The British Society for Strain Measurement

POSTGRADUATE EXPERIMENTAL MECHANICS (PGEM) CONFERENCE

7th & 8th April 2022, University of Bristol

CONFERENCE PROGRAMME

The BSSM PGEM conference showcases work by PhD/MPhil/MSc students in the field of engineering measurement and experimental techniques in stress, strain, and vibration analysis.

Welcome to PGEM 2022

Welcome to the 7th BSSM postgraduate experimental mechanics conference and to the University of Bristol. We hope that the conference will facilitate the sharing of ideas as well as helping you to add to your network of contacts in the community!

We are excited to welcome you to Bristol, which is not only home to the Clifton Suspension Bridge that Isambard Kingdom Brunel started to design with only 24 years of age (no pressure!), but also to a vibrant street art, food, and craft beer scene.

Also welcome to the University of Bristol, located in the centre of the city! The University is proud to host the BSSM PGEM conference and to support PhD, MPhil, and MSc students in the field of experimental mechanics; The University itself has a strong track record in the field with excellent research facilities. It is also home to the Bristol Composite Institute (BCI), a world leading research centre for the experimental and numerical characterisation of advanced composite materials, and world leading research groups in solid mechanics and Ultrasonic and Non-Destructive Testing (UNDT).

We hope that you will enjoy discovering the city as well as the conference program that we have put together for you.

Following the University's COVID-19 advice and guidance (more info here: https://www.bristol.ac.uk/safety/news/covid/), we have put in place the following precautions:

- Adjusted room occupancy guidelines
- We recommend that face coverings are worn where possible when inside university buildings

Looking forward to meeting you in person!

Dr Neha Chandarana (Chair)

Conference committee and organising team:

Dr Geir Olafsson, Dr Tobias Laux, Dr Eralp Demir, Dr Clementine Jacquemoud, Tamsin Dobson, Amelia Billings, Prof Janice Dulieu-Barton, and Dr Hari Arora

Your conference chairs and organising committee

Dr Neha Chandarana
PGEM 2022 Chair

Neha joined the University of Bristol in October 2021 and holds the positions of Lecturer in Bio-based and Sustainable Composites and Faculty Equity, Diversity, and Inclusivity Champion. Prior to this she undertook a PhD and an EPSRC Doctoral Prize Fellowship at The University of Manchester. Neha's research is focused on structural health monitoring for early damage detection in composite materials. She has a special interest in developing the method of acoustic emission monitoring through the use of complimentary non-destructive evaluation techniques, machine learning, and finite element based progressive damage models. Neha is passionate about promoting STEM through outreach and public engagement activities and is a board member for the Women of Science campaign (www.womenofsci.com). Neha was the winner of the BSSM PGEM presentation competition in 2019 and has since held a role on the BSSM conference scientific committee, having organised PGEM 2020 and the Young Stress Analysist 2021.

Prof Janice Dulieu-Barton
PGEM Co-chair

Janice was appointed in May 2019 as a full Professor of Experimental Mechanics in the Bristol Composites Institute at the University of Bristol. Prior to this she worked at the University of Southampton for 20 years in the School of Engineering. She received her PhD from the University of Manchester in 1993 where she started her research on the topic now known as 'Thermoelastic stress analysis'. She has published around 320 papers with 120 in archival journals, edited 11 conference proceedings and produced 8 book chapters. Janice's expertise is in imaging for data rich materials characterisations and assessments of structural performance, with a focus on lightweight structural design particularly composite structures. She has won numerous grants that have allowed her to develop novel approaches in experimental mechanics, with as special focus on the development of infra-red imaging. Janice has been very active in the European Experimental Mechanics community, notably chairing the BSSM and serving on their National Council for 14 years, chairing and organising many conferences and technical seminars, including the 16th International Conference on Experimental Mechanics in Cambridge, attended by over 500 delegates. Janice is also active in training and mentoring early career researchers; she has supervised over 30 successful PhDs and her 5-day annual workshop on Experimental Mechanics for postgraduate students has run annually for the past 10 years and attracts around 25-30 delegates internationally.

Dr Hari Arora
PGEM Co-chair

Hari is an Associate Professor in Biomedical Engineering at Swansea University. He did his undergraduate studies 2004-2008 in the Department of Mechanical Engineering at Imperial College London, where he also later completed his PhD titled "Blast loading of fibre reinforced polymer composite structures". He worked in the Mechanics of Materials Section and Soft Solids Group at Imperial 2011-2013 as a postdoc, completing computational and experimental projects related to impact, nonlinear material behaviour and fracture.

In 2013, he was awarded a Research Fellowship funded by The Royal British Legion and Imperial College London to study Lung Mechanics in the Department of Bioengineering and The Centre for Blast Injury Studies. Here, he developed his research area focused on creating optimised protection strategies against injury, through characterisation of human body biomechanics in trauma. He currently works as part of Biomedical Research Group within the Zienkiewicz Centre for Computational Engineering at Swansea University focused on lung mechanics in health, disease and trauma. He has served on the National Committee of the BSSM since 2016 and is the current Conference Committee Co-Chair.

Andrew Ramage
BSSM Chair

Since graduating from the University of Southampton with MEng Aeronautics & Astronautics, Andrew spent 14 years involved in the design and test of rotary wing aircraft at what is currently named Leonardo Helicopters. For the last 5 years Andrew has been a Director of Techni Measure Ltd, supporting UK industry with the supply and installation of strain gauges and many other types of sensors for test & measurement applications and it is in this role that Andrew became involved in BSSM. Whilst mainly experienced in bonded resistance and fibre optic strain gauges, Andrew has an ardent interest and fast growing knowledge in all methods of strain measurement. BSSM is a strong part of Andrew’s heritage since his grandfather Frank Ramage and father Ian Ramage have both been involved with the Society since its foundation in 1964.

Amelia Billings

Amelia Billings is a postgraduate research student in the Solid Mechanics Research Group at the University of Bristol. Her research is focused on the damage mechanisms of a CuCrZr alloy, a candidate material for use as the cooling pipes in the divertor exhaust component of Nuclear Fusion tokamak reactors. Her project involves a combination of mechanical testing, fractography, X-ray computed tomography and finite element modelling.

Clémentine Jacquemoud

Clémentine Jacquemoud is a Visiting Research Fellow from the French Alternative Energies and Atomic Energy Commission (CEA). Her expertise mainly concerns fracture mechanics, structural integrity and fatigue analysis for the nuclear industry in France. She is now working with the Solid Mechanics Research Group at the University of Bristol.

Eralp Demir

Eralp Demir is a Senior Research Associate from Solid Mechanics group of Mechanical Engineering Department at the University of Bristol. He has over 30 scientific publications in peer-reviewed journals. His major focus is on crystal plasticity-based finite element modelling (CPFEM) of metal plasticity problems. He has also recent studies on the design of variable stiffness composites for tow steering process. He is currently working under SINDRI project on CPFEM of electron beam welded alloy steels for nuclear applications.

Geir Ólafsson

Geir Ólafsson is a Research Associate in the Bristol Composites Institute working on the CerTest EPSRC programme grant. His research has an experimental focus using full field imaging for structural evaluation with a particular interest in composite materials. His expertise spans both white light and thermal imaging techniques, both of which have been exploited to develop new non-destructive evaluation methods.


Tamsin Dobson

Tamsin Dobson is a postgraduate research student in the Solid Mechanics research group. After spending over 10 years in the marine industry (interspersed with College lecturing positions), she developed her PhD research proposal from her work as part of the overseas in-service submarine support team at Babcock international. Her research interests include; marine corrosion, biofouling of metal structures, microstructure of Nickel Aluminium Bronze (NAB) and welding processes.


Tobias Laux

Tobias Laux is Research Associate in the Bristol Composite Institute on the multi-disciplinary EPSRC CerTest project looking at new methods to validate composite structures. His research expertise lies in conducting bespoke experiments and the development and validation of modelling frameworks for composite materials and structures.

BSSM team

We would like to express our thanks to Amanda Boaler and Biana Gale of BSSM for their continued assistance and support in the organisation of this year's PGEM conference.

Where to find us

Instron best presentation competition scoring sheets

Please help us to find the worthy winners of this year's Instron best presentation competition! Please score each presentation using the QR code provided below:

The QR code will take you to the list of presentations. Clicking on a given talk will open the scoring sheets. Points of 1 – 5 can be given in three categories: technical, visual, and delivery. Thank you for your contribution!

