "Fiberglass Pipe Design" American Water Works Association, Denver, Colorodo, USA

Vassilis Kostopoulos

Vassilis Kostopoulos is Professor and Director of Applied Mechanics & Vibrations Laboratory, Department of Mechanical Engineering and Aeronautics, University of Patras (AML/UPAT). He has a 30 year of experience in the field of composite and aerospace structures, more than 195 journal publications, more than 250 conference presentations, 4 books in the field of composites, 7 patents (3 EPO, 3 National and 1 US). Prof. Kostopoulos has extensive experience in research projects, having been the Principal Investigator for more than 40 European and more than 10 large national projects. For the last 5 years he holds the position of national delegate of Greece in the Advisory Council for Aerospace Research in Europe (ACARE) and he is vice chairman of the SRG in EU-JU-Clean Sky 2. His research interests lie in the fields of Design, Analysis and Optimization of Composite Structures, Multi-scale analysis of nano modified structural composites, Non-Destructive Inspection & Evaluation of Engineering Structures, Structural Health Monitoring, Nano-augmentation, Nano-engineering and Nano-design of structural composite materials, Fracture and Fatigue of Composites Materials and Structures, high strain rate behavior of composites, Blast behavior of Structures, Eco-design of composite structures, Natural fibers/green resin composites, Life cycle analysis of composite structures, Reuse and recycling of composites. He has been the main Supervisor of 29 completed PhD theses. His work has received more than 3780 citations and has an H-index 34.

An innovative material model calibration procedure for enhancing the fidelity of numerical solution in the case of impact loading of composites

V. Kostopoulos, E. Giannaros, A. Kotzakolios, G. Sotiriadis
Applied Mechanics & Vibrations Laboratory, Department of Mechanical Engineering and Aeronautics, University of Patras, Patras University Campus, GR-26500, Greece
E-mail: kostopoulos@mech.upatras.gr

ABSTRACT

The numerical prediction of impact induced damage to composite materials and the subsequent residual strength under compression loading continues to be a challenging task. The current study proposes an innovative material model calibration procedure to approximate the optimal combination of material model parameters that represent the experimental response of Cycom 977-2 material.

The optimization algorithm is based on the comparison of the numerical force-strain or force-displacement curves with the corresponding experimental ones and includes the most common quasi-static material characterization tests. For minimizing the parameters combinations, the calibration process was divided into two stages. The first stage includes the in-plane characterization tests (tension 0° & 90°, compression 0° & 90°, shear and open-hole tension tests) for calibration of orthotropic damage material model.

Whereas the second one consists of the mode I and mode II interlaminar fracture tests as well as the short beam shear test and targets to cohesive model calibration.

For validation of proposed methodology, low and high velocity impact tests at the energy level of 30 J were carried-out and simulated. Afterwards, the damaged specimens were tested to compression loading according to AITM 1-0010 standard.

The numerical contact force-time curve, the time history of projectile kinetic energy as well as the compression after impact maximum force are correlated with the experimentally derived results. Finally, proposals are provided for further enhancement of numerical results.

Shanmugam Kumar

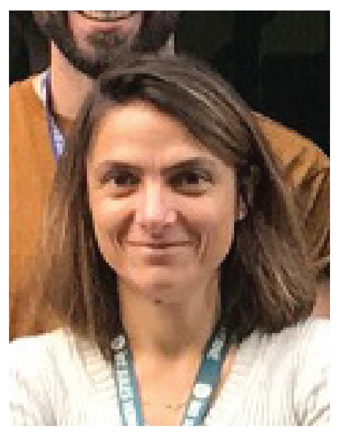
Shanmugam Kumar is a Reader in Composites and Additive Manufacturing, James Watt School of Engineering, University of Glasgow, UK. He was an Associate Professor in the Mechanical and Materials Engineering Department at the Masdar Institute (part of Khalifa University), Abu Dhabi. Dr. Kumar obtained a Ph.D. in Solid Mechanics and Materials Engineering from University of Oxford in the Department of Engineering Science. He leads the Advanced Materials and 3D Printing (AM3DP) Lab at MI. His research interests revolve around Mechanics, Materials and Design with a focus on multiscale/multifunctional attributes, particularly in the context of Additive Manufacturing for energy efficient and sustainable applications. In the last 8 years at MI, he has generated more than USD 5M through external grants as a lead Principal Investigator and has been awarded the ADEK award twice for research excellence (A2RE 2015 and A2RE 2017). He currently serves on the editorial board of the International Journal of Adhesion and Adhesives and Scientific Reports.

