EXPERIMENTAL STUDY OF FLOW-INDUCED IN-PLANE DEFORMATIONS OF SATURED FIBROUS REINFORCEMENT DURING COMPRESSION

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Introduction

Compression moulding can be described as a process where a fluid flow occurs in a deformable porous medium. During the process, the fibrous preform evolves from a lubricated through unsaturated and finally a saturated state when the targeted geometry of the designed part is reached. Nowadays, a wide panel of matrices exists, such as molten thermoplastic polymers or thermoset resins. As a consequence of the development of such material, processes have to be reliable with a huge range of fluid properties, and particularly over a range of viscosities from 10^{-2}Pa.s for reactive thermoplastic monomers or thermosets to more than 10Pa.s for high fluidity molten thermoplastics [1]. Additionally, in order to answer the high demand for industrial products, processing times continuously decrease, leading to a strong coupling between the fluid and the fibrous architecture. This coupling can induce different flow regimes. When the viscosity of the resin and the mold closing speed are low enough, drag forces induced by the flow are too low to convect the fibres and a filtration flow occurs (Figure 1a). Another regime is observable when the viscosity of the resin or the compaction velocity high enough, the drag forces become higher than friction forces and induces fibres in-plane motion or washout (Figure 1b).

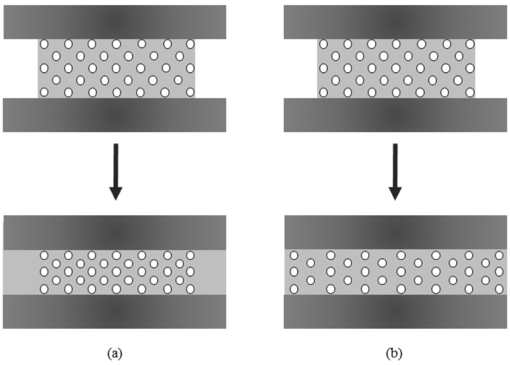

Figure 1: *(a) Filtration flow - (b) Squeeze flow convecting fibres*

The deformations of fiber beds can be visualised using a glass platen as part of the mold. Experimental transverse visualisations of flow progression and fibres bed compaction have been carried out on fiber mats [2] and woven fabrics [3]. The objective of the study is to detect experimentally the onset and quantify the tow-induced in-plane deformations.

Experimental method:

A 60cm diameter glass platen is used as lower mold mounted under an INSTRON 8805 test machine with a rotuled 30cm diameter compression platen. This setup allows the visualisation of flow in samples up to 40cm side length. A range of silicon oil (Roth) is used to impregnate the fabric until a desired saturation rate. The fibre wash-out is visualised and quantified thanks to colored dots. The two colours are placed respectively on warp and weft tows. Figure 2 presents the transition from the raw acquired image (Figure 2a) to the processed one (Figure 2b). In order to detect the onset and the magnitude of the fibre wash-out, a Matlab ® algorithm has been developed, based on dot tracking over the batch of acquired frames (Figure 2c).

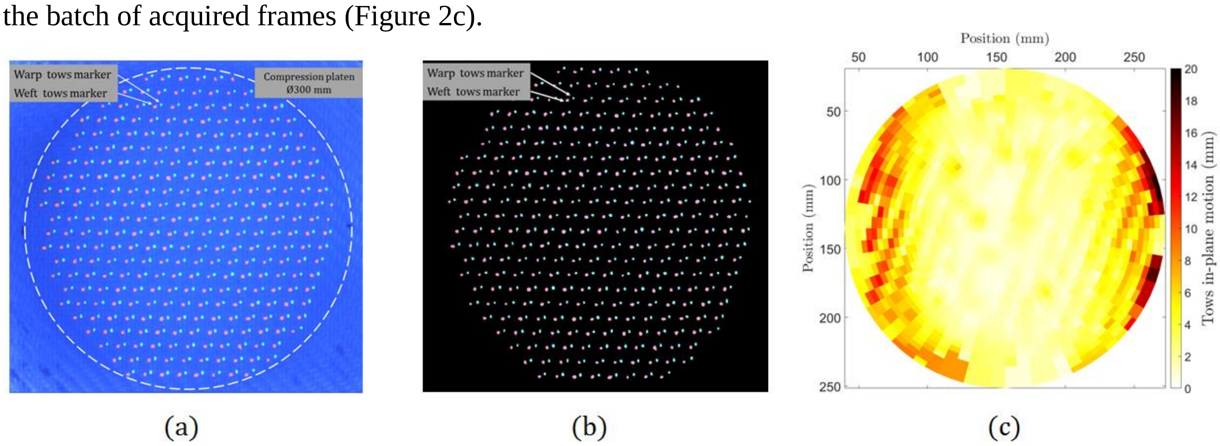

Figure 2: *(a) Raw acquired image - (b) Processed Image – (c) Full-field measurement of in-plane motion*

Results:

Depending on the fluid-solid viscous stress, a filtration flow in a static porous media or a tow convecting one occurs. Vision in-plane fibrous motion results (Figure 2c) can be confronted with compaction ones to give a precise evolution of washout phenomenon during the composite consolidation. Figure 3 presents the sample in-plane motion and the mechanical response of the saturated preform as a function of the fibre volume fraction. Results show that the onset of the in-plane washout coincides with the collapse of the saturated fibrous preform compression curve.

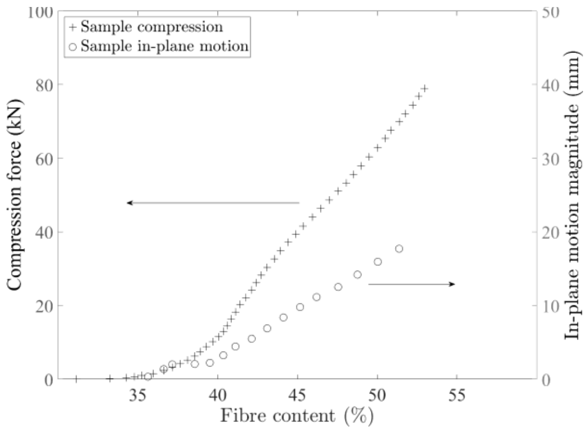

Figure 3: *Mechanical response of flow-convected fabric during transverse compression*

Conclusion:

The presented method allows the full-field measurement and the detection of the mechanical signature of the saturated fibrous preform in-plane deformation during compression.

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