BSSM PGEM Instron Awards for Best Presentation Scoring Sheets

7th April 11:10-11:25
Investigating the mechanical properties and fractography of CuCrZr with 3D stereo digital imaging correlation and scanning electron microscopy. - Amelia Billings
https://forms.office.com/Pages/ResponsePage.aspx?id=MH_ksn3NTkql2rGM8aQVG8etHdCZtjVEjF9p7SlPwANURDlIN1VBSjNQQVlRU1NHNktTSDk2MldOUC4u

7th April 11:25-11:40
Through-Thickness Compression Testing of Glass Fibre Reinforced Plastic - David Brearley
https://forms.office.com/Pages/ResponsePage.aspx?id=MH_ksn3NTkql2rGM8aQVG8etHdCZtjVEjF9p7SlPwANUNVhKNUVPQkdYSVpUVEQ2U1VEREdZNTMxTC4u

7th April 11:40-11:55
Impact and repair performance of CFRPs - Richard Brooks
https://forms.office.com/Pages/ResponsePage.aspx?id=MH_ksn3NTkql2rGM8aQVG8etHdCZtjVEjF9p7SlPwANUOThRMTNZRlZGSk9GRzBWV1VBRDZGMzg0TC4u

7th April 11:55-12:10
Developing stress corrosion cracking using a new in-situ corrosion small punch test design - Kuo Yuan
https://forms.office.com/Pages/ResponsePage.aspx?id=MH_ksn3NTkql2rGM8aQVG8etHdCZtjVEjF9p7SlPwANUNElLWlhINFRTR1VZMzZVU1YzMzYxNEtLRC4u

1. Scoring

	1	2	3	4	5
Technical	○	○	○	○	○
Visual	○	○	○	○	○
Delivery	○	○	○	○	○

Conference programme

Thursday 7th April

10:00-10:20 Arrival and coffee

10:20-10:35 Welcome to the BSSM PGEM conference
Neha Chandarana, University of Bristol
Janice Barton, University of Bristol
Hari Arora, Swansea University

10:35-11:10 Keynote 1
Chair: Geir Olafsson

Strain rate dependent behaviour and impact testing of polymers and composites
Karthik Ram Ramakrishnan, University of Bristol

11:10-12:10 Research presentations 1
Chairs: Neha Chandarana and Clementine Jacquemoud

11:10-11:25 Investigating the mechanical properties and fractography of CuCrZr with 3D stereo digital imaging correlation and scanning electron microscopy
Amelia Billings, University of Bristol

11:25-11:40 Through-Thickness Compression Testing of Glass Fibre Reinforced Plastic
David Brearley, University of Bristol

11:40-11:55 Impact and repair performance of CFRPs
Richard Brooks, Imperial College London

11:55-12:10 Developing stress corrosion cracking using a new in-situ corrosion small punch test design
Kuo Yuan, University of Bristol

12:10-13:10 Lunch and networking session

13:10-13:45 Invited presentation 1
Chair: Eralp Demir

An introduction to publishing
Olivia Reed, Wiley

13:45-15:00 Research presentations 2
Chairs: Hari Arora and Tamsin Dobson

13:45-14:00 Investigating the effect of impactor shape and hardness on the performance of carbon fibre reinforced polymer panels subjected to low velocity impact conditions for aerostructures
Zoe Hall, Imperial College London

14:00-14:15 Methodology for the Automated Spatial Mapping of Heterogeneous Elastoplastic Properties of Welded Joints
Robert Hamill, University of Southampton

14:15-14:30 Using a front coated mirror in full-field imaging systems for testing large scale structures
Emily Leung, University of Bristol

14:30-14:45 Effects of residual stress on fatigue crack growth rate in electron beam welded 316L pipes
Simon McKendrey, University of Bristol

14:45-15:00 Evaluating Audible Acoustics as a Damage Detection Method in Large Composite Structures
Marwan Naaman, Cardiff University

15:00-15:20 Tea/coffee break

15:20-16:50 Q&A panel session with recent graduates
Chairs: Neha Chandarana and Tobias Laux

Panel members
Nikita Gandhi, National Composites Centre/University of Bristol
Alexander Marek, University of Southampton
Chloe McDonnell, The University of Manchester
Caroline O'Keefe, Hexcel Composites
Emily Rolfe, National Composites Centre
Alessandra Vizzaccaro, University of Bristol

16:50-17:00 Close of conference day one

Thursday 7th April – evening event

17:30-18:00 Arrival window	Welcome drinks reception Sponsored by Wiley Publishing Venue: Lost & Found, 85 Queens Rd, Clifton, Bristol BS8 1QS
19:00	Conference dinner Venue: Browns Bristol, 38 Queens Rd, Clifton, Bristol BS8 1RE

WILEY

Friday 8th April

9:30-9:45 Arrival and welcome to conference day two
Hari Arora, Swansea University

9:45-10:45 Team building activity
Sponsored by Gom UK

Hosts: Geir Olafsson and Eralp Demir (University of Bristol)

10:45-11:15 Invited presentation 2
Chair: Tobias Laux

DIC for free!
Robert Wood, Gom UK

11:15-11:35 Tea/coffee break

11:35-12:35 Research presentations 3
Chairs: Hari Arora and Clementine Jacquemoud

11:35-11:50 Surface and subsurface damage evaluation of multi-directional laminates using a full field imaging technique
Rafael Ruiz Iglesias, University of Bristol

11:50-12:05 Real-time identification of process parameters in the context of induction-assisted manufacturing of composites
Anagnostis Samanis, University of Bristol

12:05-12:20 Multiaxial crack growth prediction
Bemin Sheen, Imperial College London

12:20-12:35 Sizing of non-sharp defects using ultrasonic array images
Shivaprasad Shridhara Bhat, University of Bristol

12:35-13:35 Lunch and networking session

13:35-14:10 Keynote 2
Chair: Hari Arora

An eclectic career: My path to PhD
Caroline O'Keefe, Hexcel Composites

14:10-15:10 Research presentations 4
Chairs: Tobias Laux and Amelia Billings

14:10-14:25 Investigation of the compressive behaviour of carbon/glass fibre hybrid composites with 4-point flexural tests
Aree Tongloet, University of Bristol

14:25-14:40 Measuring the micromechanical response of single carbon fibres & their treated interface in model composites under compression via the use of in-situ Raman spectroscopy
Cameron Woodgate, University of Bristol

14:40-14:55 Low-velocity Impact Damage of Composite embedded Electromagnetic Interference shielding Metal Mesh
Gaoyue Xing, University of Bristol

14:55-15:10 Fatigue Behaviour and the Combined Effect of Corrosion and Marine Biofouling on Plasma Welded Nickel Aluminium Bronze (NAB)
Tamsin Dobson, University of Bristol

15:10-15:30 Tea/coffee break

15:30-16:00 Awarding of prizes and close of conference
Neha Chandarana, University of Bristol
Janice Barton, University of Bristol
Hari Arora, Swansea University

British Society for Strain Measurement

Early Careers

The BSSM offers a number of exciting opportunities for early career practitioners involved in experimental mechanics and related disciplines including training, workshops and conferences that contribute to continued professional development and support your career advancement and aspirations.

We offer discounted Student membership, and as a member there are many opportunities to get involved in the Society such as joining a committee, by signing up to be a designated BSSM Early Career representative or attending or even organising a workshop. Getting involved provides many opportunities to connect with colleagues from academia and industry who are already members and join the enthusiastic network of BSSM Early Career scientists and engineers. These apply to both industrial and academic career paths. Visit https://www.bssm.org/early-careers/ to find out more.

Forthcoming events

Strain Analysis Course
9th May 2022
Sheffield, UK

16th International Conference on Advances in Experimental Mechanics
6th-8th September 2022
St Anne's College, University of Oxford, UK

Young Stress Analyst Competition YSA22
7th September 2022
St. Anne's, University of Oxford

Exhibition of Experimental Mechanics (EMex22)
7th September 2022
St. Anne's, University of Oxford

Stress Analysis and Load Measurement Course
12th-14th September 2022
Sheffield, UK

Visit https://www.bssm.org/events/ for more information.

PGEM 2020 sponsors

We would like to thank this year's conference sponsors for their support.

GOM UK

GOM UK are supporting this year's PGEM conference with an invited presentation that will be delivered by Robert Wood on Friday 8th April and by sponsoring our team building activity.

Instron best presentation competition

Instron Dynamic Systems are sponsoring this year's best presentation competition. Prizes will be awarded as follows:

1st prize: £125 2nd prize: £75 3rd prize: £50

Wiley

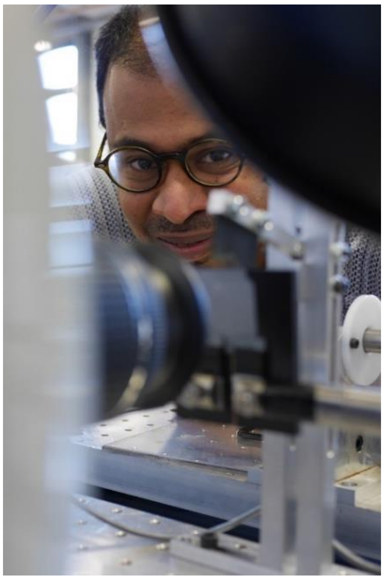
Wiley are supporting this year's PGEM conference with an invited presentation that will be delivered by Olivia Reed on Thursday 7th April and by sponsoring our drinks reception.

