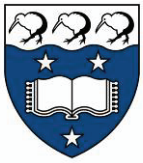
Monitoring and Simulation of the Filling and Post-filling Stages of the Resin Infusion Process

by

Quentin Paul Nicéphore Marc Marie Govignon

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy in Engineering, The University of Auckland, 2009.

Centre for Advanced Composite Materials



THE UNIVERSITY OF AUCKLAND

Abstract

The doctoral research presented in this thesis is focused on the resin infusion moulding process. The resin infusion process is part of the liquid composite moulding family where a dry reinforcement is impregnated with a liquid resin inside a closed mould to form a composite part. The specificity of resin infusion resides in the fact that only one side of the mould is rigid, the cavity being sealed by a vacuum bag. The preform compaction and fluid flow are driven by the pressure difference between the cavity and the ambient pressure. The reinforcement can therefore exhibit through thickness deformation as the resin penetrates the cavity. The aim of the research was to monitor and simulate the process. A number of previous studies have considered the impregnation process, but very little work had focused on the post-filling stage of the process, once the resin inlet is closed and the resin pressure field inside the mould is left to equilibrate.

In the first part of this study, the behaviour of two different fibrous reinforcements was experimentally characterised, and a new model was developed to replicate the compaction behaviour of the reinforcements. This model is based on elastic behaviour, but was able to account for the compaction history of the reinforcement.

A comprehensive monitoring system was designed and built to collect relevant experimental data to be compared with the simulation. This included

the development of a mould fitted with sensors, as well as a stereophotogrammetry system which provides full field monitoring of variations in reinforcement properties. This system measures local cavity thickness, allowing calculation of other parameters such as fibre volume fraction and permeability.

A 1D finite element simulation of the resin infusion process is subsequently presented. The simulation covers both the filling and post-filling stages of the process and uses a modified version of Darcy's law to govern the flow of fluid through porous media.

Finally, an investigation of different factors affecting the post-filing is presented through both simulation and experimental evaluations.

Acknowledgements

First and foremost, I would like to thank my wonderful girlfriend Sharelle for all her love and support through my PhD. Thank you for your commitment and patience in putting up with me through the hardest times during this research.

A Maman, Papa, Johana et toute la famille. Merci pour tous vos encouragements ; votre support s'est ressenti jusqu'a l'autre bout du monde. C'est grâce à vous que j'ai pu devenir qui je suis devenu.

Associate Professor Simon Bickerton, thank you for your guidance and feedback. Your advice and attention to detail were invaluable in the development of the experimental setup.

Many thanks also to Dr. Piaras Kelly for your help and guidance in developing the numerical simulation.

My gratitude to Associate Professor John Morris and Mr. Yizhe (John) Lin for their efforts in the development of the stereophotogrammetry system.

I would also like to thank all the technicians who have assisted me during my work – Callum, Jos, Rex and Steve, for their help and the technical knowledge they passed on to me.

My appreciation also goes to Professor Debes Bhattacharyya for welcoming me into CACM.

I would also like to acknowledge support of this research by the Foundation for Research, Science and Technology New Zealand through their funding.

Many thanks go to Oliver McGregor for his careful proofreading of this thesis.

Finally a very big thanks to all my friends and colleagues at CACM. Be it by discussing mine or their problems, helping in the coding of macros and programs, or through lunchtime conversation and fun, they have helped in making my study at CACM both intellectually challenging and also very enjoyable and memorable. Cheers Ming, Peter, Sanjeev, Miro, Nikhil, Andrew (both of them), Rehan, Graeme, Tom, Jamie, Gwendal, Erwan and so many others from New Zealand and all over the world.

TABLE OF CONTENT

List of Tables

List of Figures