Investigation of Thermoplastic Composite Forming Processes for Automotive and Industrial Structures Production

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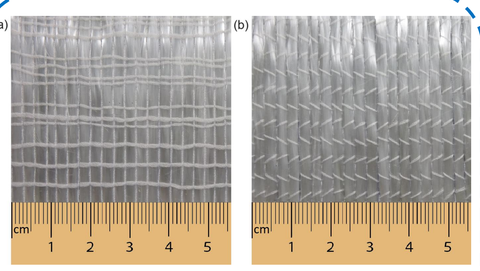
1 RESEARCH BACKGROUND

- Fibre-reinforced thermoplastic composites have gained significant interest in a range of industries where high strength and stiffness with lightweight is required.
- Research objectives include:
  - Optimisation of the sheet thermoforming process of fibre-reinforced thermoplastic composite sheets into complex shapes to improve the automotive and engineering structures
  - Prediction of processing defects such wrinkles, tearing and fibre waviness and their influence on the final mechanical properties
  - Development of appropriate characterization tests to measure mechanical properties required by the forming models
- The research focuses on both experimental and numerical modeling studies.

2 CHALLENGE

- The in-plane deformation of the fabric composite considered in this research (unidirectional non-crimp glass fabric - UDNCF) revealed a significant difference in axial force when tested using the two standard shear tests, with the Picture Frame (PF) test being significantly higher than the Uniaxial Bias Extension (UBE) test.

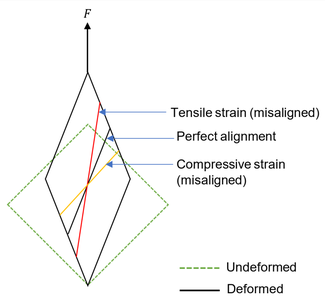


Close-up images of UDNCF (a) Front (b) Back

Reasons for the significant difference in axial forces

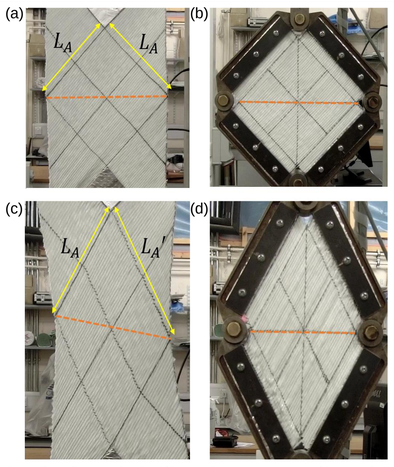
Experimental Error

Misalignment of fibres



Fibres are more likely to be subjected to tension due to accidental misalignment during the PF test

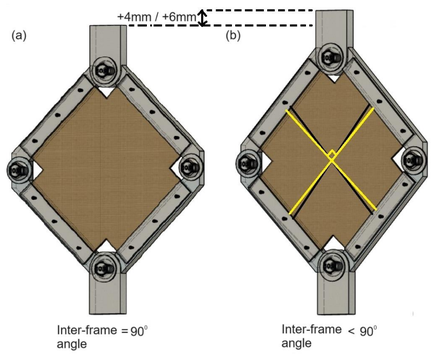
A true change in the fabric's forming behaviour between the two shear tests



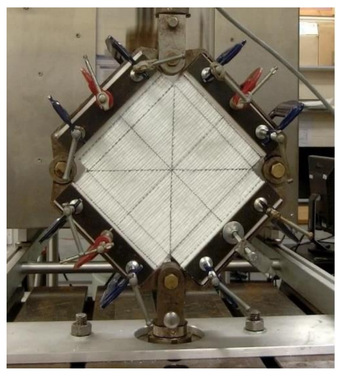
Extension in the stitch direction may reduce the shear resistance of the fabric in the UBE test

3 MODIFICATIONS OF THE PICTURE FRAME TEST

1. Pre-displaced PF test method – to minimize misalignment error by intentionally inducing compressive stress in the fibre directions during the test.
2. G-clamped Method – to reduce the misalignment error by changing the clamping conditions. The rigid bolting of the specimen was replaced by G-clamps with two different tightening pressures (low and high)



