CIMComp

EPSRC

Future Composites Manufacturing Research Hub

Newsletter

JANUARY 2023

In this edition...

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UKRI Engineering and Physical Sciences Research Council

Happy New Year and welcome to the first edition of the 2023 Hub newsletter

Hub Research (1/5)

Recently Finished Projects

Innovation Fellowship: Numerical Simulation for High-rate Compression Moulding of SMC/Prepreg
Dr Connie Qian
University of Warwick

This project aimed to develop novel process characterisation and process simulation techniques for high-rate compression moulding of SMC/prepreg. The project consisted of both experimental and simulation studies focusing on three main aspects including the processing behaviour of SMC or prepreg in a single-material compression moulding process, and the interaction between the two materials in a hybrid moulding process. The project fits the Hub's key priority areas "high-rate deposition and rapid processing technologies" and "design for manufacture via validated simulation".

High-rate compression moulding of SMC/prepreg hybrid is an attractive solution for high-volume manufacturing of high-performance, lightweight structures. The process combines the superior specific properties of continuous fibre prepreg and the high design flexibility offered by SMC. However, such manufacturing process have not been widely adopted by industry because the material behaviour of SMC and prepreg and the interaction between the two materials during a hybrid moulding are poorly understood, and consequently there is no predictive process simulation models. It is especially important to select appropriate experimental setups such that the material behaviour can be studied at typical hybrid moulding conditions (high pressure, high temperature and high strain-rate). These requirements create significant challenges for processes involving flows of SMC, as conventional rheometers cannot meet such testing condition requirements.

Hub Research (2/5)

Hybrid moulding of SMC/prepreg has already attracted great interest in the automotive industry, and the developments from this project will further promote the applications in automotive, driving the current non-structural applications of discontinuous fibre composites towards more structural applications, and potentially enable these materials and processes to be adopted in more demanding applications such as aerospace.

The potential impact of this project is in two areas:

- Sustainability: Processing of discontinuous fibre composites is an important solution to sustainable composites manufacturing, particularly in the areas of recycling and reuse, as the waste materials typically have infinite fibre lengths, meaning that they can no longer be processed using conventional forming processes.
- Promote the application of discontinuous fibre in other industries: The application of SMC has been limited to the automotive industry for decades, and primarily for non-structural applications, due to the poor understanding in the processing behaviour and mechanical properties of the material. The methodology developed in this project and the outcomes will provide better understanding in the material and facilitate the development of robust and reliable design tools, enabling SMC to be adopted in other applications where the design requirements are more demanding. The new Innovate UK – NATEP project aims to introduce SMC compression moulding to the aerospace industry.

Core Project: Fibre-Steered Forming Technology
Principal Investigator: Dr ByungChul (Eric) Kim
University of Bristol

In this project, a novel automated manufacturing process named 'Fibre-Steered Forming Technology (FSF)' was developed for high-volume production of small and highly complex composite parts, which are not manufacturable using the current AFP processes. The FSF was developed by combining three cutting-edge technologies (material, manufacturing, simulation) developed in the Bristol Composites Institute: Virtual un-forming simulation, HiPerDiF (High Performance Discontinuous Fibre) process, and CTS (Continuous Tow Shearing). The novel approach allowed for designing a 2D fibre-steered preform that can be formed into the 3D target shape and fibre trajectories through the un-forming simulation and producing the 2D fibre-steered preform using the CTS defect-free fibre steering process.

Hub Research (3/5)

The FSF process can be used with HiPerDiF highly aligned short-fibre prepregs as well as conventional continuous fibre prepregs, which allows for more sustainable high-volume manufacturing and more effective use of high-value materials for small and complex composite parts.

