The experimental investigation of shear response of epoxy matrix under compression

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Background

Unidirectional carbon fibre/polymer matrix composites exhibit excellent mechanical properties and thus are widely used in structural applications. However, these materials show poor mechanical performance upon axial compression due to the material instability and internal defects leading to kink-band formation [1]. Such instability could arise from within the polymer matrix, since the matrix between adjacent fibres will be subjected to a combined compression-shear loading until the onset of yielding [2]. A study of the composite strength prediction by considering fibre kinking and matrix shearing when subjected to combined axial compression and in-plane shear deformation has been conducted and showed that the kink-band formation is related with the shear response of the matrix [3]. It is therefore critical to understand the shear behaviour of the polymer matrix under combined stress conditions. This could be used for the development of material constitute model for the finite element modelling of carbon fibre composites. Therefore, the aim of this study is to investigate the shear behaviour of epoxy matrix subjected to prescribed compressive stresses.

Experimental investigation

Gurit Prime 37 epoxy resin was used in this study [4]. Solid cylinders were prepared from this material by casting in silicone moulds, followed by post-curing according to the manufacturer's recommendation. Hollow, cylindrical specimens of 0.5 mm nominal wall thickness were machined from the cylinders [5]. The ends of these specimens were bonded with steel plates which contain a dimple hole to locally position a ball bearing. This assembly was then bonded to a stainless steel end-cap (see Fig. 1a), as the load introduction point. The purpose of the ball bearing was to allow self-alignment whilst also transferring the compression force uniformly to the specimen.

Compression-shear tests were conducted on a Instron Electropuls E10000 fitted with a 10 kN axial and 100 Nm torsional load cell. Fig. 1b shows the test setup. Compression force of 660 N (i.e. compression stress of 20 MPa) and of 1400N (i.e. compressive stress of 43 MPa), was applied to the Prime 37 specimens at the constant strain rate of 0.001 s^{-1} without the application of any torsion loading. Once stabilised, the specimens were loaded in torsion at a constant rotation speed of 0.1°/s (whilst under the prescribed compression force) until failure. Stereo digital image correlation (DIC) was used to measure the compressive and shear strain of the specimens.

Results and discussion

Fig. 2 shows the compression stress-strain and shear stress-strain curves of a typical Prime 37 specimen tested in compression-shear tests. The compressive strain of the specimen upon axial loading was uniform across the gauge section (as indicated in the DIC images). The elastic modulus of the specimen from these measurements is 3.2 GPa and is consistent with the value from the manufacturer's datasheet. For the shear stress-strain response (Fig. 2b), it shows that the specimen shows an initially linear shear stress-strain curve, which then yields reaching a maximum stress before a short strain softening stage and then forms a stable plateau, and which is followed by strain hardening stage prior to the formation shear cracks. The inserted DIC images at different shear strains showed that the in-plane shear strain was in general uniform at the section of the constant wall thickness. Further investigations on the effect of the compressive stresses on the shear response of the material will be conducted and discussed.

Acknowledgments

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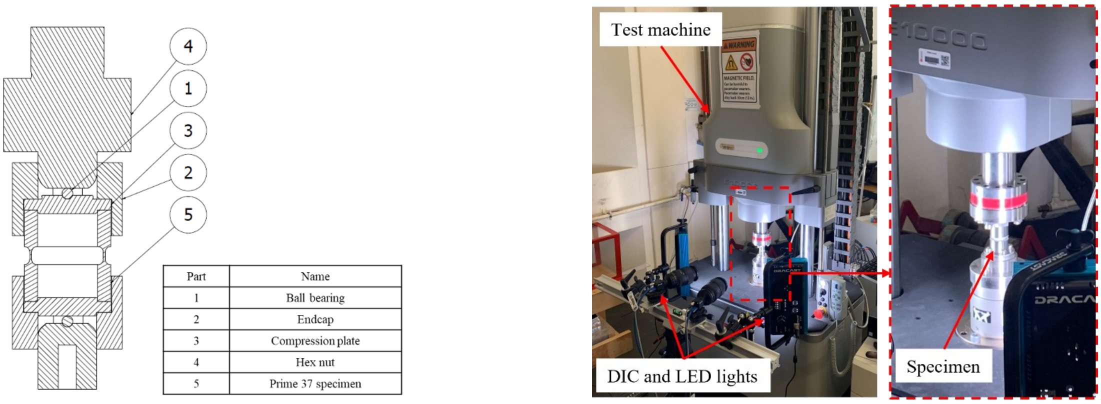
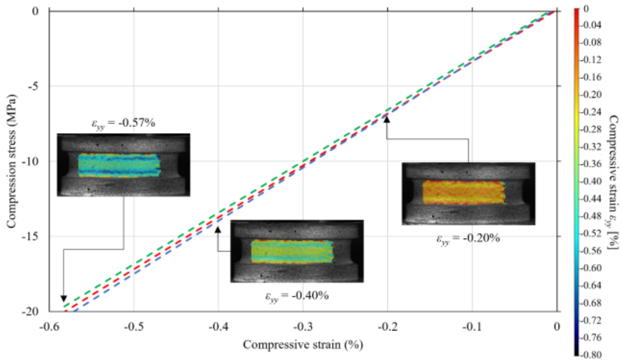
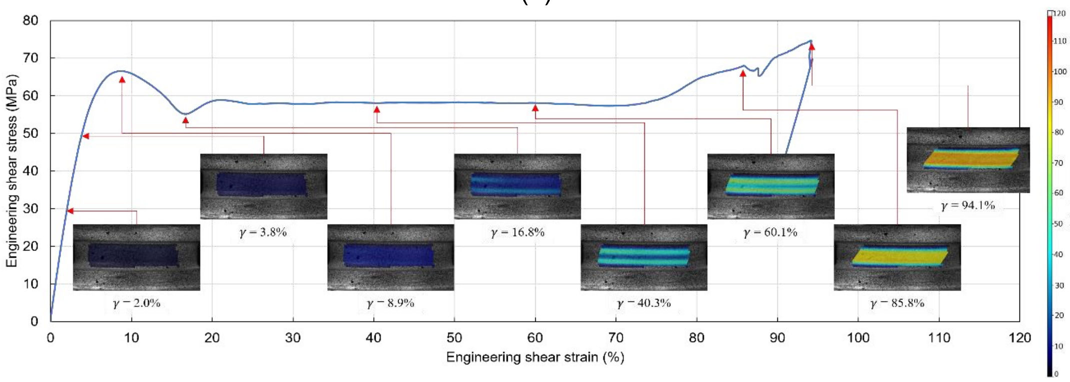


(a) (b)

Fig. 1. (a) The compression-shear specimen with ball bearing and endcap and (b) the test setup of compression-shear tests with the use of DIC system



(a)



(b)

Fig.2 (a) The compressive stress-strain plot of a Prime 37 specimen subjected to axial compression load and (b) The shear response of the Prime 37 specimen subjected to torsional deformation at the applied compressive stress.

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