Keynote lecture 1

Strain rate dependent behaviour and impact testing of polymers and composites

Lightweight materials including polymers and fibre reinforced polymer composites used in automotive and aerospace applications are frequently subjected to dynamic loads from tool drops and bird strikes to ballistic loading. Under such situations, it is expected that the behaviour of these materials will be different from that under quasi-static loads. Therefore, it is important to understand the strain rate dependent behaviour of these materials and to develop numerical models which can capture their dynamic response. This lecture will broadly focus on the experimental techniques used for mechanical characterisation of materials at high strain rate. In particular, he will explain his work on experimental impact testing of composites at different velocity regimes. His recent research on the application of full-field measurement techniques to directly provide displacement, strain or temperature contours of the specimens under testing will also be introduced. The lecture will end with some future perspectives on sustainable composites.

Dr Karthik Ram Ramakrishnan
Lecturer in Sustainable Composites, University of Bristol



Dr Karthik Ram Ramakrishnan is currently a Marie Curie Individual Fellow at the University of Bristol leading a project on full field measurement techniques for damage evaluation of composite materials. He has 10 years' experience in the fabrication, mechanical characterisation and numerical simulations of layered laminates, nanocomposites, natural fibre composites, hybrid structures, and sandwich panels. His research experience began with Master of Engineering (Research) thesis on the low velocity impact resistance of transparent polymer laminates (University of New South Wales, Australia), and his PhD project on the effect of block copolymer nano-reinforcements on the penetration resistance of sandwich composites (UNSW/ Arts et Metiers Paristech, France). His postdoctoral research experience includes 2 years at the Ecole des Mines d'Alès in France, 15 months in Tampere University (formerly Tampere University of Technology), Finland and 15 months at University of Oxford, UK.

Keynote lecture 2

An eclectic career: My path to PhD

I am going to tell you about my experiences that led me along an unusual road to pursue a PhD. I want to share some of the ups and downs I went through, as well as my motivations. I have a varied background so I'll discuss some of my previous roles and research as a firearms and vehicles analyst. I will also discuss my experience as a forensic practitioner specialising in drug detection and intelligence. I want to share some of my career decisions with you, as well as the factors that influenced those decisions.

Dr Caroline O’Keeffe
Scientist II – Strategic Research Team, Hexcel Composites

Caroline O'Keeffe is a scientist in the R&T Strategic research team of Hexcel Duxford. She is currently developing new multifunctional composite materials and establishing new platform technologies to enable new composite capabilities. Caroline recently completed her PhD at the University of Bristol (UK) demonstrating composite multifunctionality. Caroline also holds a Masters degree in Forensic Engineering and Science from Cranfield University and has extensive expertise in forensics, weapons research, and propellant development.

Q&A with panel of recent PhD graduates

We asked our panel members to answer three questions to start us off:

Q1. When you were a child, what did you want to be/do when you grew up?

Q2. What was/is the best part of your first postdoc or job you had after completing you PhD?

Q3. What piece of advice would you give to current PhD students, based on what you learned from the PhD experience?

Nikita Gandhi, National Composites Centre/University of Bristol

I am an EngD researcher working with the UoB and the National Composites Centre on improving the robustness of non-destructive testing of composite material products. This includes establishing a framework for technology mapping and design for inspection at various stages of the product development process.

Q1. Artistic set designer
Q2. The variety and different scope of projects
Q3. Explore as many options and interests as you can, your research will be more interesting as a result.

Dr Alexander Marek, University of Southampton

Dr Aleksander Marek graduated with a PhD degree from University of Southampton in 2019. His thesis dealt with developing a new algorithm for processing full-field displacement measurements to extract material properties for constitutive models. While feeling most comfortable around metals, currently he is working for the "Ultrasurge project" where he employs ultra-high speed imaging and full-field measurements to inform design of ultrasonically-powered cutting tools, understand the cutting mechanisms and study interaction of ultrasound with living matter (cells and biological tissues). His research interests include inverse methods, use of full-field measurements for model validation and identification, homogenization and interaction between computational and experimental mechanics.

Q1. Great question. I don't remember exactly but it was either an archaeologist (I loved mummies!) or a scientist. Definitely by the time I was a teenager I wanted to be a scientist either in physics or chemistry.
Q2. During my postdoc I realized that the thing I like the most about the career in research is learning new things and my current project enabled me to learn about all kinds of new things – culturing living cells, biomechanics, electronics and others! The other quite enjoyable experience is co-supervising PhD students and in general working in a group – as opposed to your individual PhD project.
Q3. Sad but true: academia is a really competitive career. Doing one post-doc is great to see if you like to be in this environment (which is quite different to doing just a PhD project), but you also need to consider what will be required to be successful in academia long term.

Dr Chloe McDonnell, The University of Manchester

Since completing her PhD in Aerospace Composites at The University of Manchester, Chloé has pursued a slight change of direction in her research career and is currently undertaking an EPSRC Doctoral Prize Fellowship in the field of Biomedical Materials and Tissue Engineering. The project makes use of electrospinning techniques to develop biomaterial scaffolds for ligament tissue regeneration. The aim of the project is to develop an optimised nanofibre yarn which can effectively mimic the mechanical properties of native ligament tissue whilst also providing an appropriate hierarchical structure to support cell activity. Chloé is passionate about promoting STEM through public engagement activities and is a member of the Biomaterials Outreach Group.

Q1. Part time dentist and part time fashion designer
Q2. The opportunity to learn new skills, for example in cell culturing, whilst applying my knowledge of engineering and textile structures to solve a biomaterials problem.
Q3. It's never too early to start writing your thesis, try to write as you go. Even if you don't use everything you have recorded, it will help to organise and give structure your ideas along the way.

Dr Emily Rolfe, National Composites Centre

In 2019 I completed my PhD at Imperial where I was investigating the blast resilience of composite sandwich panels with hybrid laminate skins. I performed lab based and large-scale experiments implementing a variety of strain monitoring methods. I then joined Atkins in Bristol and worked on a variety of projects for various clients across the aerospace, defence and transportation sectors. However, I missed the lab and freedom to research and joined the National Composites Centre just under a year ago. At the NCC I've worked on a diverse range of research projects and have enjoyed devising and instrumenting experiments again.

Q1. Air crash investigator
Q2. It taught me what I really enjoy...
Q3. Break your work down into achievable chunks and don't be disheartened if it doesn't go to plan. The ability to persevere is an invaluable skill you learn during a PhD.

Dr Caroline O'Keefe, Hexcel Composites

Q1. I always wanted to be a veterinarian.
Q2. I'm loving having more realistic discussions about technological applications and observing large-scale commercial processes.
Q3. Don't expect anything to be completed on schedule. Give everyone that a deadline that is much earlier than you anticipate.

Dr Alessandra Vizzaccaro, University of Bristol

Alessandra is a Research Associate in Engineering Mathematics at the University of Bristol under the DigiTwin programme grant. She completed her PhD in Mechanical Engineering at Imperial College London in 2021. Her research aims to develop numerical and experimental tools to model, understand, and design the dynamics of nonlinear mechanical systems, with application to large scale finite element models as well as hybrid structures and digital twins. She worked on a wide range of engineering problems, such as the structural integrity of turbomachinery components and the prediction of the behaviour of high precision MEMS devices. She currently collaborates with both industrial sponsors and research groups from UK and European universities.

Q1. I've always been passionate about Maths and other abstract subjects, although I never really had a dream job as a kid. I enrolled in an engineering degree to develop some practical skills, but only truly enjoyed the more theoretical aspects of it.
Q2. During the PhD, one has little time to plan their long-term future or to shape their idea of research. The time of the postdoc instead, is really a journey to discover what one wants to do, how to do it, and where they see themselves in the long term. It doesn't just come naturally. It requires an active effort and it is tiring at times, but it is also extremely rewarding and will provide strength and motivation for the years to come.
Q3. Be active in your community. Network, interact, ask questions to anyone you appreciate in your research field. Don't just focus on your piece of research but rather maintain the side vision open.

Invited presentation 1

An introduction to publishing

The session will give an overview of the publishing process for those who are new to publishing, covering the topics of submitting a paper, finding the right home for your paper, publishing Open Access and how to promote your published paper.

Olivia Reed, Wiley

Olivia Reed joins us today from Wiley, a leading journals publisher. Wiley has a 200- year heritage of quality publishing, publishing books, online scientific, technical, medical, and scholarly journals, and other digital content. Olivia is a Journals Publishing Manager, overseeing a portfolio of civil engineering journals.

