

A SIMPLIFIED MODEL TO SIMULATE CRASH BEHAVIOR OF HONEYCOMB

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Abstract: Although to have an accurate result of Finite Element analysis of a system is always enviable, on most of engineering problems it is worthwhile to find simpler models with less required time to solve and acceptable degree of accuracy those keep the general characteristics of system. Available numerical methods, however consider effect of different characters like air drainage and adhesive influence on crash behavior of honeycomb, but usually these assumptions are not applicable on big models especially when a complicated geometry is appraised. This paper validates a simple Finite Element model for honeycomb witch has an acceptable accuracy in crash analysis and is easily applicable on intricate problems. This model is desirable not only for simple honeycomb systems but also for sophisticated samples such as multi-layer or multi-material honeycomb based structures. A comparison with experimental results shows good rate of exactitude for new simulation.

Keywords: Honeycomb, nonlinear dynamic analysis, finite element, crash test.

1. INTRODUCTION

Honeycomb structures are used in various engineering systems such as railway, automotive and aircraft industries over the past decade [1, 2]. They have been used directly or as a supplemental system to dissipate huge amount of energy created by dynamic movements in witch impact energy is absorbed through the large compressive stroke.

Since the energy absorber works under dynamic loading, it is valuable to assess the crushing behavior under high loading rates. Plenty of analytical and experimental work has been performed under various loading situations, cell properties and boundary condition because of the anisotropic nature of honeycombs [3-5]. As an experimental test, HANZHAO and GERARD GARY [6] have developed a new application of the Split Hopkinson Pressure Bar (SHPB) for testing honeycombs under both in-plan and out-of-plan crash with using viscoelastic split bars and the two-strain measurement method. M.Yamashita and M.Gotoh [7, 8] have considered the crash behavior of honeycomb with various cell specifications and compared experimental and numerical results by using a Y cross-section column with appropriate boundary conditions. They have used quadrilateral Belytschko-Tsay shell elements [9] and solid elements to simulate honeycomb foil and adhesive respectively. They also showed that, strain rate during the test doesn't apply too much change on crash strength in honeycomb structures. Although, other parameters such as incescent in internal air pressure have been considered in available literatures, usually these assumptions are not applicable on big models especially when a complicated

geometry is appraised because of the restrictions of available computer systems and volubility of time.

This paper validates a simple Finite Element model for honeycomb witch has an acceptable accuracy in crash analysis and is easily applicable on intricate problems. A Y cross-section column with simple configuration is investigated to discover not only the effect of adhesive elimination between two aluminum foils but also a simple angle in cell corners without small curves are created in real honeycomb. This simulation method is desirable for simple honeycomb systems as well as sophisticated samples such as multi-layer or multi-material honeycomb based structures. Numerical study is carried out mainly in the numerical simulation using an explicit FEA code DYNA3D [10]. The comparison with experimental results shows good rate of accuracy of new simulation method.

2. EXPERIMENTAL CRASH TEST

The honeycomb cores impacted in this research have been produced by Cellbond Composites Ltd with an expansion of thin aluminum foils partly attached to each other in a stripe prototype. The cores have been chosen are known as 1.8-3/4-3003 in which the foil material is aluminum alloy A3003 and foil thickness is 0.063 mm, however, material property for foil is given in table 1.

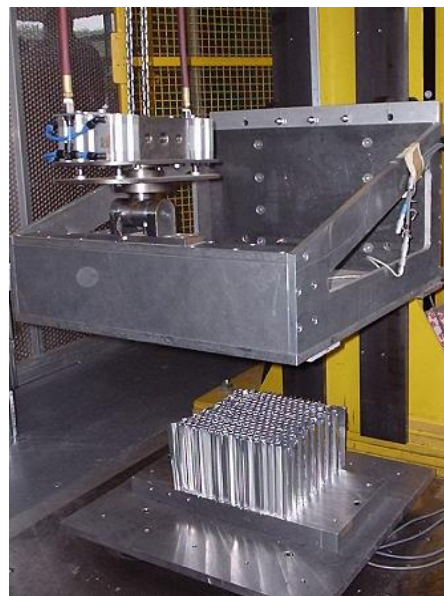
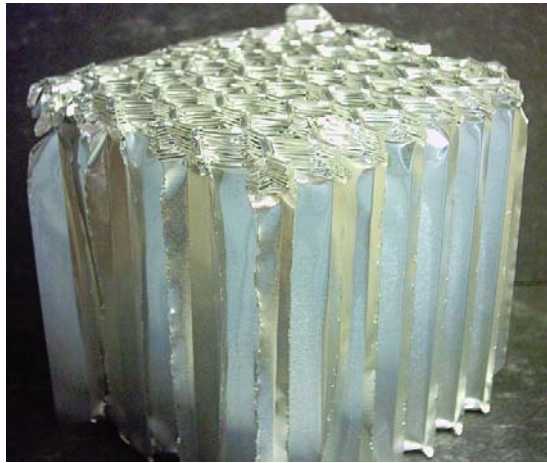


