NASA TECH BRIEF

Lewis Research Center

RESIDUAL STRESS EFFECTS ON THE IMPACT RESISTANCE AND STRENGTH OF FIBER COMPOSITES

The Problem:

Fiber composites are made by embedding fibers in a matrix when the matrix is near, or at, its molten state, i.e., at elevated temperatures. Subsequently, the composites are reduced to room or use temperatures which are usually considerably less than the temperatures at which the composites are made. Cooling down of the composites from their process temperatures to their use temperatures introduces residual stresses in both fiber and matrix. The presence of residual stresses can be detrimental to both impact resistance and strength of the fiber composites. Therefore, prediction of the magnitude of residual stresses and their influence on composite impact resistance and/or strength is of utmost importance.

The Solution:

Equations have been derived to predict the degradation effects of microresidual stresses on the impact resistance of unidirectional fiber composites. Equations have also been derived to predict the lamination residual stresses in multilayered angle ply composites. These equations are in terms of fiber and matrix mechanical and thermal properties, fiber and void volume ratios, processing temperature, and ply orientation angle.

How It's Done:

Fiber composite micro- and macromechanics and laminate theory are used to derive the governing equations. The governing equations are coded into computer programs. The computer programs are used to investigate the influence of the variables on the magnitude of composite impact resistance and lamination residual stress. Typical results are plotted in Figures 1 and 2.

Notes:

1. The detrimental effects of microresidual stress are of interest to engineers. It is also of interest to analysts and researchers in the fiber composite community.
2. Prediction of lamination residual stress magnitudes is of great interest to designers, researchers, fabricators and users of fiber composites.
3. Ply residual transverse tensile and intraply shear stresses can reach magnitudes comparable to corresponding ply strengths. As a result, they can produce transply cracks.
4. The ply residual stresses are very sensitive to ply orientation angle, number of plies in each direction, and fiber volume ratio. They are relatively insensitive to the void content.

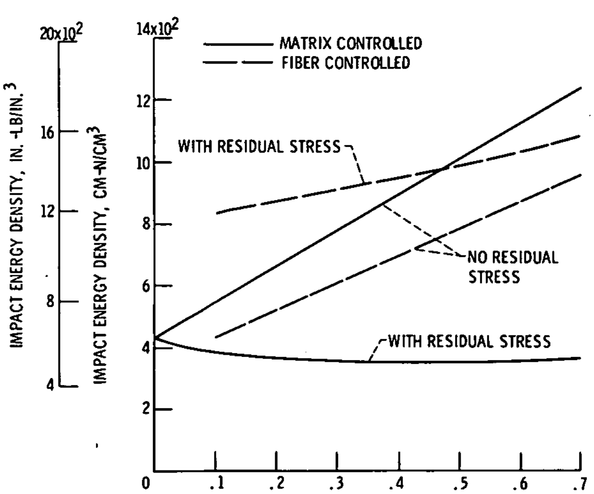

Fig. 1. - Theoretical longitudinal impact resistance of boron-silicon carbide/titanium unidirectional composite. Processing temperature, 1088° K (1500° F) and assuming good interfacial bonding.

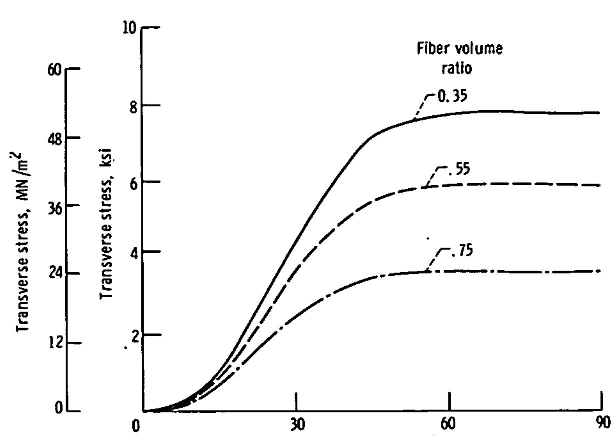

Fig. 2. - Ply residual stress in the +θ ply of composite $8[2(0), 2(\pm\theta), 2(\mp\theta), 2(0)]$. Thornel-50/epoxy composites. Processing temperature, 422° K (300° F).

(continued overleaf)

5. Transply cracking due to residual stress can generally be prevented by increasing the transverse tensile and shear strengths of the ply, decreasing the processing temperatures, decreasing the difference between fiber and matrix thermal coefficients of expansion, or by some combination of these adjustments.
6. In specific designs, the magnitude of ply residual stresses can be reduced by selecting suitable ply orientation and stacking sequence and/or increasing the fiber volume ratio.
7. The following documentation may be obtained from:

    National Technical Information Service
    Springfield, Virginia 22151
    Single document price $3.00
    (or microfiche $0.95)

    Reference: NASA TN-D-6464 (N71-32243), Design for Impact Resistance with Unidirectional Fiber Composites

    Reference: NASA TN-D-6146 (N71-16847), Lamination Residual Stresses in Multilayered Fiber Composites

    Reference: NASA TM-X-52881 (N70-41457), Lamination Residual Stresses in Cross-Plied Fiber Composites
8. Technical questions may be directed to:

    Technology Utilization Officer
    Lewis Research Center
    21000 Brookpark Road
    Cleveland, Ohio 44135
    Reference: B73-10063

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