Invited presentation 2

DIC for free!

Learn the basics of Digital Image Correlation, from the theory to how to perform a basic measurement within the free GOM correlate software. Some novel applications will be presented to help spark some ideas as to how DIC could be utilised in your PhD.

Dr Robert Wood, GOM UK

Rob Wood is a sales engineer for GOM UK. With a degree in Automotive Engineering from Loughborough University he went on to work in roles in test and measurement. As an application engineer he worked with nCode strain analysis and fatigue software before becoming involved with optical strain measurements and Digital Image Correlation (DIC) in 2007. Working across 2 DIC suppliers he has many years' experience of applications and measurements in this area at both academic and industrial levels. Rob also supports the BSSM in the role of Secretary.

After working in Derby, Sheffield, Detroit and Bristol Rob now lives in Somerset with his wife and 2 children.

Research presentations 1

Investigating the mechanical properties and fractography of CuCrZr with 3D stereo digital imaging correlation and scanning electron microscopy

A. Billings[a], Y. Wang[b], D. Victor[a], M. Mokhtarishirazabad[a], D. Knowles[a], M. Mostafavi[a]

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Plasma-facing components must withstand extreme conditions within fusion reactors, and therefore optimisation of their design is paramount. This forms an essential step in the EUROfusion roadmap to the realisation of the DEMOnstration fusion power plant [1,2]. The divertor component is the exhaust system for tokamak reactors, and efficient cooling of the component is integral to efficient energy extraction and protection of the in-vessel components. Copper-Chromium-Zirconium (CuCrZr) is a candidate material for cooling pipes within the divertor, forming part of a W/Cu/CuCrZr monoblock system. The material exhibits excellent thermal conductivity and good mechanical strength. Gaining a fundamental understanding of the failure mechanisms of CuCrZr under different stress triaxial conditions is necessary to develop and calibrate models used in engineering design against failure.

This work aimed to investigate the failure mechanism of CuCrZr (1.0 wt.% Cr, 0.1 wt.% Zr) through mechanical testing and fractography. Smooth round bar (gauge length and diameter: 25 mm, 6 mm respectively, stress triaxiality factor = 0.33) and notched round bar specimen (gauge diameter: 6 mm, notch radii 12 mm and 3.5 mm, stress triaxaility factor = 0.45 and 0.69 respectively) were tested under tension at room temperature. Digital imaging correlation was used to create a strain-field map of the surface strains during the tensile test. Scanning electron microscopy and energy-dispersive spectroscopy were used to analyse the macro- and micro-structural features of the fracture surfaces. The study found that failure occured predominantly by void nucleation, growth and coalescence. Cr-containing precipitates were identified as probable void nucleation sites. It was found that the ductility, measured in terms of the equivalent strain to fracture, decreased as the initial stress triaxiality factor increased from 0.33 to 0.69. Further mechanical testing of different specimen geometries is required to assess the failure mechanism of CuCrZr under stress triaxaility conditions outside of the tested range. This will inform models used to predict the failure behaviour of CuCrZr within the complex multi-axial stress system of the divertor.

References

[1] ITER Joint Central Team, 1994, “The Impact of Materials Selection on the Design of the International Thermonuclear Experimental Reactor (ITER),” Journal of Nuclear Materials, **212–215**, pp. 3–10.

[2] Donné, A. J. H., 2019, “The European Roadmap towards Fusion Electricity,” Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences, **377**(2141), p. 20170432.

Through-Thickness Compression Testing of Glass Fibre Reinforced Plastic

D.J. Brearley[1,a], O.T. Thomsen[1], J.M. Barton[1], M. Lakrimi[2]

[1]Bristol Composites Institute, Faculty of Engineering, University of Bristol, Bristol, UK, 2Siemens Magnetic Technology, Siemens Healthineers, Oxford, UK

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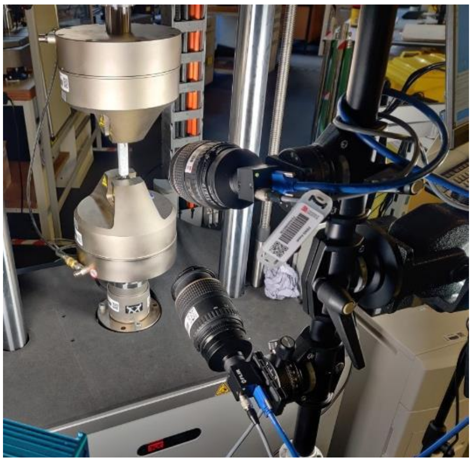
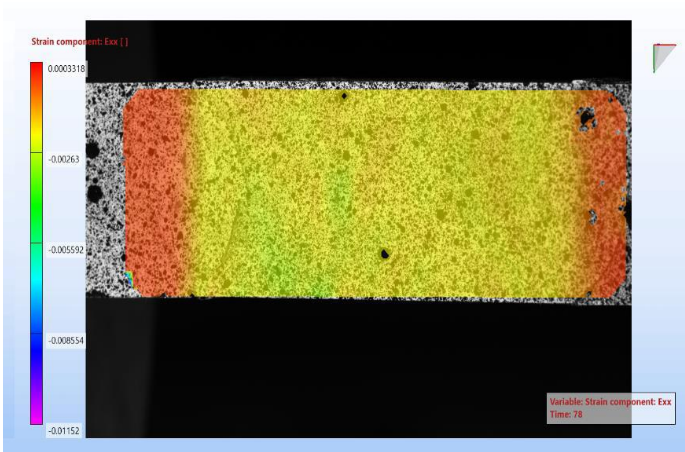
For thick walled glass fibre reinforced polymer (GFRP) cylinders, all elastic properties are important when predicting the response to complicated hoop, axial and radial stress states. Where in-plane properties (hoop and axial direction) can be approximated with classical laminate theory, if the elastic properties of the constituent fibre and matrix are well documented, the through-thickness properties (radial direction) are harder to predict. Without intra-ply reinforcements, it is presumed that these properties are governed by the matrix material properties, but experimental testing is required to confirm this and find the true values. Special attention needs to be applied to how the specimens are cut to find the elastic properties of components made from curved laminates. Even if the curvature is minimal, it still needs to be considered as different samples need to be identical in terms of their geometry to be comparable.

Uniaxial through-thickness compression testing, conducted quasi-statically, was implemented to induce a uniform strain field in end tabbed, E-glass GFRP samples where various possible sources of stress concentration were mitigated [1]. To ensure the loading was just compressive, ball bearings and dimples in the end tabs were integrated into the test set up. This is because if the loading was not purely compressive, the samples would deflect due to rotation being allowed at either end of the sample. Stereo digital image correlation (DIC) was used to measure the strain field, in the through thickness and ply directions, over the test regime and calculate the through-thickness elastic modulus (Ez), using the force acquired from the test machine, and the minor Poisson's ratio (nzx). These values, used in conjuncture with the major Poisson's ratio, taken from literature [2], were used to calculate the in plane elastic modulus (Ex) of the GFRP.





Acknowledgement

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Impact and repair performance of CFRPs

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Abstract

Carbon fibre-reinforced plastics (CFRPs) are being increasingly used in aerospace structures, in particular due to their excellent strength to weight ratio. However, due to the potential for impact due to bird strike, hail stones or runway debris, impact performance of CFRPs is of particular concern. Although impact damage may not cause immediate failure, it can weaken a structure significantly [1-4]. If the strength falls below the working load of the component, catastrophic failure could occur. Therefore, the effect of the damage on the structural integrity must be understood and corresponding action, such as repairing the structure, should be undertaken. Given the relative high cost of CFRPs, replacement of parts which have sustained impact damage is not economical, so repair is a preferred solution. However, understanding the damage resistance of composite repairs is complex, but is required to ensure the safety of repairs on commercial aircraft.

My research focuses on the impact and repair performance of CFRP material. Drop-weight tests are performed at a variety of impact energies on both pristine and repaired samples. Force-time and displacement-time data is measured to allow comparison between sample behaviour and to enable potential load drops, corresponding to damage initiation, to be identified. Portable ultrasonic C-scan equipment is used to quantify delamination damage area and produce C-scan maps. These maps, which show the delamination area present at different depths through the thickness, are compared between samples. Slow motion cameras are used to record impacts, both from above and in the horizontal plane, allowing detailed analysis of the deformation process during impact.

With a detailed understanding of the behaviour of pristine and repaired CFRP under impact conditions, the design of the repair can be optimised. This can allow both safe and economical repairs to become available in future within the aerospace industry.

