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Numerical Study of Composite Panels Subjected to Underwater Blasts

R. Bellur-Ramaswamy, F. Latourte, W. Chen, H.D. Espinosa*
Northwestern University, Department of Mechanical Engineering, 2145 Sheridan Road, Evanston IL 60201, USA
* Corresponding author: espinosa@northwestern.edu

ABSTRACT

In this work, we characterize the performance of composite panels subjected to underwater impulsive loadings by finite element analysis (FEA). First, we present a finite element model that simulates the fluid-structure interaction experiment developed in our laboratory for testing the underwater blast resistance of marine composite panels. Then, we present the methodology used to calibrate this model (possessing a high number of degrees of freedom) from available experimental data presented in another talk. Both deflection profile histories and damage maps are used as a metric to identify unknown model parameters. The dynamic model incorporates layered-shell elements, damage initiation by Hashin criterion and damage evolution laws for laminæ and interfaces. The calibrated model will help to improve the blast performance of marine structures by design optimization studies of solid and sandwich panels

Introduction

Over the years, due to advancement of computer hardware and software, computer-based simulations have become an integral part of several areas of science and engineering research. In fact, it is now considered crucial to possess computational predictive capability in order to maintain a lead in science and technology, as recently reported by World Technology Evaluation Center, Inc., supported by the leading national laboratories of the USA [1]. Furthermore it is now common in the defense and industry to possess computational capability to drastically cut down product release time and gain an edge over the competition. In light of this, predictive capabilities are being developed in newer and newer frontiers. In the present work, we are particularly interested in the design and optimization of marine sandwich composites. Although attempts have been made in developing predictive capability for foam sandwich composites [2-5], they lack validation, which is an important component of developing a predictive tool. A major aspect of composite-material based simulation is the ability to predict the initiation and evolution of damage. Several composite damage models are available in the literature, but none of them can be concluded to be the best for all given material and loading conditions [6-9]. Moreover, not many models are available to be directly applied to highly dynamic problems. This work aims at developing a predictive capability via a finite element analysis for the response of marine sandwich composite panels subjected to underwater blasts. Numerically obtained results can be correlated to Fluid Structure Interaction (FSI) experiments results (the experimental apparatus was used earlier to characterize steel sandwich panels and also validate related computational models [10-12]). The experimental results on composite panels are presented in another talk, and will be used here to attempt a calibration of the numerical model. A major interest of the validated computational model is to help designing optimized composites panels for given loading conditions. Moreover, limited information can be obtained in the underwater blast experiment because of the limitations in instrumentation and highly dynamic nature of the phenomenon. Hence, the computational model is helpful in providing additional understanding of the mechanisms of dynamic failure of composite panels, as well as assessing the capabilities of the Hashin composite failure model [13].

Finite Element Model

Because of the quasi-isotropic layup of the composite panel, only a quarter of the composite panel is modeled using layered continuum shell elements. Each shell element is a laminate with 4 plies of different orientation. The

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layers of laminates are tied together by an adhesive, which is modeled by cohesive elements [14] with standard traction-separation laws. Based on the results from the world failure exercise, Hashin-type failure model performs reasonably under tensile loading conditions and is also a simple physically based model. Therefore, it was chosen in this work to model damage initiation along with linear damage evolution law using ABAQUS/Explicit finite element package [15]. A quarter cylindrical column of water (modeled as equation of state material [10]) has surface contact interactions with the composite panel. Cavitation within the water is modeled by applying tensile failure criterion.

Model Calibration and Results

The experiments have been carried out for solid monolithic panels and sandwich panels. The experimental data for solid monolithic panels are utilized to fine tune the composite material damage model parameters. This will be done by comparing the deflection history of the center of panels and also matrix damage and delamination. These calibrated model parameters are further used in modeling the foam sandwich panels and the results will be compared with those from the experiments in terms of the panel center deflection history, panel deflection profiles, foam crushing and composite damage. Sensitivity of the response of the composite panels with respect to boundary conditions and some of the model parameters will also be presented.

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