EFFECT OF TPU INTERLAYER ON PERMEABILITY OF STACKED FABRICS TO MANUFACTURE A LAMINATE WITH VARTM PROCESS

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Motivation

- Thermoplastic polyurethane (TPU) reduces delamination in composites when subjected to impact loads.
- Composites with TPU is more effective in maintaining stiffness during multi-hit events
- TPU is impermeable; also changes fiber volume fraction, therefore affects preform permeability and could affect VARTM processing.

Objective of Research

Investigate the influence of TPU interlayer on permeability of glass fabric preforms and its effect on manufacturability using VARTM

Introduction

- VARTM experiments → measure permeability with and without TPU using simulated resin (Corn Syrup)
- Flow patterns are investigated in different layups
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Sr. No.	Experiment Name	S2 Glass Fibers	TPU with 3mm holes at center line 5 cm apart	Size
1.	Without TPU	8 Layers	Not Applicable	150 mm X 350 mm
2.	With TPU	8 Layers	One Layer	762 mm X 400 mm

- Fabric Specification as given below

#	Fabric Specification		#	Fabric Specification	
1.	Style	240	2.	Weave Pattern	Plain
3.	Fiber Type	Glass	4.	Count Ends X Picks	5X5
5.	Thickness (inch)	0.03	6.	Weight	813.74 (GSM)

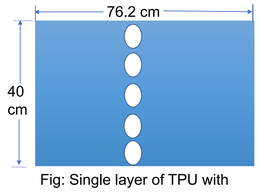


Fig: Single layer of TPU with central Hole

Fig: Layup with 8 S2 glass fabrics with one layer of TPU in between

- Corn syrup is impregnated into different types of layups.
- At the central line, holes within the TPU sheet are punched to allow the air to be extracted by vacuum pressure from layers on both sides of the TPU layer.

Mathematical modeling for evaluating permeability

Darcy's law is used to obtain relationship between volume averaged fluid velocity and fluid pressure as given below:

$$u = \frac{k_{xx} * dP}{\mu * L} - - - - - (1)$$

Also, average velocity is given by:

$$u = \Phi \frac{dL}{dt} - - - - - (2)$$

Equating (1) and (2) and integrating on both sides results in equation (3)

$$m = \frac{L^2}{\Delta t} = \frac{2 * k_{xx} * dP}{\mu * \Phi} \frac{m^2}{s} \text{ - - - - - (3)}$$

VARTM experimental setup

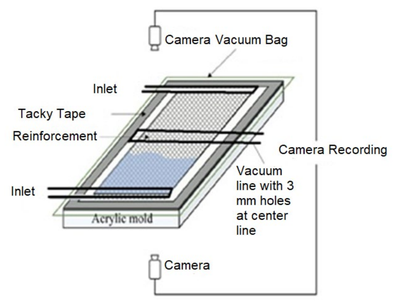


Fig: Schematic diagram for VARTM experimental setup

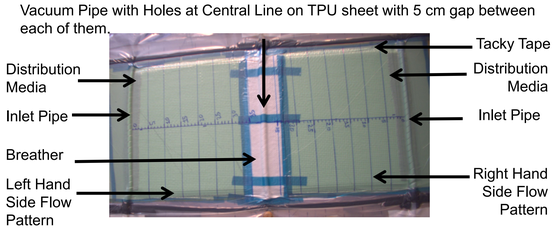


Fig: Top View of the different layups while performing the VARTM experiment.

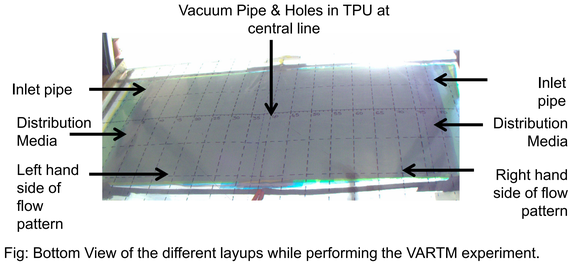


Fig: Bottom View of the different layups while performing the VARTM experiment.

Flow pattern study by plotting Length^2 (m^2) vs Time (s)

- Figure shows the flow pattern of the simulated resin through different layups.

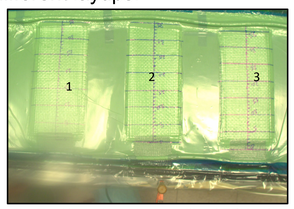


Fig: Top View of one Layup without TPU (1) and two layups with TPU (2 and 3)).