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Developing stress corrosion cracking using a new in-situ corrosion small punch test design

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Abstract

Stress corrosion cracking (SCC) may develop on spent AGR fuel cladding in cooling ponds [1], and an in-situ corrosion small punch test (SPT) setup has been designed to better study SCC in real time due to its versatility and small size of the samples [2]. Based on the traditional SPT setup, the new design using a circulation loop has been added to accelerate the corrosion process by circulating a heated corrosive solution. The concentration of the solution and the load have been studied to allow SCC to develop in a short period of time. A 395 ppm sodium thiosulphate solution was heated to 60 °C and a constant load of 1.5 kN was held on a thermally sensitised (ageing at 600 °C for 50 hours) 304 stainless steel sample. Stress corrosion cracks successfully developed in 70 hours and observed under the microscope and SEM. In future studies, digital image correlation (DIC) will be added to the system to enable monitoring the corrosion in real time.

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Research presentations 2

Investigating the effect of impactor shape and hardness on the performance of carbon fibre reinforced polymer panels subjected to low velocity impact conditions for aerostructures

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Abstract

In the last few decades, the use of composites in aerostructures has become more prominent, with modern commercial aircraft increasing the percentage of composite components and reducing the content of metals, such as aluminium and steel. This adjustment in materials can be seen when comparing the Boeing 777 and 787, with the former comprising of 50% aluminium and 12% composite materials but the more modern Dreamliner flipping these values to give 50% composites and only 12% aluminium [1]. Although metals are advantageous due to being widely available and easy to machine, composites allow for more customisation of their properties according to purpose and have excellent weight to strength ratios. To allow composite materials to be used in aerostructures, rigorous testing is required, including under impact loading conditions. Aircraft are subjected to a variety of impact scenarios during use from tool drop to bird strikes, with the former being an example of a hard, low velocity impact and the latter being an example of a soft, high velocity impact. For this reason, composite materials must be tested under both hard and soft impact conditions with different impactor shapes to ensure they are suitable for use in aerostructures. In this research, low velocity impacts of carbon fibre reinforced polymer (CFRP) panels were the focus, with flat-ended, round-nosed and rubber-ended impactors being utilised to compare the shape and hardness of each and how this influenced the damage mechanisms observed after impact. 1, 1.5 and 2 mm thick disks of rubber were adhered to flat-ended impactors to produce the rubber-ended impactors and three different impact energy levels were used, 7.5, 15 and 30 J. It was observed that there was no damage at the two lower impact energies under the blunt impact but, when a higher energy was used, the damage area from a flat-ended impactor was larger than that of a round-nosed impactor, even when using the rubber-ended impactors. The maximum load was ca 4 kN higher for the flat-ended impactor and ca 2 kN higher for the rubber-ended impactors, while the displacement was reduced by ca 3 mm for the flat-ended impactor and only ca 2 mm for the rubber-ended impactors. This suggests that the rounded impactor allows for the panel to bend more and thus absorb more of the energy to result in a smaller damage area and the rubber deforming allows for a similar occurrence just to a smaller extent. These results show that the impactor shape and hardness affect the impact performance of the CFRP, with a larger energy value being required for damage to occur with a flat-ended impactor but adhering rubber aiding in reducing the maximum load due to softening the impact.

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Methodology for the Automated Spatial Mapping of Heterogeneous Elastoplastic Properties of Welded Joints

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Abstract. A novel methodology to map the heterogeneous elastoplastic mechanical properties of varied dissimilar welded joint geometries is presented. This work extends the Virtual Fields Method (VFM), an inverse identification method which uses full-field strain measurements to determine constitutive parameters, through their automated spatial parameterisation. This extension enables the novel characterisation of welds with more complex geometries, loading conditions and dissimilar materials.

Introduction

Inverse identification methods have been previously developed to take advantage of the rich data provided through full-field measurements. The VFM is one such method which uses full-field strain measurements to determine constitutive parameters, and benefits from computational efficiency compared to other methods as no resolution of the direct problem is required [1]. The VFM has previously been used to determine the constitutive parameters of welded joints with simple butt-joint geometry, however existing work requires *a priori* spatial parameterisation of constitutive parameters [2,3]. Automated spatial parameterisation removes this limiting assumption. Hence, more complex weld geometries, loading conditions and dissimilar weld configurations can be characterised. Collaboration with the Culham Centre for Fusion Energy, part of the UK Atomic Energy Authority, has given this work a particular focus on understanding material behaviour in complex welded joints – such as the dissimilar-metal, laser-welded, T-joint shown in Fig. 1.

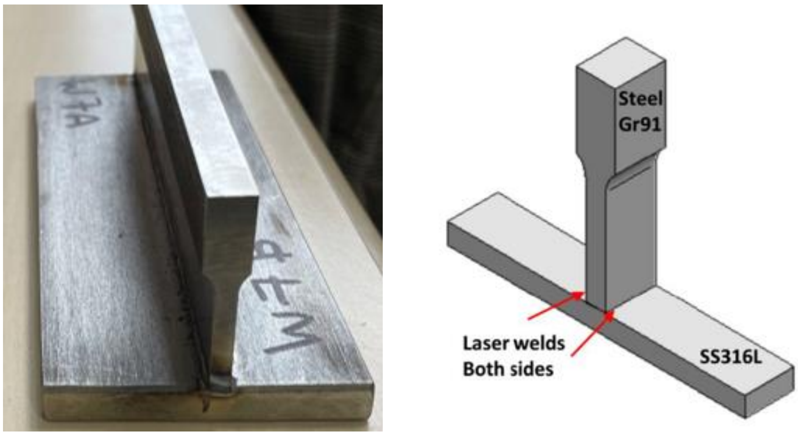

Figure 1. Laser-welded T-Joint of two high strength steels. Left: Photograph. Right: Schematic.

Methods

A data generation and identification toolchain has been developed to numerically generate synthetic data and perform identification of the material parameters. A finite element (FE) model, with selected geometry and material properties, is used to generate strain data for specified boundary conditions. This strain data is then embedded into a set of synthetic images through the process of numerical image deformation. This process deforms a selected reference image (of user-defined speckle pattern) using FE deformation data. The resultant images are the synthetic equivalent of those obtained experimentally using optical measurements, however the kinematic fields they encode are known. Digital Image Correlation (DIC) is used to obtain strain fields for each load step from the set of deformed images. Finally, an algorithm based on the VFM is used to perform the parameterisation and identification of constitutive parameters. A schematic representation of this toolchain is shown in Fig. 2, in which K represents the map of constitutive parameters and ε represents strain fields. This digital toolchain enables comparison of defined and identified results.

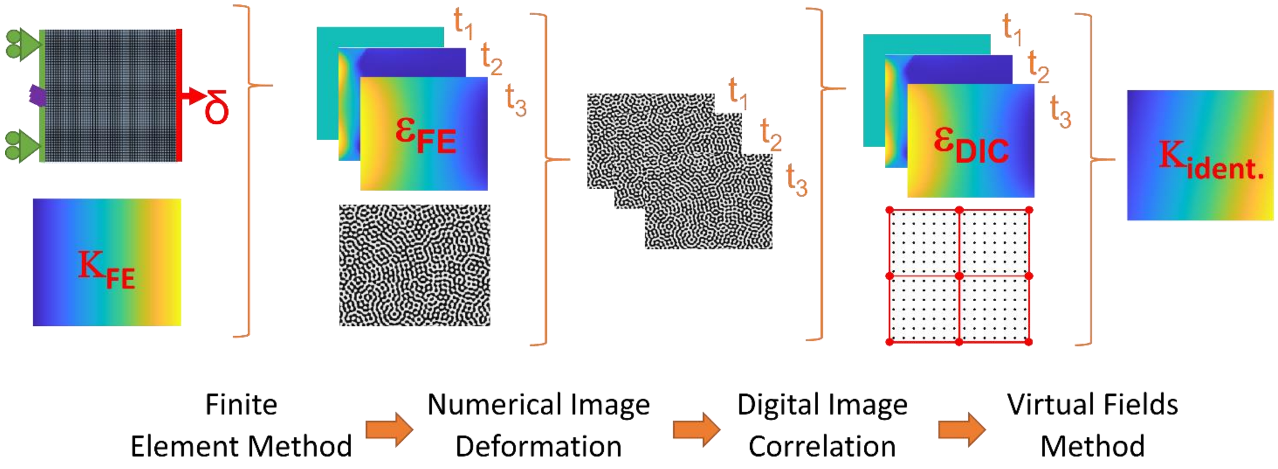

Figure 2. Toolchain showing key processes and data

Parameterisation assigns a constitutive parameter to each data point so that, in conjunction with the corresponding strain data, the stress field can be reconstructed. Discrete parameterisation using finite elements is focused on here, for which shape functions interpolate values for each data point from the element nodes. The basis of the identification process is shown in Fig. 3.

