DESIGN OF A QUASI-UNIDIRECTIONAL FABRIC FOR RTM PROCESS WITH HIGH FLUIDITY THERMOPLASTIC: LONGITUDINAL PERMEABILITY AND MICROSTRUCTURE

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Introduction

The project ThermoplAstic Process for Automotive Structure (TAPAS) was kicked in 2012, gathering several French industrial and academic partners. The mean idea of the project is the use of high fluidity polyamides - viscosity values between 5 and 25 Pa.s - suitable for Resin Transfer Molding (RTM) process. The targeted objective is to demonstrate the adaptation of these polyamides to production rates of automotive industry. However, these viscosity values remain higher than the ones for epoxies or polyesters used in "classical" RTM. To maintain acceptable process cycle time, it is essential to increase by two decades the longitudinal permeability of the fabrics. Thermoplastic polymer/fiber reinforcement couple choice depends on the balance between high permeability fabric, good drapability and high mechanical performance. Present work focuses on variations of UD fabrics with the highest permeability possible at a minimum volume fiber content V_f of 50%.

Materials and Methods

Two quasi-unidirectional woven fabrics (UD 8134 and UD 8135 developed by Chomarat) are designed with 1200 tex glass yarns (warp) and 70 tex yarns (weft). Both yarns are maintained by crimped 34 tex yarns (warp). 8135 differs from 8134 by a double density of weft yarns, i.e. one every 5mm. Areal weight is defined to be 500 g.m^{-2} for both 8134 and 8135.
Longitudinal permeability is measured experimentally along warp and weft directions in transient and saturated regimes. Samples at different V_f are elaborated by RTM using an epoxy resin and their microstructures are studied with SEM and X-ray Tomography. Different models have been tested to assess permeability: network of Poiseuille-like channels, numerical approach by mean-field homogenization [1] or higher order geometrical descriptors [2] and double-scale porosity model based on Kozeny relation [3]. The latter one expresses geometrical permeability, K_{Geo} , as the sum of the permeabilities in macropores, K_M , and in micropores, K_μ , weighed respectively with the surface fractions of the macropores, $A_A(P_M)$, and of the micropores, $A_A(P_\mu)$:

$$K_{Geo} = \frac{K_\mu A_A(P_\mu)[1 - A_A(P_M)] + K_M A_A(P_M)}{A_A(P)} \qquad (1)$$

with the global surface fraction of porosity $A_A(P) = A_A(P_\mu)[1 - A_A(P_M)] + A_A(P_M)$.

Results and discussion

Results for saturated permeability along the warp are exposed in Figure 1 where they are compared to the values of a stitched quasi-unidirectional previously studied [3].

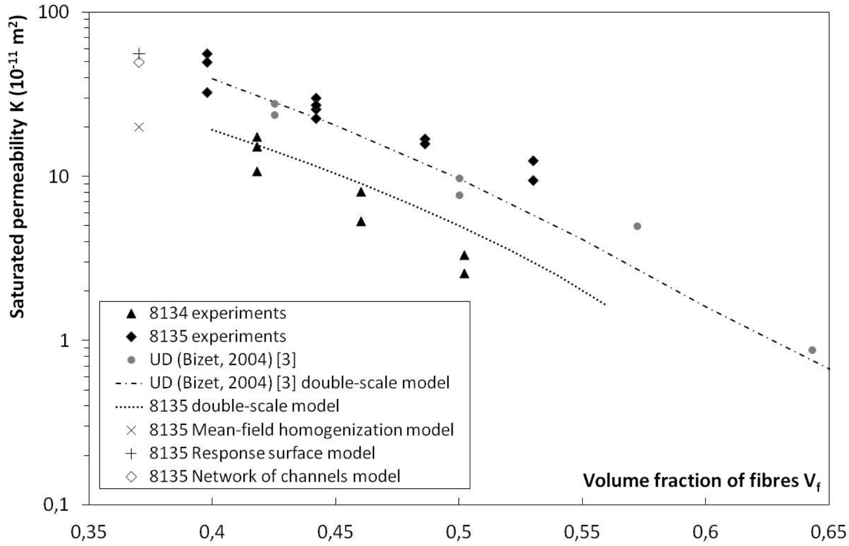

Figure 1: *Comparison of the different methods for determination of longitudinal warp permeability in saturated regime.*

At identical Vf, experimental permeability is around 50% higher for 8135 than the stitched UD whereas for 8134, it is 30% lower. This means that macropores in 8135 have a higher hydraulic conductivity than the ones in 8134. Microstructural studies confirm that macropore content is higher in 8135 than in 8134. Two models (network of channels and response surface) based on microstructure show a good agreement with 8135 experiments. Mean-field homogenization and double-scale models predict lower values.

Weaving modifications of 8135 ply will be undertaken in order to modify the geometry and the connectivity of pores inside the preform. A test with a larger crimped maintaining yarn is in progress. This type of geometry modification should improve permeability in TP-RTM while maintaining final mechanical properties of the composite parts at an acceptable level.

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