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Second Year CDT Students

Short Overviews of Posters

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Sustainable Green concrete with recycled carbon fibre

Meiran Abdo, Eleni Toumpanaki, Andrea Diambra, Valeska Ting, Fabrizio Scarpa, Adam Perriman, Gianni Comandini

Aims: For mitigating the potential environmental pollution of waste carbon fibre, the present study investigates the feasibility of collaborative use of these recycled materials in construction filed, as well as the effect of chopped recycled carbon fibre addition to the concrete mechanical properties after 7 days of curing. For this purpose, several specimens with different volumes (0%, 0.01%, 0.02%, 0.03%,0.04%, and 0.06%) of carbon fibre were examined to show the effect of recycled carbon fibre on the specimens' mechanical properties (compressive strength and splitting tensile strength).

Materials: A recycled carbon fibre length = 6 mm with [Tensile Strength MPa = 3530, Density(kg.m-3) = 1760, and E (GPa)=230], coarse aggregate a crushed stone average size of 3-6 mm , and an Ordinary Portland Cement.

Results

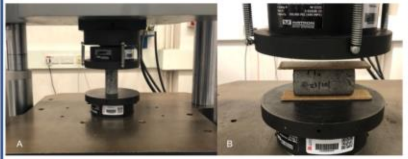

Figure 1: A) compressive strength. B) split tensile strength Test

1. Testing

For analyses simplicity, all specimens in this study were tested in accordance with ASTM C39 and ASTM C496 standards for compressive strength and split tensile strength, respectively see Fig1. The Instron 600DX machine was used for testing all samples , while a Zeiss Microscopy were used to obtain a visual images.

2. Fracture Patterns : Four major fracture patterns have been identified for the compressive strength test of the cylinder concrete at age 7 days. All four fracture patterns were reported based on ASTM C39 standard In Fig 2.

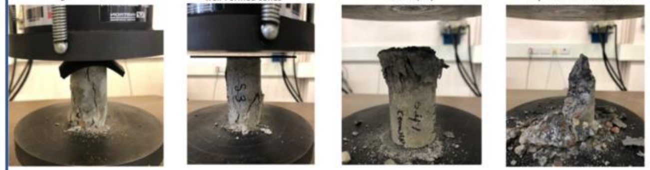

Figure 2: Figure 6 Fracture Pattern types.

Figure 3: Microstructural analysis showing carbon fibre distribution.

3.Microscopy: The microscopy in Figure.3 shows an equally distributed recycled carbon-fibre in concrete matrix; however, an evidence of fibre balling and clumping were reported due to the difficulty of carbon fibre to disperse using a hand mixing concrete method.

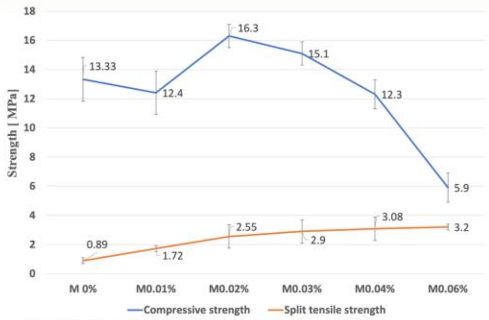

Figure 4: Relationship between compressive and Split Tensile Strength.

Conclusions :

The results in Fig.4 shows that amount the addition of recycled carbon fibre improves the compressive strength of concrete to a certain range, while The addition of recycled carbon fibre in the mixture improves the split tensile strength significantly.

Further developments:

- Introducing a Fibre reinforced polymer composites materials as aggregate replacement.
- Studying the long-term mechanical performance of FRPcrete for structural applications considering different variables.

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TMD and carbon nanocomposites for room temperature superconductivity.

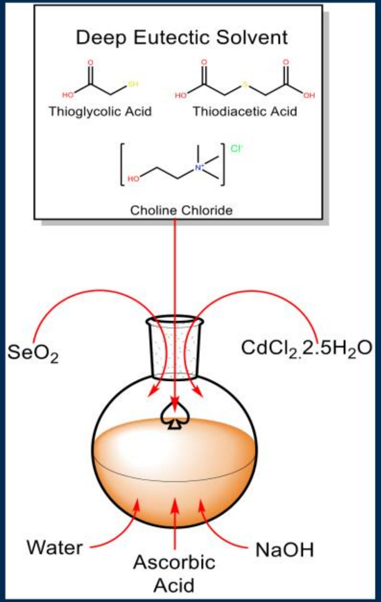
Rikesh Patel, Prof Simon Hall, Prof Steve Eichorn, Dr Chris Bell

Superconductors are materials that, below a critical temperature, exhibit 0 DC resistance and expel an applied magnetic field from within itself. Often, the critical temperature is reached through cryogenic cooling. However, a mechanism of superconductivity, known as excitonic superconductivity, has been hypothesised to allow for room temperature superconductivity, through the compositing of transition metal dichalcogenides and carbon. No excitonic superconductor has yet been realised. This project aims to take the existing theory and make it a reality.

