# Modelling of RTM Mold Fill Operation with Preform Permeability Properties for Multilayer Interlocked Fabric Preforms

**R. Alagirusamy[1], Naveen V Padaki[2], B.L. Deopura[1] and R. Fangueiro[3]**
[1]Department of Textile Technology, Indian Institute of Technology-Delhi, New Delhi – 110 016, India.
[2]Central Silk Board, Guwahati-781022. India. E Mail: naveenvpadaki@gmail.com
[3]Department of Textile Engineering, University of Minho, Guimarães-4800 058, Portugal.

Characterization of woven fabric structures and simulation of resin flow through them have been studied by several authors before [1-4]. Objectives of the present work are, to simulate RTM resin flow using determined preform permeability properties as input using Fluent software, to compare the flow predictions with experimental data and to analyze the RTM flow behaviour with respect to multilayer structure.

## Model Description

A 3D multiphase CFD model was built to simulate the resin flow through multilayer preforms during RTM operation. Prior to resin injection inside the mold through the preform, there is air or void space if a vacuum is drawn. During injection there are multiple flow areas with resin and fibers in one region and fibers and air or void space in another. Many a times transition region exists between the two where air and resin coexist in varying concentrations. Hence a multiphase flow model has been developed for the RTM flow simulation. This model not only provides visuals of resin flow (flow front) in the mold but also depicts the transient behaviour of flow of two phases (air and resin) where the initial air phase is replaced by the resin during mold fill process. Interphase of such multiphase is modeled using Volume of Fraction (VOF) - multiphase option in the Fluent software [5]. The tracking of the flow front or the interface between the phases is accomplished by the solution of a continuity equation for the volume fraction of one (or more) of the phases in VOF formulation.

## Experiments

All the RTM flow experiments were conducted with an unsaturated polyester resin system (GP grade) in uncatalysed form to maintain the transparency of the mold intact. The viscosity of the resin system was found to be 600 cP at 25°C (Brookfield viscosity, determined by spindle BS-29 at 25°C, 50 rpm). A clear view of the flow fronts was recorded during the RTM experiment using a Kodak digital camera (EasyShare C315, 5megapixels, Lens 36mm) mounted on a tripod above the mold assembly. Three trials were taken with each multilayer preform and the mold fill time and flow front videos were recorded.

## Results and Discussions

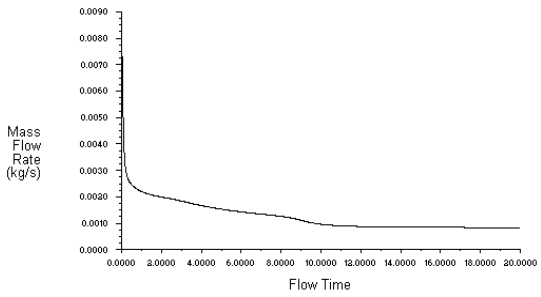



Figure 1. Mass flow rate at inlet (N2P1-1.5mm)

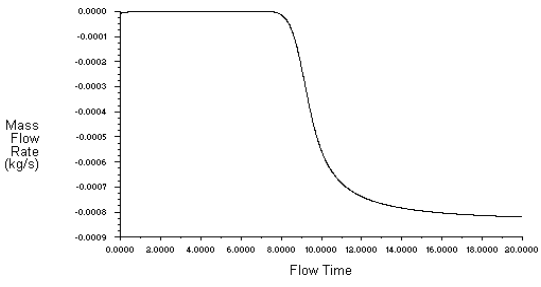


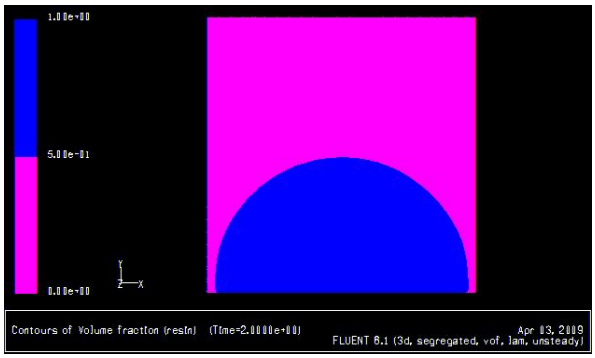

Figure 2. Mass flow rate at outlet (N2P1-1.5mm)

Figure 1 & 2 provide the resin mass flow rate plots with respect to flow time obtained by the 3D multiphase model RTM flow simulation for N2P1 sample with 1.5mm spacer thickness. It

can be observed from the outlet mass flow rate plot, that the resin starts to flow out from the outlet after 8 seconds and after 15 seconds reaches a steady rate.

**Image analysis of simulated and experimental flow front**

Images of the flow front during the RTM process at 2 seconds were taken from the simulated multiphase model results and experimental videos. The images (Figure 3) were subjected to comparative analyses by image processing technique using Image J software. Areas of resin flow in the simulated and experimental frames were calculated. It was observed that the flow are at any given time was generally higher for the multiphase model compared to the experimental results.




(a) Multiphase simulated flow area


(b) Experimental RTM

Figure 3. Contour of resin flow front in N2P1 (1.5mm) at 2 secs

A graph of flow area at 2 second flow duration against interlacement index shows that flow area decreases with increased interlacements in the multilayered preforms. This could again be explained with level of interlacements in the multilayered structures, straighter will be the yarn in fabric with lower interlacements, and hence better will be the resin flow for multilayered preforms with lower interlacement index.

**Conclusions**

A 3D Multiphase model has successively been developed to predict the time required for RTM mold filling based on the permeability properties of the multilayer fabrics. Mould fill time predicted using multiphase model (error % ≈ 8.8 & 12) is found to be reasonable compared to the experimental time for RTM mold fill. Fabric structural factor Interlacement index has significant influence on the resin flow behaviour of the preform. Higher the interlacement index of the preform higher is the time taken to fill the mold in both experimental and simulated results.

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