MANUFACTURING CARBON FIBRE COMPOSITES WITH HIGH PRESSURE RESIN TRANSFER MOULDING

Ffion A. Martin[1*], Nick Warrior[1], Suresh Advani[2], Pavel Simacek[2]
Adrian Hughes[3], Roger Darlington[3]
[1] *Faculty of Engineering, University of Nottingham, University Park, Nottingham, NG7 2RD, UK*
[2] *CCM, University of Delaware, Academy Road, Delaware, USA*
[3] *Research & Technology, Jaguar Land Rover, University of Warwick Campus, CV3 4LF*
*Corresponding author (ezxfm@nottingham.ac.uk)

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Introduction

Very short manufacture cycle times are required if continuous carbon fibre and epoxy composite components are to be economically viable solutions for high volume composite production for the automotive automotive industry. A manufacturing process variant of resin transfer moulding (RTM), denoted high pressure resin transfer moulding (HP-RTM), targets a reduction of in-mould manufacture time by reducing the time to inject and cure components. To produce high integrity automotive composite components, high confidence in the manufacture and quality of the parts is necessary and virtual tools are a significant aid to enhance the development processes.

The following study was undertaken to explore the application and development of the traditional modelling methodology using Darcy flow through porous media to simulate the high pressure resin transfer moulding process. Experiments are performed using industrial standard HP-RTM equipment. Simulation was performed using the University of Delaware LIMS software.

The implication of the top to bottom tool gap size relative to the dry preformed laminate is studied in experiments and simulation, as well as the implication in the process of variance in the preforms.

Material and Method

The non-crimp fabric reinforcement used in the experiments is an industrial NCF fabric and the matrix resin system is an experimental resin system . The HP-RTM equipment located at the UK's National Composites Centre comprises a 36000kN press from Schuler and HP-RTM injection equipment from Krauss-Maffei (KraussMaffei RimStar Compact 4/4/4) and was used for the trials.

The flat plaque manufactured in the experiments has dimensions 1240x790mm with an additional side tab from which the panel is injected measuring 318x147mm, figure 1 shows the panel geometry.

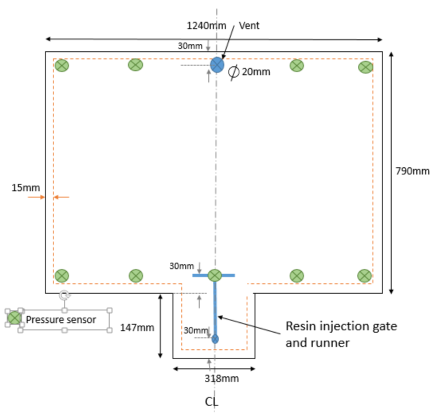

Figure 1: *Schematic of the Panel Geometry and Sensing Equipment*

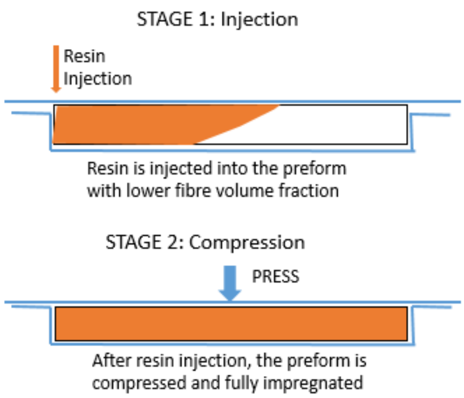

Figure 2: *Injection and Compression Stages in the Manufacture Process*

The manufacture process injects the resin at a fixed volume flowrate into the steel tool which is maintained at 120degC by an oil heating systm. The experimental resin has a cure time of 5 minutes at 120degC, thus the cavity injection must be complete prior to the rapid increase in viscosity at this temperature. A resin flow rate of 75g/s was used in the experiments. In-mould pressure was recorded by Kistler pressure sensors.

The manufacture follows a process whereby the top to bottom tool gap size is fixed at a distance larger than the nominal part thickness during the injection. After the injection is complete, the press uses a pre-prescribed amount of force to close the cavity to the part thickness.

Moulding simulation is performed in two stages: the injection stage whereby resin is injected into a cavity greater than the component thickness, and the compression stage where the press closes forcing the resin flow by volume change of the cavity illustrated in figure 2.

Results

Observations from these experiments show the presence of a racetrack resin channel around the perimeter of the mould. A parametric study is run using the flow simulation to assess the effect of racetrack permeability on flow front progression, filling time and press force. The corresponding experiment with the prescribed volume of resin injected in the first stage is compared to the simulation output.

Increasing permeability in the racetrack channels reduces the in-mould pressure measured, this is as anticipated due to the Darcy flow relation between permeability and pressure gradient. The experimental cavity pressure is somewhat enveloped by the simulation study, the results are presented in figure 3.

The time to compress the component to the absolute top to bottom tool thickness is also reduced as permeability in the racetrack channels is increased. Press force in the experiment is limited to 8500kN; no force limit was imposed in the simulation. It is apparent in figure 4 that the absolute thickness is not achieved in the experiment; simulation calculates that a press force of higher magnitude is necessary to achieve the absolute thickness, the simulation compresses at a faster rate using a larger force than the experiment.

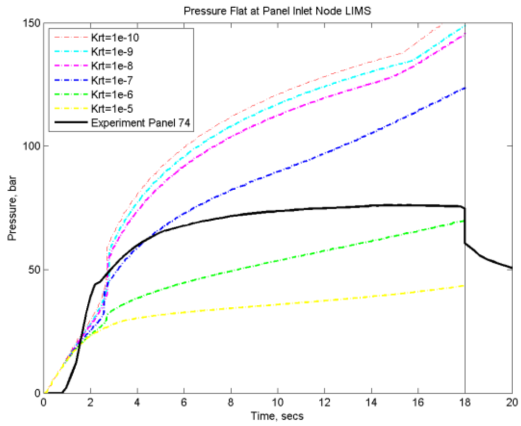

Figure 3: *LIMS Simulation Output and Experimental Data: Pressure During Injection*

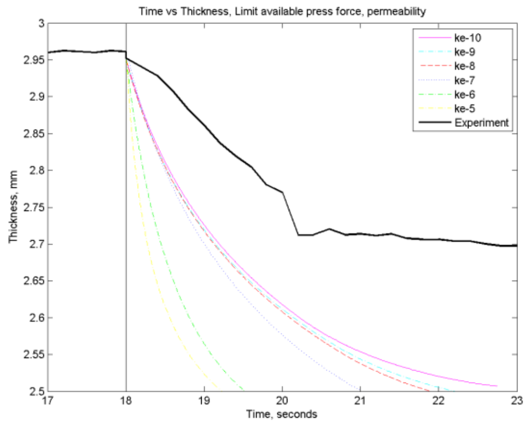

Figure 4: *LIMS Simulation Output and Experimental Data: Top to Bottom Tool Thickness During Compression*

Conclusions

The moulding simulation developed to represent resin infusion in the HP-RTM process is implemented to calculate in-mould pressure during injection and the necessary force to compress the laminate to absolute thickness. Results encompassing aspects of preform variability envelope the corresponding experiment.

Acknowledgements

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