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Characterisation of inter-ply friction of a dry biaxial non-crimp fabric during preforming

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Project Aims

Reducing the inter-ply coefficient of friction can eliminate defects during semi-automated preforming processes by enabling increased levels of inter-ply slip (Figure 1). This work aims to:

- Characterise the **effect of fabric deformation on inter-ply frictional behaviour**
- Understand the **effect of the relative inter-ply fibre angle on the coefficient of friction**

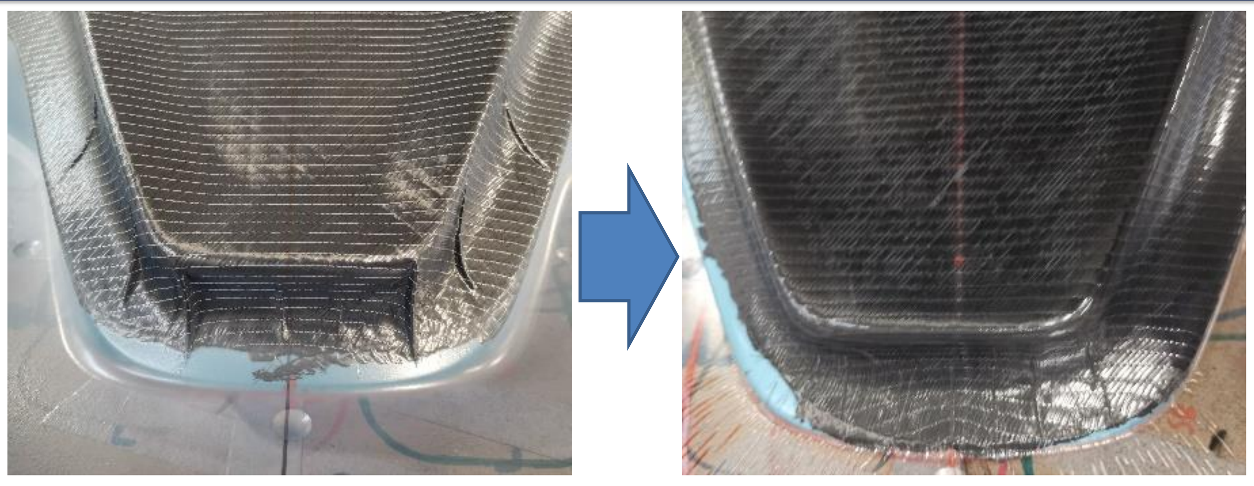

Figure 1 – Change in wrinkle distribution by reducing inter-ply coefficient of friction

Methodology

- Test developed to determine inter-ply coefficient of friction under representative fabric forming conditions
- Vacuum bag arrangement used to apply normal load to fabric samples fixed to support plates (Figure 2)
- Slip between plates generated by a universal testing frame. Force determined from load cell and displacement from video extensometer
- Data reduction required to isolate frictional forces, eliminating effect of tensile behaviour of diaphragm material and additional friction contributions

