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Characterization of Glass Fibre Polymer Laminates by Vacuum Assisted Resin Transfer Moulding with Various Parameters

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Abstract— **Resin transfer molding (R.T.M) is a competent manufacturing process for fiber reinforced polymer composite component production. As this process offers repeatable quality which is essential in production of high quality components for automotive and aerospace applications. The permeability of preform influences the resin impregnation. The present work investigates the influence of the critical parameters on the quality of end product. This paper publishes the experimental results and also discusses the relationship between the preform permeability, porosity, fiber volume fraction, and injection pressures of the resin in the control volume moulding processes.**

Index Terms— **Design, Mould and Sample Preparation, Analysis.**

I. INTRODUCTION

Alexandros A Skordos and Ivana K Partridge Liquid molding processes for the manufacture of continuously reinforced composites have received increased attention in recent years. In comparison with conventional processes, which involve laying up and autoclaving, they offer a potentially cost-efficient and easily automated alternative. Various liquid molding processes, using either rigid tooling (e.g. resin transfer molding - RTM) or flexible tooling (e.g. vacuum infusion) have been developed. In all cases, the central characteristic of these processes is that the filling/consolidation stage is separated from the curing stage, and becomes the critical phase of the manufacturing process. Therefore, resin filling and the phenomena associated with it have become points of focus for research on composites manufacturing. Models attempting to simulate the impregnation of liquid resin into a dry fabric have been developed by several groups [1-4]. These models are all based on the application of Darcys' law, which assumes that the rate at which a fluid flows through a porous medium is proportional to the pressure gradient.

The manufacturing methods found to be very effective on the bearing failure mode of pin loaded composites. The composites manufactured by

VARTM performed better than the composites manufactured by Hand Lay-up technique. The geometry of the composites also found to be very effective on the performance of both types of composites. Decreasing e/d ratios and w/d ratios resulted in decrease at sustained load for Type-1 and Type-2 specimens. While bearing, shear-out, net-tension and combination (shear + net-tension) failure modes were observed for Type-1 specimens, only bearing and shear-out failure modes were observed for Type-2 specimens.

II. INDENTATIONS AND EQUATIONS

Governing formulae:

1. Porosity:

$$\Phi = Vc - Vgf/Vc$$

Where Vc = volume of cavity

Vgf = volume of glass fibre

2. Permeability:

$$K = \frac{Q\,\mu\ \ln[rf/ri]\ x\ rf2}{AXP}$$

Q = discharge of resin flow

μ =viscosity of resin

ri = inlet radius, rf =radial flow

A=area of glass fibre, P=vacuum in the mould

3. Reynolds number:

$$Re = \frac{\rho x v x d x 1000}{\mu}$$

ρ= density of matrix

v= velocity of resin flow

d=diameter of pipe, μ=viscosity of resin

III. DEVELOPMENT OF FRICTION WELDING ATTACHMENT TO LATHE MACHINE

Concept-model:

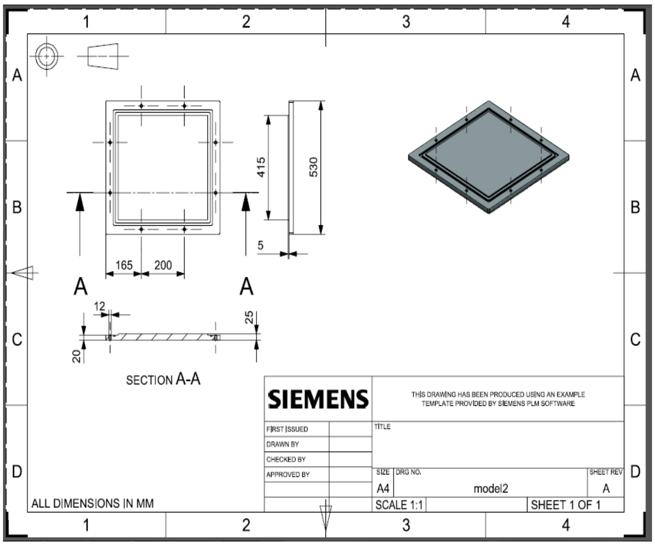


Figure .1.Design of an achrolic plate

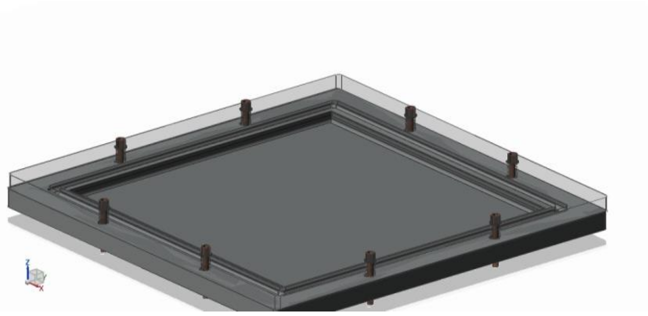


Figure .2.Isometric view of Mould

IV. FABRICATION OF METALLIC MOULD

The pressure to be applied to consolidate laminate after impregnating resign should be applied by compression as the required specimens are to be manufactured. The mould is made of MS material. The grooves had been done for sealing the two plates and to prevent the leakage of resin four dams were fixed through nuts and bolts on a 25mm thick MS plate which was having machined by facing operation on CNC lathe machine. The details of the mould is shown in figure.3.

Figure .3

Figure.4. Representation of Mould

V. SAMPLES PREPARATION

In the present work composite templates are prepared as per the required dimensions. According to the required dimensions the glass fiber mat has been cut into various orientations by making use of different mechanical equipment and measuring equipments. The excess material is removed on the surface of the mould and poly vinyl alcohol viscous liquid is applied on the surface of the mould uniformly and left for drying about 15 minutes. This liquid creates an invisible film which works as impervious layer prevents sticking to the mould surface.

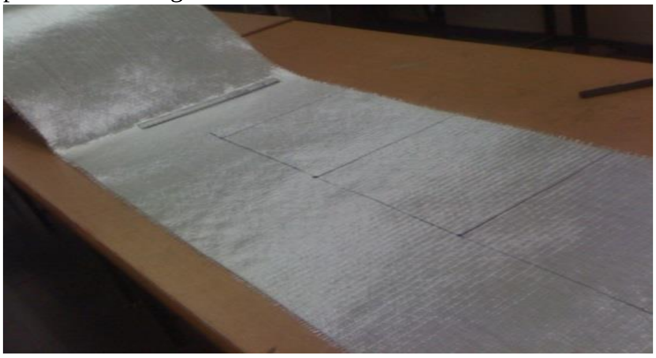


Figure.5. Marking on the fibre

Figure.6. Cutting the fibres as per dimensions

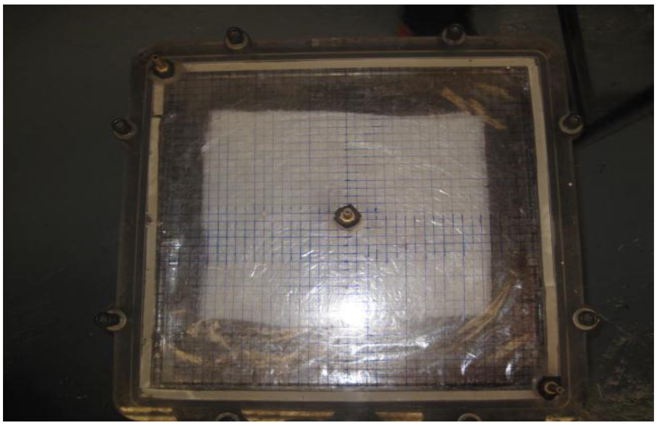


Figure.7. Arranging the fibres and close the mould

VI. EXPERIMENTATION

Figure.8. Vacuum pump and Accumulator

Figure shows the vacuum pump which is used to create vacuum pressure in the mould setup. We can adjust vacuum pressures as per flow required. Side figure shows the accumulator it is used store the excess amount of resin mixture in it without transferring into the vacuum pump. Attach a pipe to vacuum pump and accumulator.

Figure.9.Polyester resin and hardener are mixed in a jar

Mix the resin and catalyst in a jar and stir it. Catalyst required in the ratio of 1:100 to the resin. Now add accelerator to the mixture in the same ratio. Don't mix the catalyst and accelerator directly it leads to the combustion reaction.

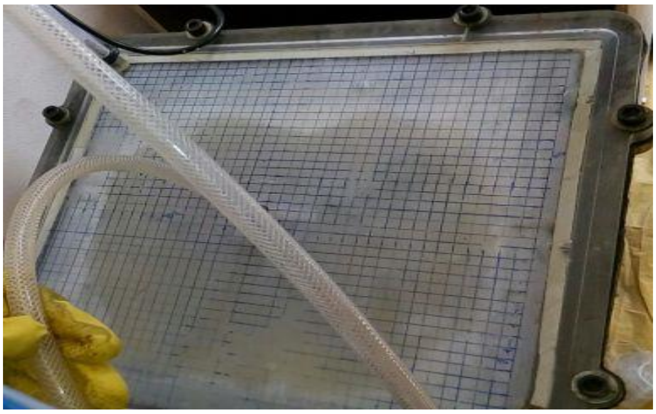


Figure.10. Total setup and resin flow process

This is the total setup required to conduct the experiment. In this setup end nozzles are connected to the resin jar where resin is transferred to the mould and the middle nozzle is connected to the accumulator. Adjacent figure shows how resin spreads over the entire mould.