The team has been focusing on experimentally validating the un-forming simulation results and carrying out forming tests with multi-ply fibre-steered preforms (both continuous fibre and HiPerDiF prepreg preforms), to enhance the industrial applicability of the FSF process. Multi-ply preform forming trials were carried out on a rugby-ball shape (positive Gaussian curvature) and a twisted plate shape (negative Gaussian curvature) in an in-house double diaphragm forming rig. The test results successfully demonstrated the superior formability of the HiPerDiF preforms and its steerability using the CTS process. It was also demonstrated that multi-ply fibre steered preforms could have dual advantages of eliminating forming defects and optimally distribute the reinforcement fibres, which enables production of ultra-lightweight small and complex composites parts.

Feasibility Study: Furthering the Uptake of Carbon Fibre Recyclates by Converting into Robust Intermediary Materials Suitable for Automated Manufacturing
Principal Investigator: Dr Thomas Turner
University of Nottingham

This study addressed the issue of composites sustainability by developing new manufacturing technologies to produce a high performance composite intermediate material from recycled carbon fibre. The format of this product is a powder-coated aligned short fibre tape with high mechanical properties and excellent formability. This project has excellent alignment with the aims of the Hub, addressing four critical topics: 1) Reduce the carbon footprint of composites manufacturing; by furthering the uptake of carbon fibre recyclates, therefore making end of life reuse a more viable option, and so reducing the loss of material to landfill disposal. 2) Step towards a new manufacturing technology; that aims to overcome barriers preventing the use of recycled carbon fibre in automated manufacturing processes. 3) Analytical study to understand material manufacturing parameters. 4) Increasing the manufacturing sustainability of high-performance structures; by enabling the use of aligned recycled carbon fibre in high-accuracy automated fibre placement technologies.

Hub Research (4/5)

Overall, the project has successfully demonstrated an improvement in usability of the existing aligned fibre tapes at low TRL. The programme of work highlighted some issues which were not foreseen at the bid writing stage which have limited progress compared to the original intentions. We have not been able to demonstrate use of the material in an automated process or in any end use demonstrator components, but we have uncovered some fundamental phenomena which will drive future development. The primary impact of this Feasibility Study is to demonstrate that, in contrast to many existing technologies, fibres recovered from end-of-life components can be turned into a format that resembles a virgin material with manufacturing characteristics (such as the ability to be stretch formed) that enhance industrial appeal.

Feasibility Study: Manufacturing Value-Added Composites for the Construction Sector Using Mixed Waste Plastics and Waste Glass Fibres
Principal Investigator: Dr Dipa Roy
University of Edinburgh

Packaging plastic wastes are mostly polyethylene (PE)-based and PE is not commonly used as a matrix in composites due to its lower mechanical properties. PE combined with reinforcement fibres, however, can produce useful composites with an optimum combination of toughness and stiffness. Here the opportunity lies in combining soft packaging waste plastics with waste reinforcement fibres. This was the main objective of this project, to develop suitable technology that can combine waste mixed plastics (wMP) with waste glass fibres (wGF) to produce value-added composite products for the construction sector. Such technologies can divert huge volumes of low value wastes (that are not currently recycled) from landfill to a circular economy. The project fits well with the Hub objectives, as recycling and reusing waste materials are the prime focus in this project.

Thermoplastic composites were manufactured with wMP/wGF; the tensile, compressive and flexure properties were investigated for the wMP/wGF specimens. Cee-section members were produced as demonstrator components with wGF/wMP (and wGF/wMP/waste carbon fibre hybrid) composites and their axial compressive performance was assessed.

Hub Research (5/5)

The preliminary results of this project have shown promising properties and two construction companies (end users) are interested in the work. A follow-on project (EPSRC Impact Acceleration Account-Commercialisation Project), which is a continuation of this project, has been funded and commenced in October 2022. There is a discussion ongoing for a patent application.

The Cee-sections produced have shown very encouraging results and there is a possibility that will be taken forward in a separate industry funded project.

