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Experimental study of the medium velocity impact response of sandwich panels with different cores

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ABSTRACT

The impact response of sandwich panels is not only dependent on the facesheet but also on the core material. This paper compares the dynamic response of sandwich panels with different core materials when subjected to medium velocity impacts. The sandwich panels were made of aluminium facesheets with five different cores, viz., low density balsa wood, high density balsa wood, cork, polypropylene honeycomb, and polystyrene foam. All the specimens were impacted by an instrumented projectile with a hemispherical steel head at three impact energies of 43, 85 and 120 J. An accelerometer attached to the projectile and a high speed camera were used to collect data and record the impact process. 3D scanning technique was used to measure the deformation of front and back faces after impact. The impact properties of the sandwich panels with the five different cores were compared in terms of contact force, energy absorption, depth of indentation, overall bending deflection, etc. Post-mortem sectioning was conducted to examine the impact induced failures such as facesheet rupture, crush of core material, and debonding between facesheet and core. Finite element modelling was also carried out to elucidate the observed experimental results and further understand the effect of core material.

1. Introduction

The increasing effort to develop lightweight structures characterised by better mechanical performance has led to the development and employment of sandwich structures. A sandwich structure may be defined as a composite component featuring a lightweight core placed between two relatively thin high-strength facesheets or skins. The facesheets are designed to resist bending loads and are usually made of aluminium or fibre reinforced polymers. The core separates and stabilises the outer sheets against buckling under edgewise compression, torsion or bending and is usually made of woods, expanded metals, polymer and metal foams, and polymer and metal honeycombs [1]. An adhesive bonding between the facesheets and core ensures the load transfer between them. Sandwich structures are lightweight composite materials that have been widely used in numerous application fields such as aerospace, marine, automotive, and energy industries for their desirable properties like high specific bending stiffness, excellent thermal insulation, acoustic damping, etc. However, sandwich composite structures are susceptible to impact loading and may be subjected to different impacts such as tool drops, bird strikes, hail stones, and runway debris during the service life [2]. These impacts may cause significant damage, such as local core crushing and debonding of the facesheet from the core, which severely compromises the structural integrity of the sandwich panel [3]. The study on the behaviour of sandwich structures subjected to impact loading is usually accomplished by experimental testing [4–6]. The effects of impact variables (such as impact velocity and energy, impactor shape and diameter) and sandwich construction parameters (core material and thickness, facesheet type) on the impact behaviour and resulting damage are the major concerns in many studies. According to Ozdemir et al. [7], the core material and thickness is one of the main factors determining the impact behaviour of sandwich structures and it was shown that the energy absorption capacity of sandwich composites increased with increasing core thickness.

The core materials are usually divided into four groups: balsa woods, corrugated sheets, honeycombs and cellular foams [8]. Aluminium honeycombs have been used in the aerospace industry but suffer from corrosion damage to the core from water ingress. According to Shipsha [8], though honeycomb cored sandwich structures offer the highest stiffness to weight ratio, many industrial applications prefer cellular foam cores such as polyvinyl chloride (PVC) foam because of their relative low cost, water resistance, and a possibility to use traditional manufacturing methods such as hand layup. Foam materials have a cellular structure with a three-dimensional array of cells and this microscopic cellular structure determines their superior performance as an energy absorbing material [9]. Another advantage of foam cores is the increased support surface for bonding with the facesheets [10]. Polymer foams that are used as core materials for sandwich structures include polyurethane foams, phenolic foams, expanded and extruded polystyrene (EPS and XPS) foams and polymethacrylimide (PMI) foams [11]. Cantwell et al. [5] compared the impact response of sandwich structures with balsa wood and PVC foam cores for use in marine applications.

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Table 1
Material properties.

Material	Al 2024-T3	Balsa LD	Balsa HD	Cork	PS foam	PP honeycomb
Thickness (mm)	1.06	10.45	10.32	10.23	9.52	10.74
Density (kg/m^3)	2614.42	101.77	145.04	150.43	32.39	145.21
Young's modulus (MPa)	73,100	10–18	10–18	5.1	8–20	97
Compressive strength (MPa)	483	2.5	2.5	0.3	0.3	2.2
Shear strength (MPa)	283	9	9	5.9	4.5	19

Bernard and Lagace [12] studied the impact resistance of composite sandwich plates with graphite/epoxy facesheets and three different cores which were aluminium honeycomb, Nomex honeycomb and Rohacell foam using low energy impact tests. Atas and Sevim [13] compared the impact damage process of sandwich samples with PVC foam and balsa wood cores by cross-examining the load–deflection curves, energy profile diagrams, and damaged specimens. Another popular type of core used for manufacturing sandwich panels is metallic foam. Mohan et al. [14] experimentally investigated the response of bare aluminium foam blocks and their sandwich panels with various tailored facesheets under a drop-weight impact loading; the results showed increase in foam thickness and the use of facesheet enhanced the impact energy absorption capacity. Rajaneesh et al. [15] compared the relative performance of sandwich plates consisting of aluminium alloy foam and PVC foam with aluminium facesheets under low velocity impact, and it was found that the contact radius was higher for a sandwich plate with a stronger foam for a given impact load. Hou et al. [16] conducted ballistic impact experiments on metallic sandwich panels with aluminium foam core, and it was revealed an approximate linear relationship between ballistic limit and relative core density. Moreover, the ballistic limit of the specimens with a thicker core had a more rapid increase with the relative density than their counterparts with thinner core.

