

## Newsletter March 2021

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## Welcome to our first newsletter of 2021!

## **MID-TERM REVIEW**

Members of the Hub have been busy preparing for the Mid-Term Review, which was held online over two days at the end of January 2021. We are pleased to announce that the review was successful and that EPSRC funding will continue to the scheduled end of the project in December 2023. The Hub management team would like to thank everyone who contributed and for their ongoing support.

#### Did You Miss Our Webinar in November 2020?

The Hub held a free to attend webinar, focused on 'Rapid **Composite Processing Technologies**'. Three technical presentations were delivered, giving an insight into some of the recently funded research. Follow the links to watch video recordings of each presentation:

#### **Optimised Manufacturing of Structural Composites via Thermoelectric Vario-Thermal** Tooling (VarioTherm)

Dr Neil Reynolds, Hub Researcher and Senior Research Fellow, Warwick Manufacturing Group



youtu.be/\_w7KXF0ZFgY

#### **Design Simulation Tools and Process** Improvements for NCF Preforming

Dr Lee Harper, Hub Manager and Associate Professor, University of Nottingham



youtu.be/CHMsJS8E8MU

#### Layer by Layer Curing

Dr James Kratz, Hub Investigator and Lecturer, University of Bristol



youtu.be/E9xC52gjKWo

## Upcoming SAMPE Media Competition – March 2021

# UK & Ireland

The Hub is pleased to support the upcoming SAMPE 'Young Engineer and Students' media competition.

This is an opportunity for students to promote their products, services or research ideas at a national level, using composites knowledge and creativity to produce an informative video that can be shown to the wider composites community.

Six teams have entered, including 3 Hub university teams and 3 from industry. The winner will be announced at the SAMPE UKI seminar on 10th March 2021.

More information on the competition can be found here:

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https://sampe.org.uk/index.php/2020/11/16/mediacompetition-2021/

## **Feasibility Studies** (1/3)

Three Hub feasibility studies were completed in December 2020 and the final reports are now available on our website.

#### Evaluating the Potential for In-process Eddy-current Testing of Composites

#### Dr Robert Hughes, University of Bristol

The experimental practicality and sensitivity of eddy-current testing (ECT) techniques was explored for the in-line monitoring of carbon fibre reinforced polymer (CFRP) composite materials during preforming. The project sought to determine whether:

a) eddy-current testing was capable of monitoring critical properties of uncured composite materials i.e. fibre orientation and fibre density

b) if certain manufacturing conditions, including applied pressure, scanning height, applied temperature, and scanning speed, affected the ability to evaluate component quality.



Figure 1. Fibre orientation comparison between cured and uncured IM7/8552 samples of equal layup structure [0/45/90/-45] showing a) the unprocessed coil impedance data in a linear plot and b) the normalised impedance changes in polar form

Key experimental results were obtained confirming the potential for ECT monitoring of fibre alignment and fibre density (pressure) in uncured composites up to a standoff of 8mm from the surface. However, the work also demonstrated that ECT measurements struggle to penetrate deeper than one or 2 ply layers in uncured composites, most likely due to the lack of cross-linking between fibres in adjacent ply layers. Important lab capabilities, academic and industrial collaborations were also developed to support continued research through PhDs and other funding opportunities.



## Feasibility Studies (2/3)

## Microwave in Line Heating to address the challenges of High-Rate Deposition

#### Prof Richard Day, Wrexham Glyndwr University

The purpose of the study was to explore whether microwave heating could be used during automated fibre placement as a method of increasing the layup rates to the 100 kg/hour target, which would enable further use of composites in a range of structures, particularly, but not exclusively for aero structures.

This project is complementary to the Core Project on the **Technology Framework for Automated Dry Fibre Placement** and fits within the high-rate deposition and rapid processing technologies research priority areas.



Figure 1 - COMSOL model of microwave waveguide used to process thermoplastic and thermosetting tapes during AFP/ATL

A microwave cavity using a truncated waveguide section was initially simulated using COMSOL and HFSS software and later developed into a laboratory-scale rig. Simulations of heat up rate in this cavity as well as practical measurements showed that it could be used to meet the target layup rate of 100 kg/hr. The research question was successfully answered. There is mileage in this approach which shows that a practical microwave system of heating during automated layup is possible and desirable. Furthermore it may be possible to combine this with other forms of heating to produce very significant layup rates.







