Investigation of the Strength of Adhesively Bonded Composite Joints Using a Modified Arcan Fixture

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Introduction

Advances in magnet technology used in magnetic resonance imaging (MRI) have led to the incorporation of glass fibre reinforced plastic (GFRP) spacers, used to separate, and electrically insulate epoxy infused spools of superconducting wire, from each other. The superconductor and the GFRP materials have markedly different material properties and therefore respond differently to the variety of loading conditions that the magnet experiences before being installed in a hospital. The different material responses can cause material failure within the composites, or at the interface of where they join. Whilst in operation, it is essential that the structural integrity of the magnet is maintained. Large electromagnetic forces are induced in the coils, by the generated magnetic field, but not in the GFRP spacers, causing the coil to apply a biaxial force on the spacer through an epoxy joint; the effect of these forces provides the motivation for the work presented in the paper.

The GFRP spacers and superconducting coils are bonded by the epoxy resin infused in the coils. Fracture could initiate in the interfacial region due to stress concentrations caused by complex interaction of axial and radial, or shear loads. This can be reproduced experimentally using biaxial loading. A modified Arcan fixture (MAF) has previously been used to test the strength of bonded assemblies where complex stress states are present at the bond lines [1]. This can be used to induce a variety of tensile/compressive-shear loads. Fig. 1 shows how the loading can be applied to a clamped specimen by changing the loading hole pair [2]. For this series of experiments, the MAF shown in Fig. 1 is used in the shear configuration. Importantly in the current context there is no need to machine test specimens to a specific shape, e.g. as in the Iosipescu shear test [3]. Instead, specimens only need to be cut to dimensions that fit the rig, without the need to introduce 'notches' at the interface region. The purpose of the present paper is to investigate the use of the MAF rig to obtain the interfacial stiffness and strength of the join between the superconducting wire and the GFRP spacer.

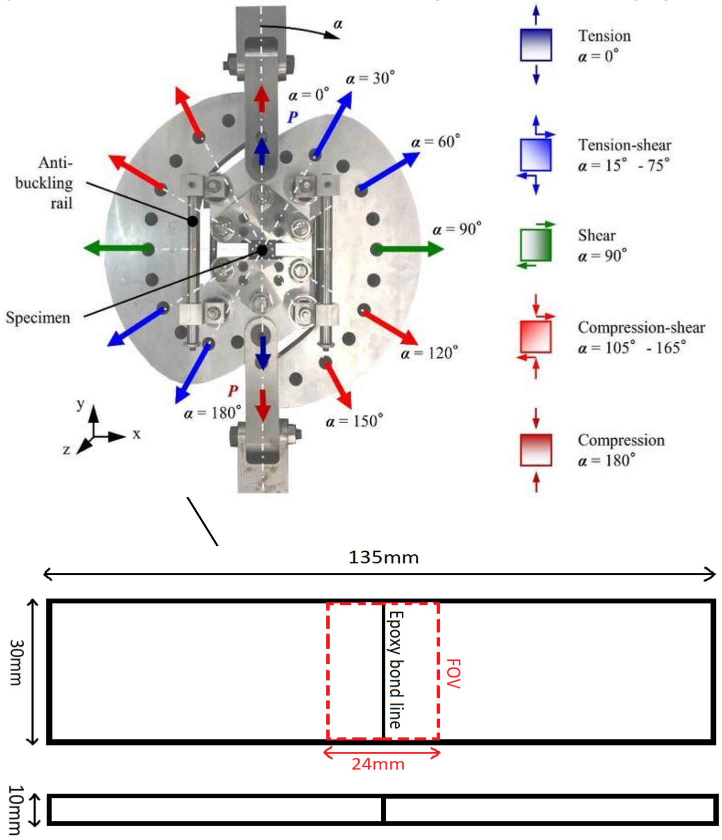

Figure 1 – Modified Arcan Fixture (MAF) [1] and specimen

Experimental Work

Method. The space between the clamps in the MAF rig is shown in Fig. 1 is 24mm, so this dictated the maximum possible width of the field of view (FOV) of the specimen. The specimens were cut from a ring section of magnet containing the GFRP spacer bonded to epoxy infused wire coil. It was cut so the test face was perpendicular to the concave face and the joint was parallel to the load direction. Load was applied quasi-statically to the specimens in displacement control with stereo digital image correlation (DIC) being used to capture the displacement and strain fields.

