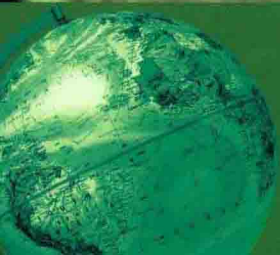


WILEY SERIES IN RENEWABLE RESOURCES

Douglas D. Stokke | Qinglin Wu | Guangping Han

Introduction to

# Wood and Natural Fiber Composites



WILEY

# Introduction to Wood and Natural Fiber Composites

DOUGLAS D. STOKKE

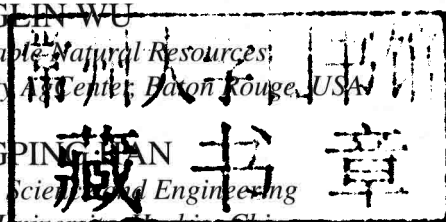
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This edition first published 2014  
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John Wiley & Sons Ltd, The Atrium, Southern Gate, Chichester, West Sussex, PO19 8SQ, United Kingdom

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**Library of Congress Cataloging-in-Publication Data**

Stokke, Douglas D.

Introduction to wood and natural fiber composites / Douglas D. Stokke, Qinglin Wu, Guangping Han.

pages cm. — (Wiley series in renewable resource)

Includes bibliographical references and index.

ISBN 978-0-470-71091-3 (hardback)

1. Engineered wood. 2. Composite materials. 3. Natural products. I. Wu, Qinglin. II. Han, Guangping.

III. Title.

TS875.S76 2014

674'.8—dc23

2013025429

A catalogue record for this book is available from the British Library.

ISBN: 9780470710913

Set in 10/12pt Times by Aptara Inc., New Delhi, India

Printed and bound in Malaysia by Vivar Printing Sdn Bhd

# **Introduction to Wood and Natural Fiber Composites**

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# Series Preface

Renewable resources, their use and modification are involved in a multitude of important processes with a major influence on our everyday lives. Applications can be found in the energy sector, chemistry, pharmacy, the textile industry, paints and coatings, to name but a few.

The area interconnects several scientific disciplines (agriculture, biochemistry, chemistry, technology, environmental sciences, forestry, . . . ), which makes it very difficult to have an expert view on the complicated interaction. Therefore, the idea to create a series of scientific books, focusing on specific topics concerning renewable resources, has been very opportune and can help to clarify some of the underlying connections in this area.

In a very fast changing world, trends are not only characteristic for fashion and political standpoints, also science is not free from hypes and buzzwords. The use of renewable resources is again more important nowadays; however, it is not part of a hype or a fashion. As the lively discussions among scientists continue about how many years we will still be able to use fossil fuels, opinions ranging from 50 to 500 years, they do agree that the reserve is limited and that it is essential not only to search for new energy carriers but also for new material sources.

In this respect, renewable resources are a crucial area in the search for alternatives for fossil-based raw material and energy. In the field of the energy supply, biomass and renewable-based resources will be part of the solution alongside other alternatives such as solar energy, wind energy, hydraulic power, hydrogen technology, and nuclear energy.

In the field of material sciences, the impact of renewable resources will probably be even bigger. Integral utilization of crops and the use of waste streams in certain industries will grow in importance leading to a more sustainable way of producing materials.

Although our society was much more (almost exclusively) based on renewable resources centuries ago, this disappeared in the Western world in the nineteenth century. Now it is time to focus again on this field of research. However, it should not mean a "retour à la nature," but it should be a multidisciplinary effort on a highly technological level to perform research toward new opportunities, to develop new crops and products from renewable resources. This will be essential to guarantee a level of comfort for a growing number of people living on our planet. It is "the" challenge for the coming generations of scientists to develop more sustainable ways to create prosperity and to fight poverty and hunger in the world. A global approach is certainly favored.

This challenge can only be dealt with if scientists are attracted to this area and are recognized for their efforts in this interdisciplinary field. It is therefore essential that consumers recognize the fate of renewable resources in a number of products.

Furthermore, scientists do need to communicate and discuss the relevance of their work. The use and modification of renewable resources may not follow the path of the genetic engineering concept in view of consumer acceptance in Europe. Related to this aspect, the series will certainly help to increase the visibility of the importance of renewable resources.

Being convinced of the value of the renewables approach for the industrial world, as well as for developing countries, I was myself delighted to collaborate on this series of books focusing on different aspects of renewable resources. I hope that readers become aware of the complexity, the interaction and interconnections, and the challenges of this field and that they will help to communicate on the importance of renewable resources.

I certainly want to thank the people of Wiley from the Chichester office, especially David Hughes, Jenny Cossham, and Lyn Roberts, in seeing the need for such a series of books on renewable resources, for initiating and supporting it and for helping to carry the project to the end.

Last but not least, I want to thank my family, especially my wife Hilde and children Paulien and Pieter-Jan for their patience and for giving me the time to work on the series when other activities seemed to be more inviting.

