**Analytical Crashworthiness Methods Applied to Composite Structures**

by

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## Abstract

Several shell deformation models are developed for use in crashworthiness analysis of rotationally symmetric structures. These models use analytical techniques to predict the crushing force versus axial crush distance characteristics of both a rigid-plastic, hemispherical shell and an elastic, cylindrical shell loaded axially by a rigid flat plate. Additional methods are proposed to determine the effects of cutout sections and internal stiffening members on the crushing force capacity of the shells. These proposed methods are applied to determine the energy absorption capability of the composite/metal nose structure of a mini submarine subjected to a head-on impact with a flat rigid wall. The nose structure is composed of a stiffened composite shell that covers and is attached to the metal, forward, hemispherical portion of the pressure hull. The complex structure is simplified to a rotationally symmetric shell model and modified to account for the effects of stiffening elements and cutout sections. Laminated plate theory, a progressive composite failure method, and the models developed are then used to determine the structure's energy absorption capacity. The fairing structure is determined to be capable of absorbing the kinetic energy associated with an impact from an initial vehicle speed of 7.5 knots. Further, the entire nose structure (the fairing and forward pressure hull) is predicted to be able to absorb the kinetic energy from a 26.4 knot vehicle impact.

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