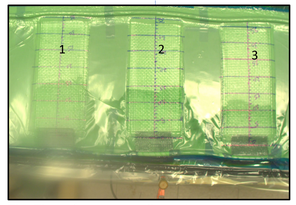


Fig: Flow of corn syrup through one Layup without TPU (1) and two layup with TPU (2 and 3).

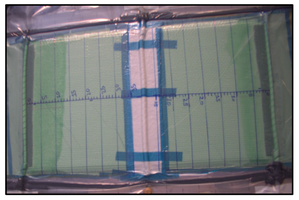


Fig: Top view of flow pattern with TPU layup

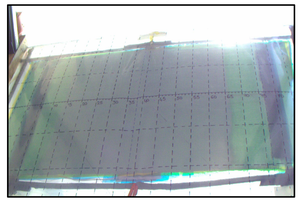
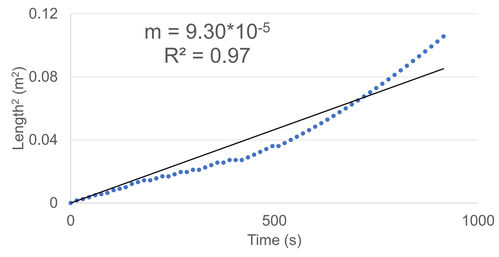


Fig: Bottom view of flow pattern with TPU layup

- Graph of L^2 vs time provides the value of the slope m in Eq. (3). From the value of m, one can determine the value of permeability using equation (3)



- Comparing the flow pattern for top and bottom view for RHS and LHS respectively for VARTM experiment with TPU layup to estimate the value of slope m.

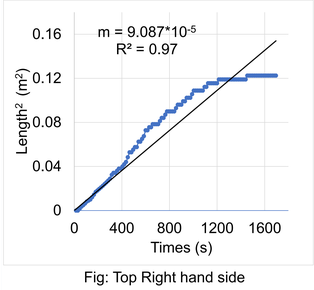


Fig: Top Right hand side

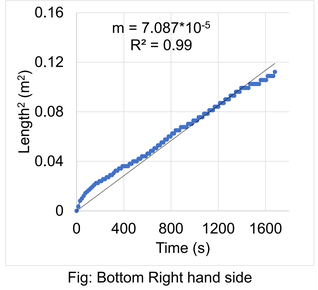


Fig: Bottom Right hand side

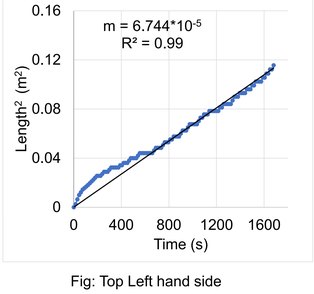


Fig: Top Left hand side

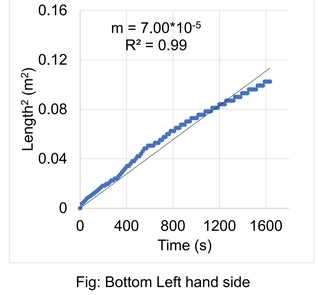


Fig: Bottom Left hand side

- Permeability value is obtained once slope m is calculated from the experiment using Eq. (3)

Sr. No.	Method	Value of Permeability (k) in m^2			
		Right Hand Side		Left Hand Side	
		Top 10^{-11}	Bottom 10^{-11}	Top 10^{-11}	Bottom 10^{-11}
1.	Experimental without TPU	2.74	2.74	2.74	2.74
2.	Experimental with TPU	2.67	2.08	1.9	2.03
3.	Difference in Percentage (%)	2.55	24	30.66	25.91

Conclusions

- The permeability value of the preform without TPU is 2.74*10^{-11} m^2.
- The permeability value of preform with TPU is approximately around 2.05*10^{-11} m^2.
- The permeability is affected by the presence of the TPU layer and is different on the left and the right side
- The flow pattern is almost uniform for the layup without TPU as compared to the layup with TPU.
- The flow pattern for the layup with TPU was uniform at the bottom as compared to the top.
- **This suggests that how the TPU layer nests between fabric layers influence the permeability and hence the flow.**

Acknowledgements

- This research was sponsored by the U.S. Army CCDC Army Research Laboratory and was accomplished under Cooperative Agreement Number **W911NF-18-2-0299**. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the official policies, either expressed or implied, of the Army Research Laboratory or the U.S. Government. The U.S. Government is authorized to reproduce and distribute reprints for Government purposes notwithstanding any copyright notation herein.
- I would like to thank Laure Moretti and Dean Vanegas for their help in conducting the VARTM experiments.