Composites Research in ACCIS and the National Composites Centre

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Topics for today

• The view on the future for composites in the UK

• The development of composites in the University of Bristol (ACCIS) and some current research directions

• The development of the NCC to date, operational models, research priorities and capabilities

• The High value Manufacturing Catapult

• Next steps at the NCC
The UK’s National Composites strategy was first set out in 2009, leading to the foundation of the National Composites Centre and updated in 2016.
The future of composites in the UK.

<table>
<thead>
<tr>
<th>Sector</th>
<th>2020 Global</th>
<th>2013 Global</th>
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</thead>
<tbody>
<tr>
<td>Aerospace &amp; Defence</td>
<td>$20bn</td>
<td>$10.6bn</td>
</tr>
<tr>
<td>Transportation</td>
<td>$15.6bn</td>
<td>$9.6bn</td>
</tr>
<tr>
<td>Construction</td>
<td>$14.1bn</td>
<td>$9.6bn</td>
</tr>
<tr>
<td>Marine</td>
<td>$2.5bn</td>
<td>$1.7bn</td>
</tr>
<tr>
<td>Energy</td>
<td>$18.2bn</td>
<td>$13bn</td>
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<tr>
<td>Wind Energy</td>
<td>$9.8bn</td>
<td>$5.6bn</td>
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Source: Bristol Composites Institute (ACCIS)
The future of composites in the UK. 2 Local

2015
- Aerospace: £270m
- Defence: £380m
- Automotive: £380m
- Rail: £60m
- Construction: £360m
- Marine: £220m
- Oil & Gas: £20m
- Renewables: £600m

2020 (Forecast)
- Aerospace: £1,160m (27%)
- Defence: £950m (16%)
- Automotive: £490m (4%)
- Rail: £100m (10%)
- Construction: £640m (10%)
- Marine: £270m (10%)
- Oil & Gas: £340m (8%)
- Renewables: £690m (2%)

2030 (Opportunity)
- Aerospace: £3,590m (17%)
- Defence: £1,150m (7%)
- Automotive: £3,490m (15%)
- Rail: £160m (9%)
- Construction: £1,520m (31%)
- Marine: £370m (3%)
- Oil & Gas: £1,100m (4%)
- Renewables: £880m

UK Total
- 2015: £2.3bn
- 2020: £4.7bn
- 2030: £12.5bn

15% CAGR

Percentage figures are Compound Annual Growth Rate (CAGR). The upper and lower forecast figures reflect the view of the UK supply chain companies researched in mid-2015.
The Mission of the NCC and ACCIS

With our partners in academia and in industry the mission we have been set is to deliver outcomes at the top end of the range of predictions by:

• Research at the highest international standards in ACCIS and by our academic partners and collaborators

• Working with industrial and government partners in the NCC to convert research outputs into fully developed and cost-effective technology

• Deliver that technology into industry

• Develop the next generation of engineers and scientists to deliver future developments in composites materials and manufacturing
Advanced Composites Collaboration for Innovation and Science

- Established in the University of Bristol in 2007 based on >20 years of prior research. Became a Specialist Research Institute of the University of Bristol in 2017
- Brings together composites research across University linking engineering, science and medicine
- Focus for collaboration between academia and industry
- ACCIS Vision: A world leading centre for composites education and research, combining cutting edge fundamental science with strong industrial links for exploitation and technology transfer
ACCIS in Numbers

In 2016 we had:

214 people in ACCIS
21 Academics, 37 PDRAs, 116 PhD and EngD students, 15 people in the support team and 25 international visitors (9 countries)

200 Publications
including 119 Journal papers and 3 book chapters, work was presented at 14 conferences and by a YouTube channel and other outreach activity

Our work was supported by EPSRC (52%), Industry (32%) EU and other (16%)
ACCIS Research Themes

- Multifunctional Composites and Novel Microstructures
  - Embedded fibres for sensing, self healing

- Design, Analysis and Failure
  - Predicting damage at notches

- Intelligent Structures
  - Morphing aerofoil

- Composites Processing and Characterisation
  - Fibre waviness in curved composite
Multifunctional Composites and Novel Microstructures

• Self healing, bleeding composites

• Composites with electromagnetic functionality

• Hierarchical microstructures

• Auxetic materials

• Modelling of novel nanostructures
Design, Analysis and Failure

- Failure mechanisms and modelling
- Optimisation and elastic tailoring
- Vibration and fatigue
- Impact and high strain rate effects
Intelligent Structures

• Morphing structures

• Multistable composites

• Structural health monitoring and acoustic emission

• Damage detection and prognosis
Composites Processing and Characterisation

Reinforcement deformation and simulation

Virtual Fabric Placement allowing the detailed simulation of lay-up in very complex geometries

Modelling the consolidation of complex 3D woven fabrics and 3D braided structures

Characterising the deformation properties of UD prepreg and other reinforcements for manual and automated processing
Composites Processing and Characterisation

Automation of composites manufacture

Robotic lay-up of woven reinforcement into complex sandwich panel geometry

Experimental and numerical simulation of the AFP lay-up process to understand the requirements to achieve full consolidation on the fly

Development of a novel approach to tow steering to improve the flexibility and performance of AFP
Composites Processing and Characterisation

Variability and defects – origins and impacts

Taxonomies of defects and sources of variability
Composites Processing and Characterisation

High performance cellulose fibre

This project is a fundamental EPSRC funded collaboration between ACCIS, Imperial College and Exeter University.

