Chapter 6
Conclusions

Abstract This book is entirely dedicated to polymer composites. In them, an overview of the basic issues related to this class of material ranging from foundations, advanced modeling to engineering applications is given.

Composite can be defined as a multiphase material consisting of two or more distinct materials (micro and macro constituents) which differs in chemical forms and composition, and that are insoluble in each other. It is composed basically of one continuous phase (matrix) and one or more dispersed phases (reinforcement).

A very wide range of possible reinforcement exist which can be used to reinforce all classes of composites. Among them, an important component is the fiber. Fiber reinforcement come in different forms (linear and interlaced fiber structure), and the glass and carbon fibers are the most used.

The resin used for composite materials include thermosetting or thermoplastic resins. The majority of the composites use thermoset resin like matrix, with particular attention to epoxies and polyesters.

There are several polymer composites manufacturing techniques such as, spray-up, hand lay-up, filament winding, pultrusion, vacuum bag molding, autoclave molding, compression molding, liquid composite molding, among others. In this context, the choice of an appropriated manufacture technique and process control are essential to obtain product with good quality (finishing and structural performance) and low cost process.

Polymer composites have expanded their use in different sectors of modern industry, such as automotive, aerospace, sports, civil construction, naval, military and biomedical.

The above applications are given only as examples of the great variety of composite products.

The content of this book has demonstrated that the resin transfer molding technique (variety of liquid molding process) is now a well-understood topic. The information related in this book proved that the RTM process is an efficient technique in the manufacturing of fiber-reinforced polymer composite. This information is related to the various advantages presented by this manufacturing method.

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An advantage of the RTM technique is that the final shape of the composite can often be achieved in one operation with little need for further expensive finishing process.

The mechanisms governing composite behavior in operations are very different from those which are encountered with traditional materials, and requires a full understanding of their constituents (reinforcing and matrix) and their interaction at the fiber-matrix interface (adhesion) or interphase. The adhesion quality is vital to mechanical performance of the composite, in order to avoid failure and damage in the composite (cracks, local deterioration, delamination).

Then, we have a lack of studying the polymer composite manufacturing, specially resin transfer molding process.

In this sense, an understanding of the resin flow front position during injection process is vital to control the process and thus, to obtain good quality of the composite after processing.

For this, standard laboratory experiments were carried out, in order to verify the flow front displacement and to estimate the porous media permeability. Two physical situations were studied: rectilinear and radial infiltration.

Further, in order to describe the fluid motions through porous media, the problem was formulated at a scale at which standard continuum theory applied to immiscible flow in porous media can be used. The advanced mathematical model predicts adequately the two-phase flow behavior inside the fibrous media and in specific cases, the interaction between the materials (air, resin and fibers).

It was showed that all rigorous mathematical treatment given to obtain the analytical and numerical solutions of the governing equations have been useful in describing the fluid flow inside the porous media. Thus, the numerical simulations proved to be an essential tool in the understanding of the RTM process.

From the presented results was verified that, both the numerical and experimental analyses of composite materials manufacture have showed that are crucial in the design of parts and that can be used to help designers, engineers and academics to make design decisions.

It was observed that $CaCO_3$ content mixed with resin, injection pressure and gate location to inlet and outlet resin affect strongly the filling time and void formation in the product. The study shows that the consideration of the sorption term in the mass conservation equation proved to be a more complete mathematical formulation to be used in the RTM process with great success. This term affects strongly the resin flow behavior inside the porous media.

Further, because the great variety of shape of parts, the use of boundary fitted coordinates allowed application of the model to predict resin flow through fibrous media in mold with arbitrarily-shaped geometries. Thus, this non-conventional approach is now well understanding as applied to RTM process.