FLOW BEHAVIOR AND PERMEABILITY CHARACTERIZATION OF FIBER PREFORMS

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OBJECTIVES

- Estimate the in-plane permeability of compressed and rigid random mat fibers, in RTM process and through the thickness permeability using PERMSTAT.
- Study the fluid flow behavior in woven fibers in RTM process when the resin floods the top surface before permeating through the thickness.
- Conduct experiments for characterization of preform permeability in the presence of race tracking for orthotropic fibers.

The R.T.M work station | Fiber Cutting station | Fiber Preforms

P4 Preform

E-Glass (5*4)

S-Glass (5*5)

ACKNOWLEDGEMENTS

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PERMEABILITY OF A P4 PREFORM

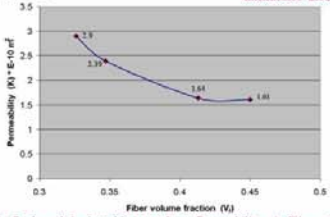
Fiber : P4 Random Mat: Thickness varying from 2.2 mm to 9.6 mm.

- The fiber is cut in right size and placed in the mold.
- The resin stimulant is injected at constant pressure using a pressure bucket.

The flow front observed through acrylic lid :

- The experiments were repeated by varying the thickness of the preform and also the thickness of spacer-frames to get different "fiber volume fractions".

Different spacer-frame thicknesses used :



The final result is plotted in a graph – Permeability v/s Fiber volume fraction

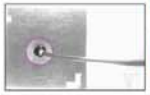
PERMEABILITY MEASUREMENTS USING PERMSTAT

- P4 fabric was used to estimate permeability with PERMSTAT and also to find the through the thickness permeability – K_{zz}

Permstat with lid open

Permstat with lid closed

- The experiments were repeated with different thickness of the preform available



Bottom Camera Capture

Fitted ellipse for flow front position determination

Permeatal Results

PERMEABILITY VALUES (m^2)

No. of layers	Thickness of each layer (mm)	Total thickness (mm)	Fiber volume fraction 'Vf'	K_{xx}	K_{yy}	K_{zz}
4	5 mm	5*4 = 20	0.35	1.60E-10	1.72E-10	1.89E-11
3	8.3 mm	8.3*3 = 24.9	0.36	2.25E-10	2.10E-10	2.50E-11
2	9.6 mm	9.6*2 = 19.2	0.36	2.63E-10	2.92E-10	3.32E-11

Permeability result display

FLUID FLOW BEHAVIOR THROUGH THE THICKNESS

- Bottom face of the mold was filled quickly using three different methods and the resin arrival along the opposite face was observed

The different methods adopted were

1) Using "distribution media" at the bottom face of the mold

2) Creation of thin gap between fiber and the bottom face of the mold

3) The gap was made more effective by constructing a bridge

RESULTS

1) There was no notable change with the use of distribution media. .
2) By maintaining a thin gap at the bottom it was seen that the fluid moved quickly through the bottom surface and then permeated up saturating the preform layers through the gaps between the fiber tows.
3) The effect of fluid rising from bottom to top was more prominent with the bridge design.

- The results were made more effective by applying "tackifier" – pretex-110 between the fiber layers which held them together and maintained rigidity.

❖ **The above effect was seen more prominent on S-Glass (5*5) fiber.**

S-Glass (5*5)

E-Glass (5*4)

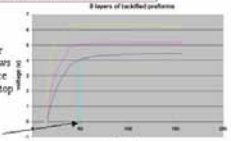
EXPLANATORY FIGURES

Results shown with S-Glass (5*5) fibers :

8 layers of Tackified preforms

Regions where the resin permeated from the bottom to the top surface

The graph obtained from sensor data connected to the mold shows that fluid fills the bottom surface rapidly and then permeates the top surface through the thickness



filling time for the bottom face of the mold

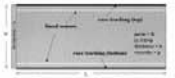
PERMEABILITY IN PRESENCE OF RACE-TRACKING

- **Repeated experiments were carried out on orthotropic preform in R.T.M workstation with constant flow rate using in order to characterize the preform permeability in presence of race tracking.**

bulk permeability K in the presence of race tracking :

$$K = \frac{\beta Q \mu}{P_i h}$$

β : flow correction factor table
Q : constant flow rate
μ : viscosity of resin
$P_i = P_{in}(t = t_i)$
h : thickness of preform



The mold geometry and location of liquid sensors using the edges to record potential race tracking

Equivalent permeability in the isotropic domain : $K_{eq} = \sqrt{(K_{11})(K_{22})}$

After iterative scaling, the problem is scaled back to original dimensions with :

$$K_{orig} = \frac{K_{eq,iso}}{\left[\prod_{i=1}^{n}\left(sc^{i}_{orig}\right)\right]^{\frac{1}{n}}}, \quad K_{orth} = \frac{K_{eq,iso}}{\left[\prod_{i=1}^{n}\left(sc^{i}_{orth}\right)\right]^{\frac{1}{n}}}$$

Where :

$$sc^{1}_{orig} = \sqrt{\frac{K_{eq}}{K_{orig}}}, \quad sc^{1}_{orth} = \sqrt{\frac{K_{eq}}{K_{orth}}}$$