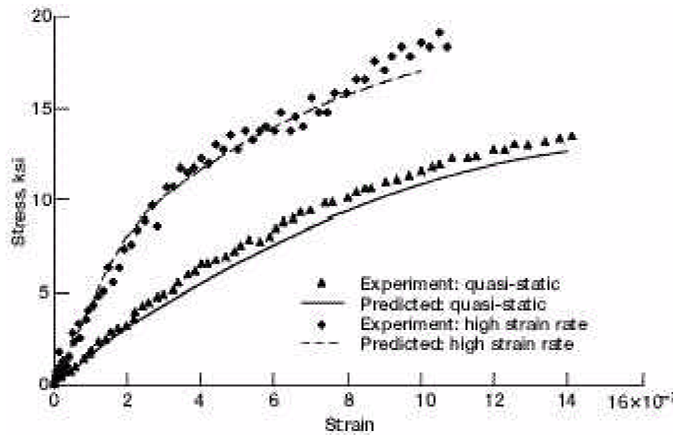
High Strain Rate Behavior of Polymer Matrix Composites Analyzed

Procedures for modeling the high-speed impact of composite materials are needed for designing reliable composite engine cases that are lighter than the metal cases in current use. The types of polymer matrix composites that are likely to be used in such an application have a deformation response that is nonlinear and that varies with strain rate. To characterize and validate material models that could be used in the design of impact-resistant engine cases, researchers must obtain material data over a wide variety of strain rates. An experimental program has been carried out through a university grant with the Ohio State University to obtain deformation data for a representative polymer matrix composite for strain rates ranging from quasi-static to high rates of several hundred per second. This information has been used to characterize and validate a constitutive model that was developed at the NASA Glenn Research Center.

To obtain the material data, Glenn's researchers designed and fabricated test specimens of a toughened epoxy resin and a carbon-fiber-reinforced composite that could be used in fan-containment applications. Quasi-static tests at low strain rates and split Hopkinson bar tests at high strain rates were then conducted at the Ohio State University. The tests indicated that both the stiffness and strength were highly strain-rate dependent for the resin. Furthermore, the strain rate dependence of the stiffness and strength were also observed for a variety of uniaxial composites with different fiber orientation angles. The resin data were used to characterize a constitutive model that was developed at Glenn to simulate the rate-dependent, deformation response of the toughened epoxy matrix material. The composite data were used to validate a composite micromechanics model which incorporates the polymer constitutive equations and was also developed at Glenn that predicts the rate-dependent deformation response of a composite based on the properties and response of the individual constituents.

In the figure, the tensile stress-strain curve of a uniaxial [45°] polymer matrix composite is shown for both quasi-static and high strain rates. The rate dependence of the deformation response can be easily seen in the figure, with the stiffness and strength of the material increasing with strain rate. Results predicted using the developed analytical model are also shown for both strain rates. The predicted results compare well with the experimentally obtained values, indicating that the analytical model is valid over a wide variety of strain rates. Further tests and analyses will be conducted on additional fiber and resin combinations, as well as on multidirectional laminates with various ply layups.



Experimental and predicted tensile response of a representative [45] polymer matrix composite for quasi-static and high strain rates.

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