Quickfire Presentations
2-minute-2-slide
Second and third year CDT students

bristol.ac.uk/composites
Running Order

Materials
• Active thermal management via embedded vascular networks – Jim Cole
• Durability of composite materials in deployable space structures – Desmond He
• Utilizing pulsed DC plasma-assisted chemical vapor deposition for nanodiamond diamond polymer composite construction – Dominic Palubiski
• Industrial scale nano-reinforced composite structures – Robert Worboys

Structures
• Local actuation of tubular origami – Steven Grey
• Advanced shell model for 3D stress field analysis – Aewis Hii
• WrapToR composite truss structures – Chris Hunt
• Aeroelastic tailoring of wind turbines through multi-disciplinary optimisation – Sam Scott

Manufacturing & Design
• New experiments for in-plane shear characterisation of uncured prepreg – Yi Wang
Active thermal management via embedded vascular networks

Jim Cole

Ian Bond, Andrew Lawrie

bristol.ac.uk/composites
Problem

- Polymer matrix limits operating temperature due to glass transition temperature, $T_g$
- Significant performance reductions
- Thermo-oxidative ageing
- Typically 100°C to 150°C for aerospace epoxy
- Emerging applications expose composites to higher temperatures:
  - Turbo-machinery
  - Battery containment
  - Hypersonic aircraft


https://boomsupersonic.com/

Active thermal management via embedded vascular networks
Solution

- **Circulate fluid** through small passages (vascules) inside the laminate (analogous to blood vessels)
- **Maintain matrix below** $T_g$ **to retain performance, extend service life**
- **Simple network** in SE70/Carbon QI layup, compressed air coolant
- **Tested in heated airflow**: 80°C, 3ms⁻¹
- **Surface temperature** recorded at various flow rates
- **Average reductions of** 5°C at 10Lmin⁻¹
Durability of composite materials in deployable space structures

Desmond He, Alex Brinkmeyer, Mark Schenk, Ian Hamerton

bristol.ac.uk/composites
Composites in Low Earth Orbit (LEO)

Composites in LEO:

• Most hazardous factor: atomic oxygen (AO)
• Both fibre and epoxy will react with AO
• The erosion can lead to loss of structural mass and mechanical properties

In this work:

• Commercial composite materials were used
• Exposed under ground based AO facility
• Characterization after exposure to access its longevity

Reaction mechanism of AO and epoxy
Composite after AO exposure

Results summary:
• Laminates have suffered significant reduction in mechanical properties after exposure
• Both resin and fibres are eroded after exposure
• FTIR data show chemical difference in matrix after exposure

Future work:
• Improve the AO resistance of the matrix in other composite materials
Composite after AO exposure

Results summary:
• Laminates have suffered significant reduction in mechanical properties after exposure
• Both resin and fibres are eroded after exposure
• FTIR data show chemical difference in matrix after exposure

Future work:
• Improve the AO resistance of the matrix in other composite materials
Composite after AO exposure

Results summary:
• Laminates have suffered significant reduction in mechanical properties after exposure
• Both resin and fibres are eroded after exposure
• FTIR data show chemical difference in matrix after exposure

Future work:
• Improve the AO resistance of the matrix in other composite materials
Utilizing pulsed DC plasma-assisted chemical vapor deposition for nanodiamond diamond polymer composite construction

D. R. Palubiski, F. Scarpa, N. Fox
The Old & The New

(a) **Top-down**

**ND of Static Synthesis**
High Pressure High Temperature (HPHT) Nanodiamond

Microdiamond

\[ 7-10 \text{GPa}, 1500-2200^\circ \text{C}, \]
Catalyst (Fe, Ni)

Smallest: 10-20nm

(substitutional N 100-200ppm)

(b) **Bottom-up**

**ND of Dynamic Synthesis**
Detonation Nanodiamond (DND)

\(5\text{nm}\)

Up to 500nm

(Nitrogen: up to 10,000ppm
Optically inactive conglomerates)

The Old & The New

Nanodiamond
The Next Step

- Thermoset Polymers
  - Prime 20
  - Hexcel® RTM-6

- Thermoplastic Polymers
  - Nylon
  - PEEK

Industrial scale nano-reinforced composite structures

Robert Worboys

Ian Hamerton, Stephen Hallett, Rob Backhouse, Luiz Kawashita

bristol.ac.uk/composites
Commercially available nano-reinforced composites

*Discrete Interlayer Reinforcement*

*Homogeneous Reinforcement*

Image captured using the SEM facilities at N12 Technologies in Boston, MA.

