AIR EVACUATION IN CONSOLIDATION MODELING OF OUT-OF-AUTOCLAVE PREPREGS

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Introduction

Partially impregnated prepregs allow the vacuum to be distributed throughout the laminate and can transport air and volatiles outside the part. Air flow through the laminate and the latency of the matrix during the curing cycle strongly influence the resin-fibre wetting process. Non-optimized curing cycle can cause incomplete wetting of the initially dry regions within the prepreg and lead to porosity formation. This work presents an approach for predicting the filling time of a prepreg tow, while taking into account the actual air evacuation state of the material.

Modelling approach

A typical cross-section of a woven partially impregnated Out-of-Autoclave prepreg (OoA) can be seen in Figure 1. The tow has limited initial impregnation and is produced by resin film deposition on one side of the prepreg. A simplified tow of rectangular cross section, thickness H_y and length L is selected as the tow equivalent for further model development. Fibre volume fraction and through thickness permeability for flow through the warp and weft tow is considered to be equal.

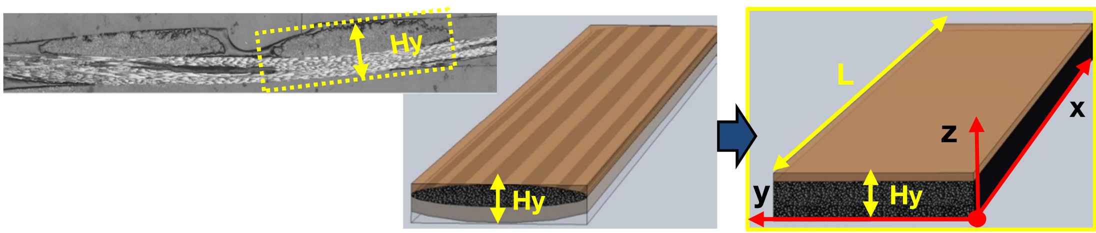

Figure 1: Characteristic tow morphology and rectangular tow equivalent used for modelling

Compaction during impregnation is not taken into account and thus permeability and porosity of the tow remains constant. Resin flow through the thickness of the tow is modelled at a quasi-steady state using Darcy's law, assuming incompressibility. The air flow along the length of the tow is expressed by the transient conservation of mass complemented with the ideal gas law, assuming the gas flow through the fibre bed is Darcian. The air flow is coupled via pressure boundary conditions to the resin flow taking place through thickness. This way the tow fill time can vary along the length of the tow, depending on the gas extraction achieved at a specific time and position of interest.

Sensitivity studies

The model has been used to investigate the effect of length and permeability to the tow filling time at various processing temperatures, presented in Figure 2. Air permeability along the length of the tow is measured for several OoA prepregs and found to be within the range of 10^{-12} to 10^{-17} m^2 [1, 2 amongst others]. Since literature on characterization of transverse liquid permeability is limited, Gebart's equation describing flow through the thickness of an idealized fibre bed with hexagonal distribution of fibres is used as the through thickness tow permeability [3].

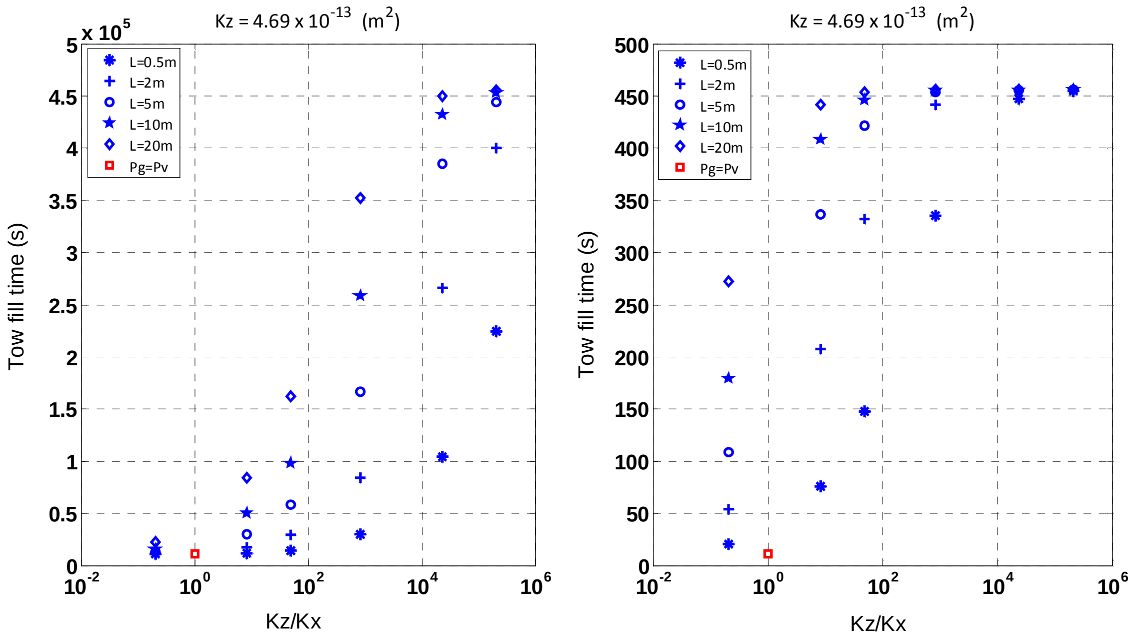

Figure 2: Time to fill a tow of various lengths and permeability ratios at 32°C – left and 130°C - right

The solution derived using the assumption of continuous gas evacuation plotted in red in Figure 2 underestimates the filling time of the tow even for very short parts. Especially in higher temperatures where the resin's cure state has advanced, capturing the actual state of gas pressure within the tow is critical for realistic predictions of filling times and accurate porosity prediction.

Acknowledgements

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References

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