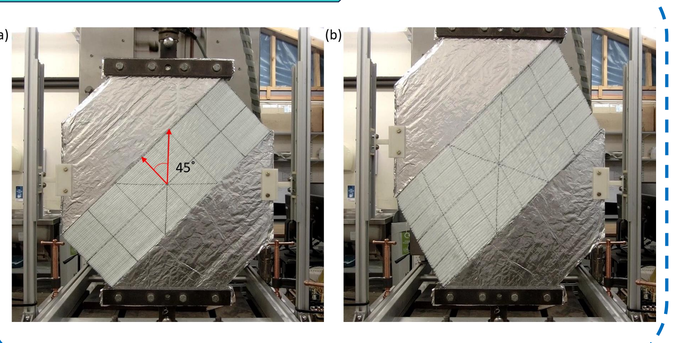
(a) Standard PF rig (b) Positively pre-displaced rig (the angle between the two black lines represents the initial inter-frame angle and the angle between two yellow lines represents the initial inter-tow angle)



Front view of the Picture Frame Test setup with G-clamps

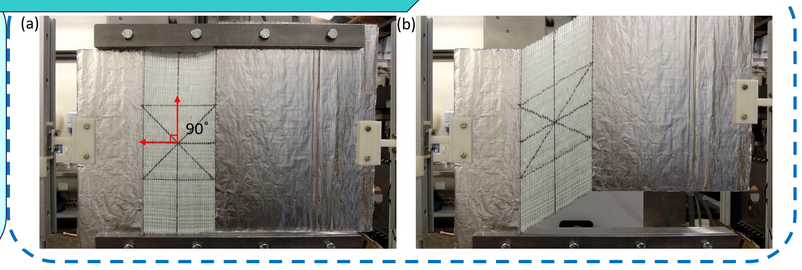
4 MODIFICATION OF THE BIAS EXTENSION TEST

- The original rectangular shape of the standard UBE specimen is modified to an octagonal shape (2Al sheet attached specimen - OS-2AL) to produce a different combination of shear and tensile strain in the stitch direction.
- The initial angle between the stitches and axial force is 45˚.



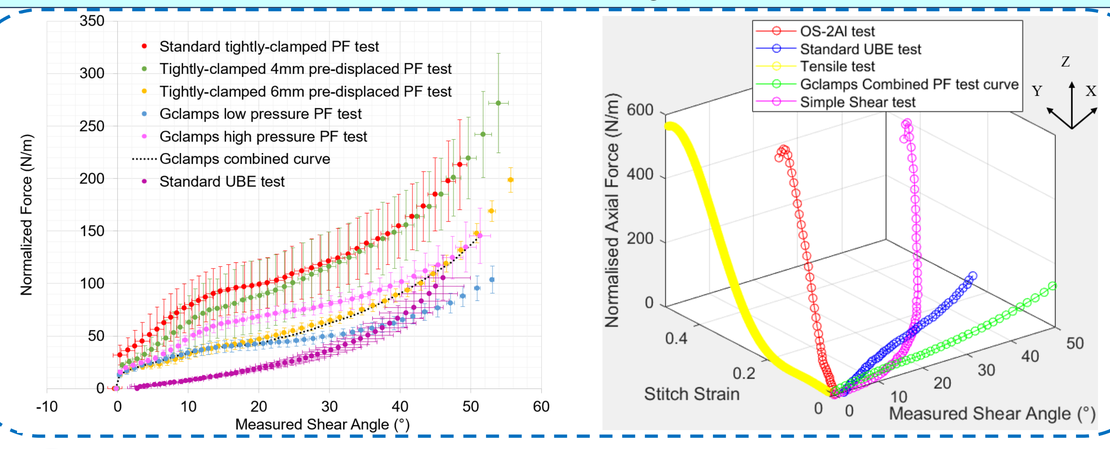
5 A NEW METHOD FOR MEASURING SIMPLE SHEAR

- The new simple shear test was designed to enhance the amount of stitch strain with uniform deformation of the sample by increasing the initial angle between stitches and axial force to 90˚.