Aims:

- → To synthesise a range of transition metal dichalcogenide nanoparticles in a controllable and reliable way.
- → To encompass these nanoparticles in a carbon shell.
- → Measure for room temperature superconductivity.

Synthesis of CdSe Nanoparticles



The resulting mixture from the synthesis to the left is refluxed at 100 °C.

The time spent refluxing determines the size of the resulting nanoparticles as can be seen from the picture on the right.

Next Steps

- → To synthesise other TMD Nanoparticles
- → To create a carbon shell
- → To determine superconductivity through SQUID Measurements

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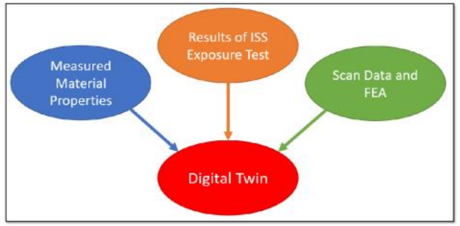
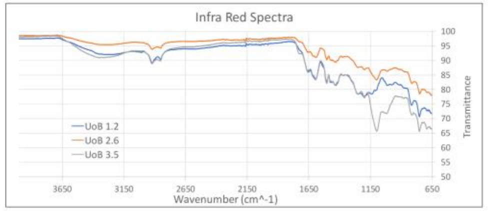
Digital Engineering of Space Composites

George Worden, Ian Bond, Kate Robson-Brown & Ian Hamerton

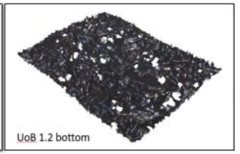
Problem and Aims

- The environment in low Earth orbit (LEO) is very hostile to materials, due to atomic oxygen, micrometeoroids, radiation and other factors.
- Testing materials in space is incredibly costly and time-consuming
- The creation of a "Digital twin" of material components in LEO would provide a method to predict degradation and therefore lifespan.
- A novel benzoxazine based polymer was developed to be resistant to the LEO environment with the addition of POSS nanoparticles.



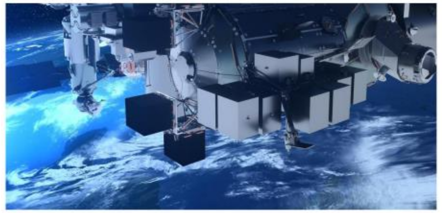



UoB 1.2


UoB 1.2 bottom

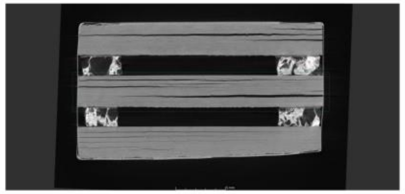
Summer 2021

- Over Summer 2021 a number of techniques were used to begin characterisation of a three composite laminates manufactured with the novel benzoxazine and varying quantities of POSS.
- Optical microscopy was used to produce high-resolution images and roughness measures of the sample surface.
- FTIR was used to characterise the chemical bonds/composition at the surface of the samples.
- DSC was used to characterise the thermal properties
- Surface properties are particularly important as that is the area that will be attacked by AO in LEO.



ISS Mission

- A number of samples of the original material will be sent to the ISS and exposed to space from the Bartolomeo platform.
- After 6 months of exposure they will be returned to Earth and the exposure data used to validate the model.



Current Work

- Development of an improved material composition to alleviate some of the issues of the first.
- Manufacture of large laminates that can be used for a wide range of mechanical/thermal tests.
- Creation of a framework for the digital twin, using CT scan data

