2-Minute-2-Slide Quick-Fire Project Introductions

Second and Third Year CDT Students
Running Order

- **Behjat Ansari**  Patient specific hip implants
- **Aewis Hii**  Numerically efficient dynamic models for early design and analysis of thick composite laminates
- **Vincent Maes**  Design of a small scale bend-twist coupled wind-turbine blade demonstrator
- **Tamas Rev**  Unidirectional hybrid composite sensors: robust tools for visual overload indication
- **Robert Worboys**  Industrial scale nano-reinforced composite structure: controlling delamination through vertically aligned carbon nanotubes
- **Andres Rivero**  Analytical modelling of the Fish Bone Active Camber (FishBAC) concept
- **Lourens Blok**  Development of improved fibre reinforced feedstocks for high performance 3D printing
- **Arjun Radhakrishnan**  Additive manufacturing of multifunctional GFRP composites
- **Bethany Russell**  Novel matrix for GFRP wind turbine blades
- **Rhys Tapper**  Development of a closed-loop recycling method for aligned, short carbon fibre composites
Patient Specific Hip Implants

Behjat Ansari

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Kate Robson Brown*, Richard Trask+, Mark Schenk, Nic Roberts

*Department of Archaeology and Anthropology (University of Bristol)
+Department of Mechanical Engineering (University of Bath)
Background and Objectives

• **Challenge**
  - Improving implant and bone integration to increase durability of hip implants
  - Reducing damage to bone cells during surgery
  - Reducing material wastage

• **Solution** – bespoke hip implants

• **Aim** – determining feasibility of solution
Methodology and Results

- **Trabecular Characterisation of acetabular micro-architecture:**
  - % bone volume
  - Trabecular thickness
  - Trabecular separation
  - Degree of anisotropy

- **FEA of the hip bone in mid stance:**

- **Future work**
  - Additive manufacturing, porous hydroxyapatite and tantalum scaffolds, structural optimisation methods
Numerically Efficient Dynamic Models for Early Design and Analysis of Thick Composite Laminates

Aewis Hii

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Luiz Kawashita, Alberto Pirrera, Stephen Hallet

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What? Why? How?

What?
- Develop efficient numerical models for dynamic structural analysis of thick laminates with complex geometry.

Why?
- Current FEM tool => High computational cost.
- Large and thick laminate parts => Need more optimisation?

How?
- Refined 1D beam model, based on Carrera Unified Formulation (CUF-FE).
- Variable order of polynomial expansion on the cross sections.
Methodology

Schematic description of CUF-FE

1D-beam model

Polynomial expansions

Example: Pinched C-beam

CUF-FE: 8,874 DoFs
Conventional FE: 352,742 DoFs
Design of a Small Scale Bend-Twist Coupled Wind-Turbine Blade Demonstrator

Vincent Maes, Dr. Terence Macquart, Prof. Paul Weaver, Dr. Alberto Pirrera

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Why?

- **Wind-Turbines:**
  - Trend for bigger:
    - + Cost of Energy
    - - Gust & Fatigue
    - - Load Alleviation
  - Previous work:
    - Limited demonstrators
    - Limited test data

McKenna et al. (2016)
Current

**Design**
New design rules to utilise & control *anisotropy* effects.

**Analysis**
Higher fidelity models with adjustments for *dрапинг*.

Future

**Manufacturing**
Monitor and study secondary effects (e.g. *thermal warping*).

**Testing**
Develop testing approach to extract *BTC coefficients*.
Unidirectional Hybrid Composite Sensors: Robust tools for visual overload indication

Bristol, 11/04/2017

Tamas Rev
Prof. Michael R. Wisnom
Dr Gergely Czél, Dr Meisam Jalalvand

HiPerDuCT
Programme Grant

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Introduction and background

- Little detectable damage/warning
- Preventing catastrophic failure
- Need for NDT → repair/maintenance
- No unexpected down-time, longer service life

Before overload

After overload

Thin interlayer glass/carbon hybrid composites
Change of appearance
Interfacial damage

