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Numerical- Experimental Study of Energy absorption of Automobile Light-Weight Composites Subjected to Impact

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Abstract:
Automobile light weight structural composites are subjected to the various loadings in their service lives. Honeycombs are increasingly used as core structures in automobile light weight structures as energy absorbers. In this paper the energy absorption of honeycomb panels under impact of cylindrical projectile is numerically and experimentally studied. The effect of the core materials and cross-ply or semi-isotropic lamination of face-sheets are checked numerically. Results shown that the aluminum cores vs. Nomex cores and semi-isotropic lamination of face-sheets have much better energy absorption aspects in impact loading.

Keywords: Sandwich composites, Impact, Numerical- Experimental

INTRODUCTION

Honeycombs are extensively used as energy absorbers, because of their individual properties like their light weight, good energy absorption and high flexural strength [1-5]. Sandwich panels with honeycomb core are used in transportation and aerospace industries because of their high stiffness and specific strength. Honeycombs are impacted indifferent situations by projectiles, and the impact damage varies from indentation of sandwich skins to complete perforation of the panel. Therefore, the study of structural behaviour of honeycombs is a high demand of advanced industries. The first study of honeycomb crush was done by McFarland [6] who proposed a semi empirical model to predict the crushing strength of cellular structures with hexagonal cells.
The impact velocity of hails was modelled between (30-200 m/s).
of thin-walled composite structures to ice impact, and to observe the resulting damage modes that occur over a wide range of velocity
In this study high velocity simulation of impact between hard materials and vehicle composite structures is investigated. So, a preliminary example problem of an impactor and a composite plate is used to model an impact between two deformable bodies and the energy absorption of honeycomb panels under impact of cylindrical projectile is numerically and experimentally studied. The effect of the core materials and cross-ply or semi isotropic lamination of face-sheets are studied numerically.

EXPERIMENTALS PROCEDURE

To validate the numerical model, several high-rate impact tests were carried out on 4 specimens 140 mm in length, 140 mm in width, and 24 mm in thickness (as shown in Fig.1). These tests were performed using a gas gun that schematically is shown in Fig. 1. The specimens were impacted by cylindrical steel projectiles of 1.7 g and 7.5 mm in diameter. For an impact velocity of 94 m/s. The primary and secondary velocities of specimens was gathered from the tests and used to estimate the projectile energy dissipation. Schematic representation of the experimental setup for impact is shown in Fig.1. These four specimens were sandwich panels with aluminum cores in the three cases and Nomex core at the other case and Kevlar-49/ epoxy face sheet.

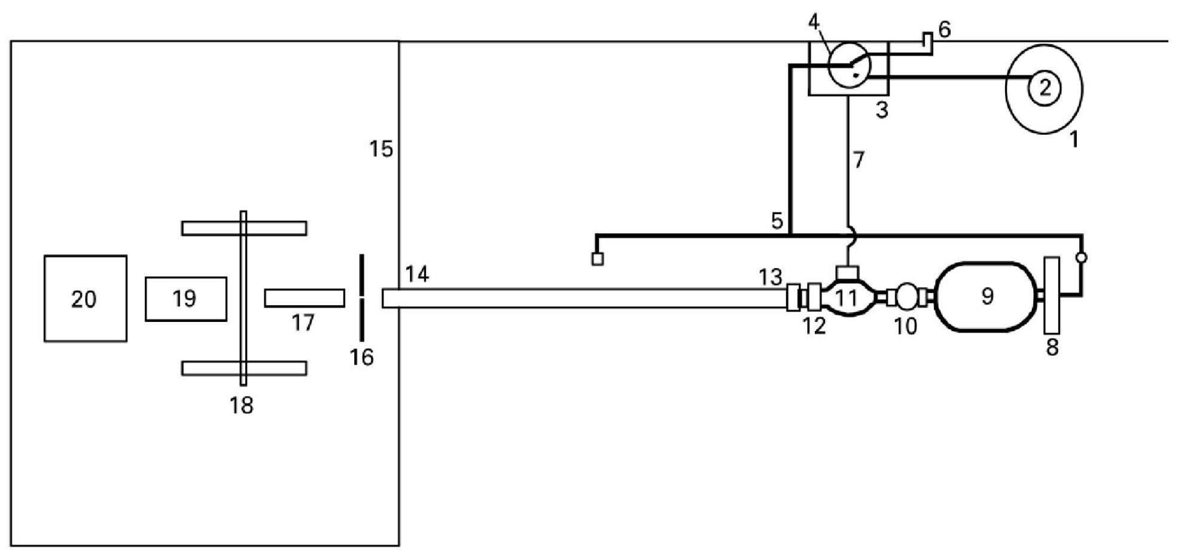

Fig. 1. Schematic diagram of the gas gun and test setup: (1) gas bottle, (2) gas regulator, (3) control box, (4) three-way valve, (5) gas line (two barrel connections), (6) gas vent line, (7) solenoid activation cable, (8) pressure gauge, (9) pressure vessel, (10) leak valve, (11) solenoid valve, (12) ball joint, (13) breech, (14) barrel, (15) hardened wall, (16) blast screen, (17) incident velocity device, (18) target support stand, (19) exit velocity device, (20) catcher box

Finite Element Modeling (FEM)

The finite element model used to analyses the sandwich impact behaviour was implemented in ABAQUS/Explicit. Since the influence of boundary conditions is negligible in the impacts with high rates, the FEM3D model included two solids: a projectile and a sandwich plate. Because of plastic deformation was found in the projectile after the experimental test, plastic behaviour was used for the steel CK 45 projectile (E=200 GPa, υ=0.3, Elongation at break= 15%). The honeycomb core was modeled by a homogeneous equivalent material as shown in Table. 2.