Multifunctional performance of engineered composites enabled by additive manufacturing and nanoengineering

Shanmugam Kumar
Advanced Materials and 3D Printing Laboratory (AM3DP), Department of Mechanical and Materials Engineering, Masdar Institute, Abu Dhabi
E-mail: s.kumar@eng.oxon.org

ABSTRACT

The emergence of micro-, nano-, and molecularly-tailored multi-material systems, particularly those enabled by additive manufacturing (AM) technologies, facilitates the design of new and enhanced functionalities. Building from advances in various disciplines including decades-long work on bulk microfiber heterogeneous composites, multi-material printing offers the possibility of cost-effective automation of the fabrication process and provides greater flexibility for locally tailoring the material architecture in three-dimensions. This talk will provide an overview of four such multidisciplinary research activities of my group enabled by AM and Nanoengineering: (i) enhanced performance of multilayers (compliance-tailoring, morphology-tailoring and surface-tailoring); (ii) biomaterials and bio-inspired design of materials (smart-nanocomposites for orthopedics, material-tailored nacreous composites, piezoresistive nanocomposites for sensing and 4D printing of morphing structures); (iii) multiscale and multifunctional fiber composites (hierarchical/multiscale composites, and camouflage composites) and (iv) architected and metamaterials (energy absorbing structures, batteries and supercapacitors, compact heat-exchangers, EMI shields, self-sensing scaffolds). Manipulating materials at ever smaller scales, in 3D and 4D, allows for strain-, stress- and functional-engineering towards enhanced performance, but also opens new opportunities in fabrication. The convergence of emerging nanoscale AM techniques and the ability to design nano- and micro-architected hierarchical structures with ever-more-tightly controlled geometry will enable the creation of new classes of materials with unprecedented properties optimized for location-specific structural and/or functional requirements.



Celine Largeau

Celine Largeau is an automotive market leader and FORCE project manager. She graduated from engineering school ISAE-ENSMA in Poitiers and obtained a Master degree in combustion/detonic in 2000. She worked for 6 years as a combustion engineer in Renault Formula 1 team (Viry Chatillon, France). Then she took the position of project manager in Renault group in 2007 and was in charge of adaptation/ technical design of the atmospheric 2l multifuel base engine on Duster 4*4 vehicle. She was coordinator of the Renault team in France and on the international stage (production in Rumania, Russia, Brazil and Colombia). In 2011 she moved to Nantes in Tristone Flowtech group where she was in charge of a team dedicated to hybrid and electrical vehicle cooling systems development. Since 2015, she works at Jules Verne Institute as R&T project manager and automotive business development. She is FORCE project manager and in charge of technical economic analysis, Business plan and market analysis.

The FORCE project: bio-based low-cost carbon fiber for a more intensive use of composites

C. Mercader[1] , C. Largeau[2], A. Rossi[3], C. Aufrère[3], S. Cassereau[2], P. Gaillard[1]
[1]CANOE, 16 av Pey Berland, 33600 Pessac
[2]IRT Jules Verne, Chemin du Chaffault, 44340 Bouguenais
[3]FAURECIA, 2 Rue Hennape, 92000 Nanterre
E-mail: celine.largeau@irt-jules-verne.fr

ABSTRACT

Carbon fiber is trading between 14 and 20 euros per kilo. This price is still too high to find composite applications based on carbon fiber in mass market applications such as automotive and sports and leisure industry. This is why we work in a large French consortium called FORCE, with the target of creating a French economic carbon fiber sector. We are now in the second phase of the project: carbon fiber production at laboratory and pilot scale. New precursors, as alternative to PAN, are evaluated: bio-sourced raw materials such as lignin and cellulose and polyethylene. The targeted mechanical properties are Young's Modulus of 250GPa and tensile strength of 2500MPa. The 2 first years of this phase were marked by noticeable progress in the different work packages of the project. The work involved has made it possible to structure the overall planning of the FORCE program with the vision of setting up the industrial line and the marketing of low-cost fiber.

FORCE project phase II is now at the pilot line scale development. A carbonization pilot line is now running in Lacq (SW of France). It has been co-funded by the Conseil Régional de Nouvelle-Aquitaine and IRT Jules Verne. It is a polyvalent continuous line able to produce enough carbon fibers for the realization of composite demonstrators, to carbonize different kinds of precursors, and to demonstrate the feasibility of further industrialization. This line is able to produce more than 1 t/year of carbon fibers.

Due to very good results with cellulose, work continues on this precursor only. This work is focused on the development of innovative formulations and processes with a number of actions such as: reducing the diameter of the filaments; investigating new technologies for heating; optimizing the carbonization step through the design of experiments, simulations, and hands-on experience. The latest results obtained with a carbonized fiber at the laboratory scale are very close to the mechanical objective. These results have already been confirmed on the pilot line in Lacq during the 2nd part of 2019.

- The work on the raw materials to obtain the best compromise between cost and performance with focus on raw materials from circular economy such as cellulose from recycled textiles containing cotton and papers.
- The different way to obtain good quality cellulose from recycled goods.
- The different chemical and mechanical treatments and processes developed for the spinning of the recycled cellulose and our future coagulation pilot line that will be installed close to the carbonization pilot line in Lacq. This new line will help us to improve the performance of the cellulose and to control all the economical aspect.
- The ongoing work to increase the carbonization yield of our precursor without decreasing the mechanical properties, using chemical and mechanical approaches with research on both commercial and new solutions.
- The ongoing computer modelling work to simulate the carbonization static oven and the thermal phenomena around and in the fiber. The main characteristics of the carbonization pilot line.
- Some highlights of industrial scale-up. The material balances and the process block diagrams for cellulose precursor are in the course of being established, through a combination of the laboratory results and the results on the carbonization pilot line and on the future coagulation pilot line.