Single fracture followed by sudden, unstable delamination

Fragmentation followed by gradual, dispersed delamination

[Czél et al. 2016]
Design and application

- Sensor geometry (length, width)
- Sensor/substrate stiffness ratio
  - Varying thicknesses
- Integration of sensors
  - Co-curing/Retrofitting
    - Various bonding methods
- Two distinct dimensions of sensing:
  - Magnitude of strain (use of different sensing materials)
  - Direction of a given overload strain

EN14781 Standard load: 1000 N

Applied load: 2700 N
Damage visualised at: 1750 N
Industrial Scale Nano-reinforced Composite Structure: Controlling Delamination Through Vertically Aligned Carbon Nanotubes

Rob Worboys, Luiz Kawashita, Stephen Hallett, Ian Hamerton, Rob Backhouse

Supported by Rolls-Royce
Increased interlaminar toughness
- Loss in global in-plane stiffness and strength
- Lower fatigue performance

Mode I Fracture Toughness

Abaqus© cohesive element model for the unreinforced test

Vertically Aligned CNT Interlayer Reinforcement

Relative $G_{IC}$
- VACNT - 1.25
- Resin - 1.15
- UR - 1.09

Stiffness Degradation (SDEG)

Crack Length

Opening Load / Load

Opening Displacement [mm]
Analytical Modelling of the Fish Bone Active Camber (FishBAC) Concept

Andrés E. Rivero

P.M. Weaver, J.E. Cooper and B.K.S. Woods

6th Annual Conference of the EPSRC Centre for Doctoral Training in Advanced Composites for Innovation and Science
Bristol, UK, 11th April 2017

www.bris.ac.uk/composites
Concept & Previous Work

FishBAC Concept

Features of Interest

- Changes in chordwise stiffness
- Spanwise displacement variations
- Asymmetric actuation inputs
- Use of composite laminates

Previous Work

1D Euler-Bernoulli Beam

Developed Model

2D Kirchhoff-Love Plate

A.E. Rivero
Results & Future Work

- **2-dimensional Displacement Fields**

- **Percentage errors out-of-plane displacement w.r.t. FEM**
  - < 3 % under uniform transverse pressure
  - <10% under non-uniform actuation loads

- **<15% DOF (compared to converged FEM)**

**Future Work**

- Coupling aerodynamic loads (Fluid-Structure Interaction)
- Optimisation
- Prototyping and wind tunnel testing
Development of Improved Fibre Reinforced Feedstocks for High Performance 3D Printing

Lourens Blok, Ben Woods, Kevin Potter, HaNa Yu, Marco Longana
3D printing feedstock

Additive manufacturing (AM) approach for composite laminates

- Build up part layer-by-layer, no need for autoclave or large press
- Fibres pre-embedded in thermoplastic filament

**Printing of microfibres**
- Stiffness: 14 GPa
- Strength: 65 Mpa
- Fibre volume content ~20%

[Ning et al.] [Tekinalp et al.]

**Printing of continuous fibres**
- Stiffness: 50 GPa
- Strength: 700 MPa
- Fibre volume content ~25%

[Anisoprint]
Improved 3D printing feedstock

Thermoplastic filament with discontinuous fibres above the critical fibre length

- Allows for full strength of fibre to be reached

[Such et al., 2014]
Improved 3D printing feedstock

Thermoplastic filament with discontinuous fibres above the critical fibre length
- Allows for full strength of fibre to be reached

High Performance Discontinuous Fibre method to pre-align dry fibres before filament forming
- Improve fibre flow dynamics during printing and obtain higher $V_f$

Strength: 1509MPa
Stiffness: 115GPa
($V_f = 55\%$)

[Yu et al., 2014]
Improved 3D printing feedstock

Thermoplastic filament with discontinuous fibres above the critical fibre length
- Allows for full strength of fibre to be reached

High Performance Discontinuous Fibre method to pre-align dry fibres before filament forming
- Improve fibre flow dynamics during printing and obtain higher $V_f$
Additive Manufacturing of Multifunctional GFRP Composites

Arjun Radhakrishnan, Ian Hamerton*, Milo Shaffer+, Dmitry Ivanov*

+ Imperial College London

www.bris.ac.uk/composites
Motivation & Background

High Carbon nanotubes (CNT) content -> Improves mechanical and functional properties

**BUT...**

Use of higher content in Liquid Composite Moulding is limited by:

- Filtration of particles  ->  Non-uniform distribution
- High viscosity of enhanced resin  ->  Poor processability

### Processing of Patterned Composites

1. **Heterogeneous solution** (powder – liquid)
   - Solid epoxy encapsulation
   - Liquid epoxy
   - CNT agglomerates
   - Before cure
   - Lower the viscosity by controlling particle size.