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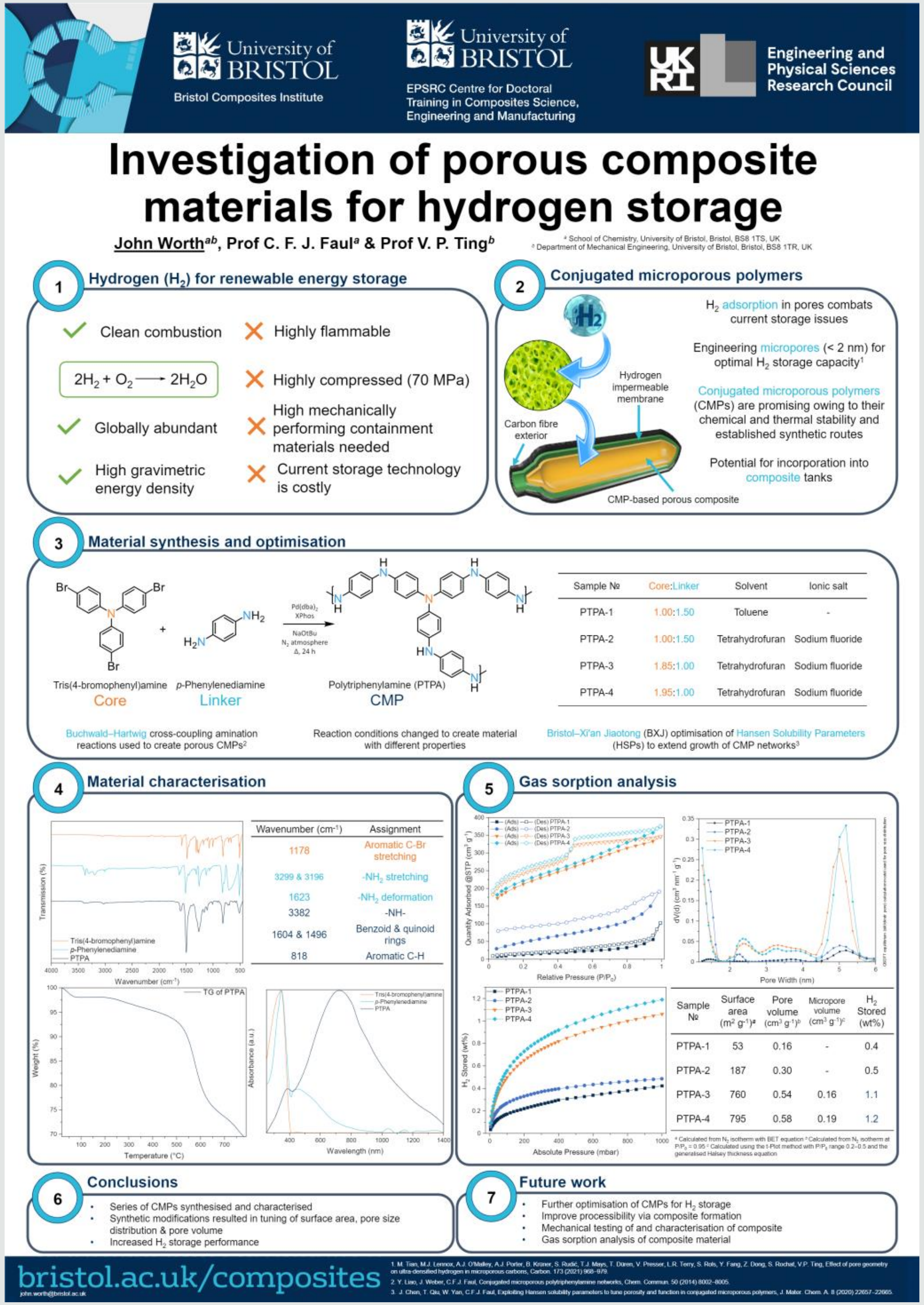
This was carried out with additional support from Mayra Rivera Lopez, Joseph Gargiuli, Yusuf Mahadik, and the BCI lab support team.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Investigation of porous composite materials for hydrogen storage
John Worth[ab], Prof C. F. J. Faul[a] & Prof V. P. Ting[b]
[a] School of Chemistry, University of Bristol, Bristol, BS8 1TS, UK
[b] Department of Mechanical Engineering, University of Bristol, Bristol, BS8 1TR, UK
1 Hydrogen (H_2) for renewable energy storage
Clean combustion
Highly flammable
$2H_2 + O_2 \longrightarrow 2H_2O$
Highly compressed (70 MPa)
Globally abundant
High mechanically performing containment materials needed
High gravimetric energy density
Current storage technology is costly
2 Conjugated microporous polymers
H_2 adsorption in pores combats current storage issues
Engineering micropores (< 2 nm) for optimal H_2 storage capacity[1]
Conjugated microporous polymers (CMPs) are promising owing to their chemical and thermal stability and established synthetic routes
Potential for incorporation into composite tanks
Hydrogen impermeable membrane
Carbon fibre exterior
CMP-based porous composite
3 Material synthesis and optimisation
Tris(4-bromophenyl)amine
Core
p-Phenylenediamine
Linker
Polytriphenylamine (PTPA)
CMP
Sample № | Core:Linker | Solvent | Ionic salt
PTPA-1 | 1.00:1.50 | Toluene | -
PTPA-2 | 1.00:1.50 | Tetrahydrofuran | Sodium fluoride
PTPA-3 | 1.85:1.00 | Tetrahydrofuran | Sodium fluoride
PTPA-4 | 1.95:1.00 | Tetrahydrofuran | Sodium fluoride
Buchwald–Hartwig cross-coupling amination reactions used to create porous CMPs[2]
Reaction conditions changed to create material with different properties
Bristol–Xi'an Jiaotong (BXJ) optimisation of Hansen Solubility Parameters (HSPs) to extend growth of CMP networks[3]
4 Material characterisation
Wavenumber (cm⁻¹) | Assignment
1178 | Aromatic C-Br stretching
3299 & 3196 | -NH2 stretching
1623 | -NH2 deformation
3382 | -NH-
1604 & 1496 | Benzoid & quinoid rings
818 | Aromatic C-H
Wavenumber (cm⁻¹)
Temperature (°C)
Wavelength (nm)
5 Gas sorption analysis
Relative Pressure (P/P0)
Pore Width (nm)
Absolute Pressure (mbar)
Sample № | Surface area ($m^2 g^{-1}$) | Pore volume ($cm^3 g^{-1}$) | Micropore volume ($cm^3 g^{-1}$) | H_2 Stored (wt%)
PTPA-1 | 53 | 0.16 | - | 0.4
PTPA-2 | 187 | 0.30 | - | 0.5
PTPA-3 | 760 | 0.54 | 0.16 | 1.1
PTPA-4 | 795 | 0.58 | 0.19 | 1.2
6 Conclusions
Series of CMPs synthesised and characterised
Synthetic modifications resulted in tuning of surface area, pore size distribution & pore volume
Increased H_2 storage performance
7 Future work
Further optimisation of CMPs for H_2 storage
Improve processibility via composite formation
Mechanical testing of and characterisation of composite
Gas sorption analysis of composite material
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Compliant fairing for folding wingtips on commercial airliners