## **Feasibility Studies** [3/3]

#### Incremental Sheet Forming of Fibre Reinforced Thermoplastic Composites

#### Dr Michael Johnson, University of Nottingham

This feasibility project, aimed to form fibre reinforced thermoplastic (FRTP) sheet material using diaphragm forming (DF), enhanced by a robotic, incremental sheet forming (ISF) process. This method is termed the Hybrid Vacuum Robotic (HyVR) forming process. The over-arching aim was to manufacture large FRTP components in medium volumes (approximately 4-6 pph) and at low cost. A lab scale HyVR cell was implemented to drive the sequencing of the DF and ISF techniques.



Figure 1. Flow diagram of the Hybrid Vacuum Robotic (HyVR) forming process

The forming strategy which drives the HyVR process through sequencing of the DF and ISF techniques was developed. In addition, experimental methods were defined to quantify the FRTP material characteristics (cone study) and associated thermal forming window. These are direct inputs to the HyVR forming strategy. Cone forming FRTP was not possible due to edge clamping of the inextensible reinforcement. Techniques to extend the forming window time still are required. Using the HyVR process, forming strategies were determined to produce single curvature parts without bridging. The quality of these components was equivalent to benchmark components made by hand layup. Forming strategies for double curvature components requiring in-plane fabric shearing were produced. While successful, further improvements to the forming strategy are required to minimise wrinkling in double curvature components. The study is aligned with the Hub Workstream (WS8): Thermoplastic Processing Technologies, within the research priority area: 'High-Rate Deposition and Rapid Processing Technologies'.



#### For more information on this project:

<u>cimcomp.ac.uk/research/incremental-sheet-forming-of-fibre-reinforced-thermoplastic-composites/</u>

## Staff News (1/2)

**Professor Emile Greenhalgh** has been awarded a Chair in Emerging Technologies (Structural Power) by the Royal Academy of Engineering. With only ten awards made each year across the engineering sector, this is a very prestigious award that recognises Emile's international reputation in the field of structural power composites. To read the full story please follow this link: <u>www.raeng.org.uk/news/news-</u> releases/2020/october/chairs-in-emerging-technology-2021

Emile is the Principal Investigator on one the Hub's core projects; Manufacturing for Structural Applications of Multifunctional Composites.

For more information on this project:

cimcomp.ac.uk/research/manufacturing-for-structural-applications-ofmultifunctional-composites/

**Dr Colin Robert** has been successful in securing a Chancellor Fellowship at the University of Edinburgh. This is a 5-year programme to support early career researchers build upon existing world leading research, including training in academic leadership and knowledge exchange. Colin is currently completing a two-year Innovation Fellowship within the Hub, entitled:

Powder-Epoxy Carbon Fibre Towpreg for High Speed, Low-Cost Automated Fibre Placement.

For more information on this project:

cimcomp.ac.uk/research/powder-epoxy-carbon-fibre-towpreg-for-high-speedlow-cost-automated-fibre-placement/

Colin commented "I would like to wholeheartedly thank the CIMComp EPSRC Future Composites Manufacturing Research Hub for its role in obtaining a Chancellor Fellowship at the University of Edinburgh. The Innovation Fellowship the Hub offered me, as well as Feasibility and Synergy Studies, were without doubt instrumental in my success. I'm very much looking forward to future opportunities to collaborate with the Hub."

## Staff News [2/2]

**Preetum Mistry**, EngD Research Engineer at University of Nottingham has been awarded first place at the IMechE Future of Rail Competition 2021- Midlands Centre Local Heats. The virtual competition took place at the beginning of February, where Preetum presented his research into the 'Design and Development of a Composite Railway Axle'. The competition is aimed at Young Engineers to present their work on the theme of the 'Future of Rail' with a focus on technological development and innovation. The panel of judges was comprised of distinguish Railway Engineers and IMechE Fellows.

