Marine Structures 40 (2015) 225–246

Contents lists available at ScienceDirect

Marine Structures

journal homepage: www.elsevier.com/locate/marstruc

Experimental and numerical investigations on laser-welded corrugated-core sandwich panels subjected to air blast loading

Pan Zhang [a], Yuansheng Cheng [a], Jun Liu [a,*], Chunming Wang [b], Hailiang Hou [c], Yong Li [a]

[a] School of Naval Architecture and Ocean Engineering, Huazhong University of Science and Technology, Wuhan 430074, China
[b] School of Materials Science and Engineering, Huazhong University of Science and Technology, Wuhan 430074, China
[c] Department of Naval Architecture Engineering, Naval University of Engineering, Wuhan 430033, China

ARTICLE INFO

Article history:
Received 29 July 2014
Received in revised form 4 November 2014
Accepted 21 November 2014
Available online 10 December 2014

Keywords:
Metallic sandwich panel
Triangular corrugated core
Air blast loading
Deformation mode
Laser welding

ABSTRACT

Experimental investigations on the laser-welded triangular corrugated core sandwich panels and equivalent solid plates subjected to air blast loading are presented. The experiments were conducted in an explosion tank considering three levels of blast loading. Results show that the maximum deflection, core web buckling and core compaction increased as the decrease of stand-off distance. Back face deflections of sandwich panels were found to be nearly half that of equivalent solid plates at the stand-off distances of 100 mm and 150 mm. At the closest stand-off distance of 50 mm, the panel was found to fracture and fail catastrophically. Autodyn-based numerical simulations were conducted to investigate the dynamic response of sandwich panels. A good agreement was observed between the numerical calculations and experimental results. The model captured most of the deformation/failure modes of panels. Finally, the effects of face sheet thickness and core web thickness on the dynamic response of sandwich panel were discussed.

* Corresponding author. Tel.: +86 27 87543258; fax: +86 27 87542146.
E-mail addresses: PanZhang@hust.edu.cn (P. Zhang), hustlj@hust.edu.cn (J. Liu).

http://dx.doi.org/10.1016/j.marstruc.2014.11.007
0951-8339/

1. Introduction

Sandwich structures, which are composed of two stiff face sheets separated by a low density core, are considered to be an excellent solution in shipbuilding for structural decks, walls, bulkheads, and ramps et al. [1–5]. Practical applications of laser welded sandwich structures in shipbuilding were realized from the mid 1990's onwards. After some very limited prototype applications in the US Navy the focus shifted to Europe. The famous European research project SANDWICH [6] enlarged the field of applications of sandwich structures in various surface transport sectors. Main reasons for the applications were due to their unique and unbeatable combination of properties, such as low specific weight, efficient capacity of energy dissipation, superior bending strength and high impact resistance [7–13].

Many researchers have focused on the dynamic mechanical behavior of sandwich structures, particularly in the last decade. A variety of such structures of different metallic cores including stochastic foams, honeycombs, prismatic topologies, and lattice topologies have been investigated experimentally and numerically, in particularly to improve their blast/impact resistance. Tilbrook et al. [14] investigated the dynamic out-of-plane compressive response of V-type and Y-type corrugated core sandwich panels using a Kolsky bar. They found that buckling of core webs is delayed at low impact velocities by inertial stabilization of the core webs while plastic shock wave effects dominate the response at higher impact velocities. Rubino et al. [15,16] examined the dynamic response of V-type and Y-type corrugated core sandwich beams and plates by firing metal foam projectiles at the central region. It is found that the sandwich constructions outperform equivalent monolithic counterparts at low levels of projectile momentum. However, these benefits will be compromised with the increase of projectile momentum. Ehlers et al. [17] performed a combined experimental and numerical investigation into the collision resistance of laser-welded X-type corrugated core sandwich panel. The influences of the laser weld properties and ship motions on the response of X-core structure were evaluated. Fleck and Deshpande [18], and Qiu et al. [19] developed an analytical methodology for analyzing the blast resistance of clamped sandwich beams and plates. In their theory, the deformation history is split into three sequential stages: fluid-structure interaction, core compression and overall structural response. Pioneering studies by Xue and Hutchinson [20,21], and Hutchinson and Xue [22] showed the superior performances of sandwich plates relative to solid plates with same mass under shock loading in water and air. Zhu et al. [23], Chi et al. [24], and Nurick et al. [25] conducted numerous experimental studies to test the structural response of aluminum alloy honeycomb sandwich panels subjected to blast load. The effects of face sheet configuration and core configuration were evaluated in detail. The failure modes of honeycomb sandwich panels were classified and analyzed systematically. Cui et al. [26] reported results from air blast experiments on tetrahedral lattice sandwich structures which were compared with honeycomb sandwich panels [23]. It was demonstrated that the tetrahedral lattice sandwich structures possess a better impulsive resistance than the honeycomb sandwich panels [26]. Dharmasena et al. [27,28] assessed the performance of sandwich panels with honeycomb cores and pyramidal lattice cores under air blast loading. Results revealed that the sandwich panels performed better than solid plates with identical mass by reducing the back face deflection and the load transmitted to supports. However, no failure criterion was included in their calculations.

Corrugated core sandwich structures, a type of prismatic topology structures, are considered as ideal cores of sandwich panels applied in naval ships to replace the conventional stiffened plates due to their high longitudinal shearing and bending strength [1,14]. Therefore, the capacity of corrugated core sandwich panel to meet the demands of blast loading is of interest to researchers. Liang et al. [5] investigated the optimum design of metallic corrugated core sandwich panels subjected to blast loads by using the Feasible Direction Method coupled with the Backtrack Program Method. Rimoli et al. [29] and Wadley et al. [30] tested the dynamic response of corrugated sandwich panels subjected to wet sand blast loading, and utilized a discrete particle-based method to investigate the dynamic deformation and fracture processes. The simulation results rationalized the existence of strong coupling between the wet-sand and the dynamically evolving shapes of tested panels, which resulted in local deformation between the core webs at panel center. Li et al. [31] performed the air blast experiment of corrugated core sandwich panels which were made of aluminum with face sheets and