Highly concentrated, injection molded fiber-reinforced polymer composites are one of the materials being considered by the automotive industry to reduce fuel consumption.

The limitation of this technology is the uncontrolled anisotropy of reinforcing fibers due to flow-induced orientation in the mold during the processing of these composites. In this study, center gated disks are used to characterize fiber orientation in the mold. An experimental method for characterization of fiber orientation is developed that requires small sample size and does not suffer from the ambiguity in identifying fiber footprints of traditional methods.

Two fiber suspensions (30 wt. % short glass-fiber Polybutylene terephthalate (PBT) and Polypropylene (PP)) with different rheological characteristics were used in these experiments.

Four flow regimes can be identified for center-gated disk geometry: Pre-gate, entry, shear and front.

The initial orientation measured in the entry region presented a fiber distribution different from the random orientation usually assumed in literature for a center-gated disk. In the advancing front region, PBT front has a ruged surface while PP front is more smooth and parabolic.

To simulate the mold filling process for thermoplastic melts, a rugged surface while PP front is more smooth and parabolic.

To identify and develop materials which can contribute to weight reduction without sacrificing strength and functionality:

- Increase the fuel efficiency
- Reduce emissions of class 1-8 trucks

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

Balance equations for injection molding
\[
\begin{align*}
\nabla \cdot \mathbf{r} &= 0 \\
\nabla \cdot \mathbf{v} &= 0 \\
\alpha = \mathbf{v} \cdot \mathbf{n} = 0 \\
\phi &= \frac{T - T_0}{T_M - T_0} \\
\end{align*}
\]

Short glass fibers

Constitutive equation: Folgar-Tucker Model with delay \( \tau \)

Evolution of orientation tensor
\[
\frac{\partial \mathbf{O}}{\partial \tau} = \frac{\mathbf{O} - \mathbf{O}_0}{\tau} + \frac{2}{3} \mathbf{O} \cdot (\nabla \mathbf{v})^T (\nabla \mathbf{v})
\]

Stress due to oriented particles
\[
\sigma = \mathbf{O} \cdot \tau \cdot \mathbf{P}
\]

Polymer matrix

Second invariant of stress
\[
\Pi = \frac{1}{2} \mathbf{v} : \mathbf{v} = \mathbf{I} \cdot (\nabla \mathbf{v})^T (\nabla \mathbf{v})
\]

Second invariant of strain
\[
\Pi \cdot \mathbf{I} = \frac{1}{2} (\nabla \mathbf{v})^T (\nabla \mathbf{v})
\]

GOAL

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Ongoing work

Simulation of fiber orientation works well for Hele-Shaw flow approximation. However, close to the advancing front, Hele-Shaw simulation overpredicts fiber orientation, especially in PBT.

Current work involves experimental work on advancing front and gate region which are important in defining the fiber orientation.

Numerical tools are being developed to solve full flow equations for the advancing front and entry region.