Figure 1. Crash test machine, total mass of trolley = 72 kg

Table 1. Mechanical properties of aluminum alloy 3003

Mass Density (KN/m ³)	28.9
Young's Modulus (MPa)	6.89e4
Poisson's Ratio	0.33
Yield Stress (MPa)	190

The cell size is 3/4 inches (19.05 mm) shows distance of opposite sides in honeycomb cell and all samples are provided in 250 mm length and width with 150 mm height. Figure 1, represents tested honeycomb core and instruments. A Drop-Hammer crash test machine which posses a total trolley mass of 72 kg, applies impact load on honeycomb samples with a selected test speed of 5.24 m/sec.



(Sample 1)



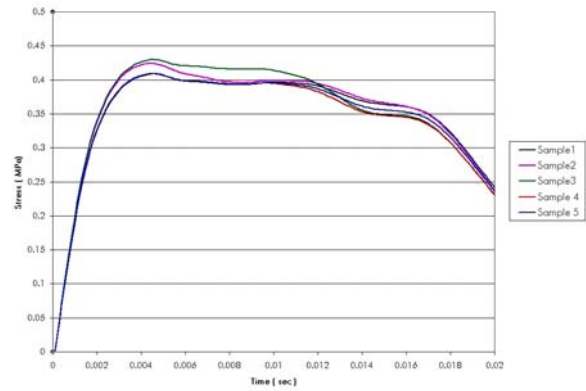
(Sample 2)

Figure 2. ¼ of crashed honeycomb core.

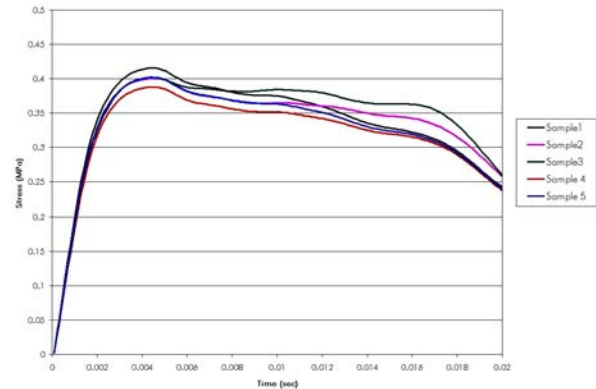
Figure 2, includes squashed honeycomb piece under test condition in which despite of uneven deformation shape on corners and boundary line a regular stroke appears on

inner parts. A total number of fifteen crash tests have been done to consider the procedure; however, results of five samples are presented in this paper. Although, available surfaces on impact hammer and support attribute an easy air flow on test, to avoid any further influence by air pressure, a sponge rigid base provides a proper air leakage during crash time.

Where, ΔP and P_0 are increment on air pressure and atmosphere pressure which is approximately 0.1 MPa. ΔH and H_0 stand for stroke and initial height of sample respectively.



(a)



(b)

Figure 3. Stress versus time. a) Simple base support b) Sponge base support

The mentioned curves give an average compressive stress which is defined in Eq. (2), where impact load F has been measured during the test and A is the whole cross-sectional area for used honeycomb cores (62500 mm²).

$$s = \frac{F}{A} \quad (2)$$

A peak point appears on all graphs immediately after hammer contact, thereafter, a smooth curve gives the crash strength which is approximately 0.37 MPa. In all samples, the squashed process started from top side affects about 50 mm with a regular stroke particularly in middle area of core. A piece of squashed sample has been taken from the whole specimen is shown in Figure 4.