Feasibility Study: Additively Manufactured Cure Tooling (ADDCUR)
Principal Investigator: Dr James Kratz
University of Bristol

ADDCUR investigated tooling to reduce embodied energy of composite manufacturing. Specifically, the project explored additive manufacturing to design the lightest possible cure tools to increase rate and quality by adjusting the heat distribution in the mould. ADDCUR supports two priority research themes: i) rapid processing technology by curing parts in half the time, and ii) design for manufacture via validated simulation by eliminating costly tool modifications that slow product development time.

This Feasibility Study has demonstrated potential to control composite curing with AM tooling to a level that is unachievable by conventional machining methods. We found that the exothermic overshoot due to curing heat released by the epoxy appears to be proportional to lattice density, while the heating rate due to the low thermal conductivity of polymers was more sensitive to the facesheet thickness. The potential to spatially match the tool properties to the composite part is possible. How this is applied to industrially relevant cases requires further work.

Hub Outreach (1/2)

Advanced Engineering Show 2022 – 2–3 November 2022 – National Exhibition Centre (NEC), Birmingham, UK

The Hub exhibited at the Advanced Engineering Show in November 2022. This show is the UK's largest annual engineering and manufacturing event, connecting OEMs, Tier 1 manufacturers, and supply chain partners with a host of interactive stands, demonstrations and a significant buzz surrounding the role of sustainability.

Prof Nick Warrior, Director of the Hub and James Whyman, Business Development Manager at the AES.

The Hub's stand provided an effective and stimulating backdrop to the Hub's activities, vision, and capabilities, attracting an array of visitors from students to consultants to academics to policymakers. New contacts were made from sectors previously un-explored, invitations to visit the labs at Nottingham were accepted with enthusiasm, and follow-up discussions are already in the works.

The two-day event was a positive and engaging experience. New contacts and refreshed existing relationships will provide a foothold for the next Hub iteration.

Hub Sustainability Event – 31 October 2022, AMRC, University of Sheffield

The Hub held its second sustainability workshop at the AMRC, Sheffield in October 2022. It was attended by representatives from several universities, research organisations, catapults and industries.

The key aims of the day were to build upon the successes of the first workshop held at the NCC earlier in the year by garnering fresh perspectives on the critical overarching sustainability themes in composites manufacturing. Lifecycle assessment, the design and manufacturing processes, sustainable materials, and recycling methodologies were discussed within four breakout sessions, from which over eighty individual challenges were identified.

Hub Research (2/2)

From here, the Hub has collated all workshop feedback under the Strategic Development Committee to implement the theme of sustainable composite manufacture into its research remit to ensure our alignment with the present and future needs of the engineering community, ultimately reducing environmental impacts and conserving energy and natural resources.

To keep up to date with our events visit:

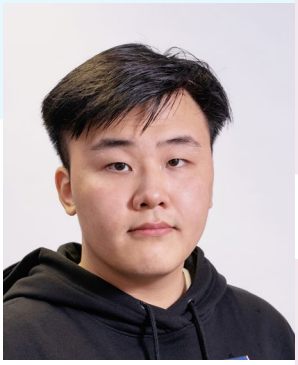
https://cimcomp.ac.uk/hub-news

Hub Staff News (1/2)

The Hub would like to welcome the following new PhD students:

Joseph Humphries, University of Nottingham. Joseph graduated from the University of Nottingham in 2022, receiving an MEng in Aerospace Engineering. Joseph is now continuing his academic studies as a PhD student at the University of Nottingham. His current research will focus on modelling 3D woven textile reinforced composites. This work aims to see development of code for the open-source textile modelling software TexGen, developed at the University of Nottingham, which can model novel 3D woven preforms.