Student: Nuhaadh Mahid

Supervisors: Dr Benjamin Woods, Dr Mark Schenk, Dr Branislav Titurus

1. Folding wingtips – why?

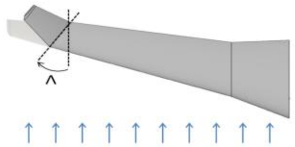
- Increase wingspan while fitting within current airport gate sizes
- Alleviate gust load to minimize structural penalty of increased span

But why?

- To minimize fuel costs and emissions

1a. Minimize gust load – how?

High flare angle (Λ), low torsional stiffness and damping of the hinge, along with low wingtip mass has been shown to alleviate gust load [1]



Schematic of a starboard wing with a flared wingtip [1].

2. A morphing fairing – why?

- To protect the hinge from debris, particularly during take-off and landing
- To avoid the excessive vortices generated by an exposed hinge which is not aligned with the flow

Wing-tunnel model of a folding wingtip with flared hinge [2].

4. Conclusions

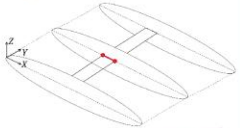
A compliant fairing using stiffness-tailored sandwich panel with cellular core and elastomeric skin has potential to achieve:

- Robust cross-section shape for aerodynamic surface
- Reduced folding stiffness

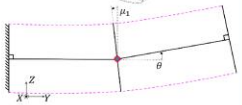
3. Compliant fairing: challenges and solutions

High strain across the hinge due to folding

➢ Minimize strain via pivoted ribs to redistribute the strain over a longer length of skin



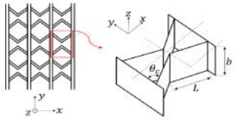
Isometric view of the pivoted inner-rib design. Folding hinge and the hinge of the rib are co-located.



Rear view with folding angle (θ) and rib rotation angle (μ).

Distortion of cross-section due to:

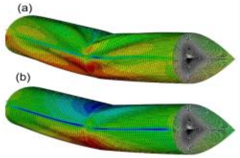
- Bending of skin under pressure load
    - ➢ High out-of-plane stiffness via sandwich panel with fibre-reinforced elastomeric facesheets away from mid-plane
- Poisson's ratio effects along the hinge
    - ➢ Near-zero Poisson's ratio via anisotropic cellular core and fibre-reinforced elastomeric facesheet [3]



Ribs make the core stiff along y-axis and bending of chevron walls gives flexibility along x-axis.

