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MATERIALS AND STRUCTURES SYMPOSIUM (C2)
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INFLUENCE OF PLY ANGLE ON THE FABRICATION STRESSES OF COMPOSITE TUBES USED IN SPACE APPLICATIONS

Abstract

Laminated composite materials are becoming increasingly prevalent in space applications due to their inherent dimensional stability under a varying thermal environment and their comparative low mass. Important space applications of composite tubes are the deployment structure of membrane antennae and deployment structures for instruments which require separation from the spacecraft to minimize interference. Using composite tubes brings other challenges, as many design variables must be considered such as the influence of ply angle and stacking sequence. Undesired deformations or stresses may be generated, despite the low coefficient of thermal expansion of the composite material, especially under the kind of thermal cycling seen in space. Attempts to minimize or eliminate these undesired deformations can involve careful laminate design where forces such as shear are balanced ply by ply. This ignores the influence of error during manufacturing which can cause deviations from intended ply angles. While the variation in per-ply error is likely to be constant, the effect of this error on fabrication stresses in this case is nonlinear. The effect of these layup errors on the twist of composite tubes and a method to minimize the twist response under thermal load is investigated in this paper.

The influence of error sensitivity is used to explain the behavior of tubes which unexpectedly twist under current design assumptions. Lay-up error is assumed to be normally distributed and constant. It can be shown that certain ply arrangements will produce different distributions of twist as a result of these errors. These different distributions may be quantified and sensitivity to error for arbitrary ply angles is found. A method of correcting design ply angles to produce an average twist of zero is also presented. Numerical analysis of these varying tube designs demonstrates significant advantages in terms of twist response to thermal loading for specific layups calculated with this model.

The theory was used to design several physical tubes which were tested in a controlled manner over a wide temperature range to simulate thermal cycling in a space environment. Measurement methodology using the ARAMIS 3D image correlation system is presented along with a discussion of results, the correlation with theory, and implications for future design of space components.