MODELING AND VALIDATION OF THROUGH-THICKNESS FLOW IN FULLY WETTED TEXTILES DURING CONSOLIDATION

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Introduction

Prepreg systems can be designed to bleed out resin in excess during the consolidation phase in through-thickness direction. The resin bleeding enhances the extraction of entrapped gases and moisture from the laminate. However, the transverse flow induces an uneven distribution of fibre volume content. Those inhomogeneities may persist in the cured laminate; therefore, a reliable model of the consolidation phase is essential in the design of robust prepreg processing. In the literature, several models exist which describe the consolidation of a wet laminate [1-2]. In this study, we develop a fully coupled model, which considers the interactions between the resin flow and the textile deformation. Up-scaling rules describing the influence of viscosity and laminate thickness on the pressure evolution are derived. Furthermore, the model is validated by comparing the fluid pressure measured at the bottom of the laminate and the laminate consolidation with numerical results.

Model description

The presented flow model describes the saturated transverse flow of a non-reactive fluid through a compressible porous media under isothermal conditions. The model is implemented in COMSOL® Multiphysics, describing the flow by using a heat transfer model (see also [3]) and coupling the structural response of the textile as a function of fluid pressure by defining an appropriate coefficient of thermal expansion. The material data, through-thickness permeability and fibre compaction are defined based on experimental measurements performed using the procedures described in [4].

Experimental Setup

The experimental setup consists in pre-impregnated plies of the carbon fibre woven fabric CF5804-A from Sigmatex laid down on a tool with an embedded pressure sensor, which enables the monitoring of the fluid pressure at the bottom of the layup. A honeycomb aluminium core is placed on the top of the laminate to ensure free flow of the fluid in transverse direction. Two different silicon oils are used to impregnate the textile: Bluestar 47V5 with a viscosity of 5Pa*s and Bluestar 47V30 with a viscosity of 30 Pa*s. The setup is embedded in a vacuum bag, in which the vacuum pressure is controlled through a valve and a laser sensor is positioned on the top to measure the laminate consolidation.

Results and discussion

In the study, three different setups are considered: 8 layers of fabric and V5 oil, 12 layers of fabric and V5 oil and 8 layers of fabric and V30 oil. Figure 1a shows the simulated fluid pressure drop at the bottom of the layup for the three different configurations. The curves correspond qualitatively quite well with the experimental results (figure 1b). The flow time in transverse direction shows a quadratic relationship to the number of layers (laminate thickness) and a linear dependency to the fluid viscosity. Figures 1d and 1e show that the pressure curves normalized according with those up-scaling rules coincide very well in the numerical simulations as well as in the experiments. The comparisons between experimental and numerical results show generally good agreements, as it can be seen in figure 1c and 1f for the experiment with 12 layers and the V5 oil. Small discrepancy may be accredited to the viscoelastic behaviour of the fabric.

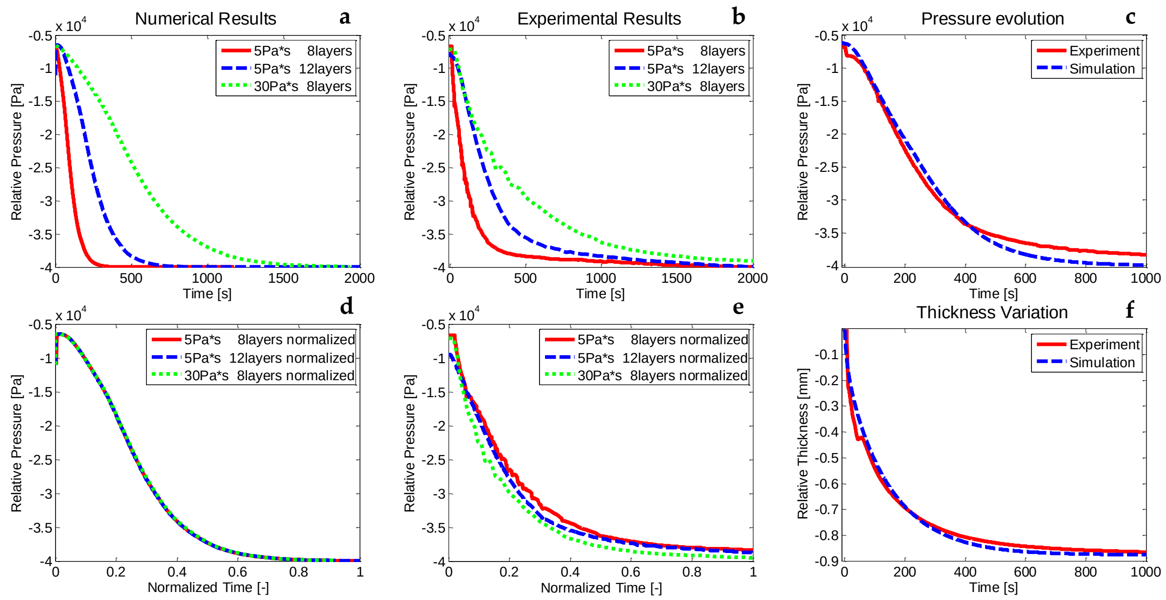

Figure 1: *Numerical (left: a,b) and experimental (center: b,e) fluid pressure evolution and model validation (right: c,f).*

Conclusion and Outlook

In this study, we used a combined experimental/numerical approach to quantify the influence of process parameters and material properties in the prepreg consolidation process. We derived up-scaling rules which describe the dependency from the fluid viscosity and the number of layers of textile. Moreover, the proposed model has been validated, showing good agreement with the experimental results. Further investigations will aim to study the influence of the viscoelastic behaviour of the textile on the fluid flow.

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