2D Simulation and Validation for Highly-Concentrated, Glass Fiber-Reinforced, Injection Molded Thermoplastic Composites

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ABSTRACT
Highly concentrated, injection molded fiber-reinforced composite one of the strategies considered by the automotive industry to reduce fuel consumption. The bottleneck of this technology is the uncontrolled anisotropy due to the flow-induced orientation that happens during the forming stage on the parts. The use of simulation software able to compute the fiber orientation can solve this limitation, but commercial software are able only to qualitative describe the orientation. This paper presents the use of a rheological based model for the orientation capable to predict the fiber orientation in center-gated disk and the validation of those predictions with experimental orientation results. A 2-D finite element code that couples the flow field described by Hele-Shaw flow approximation and the equations governing fiber orientation simulate the filling stage of a glass-fiber suspension within commercial concentration. In these simulations, an asymmetric orientation measured at the gate by a modified version of one method of ethane is used as initial condition or orientation. The prediction of fiber orientation evaluated in several locations of incomplete center gated parts (10, 40, and 90% of the radial dimension) is compared with experimental results. The experimental results show an asymmetric profile related to the multilayer structure of orientation that that fades from the gate to the end-of-fill region of the molded part more slowly than the predictions do. In addition, the discrepancies observed close to the mid-of-fill region can be attributed to the external flow in this region, but ignored by use of the approximated flow field used in the simulations. Apparently, coupled simulations including the frontal flow and slow evolution model of orientation are necessary to predict quantitatively the fiber-induced orientation.

BACKGROUND
High Strength Weight Reduction Materials
Office of FreedomCAR and Vehicle Technologies

To identify and develop materials and processing technologies which can contribute to weight reduction without sacrificing strength and functionality.

GOAL
To combine numerical simulation and experimental programs to improve the prediction of microstructure in short glass reinforced thermoplastics

OBJECTIVES
To simulate the mold filling process for thermoplastic melts reinforced with short fibers using constitutive relations (i.e. stress tensors coupled with a generation expression) which allow coupling between the flow and particle orientation.

A key aspect of this work will be an experimental evaluation of the predicted fiber or particle orientation distribution throughout an injection molded part.

INNOVATION
Use of constitutive relations, which contain the micro-structural aspects of the reinforced melts.

SIMULATION RESULTS

COMPOSITE MATERIAL
Material properties
Matrix: PBT (Newfrost )
Fiber: 30wt% short glass fiber
Aspect ratio: 30

Model parameters obtained from rheometry

EXPERIMENTAL DETERMINATION OF FIBER ORIENTATION

Procedure:
Polishing
Plasma etching
Image acquisition (reflective microscopy, using motorized stage)
Semi-automatic image analysis (customized)

Results
Eliminate ambiguity problem using the shadow
Obtain fiber orientation close to the wall
Characterize fiber orientation in full flow domain

FINDINGS
Model parameters determined by rheometry can be used to simulate fiber orientation
Modified procedure let us to improve the fiber orientation measurement using reflective microscopy.
Experimental measurements show asymmetric profile of orientation that evolves from the gate to the flow front.

The delay model and coupled flow and orientation improve prediction of fiber orientation.

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