3. ENERGY ABSORPTION PROCEDURE

With respect to out-of-plan crash performance of honeycomb, it is axiomatic that the whole applied energy which is subjected by any external drive is dissipated by huge deformation on honeycomb foil elements. The Strain Energy for a generalized State of Stress can be calculated using Eqs. (3) and (4):

$$E_s = \sum_{i=1}^3 \sigma_{ii} \varepsilon_{ii} + \frac{1}{2} \sum_{i=1}^3 \sum_{j=1}^3 \sigma_{ij} \gamma_{ij} \quad i \neq j \quad (3)$$

and

$$\varepsilon_{ii} = \frac{1}{E} [\sigma_{ii} - \nu (\sigma_{jj} + \sigma_{kk})] + \alpha \Delta T \quad (4)$$

$$\gamma_{ij} = \frac{2(1 + \nu)}{E} \sigma_{ij}$$

Eq.(3) illustrates saved energy in a general mechanical system as a function of normal and shear stress and corresponding strains in which, σ_{ij} , ε_{ij} and γ_{ij} are stress, displacement and angular strain components respectively. In the case of honeycomb crash test, due to low amount of temperature performance on whole system, strain could be considered as a consequential of displacement component. Although, it is possible to work the total absorbed energy out with using approximated sinus deformed curve and surface integration on all foil area [11], with regarding to equality of transmitted kinematics energy with absorbed strain energy considering movement of drop hammer will provide more convenience on energy investigation. The total kinematics energy for a moving mass could be caught by Eq. (5).

$$E_k = \frac{1}{2} \int_{Volume} m v^2 dV \quad (5)$$

in that, m and v represent mass per unit and velocity function throughout the system, respectively. In a one-dimensional movement, the Eq. (5) appears in a simple feature as seen below:

$$E_k = \frac{1}{2} M .v^2 \quad (6)$$

in which, M is the total mass of moving system. Figure 4, shows drop hammer's kinematics energy curves versus the crash process time.

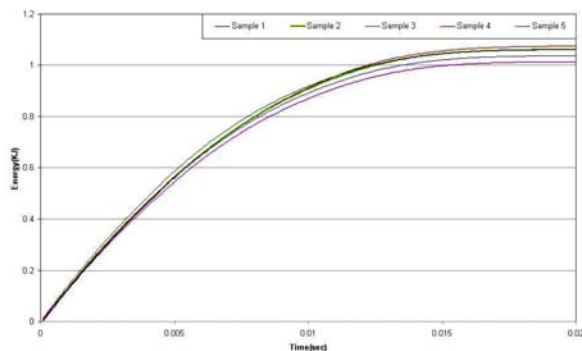


Figure 4. Drop hammer's kinematics energy

4. NUMERICAL SIMULATION PROCEDURE

Due to geometrical symmetry of honeycomb structure, a Y shape cross-section has been developed (Figure 5). In this model the adhesive between foils has been neglected as well as a small curve in corner which is as a result of expanding stacked foils in manufacture process. This is to consider the efficiency and accuracy of recommended simplified model. The powerful explicit FEA code DYNA3D is recruited to simulate the crash action. It is not necessary to consider strain-rate effect in this simulation[7, 8]. Thus an Isotropic-Elastic-Plastic material card is suggested to describe foil properties and quadrilateral Belytschko-Tsay shell elements make the honeycomb structure where two rigid plan and moving wall facilities act as support and drop hammer respectively and material properties are corresponded to table 1.

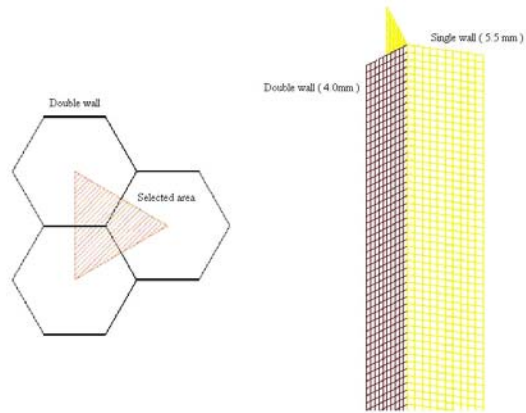
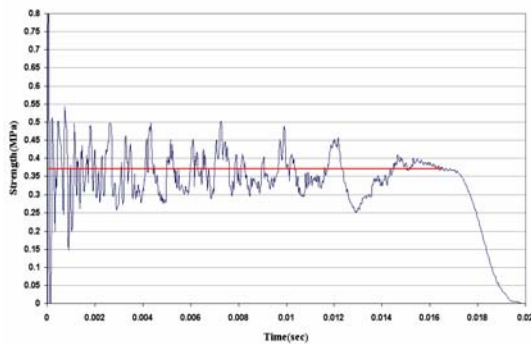