The initial target is to develop reinforcing fibres based on cellulose biomass that would be comparable with glass fibres on a specific strength and stiffness basis – using a novel spinning process.

The second target is to convert suitable cellulose or other biomass based fibres (developing IP) into carbon fibre to deliver more sustainable high performance reinforcements.
Composites Processing and Characterisation

Discontinuous fibre processing

Ply chamfering can be used to eliminate stress concentrations and delaminations from ply terminations, giving a significant increase in laminate strength.

A novel approach to the manufacture of very well aligned short fibre reinforcements offers very interesting opportunities in carbon fibre recycling and hybridisation.
Industrial Partnerships

• Rolls-Royce Composites UTC - focus on validated analysis methods

• Agusta Westland Rotorcraft UTC

• Extensive collaborations directly and through the NCC with a wide range of companies from SMEs to OEMs in aerospace, automotive, wind energy, civil engineering, oil and gas and other industrial sectors
Academic Partnerships

EPSRC Programme Grant
High Performance Ductile Composites
£6M Collaboration with Imperial College
Led by Prof. Michael Wisnom at Bristol

EPSRC Centre for Innovative Manufacturing in Composites
In collaboration with Nottingham University and other institutions
£10M project led by Prof. Andrew Long
Bristol activity led by Prof. Kevin Potter
ACCIS Doctoral Training Centre

£7M awarded by EPSRC in December 2008 to establish a Composites Doctoral Training Centre for 5 years, extended in 2013

First year taught element – Composites MSc

Paul Weaver is Director

Successful EPSRC mid-term review

Strong industrial engagement - projects with Agusta Westland, Airbus UK, dstl, GE Aviation, Haydale, Rolls-Royce and Vestas

Collaboration with Imperial, Nottingham, Manchester, Cambridge
EPSRC Centre Industrial Doctorate Scheme

£3.8M from EPSRC to support a cohort of 10 Research Engineers p/a, for 3 intakes starting October 2012 to work on Composites Manufacturing projects, extended for 5 years in 2013

- TRL 3-5 projects, 75% time within company

‘Home-base’ at the NCC; 25% taught component delivery centred there, also most dissemination events

Open to all UK composites industry and academia

- most appropriate company-RE-supervisor set
- overarching management structure already in place
- eligible Research Engineers to be offered stipend of £20k p/a

Bespoke ‘required background’ M-level modular course developed for the Research Engineers will be accessible to the EPSRC Centre PhDs and more widely to UK academic institutions

Newly created knowledge base utilised to define and develop unique, highly specialised M-level course in ‘composites manufacturing’ for future wide access
ACCIS Facilities

- New £5.4M centre opened May 2010
- Integrates staff and researchers
- Hot desks for collaborators and visitors
- ACCIS annexe to provide additional space
- New robot facility installed

Ground floor lab extension

Open plan research offices on 2 floors adjacent to staff offices
National Composites Centre

Phase 2. 2014

Composites “footprint” in Bristol University has expanded by almost x40 in 10 years

~ 1400 sqm

Current status

National Composites Centre

Phase 1. 2011
ACCIS/NCC collaborations

- ACCIS and the NCC are currently working together on a range of projects such as:
  - Aspects of Automated Fibre Placement (2 EngD projects)
  - Knowledge capture and management (EngD project)
  - Aspects of through thickness reinforcement (EngD project)
  - Thermoplastic press forming (EngD project)
  - Cure monitoring (EngD project)
  - Development of training aids and laminator support aids including VR/AR (EPSRC Impact Acceleration project)
  - NCC involvement in a range of CIMComp projects
  - High pressure RTM (EngD project)
  - Design for Manufacture (2 EngD projects)
  - Support for the NCC Core Research Programme

- Other potential projects are under discussion and mechanisms are being developed to deliver a pipeline of appropriate technologies from University Research to the NCC and beyond
The development of the NCC

In 2009 the UK government issued a National Composites Strategy that identified the need to invest in a National Composites Centre. Bristol University was awarded funding to build the NCC in 2010 and delivered the centre in 2011 on time and on budget. The need for a larger facility was established very quickly and was delivered in 2015.
The NCC is a not for profit company, owned by the University of Bristol but operated independently on behalf of its members, stakeholders and the wider community.

It is open access to companies having a UK presence on a “pay for use” basis in addition to having three tiers of membership available.