Image captured using the SEM facilities at Wolfson Bioimaging in Bristol, UK.
Material characterisation and design opportunities

Experimental Fractography

Unreinforced laminate
Initial failure location

Controllable Failure

VACNT reinforced interfaces
Initial failure location driven towards surface

Nano-reinforced composites
Local actuation of tubular origami

Steven Grey, Fabrizio Scarpa, Mark Schenk
Methods

- Miura-ori Pattern – 1DoF

- Bending between the folds causes decay of actuation

- Investigated using:
  - FEA (above)
  - Experimental laser scanning (right)
Results

- FEA (dashed) to Experimental (solid) comparison
- Both have elastic decay and a ‘spring-back’
- FEA model can be used to show effect of elastic stiffness
- Target: Design guidelines for embedded actuators in origami
Advanced shell model for 3D stress field analysis

Aewis Hii

Sergio Minera, Rainer Groh, Alberto Pirrera, Luiz Kawashita

bristol.ac.uk/composites
Overview

Challenge:

*High computational costs* in the 3D analysis of composite shell structures.

Our work:

Improve numerical efficiency for industrial applications

Requirements:
- Accurate transverse stress field
- Discontinuity

Solid finite elements → Shell finite elements

Advanced shell model for 3D stress field analysis
Progress and future work

Static 3D stress field

Other developments:
- Nonlinear static
- Nonlinear transient dynamic (explicit)

On-going works:
- Delamination analysis
- Increase explicit timestep

Advanced shell model for 3D stress field analysis
WrapToR composite truss structures

Chris Hunt, Michael Wisnom, Benjamin Woods

bristol.ac.uk/composites
**Wrapped Tow Reinforced Truss**

- Novel manufacturing process
  - Modified filament winding
  - Automatable
  - Low-cost constituents

- Truss geometry with all fibres in element loading direction
  - Extremely efficient

- Low-cost manufacturing process

**WrapToR composite truss structures**
Work so far

- Winding machine design and build
- Truss testing

Future work

Analysis
- Develop ability to predict structural response
- Focus on strength

Concept scaling
- Going bigger!

Optimisation
- Use analysis tools to optimise truss geometry

Further testing
- Verification of analysis
- Variety of loading conditions
Aeroelastic tailoring of wind turbines through multi-disciplinary optimisation

Samuel Scott - ss1870@bristol.ac.uk

Supervisors: Terence Macquart, Alberto Pirrera, Peter Greaves (OREC)
Background and Project Aim

• Aeroelastic Tailoring: Exploiting interactions between aerodynamic/inertial loading and deflections

• Bend-twist coupling offers load alleviation

• Multidisciplinary optimisation appropriate for navigating complex design spaces

Project Aim
Develop and apply an optimisation framework capable of evaluating the benefits of aeroelastic tailoring for cost of energy
XP (complete)
- Optimisation framework
  - Parameterisation of real blade for optimisation
  - Preliminary application of sub-optimisation routines

PhD (in progress)
- Model Setup (current)
  - Aerodynamic modelling of curved blades
  - Efficient structural feasibility assessment
- Optimisation setup (future)
  - Implement optimisation framework
  - Investigate alternative optimisation architectures
- Design and Optimise (future)
  - Evaluate benefits of aeroelastic tailoring on cost of wind energy
New experiments for in-plane shear characterisation of uncured prepreg

Yi Wang, Dmitry Ivanov, Jonathan Belnoue, James Kratz, BC Eric Kim, Stephen Hallett
Research idea

Defects generation

- **How to deal with problems?**
  - Trial and errors
    - Based on experience and trials
    - Very expensive (time & money)
  - Process modelling and simulation
    - Based on process physics and calculations
    - Cost effective

- Defects generation related to:
  - In-plane behaviour (**shear**, bending)
  - Out of plane behaviour (tackiness, friction)

 AFP machine

Deposition defects

New experiments for in-plane shear characterisation of uncured prepreg
Test method & Results

• Test method
  • 10° off-axis tensile test
  • Shear strain-DIC & shear stress-local stress state
  • Cover the real AFP deposition parameters
  • Study on thermoset prepregs-IM7/8552

• Test results

• Future work
  • Finish the in-plane shear tests and propose a description numerical model
  • Investigate on other properties and propose an overall deposition model