Preetum said "I am thoroughly looking forward to presenting my research in the IMechE National Finals later this year, discussing the future of rail and the use of composites in rolling stock design. It is a privilege to represent the Composites Research Group and showcase some of the innovative research that goes on at the University of Nottingham."



Welcome to **Keri Montague**, Business Development Manager at the University of Bristol. Keri joined the Hub team in October 2020 and is on the board for the British Composites Society and a Fellow of the IOM3. With over 20 years' experience in the composites industry, Keri's background is in aerospace and education.

In her early career she was an integral part of the British Experimental Rotor Programme 4 research and development team, looking at novel materials and manufacturing techniques at Westland Helicopters. Keri then moved from industry to education and ran the composites department at Yeovil College, delivering training and education to industry and apprentices across a range of industries including aerospace, marine and motorsport and leisure.

Keri was heavily involved in the development of the composite level 3 Trailblazer qualification and is an author for Pearson, writing composite qualifications. Keri also works as the composites CDT Industry Engagement Manager at the University of Bristol.

## **Our New Research and PhD Students** (1/2)

#### Andrea Codolini



Dr Andrea Codolini is a Research Associate at the University of Cambridge working on the Hub Core Project; **Design Simulation Tools and Process Improvements for NCF Preforming**.

cimcomp.ac.uk/research/design-simulation-tools-andprocess-improvements-for-ncf-preforming/

He completed his i-case PhD at The University of Manchester on mineral-filled polymers, with a specific focus on efficiency of material modelling

implementation in Finite Element codes for automotive sponsors. Andrea worked on an Innovate UK funded project (ALPA2) developing innovative preforming technologies whilst at the McLaren Composites Technology Centre. His current research interest is the exploitation of artificial intelligence to design for manufacturing of composite structures within

#### Rajan Jagpal



Rajan is a final year PhD student at the University of Bath working on non-crimp fabric forming and process design for predictive modelling. Having graduated with an MSc in Engineering Design, Rajan likes to approach problems creatively.

With industrial sponsorship from GKN, he is working on using magnetic distributed clamping to alter the boundary conditions during fabric forming, creating a process that is more amenable to optimisation. Rajan will be supporting the Core Project;

Design Simulation Tools and Process Improvements for NCF forming.

cimcomp.ac.uk/research/design-simulation-tools-and-process-improvements-for-ncf-preforming/

#### **Guy Lawrence**



Guy received an MEng in Mechanical Engineering in 2020 from the University of Nottingham, after completing a year in industry working for Aston Martin. His PhD research focuses on characterising and predicting the frictional behaviour of noncrimp fabrics, supporting the Core Project; **Design Simulation Tools and Process Improvements for NCF Forming**.

cimcomp.ac.uk/research/design-simulation-tools-andprocess-improvements-for-ncf-preforming/

## **Our New Research and PhD Students** [2/2]

#### Ángela Lendinez Torres



Ángela is an aerospace engineer, with postgraduate qualifications oriented towards advanced materials. Her research project consists of a study of the fibre orientation and its effect in composites forming process. She aims to understand how fabrics deform during preforming, in order to improve the prediction of wrinkles. Ángela is supporting the Core Project; **Design Simulation Tools and Process Improvements for NCF Forming.** 

cimcomp.ac.uk/research/design-simulation-tools-andprocess-improvements-for-ncf-preforming

#### **Gwladys Popo**



Gwladys graduated from IMT Lille-Douai (French Engineering School) with a Master's Engineering degree in Plastics and Composite Materials in 2019. In parallel of her engineering studies, Gwladys worked as an apprentice engineer in an automotive company where she focused on the development of a new laser welding technology for thermoplastic composite parts. Gwladys commenced her PhD at The University of Nottingham in February 2020, supporting the Core Project; **Resin Injection into Reinforcement with Uncertain Heterogeneous Properties: NDE and Control**.

Her aim is to investigate the solutions to monitor and control online the resin flow during the Resin Transfer Moulding (RTM) process cycle. Gwladys's research work is centered on the development of an optimal sensing architecture and the definition of the most adequate corrective actions depending on the resin filling scenario.

