EXPERIMENTAL PERMEABILITY EVALUATION OF BINDERED PREFORM

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Introduction

It is well known that textile reinforcement preforming operation affects the mould filling process during composites liquid moulding processing [1] [2]. The objective of this paper is to investigate the influence of different preforming methods on in-plane and transverse preform permeability.

Method

The information related to the preform fabrication is shown in Table 1. All preforms are made of 5 plies of 5 harness 6K carbon fabric with Fabric A and B having a dry areal weight of 380 g/m² and 382 g/m² respectively. Fabric B is supplied with a coated epoxy powder on both sides representing 4% of its equivalent dry areal weight. The epoxy powder 2 is manually scattered on the fabric then fused by applying heat and pressure using a vacuum bagging process. Copolyimide films are coated on Fabric A by the supplier using a heated pressure laminating process. The preforms are stacks of coated fabric layers except for *P1-D* which is debulked. The debulking operation is done by applying heat and pressure using a vacuum bagging process on a stack of fabrics. Then the stack is cooled down while keeping the consolidation pressure. The result is a rigid, well-consolidated debulked preform. The binder layout used on preform *P2-L* simulates localized binder application.

Table 1: *Preforms construction information*

Preform	Fabric	Binder material	Coating parameters	Preforming parameters
REF	A	None	None	None
P1-D	B	Epoxy powder 1 ≈ 4% *wt* (14 g/m²)	Supplier's application	Debulking (-47.4 kPa | 65°C | 60 min)
P1	B	Epoxy powder 1 ≈ 4% *wt* (14 g/m²)	Supplier's application	None
P2	A	Epoxy powder 2 ≈ 5% *wt* (19 g/m²)	Manual sintering + Vacuum bag (-98.2 kPa | 85°C | 45 s)	None
P2-L	A	Epoxy powder 2 ≈ 5% *wt* (19 g/m²)	Manual sintering + Vacuum bag (-98.2 kPa | 85°C | 45 s)	None
W1	A	Copolyamide film ≈ 3.4% *wt* (12.9 g/m²)	Pressure laminating 344 kPa | 93°C | 3.05 m/min	None
W2	A	Copolyamide film ≈ 10.5% *wt* (40 g/m²)	Pressure laminating 344 kPa | 126°C | 4.57 m/min	None

The in-plane permeability (Figure 1) is measured from longitudinal injections at constant injection pressure [3]. All injections are performed on $[0°]_5$ 38.1 cm long and 8.6 cm wide stacks. The transverse permeability (Figure 2) is measured from through thickness injections at constant pressure. Measurements are performed on circular $[0°]_5$ preforms of 76.62 mm in diameter. The target mould cavity thickness is 1.95 mm for a fibre volume fraction of approximately 55%.

Results

The results show a reduction of in-plane permeability with the addition of binder material. The highest average in-plane permeability ($K_x = 5.9825 \times 10^{-11}$ m²) is obtained for the preform made of dry fabric (*REF*) while the lowest permeability ($K_x = 2.0285 \times 10^{-11}$ m²) corresponds to the 5 plies debulked preform of fabric coated on both sides with the epoxy powder (*P1-D*). Significant flow front instabilities are observed through the transparent mould surface. The presence of coated adhesive film on preforms *W1* & *W2* increases the fabric shear stiffness. The resulting high nesting resistance of these preforms generates channels on the top of the preform after mould compaction leading to flow front instabilities similar to a fingering effect. The preforms where the binder material is coated by an industrial process (*P1*, *P1-D*, *W1* & *W2)* show less in-plane permeability variability compared to a manual binder application process (*P2* & *P2-L*).

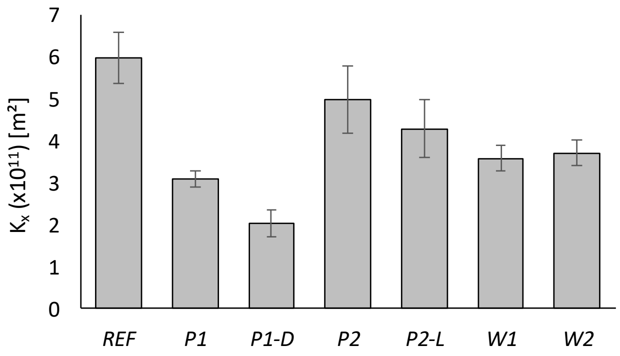

Figure 1: *Summary of measured in-plane permeability K_x.*

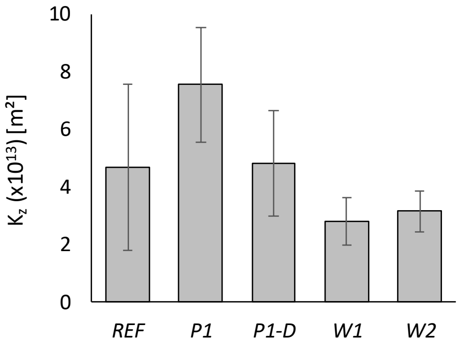

Figure 2: *Summary of measured transverse permeability K_z*

The coefficients of variation evaluated range from 5% to 15 % and 20% to 60% for the in-plane and transverse permeability respectively. The experimental process for measuring the transverse permeability was more challenging as the process of adjusting precisely the cavity height was inaccurate, thus potentially impacting the sample fibre volume fraction. Nevertheless, the results obtained confirmed previous findings on the impact of the preforming process on transverse permeability [2]. Shear deformation during the draping process and hydrodynamic compaction caused by the injection pressure can lead to the deformation of the fabric. Binder material help preventing fabric deformations, thus keeping the transverse flow channels open. The presence of non-activated binder material can reduce the nesting effect during the preform compaction, thus facilitating transverse flow (K_z *P1* > K_z *REF*). However, melted binder material due to activation process will cover more surface thus blocking some of these transverse flow channels (K_z *P1* > K_z *P1-D*).

Conclusion

This study shows that the preforming technique can potentially affect the mould filling during liquid moulding as it can cause significant in-plane and transverse permeability variations. The combination of the coating and preforming processes (pressure, temperature and time), and the binder form (powder or film) controls the final binder location and morphology. Thus, the preform binder distribution causes local variations of the preform porosity affecting the fibre bed tortuosity and consequently the permeability.

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