12th International Conference on Composites Testing and Model Identification
J. Varna (Editor)
Riga, 2024

IN-PLANE SHEAR BEHAVIOR OF CARBON FIBRE REINFORCED THERMOPLASTIC COMPOSITES

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Keywords: Thermoplastic composite, Plasticity, Damage, Fiber orientation

ABSTRACT

Although carbon fibre reinforced thermoset composites (CFRTS) have been widely used in engineering structures owing to their high specific strength and stiffness, recycling them is difficult. On the other hand, carbon fibre reinforced thermoplastic composites (CFRTP) have been considered as a potential alternative due to their easier recyclability. However, the behaviour of CFRTPs is more complicated due to the presence of various mechanisms, namely plasticity, damage (ply damage and delamination) and possible fibre reorientation due to extensive deformation. This can be seen in its highly non-linear response during in-plane shear tests. While existing models can accurately capture the in-plane shear behaviour for CFRTSs [1, 2], no such model has been demonstrated for CFRTPs. To address the gap, this works aims to study the in-plane shear behaviour of CFRTPs and build a model that includes all the main failure mechanisms.

The material used in this work is T700 carbon fibre reinforced nylon-6 (CF/Nylon) prepreg supplied by Maruhachi Group. The composite plates are consolidated in a hot-press machine under 260°C and 4 bar pressure. The in-plane shear properties were characterized based on tensile tests of a $[\pm 45°]_{4s}$ laminate (ASTM D3518). To further study the mechanism of the laminates, interrupted tests were done at different strains, and microscopic observation on the samples were done after the tests.

The engineering shear strain–stress curves up to final failure is shown in Figure 1. It is shown that maximum shear stress and shear strain are about 140 MPa and 58% respectively. Three observations on a typical failed specimen are shown in Figure 2. Firstly, there is a necked area showing a width reduction of 23%-25%. Secondly, fibres tend to realign to the loading direction in the middle of the specimen, leading to significant fibre rotation. The largest change in fibre angle is about 15° and observed at the necked area. Lastly, although final failure occurs at the necked area, extensive matrix damage and fibre breakage were observed throughout the length.

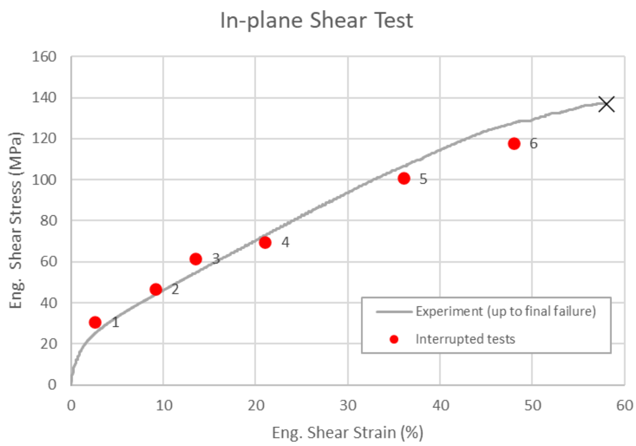

Figure 1: Experimental result of in-plane shear test

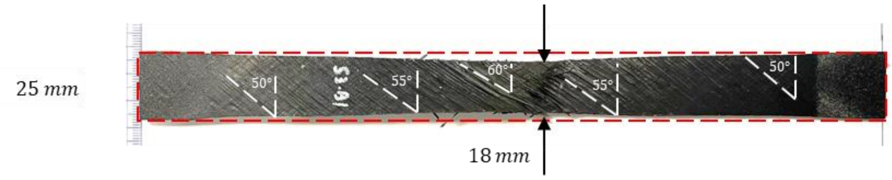

Figure 2: Representative failed specimen loaded along horizontal direction

A model incorporating plasticity, damage, delamination and fiber rotation has been proposed to study the response of CFRTP. Firstly, Hill's anisotropic yield criterion and strain hardening rule [3] is used to describe the transverse and shear plastic behaviour, while the fiber-direction behaviour is assumed to remain linear elastic. Secondly, the model uses a smeared crack model to capture intralaminar damage. Thirdly, cohesive elements are inserted between adjacent plies to model delamination [4]. Lastly, fibre rotation is considered in the model [5].

Preliminary result of the model with plasticity and fibre rotation only is presented in Figure 3. When the applied displacement in the simulation exceeds 16 mm, the simulation is unable to converge. The results show that the model gives good prediction until applied displacement of 12.5 mm. Beyond that, the model offers higher prediction of force compared to the experiment data, indicating that the inclusion of damage modeling is necessary.

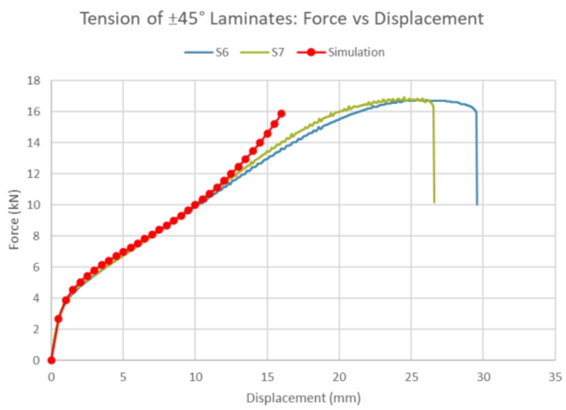

Figure 3: Comparison between experiment and simulation of $\pm 45°$ laminate under tension

In conclusion, the highly non-linear behaviour of ±45° laminates under tension results from plasticity, damage and fibre reorientation. The simulation results of the model combining plasticity and fibre reorientation has shown good agreement with experiment up to 16 mm applied displacement. This suggests that the presence of damage in the model is needed to fully capture the behaviour of the laminates. The inclusion of damage and delamination into the existing model and determination of the damage parameters are on-going.

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