<u>cimcomp.ac.uk/research/resin-injection-into-reinforcement-with-uncertain-heterogeneous-properties-</u> <u>nde-and-control/</u>

#### **George Street**



George graduated from The University of Nottingham in 2019 with a First-Class degree in Mechanical Engineering MEng. He worked alongside Dr Michael Johnson on his 4th year project looking at the feasibility of using CFRP on rail freight vehicles, specifically pressurised tank wagons. He has since spent 18 months at SNC Lavalin-Atkins on their dedicated Rail Consulting Graduate Scheme in which he was able to develop further skills working with industry-leading experts in rail vehicle structures, dynamics, and systems.

George will be conducting research into a hybrid manufacturing process for producing large thermoplastic composite components – **The HyVR Process** and his work will support the Hub Thermoplastic Workstream.

## More Hub News (1/2)

#### **Hub Members Awarded DETI Funding**

Hub investigators, Prof. Stephen Hallett and Dr Jonathan Belnoue from the University of Bristol Composites Institute, have been awarded funding by the DETI initiative led by the National Composite Centre, to further develop software simulation tools developed within CIMComp.

The DefGen project, originally funded by the CIMComp Centre in 2014, investigated "Defect Generation Mechanisms in Thick and Variable Thickness Composite Parts", resulting in a series of numerical tools for predicting the formation of fibre-path defects in thick composite parts manufactured from prepreg. Further advancements in the EPSRC-funded follow-up project **SIMPROCS** (see figure), improved the computational efficiency of the original tools, enabling prediction of defects in large scale labspecimens in tens of minutes instead of weeks! This latest funding will be used to develop these academic tools into software suitable for industry to use. This 2-year project started in September 2020 and is a good example of how Hub research is benefitting the wider composite sector.



#### **Hub Feasibility Study Ongoing Development**

The low-cost thermoplastic fibre-metal laminate technology, developed by the University of Edinburgh during a previous Hub funded Feasibility project "Manufacturing Thermoplastic Fibre Metal Laminates by the InSitu Polymerisation Route", has now received support from the Offshore Renewable Energy (ORE) Catapult. This technology has great potential in the renewable energy sector and the Hub is pleased to hear that this work is continuing.

https://ore.catapult.org.uk/stories/thermoplastic-fibre-metal-laminates-for-blade-applications/



## More Hub News (2/2)

#### **Hub Welcomes New Industry Partner**

The Hub is pleased to welcome PAC Group, Northern Ireland, as the latest company to join the consortium as an Industrial Partner.

PAC Group is a leading and innovative provider of high quality and specialist electrical and mechanical engineering solutions and applications. Working across a diverse range of industries and sectors, the company's Composites division is renowned for its ability to deliver expert advice and highly specialist solutions for the aerospace, automotive, and composites sectors. This includes the design, manufacture, and installation of automated machinery, manufacturing systems, and high-spec equipment such as carbon composite hot drape preformers.

Specialising in bespoke and innovate design, membership of the Hub will enable PAC Group to develop solutions to support fundamental research activities, whilst adopting processes and technologies to benefit their customer base.

Elwyn Agnew, PAC Group Engineering Director, said: "As an industry leader in composite forming technologies, we're delighted to join the Hub as an industrial partner and we look forward to collaborating with the other members on key R&D projects to help secure the UK's future as a leader in composites manufacturing."

Dr Richard Gravelle, Hub Research & Business Development Manager, said: "We are delighted to welcome PAC Group to the Hub. Their forward-thinking approach to R&D and innovation, and in-depth understanding of automated composites manufacturing processes, will greatly strengthen our activities in this area."

For more information about PAC Group, please visit: <u>www.pacgroup.co.uk</u>



### **2021** Publications (1/3)

Take a look at some of the recent publications produced by Hub members in 2021.

Elkington, M., Almas, E., Ward- Cherrier, B., Pestell, N., Lloyd, J., Ward, C., Lepora, N. **Real Time Defect Detection During Composite Layup via Tactile Shape Sensing** 

Journal of Science and Engineering of Composite Materials, 2021 https://doi.org/10.1515/secm-2021-0001



Image of the TacTip tapping down onto a prepreg ply with wrinkle

Gautam, M., Sivakumar, S., Barnett, A., Barbour, S., Ogin, S.L., Potluri, P.