Christian V. Stevens  
Faculty of Bioscience Engineering  
Ghent University, Belgium  
Series Editor Renewable Resources  
June 2005

# Preface

The objective of this book is to draw together widely scattered information concerning fundamental concepts essential to the manufacture of wood- and natural-fiber composites. Information from the scientific literature was synthesized into a form that is intended to provide a context and content presentation that will be understandable by upper-level undergraduate students, graduate students, and practicing professionals. The topics addressed include basic information on the chemical and physical composition of wood and other lignocellulosic materials, the behavior of said materials under thermocompression processes, fundamentals of adhesion, specific adhesive systems used to manufacture composite materials, the industrial technology of said material manufacturing, and a chapter devoted to fiber/plastic composites. To my knowledge, there is no contemporary book that attempts to bring both fundamental and applied science together to form a textlike presentation of these subjects.

The vision for undertaking this project originated in my experience of teaching several iterations of an upper-division undergraduate course on wood-based composites. During the iterative development of my course, I found no adequate textbook to address the key topics that I think are essential for a foundational understanding of lignocellulosic composites. Among these are a basic overview of lignocellulose composition, behavior of such materials under thermocompressive processing (the major technological umbrella under which most extant manufacturing processes may be categorized), and fundamentals of adhesion, combined with an overview of manufacturing technology. In order to address these topics, it was necessary to draw readings from the scientific literature. My experience was that although I found many excellent research papers that I deemed applicable and instructive, most undergraduate students were unable to adequately digest the information. It is my belief that even though these students should be able to comprehend and apply the scientific literature, they need a degree of interpretation and what I call "contextualization" to enable the learning process. This is particularly true for the technology-oriented (rather than engineering-oriented) students with whom I work. These students are representative of those traditionally enrolled in wood science/forest products curricula, industrial technology, or manufacturing. Students who gravitate to these majors tend to be visual and active learners with a high propensity for hands-on learning experiences. They tend not to learn as readily when faced with an "inordinate" degree of theoretical concepts. However, it is crucial that these students master important fundamental, theory- and experimentally-based concepts as it is often these very students who will be tasked with



operating, monitoring, troubleshooting, and improving industrial processes when they enter the professional world. Likewise, those already in employment may be required to function in operational areas of wood- and natural-fiber processing, with little background on either material properties or basic manufacturing processes. It is thus my hope that this book will be valuable to both students and professionals in analogous situations.

As outlined, this book could be viewed as consisting of four essential components or modules, with the first two largely fundamental or foundational in character, and the remaining two of a more applied nature. Following an introductory chapter, the first major topic addressed is an overview of lignocellulosic material (its chemical and physical nature) and the response of this material when subjected to heat and pressure. In this section, relatively recent research on the application of polymer theory to lignocellulose is significant. This module is contained in chapters two, three, and four. The second fundamental component or module is a discussion of adhesion/adhesion theory. This is contained in Chapter 5. The third component, of an applied nature, is a discussion of the specific types of adhesives used to bond lignocellulosic composites. This is presented in Chapter 6. The final module, also of an applied nature, is an overview of the manufacturing technology of major product types (Chapter 7) and a consideration of the growing field of fiber/plastic composites (Chapter 8).

It was our earnest goal to compose a text with the major aims of readability and comprehension for technology-oriented students. That is, our main audience is not students or practitioners of engineering analysis, but it is for those studying the field of forest products and wood science who need to both understand and manage the materials and technology at an operations management level.

Douglas D. Stokke

# Acknowledgments

The preparation of this book involved the contributions of many individuals and organizations in sundry capacities. First, my thanks to Sarah Hall, our Commissioning Editor at John Wiley & Sons, for much encouragement and guidance through the initial proposal and review process, during which the comments of several anonymous reviewers provided further reassurance that this endeavor was worthwhile. Sarah Tilley, Senior Project Editor in the Chemistry, Physics, and Material Sciences division of Wiley, was eminently patient when the reality of the task extended the project well beyond the initial deadline. I am also grateful to the office of the Vice President for Research and Economic Development at Iowa State University for approving the subvention publication grant that provided funding for my invaluable student assistants, Gabriele Frerichs, Alexa Dostart, and Crystal Krapfl. Gabriele (Gabbi) proved a most able Editorial Assistant, reading and thoughtfully commenting on draft manuscripts. Gabbi also prepared most of the graphs and computer graphics in this text, including the chemical structures, all the while injecting a healthy “can do” attitude. I honestly think this book never would have been completed without her assistance. Alexa Dostart created the exquisite original art that adorns the book. Her pencil drawings showcase her marvelous talent as an artist, and bring a fresh visual appeal to the project. Thank you, Alexa! Crystal provided valuable assistance with reference citations and tables.

I am indebted to my coauthors, Dr. Qinglin Wu and Dr. Guangping Han, for allowing me to draw them into a project that entailed much more time and effort than we had dreamed. I am grateful for their expertise, contributions, and friendship.

To the many scientists and engineers whose splendid work we have sought to capture and package for our intended audience, thank you for sharing your results and insights through your publications and presentations. I am also obliged to my students on whom I have tried various means of communicating scientific and technical information cognate to our topic.

Finally, I owe my utmost thanks and gratitude to my wife, Jodie, and our daughter, Melody, for their unfailing love and patience. Thank you for granting me the freedom to expend seemingly countless hours on the research and preparation of this work, and for allowing me to pile so many books and papers in our home office while I monopolized our computer! Jodie,

your gentle encouragement and understanding have always underpinned our marriage, and your patience allowed me to complete this project even when I did not think I could. I thank God for you and for granting me life and health sufficient for the task.

Douglas D. Stokke  
Story City, Iowa  
April 2013

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