Energy Absorption Analysis of Metallic Corrugated Core Sandwich Panels under Air Blast Loading

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ABSTRACT
In this paper, energy-absorbing characteristics of the metallic corrugated core sandwich panels subjected to air blast loading are discussed. The dynamic responses investigated using a fully coupled simulation approach reveal that the face sheets undergo large stretching and bending deformation to dissipate the transmitted energy, while the core webs experience plastic bucking failure. The effect of key design parameters including core configuration and face sheet thickness on the energy absorption ability of panels under blast has been discussed. Results show that the core web thickness and cell size have an effect on its crushing properties and increase in relative density of core can improve the energy absorption ability of panels under low stand-off distance. Increasing the impulse level and the face sheet thickness can increase the plastic energy dissipation. Specific absorbed energies of the sandwich panels are compared to those of solid plates with same mass. The sandwich panels are superior to solid plates based on an areal density for stand-off distances above 50 mm:

KEY WORDS: Energy absorption; sandwich panel; air blast; corrugated core; AUTODYN.

INTRODUCTION
The topics of development of energy-absorbing structures and materials, which dissipate kinetic energy during impact or intense dynamic, have gained attention since the 1970s (Johnson and Reid, 1978). The emergence of sandwich structures consisting of two stiff face sheets and a low density core, provides potential means for absorbing energies from blast/impact loads (Yuen, Nurick, Theobald and Langdon, 2010).

Sandwich structures as a novel construction, famous for their light weight, high specific strength and good energy dissipating properties, are widely used in packaging, automobile and military industries (Gibson and Ashby, 1999; Lu and Yu, 2003). To date, some studies have been conducted on sandwich beams, panels and shells with stochastic material or prismatic material as cores, and the plastic deformation, failure mechanism and energy absorption of them have been investigated experimentally, theoretically and analytically (Fleck and Deshpande, 2004; Jing, Xi, Wang and Zhao, 2013; Rubino, Deshpande and Fleck, 2008; Zhu, Zhao, Lu and Wang, 2008a; Zhu, Zhao, Lu and Wang, 2008b). The theoretical model developed by Taylor (1963) shows that the reflected impulse can be reduced when the impacted plate is able to move away from the impulse in water, then the advantage of sandwich panel were exploited for shock mitigation during underwater loading (Hutchinson and Xue, 2005; Liang, Spuskanyuk, Flores, Hayhurst, Hutchinson, McMeeking and Evans, 2007; Wei, Deshpande, Evans, Dharmasena, Queheillalt, Wadley, Murty, Elzey, Dudt, Chen, Knight and Kiddy, 2008). For air blasts, the acoustic assumption is not available any more, and the nonlinear compressibility effects of air are required to take into account (Kambouchev, Noels and Radovitzky, 2006). Vaziri and Hutchinson (2007) based on the new fluid structure interaction (FSI) theory of Kambouchev, Noels (2006) to study the performance of all-metallic sandwich panels with square honeycomb core or folded plate core using a decoupled method to treat air blast load. Dharmasena, Wadley, Xue and Hutchinson (2008) and Dharmasena, Wadley, Williams, Xue and Hutchinson (2011) demonstrated that the honeycomb and pyramidal lattice core sandwich panels suffered smaller back face deflections and smaller vertical component forces transmitted to supports compared to solid counterparts under high intensity air blast loading, however the efforts to further enhance the FSI effect by reducing the inertia of front face aborted by face penetration. Jing, Xi (2013) experimentally investigated the failure mechanism of cylindrical sandwich shells with closed-cell aluminum foam cores, and drew the influence rules of face sheet thickness, core relative density and curvature radius on the energy absorption capability of shells. To the authors’ knowledge, most public research works about energy absorption analysis of sandwich panels concentrated on the panels with continuous form cores, and correlational studies on the panels with discrete form cores are limited.

Here, we employed commercial software AUTODYN to investigate the dynamic response of metallic corrugated core (which is a type of discrete form core) sandwich panels subjected to air blast loading. The primary objective is to give a deep insight into the effect of explosion loads and geometrical configurations on the energy-absorbing characteristics of sandwich panels. Following this introduction, a detailed geometry description is presented and the parameters of calculated cases are given. Then, the formulation of computational model used to capture the structural response is explained, and the validation results are given. Finally, we evaluate the contribution of each component of the panels, and the effect of panel configurations on the energy-absorbing ability is analyzed.

GEOMETRY DISCRIPTION
All sandwich panels with a 280 mm × 300 mm exposure area to receive blast consist of two equal thickness face sheets $t_f$ and corrugated core with a given web inclination angle of 60°. The dimension of cylindrical TNT explosive is 37.2 mm high, 17.5 mm in radius. Four face sheet thicknesses $t_f$ (1.2 mm, 1.6 mm, 2.0 mm, and