

**INFLUENCE OF MULTILAYER INTERLOCKED  
WOVEN STRUCTURE ON IMPREGNATION  
BEHAVIOUR OF PREFORMS AND IMPACT  
PROPERTIES OF THE COMPOSITES**

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**INDIAN INSTITUTE OF TECHNOLOGY DELHI  
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By

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Submitted

In fulfillment of the requirements of the degree of

**Doctor of Philosophy**

To the



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**March 2010**

*Dedicated to my Parents*

## CERTIFICATE

This is to certify that the thesis titled “Influence of multilayer interlocked woven structure on impregnation behaviour of preforms and impact properties of the composites”, being submitted by Mr. Naveen V Padaki to the Indian Institute of Technology, Delhi, for the award of the degree of Doctor of Philosophy is a record of bonafide research work carried out by him. Mr. Naveen V Padaki has worked under our guidance and supervision and fulfilled the requirements for the submission of the thesis.

The results contained in this thesis have not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.



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## **ABSTRACT**

This dissertation work is a comprehensive effort to quantify and characterize the influence of multilayer interlocked woven structure on the preform properties, resin impregnation behaviour and low velocity impact properties of composites. A total of nine different multilayer interlocked woven fabrics consisting of 2-ply and 3-ply structures with different interlacement patterns have been developed for the present study. The structures of these multilayer fabrics were characterized using “Interlacement index’ based on the ‘Crossing-over Firmness Factor (CFF)’ proposed by Morino et.al. (2005). Influence of fabric structure in terms of interlacement index on the preform properties relevant for resin transfer moulding (RTM) of composite manufacture, such as compression, permeability and tensile behaviour have been studied. Permeability properties of these structures were evaluated based on horizontal wicking and tensiometric contact angle tests. It has been observed that the influence of interlacement is greater on tensile and fluid flow properties than the compression behaviour of these multilayered fabrics.

Resin flow through the porous reinforcement inside the moulds during RTM process was simulated using the permeability properties of these multilayer fabrics. Single-phase (resin only) and Multiphase (air and resin) flow models were developed for the simulation using CFD-Fluent software. The average inlet and outlet velocities were obtained through simulation and the mould

filling time were compared. Experimental validations of results with respect to mould filling time were done on the fabricated resin transfer (RTM) process setup in the laboratory. Results show that the time required for experimental mould filling is dependent on the permeability of the fabric and the resin flow during RTM mould fill operation can be simulated using multiphase model. Fabric structural factor Interlacement index has significant influence on the resin flow behaviour of the preform. Higher the interlacement index of the preform higher is the time taken to fill the mould in both experimental and simulated results.

Studies on the influence of interlacement in the multilayer fabrics on the low velocity impact properties of the composites reinforced with them have been carried out. Impact testing was done on an instrumented drop weight impact tester to obtain load-elongation-time plots of the impact event. Multilayer structures have significant influence on the impact behaviour of composites reinforced with them. Higher interlacement index in the reinforcement result in better impact strength of the composite. Further, post impact damage area studies have been carried out, through image processing, to ascertain the influence of interlacement on the impact induced failure behaviour of these composites. Increased interlacements in the multilayer structure cause lower fibre failure regions and higher interfacial failure regions in the composites, which are due to better dissipation of load in the multilayer structure through interlacement points.

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Sd/- 

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