Jinsong Leng

Jinsong Leng is Cheung Kong Chair Professor and Director of the Center for Smart Materials and Structures at Harbin Institute of Tech¬nology (China). His researches cover Stimulus Responsive Polymers (Shape Memory and Electro-Active Polymers) and their composites, 4D printing, Sensors and Actuators, Structural Health Monitoring, Multi¬functional Nanocomposites, etc. Prof. Leng has served as the Vice Pres¬ident of International Committee on Composite Materials (ICCM), Vice President of Chinese Society for Composite Materials (CSCM). He has also been elected as Foreign Member of Academia Europaea, Member of the European Academy of Sciences and Arts, World Fellow of ICCM, Fellow of AAAS, Fellow of the SPIE, Fellow of IOP, Fellow of RAeS, Fellow of IMMM and Associate Fellow of AIAA.

Shape memory polymer composites and 4D printing for aerospace and biomedical applications

Jinsong Leng
Centre for Composite Materials and Structures, Harbin Institute of Technology
E-mail: lengjs@hit.edu.cn

ABSTRACT

Shape memory polymers (SMP) and shape memory polymer composite (SMPC) can automatically deform when actuated by stimulus, which have the advantages of fast response, high rebound rate, light weight, low cost, easy processing and applications in various intelligent structures and devices [1,2]. Four dimensional (4D) printing refers to adding new additive manufacturing technology on the basis of four dimensional time. The four-dimensional printing of SMPs/SMPCs can rapidly manufacture reconfigurable structures in aerospace, medical and other professional fields. Our team has developed a series of 4-D printed SMPs/SMPCs structures, such as bone scaffolds, vascular scaffolds and expandable spatial structures that can change shape or size in outer space. By de¬signing the molecular structure of shape memory polymer and adding special functional fillers, the printing structure can be driven remotely by light, electricity and magnetic field. It believed that 4D technology will continue to bring more and more opportunities in many fields in the next few years.

REFERENCES

[1] C. Lin, J. Lv, Y. Li, et al. 4D-Printed Biodegradable and Remotely Controllable Shape Memory Occlusion Devices. Advanced Functional Materials, 2019:1906569.

[2] W. Zhao, L. Liu, J. Leng, et al. Thermo-mechanical behavior prediction of particu¬late reinforced shape memory polymer composite. Composites Part B: Engineering, 179:107455 (2019).

[3] H. Wei, Q. Zhang, Y. Yao, et al. Direct-write fabrication of 4D active shape-changing structures based on a shape memory polymer and its nanocomposite. ACS applied materials & interfaces, 9(1): 876-883 (2016).

[4] J. Leng, X. Lan, Y. Liu, et al. Shape-memory polymers and their composites: stimulus methods and applications. Progress in Materials Science, 56(7): 1077-1135 (2011).

Gilles Lubineau

Pr. Gilles Lubineau is professor of Mechanical Engineering and Chair of the Faculty of Mechanical Engineering at KAUST. He is principal investigator for COHMAS (COmposite and Heterogeneous Materials Analysis and Simulation, an integrated environment for composite engineering that he created in 2009 when joining KAUST).

Following his "aggregation" in theoretical mechanics, Pr. Lubineau earned a PhD degree in Mechanical Engineering from École Normale Supérieure de Cachan (ENS-Cachan), France. Before joining KAUST, Pr. 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.

His fields of research 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, nano and/or multifunctional materials. He covers a wide expertise related to most fields of composite materials, with over 200 published papers in journal spanning from material science (Advanced Materials, Macromolecules, etc..) all the way to theoretical mechanics (JMPS, CST, Scientific Reports) and applied maths (IJNME, CMAME, etc.).

He is also board member for various journals, including the International Journal of Damage Mechanics. Prof. Lubineau is an elected Member of the European Academy of Sciences and Arts.

Towards high performance adhesive bonding by substrate and/or adhesive texturing

Gilles Lubineau
King Abdullah University of Science and Technology (KAUST), Physical Science and Engineering Division (PSE), COHMAS Laboratory, Thuwal 23955-6900, Saudi Arabia
E-mail: gilles.lubineau@kaust.edu.sa

ABSTRACT

To reduce emissions of pollutants, automotive and aerospace industries are seeking new solutions to create lighter structures. Extreme lightweight structures can today be obtained by using high-performance composites based on continuous fibers and polymeric matrices. Assembling composite parts is however still a challenge that often jeopardizes the energy efficiency (e.g. bolting or riveting). Integral adhesive bonding is not used for primary structure today, because of its extreme sensitivity to the quality of the substrate preparation that can largely modify the intrinsic performance of the joint. More important for us, the failure of adhesive joints is often unstable: the joint behaves well until the development of a catastrophic crack that would propagate throughout the whole joint.

Our objective is here to introduce new strategies to equip by design adhesive interfaces with crack arrest features. From a practical point of view, we are manipulating the R-curve of the interface by introducing non-local dissipative mechanisms, such as bridging, that will add to the classical cohesive energy of the adhesive.

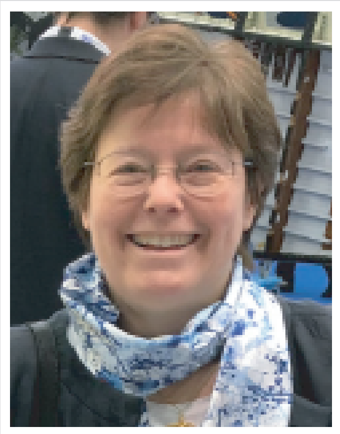
Two different technologies are introduced to realize this toughening objective.

