Process simulation of LPM (Liquid Polymer Moulding) in special consideration of fluid velocity and viscosity characteristics

Matthias Repsch
Institut für Verbundwerkstoffe GmbH
Dipl.-Ing. MSc

Matthias Repsch1, Ulrich Huber1 Stefan Rief2, Dirk Kehrwald2, Konrad Steiner2

1Institut für Verbundwerkstoffe GmbH,
Erwin-Schrödinger-Straße 58, · D-67663 Kaiserslautern 2Fraunhofer Institut für Techno- und Wirtschafsmathematik,
Europaallee 10, D-67657 Kaiserslautern

ABSTRACT

In-situ polymerizing thermoplastics are an interesting option regarding resins for a low to mid volume production of LCM (Liquid Composite Molding) components. The advantage of a low initial viscosity allows to reduce the cycle time of the whole process significantly even at a high fiber volume fraction. A disadvantage of this process is the poor prediction quality of Darcy's Law based simulation software for the mold filling. Main reason for this difficulty is the fluid passing during injection through three flow stages starting with fast newtonian flow, flow fulfilling the restrictions of Darcy's law and ending up in a slow flow affected mainly by visco-elastic flow behavior. Regarding to the high polymerization temperature of the thermoplastic during injection the several flow stages are investigated separately by the us of newtonian and visco-elastic substitution fluids on a visual permeameter. Based on a non-crimp fabric reference fiber bed with known permeability the influence of viscosity characteristic and fluid velocity for the flow front evolution are measured. Fast flow (low viscosity) shows that Darcy's law is predicting due to inertia effects a faster flow front evolution than observed in the experiments. The stage of visco-elastic fluid characteristics also shows a slower flow front evolution than calculated by a simulation because of capillaric effects.
The results from these experiments are the basic to decide whether an alternative flow model has to be chosen (e.g. Forchheimer) or Darcy's law has to be modified for the first and last flow stage. To align the mathematical models for a precise simulation the microstructure of the fiber bed is analyzed over the flow path by polished micrograph sections. Herein attention is paid to the distribution of the rovings at the specimen cross-section and the filament distribution inside the rovings.
The results of these investigations are the basis for a micro structural simulation with a focus on newtonian and visco-elastic fluid characteristic for microscopic and macroscopic flow. Resulting from these simulations the fluid velocity distribution and in case of visco-elastic fluid behavior the viscosity distribution is calculated inside the fiber bed. Constitutive on the micro structural simulation a flow model is built up for all three

flow stages including the possibility to precisely simulate varying flow characteristics and to handle the transitions between the single flow stages.