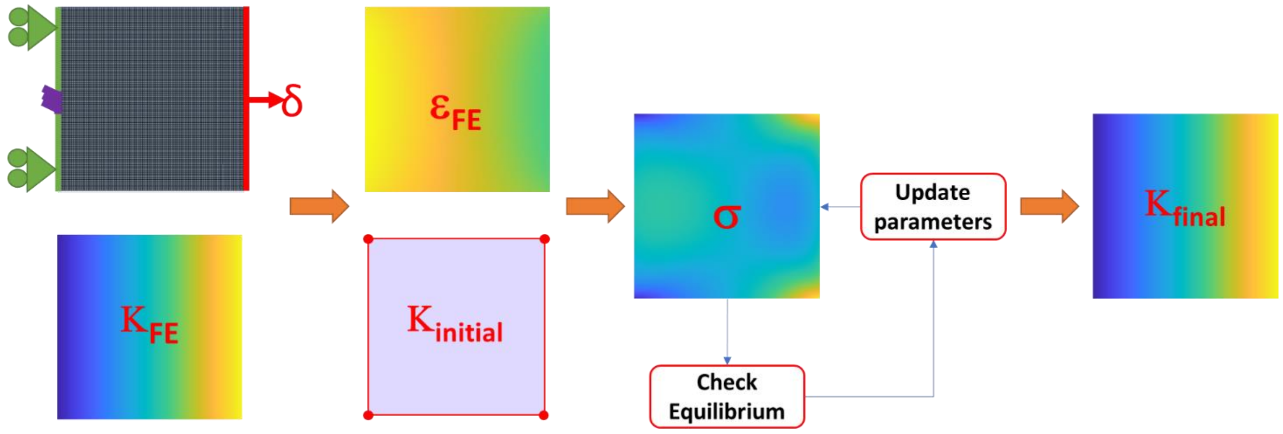

Figure 3. Constitutive parameter identification using the VFM

Discussion

Preliminary results indicate this novel methodology shows promise in enabling the characterisation of welds of more complex geometry, loading conditions and dissimilar materials. Automated parameterisation using finite elements appears fruitful, however, questions have arisen around identification sensitivity and computational efficiency due to optimisation overfitting. Further investigation is required to increase robustness, after which experimental testing will be conducted.

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Using a front coated mirror in full field imaging systems for testing large scale structures

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Abstract

Full field imaging techniques are a non-contact, non-destructive testing methodology, and are widely used in a range of applications to investigate and characterize the deformation of structures. For a stereo Digital Image Correlation (DIC) approach there are certain requirements on hardware set-up, such as distance from cameras to object, distance between cameras and the stereo-angle. Without the correct set up, it might difficult to correlate information or error can be present in the data. For large scale structures or those with complicated geometry, it may be impractical to apply these techniques.

This study focuses on developing the use of mirrors to view inaccessible areas with optical techniques. DIC and an aluminium fronted coated mirror were used in this study. The mirror was placed underneath a specimen for capturing the displacement and the strain field of the bottom surface of a sandwich structure in three-point bending. DIC data were then compared with the experimental and analytical results. A fronted coated mirror study was conducted to ensure the mirror can be used in Infrared (IR) Thermography for future testing.

Effects of residual stress on fatigue crack growth rate in electron beam welded 316L pipes.

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Abstract

Abstract Electron beam (EB) welding has the potential to reduce the cost of manufacturing processes due to its capability to be readily automated. It also has a smaller heat affected volume than other techniques such as gas tungsten arc welding and has a lower total heat input [1]. EB welding has existed for over seventy years, but the attention of safety critical industries has only recently turned towards it with a focus on its possible failure mechanics. This paper investigates the effect of residual stress created during the EB welding process on fatigue crack growth. EB welds create complex microstructure around the fusion zone (FZ) as well as multi-axial residual stress fields which can have a noticeable effect of the fatigue behaviour of the material. The project focusses on investigating 316L pipe sections.

First the residual stress present within the pipe near the weld is measured using a combination of contour method, x-ray diffraction, and incremental deep hole drilling. Contour measurements carried out by VEQTER Ltd shown in Figure 1 shows maximum residual stresses of approximately 400MPa [2]. Mechanical properties of the weld and parent are measured using a laser micrometre tensile test method. Compact test (CT) specimens were chosen to conduct the fatigue crack growth rate tests in line with ASTM E647. The CT specimens are cut from the parent material and weld region. The position of the CT samples cut from the weld region is determined by cutting three initial CT samples each with differing notch position, being on the weld centreline and around the FZ boundary. These tests help to identify the most critical location to carry out the full-scale tests.

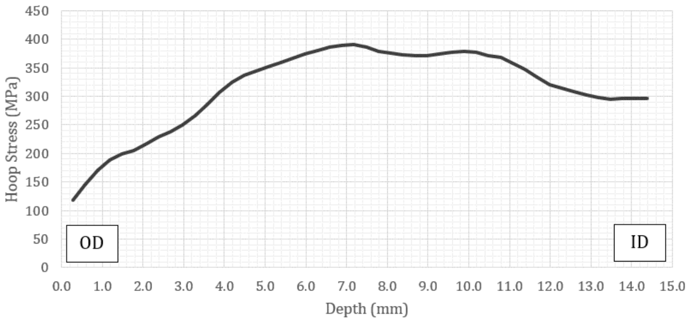

Figure 4- Contour plot showing averaged hoop stress through thickness of the weldment, OD is outer diameter and ID is inner diameter

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Evaluating Audible Acoustics as a Damage Detection Method in Large Composite Structures

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Abstract

There is a continuously increasing demand for non-invasive damage detection methods in aerospace certification testing. This demand is driven by increasing cost effectiveness of these tests by reducing time for inspection. This paper aims to evaluate the usefulness of using an audible acoustic camera to detect and locate damage within a relatively large structure under bending loads. An acoustic camera is a microphone array of known dimensions, which uses a ‘delay-and-sum’ beamforming numerical model, which can detect sources of sound. Under the assumption that damage produces sound, this tool should aid in detecting damage. This method of damage detection was validated against strain gauge, LVDT data, and video recording showing the damage propagation. This paper concludes the acoustic camera’s successful ability to locate the damage sound origin in a realistic aerospace structure. The results show a unique acoustic signature for the detected damage and finds acoustic cameras to have the potential to become a stand-alone detection tool. The authors suggest developments and future work to the existing system which could potentially produce a more comprehensive system in order to not only detect damage location but also damage mode.

Research presentations 3

Surface and subsurface damage evaluation of multi-directional laminates using a full field imaging technique

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Abstract

In laminated composite structures, damage can initiate and propagate in both the surface and subsurface plies. Current experimental techniques for identifying damage propagation deal with surface damage. Some advances have been made with in-situ X-ray CT, but specimens are limited in size and this as well as other NDE techniques only identifies the size and shape of defects. Thermoelastic Stress Analysis (TSA) is a full-field infra-red imaging technique which has traditionally been used to infer the stress state of a component undergoing cyclic load. A recent publication [1] showed that subsurface thermoelastic response could be obtained at low loading frequencies where adiabatic conditions break down and through thickness heat diffusion can occur. Digital Image Correlation (DIC) is a full-field surface measurement technique which employs white light imaging to track changes in contrast to obtain the material surface displacements and strains. Since DIC relies on the laminate surface kinematics and consequently is independent of heat diffusion the laminate surface thermoelastic response under adiabatic conditions can be derived from the measured DIC strains. Hence, it is possible to subtract the surface response to reveal subsurface information and carry structural assessment. In [2] three different models were used to convert the measured strains into thermoelastic response: $\Delta T_{\text{Resin Rich Layer}}$, $\Delta T_{\text{Surface Ply}}$, $\Delta T_{\text{Global laminate}}$. It was shown that for CFRP (IM7/8552) the response was dependent on loading frequency and at very low loading frequencies it was homogenised throughout the laminate. The paper shows that in simple strip specimens under uniaxial tension loading it is possible to identify subsurface damage in a variety of multi-directional lay-ups by tuning the loading frequency to the ply location. Figure 5 shows the difference in response of a $[0,90]_{3S}$ CFRP laminate for the undamaged condition below the first ply failure load (a) and when severe damage has occurred (b) in the subsurface 90° ply. It is apparent that the thermoelastic response at the low loading frequencies is markedly less for the damaged case. The damage in the subsurface 90° ply reduces the stress induced temperature change and less heat is transferred to the surface ply. In the research will be shown how the non-adiabatic thermoelastic response can be exploited to derive the stresses in subsurface plies and provide an indication of the damage severity, demonstrating the applicability of this full-field methodology for composite structures evaluation.

