SPRINGER BRIEFS IN
APPLIED SCIENCES AND TECHNOLOGY

João M. P. Q. Delgado
Antonio Gilson Barbosa de Lima
Mariana Julie do Nascimento Santos

Transport Phenomena in Liquid Composite Molding Processes

Springer

SpringerBriefs in Applied Sciences and Technology

SpringerBriefs present concise summaries of cutting-edge research and practical applications across a wide spectrum of fields. Featuring compact volumes of 50–125 pages, the series covers a range of content from professional to academic.

Typical publications can be:

- A timely report of state-of-the art methods
- An introduction to or a manual for the application of mathematical or computer techniques
- A bridge between new research results, as published in journal articles
- A snapshot of a hot or emerging topic
- An in-depth case study
- A presentation of core concepts that students must understand in order to make independent contributions

SpringerBriefs are characterized by fast, global electronic dissemination, standard publishing contracts, standardized manuscript preparation and formatting guidelines, and expedited production schedules.

On the one hand, **SpringerBriefs in Applied Sciences and Technology** are devoted to the publication of fundamentals and applications within the different classical engineering disciplines as well as in interdisciplinary fields that recently emerged between these areas. On the other hand, as the boundary separating fundamental research and applied technology is more and more dissolving, this series is particularly open to trans-disciplinary topics between fundamental science and engineering.

Indexed by EI-Compendex, SCOPUS and Springerlink.

More information about this series at http://www.springer.com/series/8884

João M. P. Q. Delgado ·
Antonio Gilson Barbosa de Lima ·
Mariana Julie do Nascimento Santos

Transport Phenomena in Liquid Composite Molding Processes

Springer

João M. P. Q. Delgado
Faculty of Engineering, CONSTRUCT-LFC
University of Porto
Porto, Portugal

Mariana Julie do Nascimento Santos
Department of Mechanical Engineering
Federal University of Campina Grande
(UFCG)
Campina Grande, Paraíba, Brazil

Antonio Gilson Barbosa de Lima
Department of Mechanical Engineering
Federal University of Campina Grande
(UFCG)
Campina Grande, Paraíba, Brazil

ISSN 2191-530X ISSN 2191-5318 (electronic)
SpringerBriefs in Applied Sciences and Technology
ISBN 978-3-030-12715-2 ISBN 978-3-030-12716-9 (eBook)
https://doi.org/10.1007/978-3-030-12716-9

Library of Congress Control Number: 2019930633

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Preface

The progress in the field of composite materials has been given for many professionals from the chemical, materials, mechanical and manufacturing engineering, and other scientific areas.

In the present days, the development of new and advanced composite manufacturing processes has allowed the manufacture of innovative products with high quality from the technological and structural performance points of view. These products are being made by several industries such as automotive, marine, aerospace, sports, and products.

In the majority, they are manufactured by the liquid molding process, with special reference to resin transfer molding (RTM) process. In fact, this technique has gained the preference because it offers several advantages in terms of high surface finish quality and good mechanical properties to the manufactured products.

Despite the importance, unfortunately, this topic has been shortly discussed in textbooks available in the literature, which provides a gap for new academic books aimed at this issue. In this sense, this book is intended to provide valuable information about polymer composite manufacturing with emphasis in liquid molding processes and the resin transfer molding (RTM) technique. In this document, emerging topics related to foundations, engineering applications, advanced modeling, and experiments of the RTM process are presented and discussed.

For many years, we have the enormous pleasure of working with various talented researchers including our current and former students (undergraduate, graduate, and postgraduate levels), in the theme "composite manufacturing." Then, the intention of this book is to document our research progress at this field.

The book contains five chapters about composite materials manufacturing with particular reference to RTM process. Following the steps of the book, in Chap. 1, an introduction is given to the polymer composite reinforced with fiber, and the motivation to study the liquid composite molding process. Chapter 2 is devoted specially to the resin transfer molding technique. The main issues, including foundations, processing stages, process control, advantages and disadvantages associated with the use of the RTM technique and application at different areas, are presented and discussed. The experimental techniques that have been developed by

our research group related to resin transfer molding are presented in Chap. 3. Two important topics related to the RTM process are presented: rectilinear and radial infiltration processes, with or without fillers (reinforcements). Chapter 4 presents a comprehensive and rigorous analysis about fluid flow in porous media with particular emphasis to RTM process. In this chapter, different approaches (analytical and numerical) for description of air and resin flow in fibrous media are given. An advanced mathematical modeling is proposed which includes different effects of process parameters such as injection pressure, fluid viscosity, porous media permeability and porosity, and mold geometry. In Chap. 5, we present our conclusions about the different chapters' content and the main results present in them. The idea is to help professionals, engineers, industrials, and academics involved in this advanced and interdisciplinary field.

Porto, Portugal — João M. P. Q. Delgado
Campina Grande, Brazil — Antonio Gilson Barbosa de Lima
Campina Grande, Brazil — Mariana Julie do Nascimento Santos

Acknowledgements

We would like to thank Prof. Dr. Sandro Campos Amico, Jeferson Avila Souza, Brauner Gonçalves Coutinho, Iran Rodrigues de Oliveira, and Felipe Ferreira Luz for providing excellent researches about this field and contributions in this book.

We thank our Publisher and Editors for making valuable suggestions to the contents of the book, and especially to Prof. Dr.-Ing. Andreas Öchsner for believing in this project. Finally, we express our gratitude for each one of the cited authors and researchers, and also to the Portuguese and Brazilian (CNPq, CAPES, and FINEP) research agencies for the financial support.

Contents