Getting clever with composites

In the shadows of soaring skyscrapers, the red brick chimneys of Manchester's nineteenth century cotton mills are modest relics of their former triumphs. Once drivers of the industrial revolution, the mills which remain today stand quiet, converted into the apartments and offices of Manchester's new economy.

The National Composites Certification and Evaluation Facility is an independent ISO 17025 accredited test laboratory, which is run as the commercial arm of the North West Composites Centre (NWCC). It responds to short term industrial needs that could lead to longer term research contracts and partnerships. The facility uses state-of-the-art Instron testing machines, equipped with environmental chambers (-100ºC to 350ºC) and extensive non-destructive evaluation facilities, to characterise the performance and properties of a full range of novel composite materials and components for more than 30 clients, including Airbus, Rolls-Royce and BAE Systems.

But in the laboratories of the North West Composites Centre (NWCC) on Sackville Street the clatter of weaving looms continues; Manchester finds itself yet again at the centre of a weaving revolution.

From delicate cotton, specialist looms now weave super-tough carbon fibres, using both traditional patterns and new ones inspired by the latest textiles research within the School of Materials. These carbon fibre sheets will be infused with polymer resins and cured to create the very latest high-performance carbon fibre reinforced plastics (CFRPs).

CFRPs are composite material systems which combine the strength of the carbon fibres with the versatility and variety of different polymers. The synergy of these components produces materials that are stiffer, lighter and stronger than most traditional materials, including advanced aluminium alloys.

3D weave

Professor Constantinos Soutis, Director of NWCC, sweeps through the laboratories where rolls of black carbon fibre matting, called ply, contrast with the bright coloured yarns that once crammed the local warehouses. He points proudly to a strange looking device; a long black tube is being knitted together, threads of carbon protruding and winding around it from all directions. "This is our nine-axis robotic complex winding machine, developed here by my colleague Dr Prasad Potluri. It can produce 3D objects like pipelines and barrels with highly complex fibre architectures," he says as he pulls out another piece of pipework, this time in black and white. "We can even mix glass and carbon fibres together," he smiles. "We make components with unique properties that can withstand compression, stretching and shear stresses due to twisting forces."

Professor Soutis explains how more conventional Jacquard looms can also produce 3D weaves as they are programmed to stitch plies together. "We typically make composite materials from many thin layers or plies, 0.125 mm thick, each orientated to give the overall material its specific characteristics. To prevent these layers coming apart, or delaminating – a common problem – we are looking at how to stitch the ply together with carbon or glass fibre threads. Mathematical models help us to create specific weave architectures that can give the material a characteristic stress resistant profile, for example to withstand the twisting forces experienced by wind turbine and jet fan blades without delaminating."

Aircraft repair

As he often likes to do with the students around him, Professor Soutis now throws out a question: "Everyone from luxury car makers to aircraft manufacturers, are using composites for their strength and durability, but what do you do when the material is damaged?"

He elaborates on the problem, describing how the composite material of an aircraft may be dented or damaged by a clumsy mechanic or an unfortunate goose. Traditionally, the maintenance team can remove a damaged section of metal and simply rivet a new panel in place. "You can't do that with composites," Soutis points out. "They are incredibly hard to cut and you can't use rivets, since drilling holes damages fibres and hence weakens the structure. So what do you do?"

He pulls out the answer from his pocket: a small piece of blackish-grey plastic with some oval holes. "This is what we have done in the lab," he proclaims. "This really is the cutting edge of composite repair."

Cool lasers

The dull piece of plastic is a piece of aircraft composite. The holes have been cut with a powerful 'cool' laser, one of many at The University of Manchester. Research at NWCC has shown how a laser can precisely cut a shaped section from composite material with an extremely smooth, undamaged edge. The high power (400 W) short pulse laser prevents the composite material from heat damage which would normally lead to delamination.

The width of the cut is also so fine that new material will fit tightly within the hole. The same cool laser can even 'burn off' a single ply from the surface of a composite, making it possible to remove superficial damage and replace it with a small section of new 'skin'.

Wielding his plastic trophy, Professor Soutis talks about how ground crews at airports could use a laser on a robotic arm to cut out damaged material and slot in replacement 'patches'. "We'll put sensors across the join or between plies to monitor the integrity of the repair and provide maintenance staff with information on local stresses that can be used to estimate residual strength and fatigue life."

In just a few steps, Professor Soutis moves from Jacquard looms to robotic repairs. But this is the essence of NWCC, he exclaims: "We can take the most mundane of materials – simple plastics, basic carbon fibres – then bring them together in clever ways to create new materials and structural components with exciting, even spectacular thermo-mechanical and electrical properties and performance."

PROFESSOR CONSTANTINOS SOUTIS DIRECTOR NWCC

Professor Constantinos Soutis joined the University of Manchester as Director of the Northwest Composites Centre in October 2012. He has over 25 years of experience in working with composite structures and designs and an international reputation in the field of composites research.

Full of infectious enthusiasm for this rapidly developing field, Professor Soutis provides new vigour to NWCC as it builds its reputation for partnership and commercial research, especially in the automobile and aerospace sectors. A firm believer in open collaboration, he is strengthening the original NWCC partnership between The University of Manchester and the universities of Bolton, Lancaster, Liverpool and Glyndwr to provide industry and academia with local access to research expertise as well as the laboratory facilities and staff based in Manchester.

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