The understanding of the impact phenomenon and the damage mechanisms are essential for developing improved materials [17]. The impact problem can be classified as low velocity impact by a large mass (like a dropped tool), which is simulated using a falling weight or a swinging pendulum, and medium/high velocity impact by a small mass (such as runway debris and small firearms), which is simulated with a gas gun or some other ballistic launchers [18]. It is generally accepted that low velocity impact are impacts at velocities below 10 m/s, medium velocity impact has velocities ranging from 10 to 50 m/s, and high velocity impact occurs in the 50 to 1000 m/s velocity range [18,19]. While low velocity impact [14,15,20–23] and high velocity impact [4,16,24] response of sandwich panels are well represented in the literature, the response of sandwich panels subjected to medium velocity impacts has rarely been studied experimentally. In this paper, sandwich panels with aluminium facesheets and five different core materials are impacted at different energies using a medium velocity gas gun and a comparison based on the force–displacement response and failure modes of the panels is presented. Numerical modelling of the impact response of two representative sandwich panels was also conducted using the finite element software LS-Dyna to explain the observed results in the experiment.

2. Experimental methodology

2.1. Materials used

The sandwich panels tested in this study were manufactured of identical facesheets combined with five different core materials using a wet layup process. The material of the facesheet was Aluminium

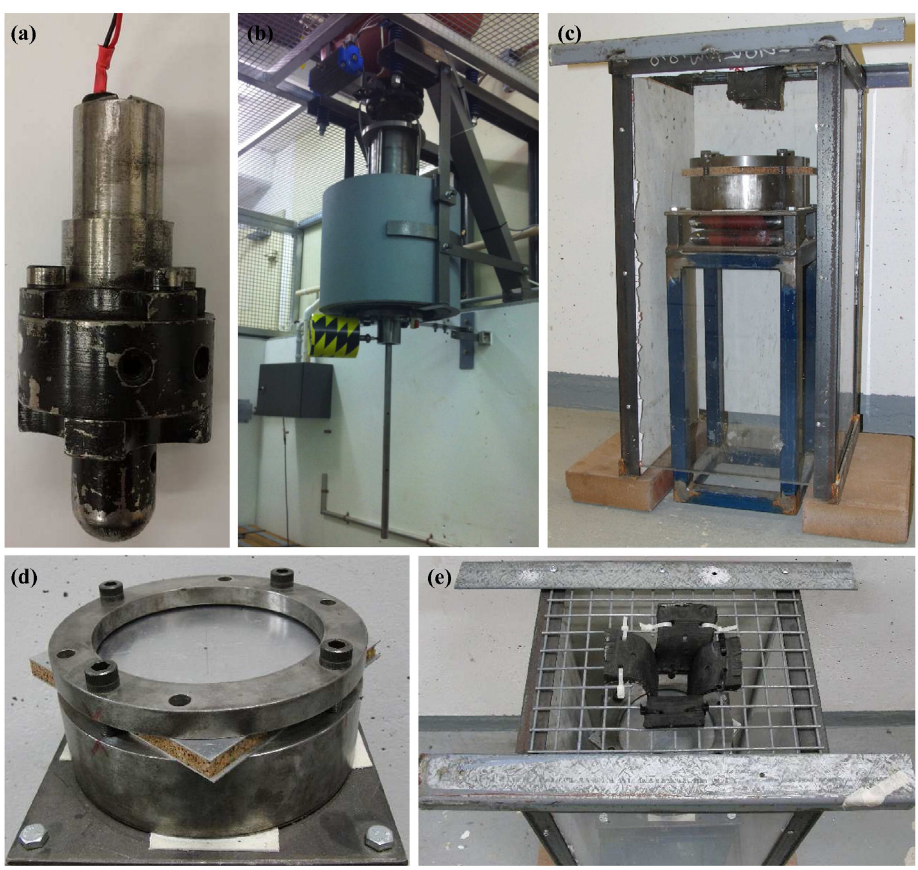

Fig. 1. Experimental setup: (a) instrumented projectile; (b) vertical gas gun; (c) protection cage; (d) clamping device; and (e) rubber 'rebound catcher'.