Modeling of Composite Preform Manufacturing

Lightweight Materials

U.S. Department of Energy

Energy Efficiency and Renewable Energy Program

Oak Ridge National Laboratory

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Transportation

FOR THE 21ST CENTURY

Background

Lightweight chopped-fiber materials, such as glass fiber and carbon fiber composites, have been commercially successful for many engineering applications. However, producing them in the volume and the cost range needed for wider use in automobiles remains a challenge. A new composite manufacturing method, the programmable powdered preforming process (P4), has been developed in recent years to provide a low-cost, high-volume process for producing chopped carbon fiber preforms for automotive body components. P4 allows a single preform to be molded into a completed part.

In the P4 process, tow, the least expensive form of fiber, is fed into a programmable robotic gun, chopped, and then sprayed along with a resin binder onto a steel screen to form a component. To take full advantage of the versatility of the P4 method and to support the design of high-performance materials, it is necessary to understand the effects that the preform structure has on the material properties. One of the most important aspects of the structure is the multi-scale disorder of the fibrous microstructure, which is a result of the material manufacturing processes.

The Technology

A new computer simulation program, FN-Sim, was developed at ORNL to model the P4 fiber deposition process and analyze the structure and properties of the resulting fiber networks. FN-Sim can simulate process parameters including a variety of fiber deposition patterns, fiber orientations, types, layers, fiber network densities, and preform thicknesses. Its capabilities could be extended to model various preform shapes and the adherence of fibers to preforms. The tool also can be adapted for use in modeling other advanced preform manufacturing techniques, such as the slurry process or hypothetical deposition mechanisms.

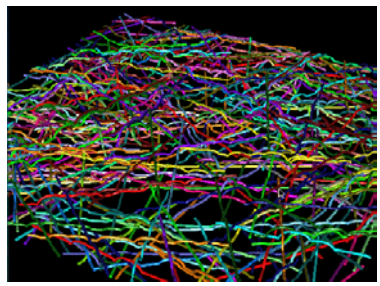
The preform models generated by FN-Sim can be analyzed and correlated with experiments to relate P4 process parameters to the measured physical properties of the parts produced. Parameters derived from FN-Sim fiber preform simulations have been used to develop a material model for random carbon fiber composites.

Commercialization

The FN-Sim software was developed with internal funding from ORNL. Additional work is needed before it is ready for commercialization, including additional features, relevant processing models for fiber deposition, models that better describe the actual P4 manufacturing system, and more analytical options for characterizing P4. The tool also needs to be rendered more user-friendly and computationally efficient.

Benefits

- Available options can model the effects of fiber type, orientation, length, shape, flexibility, layering, and so forth.
- Quickly design and evaluate the manufacturing feasibility of the fiber and layer distribution
- It provides quantitative measures of the fiber preform, such as void distribution, connectivity, and porosity. In conjunction with experiments, these measures can be used to correlate effective permeability and develop a method for predicting molding parameter feasibility.
- Analyzes fiber network structure and provides parameters that are used in constitutive models for FEM analysis



Output of FN-Sim simulation of a flexible-fiber, low-density preform deposited on a flat substrate

For more information on how DOE is helping America remain competitive in the 21st century, please contact:

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Success Story