QUB - Mechanical and Aerospace Engineering
PhD Project Description

Title: Welding of advanced thermoplastic aero-structures

Theme: Composites

Project description:
Aerospace-grade polymers such as polyetheretherketone (PEEK), polyphenylsulfone (PPSU), polyetherimide (PEI), and polyetherketoneketone (PEKK) provide a reliable and cost-effective way to reduce weight. More importantly, they add value beyond weight reduction for many applications. High-performance thermoplastics meet stringent flame, smoke, and toxicity (FST) standards better due to their inherent flame resistance or, in some cases, flame retardancy. Another crucial feature for aerospace is corrosion resistance. This is something that thermoplastics excel at, especially when compared to aluminium and steel.

As aerospace manufacturing leans towards using thermoplastic composite fuselages, metallic structural brackets and other associated causes of galvanic corrosion are being replaced, creating overall, safer aircraft. Moreover, thermoplastics can be machined to extremely tight tolerances - up to 0.002mm - which is critical for aerospace applications. Processes such as welding, rapid thermoforming, autoclave processing, tape and fibre placement techniques, and press forming are also all possible with thermoplastic polymers and composites.

Resistance welding is a low-cost joining solution for thermoplastic materials that consists of three steps: i) placing a conductive material (hereinafter denominated as insert) between the bonding surfaces; ii) applying an electric potential for the heating of the insert, consequently leading to the controlled melting of the mating surfaces; iii) and their consolidation under applied pressure. Resistance welding is particularly interesting for aerospace industry since it allows the welding of large structures in an easy and effective way (Figs.1&2).

Fig. 1: Thermoplastic rear pressure bulkhead

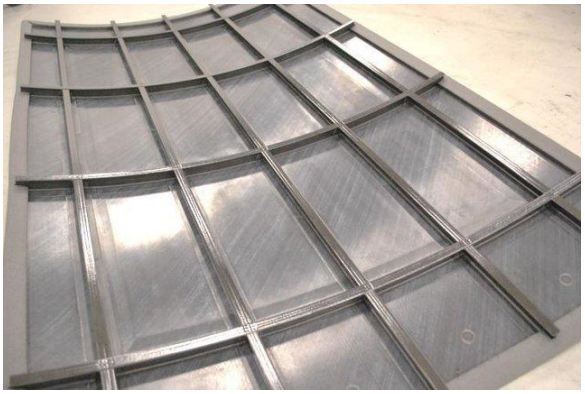
Fig 2: Thermoplastic stringers welded to fuselage

Current practice entails the use of inserts made of metal meshes or carbon fibres that act as the heating elements and that remain in the joint after welding. Metal inserts may have a detrimental effect on the mechanical performance of the joint, add to the weight of the assembly, and be susceptible to corrosion. Carbon fibres are light and resistant to corrosion, but they are stiff and difficult to introduce at geometrically complex interfaces. Moreover, they may also cause a reduction in mechanical properties and poor weld reproducibility, especially when a large quantity of fibre is used. Electrical connections between the electrodes and the carbon fibres are also problematic. Such factors hinder the process of scaling up the technology.

The Advanced Composite Research group at QUB has recently developed a CNT-web welding technology that uses an innovative resistive susceptor. This is made by embedding CNT-webs between two polymeric films and adding a couple of electrodes. Placing it in between the surfaces to join, and applying electrical power, you can melt the material and weld the two parts. The material has been tested using both neat resins (from PP to PEEK) and fibre-reinforced thermoplastics. Our technology is able to address the shortcomings of the current solutions: highly-aligned CNT-webs are light, flexible, and extremely thin. They are resistant to corrosion and their presence do not have any detrimental effect on the strength of the joint. Finally, they have

low electrical resistance and the welding process is very energy-efficient.

The next step is now to validate the use of this welding technology in aeronautics. Fokker (a GKN Aerospace company) is interested in validating this technology and will support the PhD project providing guidance and advice, supervision to the student (Mr Bas Tijs, R&D engineer at Fokker will be the third supervisor), an internship to the student (in the Rotterdam Area, Netherlands). There is a possibility of top-up.

Aims and Objectives:

- Understanding the science behind the welding when using the CNT-web based technology and in particular, understanding the polymer diffusion mechanism and the time associated to it; how the crystallinity of the polymer is affected; how the presence of the web affects the polymer diffusion; the range of polymers for which this technology can be used.
- Optimising the process parameters for a particular application: number of webs, layup, specific electrical power, time, way of tailoring the heating, etc.
- Testing the welding joint and assess their structural integrity. Determining their strength and fracture toughness.

Key skills required for the post: Applications are invited from students of high academic merit with a background in composites, polymer engineering and structural analysis. Applicants are expected to graduate with a minimum of a 2:1 honours degree in mechanical engineering, material science, physics or related field.

Key transferable skills that will be developed during the PhD: independent analytical thinking, problem solving, time management, leadership, ability to effectively communicate research outcomes to academic peers and industry.

Lead supervisor:	Giuseppe Catalanotti (g.catalanotti@qub.ac.uk)
Other supervisor(s):	Ali Aravand (QUB), Brian Falzon, Bas Tijs (Fokker)
Funding mechanism:	Yet to be secured
Application closing date:	Until suitable candidate appointed.
Guaranteed stipend:	This can include a basic stipend and any guaranteed top-up (if available). N.B. Stipend for 20-21 is not yet confirmed. Base stipend for 19/20 is £15,009.
Conditional top-up available:	Top-up is currently been discussing with Fokker and decision will be taken by Fokker management soon. Contact Dr Catalanotti if interested.

PhD students in the School may have the opportunity to apply to be demonstrators on undergraduate modules. Compensation for this can amount to in excess of £2,400 per year.

Queens University Belfast is a diverse and international institution which is strongly committed to equality and diversity, and to selection on merit. Currently women are under-represented in research positions in the School and accordingly applications from women are particularly welcome.