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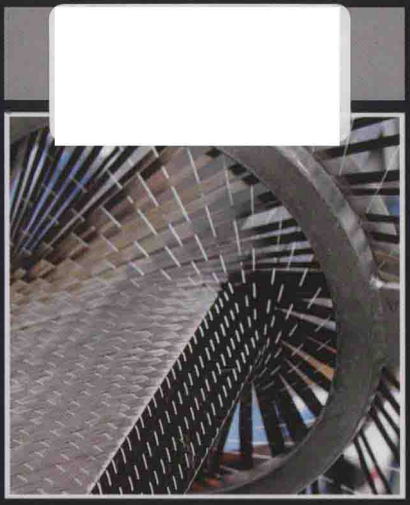

Advances in Composites Manufacturing and Process Design

Edited by Philippe Boisse

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Preface

Composite materials allow the manufacturing of structures with high mechanical properties with reduced mass. Consequently, they are a possible way to reduce energy consumption in the transportation industries. Their development is important in particular for civil planes. The structures of the most recent long-range transport aircraft are made of composite materials. In the automotive industries, many projects aim to use composite materials in future cars. In civil engineering, composite materials are used to repair and reinforce buildings.

A composite material is the association of a fibrous reinforcement and of a matrix. The fibers can be short or continuous. The structures strongly loaded need continuous fibers. The fibers withstand loadings. The matrix aims to prevent the motion between fibers and, consequently, to constitute a solid. There are many kinds of fibers and matrices. They can be associated with many manufacturing methods. Finally, the resulting composite materials are numerous.

The first part of this book presents new advances in composites manufacturing and process design:

Braiding is a versatile and cost-efficient process for the production of fiber preforms for composites. The range of shapes with different characteristics is very wide. The material waste can be reduced to a minimum, which is even more important when expensive carbon yarns are used.

Knitting processes are efficient ways to manufacture automatically net-shape preforms of technical fibers. 3D preforms can be knitted with one or several types of fiber, with various local knitting patterns and, thus, various local thicknesses and properties.

Weaving processes can be adapted to manufacture composite preforms. These textile structures are near-to-shape designed and produced on adapted processes. Loom adaptations have been made to achieve the production of 3D warp interlock fabrics. These textile structures have been revealed to be particularly adapted to the dry forming process.

Fiber placement involves the laying down of reinforcing fibers along predefined trajectories in the component. The goal of fiber placement is to maximize the performance of a particular part by utilizing the highly directional strength of fiber reinforcement.

Drape processes are required to cover a doubly curved tool surface with sheets of reinforcement or prepreg. They are both manual and semiautomated manufacturing processes. They are based on the very specific deformation behavior of textile materials.

Thermoforming or hot press forming is a fast manufacturing process of thermoplastic composite laminates. The forming stage can be executed rapidly with preconsolidated

thermoplastic composite laminates, as only heating is required to transform the material from a strong and stiff to an easily formable state and subsequent cooling to achieve the reverse transformation.

The advantages of *3D fabrics* are high delamination and crack propagation resistance, which leads to good impact and fatigue properties. Overbraiding and 3D braiding technology offer diverse opportunities to manufacture near net-shape preforms.

The chemical vapor infiltration (*CVI*) process is used to fabricate the interphases and matrices of CMCs. This process involves complex physicochemical phenomena such as the transport of precursor, carrier, and by-product gases in the reactor and inside a fibrous preform, chemical reactions, and the structural evolution of the preform.

Machining operations on composite material are necessary. The heterogeneity and anisotropy of these materials makes their machining difficult. The effect of these processes using conventional and nonconventional machining on the nature of the damage generated as well as on the mechanical behavior of composite parts made of carbon/epoxy is investigated.

The best damage tolerance of composite solution has been shown but also the necessity to define optimized *repair* solutions. A global vision of repair is proposed through a case study.

The second part of the book introduces the mechanical properties of reinforcements and matrices and the simulations of manufacturing processes.

A digital representation of 2D *woven fabric* structure is based on the forms of crossover in different repeat units. Six modes of deformation are considered: in-plane, two tensile and shear, out-of-plane, two bending, and twist. Energy minimization is used to model these properties.

Noncrimp fabrics arose from the challenge to create reinforcements that combine unidirectional fibers with integrity, ease of handling, and drape of textile fabrics. From this challenge, several noncrimp textile structures were created with different manufacturing processes and different bonding solutions.

Epoxy/amines systems are studied during their synthesis and once they are synthesized. The polyepoxies have an exceptional place among the thermosets because of their wide range of applications, especially in manufacturing of composites-based polymers. They are the result of the reactions between epoxy resins and hardeners.

FE analyses of composite reinforcement *forming* are presented at macroscopic and mesoscopic scales. Simulations of 3D interlock fabric deformations are based on a hyperelastic model. A simulation at mescoscale of the deformation of a textile composite reinforcement is presented. The FE model is obtained from X-ray computed tomography of the fabric in order to be close to the real geometry.

Numerical modeling and simulation approaches for the *resin flow* analysis in textile composites manufacturing processes are presented. According to the computational scale, which can be classified by textile microstructure, different governing equations for the resin flow are suggested.

Numerical modeling strategies are presented for the *pultrusion* of thermosetting composite profiles. The focus is particularly on the forming die and postdie region in which the multiphysics take place.

Finally, works developed for *CVI modeling* are presented, ranging from simple analytical estimates to multiscale, multiphysics detailed numerical modeling.

Philippe Boisse

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