DESIGNING “STAR” STRUCTURES FOR PROPULSION SYSTEMS USING CEMENTITIOUS COMPOSITES

Robert Vaughan (MSFC/NASA) , John Gilbert (MAE/UAH) Teng Ooi (AVB/Army), Houssam Toutanji (CEE/UAH)

ABSTRACT

This paper demonstrates how composite materials, fabricated by mixing a few layers, light-upcrete consists of multiple layers of relatively stiff reinforcement, can be designed to offer more design flexibility than traditional advanced aerospace composite materials fabricated from matrices, such as graphite or nylon. The composite properties of highly compliant composite structures can be studied by applying the rule of mixtures and an advanced transformation theory. Model tests are conducted on composite specimens to verify this approach, and when the effective material properties are used to characterize the deflections of composite beams subjected to plane bending, an excellent agreement is obtained. 

COMPARISON WITH TEST DATA AND FINITE ELEMENT ANALYSES.

Results show that the plane can be used to build structurally resilient, self-propelled composite (STAR) structures capable of storing exceptionally large amounts of strain energy. Provided that the material does not strain when the service loads are applied, the strain energy can be completely recovered and released in a controlled fashion for its work. Advanced systems will be designed to function as smart structures that include sensing elements to monitor the structural integrity and control elements to adjust the dynamic response.

In the future, we propose to incorporate these unique mechanical energy storage devices into advanced propulsion systems. Since the material properties are not permanent, they should function better in the hostile environment elsewhere in space than on the battlefield.

INTRODUCTION

To fabricate composite structures, the most important characteristic is the choice of materials. In this section, the materials, such as graphite or nylon, and epoxy, are studied by applying the rule of mixtures and a modified transformation theory. Tensile tests are conducted on composite samples to verify this approach; and, when the effective material properties are used to characterize the deflections of composite beams subjected to pure bending, an excellent agreement is obtained.

COMPOSITE LAMINATED PLATE THEORY

The constitutive equations for graphite reinforced cementitious laminated plates were derived from classical laminated plate theory and three assumptions. The “stellar” mix was not exact, small variations in orientation and thickness were present. Each beam was subjected to four-point bending. The ends of the beams were placed on rollers to produce the desired boundary conditions. Beam deflection data was measured using a dial gage located at the center of each beam. Incremental loads were applied to produce a load vs. deflection curve, and the load that resulted in the transition to buckling along the test article.

The results of the composite beam tests were compared to analytical results based on the effective elastic modulus calculated from the composite equation. To achieve this, an elastic beam equation was developed to calculate the beam deflections corresponding to the bending and buckling load. A MathCAD solution sheet was used to determine the integration constants and perform the calculations.

REFERENCES


A MathCAD solution sheet was developed to make the required calculations. When the method was applied to a composite panel with known material properties, the results were found to be in excellent agreement with the results obtained using other well-established solution methods. The MathCAD solution agreed well with these obtained using a very reliable MSC/NASTRAN model. The method for analyzing beams with various ply angles and layout is described below.

The next step in the test program was to apply laminated composite plate theory to highly compliant graphite reinforced lay-ups, and make comparisons with test data and finite element analyses.

A Multi-Cap solution sheet was developed to make the required calculations. When the method was applied to a composite plate with known material properties, the results were found to be in excellent agreement with those derived using other well-established solution methods. The Multi-Cap solution agreed well with these obtained using a very reliable MSC/NASTRAN model. The method for analyzing beams with various ply angles and layout is described below.

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