In the first approach [1-3], we are introducing heterogeneous interfacial properties (strength and toughness) between the adhesive layer and the substrate. The introduction of inclusions with higher strength results in separating the main crack into two sub-cracks that are propagating simultaneously and are increasing the effective toughness. In a second approach [4], bridging ligaments are triggered by introducing a non-symmetric thermoplastic inclusion inside the thermoset based adhesive layer. The progressive stretch of the thermoplastic ligaments results in an extra dissipation that participates in toughening the joints.

For each approach, this presentation will cover the fundamental concept via simulation of the joint failure. Guided by these, an extensive experimental campaign has been performed in which we successfully demonstrated that controlling ligament bridging is possible via simple manufacturing techniques or structuration of the interface. These strategies open new directions towards more trustable adhesive bonding-based solutions.

REFERENCES

[1] R. Tao, M. Alfano and G. Lubineau. Laser-based surface patterning of composite plates for improved secondary adhesive bonding. Composites Part A, 109:84-94 (2018).
[2] R. Tao, M. Alfano and G. Lubineau (2019). In situ analysis of interfacial damage in adhesively bonded composite joints subjected to various surface pretreatments. Composites Part A, 116:216-223 (2019).
[3] R. Tao, X. Li, A. Yudhanto, M. Alfano and G. Lubineau. On controlling interfacial heterogeneity to trigger bridging in secondary bonded composites: an efficient strategy to introduce crack-arrest features. Composites Science and Technology, 188, Article 107964
[4] A. Yudhanto, M. Almulhim, F. Kamal, L. Fatta, R. Tao, M. Alfano and G. Lubineau. Enhancement of fracture toughness in secondary bonded CFRP using hybrid thermoplastic/thermoset bondline architecture. Under review.



Véronique Michaud

Véronique Michaud is currently Associate Professor and head of the Laboratory for Processing of Advanced Composites, and Associate Dean of Engineering for Education, at the Ecole Polytechnique Fédérale de Lausanne, in Switzerland. She obtained an engineering degree in 1987 from Ecole des Mines in Paris with, a PhD in Materials Engineering in 1991 from MIT, and Research Habilitation in 1994 from INPG, France. After a post-doctoral research stay at MIT, she spent 3 years at Ecole Centrale in Paris for teaching and research in the Laboratory for Materials, Structures and Soils Mechanics, before joining EPFL in 1997. Her fields of research are fundamentals of composite materials processing, as well as smart materials and structures including self-healing, shape and vibration control and tailored damping.

Composites for a more sustainable future...tough, healable, recyclable?

Amaël Cohades, Robin Trigueira, Nathan Hostettler, Cecilia Scazzoli, Véronique Michaud[1]
[1]Laboratory for Processing of Advanced Composites (LPAC), Ecole Polytechnique Fédérale de Lausanne (EPFL), Station 12, CH-1015 Lausanne, Switzerland
E-mail: veronique.michaud@epfl.ch

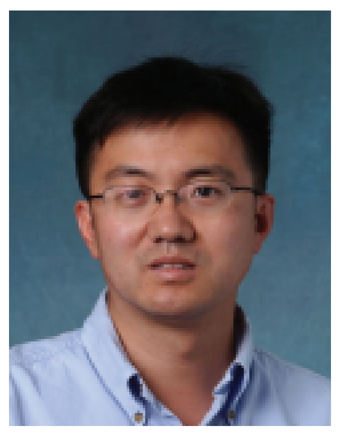
ABSTRACT

Fiber reinforced thermoset composites (FRP) are found in many applications, including mobility, energy generation, or sport equipment. However, the brittleness of the thermoset matrix results in high sensitivity to small damage events through early matrix cracking. A commercially available approach to limit damage growth is to toughen the matrix by dispersing small rubbery or thermoplastic particles in the thermoset; however this tends to impact production processes, does not prevent costly repair operations, and these materials remain difficult to recycle. Thermoplastic based composites, on the other hand, gain market shares as they are more easily recyclable, but remain costly, or suffer from a lack of stiffness at moderate temperatures. A compromise can arise from the use of thermoplastic/thermoset blends, which, if the microstructure is well engineered, can lead to tough and damage tolerant materials, which can also be easily repaired and recycled, thus enhancing their potential for increased sustainability.

We recently showed that healing matrices based on thermoset-thermoplastic (more specifically epoxy and polycaprolactone) phase-separated blends demonstrated a large potential for heat-assisted repair [1-5]. The thermoplastic phase expands upon melting at moderate temperature, filling (repeatedly) small cracks. When integrated to FRPs (through conventional liquid composite molding process), the developed healing matrix led to composites with similar stiffness and bending strength to that of pure epoxy composites, but also to full recovery of compression after impact strength for low damage extent (impacts of 8.5 J), however the toughness of the material was quite reduced. By playing on the composition of the blend and the reaction kinetics of the thermoset phase, a wide range of promising materials were found, that lead to good structural properties at room temperature and improved initial toughness. If needed, these materials can also accommodate SMA stitches, which improve crack closure and provide even higher initial toughness to the material. We are now able to propose a structural FRP that (i) is tougher than benchmark epoxy-based composites, (ii) can repeatedly heal matrix microcracks (iii) has a manufacturing route compatible with large scale industrial processes (iv) shows better recyclability than benchmark epoxy alternatives. We will present this new composite material combination, as well as its static, fatigue and impact healing properties.

