Impact and Energy Absorption of Laminated and Sandwich Composites

by

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Submitted to the Department of Mechanical Engineering, on May 11, 2008 in Partial Fulfillment of the Requirements for the Degree of Master of Science in Naval Architecture and Marine Engineering

Abstract

Advanced fiber reinforced composites combine high specific strength and stiffness. Advanced composites are currently being introduced into modern U.S. Navy ships to achieve weight savings, maintenance reduction, and signature reduction. These advancements manifest themselves in Naval ships as increases in survivability, payload, range, speed, and weapon systems performance.

In this thesis, **vinyl ester** resin matrix laminates and sandwich composites are emphasized since they are increasingly being used in naval applications. Impact damage of laminated and sandwich composites under low-velocity and high-velocity impact are investigated. Delamination damage is explored in detail since delamination is one of the major failure modes of many advanced composites structures. Delamination initiation loads for various laminates having different stacking sequences are compared. In many laminates containing various stacking sequences, placing the 90° laminae on the outside (as opposed to the inside) will reduce the delamination initiation load under impact. Moreover, an open literature survey of numerous laminated and sandwich composites having different stacking sequences and

thicknesses and subjected to low-velocity impact is undertaken. The failure mode, failure load, and displacement at failure of these composites are summarized.

Other topics investigated include (1) effects of a composite's constituents on damage susceptibility, (2) post-impact residual characterization and strength, and (3) nondestructive testing techniques. Prediction methods for residual strength are tabulated based on the impact damage type for laminated and sandwich composites. Further, NASA and Boeing compression-after-impact tests are summarized for laminated composites after low-energy impacts. Damage and residual strength are analyzed for epoxy and PEEK resin laminates. An initial sorting for the selection of nondestructive testing methods for specific composite discontinuities is summarized.

Extensive presentations of tables and figures are used to summarize the results of the literature surveys on impact resistance and energy absorbing capabilities of composites. Particular attention is given to methods for impact resistance improvement. Impact resistance improvement methods are compared according to increases in interlaminar Mode I and Mode II fracture toughness and in residual strength. These comparisons support data for the selection of impact resistance improvement.

Numerous laminates having different lamina orientations are compared to understand the influence of stacking sequence on impact damage resistance and energy absorption capability. Matrix properties are investigated for many laminates and it is noted that higher interlaminar fracture toughness of matrix materials will increase energy absorption capability. The effects of other constituents of a laminate on impact resistance and energy absorbing capability are also summarized. Among the types of composites investigated in this thesis, carbon fiber/PEEK laminates exhibited the highest specific energy absorption.

Recommendations for further studies are offered based on these summaries.

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