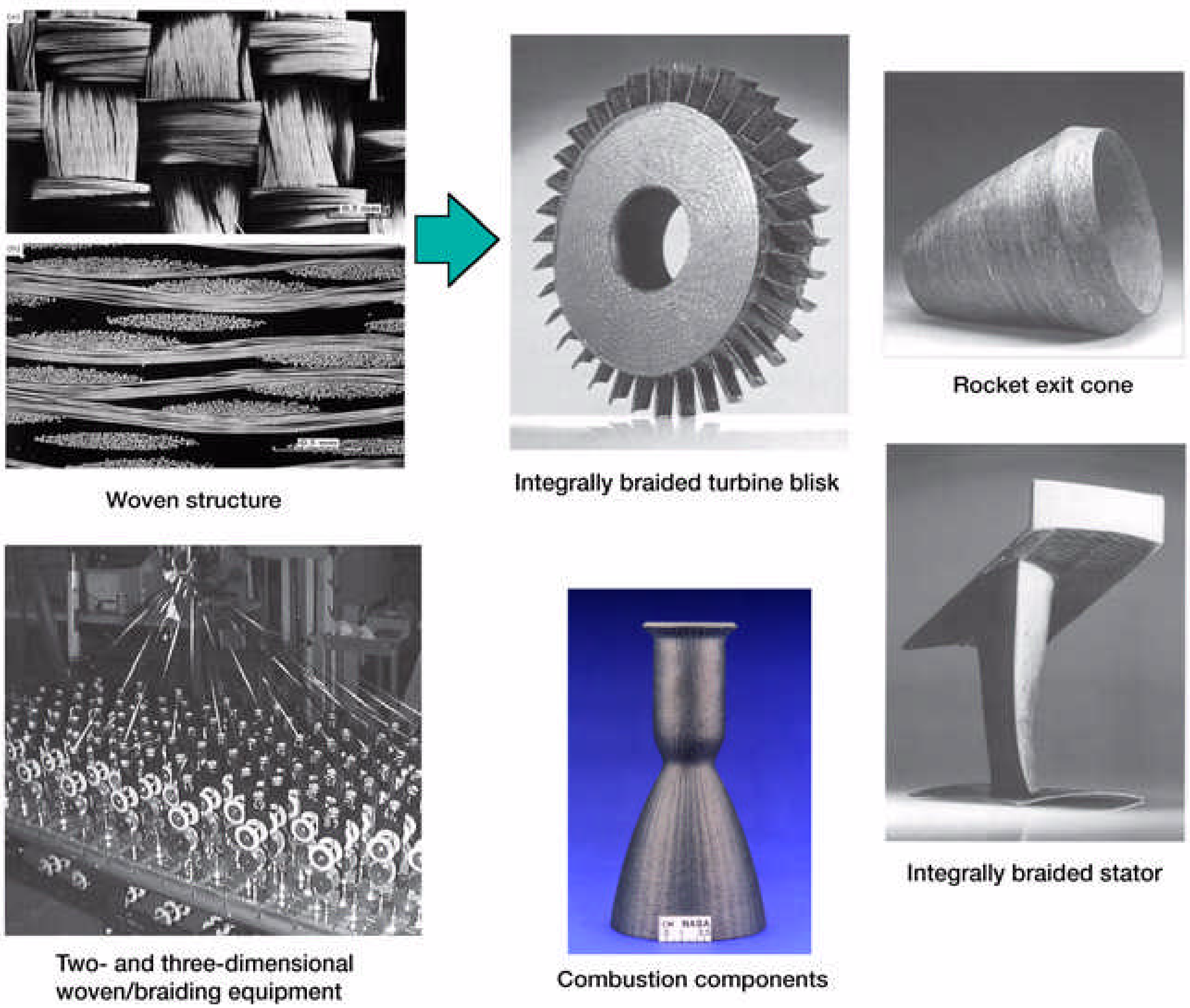
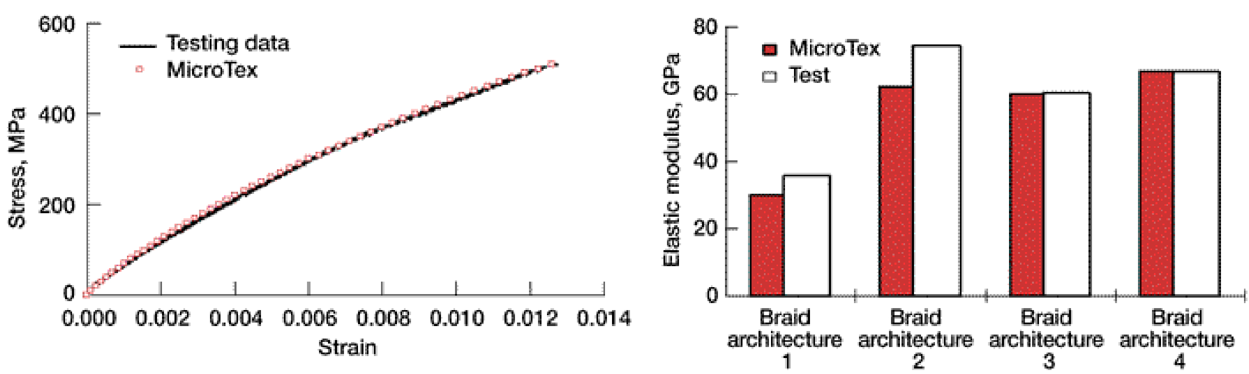
Analytical Failure Prediction Method Developed for Woven and Braided Composites



