Liquid penetration into paper

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A thesis submitted for the degree of
Doctor of Philosophy at
The Australian National University

THE AUSTRALIAN NATIONAL UNIVERSITY

September 2004

Typeset in Times by TEX and LATEX 2ε.

To get the necessary image quality it was necessary to print this thesis one page to a sheet.

Except where otherwise indicated, this thesis is my own original work.

Raymond John Roberts
10 August 2005

Rags make paper

Paper makes money

Money makes banks

Banks make loans

Loans make beggars

Beggars make rags

Author unknown, circa Eighteenth century

Acknowledgements

I acknowledge the initial overall supervision of this research while studying part time by Dr Phillip Evans, then Reader in Forestry ANU who encouraged me to undertake the project and helped set up its original scope. When Phil left ANU to take up the position of Professor and Director at the Centre for Advanced Wood Processing Department of Wood Science University of British Columbia the role of overall supervision went to Dr Mark Knackstedt Associate Professor, Department of Applied Mathematics, Research School of Physical Sciences and Engineering, ANU. I acknowledge Mark's intellectual leadership, superb editing skills and friendship.

I also acknowledge the intellectual support, supervision, assistance with experimentation and friendship of Dr Tim Senden, Senior Research Fellow, Department of Applied Mathematics, Research School of Physical Sciences and Engineering, ANU. The friendship and support of Mark and Tim especially in the last year of the project where other issues could have created difficulties with the successful completion of the project is especially acknowledged and greatly appreciated.

I also acknowledge the support of Dr Roger Heady of the Electron Microscope Unit, ANU who provided so much assistance with the Cambridge Scanning Electron Microscope especially on weekends while studying part time. I especially appreciate the way in which Roger always managed to find a slot on the SEM for me for those last minute jobs that seemed to be unending.

I also acknowledge the support of:

Mr Anthony Hyde Senior Technical Officer Department of Applied Mathematics, Research School of Physical Sciences and Engineering, ANU who gave me great assistance in the design and in liaising with the workshop in the construction of the two cryo-cell units for the CLSM.

Dr M. Bruce Lyne President of the YKI Institute in Stockholm for organising various laboratory papers used in this thesis.

Mr Ross Cunningham of the Statistical Consulting Unit, The Graduate School ANU for advice and assistance in the design of experiments and analysis of data.

Mrs Christine Donnelly of the Statistical Consulting Unit, The Graduate School ANU for advice on the use of the statistical programme Genstat.

Dr Jeff Wood of the Statistical Consulting Unit, The Graduate School ANU for statistical advice.

Ms Jocelyn Paton and Ms Carolyn Carlile, Carter Holt Harvey Panels, Tumut for their

assistance in sample acquisition and preparation.

Mr Adrian Paalvast Manager, Carter Holt Harvey Panels, Tumut who provided support while I was employed part time at CHH.

Dr Vincent Otieno-Alego for access and assistance in the use of the Raman Microscope at the University of Canberra.

Mr John Barnard, Deparment of Chemical Engineering, Monash University for his assistance with mercury intrusion porosimety.

I am indebted to my parents Ruth and Bill who provided a place for me to stay in Canberra while I studied part time.

I am also indebted to my dear sons Will and Simon who missed out on a lot of time with dad and who understood the need for their dad to undertake this project at the expense of time with them on the farm. Their love and support meant so much and is impossible for me to put into words.

I acknowledge the financial support of the Cooperative Research Centre for Functional Communication Surfaces and also BASF AG Ludwigsafen for their financial support for the project and access to their 2-photo confocal laser scanning microscope at the Central Research Laboratories. I particularly acknowledge the assistance of Dr Wolfgang Schrof Group Leader Polymer Physics BASF Ludwigshafen who enabled me to use the CLSM exclusively while in Ludwigshafen and who supplied technical assistants while there.

I acknowledge the financial help of CSR who provided a research grant to enable me to purchase a high speed video camera and who supported my part time study while I was still employed as Technical Manager at the Tumut plant.

I acknowledge the support of Carter Holt Harvey Panels when I became a full time student in employing me part time as a treater specialist.

Finally I wish to acknowledge the leadership and support of Mr Mike Alston who was my manager at Tumut. Mike was the one who started this process by telling me to ”go and do some science” to solve a problem that no-one in the world was able to shed any light on. However I mainly acknowledge and deeply appreciate the friendship he gave me all the way through and his ability to fight off the corporate diversions from above and his efforts to gain corporate support for me after the takeover of CSR Panels by CHH when I became a full time student.

I look forward to a long association with all the people mentioned above.

Abstract

The origin of this thesis lay in the production of defects associated with manufacturing LPM impregnated panels. The causes of these defects were unknown as was their exact nature. In identifying the actual nature and cause of these defects, it is necessary to research the fundamental mechanisms of fluid flow into paper as well as identifying how certain structural characteristics of paper, as well as characteristics of the penetrating liquids, affected fluid flow within paper.

To understand the affect of different liquids on impregnation into porous media, simple isotropic micromodels are used to quantify the effects of surface tension and contact angle on the rate of fluid flow. The use of the Lucas-Washburn equation is questioned.

Using cryo-SEM and a newly developed technique of cryo 2-photon confocal laser scanning microscopy, the actual mechanisms of fluid flow in unsized paper are identified. These are due primarily to the advance of the wetting fluid in the form of bulk liquid films along channels formed by fibre overlaps. This is in contrast to the common description of fluid penetration, where the primary flow mechanism is based on the bulk filling of pores. These channels, formed by fibre overlaps are shown to form a highly interconnected dense network of flow paths which efficiently transport the wetting fluid. The flow rates associated with penetration along a number of potential flow paths within the fibre web are calculated. The experimentally observed penetration rate is consistent with a film flow process through inter-fibre channels which is significantly slower than a penetration process dominated by meniscus flow through pores. In addition the mechanism of fluid flow in internally sized papers is presented.

The effects of different fillers on paper structure, flow path morphologies and imbibition rate are also quantified. Laboratory papers with different types and amounts of filler are studied using SEM and cryo-SEM and a newly developed technique of high speed video microscopy to quantify such effects.

Contents

List of Figures

List of Tables