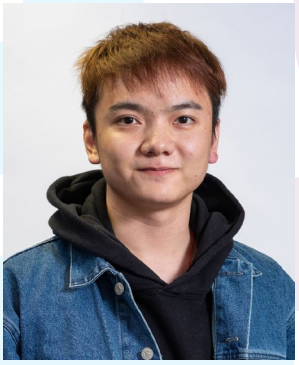
Yilong Li, University of Cambridge. Yilong is funded by EPSRC DTP studentship, under the supervision of Prof. Michael Sutcliffe and is working on the Hub Core Project **Design Simulation Tools and Process Improvements for NCF Preforming**. Yilong's research concentrates on modelling the multi-layer preforming process of NCF composite, including simulating with the FE model and providing optimization methods to avoid defects. Prior to joining the University of Cambridge Yilong completed his MSc at Imperial College London in Advanced Aeronautical Engineering and achieved his bachelor's degree in Mechanical Engineering in 2021.



Sandy Guo, Loughborough University. Sandy is currently working on the Hub Synergy Project **Energy Efficient Composite Tooling with Integrated Self-Regulating Heating and Curing Capabilities based on Recycled Composite Waste (ECOTOOL)**.

Before commencing his PhD, Sandy received his MSc degree in Physics from the Physics and Astronomy Department, University of Sussex. His current research area is focusing on the 'Multifunctional polymer composites for next-generation integrated strain and temperature sensor' for human body health tracking devices. His project aims to create an 'all-in-one' health monitoring device that not only senses but also has a smart active epidermal temperature regulating system.

Hub Staff News (2/2)



Lichang Lu, Loughborough University. Lichang completed his BEng at Sichuan University and MSc at Loughborough University in Polymer Materials and Engineering. Lichang completed a research project on PPVC recyclability at Loughborough University as an exchange student and went to Nanyang Technological University for an academic camp on polymer-based composites. He is working on conductive polymer composites and phase change composites for his PhD at Loughborough, specifically for the smart temperature control and thermal management of batteries and wearable devices. Lichang is currently working on the Hub Synergy project; **Energy Efficient Composite Tooling with Integrated Self-Regulating Heating and Curing Capabilities based on Recycled Composite Waste (ECOTOOL).**

The Hub would like to welcome **Dr James Davidson** as a Research Associate at the University of Edinburgh. James recently completed his PhD "Investigations on Advanced Joining Methods for Composite Materials and Fibre Reinforcements" and is currently working on the Hub Synergy project; **Thermoplastic in-situ polymerisation (TPIP) and double diaphragm forming (DDF) for moulding of complex parts at scale.** The project aims to develop techniques for improving the manufacture of large-scale thermoplastic structures using affordable, low temperature processes. More specifically, James' work is associated with the development and integration of an automated mixing and injection system for Nylon-6. His primary research interests are machine design/prototyping, finite element analysis, (meta-heuristic) optimisation algorithms, composite joining, mechanical testing, and pneumatic splicing.

The Hub congratulates **Monali Dahale** for achieving Ulster University's Convocation Postgraduate Student of the Year 2022 for her work on crashworthiness of composites. More details of the award can be viewed here.

www.ulster.ac.uk/updates/2022/december/15836

Other Hub News (1/2)

Researcher Network Awards Event – 2 December 2022, University of Nottingham

Following the success of previous Researcher Awards, the Researchers Network launched its final call and invited applications from Postdocs and Research students to put forward new research ideas for funding short research projects. The funding of up to £10k per project is to be shared between at least two universities within the Hub spokes. The aim of the award is to facilitate activities, explore and promote synergies between the Hub universities, encourage collaboration and create new connections between composites manufacturing and other areas.

The criteria of the call were that that each proposal must focus on the sustainable manufacturing of composites, and address at least one of the five Hub priority areas:

- High-rate deposition and rapid processing technologies
- Design for manufacture via validated simulation
- Manufacturing for multifunctional composites and integrated structures
- Inspection and in-process evaluation
- Recycling and re-use

Applications that met the first stage criteria were invited to the University of Nottingham to present a 10-minute overview to an industrialist panel made up of representatives from the Hub's industry partners. The following projects were successful:

1. "**Manufacturing and modelling of variable thickness near-net-shaped 3D woven composites for complex aerospace structures**" Monali Dahale, Ulster University, Antony Samy, Ulster University, and Joseph Humphries, University of Nottingham.
2. "**AITROCOMPS: AI-driven through-thickness reinforcement design optimisation for multifunctional composite structures**" Akram Zitoun, Brunel University and Mehdi Asareh, Cranfield University.