The DIC system used for data acquisition and post processing was by MatchID. The strains were calculated by creating virtual strain gauges with the subset displacements between each image. The strain components normal (ε_x) and parallel (ε_y) to the bond line, as well as the engineering shear strain (γ_{xy}) were obtained with post processing after the test.

Results. To check if the failure that occurred was predominately in mode II (shear) both the normal and engineering shear strain distribution maps obtained from the DIC just before failure were analysed. It can be seen that the shear strain at the interface (Fig. 2b) is an order of magnitude larger than the normal strain measured (Fig. 2a).

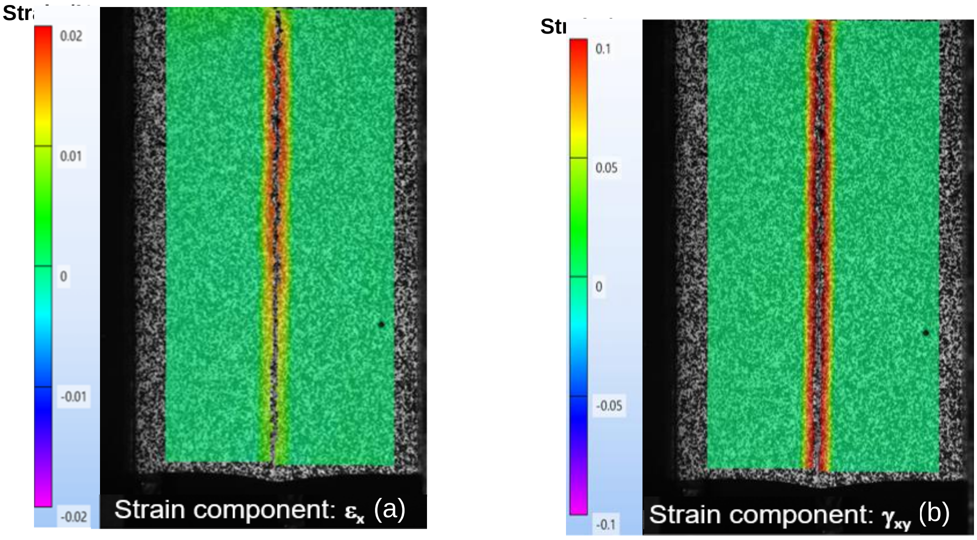

Figure 2 – ε_x (a) and γ_{xy} (b) distribution just before failure

It is clear from the images that the load is being transferred in shear and that the stiff adherends minimise any peeling. Plots of average shear stress (σ_{xy}) (load/area in shear) against the average engineering shear strain (γ_{xy}) across the length of each specimen are given in Fig. 3.

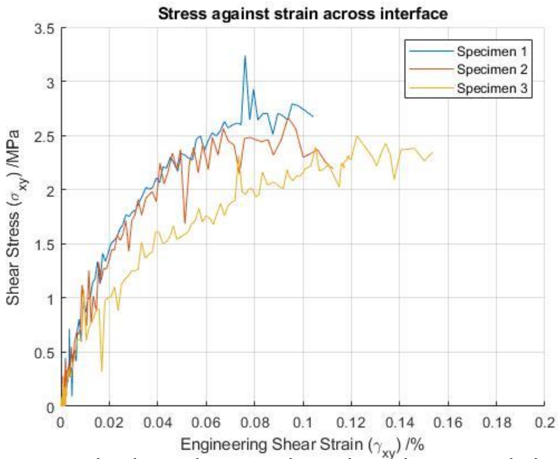

Figure 3 – Shear stress(σ_{xy}) against engineering shear strain(γ_{xy}) for all specimens

The stress-strain relationships of 2 out of 3 specimens tested were similar, with the failure stress being around 2.5MPa.

Conclusion

In this study, an adhesively bonded composite joint is tested in a MAF rig, using its shear loading configuration. Stereo DIC was used to capture the resulting displacements and processed the data into strain maps. This use of full-field imaging was important to check the loading was correctly applied to obtain a shear failure case. Future work will concentrate on the application of shear loading, to determine if the failure stress can be accurately described as the shear strength, and the use of other bi-axial loading modes to study the effect of applied tension and compression on the failure stress.

Acknowledgement

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References

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