Wrinkling on the skin as wingtip folds

➢ Spatially varying stiffness, using curvilinear fibres on the facesheet along with varying rib direction in the core



Finite element simulation of (a) a highly wrinkled skin, and (b) a skin with reduced wrinkling.

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[1] A Castrichini, "Parametric Assessment of a Folding Wing-Tip Device for Aircraft Loads Alleviation," PhD Thesis, University of Bristol, 2017

[2] RCM Cheung, D Rezgui, JE Cooper, and T Wilson, "Testing of a Hinged Wingtip Device for Gust Loads Alleviation," Journal of Aircraft, vol. 55(5), 2018

[3] EA Bubert, BKS Woods, K Lee, CS Kothera, and NM Wereley, "Design and Fabrication of a Passive 1D Morphing Aircraft Skin," Journal of Intelligent Material Systems and Structures, vol. 21(17), 2010

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Intelligent composites forming: simulations for faster, higher quality manufacture

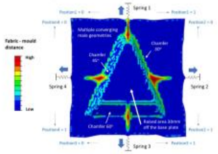
Siyuan Chen, Adam Thompson, Tim Dodwell (Exeter University), Stephen Hallett and Jonathan Belnoue

Composites are becoming increasingly important for light-weight solutions in the transport and energy sectors. In the field of composites manufacture, resin transform moulding (RTM) is a cheaper alternative to traditional manufacturing method. Before resin infusion, the fabric is to be formed into shape, however, the quality of forming is a highly sensitive to wrinkles and bridging. These defects must be eliminated by optimising the forming parameters such as pressure, tensile forces or the geometry of the tooling. Simulation is a good way to understand and achieve this process. Current BCI's forming process simulation tool can make high quality predictions but have long run times. On the other hand, we need large batches of simulations to find the forming conditions that minimize defects.

The project aims at exploring a new framework for the efficient optimisation of the processing conditions in the dry fibre forming process. This is achieved by building a Gaussian Process (GP) emulator that is trained from finite element (FE) simulation data. Longer term, a fully autonomous forming rig that allows defect mitigation by automatic adaptation of the process based on in-situ measurements and predictions from the GP will be built.

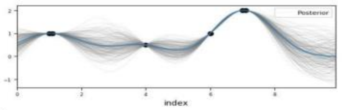
FE simulations

- Industrial inspired mould geometry.
- Double-diaphragm forming
- Springs connected to fabric on each side to provide tensile forces. The springs stiffness and position can be varied through Python scripting facilitating the study of the effect of different process conditions.

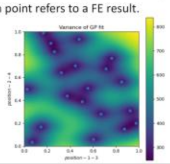


Gaussian Process (GP) emulator

- A **machine learning method**.
- Allows almost **immediate** prediction.
- Only needs a few data points to make accurate predictions.
- Also provides **uncertainty quantification.**
- An example of a 2-dimensional GP variance (reflects the uncertainty predicted by GP) for the forming case described in the "FE simulations" box is given on the right hand-side of the present section.

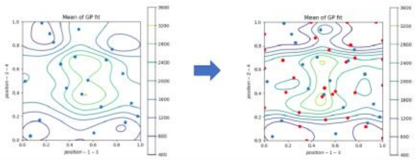


- **Inputs**: Positions of springs 1 & 3, and 2 & 4 respectively. The spring positions are coupled by pairs.
- **Output**: Sum of the distances between the fabric nodes and the mould surface (characterises defect severity).
- **Initial training batch**: 20 data points generated by Latin hypercubic sampling.
- Each point refers to a FE result.



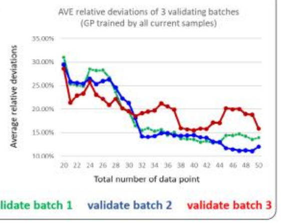
Sequential design (SD)

Iterative addition of supplementary data points (in red on the figure on the right), to improve model predictive capabilities.



Validation of the GP

- Three validation batches of 10 data points each.
- Sequential design significantly improves the GP's predictive capabilities.



Long-term ambition:

- A fully autonomous forming rig that allows zero-defect forming of dry textiles will be built.
- This will be made possible by "on the fly" adaptation of the manufacturing conditions based on in-situ sensing and real-time optimisation using the GP presented here.

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Acknowledgement: this project is funded by the China Scholarship Council, the University of Bristol and the EPSRC via the CoSEM CDT.

