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TITLE:

Modelling and validation of novel vacuum assisted thermoplastic melt compression impregnation process

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ABSTRACT:

Thermoplastic melt composites offer desirable properties for engineering applications; they have good mechanical properties, do not require a curing cycle, and offer end-of-life re-use/recycling potential. However, processing and impregnation challenges limit adoption. The primary challenge is related to the high viscosity of the thermoplastic melt, being orders of magnitude greater than that of thermosetting resins. While current thermoplastic melt processing techniques can produce high quality thermoplastic composites, compromises are made. For example, automated tape layup is slow as it requires an impregnation and consolidation step, and sharp geometry is unachievable.

In compression moulding processes, the thermoplastic melt is impregnated transversely to the textile with a relatively short impregnation length. However, when using dual scale (e.g. woven or stitched) textiles it has been found that complete impregnation in the intra-tow region is difficult. This void content can be attributed to the entrapment of air bubbles inside the tows, which result from the inequal impregnation speed between the inter and intra-tow permeability. At a high level, this work aims to investigate the mechanisms of transverse thermoplastic melt impregnation to improve the final composite quality.

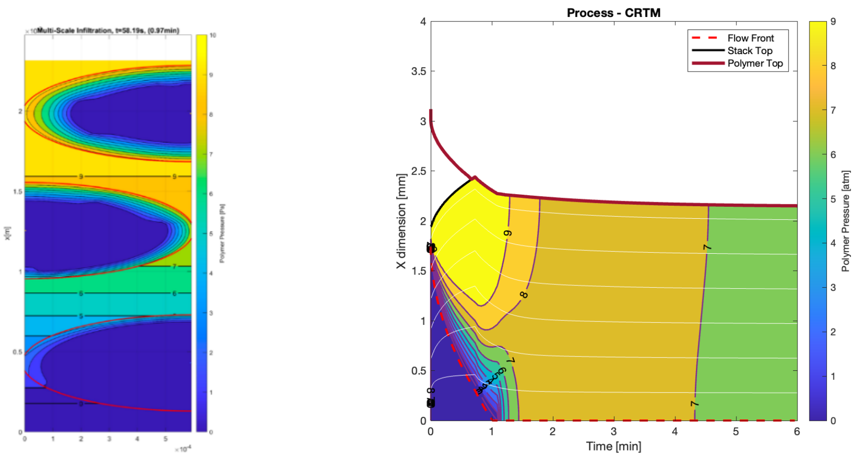

Figure 1: (a) Impregnation cross section (b) Inter-tow polymer pressure timeseries

A computational model (Figure 1) has been developed to model the impregnation of a thermoplastic melt into a dual scale textile. It captures the compressibility of the textile flow fronts across both the inter-tow and intra-tow regions, modelling air entrapment and dissolution. In addition, the model has been used to explore the effect of vacuum assistance on improving the quality of the produced composite. Preliminary results show void content reducing from the over 10% to less than 1%.

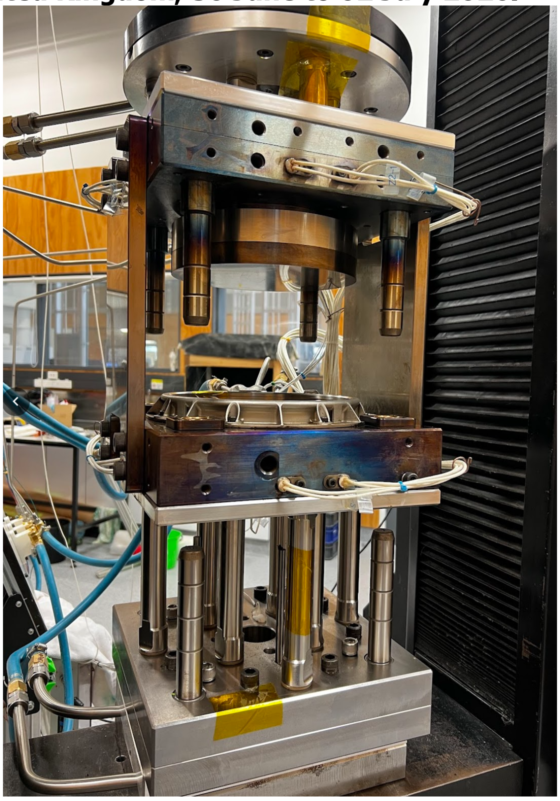

Figure 2: Vacuum assisted thermoplastic melt impregnation tool

To validate the computational model, a novel vacuum-assisted compression moulding die and computational impregnation model has been developed (Figure 2). The experimental die uses a Vario-thermal system to seal create an in-situ air seal during impregnation to maintain a vacuum. It is mounted in a Universal Testing Machine (UTM) for accurate measurement of textile compressibility and deformation.

This work discusses the novel vacuum assisted thermoplastic melt impregnation tool and the boundary conditions required. The modelling strategy is discussed in depth, exploring the challenges encountered with the method. The coupling between the deformable inter-tow region and assumed-rigid intra-tow region is of particular interest. It is understood that the modelling strategy is complex, so various simplifications to the model are explored against a set of analytical and experimental validation data. Finally, insights gained from this modelling exercise is discussed for future implementation. This research attempts to address a critical hurdle in processing higher viscosity thermoplastic composites with acceptable quality.