REFERENCES

[1] [1] A. Cohades, C. Branfoot, S. Rae, I. Bond, V. Michaud, Progress in Self-healing Fiber reinforced Polymer Composites, Progress report, Advanced Materials Interfaces, 5(17), Article 1800177 (2018)
[2] A. Cohades, N. Hostettler, M. Pauchard, C.J.G. Plummer, V. Michaud, Stitched shape memory alloy wires enhance damage recovery in self-healing fiber reinforced polymer composites, Composite Science and Technology, 161:22-31 (2018)
[3] A. Cohades, E. Manfredi, C.J.G. Plummer, V. Michaud, Thermal Mending in phase-separated Epoxy -polycaprolactone blends, European Polymer Journal, 81:114–128 (2016)
[4] A. Cohades, V. Michaud, Damage recovery after impact in E-glass reinforced Poly(ε-caprolactone)/epoxy blends, Composite Structures, 180:439–447 (2017)
[5] A. Cohades, V. Michaud, Thermal mending in E-glass reinforced Poly(ε-caprolactone)/epoxy blends, Composites Part A, 99:129–138 (2017)



H. Jerry Qi

H. Jerry Qi is Professor and the Woodruff Faculty Fellow in the School of Mechanical Engineering at Georgia Institute of Technology. He received his doctoral degree from MIT in 2003. He joined University of Colorado Boulder as an assistant professor in 2004 and moved to Georgia Tech in 2014. Prof. Qi's research is in the broad field of nonlinear mechanics of active polymers. He and his collaborators have been working on a range of active polymers, including shape memory polymers, light activated polymers, covalent adaptable network polymers, for their interesting behaviors such as shape memory, light actuation, surface patterning, surface welding, healing, and reprocessing. In recent years, he has been working on investigating integrating active materials with 3D printing. He and his collaborators pioneered the 4D printing concept. Prof. Qi is a recipient of NSF CAREER award (2007) and was elected to an ASME Fellow.

Multimaterial additive manufacturing for printed active composites

H. Jerry Qi
Georgia Institute of Technology, School of Mechanical Engineering, Atlanta, GA 30068, USA
E-mail: qih@me.gatech.edu

ABSTRACT

3D printing (additive manufacturing) where materials are deposited in a layer-by-layer manner to form a 3D solid has seen significant advances in recent decades. 3D printing has the advantage of creating a part with complex geometry from a digit file, making them an ideal candidate for making architected materials. Multimaterial 3D printing is an emerging field in recent years in additive manufacturing. It offers the advantage of the placement of materials with different properties in the 3D space with high resolution, or controllable heterogeneity. It also provides new opportunities to create a new class of composites, active composites, where active materials are used together with non-active materials to fabricate a composite that can intelligently respond to environmental stimuli, such as temperature, pH, etc. In this talk, we present our work in using additive manufacturing, in particular, multimaterial additive manufacturing, to fabricate active composites [1]. We start by using a commercial polyjet 3D printer, in which one of the materials is a shape memory polymer. Through careful design of spatial distribution of active and non-active materials, we are able to create active composites that can change their shape upon environmental stimuli [2], such as temperature (Fig. 1). We then present a new development of a novel multi-material multi-method (m4) 3D printing where we integrate four types of additive manufacturing methods and two complementary methods into one platform [3]. This highly integrated multi-material hybrid printing system allows us to integrate materials of dramatically different properties, such as polymers, liquid crystal elastomers, and conductive materials into one composite, and thus enables unprecedented functionalities. Finally, the future challenge of additive manufacturing for active composites will be discussed.

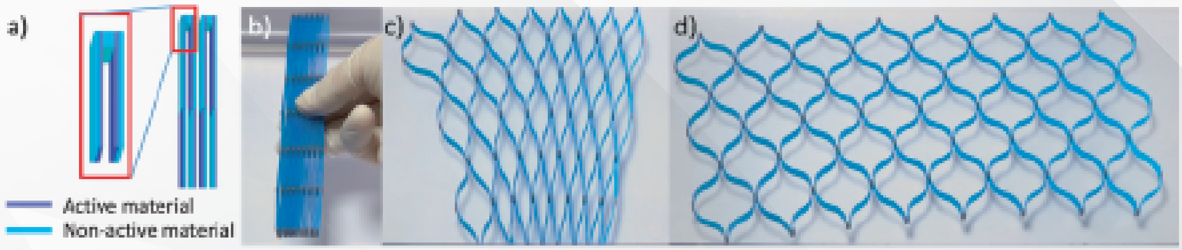


Figure 1: Printed active composites: an expanding lattice [2]: (a) both active and non-active materials are used, (b) the as-printed lattice, (c) it expands upon heating, (d) the fully expanded lattice.

REFERENCES

[1] Q. Ge, H.J. Qi, and M.L. Dunn, Active materials by four-dimension printing. Applied Physics Letters, 103:131901 (2013)
[2] Z. Ding, C. Yuan, X. Peng, T. Wang, H.J. Qi, and M.L. Dunn, Direct 4D printing via active composite materials. Science Advances, 3(4):e1602890 (2017)
[3] D.J. Roach, C.M. Hamel, C.K. Dunn, M.V. Johnson, X. Kuang, and H.J. Qi, The m4 3D printer: A multi-material multi-method additive manufacturing platform for future 3D printed structures. Additive Manufacturing, 29:100819 (2019).

