IMPREGNATION OF COMPOSITES AT THE UNIT CELL LEVEL

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Introduction

Thermoplastic composites have a good potential to improve the cost-effectiveness of polymer fabric composites. The impregnation process of standard thermoplastic materials is however not straightforward due to their high viscosities [1]. The impregnation process should however be void free in order to reach optimal properties.

The prediction of the impregnation process is not straightforward and is generally done with continuum models. These models often use permeability measurements as input for the analyses. The effective permeability of the fabric is highly affected by the fibre distribution and is generally anisotropic. Furthermore, the fabric will deform during impregnation.

Here, the prediction of the permeability is addressed with a new modelling technique developed by ESI software. The Finite Pointset Method (FPM) [2] is a meshless modelling technique which can incorporate the Fluid Structure Interaction (FSI) between the thermoplastic material and the still dry preform. The FPM method is validated by a flow case and its applicability is shown by impregnation of a fabric unit cell at the meso level.

Validation case

Validation of the FPM method was done by measuring the deformation of a rubber rod in a pipe due to flow. The flow rates in the experimental set-up remain low (less than 10 cm/s), limiting the Reynolds numbers, and preventing flow instabilities. The experimental set-up is shown in figure 1.

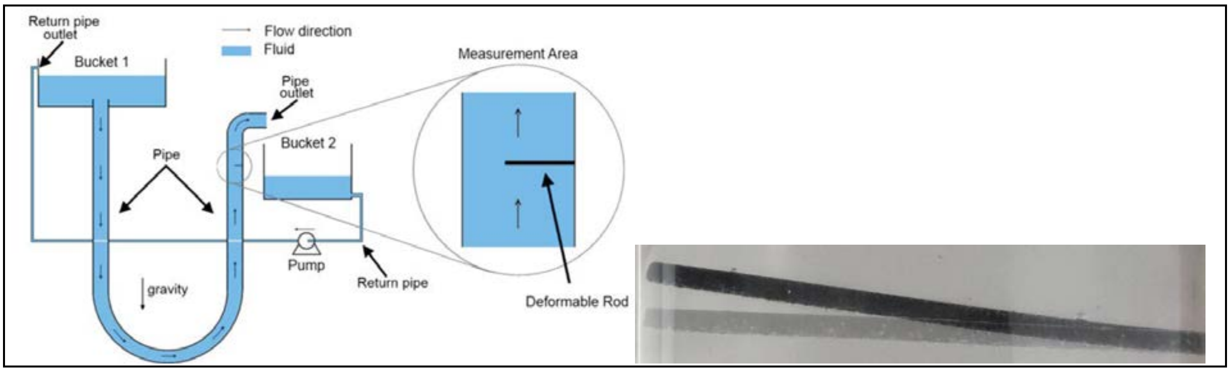

Figure 1: *Experimental set-up to measure the flow induced deformation of a rubber rod. The left hand side shows the schematic setup of the experiment while the right hand side shows the detail of the rod in the pipe during the experiment. The deformed (black) and undeformed (grey) shape are shown in the photograph.*

The measurement area is positioned in the area where the flow is fully developed. Syrup (60% sugar in H_2O) was used as the flow medium in the experiments. The viscosity of the syrup was measured in a rheometer (Newtonian flow). The inner diameter of the transparent pipe is 54 mm. The 48.7 mm long rubber rod with a diameter of 2.3 mm has a tensile modulus of 9 MPa. The rod is glued into a side of the pipe-wall, whilst the other end of the rod is free to deform. The experimental tip displacement of the rubber rod due to syrup flow and the modelling results are shown in figure 2.

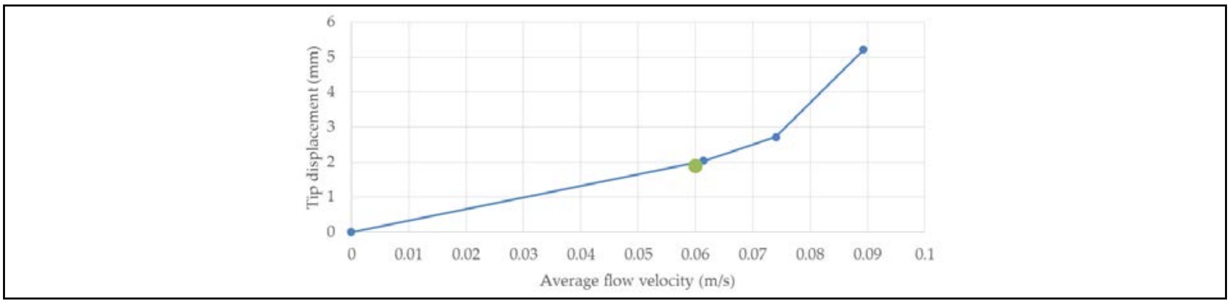

Figure 2: *Experimental and modelling results. The graph shows the average flow velocity (m/s) versus the tip displacement of the rubber rod (mm). The blue line represents the experiments, the green dot the simulation results.*

Impregnation of unit cell

Unit cells are commonly used to predict the mechanical properties of fabrics. Here, a plain weave unit cell is used to show the applicability of the FPM method. The plain weave unit cell is impregnated at the meso level, ignoring impregnation at the intra yarn level, allowing a surface based approach for the interface of the rigid yarns. The results of modelling are presented in figure 3.

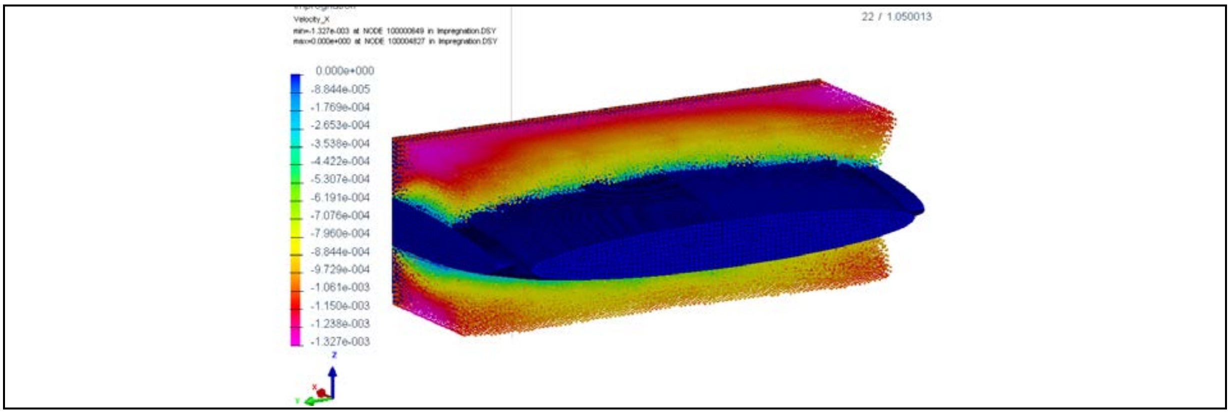

Figure 3: *Impregnation of a plain weave unit cell at the meso level showing the velocity profile (m/s) during inflow with a constant velocity. A no-slip condition was used at the yarn interface surface and slip conditions at the other surface.*

Acknowledgements

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