CAPTURING THE VARIABILITY OF TEXTILE PERMEABILITY FROM SCANNED IMAGES; A TOOL TO AUTOMATICALLY COMPUTE A TEXTILE PERMEABILITY MAP

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Introduction

Liquid Composite Moulding (LCM) process simulations are increasingly used as process design tools to select optimal manufacturing parameters for fibre reinforced polymer (FRP) composite materials [1]. Accurate permeability data of reinforcing textiles is essential input for these simulations. It is desirable to capture the textile's permeability as well as its spatial variation in order to improve the accuracy of the process simulation. For this, a tool has been developed to predict the permeability map of single layer woven textiles compacted at different thickness. The resulting permeability maps have then been used to predict the flow front positions and have been validated against experimental results.

Permeability Prediction Process

An automated tool has been developed, utilising textile modelling techniques to generate permeability predictions for unit cells. Figure 1 outlines the steps involved in this prediction process. These steps are performed directly from the Matlab environment without any user intervention. When a step is completed using an external software package, the appropriate scripts are generated and executed from within Matlab. Such an automated tool enables the efficient analysis of a large number of unit cells. The unit cells can then be used create a permeability map for a range of textile samples.

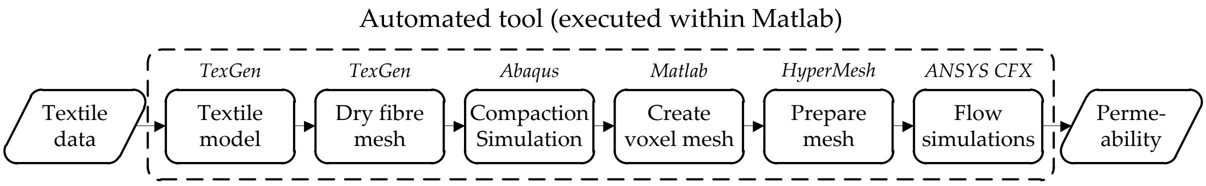
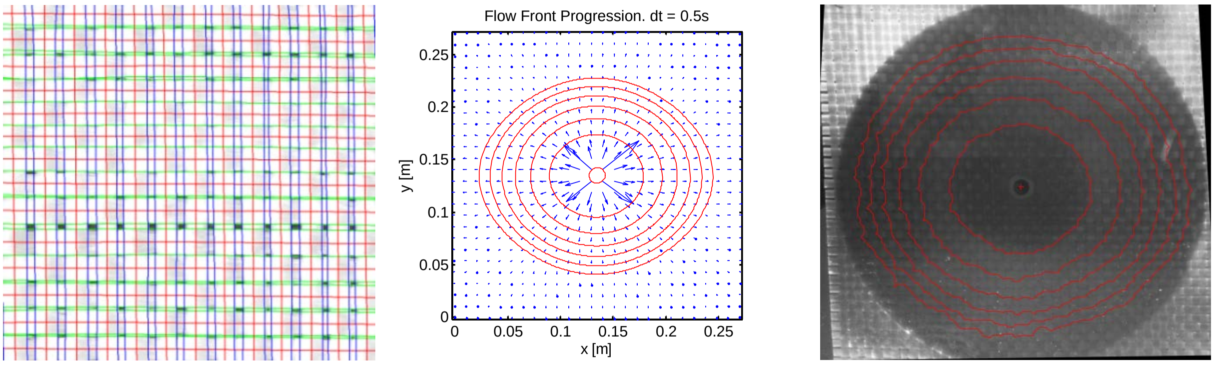


Figure 1: *Automated tool steps*

A scanning set up has been incorporated into the existing 2D in-plane permeability facility at the Centre for Advanced Composite Materials [2]. This provides high resolution scans of the reinforcing textiles prior to compaction and injection without the risk of further handling deformations. These scans are used to determine the uncompacted textile geometry using a previously developed image analysis technique [3]. The scanned material geometry data is used to generate a range of unit cell geometries in TexGen [4]. Here, the yarns are treated as solid volumes with the cross section shape defined as the smallest ellipse that encompassed all the fibres within the yarn.

Compaction simulations are applied to the unit cells, reflecting the change of geometry due to the compaction step of the LCM process. Simple linear elastic material properties are applied to the yarn bundles, capturing the predominant changes in geometry. A novel algorithm to automatically generate a voxel mesh representing the volume of resin around the compacted mesh geometry is then applied. This works automatically and can account for cases where the compacted mesh contains small element intersections. The voxel mesh is then automatically cleaned to delete any floating elements and the boundary regions are defined.

Flow simulations are carried out in Ansys CFX, with a pressure gradient imposed between the inlet and outlet boundaries. Non-slip wall conditions are imposed on the top and bottom surfaces of the unit cell as well as the boundaries between the fluid domain and the fibre yarns. Translational periodic boundaries are used for the two sides, to reflect the periodic structure of the textile [5]. The resulting mass flow rate is used to compute the unit cell meso-scale permeability through the application of Darcy's law [6]. In order to compute the permeabilities of the unit cell in the different directions (e.g. weft and warp), the location of the boundaries are altered, however the same mesh is used.



(a) (b) (c)

Figure 2: *Output results; (a) section of textile geometry identified using image analysis techniques, (b) Predicted flow front evolution from predicted permeability map and (c) actual flow front evolution observed*

Tests were conducted on single layer samples of 800 gsm plain weave and 300 gsm 2x2 twill weave glass textiles at different cavity thicknesses and a predicted permeability map generated for each. These permeability maps were used to execute the process simulations and compute the predicted flow front positions, which were then compared with the observed ones obtained by conducting the permeability experiments on the textiles examined as shown in Figure 2. By scanning the textile directly within the permeability testing facility, a permeability map is able to be generated for the textile in its final form, enabling direct comparison of the predicted and the observed flow front during injection.

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