Figure.11.The laminates are ready

Vacuum Assisted Resin transfer molding (V.A.R.T.M) is a competent manufacturing process for fiber reinforced polymer composite component production. As this process offers repeatable quality which is essential in production of high quality components for automotive and aerospace applications. The permeability of preform influences the resin impregnation. The present work investigates the influence of the critical parameters on the quality of end product. This paper publishes the experimental results and also discusses the relationship between the preform permeability, porosity, fiber volume fraction, and injection pressures of the resin in the control volume molding processes.

The main objective of this study is to find the influence of critical parameters on the quality of the laminate. For this purpose the filling time and flow front velocity is calculated by image processing technique and video to jpg converter software and parameters like permeability and volume fraction is calculated from the governing formulas

POROSITY:

Chopped stand Mat:

Layers	**Porosity**
4	0.85
5	0.81
6	0.78

PERMEABILITY:

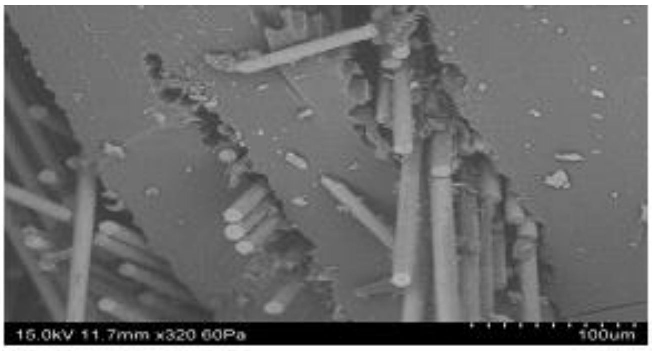
Layers	**K cm^2**
4L	0.92
5L	0.63
6L	0.07

S No	Specimen-Layers-Force	Average Value of Tensile Strength (N/mm^2)
1	1-4L-100 mm of hg	17.6
2	2-4L-200 mm of hg	22.75
3	3-4L-300 mm of hg	18.97
4	4-4L-400 mm of hg	24.537
5	1-5L-700 mm of hg	23.058
6	2-5L-100 mm of hg	24.421
7	4-5L-300 mm of hg	27.39
8	5-5L-400 mm of hg	20.923
9	1-6L-100 mm of hg	51.74
10	2-6L-200 mm of hg	52.9
11	3-6L-300 mm of hg	55.2
12	4-6L-400 mm of hg	57.38

S. No.	Average Value of Impact Strength (N/Mm^2)
1	3
2	6
3	4
4	2
5	6
6	3
7	4
8	6
9	7
10	3
11	4
12	4

VII. SEM ANALYSIS

The fractured specimens by the impact test were exposed to scanning electron microscope to understand failure mechanism by impact test. All fractro graphs are furnished in the Figure.12.