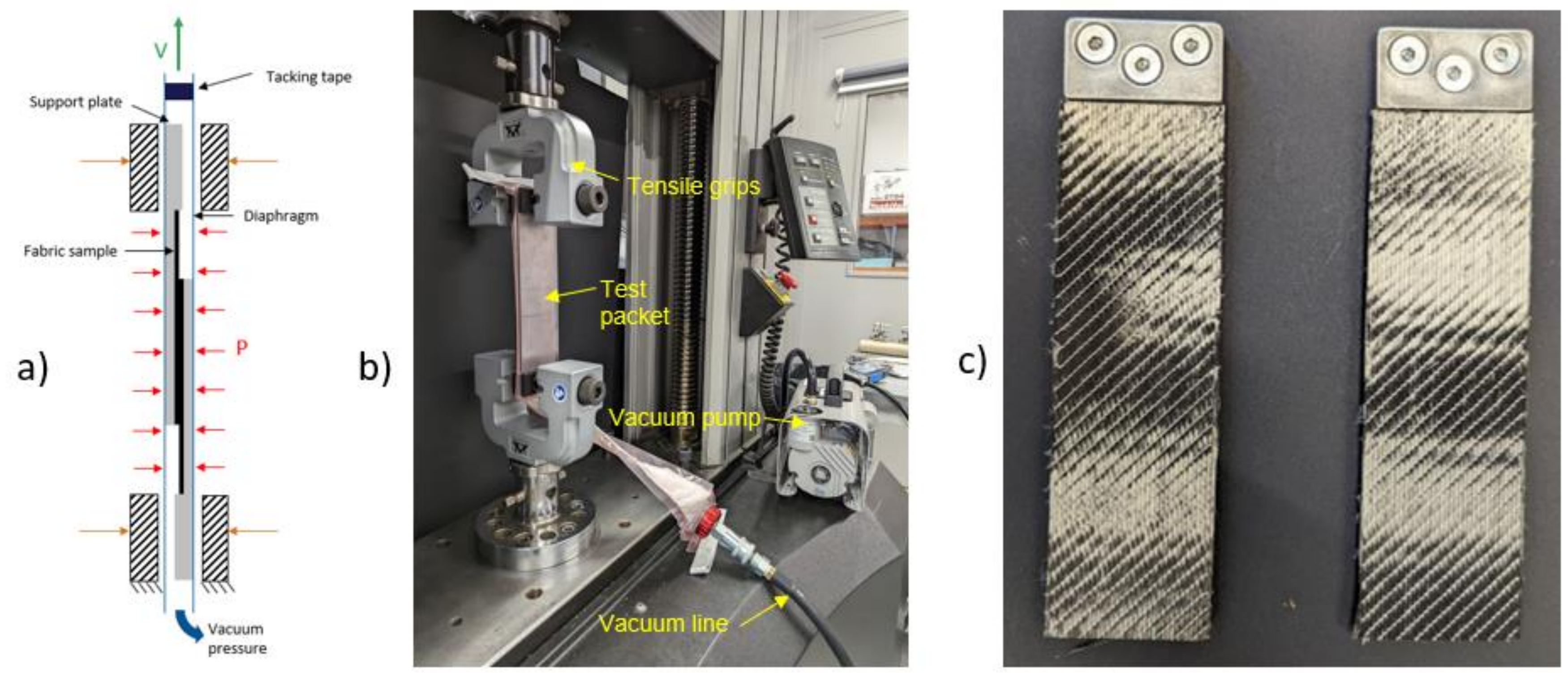

Figure 2a) Overlap test schematic. b) Test packet in-situ. c) Fabric samples mounted on support plates

