Transient Rheology of Polypropylene Melt Reinforced with Long Glass Fibers

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Motivation for Research
Create long fiber reinforced thermoplastic (LFT) materials as a function of processing design for:

- Increased strength properties
- Production of lightweight materials
- More energy efficient transportation

Scope of Research

- Long fibers exhibit flexibility... Should this be accounted for in an orientation model?

Orientation Representation and Theory

\[
\mathbf{A} = \int \nu \, \psi(\mathbf{r}, t) \, d\mathbf{r}
\]

\[
\mathbf{A} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}
\]

Random Fully ordered in \(x_1\) direction

Folgar-Tucker Orientation Model

\[
\frac{DA}{Dt} = \frac{\Delta \mathbf{A} \mathbf{A}^T + \mathbf{A} \Delta \mathbf{A}^T}{2} + C_1 \mathbf{R} \left( \mathbf{A}^T \mathbf{A} - 3 \mathbf{I} \right)
\]

Bead-Rod Orientation Model

\[
\frac{DA}{Dt} = \frac{\Delta \mathbf{A} \mathbf{A}^T + \mathbf{A} \Delta \mathbf{A}^T}{2} + C_2 \mathbf{R} \left( \mathbf{A}^T \mathbf{A} - 3 \mathbf{I} \right)
\]

Lipscumb Stress Model

\[
\sigma = C_2 \mathbf{D}^2 + \eta \mathbf{D}^2 + \eta_s \mathbf{D}_s^2 + \eta_k \mathbf{D}_k^2
\]

Stress Model Parameters:

- \(C_2\), steady state viscosity
- \(\eta_s\), magnitude of the viscosity overshoot
- Orientation model parameters (C, and/or k)

Experimental Methods and Results

- Redlinear homogenous flow
- Reduces unwanted fiber/fiber and fiber/wall contacts
- Localized stress measurements reduce edge effects
- Fiber Orientation Analysis:
  - Digital imaging method of Leed's

Conclusions and Future Work

- Long fibers are observed to exhibit flexibility
- Sliding Plate efficiently allows for the study of LFT rheology
- Bead-Rod model provides larger overshoot predictions (when compared to Folgar-Tucker) using the Lipscumb model, and can be used to slow orientation kinematics
- Combination of stress and orientation models are NOT fully consistent. Final orientations are over predicted in this case.
- Future desire to account for flexibility from fiber interactions
- Future investigation of Bead-Rod behavior in complex flow

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3 mm 1 mm