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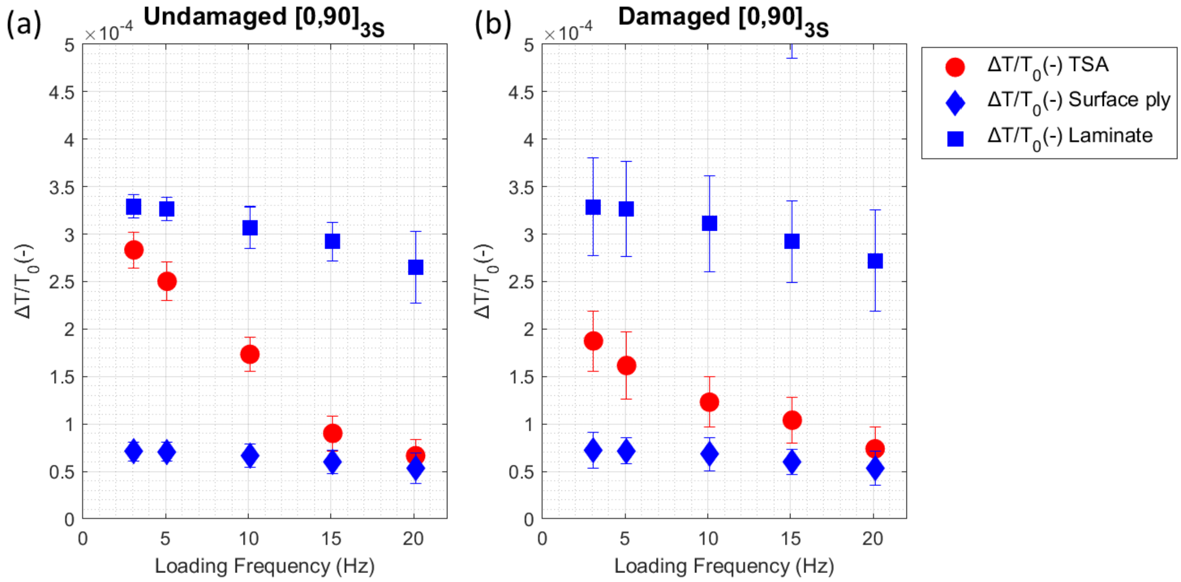

Figure 5. Normalised $\Delta T/T_0$ vs Loading frequency of CFRP (a) undamaged $[0,90]_{3S}$ (b) damaged $[0,90]_{3S}$.

Real-time identification of process parameters in the context of induction-assisted manufacturing of composites

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Abstract

Manufacturing processes of composites have significantly drawn the attention of scientific community in recent years in terms of efficiency, quality of final product and process time, posing challenges for optimisation and improvement. Fast curing resins have been developed so far, offering high potential of decreasing drastically the curing times of thermosetting resins in infusion processes, while heating using electromagnetic induction technique is able to supply high amounts of heating load to composites contributing more to the reduction of infusion process time [1]. While reducing process time in resin infusion is a key thing to improve efficiency, high amounts of heating load may instigate uncontrolled exothermic reactions which could be catastrophic for the composite material, leading to its overburn and complete damage. As exothermic reactions are highly dependent on resin properties and its behaviour during curing phase and solidification process, precise knowledge of its critical parameters related with heat transfer phenomena (heat capacity, thermal conductivity) would be essential to prevent damages. It has been proved [2] that heat capacity and thermal conductivity of curing resins are varying during the infusion and curing process due to being affected by changes in temperature and material state (resin degree of cure). An accurate thermography of the composite panel undergoing the thermal process, would give important information about temperature evolution in all points of the material as well as ensuring precise knowledge of process parameters. This could be useful not only in controlling the smooth evolution of the infusion process but also in preventing abrupt occur of exothermic phenomena resulting in the reduction of the total process time.

This work proposes a methodology of capturing critical parameters of heat capacity and thermal conductivity of a composite during its infusion process while being induction heated. A system identification technique is developed, acting as a process estimator, which calculates the critical process parameters based on temperature measurements from sensors. A mathematic model is introduced by coupling heat transfer and cure kinetics phenomena occurring during the process. Estimator updates model parameters of heat capacity and thermal conductivity in real time providing estimates that converge to the true values. This method is also useful in providing precise estimations of induction heating process parameters (such as exponential rate of through thickness heat propagation, coefficients related with amounts of produced heat) and coefficient related with the contribution of exothermic reaction to the heat balance of the system. By learning process parameters related with induction heating and thermal properties of resin, a full thermography of the heated composite material could be acquired, assisting in predicting system's behaviour. Combining this learning outcome with proper manipulation of coil current, a smooth and efficient operation of the infusion process can be achieved, avoiding also unwanted exothermic phenomena. Experimental procedure regenerating different process situations is necessary to create a robust identification algorithm to capture process parameters in a wide range of conditions improving learning output and control efficiency.

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Multiaxial crack growth prediction

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Abstract

Bladed disks are subjected to foreign object damage which results in the initiation of cracks. Blisks in aero-engines are affected by a combination of loads which grow a crack in a multiaxial stress field. Depending on the local stress field, a crack may propagate through the blade, or more undesirably grow towards the bore of the disc due to hoop stress. The overall trajectories of cracks initiating near the base of the blade are particularly difficult to predict. Classical crack trajectory criteria, which are often based on the strain energy density or maximum principal stress during a cycle, are insufficient for predicting the growth of cracks under non-proportional and multiaxial loads. Additionally, a combination of inter-related factors including mode-mixity, cyclic plasticity, and crack closure are also influential on non-proportional crack growth [1]. Therefore, an improved crack trajectory criterion is needed.

To create this criterion, a series of fatigue tests are being carried out on representative Ti-6Al-4V test samples to build a database of experimental results. The test rig and a cruciform shaped test samples have been designed to capture the key features of crack propagation in a blisk. Specimens are loaded in three axes using a biaxial machine and hydraulic fixture. This arrangement aims to reproduce the combination of steady and dynamic loads in a crack in a blisk. The ratio of the applied loads has been determined from fatigue simulations in FRANC3D, a software package which simulates crack growth using linear elastic fracture mechanics. The results of the ongoing tests will help to update the crack growth model to gain an agreement between the simulated and experimental results of the test specimen. The final crack growth model will be used to accurately predict the trajectory of cracks initiating in blisks subjected to non-proportional loading.

Simulations on blisk geometries in FRANC3D have shown a good agreement with existing data from literature. Results obtained from the completed fatigue tests have been presented and compared to the results from the simulated specimen.

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Sizing of non-sharp defects using ultrasonic array images

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Abstract

The existing structural integrity (SI) assessment procedures (e.g. API 579/R6/BS7910) assume flaws to be infinitely sharp, and often this assumption is over-conservative, leading to a pessimistic assessment of structural components and a severe underestimation of their safety margin against fracture. In practice, many defects formed during manufacturing or in service are not sharp (such as weld defects, porosity or corrosion pits), and for such defects the local elastic-plastic stress & strain field are known to be less severe than those at the tip of a sharp crack, resulting in increased capacity to sustain the load. With the existing S.I. assessment procedures, assuming flaws to be infinitely sharp can lead to components being rejected, repaired, or re-inspected, eventually increasing the operating cost and/or reducing service life. In the past, several studies have demonstrated the influence of non-sharp defects on (i) fracture toughness [1], (ii) burst pressure in pipelines [2], (iii) fatigue strength under corrosive environments [3]. Over the last two decades, quantitative non-destructive evaluation (NDE) based on ultrasonic techniques has grown rapidly, capable of locating defects and determining key parameters such as size, shape, and orientation in structural components. This research aims to examine the performance of the ultrasonic array image-based approach in distinguishing sharp and non-sharp defects. Towards this goal, we will first discuss the sizing limitation and accuracy of estimating notch depth (***a***) & notch width (***b***) using ultrasonic array image-based sizing methodologies. Using a few case studies, the impact of ultrasonic sizing on the structural integrity assessment of components will be discussed

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Research presentations 4

Investigation of the compressive behaviour of carbon/glass fibre hybrid composites with 4-point flexural tests

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Abstract

Carbon fibre composites are widely used in aeronautical vehicle structures, motorsports and high specification sports equipment because of their high specific mechanical properties and their ability to be tailored to meet specific mechanical performance. However, the design of carbon fibre composites is often limited by the catastrophic failure due to the brittleness of the material. Hybridising high strain and low strain materials is a common way to avoid the catastrophic failure from carbon fibre because the applied load can be transferred to high strain fibres [1, 2]. For example, glass layers hybridised with one or two layers of thin carbon have exhibited a metal-like pseudo-ductile stress-strain behaviour, which is governed by progressive fibre fracture (fragmentation) in the thin carbon plies. [1, 3, 4].

