FASERINSTITUT FIBRE BREMEN

PROJECTS

Project PETER

Pressure dEpendent modelling of Thermoset Epoxy Resins

Motivation

Process simulation plays an important role in composite manufacturing science. It provides significant insights, which are required to understand, optimize and design a robust and stable process. In most of the manufacturing processes of composite parts, pressure is low (< 8 bar) and its influence is considered negligible throughout most of the literature. Nevertheless, curing of epoxy resin under high pressure, up to 200 bar, occurs for example during the high-pressure resin transfer moulding (HP-RTM) process. This method results in shorter injection times as well as in the reduction of cycle times and process costs in comparison to the traditional RTM process. Its process chain is shown schematically in figure 1.

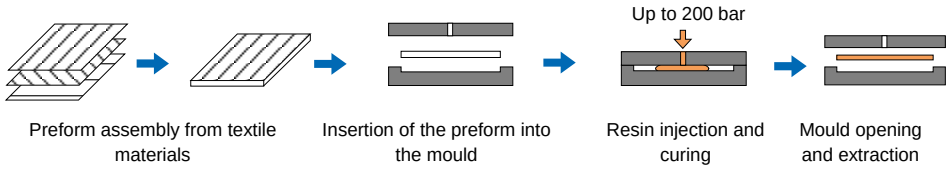

Figure 1: High pressure RTM process chain

Former investigations have shown that those high pressures, occurring during the HP-RTM process, have a significant influence on the curing reaction and the material properties of epoxy resins. For example, as shown in figure 2, the final degree of cure of samples cured at the same isothermal temperature increases with increasing pressure. It can be assumed that this effect is caused by the decreased distance between reacting molecules. Consequently, the influence of pressure should no longer be neglected for the material model.

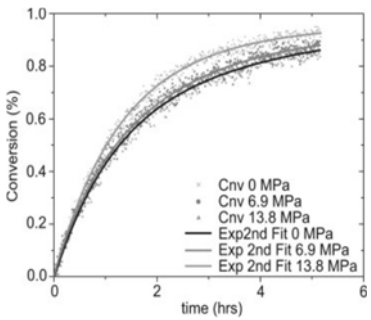

Figure 2: Effect of pressure on the curing reaction of epoxy resin

[Cruz, J. C., Osswald, T. A, (2009), Monitoring Epoxy and Unsaturated Polyester Reactions Under Pressure – Reaction Rates and Mechanical Properties, Polymer Engineering Science, vol. 49, pp.2099-2108]

The research project PETER aims at the investigation on the influence of high pressure on the curing behaviour of epoxy-resins as well as on the properties and process-induced distortions of the final composite part. This shall be achieved by augmenting an existing material model using free-volume theory, which is capable to describe the compression of the material caused by the high pressure.

Approach

The central task of the project is the creation of a material model allowing to perform process simulation for the HP-RTM-process. Initially, this implies the material characterization of the applied high reactive resin system as well as the composite material in order to provide actual values for the model creation. The effect of pressure on the free volume will be investigated by dielectric measurements during the cure at different pressures. The model creation will be done within three sub-packages. First, a material model based on the free volume theory is created for the epoxy resin. The pressure

dependency is then implemented in the second sub-package. Finally, mixture rules are deduced, in order to calculate the properties of the composite material.

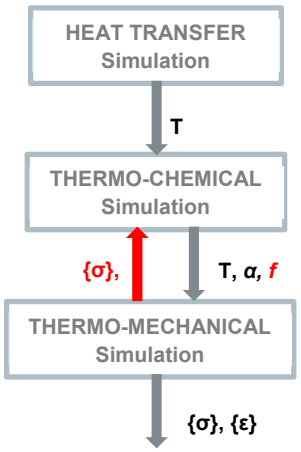

Figure 3: Extension of the simulation scheme for the RTM-process

Process simulation tools for the RTM-process have already been developed at the Faserinstitut Bremen e.V. (FIBRE). The existing simulation consists of three modules, which model the occurring chemical and physical processes during cure (see figure 3). The HP-RTM model shall be created by augmenting the existing simulation for the RTM-process using the fractional free volume *f*, which is defined as free volume divided by the specific volume. Thereby a strong coupling between the pressure acting on the resin and its thermo-chemical properties has to be introduced. This shall be achieved by a temperature, pressure and cure dependent formulation of the free volume as well as a free volume dependent model for all material parameters.

In order to validate the created material model, different specimens will be produced using different processing conditions and the final properties will be measured. The same production processes will be simulated and the comparison of the results will show the quality of the material model created.

Possible Applications

- HP-RTM process simulation and optimization

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Project Partners

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Faserinstitut Bremen e.V.

The Faserinstitut Bremen e.V. is active in research and development tasks in areas of testing, development and processing of fibres, textile preforms and carbon fibre reinforced plastics. The department of Composite Structures and Processes focuses on the examination of continuous process chains and the design of components for aircraft and automotive industry and other industrial fields.

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