These projects cover participants from four Hub partner universities and five applicants in total.

Other Hub News (2/2)

The activity offers early career researchers a valuable first step into applying for research grants and the outcomes for these short research projects can provide a platform to scale up the project and apply for further grants and funding. The projects will commence by March 2023 and complete by September 2023. The Hub look forward to seeing the projects develop.

Hub Equality, Diversity and Inclusion (EDI) (1/3)

In this edition, we welcome an EDI experience provided by **Dr Clara Frias, Head of the Composites Centre, AMRC, University of Sheffield.**

"I did all my academic study in my home country Portugal. After finishing my first degree in Mathematics, I wanted to challenge what I learned by finding applications for it and my academic tutor encouraged me to pursue a study in engineering. Therefore, I did a PhD in science of engineering, in a topic linked to structural health monitoring for biomedical devices. Although it was not directly linked to composites, my PhD supervisor was the head of a composites centre for an RTO (Research and Technology Organisation) in Portugal, therefore I was based in a composites team and fell in love with composites. I stayed in the same composites centre after my PhD, as an R&D Project Manager focusing on structural health monitoring for composites.

In 2010, I decided to move to a country where I could be more exposed to the composites industry, and the UK was at the top of my list, and I was lucky to be offered a Research Engineer role at NetComposites. I spent around 4 years at NetComposites during which I worked with a wide range of materials such as thermoplastic composites, graphene, and bio composites. Following NetComposites I was appointed as a Research Programme Manager at the University of Manchester. The research was in aerospace but with a big focus on composites because of my background. After 3 years at Manchester, I was offered a technical lead position at AMRC, part of the HVMC. This role allowed me to have even more engagement with industries, but also maintain some low TRL research, through which I could push young engineers to pursue a PhD study. Alongside with my day-to-day role, I am also one of directors at the Composite UK of Directors allowing me to be even more close with the UK Composite industry.

Hub Equality, Diversity and Inclusion (EDI) (2/3)

In 2019, I became the Head of the Composites Centre at AMRC, focusing on the running of the centre from strategy, operation, capability and technology point of views, restructuring a team so that we could continue to support the UK composites industry. This role is different from my previous roles because it is less hands-on but more focused on leadership and mentoring junior members, and I am really enjoying it.

COVID came along shortly after I became the Head of the Composites Centre. It was an incredibly challenging time for me – I took the role and suddenly the world just closed down. I needed to make sure the team could carry on delivering, and I also took extra care of their well-being. In our team we had people who were stuck in their house with their family and trying to work in that situation, and people whose family were in a different country, and they were blocked from seeing their family. I was lucky to have a strong senior team supporting the centre. We maintained regular contact with our team members to make sure they were OK, rather than just chasing for work. It was a challenging time, but we did well. We have kept innovative ideas coming and we are growing.

I feel incredibly lucky that throughout my career there were many people who encouraged me to take the next steps. I also care about the legacy I leave behind. I feel it is my duty to support young engineers, help them to achieve their goals and overcome challenges that they face. I was born in a small village in the north of Portugal, and when I was young it was common to think females should be responsible for raising family, and academic study and career should not have high priorities. I received great support and advice from my mother – she was not as lucky as me to receive great education, but she helped me to build my resilience, so that nothing could stop me to go where I want to go, where I want to study, where I want to leave a legacy and make a better world. There were three other girls like me in my village I felt incredibly lucky to see them following their dreams like me. Throughout my career I have never felt I was given less because I am a female, and I am immensely proud to be the first female head of a research centre at AMRC."