Tensile failure of hybrid composites has been presented in various studies [5-7], but the compressive behaviour of the glass/thin carbon hybrid composites is still not well understood. The previous works on hybrid composites showed that gradual carbon fibre failure in compression has been achieved with a pseudo-yield point on the stress-strain curve [8, 9]. In addition, the traditional direct compression test method creates stress concentrations at the grips, resulting in premature failure in composites.[8]. Therefore, a four-point flexural test of a sandwich beam with a wood core has been introduced in the present work to achieve pure compressive gauge section failure [8, 9]. This study aims to investigate the compressive behaviour of the glass/thin high modulus carbon hybrid composites and to obtain a baseline compressive failure strain for the carbon fibre composite.

The sandwich beam was designed to investigate the compressive behaviour of S-glass/ high modulus carbon fibre hybrids with a series of different carbon to glass ratios. Fragmentations in the high modulus carbon fibre layers on the compression side of the beam have been observed without premature failure such as core shear failure, localised roller failure or tensile failure on the bottom layer. Gradual stress-strain curves have been observed in all layups. The results suggest that the ratio between glass and carbon layers plays a significant effect on the failure. The low carbon to glass ratio created progressive carbon fractures, which is similar to the previous study [9]. A higher carbon/glass fibre ratio has generated a lower compressive strain and longer average carbon fragment lengths. It is suggested that an optimum hybridisation could help suppress the catastrophic compressive failure of carbon fibre composites.

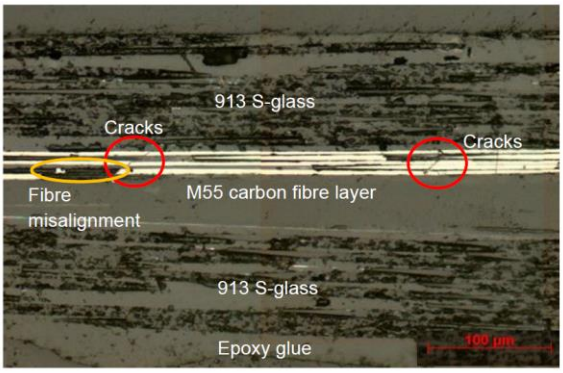

Figure 1: Cracks on M55 carbon fibre/S-glass hybrid composite. The cracks show fibre fracture at an angle and localised delamination between the M55/S-glass interface was observed.

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Measuring the micromechanical response of single carbon fibres & their treated interface in model composites under compression via the use of in-situ Raman spectroscopy

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Abstract

The compressive strengths of unidirectional carbon fibre reinforced polymer composites (CFRPs) can be less than 60% of their tensile strengths [1]. This lack of compression strength is often a design limiting feature of CFRPs. Assessing the compressive behaviour of composites is a challenge due to the complexity of many variable failure modes within the composite itself as well as the behaviour of individual fibres. To improve the compression performance of CFRPs it is critical to have an in-depth understanding of how failure occurs at the fibre level.

Determining stress-induced changes in individual atomic bonds by measuring vibrational frequency variation with non-destructive spectroscopic methods can provide information on single fibres' micromechanical response to compressive deformation. Laser Raman spectroscopy has been widely used as an effective tool to observe & quantify stress states within graphitic materials such as carbon fibres. By measuring the Raman shift of the deformation sensitive 2D vibrational mode's peak position, present in high modulus carbon fibres, with respect to applied compressive deformation, an accurate value of the stress in the fibre can be obtained. This band shift is used to estimate the fibres' mechanical properties such as Young's modulus, strength & strain to failure. By mapping along a length of fibre and collecting the positions of Raman bands, the variation in the stress state along the fibre can be obtained and interfacial stress transfer derived.

Here, high modulus PAN-based carbon fibres are coated with carbon nanotubes (CNTs), which has previously been shown to improve the interfacial adhesion between fibres and the matrix, thus increasing the interfacial shear strength [2]. Raman spectroscopy is used to examine the changes that altering the interface may have on the compressive properties of a model fibre-matrix composite.

In this work, we use in-situ laser Raman spectroscopy to characterise single high modulus carbon fibre model composites to gain an understanding of microstructural behaviour of reinforcing fibres and their stress-strain response in compression. Additionally, we aim to investigate the effect of introducing CNTs to the fibre's interface and interphase on the compressive behaviour of the model composites.

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Low-velocity Impact Damage of Composite embedded Electromagnetic Interference shielding Metal Mesh

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Abstract

Electromagnetic Interference (EMI) generated by electromagnetic waves interfere with on-board and air-to-ground communications and electronics on an aircraft, which is a significant phenomenon to be considered on electrified aircraft. EMI shielding is based on the Faraday Cage model, of which close surface bounded by conductive materials prevent electromagnetic waves from entering [1]. Metallic aircraft frames have been safely served due to their (e.g. aluminium) have been safely served for over half a century due to their excellent electrical conductivity. Over the past decades aerospace industry are seeking for lighter weight and less fuel consumption aircraft designs by applying composite structures in order to replace metal. Fibre-reinforced polymers (FRPs) allow structures attain significant improved mechanical properties such as high specific stiffness and strength [2]. However, FRPs are not able to provide conductivity and prevent EM waves from entering. In most conditions, EMI produce harmless effect, however, in some situations it would lead to vital disturbance to sensitive devices, which causes permanent damage. Therefore, a solution is required to provide EMI shielding function. EMI layers embedded or integrated with composites are mostly applied to cockpit, fuselage and main wing, which is likely to be damaged by LVI caused by bird strike and landing off. Barely visible impact damage (BVID) is the most common result of LVI and is defined as the type of damage that may not be visible to naked-eye observation but can be detected by non-destructive testing techniques such as CT-scan [6]. Laminated composites are unlike to metallic materials, they rarely leave trace that can be directly observed, but BVID can significantly degrade composite structure's load-bearing capability especially under further compression and fatigue [3]–[5]. This paper presents comparison of low-velocity impact (LVI) damage between composites with and without embedded Electromagnetic Interference (EMI) shielding material at different energy levels. Due to the weaker interfacial properties between EMI mesh and composite plies, the damage area (delamination and debonding between EMI shielding material and composite plies) is normally much higher in EMI embedded composite (EMIeC) compared to pristine composite for impact events with low impact energy level. However, the delamination at lower sublaminate is much reduced in EMIeC compared with pristine composites under impact. For higher energy level of impact, the delamination at lower sublaminate is reduced further even prevent fibre breakage from happen in EMI composite. By introducing a stronger (in flexural deformation) layer but with weaker interfacial property to composite, the impact damage of the composite is reduced, which in turns leads to higher impact resistance. This project provides a general comparison between pristine composites and EMIeC and basic understanding of metal-composites hybrid materials' fundamental mechanical behaviour under LVI, which is also a reference study for further numerical and analytical investigation.

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Fatigue Behaviour and the Combined Effect of Corrosion and Marine Biofouling on Plasma Welded Nickel Aluminium Bronze (NAB)

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Abstract

This research investigates the combined effect of corrosion and marine biofouling on the fatigue life of plasma welded Nickel Aluminium Bronze (NAB). The understanding gained will be used to improve preventative maintenance and inspection procedures used by the marine industry.

NAB [1] is used extensively by the marine industry in applications such as ship propellors and sea valves due to its relatively high corrosion resistance and good strength [2]. However, when in service within components in the marine industry, NAB is often exposed to biologically active and corrosive environments whilst experiencing highly complex fatigue cycles (e.g. a culmination of wave loading, tension and compression due to ship movements, loading due to valve use etc.). Numerous studies have investigated the corrosion behaviour of cast NAB in sea water (e.g. [3] and [4]), but none have focussed on the combined effect of welding, biofouling and corrosion and their effect on failure

NAB has a complex microstructure involving multiple phases and experiences selective phase corrosion (SPC) due to the micro-galvanic coupling between the α and κ phases [5]. This has been shown to be particularly severe in the HAZ of a weld [3]. In the present study, SPC has been seen in samples deployed in the marine environment off the coast of Plymouth, UK as the corrosion products were found to contain high percentages of Aluminium.

The samples deployed in the present study were observed to become biofouled within the first month of deployment. Marine slime became visible after 1 month of submersion and more complex organisms were seen after 3 months.

In addition to the deployment studies, numerous fatigue tests have been undertaken both on parent samples of NAB and on samples of plasma welded NAB. These tests confirm the high fatigue strength of the parent material and have consistently shown crack initiation at the weld toe of bead-on-plate style plasma welded samples. Some of the welded and cracked samples have been x-ray CT-scanned and the resulting images show complex crack geometries running perpendicular to the weld toe.

Image based models were imported into FEA software to measure stress concentration factors. As expected, SCFs around the weld toe were seen. Future work will consider the geometric effect of the weld bead and measure the stress field around cracks that have been imaged using x-ray CT-scans.

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