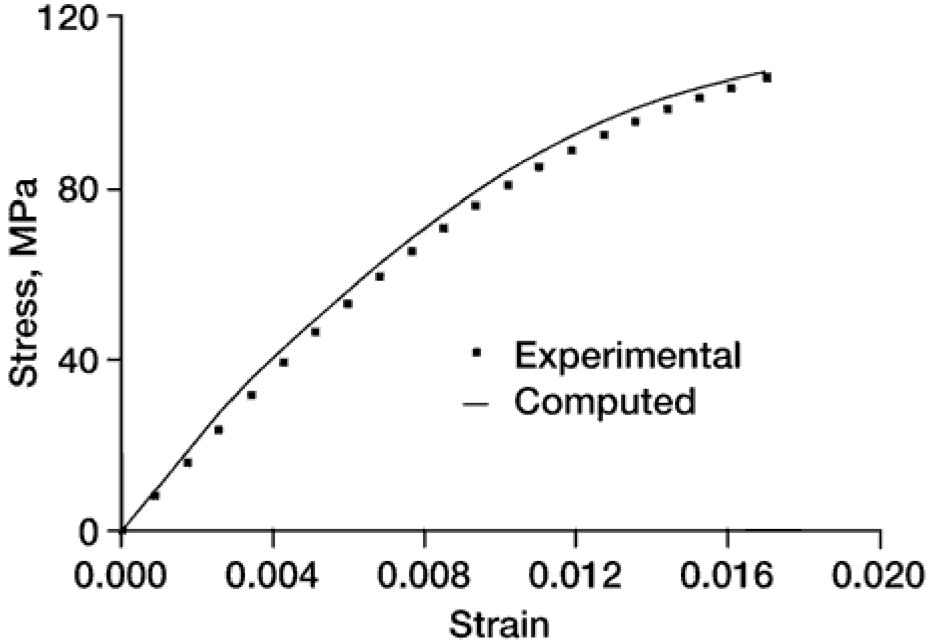
# Nonlinearity and Strain-Rate Dependence in the Deformation Response of Polymer Matrix Composites Modeled

There has been no accurate procedure for modeling the high-speed impact of composite materials, but such an analytical capability will be required in designing reliable lightweight engine-containment systems. The majority of the models in use assume a linear elastic material response that does not vary with strain rate. However, for containment systems, polymer matrix composites incorporating ductile polymers are likely to be used. For such a material, the deformation response is likely to be nonlinear and to vary with strain rate. An analytical model has been developed at the NASA Glenn Research Center at Lewis Field that incorporates both of these features.

A set of constitutive equations that was originally developed to analyze the viscoplastic deformation of metals (Ramaswamy-Stouffer equations) was modified to simulate the nonlinear, rate-dependent deformation of polymers. Specifically, the effects of hydrostatic stresses on the inelastic response, which can be significant in polymers, were accounted for by a modification of the definition of the effective stress. The constitutive equations were then incorporated into a composite micromechanics model based on the mechanics of materials theory. This theory predicts the deformation response of a composite material from the properties and behavior of the individual constituents. In this manner, the nonlinear, rate-dependent deformation response of a polymer matrix composite can be predicted.



*Model prediction for [45°] IM7/977–2 laminate compared with experimental results.*

In the figure, the tensile deformation response of a representative composite material that could be used in a fan-containment application is predicted. The predicted results compare favorably with experimentally obtained values. Currently, the deformation model is being implemented into a transient, dynamic finite element code. High-strain-rate data, which are required for the model, are also being obtained. The high-strain-rate data and the deformation model will be used to simulate ballistic impact tests that will be conducted in Glenn’s Structures and Acoustics Division Ballistic Impact Facility.

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