Sanjay Rastogi

Sanjay Rastogi is a full professor at KAUST since October 1, 2020. Prior to joining KAUST he was a professor at Maastricht University, and Eindhoven University of Technology in the Netherlands. He holds more than 25 years of experience working with chemical industry, while maintaining his base in the academia. For a period of 7 years he has been a Global Technology leader of Teijin while based in the Netherlands, and has transferred fundamental knowledge developed in his laboratory to the commercial development of the strongest man-made tape sold under the brand name of Endumax. He has been a recipient of Max-Planck Society fellowship at the Max Planck Institute for Polymers in Mainz, and a recipient of Outstanding Scientist position at Council of Science and Industrial Research (CSIR), India while affiliated with the National Chemical Lab in Pune. He holds Executive MBA degree from the Rotterdam School of Management, financially supported by Teijin. Following the chain-of-knowledge approach in Polymer Science and Technology, Sanjay is engaged in setting a lab at KAUST dedicated on polymer synthesis, physics, rheology, processing including additive manufacturing, and mechanical properties. He is also involved in setting a syllabus for teaching the students and industrial partners along these lines.

One component recyclable high performance composites

Sanjay Rastogi, Dario Romano, Joris van der Eem
Division of Physical Science and Engineering, King Abdullah University of Science and Technology (KAUST)
Thuwal, Saudi Arabia
E-mails: sanjay.rastogi@kaust.edu.sa

ABSTRACT

It is apparent that the increasing societal requirement demands materials that are sustainable and environmental friendly. This requirement of today, and future, is to be addressed at different scales from retrieving of the monomer, to its conversion into a product and reuse of the same product at the end of its lifetime with added value.

In this presentation, I will address this challenge by showing a route to develop the high performance materials that brings the commodity plastic into a domain of engineering polymer while using the easily accessible monomers such as ethylene, propylene, carbon mono-oxide, methyl pentene-1, etc. These polymers on their own are easy to process and hold the potential of opening the new horizon in terms of mechanical and physical properties. Retrospectively, providing solutions for recyclable reinforced thermoplastic composites meeting the requirements in the sector of oil & gas transportation, health, body and vehicle armor protection, automotive, packaging, etc. The polymers when mixed with the commodity plastic enhances the mechanical response of the blended polymeric material with the potential of replacing, difficult to recycle, composites made from two or more thermosets and thermoplastics.

T.E. (Tong-Earn) Tay

T.E. (Tong-Earn) Tay is a Professor at the Department of Mechanical Engineering, National University of Singapore (NUS). He obtained his Bachelors of Engineering (First Class) and PhD in Solid Mechanics from the University of Melbourne, Australia. His research interests are in computational modeling and analysis of progressive damage, failure, fracture, impact, integrated design and manufacturing, multiscale modeling of fiber-reinforced composite materials and structures. He is an Associate Editor for the Journal of Reinforced Plastics & Composites, and serves on the editorial boards of the Journal of Composite Materials, International Journal of Damage Mechanics, Applied Composite Materials, and Multiscale and Multidisciplinary Modeling, Experiment and Design. He has served on a number of scientific advisory committees of international conferences on composites and presented several keynote, plenary and invited talks. He is the author or co-author of 148 international journal papers, 3 invited book chapters, 3 patents and 245 conference and seminar presentations. He has obtained research funding from various agencies and industry, including Rolls-Royce, Airbus Germany, Haliburton Far East, Vestas, US Air Force Office of Scientific Research (AFOSR), A-Star Science & Engineering Research Council (SERC), Defence Science Organization (DSO), Marine Port Authority (MPA) and Ministry of Education. He is a recipient of JEC Life Achievement Award, a registered Professional Engineer (PE), Chartered Engineer (CEng), Founding Fellow of the Singapore Academy of Engineering (FSAE) and Council Member of the Asian-Australasian Association for Composite Materials. He was Head of Department of Mechanical Engineering, NUS, from Oct 2011 to Dec 2015, and Vice-Dean for Research for Faculty of Engineering, NUS, from Nov 2009 to Sep 2011.

High-fidelity computational failure analysis of composite structures

Tong-Earn Tay, Vincent Tan, Jie Zhi, Xin Lu, Karthikayen Raju

National University of Singapore (NUS), Department of Mechanical Engineering, 9 Engineering Drive 1, Singapore 117576
E-mail: mpetayte@nus.edu.sg

ABSTRACT

Fiber-reinforced composites offer lightweight, high-strength and high-stiffness solutions for many structural applications. The trend of increasing composites use is anticipated to continue well into the future as the drive for sustainable solutions gains urgency. However, due to their anisotropic and laminated nature, the fracture and damage mechanisms of such structures are coupled and complex. The prediction of structural performance of composite structures is critical to their design and optimization of material usage. This requires understanding of the interaction and evolution of damage mechanisms and their accurate modeling in computational analysis, often at multi-scale levels. Recently, advanced and innovative computational methods have been devised to improve failure prediction based on underlying mechanics and progressive damage observations. This lecture will overview the advantages of some recent discrete crack approaches [1,2] for composites as well as high-fidelity methods such as an adaptive discrete-smeared crack (A-DiSC) method [3] that could point the way to model impact damage and failure of large composite structures. Innovative finite element squared (FE2) methods [4] have potential to solve multi-scale fracture and damage problems in composites by directly incorporating failure mechanisms at the micromechanics levels and enable efficient structural modeling of complex 3D-printed structures. A brief overview of the research activities of the composites materials and structures group at the Department of Mechanical Engineering, National University of Singapore, will also be included in the presentation.