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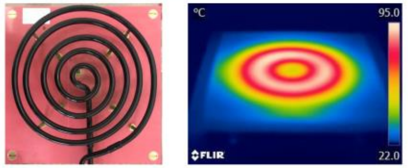
Modelling inductive heating for optimised composite processing

James Uzzell, Dmitry Ivanov, Laura Pickard and Ian Hamerton

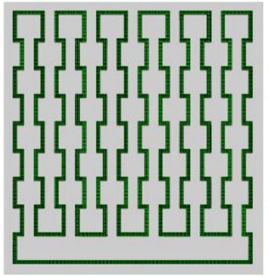
An iterative design process has been used to optimise the design of an inductive coil to improve the efficiency and in-plane uniformity of induction heating for carbon fibre reinforced composites.

Heating via induction is highly energy efficient due to the direct volumetric heating produced in the conductive regions of the specimen. Standard pancake induction coils used for metallic processing produce nonuniform, ring shaped, heating patterns. To account for this, a new coil geometry has been designed for the inductive heating of composites to directly account for their lower electrical and thermal conductivity compared to metals. Numerical modelling has been used to model Joule heating and thermal propagation. Ferritic flux concentrators and a metallic liner were modelled to understand their effect on both the in plane uniformity and heating efficiency. It is hypothesized that the use of ferritic flux concentrators along with a metallic liner attached to the coil will improve the in plane uniformity and heating efficiency in finite element models.

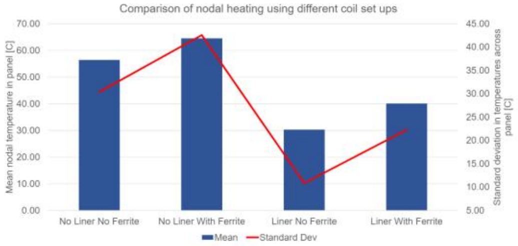
In all models, the addition of the ferritic flux concentrator significantly increased the heating efficiency however this impacted the uniformity of the heating. Conversely, the metallic liner improved the uniformity at the cost of efficiency. In-plane uniformity has been regarded as the most important factor in judging a successful induction coil so a design involving a coil and liner set up has been proposed.



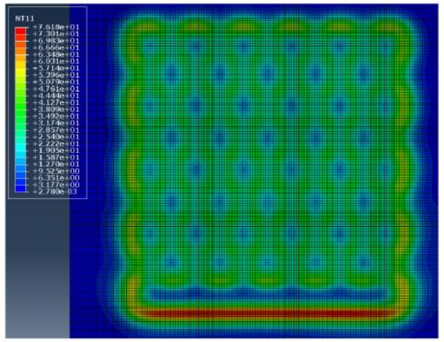
Above: (Left) Photograph showing standard pancake coil design used for metallic processing. (Right) Thermal image showing the ring shaped heating pattern produced using the pancake coil.



Above: Complex coil geometry involving square cells in a 6x4 design. An iterative process was used to compare the individual cell size and shape as well as the total number of cells and their layout.
Below: Thermal results for a QI panel heated using the coil geometry shown above along with a metallic liner.



Above: Comparison of average nodal temperature and standard deviation across a QI panel heated using coils with differing set ups.
Ferrite impact: Average temperature of the panel increased by 10 degrees with standard deviation also increasing by 15 degrees on average.
Metallic liner impact: Average temperature decreased by 25 degrees with standard deviation also decreasing by 20 degrees.



The optimised coil geometry uses a wide coil geometry along with a metallic liner, shown to help widen the flux path. This has been found to be superior to the conventional pancake coil in terms of in plane uniformity when heating composites due to their lower thermal and electrical conductivity.

The future of this work is to validate these modelling results before manufacturing a coil capable of composite processing in application such as rapid cure and in-situ repair.

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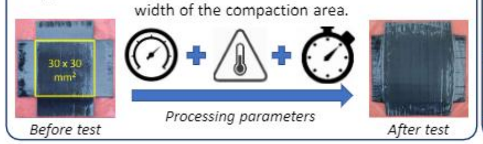
Influence of AFP processing parameters on the consolidation of out-of-autoclave prepreg

Axel Wowogno, Iryna Tretiak, Stephen R. Hallett and James Kratz

Autoclave curing, one of the commonly used manufacturing processes for composites, creates a bottleneck in the production workflow despite its effectiveness for part consolidation. This reveals the need for a novel curing technology that would remove the need for an additional curing step after the material deposition. Making use of the Automated Fibre Placement (AFP) process, an online out-of-autoclave (OOA) Layer-By-Layer (LBL) consolidation approach has been developed for component creation [1]. In order to fully comprehend the impact of the main process parameters, this study aims to assess the selected material's behaviour.

