Response of Composite Panels Subjected to Varying Impact Energies

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ABSTRACT

The advantages of using fiber reinforced plastics, composed of glass fibers embedded in a resin mix, for offshore structures and shipbuilding have been recognized for many years. These advantages include: (a) reduced weight, (b) better corrosion resistance, (c) lower life cycle costs, (d) no hot work required for retrofitting and (e) better thermal, acoustic and vibration properties. For naval vessels, they have the added advantages of lower signatures and the elimination of fatigue crack issues between steel decks and composite deckhouses. Despite this, their use on large scale structures as primary members has been restricted in the offshore industry. Naval applications have recently increased from the traditional mine countermeasure vessels to large hangers on destroyers. Many other naval applications are being proposed and a large volume of research is currently being undertaken. One of the drawbacks with composites is the lack of robust damage models applicable to large composite structures capable of reliably predicting damage growth and ultimate failure loads. This is particularly so in the prediction of delamination which can occur when composites are subjected to lateral impact or shock loads. The focus of this research is to examine the effects of low-velocity impact loading on the behavior of large-scale composite panels. Comparisons of the contact force and panel displacement are made using both an energy balance model and non-linear finite element analysis (FEA).

KEY WORDS: Impact testing; composites; delamination; damage; finite element analysis; cohesive layers.

INTRODUCTION

The need for increased operational performance and reduced costs has driven the development of composite materials for naval structures. Improvements to warships and submarines are sought in numerous areas such as stability, corrosion resistance, payload and resistance to impact and explosive shock, where composite materials are advantageous. Thus the ability to model the damage incurred from a dynamic load is of increased importance.

Commercial finite element (FE) codes are currently implemented to model impact of composite plates but most still lack effective constitutive models for laminates experiencing damage. Experimental data are also scarce on composites, relating particularly to contact force history, which according to Zhou and Greaves (2000) is one way of revealing the dominant damage mechanisms by examining the peaks.

The initiation of damage in composite materials is the point at which the stresses or strains in the material are large enough to create some permanent deformation in the form of matrix cracking. Stress or strain based criteria have been the most common tools to model failure on a macro-scale but in a basic way, degrading the properties once only down to a residual value. Currently however, continuum damage mechanics (CDM) is becoming increasingly popular but has yet to be introduced in many finite element packages for composites modeling on a macro scale.

Transverse cracks i.e. cracks that run perpendicular to the plies, are created by in-plane stresses and can severely reduce the composite’s stiffness. These can also create in-plane cracks between the plies; this is more commonly referred to as delamination damage. The damage incurred from shock loading of a composite panel takes the predominant form of matrix cracking and delamination, followed by fiber failure if the peak over-pressure is large enough. Delamination is sometimes difficult to detect when the material is in service. It can be quite extensive, internal, and often undetectable with the naked eye and its effect often deceiving as the composite structure can often survive the impact/blast and maintain its integrity even if severely reducing its strength. Delamination therefore becomes the most critical and destructive failure mode.

One simple method of modeling delamination involves the implementation of resin-rich layers. These have been discussed by Elder et al. (2004) as a method of modeling delamination damage and were tested by Boh et al. (2005) giving good results. However, they do not model the physical separation and ensuing contact condition of the delaminated layers. It is evident that to effectively model the reduction in contact force, cohesive elements are an attractive option. Cohesive elements are used by authors such as Espinosa et al. (2000), Chen et al. (1993), Scheider (2001), Camanho (2003), and Turon et al. (2005). More recently and more specific to naval composites, Lemmen et al. (2006) proposed a damage mechanics-based model for quasi-static...