Examples of textile composite components.

Historically, advances in aerospace engine performance and durability have been linked to improvements in materials. Recent developments in ceramic matrix composites (CMCs) have led to increased interest in CMCs to achieve revolutionary gains in engine performance. The use of CMCs promises many advantages for advanced turbomachinery engine development and may be especially beneficial for aerospace engines. The most beneficial aspects of CMC material may be its ability to maintain its strength to over 2500 °F, its internal material damping, and its relatively low density. Ceramic matrix composites reinforced with two-dimensional woven and braided fabric preforms are being considered for NASA’s next-generation reusable rocket turbomachinery applications (for example, see the preceding figure). However, the architecture of a textile composite is complex, and therefore, the parameters controlling its strength properties are numerous. This necessitates the development of engineering approaches that combine analytical methods with limited testing to provide effective, validated design analyses for the textile composite structures development.

A micromechanics textile composite analysis code has been developed at the NASA Glenn Research Center to predict progressive damage for textile composite structures, especially for brittle material composite systems. The repeating unit cell (RUC) of a textile composite is usually used to represent it (ref. 1). The thermal and mechanical properties of the RUC are considered to be the same as those of the composite. In this study, the micromechanics, the shear lag, and the continuum fracture mechanics models were integrated with a statistical model in the RUC to predict the progressive damage failures of textile composite structures. Textile composite failure is defined as the loss of the loading capability of the RUC, which depends on the stiffness reduction due to material slice (matrix slice and yarn slice) failures and nonlinear material properties. To account for these phenomena in a more accurate manner, we developed a new analysis code to demonstrate the proposed methodologies with comparisons to material test data obtained with carbon-fiber-reinforced silicon carbide matrix plain-weave composites as well as various polymer matrix composites (PMCs) available in the literature for a code validation, and some of the results are presented in reference 2. Good comparisons with a full range of the test data have established the feasibility of the proposed analysis techniques and their ability to model the progressive failure analysis for the textile composite structures, as shown in the following graphs.



Top: Stress-strain for [0°/90°] C/SiC plain-weave composite. Bottom: Comparison of elastic modulus for four different braided architectures.

References

1. Naik, Rajiv A.; Ifju, Peter G.; and Masters, John E.: Effect of Fiber Architecture Parameters on Deformation Fields and Elastic Moduli of 2-D Braided Composites. J. Comp. Mater., vol. 28, no. 7, 1994, pp. 656-681.

2. Min, J.B.; Shi, Y.; and Card, M.F.: Progressive Failure Analysis Modeling Techniques for Ceramic Matrix Textile Composites. AIAA Paper 2002-1400, 2002.

Glenn contact: Dr. James B. Min, 216-433-2587, James.B.Min@nasa.gov
Author: Dr. James B. Min
Headquarters program office: OAT
Programs/Projects: RLV, UEET, TBCC, RBCC, ASTP