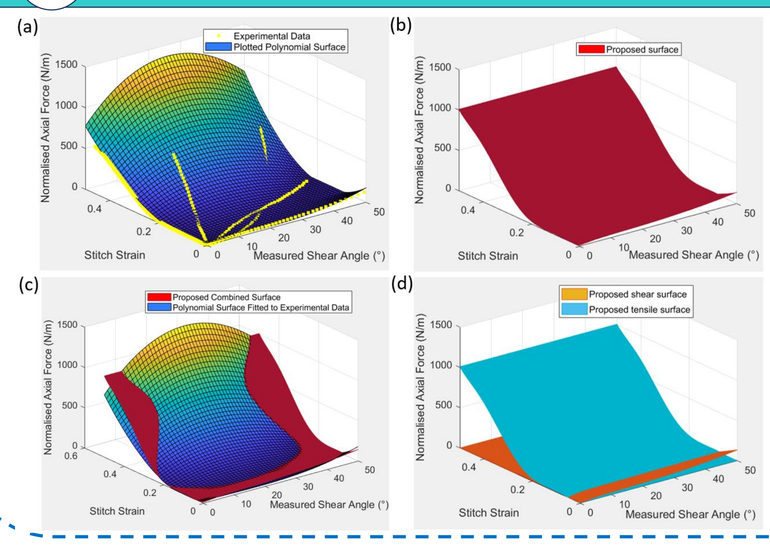


6 RESULTS

- In the PF test modification, the resulting combined G-clamped test curve is almost identical to the 6mm pre-displaced PF test result.
- The results of all shear tests are plotted in a 3D space to see how the test results changed in relation to normalized axial force, measured shear angle, and stitch strain



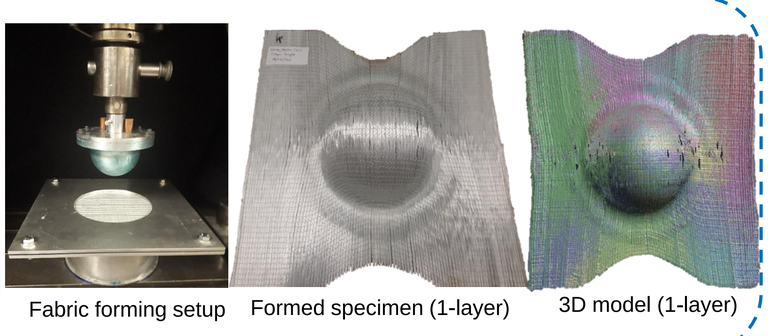
7 DECOUPLING OF SHEAR AND STITCH STRAIN CONTRIBUTION



- This decoupling process enables to gather approximate data, which is essential for the development of material constitutive models used in forming simulations

8 FABRIC FORMING

- One-layer (i.e., tow angle 90˚ & 45˚) & two-layer (i.e., tow angles 0˚/90˚, +45˚/-45˚ & 0˚/45˚) hemispherical specimens were formed.
- The specimens were scanned with a structured light scanner.



Fabric forming setup | Formed specimen (1-layer) | 3D model (1-layer)

9 CONCLUSIONS AND FUTURE WORKS

- It was postulated that the difference in behavior between two standard shear tests could be due either to: (a) experimental error or (b) a real change in forming behavior of the fabric in the two tests. Several novel tests are conducted to explore options (a) and (b).
- G-clamp combined PF test curve is almost identical to the 6mm pre-displaced PF test curve, which is significantly less than the standard PF test. However, the normalized force measured in the standard UBE test is low for the UDNCF at low shear angles.
- Novel test methods (OS-2AL and simple shear tests) were designed to overcome the complex non-homogeneous kinematics of the standard UBE test. In addition, these tests are more important for characterizing non-crimp fabrics, particularly those with stitch stretching, because they provide well-defined kinematics with different amounts of stitch strain.
- A novel approach was developed to extract the approximate shear signal by decoupling the proposed surface drawn to the experimental data. The true shear data extracted from this decoupling method will eventually be used to create appropriate material constitutive models. In the future, multiscale modelling approaches can be used to predict the input parameters for macroscale constitutive models for forming behavior.

10 ACKNOWLEDGEMENT

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