2. **Liquid Resin Printing**
   - Localised introduction of matrix into a preform.
   - Force
   - Syringe
   - Solution
   - Needle
   - Preform
   - Injected solution

3. **Consolidation**

4. **Resin infusion of patched preform**
Current Development

Characterisation

**Patch Morphology**
- Infused region
- Graded interface
- Flow/filtration
- Patched region

**Conductivity map**
- Through thickness electrical conductivity (S/m)
- Distance from injection site

**Open hole tension test**
- Graded CNT-patched composite
- Reference

**Key Points**
1. Higher CNT loadings of up to 3.5 wt%.
2. Controlled grading of composite properties.
3. Localised improvement of mechanical and functional properties.

Increase of 17% and 24% of strain-to-failure and strength respectively.

Patch morphology can be controlled via the consolidation parameters.
Novel Matrix for GFRP Wind Turbine Blades

Beth Russell
beth.russell@bristol.ac.uk

Ian Hamerton, Carwyn Ward and Shinji Takeda*

* Hitachi Chemical Company Ltd.

www.bris.ac.uk/composites
Context

- HCCL has developed a resin system which they claim has:
  - Improved interlaminar properties
  - Excellent mechanical properties
  - Low viscosity resin suitable for infusion

- Targeted use for wind turbine blades
- Initial characterisation of resin and its interlaminar properties in a GFRP system:

<table>
<thead>
<tr>
<th>Property evaluated</th>
<th>Property evaluated</th>
<th>Value</th>
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</thead>
<tbody>
<tr>
<td>Polymerisation enthalpy</td>
<td>Resin shrinkage</td>
<td>6.8%</td>
</tr>
<tr>
<td>Glass transition temperature</td>
<td>Interlaminar shear strength</td>
<td>64.4 MPa</td>
</tr>
<tr>
<td>Reaction kinetics – activation energy</td>
<td>Processing window (pot life) at 50°C</td>
<td>&gt; 4 hours</td>
</tr>
</tbody>
</table>
  - 10.6 kJ/mol (Ozawa)
  - 77.14 kJ/mol (Kissinger)
Manufacture Outputs

- **Cure cycle optimisation**
  - Cure cycle at 75 °C for 12 hours can be halved to 6 hours
  - Need to maintain thermo-mechanical properties

- **Laminate manufacture and quality testing**

- **Future work: Larger turbines -> demand for CFRP systems**
  - Is this matrix transferable to a carbon system?
    - Mechanical properties
    - Manufacturing process over complex geometries
Development of a Closed-loop Recycling Method for Aligned, Short Carbon Fibre Composites

Rhys Tapper, Marco Longana, Hana Yu, Ian Hamerton, Kevin Potter
Closed-Loop Methodology

DCF Thermoplastic component

Polymer Solution + Fibre

Solvent recycling

Polymer Solution

Filtration

Fibres

HiPerDiF Alignment

Compression Mould

Polymer Granules

Polymer Veil
Polypropylene Results

### Stiffness

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<tr>
<th>V</th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>(GPa)</td>
<td>1.39 ± 3%</td>
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</table>

### Shear strength

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<th>V</th>
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<tbody>
<tr>
<td>(MPa)</td>
<td>Δτ(ν-3) = 19%</td>
<td></td>
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### Yield strength

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<th>V</th>
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<tr>
<td>(MPa)</td>
<td>σ₀.₂ = 13.5 MPa ± 6%</td>
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</tbody>
</table>

**Future work**

- Molecular weight analysis of polypropylene.
- Additives analysis.
- Nylon-66 closed-loop recycling.
- Fibre impregnation and composites testing.