Effects of Preforming Process Parameters on Carbon Fibre Preform Properties and Resin Transfer Moulding Filling Behaviour

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Keywords: *Preforming; Resin Transfer Moulding; Flow Visualisation; Mould Filling*

Introduction

The resin transfer moulding process is increasingly used in the automotive and aerospace sector to produce complex shaped, fibre reinforced plastic components. Manufacture of the fibre preform is a key step prior to infusion with a polymeric resin. This paper addresses quality issues related to the parameters of preforming; demonstrating subsequent influences on preform properties and mould filling.

Material details and layup properties

A 330g/m^2 carbon fibre unidirectional non-crimp fabric (NCF) was used in this study. This material includes a small percentage by weight of a non-reactive thermoset binder material sintered to one side to facilitate interlaminar bonding in the stacks after preforming. The stack layup utilised for both presented experimental studies consisted of nine layers of the NCF with layers oriented such that the binder coated side faced towards the centre of the stack, being flipped about the fifth layer.

Influence of manufacturing parameters on preform properties

The influence of both hot press temperature and cold press thickness on preform properties were investigated as part of this study. Preforms were manufactured with hot press temperatures of 165°C, 180°C, and 195°C, and cold press thicknesses of 2.9mm, 3.2mm, 3.4mm, 3.6mm, and 3.8mm.

Microscopy analysis of the preform layer interfaces showed that increasing hot press temperature resulted in more binder being drawn into the fibre tows, most noticeably in the outermost preform layers, while decreasing cold press thickness resulted in binder spreading over a larger area seen in Figure 1. Image analysis results revealed that when averaged across all layer interfaces, decreasing cold press thickness results in a higher binder areal coverage ratio as shown in Figure 2a, calculated by dividing the binder covered area by the total area, while increasing hot press temperature has no significant effect.

a) b)

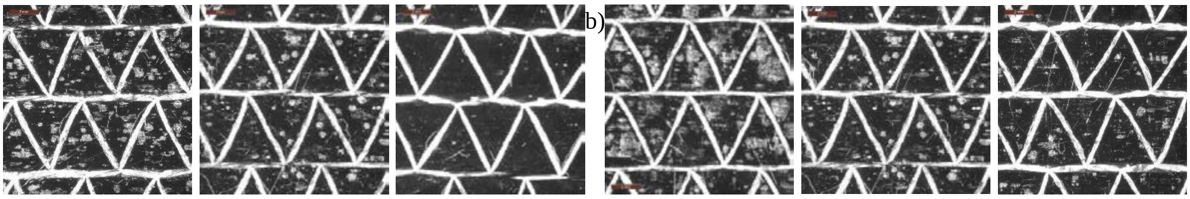

Figure 1: *a) Layer interface binder dispersion hot pressed at 165°C, 180°C, 195°C with 3.2mm cold press thickness*
b) Layer interface binder dispersion cold pressed to 2.9mm, 3.2mm, 3.8mm with 180°C hot press

Compression testing of the samples was undertaken by compacting the preform to the target thickness at a constant speed and recording the peak force. Cold press thickness was found to influence peak compaction force, with increasing thickness resulting in higher recorded forces and an increasing spread in measured values as shown in Figure 2b. Hot press temperature was found to have no significant effect on compaction force.

Permeability of the samples was measured in both the in-plane and through-thickness directions, with oil being used as a resin substitute. Hot press temperature was found to have no influence on either in-plane or through-thickness permeability. Cold press thickness was found to have no influence on in-plane permeability, but did correlate with preform permeability in the through-thickness direction. Increasing thickness resulted in higher permeability and an increase in variation in the measured values as shown in Figure 2c.