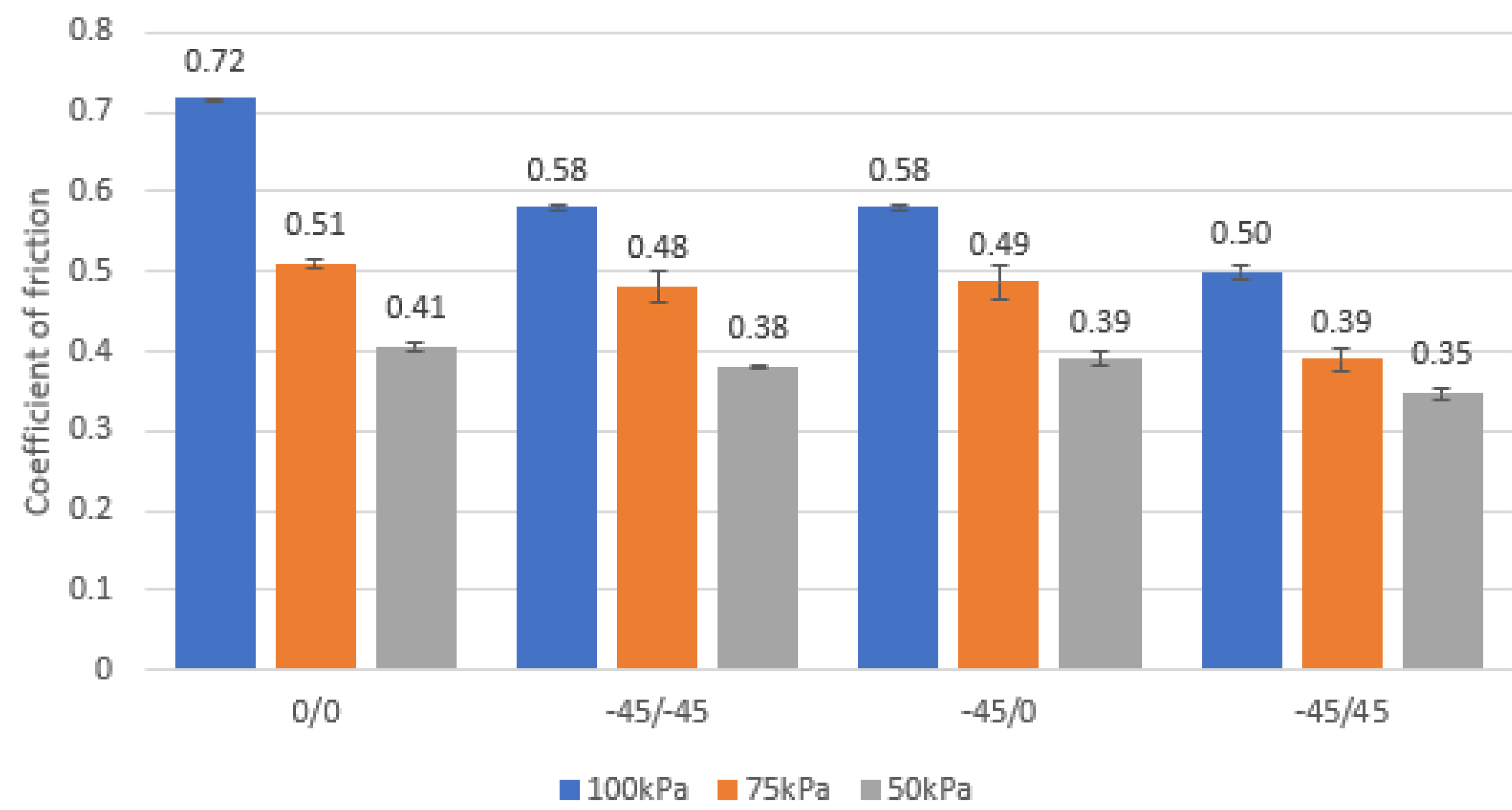

Figure 3 – Variation in dynamic coefficient of friction for 4 surface interaction orientations over 3 applied pressures. The relative inter-ply fibre angle increases from left to right