Hub Equality, Diversity and Inclusion (EDI) (3/3)

In engineering there has always been a lack of females. I am happy that I have the opportunities to support other female engineers. I like being there when they need me and if they are open for some support we should offer it to them, sometimes it is just listening. EDI is an important element of sustainability. Until we can make sure there's fair treatment and opportunities to all, our decisions are going to be imbalanced. We have the obligation to demonstrate to show the value of the benefit of adding EDI – we can achieve more. We have quite a diverse team at AMRC – people with different genders, different educational, professional backgrounds and cultural backgrounds, you can hear people speaking different languages in the office! We appreciate everyone's opinion and that has enabled us to achieve so much. We also try to understand different personalities and that has helped us to bring the most out of people. There is still a lot to be done but we are getting there!

If you are interested in joining the Equality, Diversity and Inclusion committee please contact the EDI Champion, Dr Connie Qian:

cimcomp.ac.uk/people/connie-qian/

Hub Training (1/2)

Following the success of the summer training programme delivered by Pentaxia in Derby, the Hub organised a second 5-day intensive training course, covering Mould Design, CNC Programming, WI creation / Kit templating & nesting, Laminating and Inspection.

The training was aimed at all Hub students, researchers, and the IDC students to develop their practical skills and abilities. Six students and researchers from across all Hub academic partners attended the course and it proved to be a continuing success from the positive feedback received.

Several responses from a post training survey were received:

"The course successfully met my objective, by generating an understanding of how the composites industry operates, getting practical experience with material (prepreg) and improving shop floor skills. I found the most useful element of the training was being involved in the practical aspects of each process (lamination, press operation, trimming, etc) - seeing the whole process from start to end gave me a better understanding of the manufacturing chain. I found the training course an invaluable opportunity to learn about the composite world and a game-changer in terms of outreach (other SMEs, even OEMs should look to deliver similar initiatives given the variety of applications for composite manufacturing). A possible extension would be getting participants to scan a legacy mould using the Absolute Arm and manipulate it in CAD - might help reinforce ongoing activities to Industry 4.0?"

"My objective of the training course was met successfully, as it provided me with an insight to how a company operates within the composites industry. I found that looking at the process of manufacturing a part from 'start to finish' and how this is accomplished in industry was the most useful element of the course. As a result of the course I will aim to get into the lab more, and consider how my work could be implemented in industry more often."

Hub Training (2/2)

The Hub group showcasing their finished components next to the large autoclave – Top: Sangeet Sivakumar (Manchester), James Whyman (Nottingham), Bottom left to right: Kazi Sowrov (Manchester), Umeir Khan (Bristol), Liam Sprake (Nottingham), Joseph Humphries (Nottingham), Albert Gibbs (Pentaxia).

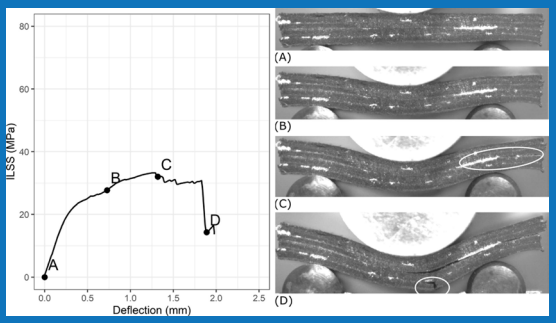
Joseph Humphries trimming the composite part he made throughout the week ready for final polishing.