In this work, square sandwich specimens (140 mm×140 mm and 24 mm thick) were used. The skins were plain woven laminates of Kevlar-49 fibers and epoxy resin 5052 and with 2 mm thickness. The core was a 3003 aluminum honeycomb of 10 mm thick and 72 kg/m^3 in density. The cells were hexagonal, with 4.8 mm in cell size and wall thickness of 0.6 mm. The properties of the composite skins and the honeycomb core that was used in numerical model were determined by characterization tests and literature. The properties of the Kevlar-49/epoxy woven laminate and core material are shown in Table 1 and Table 2. For the comparison purposes the projectile aspects was modeled similar to experimental tests.

Table 1. Mechanical properties of Kevlar-49/5052 [20]

E_1 (GPa)	E_2 (GPa)	G_{12} (GPa)	ν_{12}	S_{ut}(MPa)	S_{uc}(MPa)	S_{us}(MPa)
130.5	130.5	3.7	0.2	795	860	98

Table 2. Mechanical properties of the aluminum core and Nomex core [17]

	σ_{comp} (MPa)	σ_{crush} (MPa)	E_{comp} (MPa)
Alominum core	3.76	1.8	400
Nomex core	2.57	1.5	430

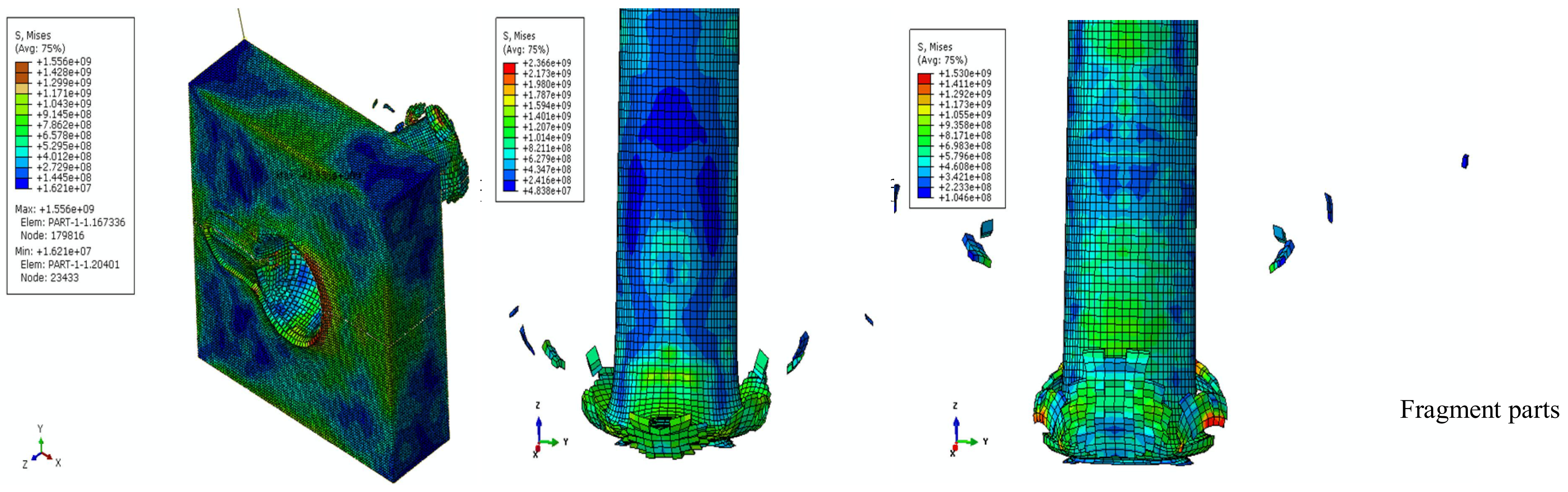

Fig. 2. Stress contour (MPa) in the composite structure (left) and projectile (mid figure and the right one) in 0.07 sec.

CONCLUSIONS

The drawback of the experimental impact tests was the limited information concerning the evolution of the projectile during the impact. There are three different trends corresponding to the three components of the sandwich (front skin, core, and back skin). In the first region, the composite front skin caused a sudden drop in velocity at the beginning of the impact event, so that the projectile reached the honeycomb core at a velocity of nearly 50 m/s.
Secondly (25–60 m/s), the velocity remained almost constant as the projectile went through the honeycomb core, when the projectile reached the back skin, its velocity was nearly 45 m/s. In the back skin a new drop in velocity was observed for a residual velocity of over 35 m/s. The projectile lost 44% of its impact kinetic energy, front and back skins absorbed 43% and 40% of the absorbed energy, respectively, and the honeycomb core absorbed 13%. This analysis was made on each numerical test, calculating the energy absorbed by the three components of the sandwich plate. The skins were the main factor responsible for the energy adsorption, while the energy absorbed by the honeycomb core was lower. Also the honeycomb embeds the large deformations of the top skin and prevents large deformation of the sandwich panel. The percentage of the energy absorbed by each component was almost constant.
The experimental tests indicated that the region of the honeycomb over which the projectile impacted had a very small influence on the results. The impact wave is absorbed with honeycomb cells and the deformation of the second skins was reduced. The numerical simulations showed that the semi-isotropic face-sheets absorbed the impact energy 6.25% more than cross-ply laminations.

Important References:

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