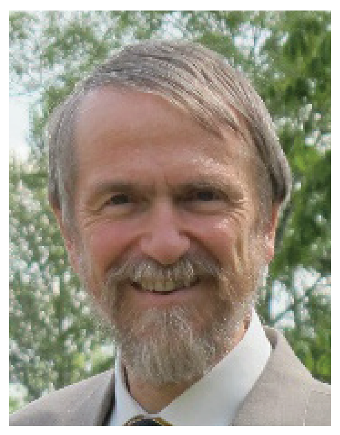
REFERENCES

[1] J. Zhi, T.E. Tay, Explicit modelling of matrix cracking and delamination in laminated composites with discontinuous solid-shell elements, Computer Methods in Applied Mechanics and Engineering, 351:60-84 (2019)

[2] X. Lu, B.Y. Chen, V.B.C. Tan, T.E. Tay, A separable cohesive element for modelling coupled failure in laminated composite materials, Composites Part A, 107:387-398 (2018)

[3] X. Lu, M. Ridha, V.B.C. Tan, T.E. Tay, Adaptive discrete-smeared crack (A-DiSC) model for multi-scale progressive damage in composites, Composites Part A, 125:1-16 (2019)

[4] V.B.C. Tan, K. Raju, H.P. Lee, Direct FE2 for concurrent multilevel modeling of heterogeneous structures, Computer Methods in Applied Mechanics and Engineering, 360, Article 112694, 2020



Michael Wisnom

Michael Wisnom is Professor of Aerospace Structures at the University of Bristol. He is Director of Bristol Composites Institute (ACCIS), which builds on the work of the Advanced Composites Collaboration for Innovation and Science which he founded in 2007. He is a leading expert on the mechanics and failure of fibre reinforced composites, with over 400 published papers. He is a member of the steering board of the UK National Composites Centre, Editor in Chief and European Editor for Applied Science and Manufacturing of the international journal Composites Part A, and was Director of the Rolls-Royce Composites University Technology Centre from 2007-2017. He is a Fellow of the Royal Academy of Engineering, of the Institution of Mechanical Engineers and of the American Society for Composites. Professor Wisnom received a Royal Society Wolfson Research Merit Award in 2005 and was President of the International Committee on Composite Materials from 2009-2011.

Thin-ply hybrid composites with pseudo-ductile response in tension, compression and bending

Michael Wisnom
Bristol Composites Institute (ACCIS), University of Bristol. Queens Building, University Walk, Bristol BS8 1TR, U.K.
E-mail: M.Wisnom@bristol.ac.uk

ABSTRACT

Composite materials have excellent specific strength and stiffness, but a major drawback is their lack of ductility. This paper shows how thin-ply hybrid laminates can be created that give a more gradual failure, drawing on the work of the High Performance Ductile Composite Technology programme (HiPerDuCT) between the University of Bristol and Imperial College.

Thin plies can suppress matrix cracking and delamination and prevent premature failure. Thin-ply hybrid composites, for example of glass and carbon, or different grades of carbon fibres, can produce stable fibre fracture in the low strain to failure material without delamination occurring. This ply fragmentation creates a plateau on the tension stress-strain curve as progressive fragmentation occurs with load transfer onto the higher strain material, Fig. 1a. Nonlinear behavior due to ply fragmentation can also occur in compression by deformation on angled compression cracks and localized delamination, Fig. 1b. The pseudo-ductility allows load redistribution around stress concentrations, making the material less notch sensitive and potentially more damage tolerant. This paper describes the pseudo-ductile behaviour of thin-ply hybrids in tension, compression and bending and shows how they can produce a more gradual failure response.

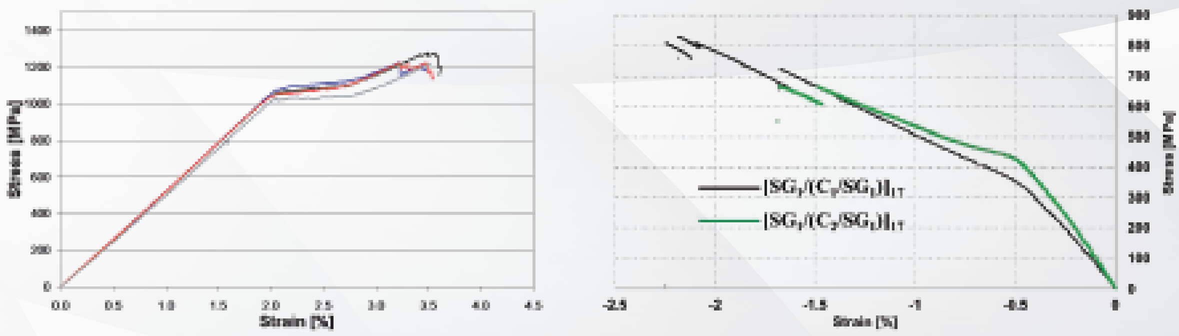


Figure 1: Pseudo-ductile stress-strain responses of glass/carbon hybrid laminates

