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ScienceDirect

Procedia Engineering 167 (2016) 176 – 181

Procedia Engineering

www.elsevier.com/locate/procedia

Comitato Organizzatore del Convegno Internazionale DRaF 2016, c/o Dipartimento di Ing. Chimica, dei Materiali e della Prod.ne Ind.le

X-ray CT analysis after blast of composite sandwich panels

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Abstract

Four composite sandwich panels with either single density or graded density foam cores and different face-sheet materials were subjected to full-scale underwater blast testing. The panels were subjected to 1 kg PE4 charge at a stand-off distance of 1 m. The panel with graded density core and carbon fiber face-sheets had the lowest deflection. Post-blast damage assessment was carried out using X-ray CT scanning. The damage assessment revealed that there is a trade-off between reduced panel deflection and panel damage. This research has been performed as part of a program sponsored by the Office of Naval Research (ONR).

Peer-review under responsibility of the Organizing Committee of DRaF2016

Keywords: air blast; underwater blast; sandwich structures; composites

1. Introduction

Composite sandwich panels offer many advantages over traditional ship building materials and are hence becoming increasingly commonplace. There is a wide variety of choice for the constituent materials and research into the optimal combinations are ongoing. Styrene acrylonitrile (SAN) foam is commonly used as the sandwich panel core material and Gardener, Wang and Shukla have investigated the air blast performance of stepwise graded density SAN foam cores [1]. The graded density panels were shown to absorb more blast energy in the front, lower density layers leaving the back face-sheet intact. Additionally, the performance of glass fiber reinforce polymer

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Peer-review under responsibility of the Organizing Committee of DRaF2016
doi:10.1016/j.proeng.2016.11.685

(GFRP) face-sheets against carbon fiber reinforced polymer (CFRP) face-sheets, both with SAN foam cores, against air blast loading has been investigated by Arora et al [2]. The CFRP face-sheets were shown to suffer from less damage.

Underwater blast performance of composite sandwich panels is important for naval structures. Arora et al investigated the performance of GFRP sandwich panels and GFRP tubes during underwater blast loading [3]. Due to the expensive nature of blast testing, alternative testing methods have been developed including the water filled conical shock tube (CST). LeBlanc and Shukla have used a CST to research into the effect of plate curvature and poly-urea coatings on composite sandwich panels under shock loading [4].

Air blast testing into different constituent materials has revealed the advantages of employing a graded density foam core into a sandwich panel along with the benefits of using CFRP face-sheets. The research reported in this paper investigates whether these materials perform as well when subjected to underwater blast loading.

2. Materials

Four composite sandwich panels were selected for underwater blast testing to compare the relative performance of their materials. Two of the panels had 30 mm foam cores consisting of a single density SAN foam, one panel employed GFRP face-sheets and the other CFRP face-sheets. The other two panels had 30 mm graded density foam cores. This consisted of 10 mm layers of three SAN foams with different densities. The foams were arranged such that the lowest density foam was facing the blast, the highest density foam was furthest from the blast and an intermediate density foam was between the two. Again one panel employed GFRP face-sheets whilst the other had CFRP face-sheets. Table 1 details the four panels tested.

Table 1. Summary of panel types.

Face-sheet fiber type	Core material	Core density (kg/m^3)
Glass	SAN M130	140[1]
Carbon	SAN M130	140[1]
Glass	Graded SAN (M100/M130/M200)	108/140/200[1]
Carbon	Graded SAN (M100/M130/M200)	108/140/200[1]

3. Experimental Procedure

This section details the experimental setup and instrumentation of the underwater blast experiment along with the post-blast damage assessment that was carried out using X-ray CT scanning. The blast testing was performed at GL DNV, RAF Spadeadam in Cumbria, UK and the X-ray CT scanning was carried out at the University of Southampton.

3.1. Underwater blast setup

The 0.8 m x 0.8 m panels were bolted in a welded steel channel box which had an enclosed volume of air behind the panel leaving an unsupported area of 0.65 m x 0.65 m. The charge was a 1 kg plastic explosive 4 (PE4) that was held 1 m from the center of the panel using a pine frame, this charge has an equivalent TNT weight of 1.28 kg. This load was chosen as it would cause full compressive failure of the foam cores and failure of the face-sheets. A reflected pressure gauge was adhered to the top of the steel box and a side-on pressure gauge was held at the same height and distance from the charge as the center point of the panel using a steel rod. The response of the panel was measured using electronic foil strain gauges; 14 were adhered to the front face-sheet and 16 to the rear face-sheet. These were situated along the horizontal, vertical and leading diagonal axes. Since the sandwich panels were square, only one quarter of each panel had strain gauges attached. The whole assembly was suspended from a crane and the center point was lowered into the test pond to a depth of 3.5 m. The setup of the blast test is shown in Fig. 1.