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

NAVEEN V PADAKI

INDIAN INSTITUTE OF TECHNOLOGY DELHI
March 2010

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

By

NAVEEN V PADAKI

Department of Textile Technology

Submitted

In fulfillment of the requirements of the degree of

Doctor of Philosophy

To the

INDIAN INSTITUTE OF TECHNOLOGY DELHI
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.

Prof. B.L. Deopura
Professor
Department of Textile Technology,
IIT Delhi,
New Delhi - 110016,
India

Prof. R. Alagirusamy
Professor
Department of Textile Technology,
IIT Delhi,
New Delhi - 110016,
India

Dr. Raul Fangueiro
Auxiliary Professor
Department of Textile Engineering,
University of Minho,
Guimarães – 4800058
Portugal

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.

ACKNOWLEDGEMENT

First and foremost, I acknowledge the love and blessings of the invisible force – God, for helping me to be what I am today.

I would like to express sincere and deep gratitude to my supervisors Prof. BL Deopura, Prof. R Alagirusamy and Prof. Raul Fanguiero for their constant support, guidance and encouragement during this study, without which this work would have not been accomplished. I wish to thank Prof Alagirusamy in particular, for many helpful discussions, with great insight to things, about the probable endpoints which this thesis has found.

I am deeply indebted to Dr. BS Sugun, FRPP Division, National Aerospace Laboratories, Bangalore for his invaluable help and useful suggestions during this research work.

With great pleasure, I wish to convey heartfelt thanks to faculty members, all the research scholars and staff members of Department of Textile Technology, IIT Delhi for their assistance during the course of this work. Special appreciation to my friends Kausik Bal, Ajit Patnaik, Raghunath Reddy, Vijay Yadavji, Ajay, Guru, Swapna, Thiru, Raghu, Divu, Pakya, Suni, Rajendra Verma and countless other friends whom I have not mentioned here – you know that you are in my heart for keeping me in good spirits throughout and for being perpetual help during the times of adversity.

I sincerely thank Sri Subroto Roy, Director, CSTRI, Central Silk Board, Bangalore and Sri Sarat Deori, Joint Secretary (Tech), RDO, Central Silk Board, Guwahati who always encouraged and motivated me to complete the thesis work.

My heartfelt thanks to my dear friend, research colleague and life partner Brojeswari, who patiently shared and supported through the ups and downs of our research tenure. I wish to express my gratitude to the twin gems Archana and Aparna, my sisters for the unconditional support, warmth and lively action to involve me in family matters, which helped me to divert my mind away from research occasionally. Finally and most importantly, I would like to thank my parents, Sri Vijay R Padaki and Smt Rajani V Padaki for always supporting me with unhindered love and giving me the opportunity to pursue an advanced education.

Sd/-

Naveen V Padaki

CONTENTS