REFERENCES

1. G. Czél, M. Jalalvand, M. R. Wisnom, Design and characterization of advanced pseudo-ductile unidirectional thin-ply carbon/epoxy-glass/epoxy hybrid composites, Composite Structures, 143, 362–370 (2016)
2. P. Suwarta, G. Czél, M. Fotouhi, J. Rycerz, M. R. Wisnom, Pseudo-ductility of Unidirectional Thin Ply Hybrid Composites in Longitudinal Compression, ASC 33rd Annual Tech. Conf., Seattle, Sept. 2018.

Recep Yaldiz

Recep Yaldiz is a Staff Scientist in Advanced Thermoplastic Composites of SABIC Specialties, The Netherlands. He obtained his MSc degree in Aerospace Engineering from Delft University of Technology (Departments of Constructions & Computational Mechanics and Production Technology). After that, he worked about a year at AIRBUS in Germany on the development of A380 double deck aircraft. He then returned back to the Netherlands and worked 4 years at DSM as an Application Development Engineer. Recep joined SABIC in January 2008 and worked on development of applications with thermoplastic composites (TPCs). Since January 2017, he is the focal point from SABIC for the Airborne partnership as the program & project manager targeting development and implementation of Digital Composites Manufacturing Line (the first full Industry 4.0. solution for TPCs).

Mass-scale production of Composites via Automation and Digitalization – DCML "a breakthrough technology to address an industry need"

Recep Yaldiz[1], Nikhil Verghese[2]
[1]SABIC Specialties, Geleen, The Netherlands
[2]SABIC Specialties, Houston, USA
E-mails: Recep.Yaldiz@SABIC.com; Nikhil.Verghese@SABIC.com

ABSTRACT

Thermoplastic composites are increasingly being considered for large volume applications that involve replacing incumbent materials such as metals. The Consumer Electronics space in particular, offers an interesting opportunity to capitalize on the performance of fiber-reinforced composites because of the general need to go to thinner structures while being frugal with changes in weight in applications like mobile computing and communications [1, 2]. These applications tend to lean towards a large part build volume, typically in the range of a million parts per year. The model platform also tend to be short lived, which means there is a constant need to stay on top of what the customer's perceived needs are and adapt accordingly with new models. This makes the designed flexibility of the manufacturing line very important. All of this creates the perfect opportunity to explore automation driven production approaches. The development challenges however for this automation driven production approach were identified to be: high speed production, with minimal scrap and minimal human intervention resulting in low conversion costs, while still maintaining a high degree of flexibility [2].

An end-to-end automated manufacturing line in which all steps are integrated and automated into a consolidated system, thus producing a constant production flow was developed through a partnership between Airborne and SABIC. In many cases, automation technology is developed separately from material development community, yielding sub-optimal results. Here we take a holistic view and develop the most effective technology taking into account all these aspects, in material development, automation and product design. The technology developed is also suited for high-end products in other markets, such as automotive, aerospace or sporting goods.

The ultimate goal of this line is to be fully digital and designed for minimal human intervention. It features full in-line inspection of the input material as well as the finished part. This information is processed in real time allowing online process optimization to adapt the process settings on-the-fly, based on the measured data and required output quality. Ultimately, this can deliver flexibility in order to accommodate changes that the industry demands.

REFERENCES

[1] Malnati P., Francato G., Yaldiz R., Scott D., Stanworth A. Consumer Electronics: hybrid composite cases/covers. Composites World Magazine, August 2019.

[2] Muilwijk M., Yaldiz R., Kremers M, Verghese N., Van Zyl, A., Industrialized and digital manufacturing of Thermoplastic Composites, ITHEC, November, 2018.

Campus Map


Extension
Pelican Lane Park
Nakheel Park
Safron Lane Park
Sawsan Lane
Butterfly Lane
Carob Tree Park
Bougainvillea Lane
Nargis Lane
Sagger Lane
Residential
Tennis Court - 3 - HSC
Soccer Pitch - HSC
Primary Basketball Ground
Black Iris Road
Inspiration Avenue
Bayt Al Hikmah Boulevard
Discovery Boulevard
Beacon Avenue
Hope Avenue
Peace Avenue
Heli Pad Lane
King Abdullah Boulevard
Academic Campus
Town Center
Unity Boulevard
Research Incubator
South Research Road
Achievement Road
CMOR
Red Sea
Cup Utility Plants
South Future
21
20
19
18
5
5
4
4
15
16
9
21
12
13
1
1
3
3
6
7
2
2
14
24
22
23
28
26
27
25
36
37
35
34
38

flexible
piezoresistivity
multiphysics
fibers
soft
sensors
micromechanics
composites
thermosets
laminates
mechanics
aging
thermoplastics
integrity
stressesmoisture
impact
glass
homogenization
residual
multiscale
microstructure
actuators
robotics
strechable


ectronics
amination
nment
bon
baqus
mechanics

Mechanics of Composites for Energy and Mobility

FUTURE COMPOSITES

https://composites.kaust.edu.sa