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Effect of impactor shapes on the low velocity impact damage of sandwich composite plate: Experimental study and modelling

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ABSTRACT

An experimental and numerical analysis of the influence of impactor shapes on the low velocity impact performance of aluminium sandwich composite plates has been carried out. The aluminium composite panels were manufactured by using two aluminium sheets and a low density polyethylene core under heat and pressure, which shows the outstanding properties of low weight, good rigidity and impact resistance. Experimental tests were performed using drop weight test machine, samples were impacted using steel conical, ogival, hemispherical and flat impactors, all 12 mm in diameter, for different initial impact energies of 29.43 J and 44.15 J and specimen thickness of 4 mm containing three different parts (0.5 + 3.0 + 0.5). A three dimensional non-linear finite element model is developed for simulating the impact behaviour of sandwich composite plate and the ABAQUS/Explicit commercial program was used. The face sheet material aluminium alloy 3003-O of the plate was modelled as isotropic with elastic–plastic characteristics. The description of the material characteristic of the attenuator was made by means of the Johnson–Cook elastic–plastic law. The material constitutive law of the Al 3003 plates has been implemented in a user-defined subroutine UMAT. The foam core was modelled as a crushable foam material. The finite element results showed a good correlation to the experimental data in terms of contact-force histories, energy histories, absorbed energy, and failure of the sandwich composite was observed between the experimental data.

1. Introduction

Structural sandwich composite materials can be effectively used as a suitable alternative of structural materials in vehicular or aircraft body. Structural design of composite parts has already passed the so-called "replacement phase" and in a number of applications moves toward a "design phase" with a complete redesign of the part in order to take advantage of the customs of this class of materials. However, impact design of composite material structures is still in the early stage of the "demonstrative phase": the designer is still trying to confirm whether some parts could be constructed with a composite material as energy absorber or not. In other way, upon impact, a series of physical phenomena takes place: elastic, shock, and plastic wave propagation, fracture and fragmentation, perforation, etc. Civil and military applications require designing high performance and high energy absorbing materials and structures. For example, in the aerospace industry, new composite wing structures resisting hail and bird impacts are of relevance. Designing energy absorbing materials is challenging since various mechanisms—wave propagation, dynamic cracks, and delamination, thermal effects, dislocation generation, growth, and motion, etc.—are acting concurrently, at different material scales, and intertwined during impact. The sandwich composite materials which have high strength with respect to weight ratio offer a wide range of applications in transportation engineering industries such as automotive, aerospace, marine, and civil engineering. In those applications, composites might be exposed to impacts from foreign objects, such as drop of tools during their life-time of service or operations of assembly and maintenance. These impacts can cause local deflection of the face sheet, delamination, and nucleation of interfacial cracks. These damages may extend during their life-time