If students and researchers have suggestions for specific training opportunities which the Hub can support, please get in touch:

EN-INFO-CIMCOMP@exmail.nottingham.ac.uk

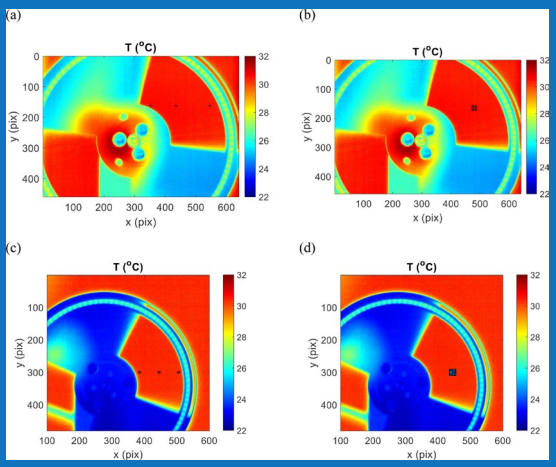
Publications (1/3)

1. Campbell, I., Mulvihill, D.M., Harrison, P. **The Influence of Residual Tin Following Induction Melt Thermoforming of Composite Parts**, 2023, Composites Part A: Applied Science and Manufacturing, Volume 164, 107286. https://doi.org/10.1016/j.compositesa.2022.107286



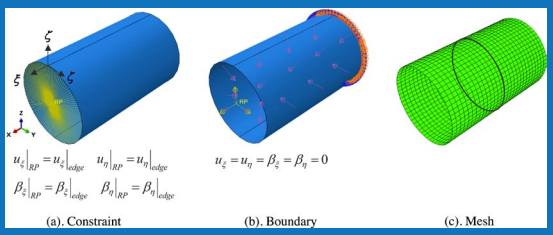
Interlaminar shear stress versus deflection for a selected sample containing high quantities of residual tin (from disc 'Tin-IA2'). Inset photos show the progression of deformation and failure corresponding to points (A to D) on the loading curve. Failure initiates near the location of high tin content which also corresponds roughly with the location of the maximum shear stress in (C). Further cracking is apparent later in (D) due to tensile bending stress. Stress-deflection plot shows a sudden 'brittle like' failure.

2. Jimenez-Fortunato, I., Bull D.J., Thomsen O.T., Dulieu-Barton J.M. **Quantitative Microbolometer-based Thermoplastic Stress Analysis**, Optics and Lasers in Engineering, Vol 160, January 2023, 107276. https://doi.org/10.1016/j.optlaseng.2022.107276



Temperature (°C) field images of the optical chopper placed in front of the blackbody showing the (a) single pixel measurement points (NR on), (b) an averaged 10×10 pixel region (NR on), (c) single pixel measurement points (NR off) and, (d) an averaged 10 x 10 pixel region (NR off).

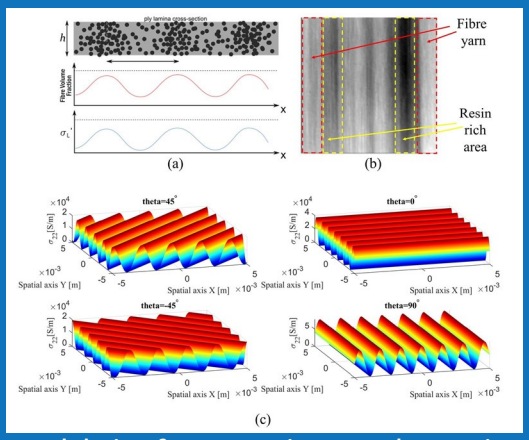
3. Li, S., Johnson, M.S., Sitnikova, E., Evans, R., Mistry, P.J. **Laminated Beams/Shafts of Annular Cross-section Subject to Combined Loading**, Thin-Walled Structures Volume 182, Part A, January 2023, 110153. https://doi.org/10.1016/j.tws.2022.110153



Typical finite element model of annular tube in validation exercises: (a). Constraint at the loading edge; (b). Boundary conditions at the fixed end; (c). Mesh. Notations 'β' signifies the rotation about the respective axis.

