Visualization of Fiber Orientation in Highly-Concentrated, Glass Fiber-Reinforced, Injection Molded Thermoplastic Composites Using Web3D Technology


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ABSTRACT
Orientation tensors are commonly used to represent orientation in fiber composites. They are excellent and compact tool to describe the orientation in mathematical terms. However, the visualization of the orientation tensors is not straightforward. Therefore, in this paper we present a simple method to visualize fiber orientation in composites using a virtual reality modeling language (VRML) tool. This tool is used to describe the experimental orientation and simulation results for an injection molded center-gated disk. The results show an easy way to visualize and understand the complex structure of orientation in composites.

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

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 IN VISUALIZATION
We have introduced virtual reality tools through Web3D to visualize the micro-structure of fiber reinforced melts.
- An effective environment for the unified visualization of 3D orientation data from experiment (microscopy) and numerical simulation.
- Interactive Web3D publication provides a simple and intuitive tool to understand fiber orientation data.

WEB 3D
Refers to the International Standards Organization (ISO) standards of the Web3D Consortium (web3d.org). Declarative languages like Virtual Reality Modeling Language (VRML) and Extensible3D (X3D) enable interactive 3D multimedia environments and animations to be deployed over web protocols. These standards are by nature cross-platform (e.g. desktops, CAVE) and integrate with common web technologies such as XML and Webservices.

EXPERIMENTAL DETERMINATION OF FIBER ORIENTATION
- Procedure:
  - Polishing
  - Image acquisition (reflective microscopy using motorized stage)
  - Semi-automatic image analysis (customized)

EXPERIMENTAL RESULTS
- Elimination of ambiguity problem using shadows
- Visualization of orientation using mutually perpendicular planes

BACKGROUND MULTILAYER STRUCTURE
Shell Parallel (A11 ≈ A33)
- Constitutive equations: Folgar-Tucker Model with delay (\( \alpha_1 \))
- Aspect ratio: 30
- Matrix: PBT (Newtonian)
- Fiber: 30wt% short glass fiber
- Evolution of orientation tensor:
  - Short glass fibers
  - Linear equations for injection molding
  - Newtonian matrix: \( \mathbf{P} = 2\mathbf{I} \)

OBJECTIVES
- Plot experimental data and averaged data
- 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.
- The delay model and coupled flow and orientation improve prediction of fiber orientation.
- In the investigation of fiber reinforced melts, Web3D and interactive visualization environments provide a low-cost and effective means to analyze the relationships between experimental and simulated results.

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