#### On the Behaviour of Flattened Tubular Biaxial and Tri-axial Braided Composites in Tension

Composite Structures, Volume 261

https://doi.org/10.1016/j. compstruct.2020.113325

#### Harrison, P., Camacho, L. F. G. Deep Draw Induced Wrinkling of Engineering Fabrics

International Journal of Solids and Structures, Volume 212, 2021, Pages 220-236 https://doi.org/10.1016/j. ijsolstr.2020.12.003 Karim, N., Sarker, F., Afroj, S., Zhang, M., Potluri, P., Novoselov, K.S. Sustainable and Multifunctional Composites of Graphene-based Natural Jute Fibres Advanced Sustainable Systems

https://doi.org/10.1002/ adsu.202000228

Matveev, M., J., Endruweit, A., Long, A.C., Iglesias, M.A., Tretyakov, M.V. **Bayesian Inversion Algorithm for Estimating Local Variations in Permeability and Porosity of Reinforcements using Experimental Data** Composites Part A: Applied Science and Manufacturing, Volume 143 https://doi.org/10.1016/j. compositesa.2021.106323



Predicted defect probability

## **2021** Publications (2/3)

Viisainen, J.V., Hosseini, A., Sutcliffe, M.P.F. Experimental Investigation, Using 3D Digital Image Correlation, into the Effect of Component Geometry on the Wrinkling Behaviour and the Wrinkling Mechanisms of a Biaxial NCF During Preforming

Composites Part A: Applied Science and Manufacturing, Volume 142, 2021, 106248 https://doi.org/10.1016/j. compositesa.2020.106248



A quantitative wrinkling and surface strain comparison of representative fabric samples formed over the four punch geometries investigated (hemisphere, double dome, tetrahedron and triangular prism), measured at the end of forming (punch displacement (PD) = 75 mm): a) wrinkle amplitude (aw) surface b) wrinkle area (Aw) surface c) shear angle

#### Yousefi, N., Evans, A. D., Harper, L.T., Maples, H. A., James, T., Bismarck, A. Solid Epoxy Resin Systems for Automated Composite Manufacturing

Composites Part A: Applied Science and Manufacturing, Volume 142, 2021, 106205 https://doi.org/10.1016/j. compositesa.2020.106205 Iglesias, M., Yang, Y. **Adaptive regularisation for ensemble Kalman inversion** Inverse Problems, Volume 37 (2021), Number 2, 025008

Yu, F., Chen, S., Harper, L. T., Warrior, N.A. Simulating the Effect of Fabric Bending Stiffness on the Wrinkling Behaviour of Biaxial Fabrics During Preforming

Composites Part A: Applied Science and Manufacturing, Volume 143, April 2021, 106308 https://doi.org/10.1016/j.compositesa.2021.106308



Experimental wrinkle amplitude for the NCF from Case A measured by SWLS. Corresponding simulated wrinkle amplitudes using (b) Non-linear bending model (NLBM), (c) linear bending model (LBM) using Binit, (d) LBM using the bending stiffness derived from a constant angular deflection of 41.5 according to BS EN ISO 9073-7 and (e) LBM using the asymptote





## **2021** Publications [3/3]

#### Xiao, Z., Harrison, P.

Design of Buckling and Damage Resistant Steered Fibre Composite Laminates using Trellis Shear Kinematics

Composite Structures, Volume 260, 2021, 113526 https://doi.org/10.1016/j.

compstruct.2020.113526



Comparison between (A) a (300mm X 400mm) steered fibre pattern generated by SteerFab and (B) orientations of fibres running from lower left to upper right mapped to one ply within element section and (C) orientations of fibres running from upper left to lower right mapped to another ply within element section



A full list of publications can be found on our website: *cimcomp.ac.uk/publications/* 





# Coming soon

#### Announcement of the Next Round of Hub Feasibility Studies

The call will be announced shortly; please check the CIMComp website for updates:





