Full Field Nondestructive Techniques for Imaging Composite Fiber Volume Fraction

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Abstract

In a composite the matrix distributes the load onto and between the fibers. It is therefore important to know the volume fraction of fibers to ensure proper load distribution and predicted structural performance. The most common method of determining composite fiber volume fraction (FVF) involves removal of the matrix by burn off or acid digestion. While estimates of the fiber, matrix and void volume fractions are obtained using this destructive method, it is time consuming and requires the disposal of toxic waste. This technique also requires the removal of a small composite section to be destructively tested. Structural parts in production are sometimes made with an excess area designated for removal for destructive testing. This type of testng determines the FVF only within that area thus making it a localized measurement. This causes uncertainty when the FVF varies within the manufactured part.

In this study the application of several nondestructive evaluation (NDE) imaging techniques to map out FVF variations were performed. The technologies investigated were thermography, ultrasound, and radiography. Theoretical models of each measurement (e.g. ultrasonic velocity, thermal diffusivity) to the FVF. For practical applications to varied ply orientations, measurements were made where no knowledge of the ply lay-up was required. Images were generated of the measured FVF and these results were compared to the destructive testing FVF images using a mean square difference metric.

On the basis of this metric it was found that the thermal technique provided the best agreement to the destructive results by a factor of 10 as compared to the ultrasonic velocity measurement for T-300 fibers in a 934 resin. The difference in transverse modulus between 934 resin and T-300 fiber was not significant enough to measure FVF ultrasonically, however it was very sensitive to porosity. The X-ray technology did not provide quatitative results. Mapping thickness variations of less than 5 percent did not significantly prove worthwhile in reducing the mean square difference. Finally the combined technique of using ultrasonic velocity to measure porosity and incorporating that information in the thermal model proved best overall in measuring FVF for porosity levels less than 5 percent.