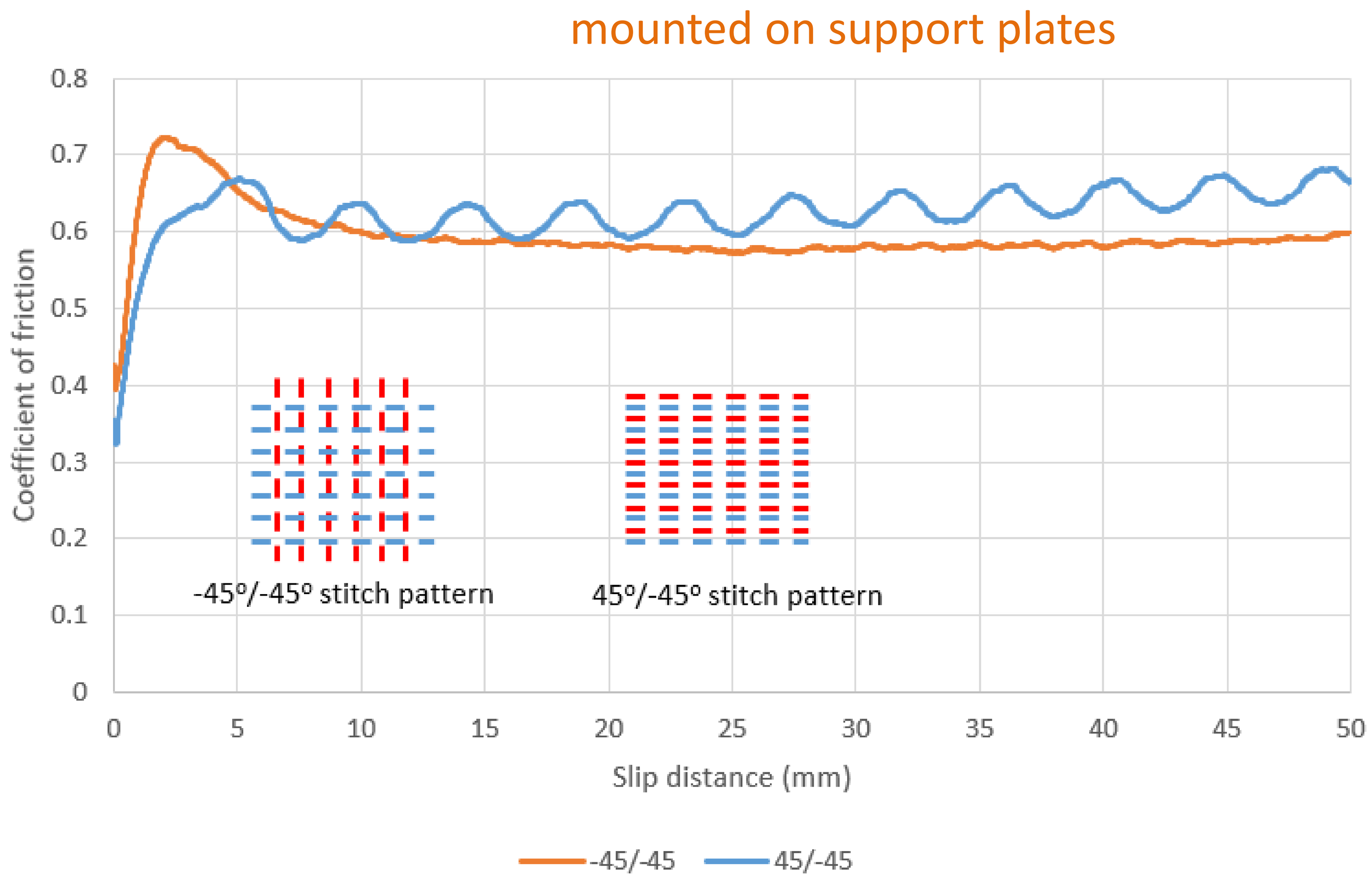

Figure 4 – Comparison of variation in coefficient of friction highlighting oscillations in frictional forces caused by stitch interference

Results and Key Findings

- **Coefficient of friction (CoF) is proportional to applied normal pressure**
  - CoF is 60% higher than values previously measured using other friction test methods (Figure 3)
  - Fabric deforms at higher compaction pressures and inter-ply contact area increases as fibre nesting occurs
- **Anisotropic behaviour**
  - CoF decreases as inter-ply fibre angle increases
  - Orthogonal fibres exhibit reduced nesting compared to parallel fibres and therefore lower CoF
- **Stitches affect sliding behaviour**
  - Parallel stitches produce oscillations in frictional force as they slide over each other (Figure 4)
  - Wavelength of oscillations corresponds to distance between stitches
  - Wavelength increases with inter-ply stitch angles

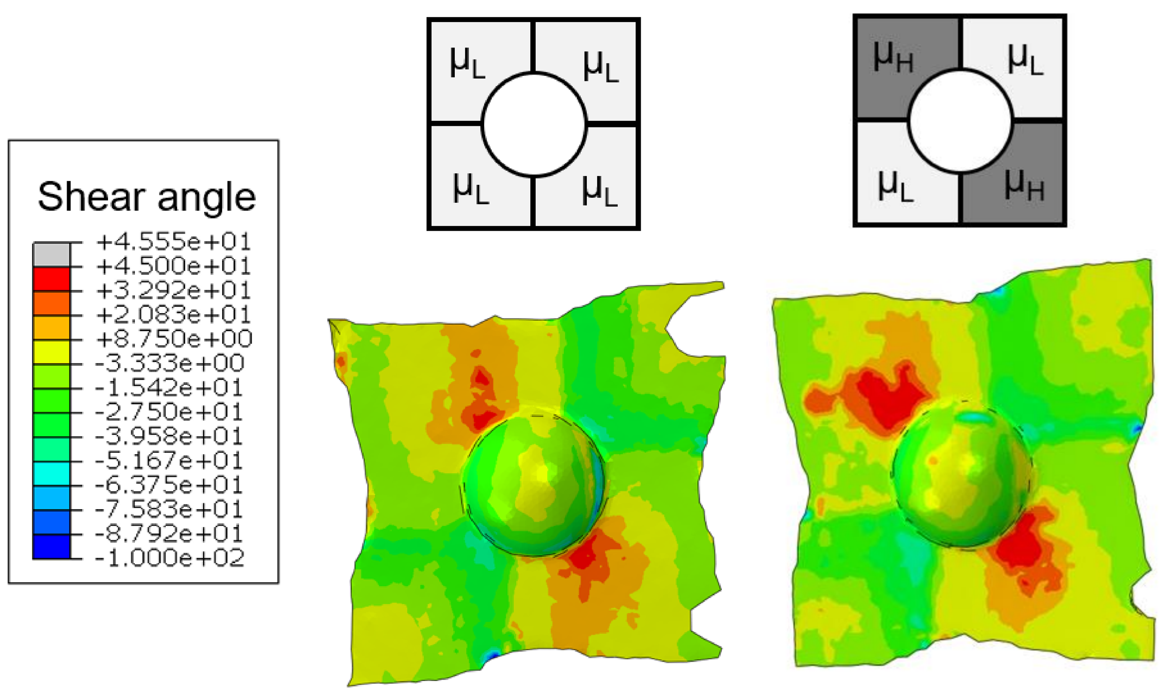

Figure 5 – Effect of varying tool-ply coefficients of friction on the local shear angle of a hemisphere preform

Future work

- Understand significance of local friction variation on formability of preforms (Figure 5). Initial results suggest that variation caused by pressure is significant.
- Predict frictional behaviour using a VFRICTION subroutine in Abaqus Explicit, capturing anisotropic behaviour
- Mitigate wrinkling defects during preforming by manipulating coefficients of friction

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