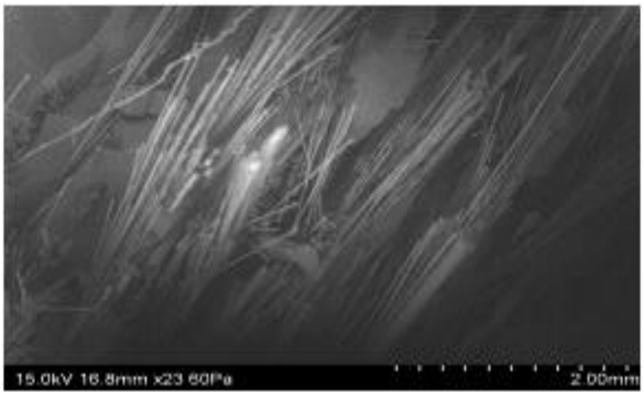
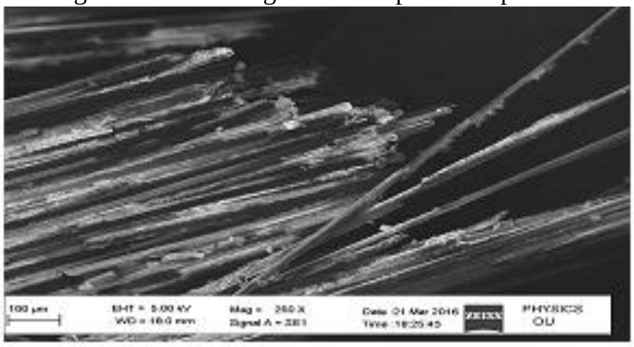
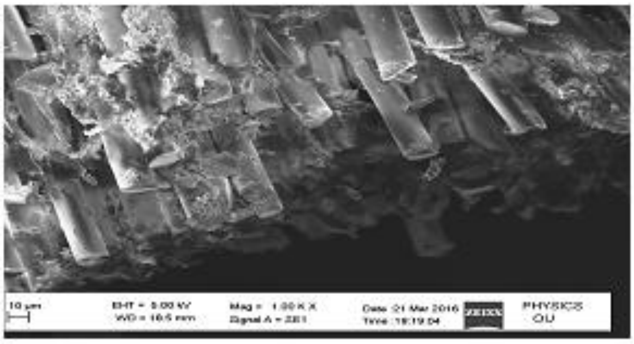
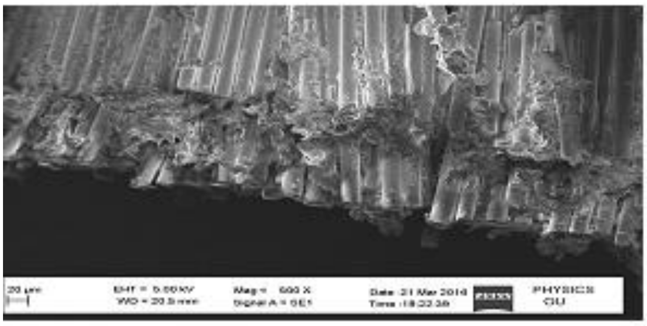


Figure.12.SEM Images -Izod impact test specimen



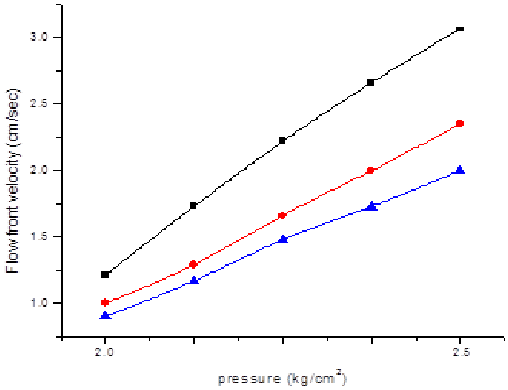




VIII. RESULTS AND DISCUSSION

Analysis was performed on the experimental results of the critical parameters investigation that influence the quality of laminate by using V.A.R.T.M process. it is clear that when the pressure is increasing the flow front velocity is also increasing in all 6,7,8 layers of chopped strand mat and at the same time the flow front velocity is more in 6layers than 7 and 8 layers of perform at constant pressure.

The results pertaining to the permeability of 6,7,8 layers of chopped strand mat glass fiber and investigated that the permeability is going on increasing with the increase in resin injected pressure and permeability decreases with the increase in the number of layers that means 6 layers preform is going to have more permeability than 7 and 8 layers of fiber perform Variation of volume fraction with the resin injected pressure depicts that the volume fraction of fiber is nearly same value from 200mm of Hg to 300mm of Hg and decreases at 400mm of Hg of resin injected vacuum pressure.



Variation of flow front velocity with pressure of general purpose polyester resin for 6, 7, 8 layers of chopped strand glass fiber mat.

IX. CONCLUSIONS

The experiments were performed on the chopped strand mat of 450 GSM on 6,7,8 layers and woven fibre of 610 GSM by injecting polyester resin of viscosity 475 cp with varying pressures from 200 mm of Hg to 400mm of Hg by V.A.R.T.M process. The experimental results revealed the facts that the optimum number of layers of chopped strand mat is possible up to 8 layers because, for higher number of layers, the critical parameters like flow front velocity, porosity, permeability are very low and volume fraction of fiber is more compared with that of the other layers. The critical pressure by which the polyester resin should be injected should be from 200mm of Hg to 400mm of Hg because the volume fraction of fiber at 500 to 600mm of Hg is decreasing, where there is fiber washed out with resin that means the resin impregnation on fiber is critically low in this controlled volume molding process.

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