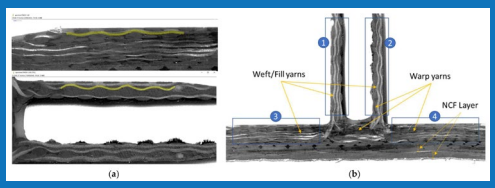
Publications (2/3)

4. Yi, Q., Wilcox, P., Hughes R. **Modelling and Evaluation of Carbon Fibre Composite Structures using High-frequency Eddy Current Imaging**, 2023 Composites Part B: Engineering. https://doi.org/10.1016/j.compositesb.2022.110343



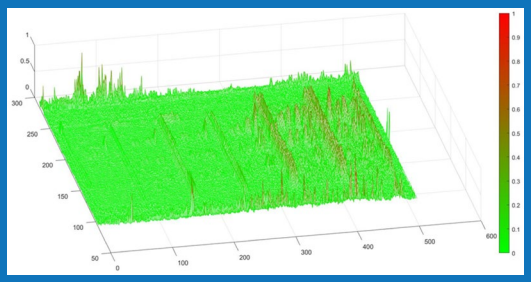
Novel eddy current modelling using conductivity tensor modulation for composites non-destructive evaluation.

5. Budwal, N., Kasper, K., Goering, J., Ward, C. **Tooling and Infusion Design Strategies to Reduce Trade-offs in Forming and Infusion Quality of Multi-textile CFRPs**, Journal of Manufacturing and Materials Processing, Volume 6, Issue 3, 62. https://doi.org/10.3390/jmmp6030062



(a) Example of tracing tool for measuring yarn paths in ImageJ; (b) Cross-sectional image of Pi-NCF component labelling warp and weft yarns, NCF layers, and crimp measurement zones.

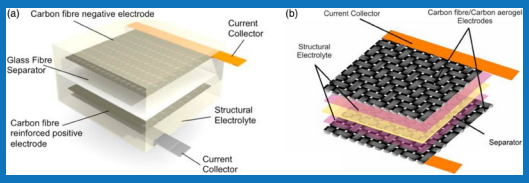
6. Gandhi, N., Rose, R., Croxford, A., Ward, C. **Understanding System Complexity in the Non-Destructive Testing of Advanced Composite Products**, Journal of Manufacturing and Materials Processing, Volume 6, 71, 2022. https://doi.org/10.3390/jmmp6040071



Normalised standard deviation of amplitude variation across component M1.

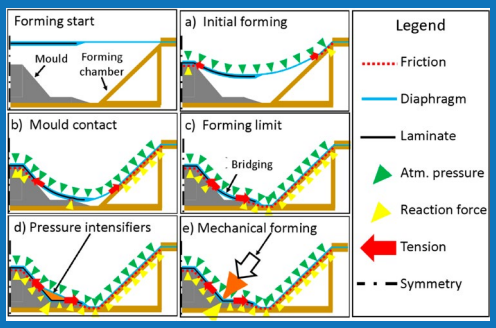
Publications (2/3)

7. Ishfaq A., Nguyen S.N., Greenhalgh E.S., Shaffer, M.S.P., Kucernak, A.R.J., Leif, E. Asp., Zenkert, D., Linde, P. **Multifunctional Design, Feasibility and Requirements for Structural Power Composites in Future Electric Air Taxis,** Journal of Composite Materials.2022;0(0). https://doi.org/10.1177/00219983221132621



(a) Structural battery1 and (b) structural supercapacitor7 composite architectures.

8. Elkington, M.P., Mistry, P.J., Johnson, M.S., Ou, H. **Hybrid Vacuum-robotic Forming of Reinforced Composite Laminates**, 2022, Journal of Reinforced Plastics & Composites. https://doi.org/10.1177/07316844221135211



(a–c) Progression to 'bridging' during diaphragm forming and two methods for preventing this defect using (d) 'pressure intensifiers' and (e) 'mechanical forming'. (Note: these figures present half of the mould indicated by a line of symmetry).

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If you would like to contribute to our quarterly newsletters, please contact Joanne Eaves:

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