CHARACTERIZATION OF THE MATRIX GLASS TRANSITION IN CARBON-EPOXY LAMINATES USING THE CSD TEST GEOMETRY

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INTRODUCTION

The mechanical properties of carbon-epoxy laminates display limited viscoelastic behavior when tested in the plane of the laminate for most stacking sequences. While there are certain stacking sequences which display strong matrix dependence, such as a zero degree layup tested in the 90° direction, these layups are not generally used for structural components. It would appear that a need exists for a test geometry which is sensitive to matrix behavior and which can be performed on standard (structural) stacking sequences.

In this paper, a newly developed test geometry is described which has several useful attributes: (1) the geometry is very sensitive to matrix behavior; (2) both transient (creep and stress relaxation) and dynamic mechanical tests are readily performed over a wide range of timescales; (3) the test geometry provides viscoelastic dispersion data which are independent of angular orientation of the sample; consequently sample alignment problems are eliminated; (4) the same test geometry may be used to provide information on delamination strength; (5) relatively small test specimens are required; (6) the test geometry is sufficiently sensitive to matrix changes to allow its use for postcuring, humidity, crosslink density and other matrix change studies.

TEST GEOMETRY

The test geometry used to obtain the data presented here will
be referred to as the centro-symmetric deformation (hereafter CSD) test geometry. The sample consists of a thin disc, typically 6 to 14 plies thick, having a nominal diameter of 30 mm. The disc is freely supported on a circular anvil around its entire perimeter at a diameter of 25 mm. The load is applied to the center of the disc using a ball bearing nosepiece having a diameter of 8 mm. The sample is not clamped in anyway; consequently, the sample may be mounted on the test fixture in seconds. The lack of clamping also provides for a high degree of reproducibility in the test method since variations of clamping stresses and jaw slippage are a major source of errors and lack of reproducibility, especially for stiff samples.

The absence of clamping requires that the load must always be applied in the same direction as shown in Figure 1. This presents no difficulty in transient testing; however, in dynamic tests it is necessary to apply a static load at least as large as the peak to center amplitude of the dynamic sinusoidal load, thereby insuring that the ball bearing nosepiece remains in contact with the sample. This posed no problem in the apparatus used since the static and dynamic loads are independently programmed when in closed loop load control.

![Figure 1. Schematic of the CSD Test Geometry.](image)

With reference to Figure 1, the sample is subjected to a circularly symmetric set of boundary conditions. If \( R \) is the radius of the anvil support, then there are no deflections or moments (freely supported) at \( R \) and \( W(R) = 0 \) and \( M(r) = 0 \) where \( W(r) \) is the out of plane deflection of the disc and \( M(r) \) is the out of plane moment. An analysis of the CSD geometry has