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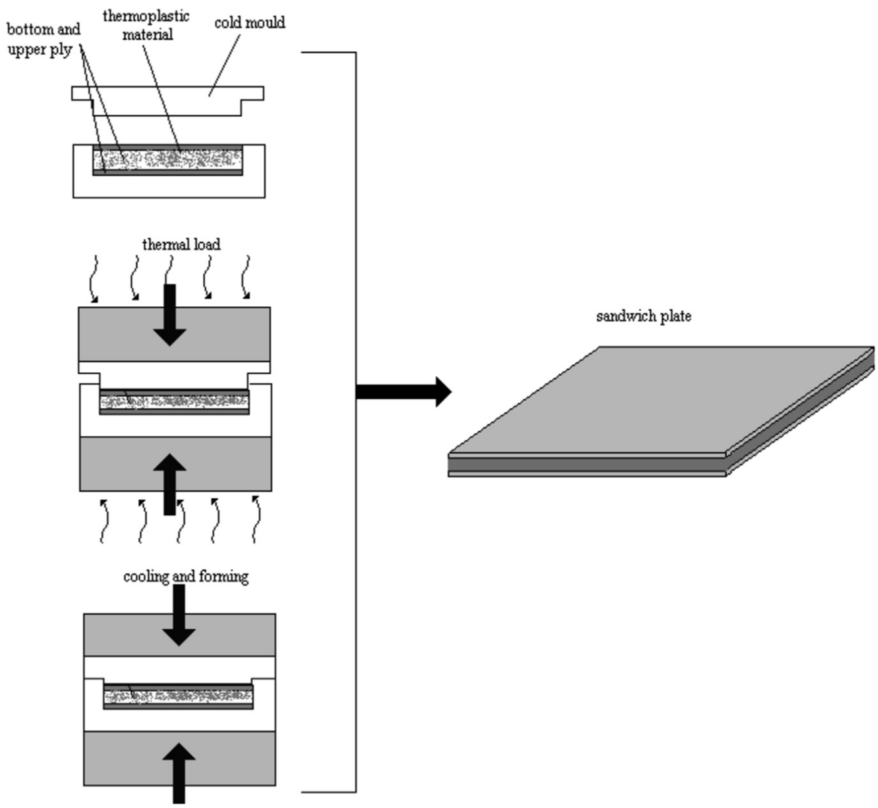

Fig. 1. Processes for aluminium-thermoplastic sandwich manufacturing: isothermal compression moulding.

of service, possibly causing a catastrophic failure of the sandwich composite plate. The impactor shapes may affect impact response of sandwich plate and failure. Therefore, it is necessary to determine the effect of impactor shapes on the impact response of sandwich composite plate.

Recently, numerous researchers have been studying the impact response of composite laminate [1–13]. The previous work can be classified into three categories: (1) impact response of composite laminates, (2) damage characterization, and (3) contact mechanism in composite structures by impact load.

Zhou et al. [6] investigated the parameters effect on the low velocity impact response of foam-based sandwich panels using experimental and numerical method and noted that the sandwich panels is strongly dependent on the properties of the foam core. Suvorov and Dvorak [14] improved damage resistance of sandwich plates using a compliant and compressible elastomeric foam (EF), and a stiff and incompressible polyurethane (PUR), together with the same face sheet and core materials. Their findings showed that the PUR interlayer reduces both local deflections of the face sheet and overall, and also the local compression of the foam core and the residual stresses left after unloading.

Table 1
Properties of sandwich composite plate.

Properties		Unit
Thickness	4	mm
Density	1.35	g/cm^3
Weight	5.49	kg/m^2
Tensile strength	48.3	MPa
Yield strength	43.2	MPa
Elongation rate	0.15	
Young's modulus	44	MPa

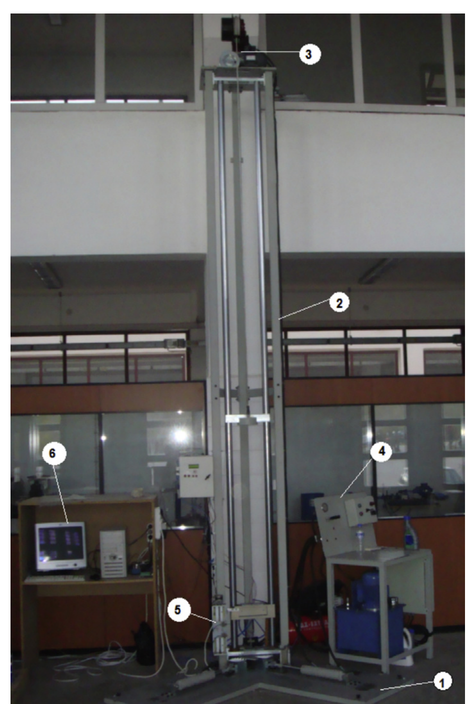

Fig. 2. Drop-weight test machine developed at Dumlupinar University: 1—L shape table, 2—weight drop tower, 3—lift engine, 4—control unit, 5—reboun breaking system, 6—data acquisition unit.