Figure 5. Numerical simulated model for honeycomb (branch angle 120°)

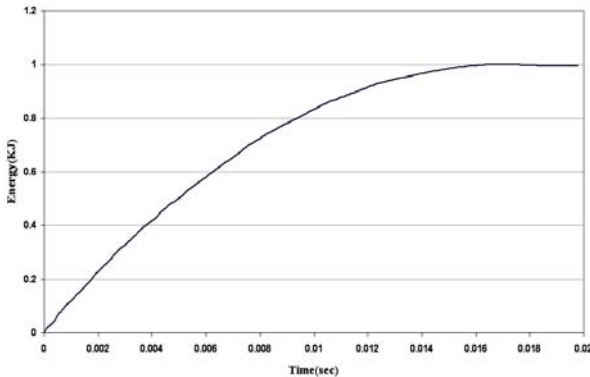
Although, the yield stress was reported in range of 170 MPa and 215 MPa by manufactures, an average amount of 190 MPa applies on this model and partial mass of Rigid-Wall is 1.49e-1 Kg with drop speed of 5.24 m/sec and impact load applied at the upper side of model.

5. OUTCOMES AND DISCUSSIONS

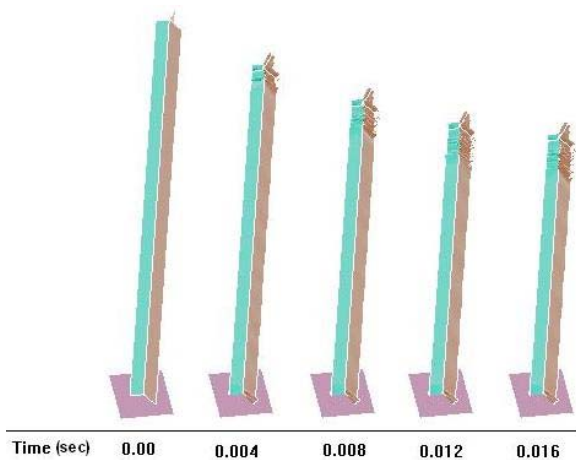
The average stress on base with regarding to Eq. (2) and deformed patterns in numerical simulation are shown in Fig. 6.a. A sharp peak point appears in numerical stress curve that refers to compressive force concentration before first cyclic buckling due to ideal geometric created model with no initial bend on impact side (these cambers are normally exist on honeycomb cores because of manufacture course). However, after first buckling phenomenon, the graph meets an average amount of 0.37 MPa which is fairly closed to experimental data and illustrates almost design strength for this honeycomb core. A good adjustment appears on calculated energy graph (Fig. 6.b) in a comparison with experimental crash test which is presented in Fig. 4. As can be found in Fig. 6.c, the squashing pattern starts from impact side, where as, some minor cycles appear closed to base but never expand until join to stroke from upper side and system follows a relative regular cyclic folding procedure.



a. Calculated strength of Honeycomb core



b. Deformation style in numerical simulation



c. Deformation style in numerical simulation

Figure 6. Calculated results from simplified model

6. Conclusion

A simple dynamic Finite Element model utilising LS-DYNA3D for honeycomb with an acceptable accuracy in crash analysis and is easily applicable on intricate problems has been developed. The model is desirable not only for simple honeycomb systems but also for sophisticated samples such as multi-layer or multi-material honeycomb based structures. A comparison with experimental results shows good rate of exactitude for new simulation. A Y cross-section column with simple configuration is investigated to discover not only the

effect of adhesive elimination between two aluminum foils but also a simple angle in cell corners without small curves are created in actual honeycomb. It was observed that after first buckling phenomenon, the graph meets an average amount of 0.37 MPa which was closed to experimental data and illustrates the design strength for the honeycomb core used. A good adjustment appears on calculated energy graph in comparison with experimental crash test which is presented.

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