Study's goal

Analyse the material behaviour, by exposing prepared samples to various pressure magnitudes, temperatures and pressure application times, and by monitoring the thickness and the width of the compaction area.



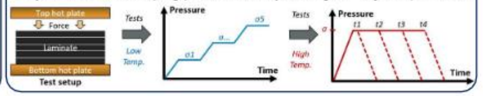
Materials and Methods

Material : OOA Prepreg - Carbon Fibre / Epoxy (IM7/M56)

HexTow® IM7 Carbon Fiber + HexPly® M56

Method : Compaction test, using custom made heating plates, mounted onto a universal Instron testing machine.

***Step 1** : Low T° & varying pressure / **Step 2** : High T° & fixed pressure*



Procedures

Laminate preparation : Cruciform layup of unidirectional 30 x 50 x 0.25 mm plies. 2mm thick samples were made (8 plies).

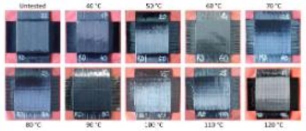
Test setup : Unrestrained and on release film, the samples were centered on the heating plates (same temperature for top and bottom for each test).

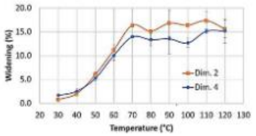
Program 1 : "Ramp & Dwell" method
This method executes a fast application of load followed by long creep intervals, while incrementally covering a range of pressures commonly seen in the AFP conditions. Test temperatures vary from 30 to 120 °C (with 10°C increments), with a fixed length of time (20 min). This allows to assess the temperature's effect.

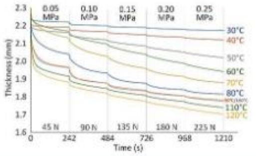
Program 2 : "Hold" method
This method is performed with a fixed pressure (chosen from previous results), for short amounts of time (1, 2.5, 5, 10s), at test temperatures varying from 120 to 210°C (30°C increments). This allows to assess both time & temperature's effects.

Results - Program 1

Figures below show how the compaction area expands with temperature, that its widening stagnates after 70°C and that the samples' thickness didn't greatly vary after application of 0.1MPa. This makes them the minimum compaction values.

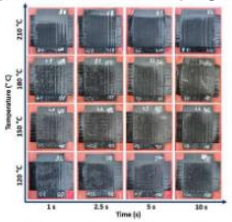


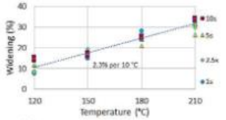


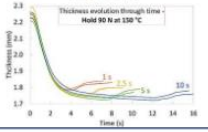


Results - Program 2

From previous results, 0.1 MPa was here chosen as fixed pressure value. Figures show the compaction area's evolution, its widening rate (2.3% per 10°C). Thickness analysis reveals a noticeable springback.







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[1] A. Skordos and J. Kratz, "Layer by layer curing (LbL) - Feasibility Study Final Report," 2018.

