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New Structural Approach for Determining Load Carrying Capability of Filament Wound Composite Materials

An analytical procedure for determining critical buckling loads of both orthotropic and isotropic filament wound composite cylinders subjected to axial compression loading has been developed. Both general instability and local instability modes have been considered; classical netting theory and conventional theory of discontinuity were applied to analyze lined pressure vessel test configurations. The superior characteristics of high strength and minimum weight exhibited by filament wound composite materials indicate their potential in the shipbuilding and pressure vessel industries. Additional applications include the aircraft and chemical industries, and in structural hardware requiring low weight and high strength configurations.

The theory of analyzing a metallic or filament composite structure subjected to internal or external pressures has been well established. However, based on a literature survey, there is only limited theoretical information available regarding the general instability of filament composite structures subjected to pure axial compression. Therefore, this analytical approach was formulated for determining the axial compressive load carrying capability, applying a more rigorous treatment of axial, transverse and shear modulus of elasticity of the composite material than previous studies (metallic shells). As a result, the key parameters used for buckling stress evaluation for filament composite shells proved very different than those for metallic structures. This analytical technique, when completely verified by tests, may be used in design for sizing filament composite stiffened or monocoque cylinder elements of various configurations and for analytically predicting their load carrying capability.

A theoretical equation was derived to predict the buckling failure stress for the general instability mode of failure. Derivation of this equation included consideration of large deflection theory and initial imperfection level in conjunction with the well known principles of strain energy and work.

This study and analysis have produced the following results:

(1) Application of the general instability stress equation for stability critical filament composite cylindrical shell structures offers a significant weight saving of about 36% over the equal sized aluminum construction. Use of netting theory stress equations for metal lined filament composite pressure vessels offers a weight saving of about 47% over aluminum, 55% over HY-140 steel, and 25% over maraging steel. These predicted weight saving results are consistent with industrial test data recently surveyed. The high strength/modulus to weight ratios of boron and graphite composites make them desirable for monocoque stability critical shells.

(2) Diffusion bonded boron filament-aluminum (6061) matrix laminate showed remarkable longitudinal transverse and shear stiffness which resulted in a much larger compressive load carrying capability, particularly for a stiffened configuration with ring reinforcement. Weight savings in this type of stiffened composite shell could be largely increased if composite reinforced rings are used in place of the aluminum rings.

(3) Boron filament-epoxy matrix with stainless steel liner may be suitable for pressure vessel construction subjected to elevated temperature environments.

(4) High strength lightweight S-glass filament-epoxy resin matrix with aluminum (6061-T6) liner should be considered for cryogenic tanks application for low cost and light weight objectives.

(continued overleaf)

Note:

Requests for further information may be directed to:

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No patent action is contemplated by NASA.

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