SIMULATION OF THE COMPRESSION RESIN TRANSFER MOULDING FOR FAST CURING RESINS

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Introduction

Lightweight structures are of particular benefit for CO_2 reduction in various fields of transportation. However, carbon fibre reinforced polymers have not yet achieved a broader success due to slow manufacturing processes, making them inadequate for high volume production. The compression resin transfer moulding (CRTM) process is characterized by having a very short impregnation flow in out-of-plane direction compared to the resin transfer moulding (RTM) process, where flow is mainly in-plane. Furthermore improved interfacial properties have been reported for the CRTM process, indicating a synergistic effect between short cycle time and part performance [1]. Processing limits could be identified by representing the interaction of viscous forces, fabric compaction and permeability over time.
The goal of this study was the evaluation of the CRTM process for very fast production of epoxy matrix composite parts.

Experimental

The epoxy resin system XB 3585 / XB3458 was supplied by Huntsman Advanced Materials GmbH, Switzerland. As reinforcement, non-crimp fabrics from Saertex GmbH & Co. KG were used, resulting to a final layup of [45°/0°/-45°/-45°/0°/45°/0°]s. The CRTM tool had a cavity size of 380mm x 180mm. In a typical processing schedule, the fabrics were inserted into the mould, the mixed resin was applied on the top of them and then the tool was closed in a controlled speed allowing the resin impregnation through-thickness of the fabrics. Under a given constant pressure and temperature, the curing would finally take place. It was demonstrated that plates could be cured within 3 min at 100°C. A fiber volume content of 55-60% was determined while the void content was lower than 3% as measured by microscopical image analysis. The interlaminar shear strength (ILSS) was measured according to ISO 14130 showing values of 50-56 MPa.

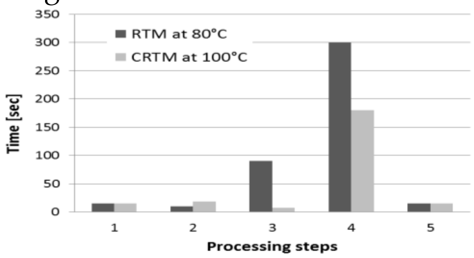

Figure 1: *Comparison of the RTM and CRTM processing steps for the same resin system. RTM: 1. Place preform, 2.Close mould, evacuate, 3. Inject resin, impregnate, 4. Cure, 5. Demould. CRTM: 1. Place preform, 2. Inject resin, close mould, 3. Impregnate, 4. Cure, 5. Demould.*

In Figure 1 the processing steps of CRTM and RTM are compared. Due to the faster through-thickness impregnation, CRTM enables the processing at 100°C resulting in this way in shorter curing time. In total, a processing cycle reduction of 45% was achieved compared to RTM, for the same resin system.

Modelling

One specific attribute of this process is related to the viscous forces of the flow permeating in the preform influencing the fibre compaction and hence the out-of-plane permeability of the unsaturated preform [2, 3]. The flow process was modelled by establishing the corresponding constitutive laws for a one-dimensional domain as shown in Figure 2, taking into account the respective physical interactions and solved in an explicit time integration scheme. The model showed agreement with experiments using high viscosity liquids at different constant pressures. The results on fast curing resins revealed processing limits for highly compactable preforms, such as non-crimp fabrics or unidirectional braiding, which are prone to reduced permeability and hence bad impregnation.

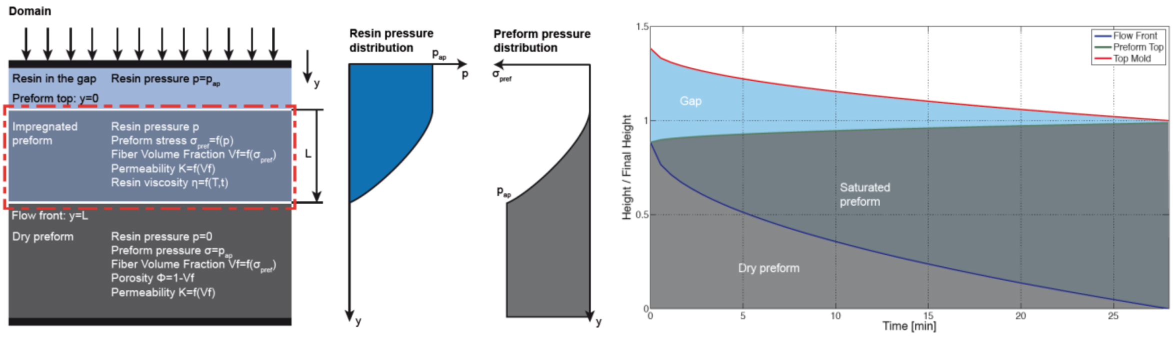

Figure 2: *left - description of the simulation domain; centre - evolution of resin pressure and preform pressure in the domain; right - evolution of the impregnated domain over time at constant pressure.*

Concluding remarks

The preliminary results of the use of CRTM process in combination with fast curing epoxy resins showed the possibility to reduce dramatically the manufacturing process compared to RTM. The main advantage of CRTM is the through-thickness impregnation which decreases significantly the injection stage versus the in-plane impregnation of RTM. Further experimental and simulation studies are currently in progress for understanding the resin dual flow during CRTM and optimize the process parameters.

Acknowledgements

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