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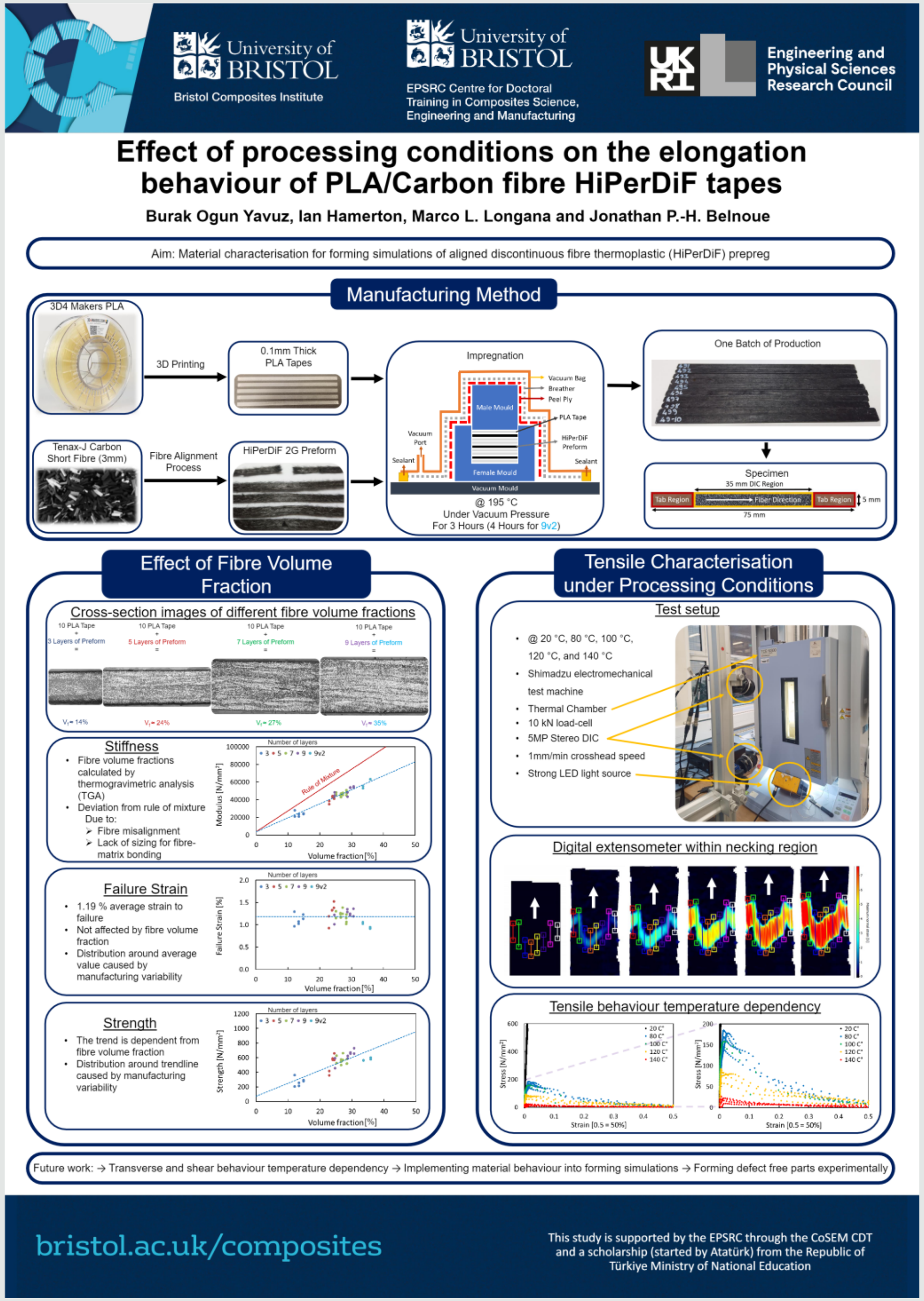
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EPSRC Centre for Doctoral Training in Composites Science, Engineering and Manufacturing
UKRI Engineering and Physical Sciences Research Council
Effect of processing conditions on the elongation behaviour of PLA/Carbon fibre HiPerDiF tapes
Burak Ogun Yavuz, Ian Hamerton, Marco L. Longana and Jonathan P.-H. Belnoue
Aim: Material characterisation for forming simulations of aligned discontinuous fibre thermoplastic (HiPerDiF) prepreg
Manufacturing Method
3D4 Makers PLA
3D Printing
0.1mm Thick PLA Tapes
Tenax-J Carbon Short Fibre (3mm)
Fibre Alignment Process
HiPerDiF 2G Preform
Impregnation
@ 195 °C
Under Vacuum Pressure
For 3 Hours (4 Hours for 9v2)
One Batch of Production
Specimen
Effect of Fibre Volume Fraction
Cross-section images of different fibre volume fractions
Stiffness
Fibre volume fractions calculated by thermogravimetric analysis (TGA)
Deviation from rule of mixture Due to:
Fibre misalignment
Lack of sizing for fibre-matrix bonding
Failure Strain
1.19 % average strain to failure
Not affected by fibre volume fraction
Distribution around average value caused by manufacturing variability
Strength
The trend is dependent from fibre volume fraction
Distribution around trendline caused by manufacturing variability
Volume fraction [%]
Tensile Characterisation under Processing Conditions
Test setup
@ 20 °C, 80 °C, 100 °C, 120 °C, and 140 °C
Shimadzu electromechanical test machine
Thermal Chamber
10 kN load-cell
5MP Stereo DIC
1mm/min crosshead speed
Strong LED light source
Digital extensometer within necking region
Tensile behaviour temperature dependency
Future work: → Transverse and shear behaviour temperature dependency → Implementing material behaviour into forming simulations → Forming defect free parts experimentally
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This study is supported by the EPSRC through the CoSEM CDT and a scholarship (started by Atatürk) from the Republic of Türkiye Ministry of National Education