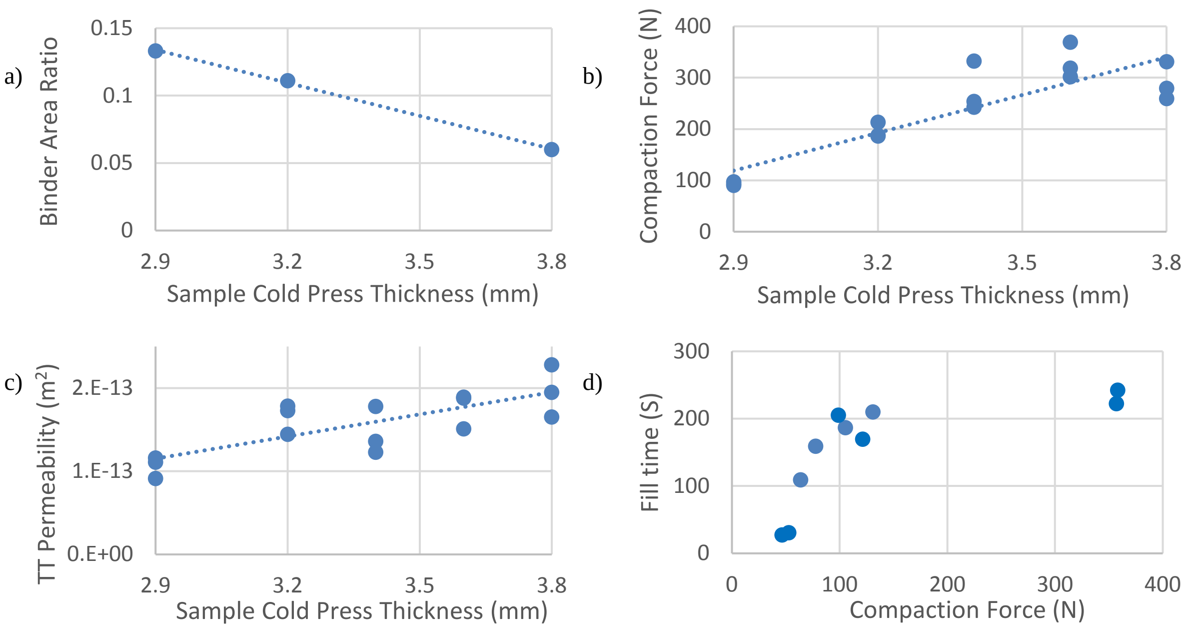

Figure 2: *a) Plot of binder area ratio against cold press thickness, b) Plot of peak applied compaction force against cold press thickness, c) Plot of through-thickness permeability against cold press thickness, d) Plot of mould fill time against preform compaction force*

Influence of preforming parameters and variation on mould filling behaviour

The influence of preforming parameters on mould filling behaviour along with natural defects and variation were investigated in this study utilising flow visualisation experiments. 270x270 mm preform samples were infused in a single sided mould against a glass base using a pressure pot at constant pressure. Figure 3 presents the flow fronts for two samples with differing compaction force. The flow front has been captured visually and presented here as a binary image with white and black representing filled and unfilled textile respectively. The results demonstrated that preforming process parameters, material variation and localized defects have differing levels of influence on RTM mould filling behaviour. The combination of peak compaction force and through thickness permeability, preform properties shown to be affected by cold press thickness, have a significant effect on the filling rate and filling behaviour during the subsequent infusion process. For the carbon fibre textile/binder material studied, high peak compaction force correlated to slow filling with stable two dimensional flow fronts, whereas low compaction resistance correlated to rapid filling primarily in-plane in the upper layers and then in the through-thickness direction. This can be seen in Figures 2d and 3. The applied fluid driving pressure was also shown to influence filling behaviour in low compaction resistance samples, where higher pressures sustain the through thickness mould filling behaviour over a longer distance from the inlet.

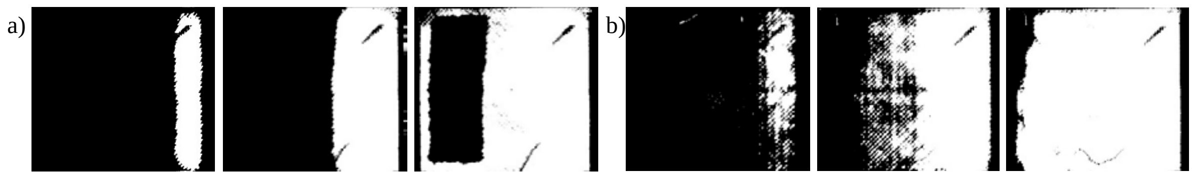

Figure 3: a) *High compaction force sample: captured flow fronts at 3, 45, and 180 seconds.*
b) Low compaction force sample: captured flow fronts at 3, 11, and 22 seconds.

It is hypothesised that the significant differences in mould filling behaviour observed in low compaction force samples is due to the change in the ratio of in-plane and through-thickness permeability, caused by over compaction during preforming. Decreasing through-thickness permeability combined with reduced compaction force resulting in fluid flowing preferentially along the upper surface of the mould, with flow occurring in the through-thickness direction upon saturation, resulting in the observed filling behaviour.