RESEARCH ARTICLE

Surface Engineering Metal - Composite Hyperjoints

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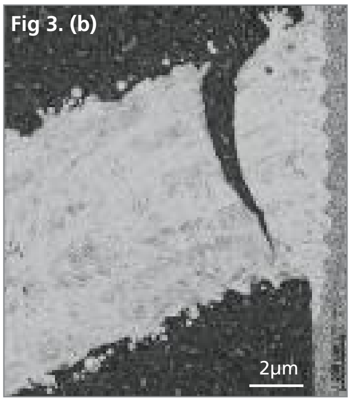
The use of composites is increasing in advanced civil airframe designs to improve fuel efficiency. However, metallic materials, and in particular titanium alloys, still feature strongly where a higher temperature capability or multi-axis loading is required. For example, the new A350XWB 'composite' aircraft is actually a multi-material design and contains over 40% metallic structure. Producing reliable joints between high performance titanium alloys and composite components is challenging because of their very different chemical and physical properties and there is a need to improve load transfer efficiency and move away from the reliance on fasteners, which create bearing issues in composite laminates. At the same time, adhesive-only metal-composite joints currently do not have a long enough safe design life, or load transfer capability without a large overlap area, which increases weight.

Recently, a new class of joints has emerged in which both mechanical and adhesive bonding elements are integrated into one design. With this approach, arrays of locking features are engineered on to the metal part that are imbedded into the composite laminate to increase the shear transfer, via both better adhesion and mechanical 'fit', through the thickness of the laminate. Such hybrid joints have become known collectively as 'hyperjoints' and can greatly improve the joint strength and failure energy.

A typical hyperjoint design requires the ability to reliably manufacture arrays of small pins (typically ~ 1 mm diameter) with an accurate geometry on a titanium substrate (Figure 1). In partnership with the European Aeronautic Defence and Space (EADS) Company, within LATEST2 we have been exploring methods of assessing the quality and predictability of the failure load of hyperpins manufactured by different techniques, so that an industrially viable process can be identified for their full-scale manufacture. Approaches that have been explored, to date, include electron beam surface sculpting (Surfi-Sculpt®) laser additive manufacture (AM), and micro-welding technologies that can be used to attach pre-forged pins sufficiently rapidly for industrialisation. Such methods can have drawbacks including restrictions in the pin shape (Surfi-sculpt) and slow production rates (AM). In LATEST2 we have studied the metallurgical issues associated with each approach, including the critical area between the base of the pins and component substrate (Figure 2) where there is usually a sharp microstructural gradient. Methods have also been developed to test and model the performance of individual pins (Figure 3), as well as to study the damage that develops in a laminate joint assembly under load using the 3-D imaging X-ray Computed Tomography (XCT) facilities in the Manchester X-Ray Imaging Facility (MXIF). Within Theme 3 on surface engineering, work is also ongoing to understand how to use electro-chemical treatments more effectively to tailor titanium surface oxide film pore structures to improve adhesion on metal surfaces.

A potentially viable manufacturing route has now been identified and plans are afoot to expand this activity to investigate the issues associated with scaling up the technology for industrial application.



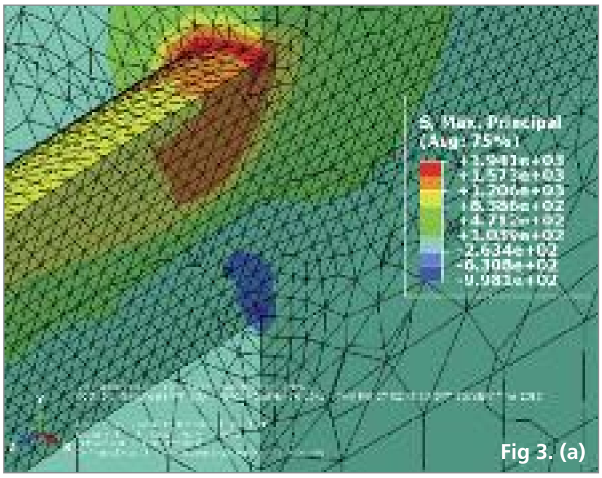


Fig. 3 (a) FE model of an individual hyper-pin under shear load, and cracking in LSM additive manufactured pin during shear testing, **(b)** optical image and **(c)** α phase EBSD map, with prior β grains outlined.

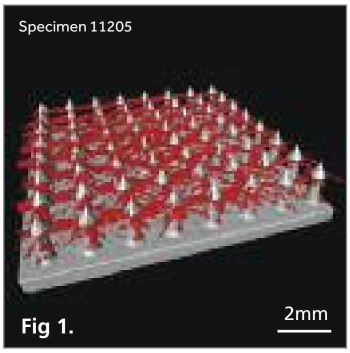


Fig. 1 X-ray microtomography image showing the hyper-pin array in a loaded lap joint with the development of damage in the composite indicated in red.

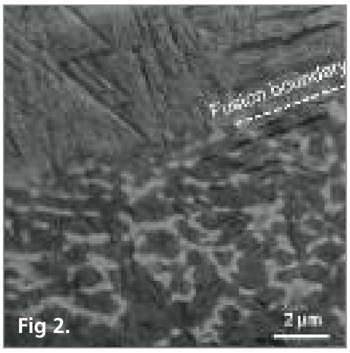


Fig. 2 High resolution SEM image showing the microstructure variation across the melt pool fusion boundary of a 'welded on' hyper-pin with a Ti64 rolled plate substrate.

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Publications: R. J. Oluleke, D. Strong, O. Ciuca, J Meyer, A. De Oliveira and P. B. Prangnell, Mechanical and Microstructural Characterization of Percussive Arc Welded Hyper-Pins for Titanium to Composite Metal Joining, in LMT2013, 6th Int. Symp. on Light Metals Technology, Mat Sci Forum, 765 (2013) pp 771-775.