Through its membership of the High Value Manufacturing Catapult it has access to ongoing funding to maintain and expand its capability.
NCC operational model

Tier 1 members are large companies that have a voice in the management committees of the NCC.

Half of their fees fund a Core Research Programme where the IP is held by the University of Bristol and available freely to the companies.

The other half of the fees fund company-specified work where they hold the IP.

Some of the Tier 1 members are funding other programmes in the NCC that are much larger than their membership fees.
NCC operational model

Tier 2 members are generally smaller supply chain companies that do not have an individual voice in the Management Committees.

In essence their membership fees are pre-payment for work to be carried out by the NCC and can also be used to buy into elements of the Core Research Programme.

Associate members are generally companies providing an in-kind service to the NCC to the same sort of value as a member company.
Some current NCC members

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<th>AgustaWestland</th>
<th>AIRBUS</th>
<th>CYTEC</th>
<th>Rolls-Royce</th>
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<tr>
<td>Vestas</td>
<td>GE</td>
<td>Dassault Systèmes</td>
<td>SGS</td>
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<td>AGC AeroComposites</td>
<td>COBHAM</td>
<td>dyson</td>
<td>Altair</td>
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<td>Surrey Technology Ltd</td>
<td>Thompson</td>
<td>3M</td>
<td>Tencate</td>
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<td>GÜDEL</td>
<td>Heraeus</td>
<td>esi</td>
<td>Hexcel</td>
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<tr>
<td>Sigmatex</td>
<td>EPM: technology group</td>
<td>Walter</td>
<td>Coriolis Composites</td>
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<td>Composite Integration</td>
<td>BAE Systems</td>
<td>Lucintel</td>
<td>MSC Software</td>
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<tr>
<td>Huntsman</td>
<td>Enriching lives through innovation</td>
<td>Williams</td>
<td>Krauss Maffei</td>
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<td>NPL</td>
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NCC current activity breakdown by sector
The High Value Manufacturing Catapult has brought together 7 facilities working across a range of technologies and sectors to work together to maximise their impact on the UK manufacturing sectors.
Bridging the valley of Death

Linking academic and other research across the “Valley of Death” to successful implementation is the mission of the High Value Manufacturing Catapult.
Achieving full exploitation of composites

Brings Industry & Academia together

World-Class Facilities, People and Knowledge

Open Innovation Environment

Part of UK’s High Value Manufacturing Catapult
NCC strengths today

Material Properties
Design
CAE & Simulation
Industrial Processes

Integrated Research and Development Facility
200+ Engineers & Technicians
190,000sq feet of workshops, offices and training rooms

Prototype manufacture
Process optimisation
Knowledge capture & training
NCC strengths today

- Hand Cutting
- Manual lay-up
- Manual quality checks
- Curing
- Design & Simulation
- Automated lay-up
- Automated Preforming
- Digital Manufacturing
- Braiding & 3-D Weaving
- Press moulding
- Local reinforcement
- In Process Inspection

Increasing Productivity through High Rate Repeatability Lower Cost
NCC Research 1. CT scanning through Cure

By using CT scanning through the cure process we can track the development of microstructure and defects as the prepreg cures.
NCC Research 2. Process understanding in AFP

Dynamically pressure mapping the lay up by Automated Fibre Placement over complex geometry features allows us to develop design, processing and programming guidelines and implement them in the development process.
NCC Research 3. TTR via tufting

Without TTR delamination initiates at the skin/stringer transition

With TTR at the ends of the stringer this failure mode is suppressed and failure initiated by delamination at the skin/stringer interface under the web, and by web splitting

Additional tufting at the skin/stringer interface under the web increased the stiffness of the joint and increased the peak load.

Neither TRR approach was able to completely suppress the initiation of delamination damage, but significantly impacted the post-initiation damage growth
Next steps at the NCC

Major new facilities are being procured to keep the NCC at the cutting edge internationally.

2017

- Thermoplastic composites, over-moulding, advanced braiding, tension fibre placement

2019

- High rate AFP & ATL technologies, Net-shape preforms, automated quality assurance
- Automated Dry-fibre pilot line, curing oven, large scale resin infusion
The skills and training challenge

The NCC will need to recruit 40-50 technical staff with composites skills each year for the next few years to meet its current growth targets.

Industry will need to recruit at an even higher level, with one NCC member needing to train >200 staff very quickly.

With the industry transitioning from manual to automated processing even current composites experts will need to be retrained in new ways of working.

But the UK universities are a long way from delivering enough graduates with composites experience.
Skills and training, the response

With the University of Bristol the NCC is developing a Composites Conversion Course to take engineers with some years of experience and retrain them in a suite of composite skills.

The University of Bristol is seeking funding to develop a range of curriculum and teaching materials that can be used across a range of institutions, settings and levels to provide academically sound and industrially relevant training to help close these skills and training gaps.
The NCC, ACCIS and their partners and collaborators will continue to develop composites technology at scientific, technical and commercial scales to deliver the UK national strategy.

Questions?