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Analytical Investigation of Energy Absorption of Sandwich Panels with Honeycomb Core

S. S. Jafari[1], S. Feli[2]*

1- Ph.D. Student, Young Researchers & Elites Club, Hamedan Branch, Islamic Azad University, Hamedan, Iran
2- Associate Professor, Mechanical Engineering, Razi University, Kermanshah, Iran

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ABSTRACT

In this paper, a new analytical model has been presented for energy absorption of aluminum-Honeycomb sandwich panels under ballistic impact. The panels consist of hexagonal honeycomb core sandwiched between two aluminum skins. In analytical model, cylindrical rigid projectile with flat ended has been considered. In quasi-static loading, by using the springs-mass model, energy absorption of aluminum skins by considering different energy absorption mechanisms has been calculated. In addition, the energy absorption of honeycomb has been determined by the Wierzbicki model. The energy balance equation has been employed for determination of ballistic limit and residual velocity of striker. The results of ballistic limit and residual velocity of striker computed by new model show good agreement with experimental results. Also the effects of projectile mass and diameter and honeycomb cell diameter in energy absorption of sandwich panel have been investigated.

KEYWORDS:

Sandwich Panel, Honeycomb, Aluminum, Perforation, Energy Absorption.

* Corresponding Author, Email: felisaeid@razi.ac.ir

1- Introduction

Aluminum honeycomb sandwich panels are used extensively in aerospace and transportation industries. The panels consist of hexagonal honeycomb core sandwiched between two aluminum skins. This structure has high specific strength and stiffness. Over the past several decades, many researchers have focused on experimental and theoretical investigation on the transverse impact response of sandwich panel and energy absorption mechanisms and the ballistic impact behavior. Hoo Fatt and Park [1] presented an analytical solution for ballistic limit of a sandwich honeycomb panels subjected to a normal impact by blunt and spherical projectiles. Feli and Namdaripour [2] developed an analytical model the composite sandwich panels with the honeycomb core subjected to high-velocity impact. Xie et al. [3] investigated local indentation response of sandwich panels with metallic foam core under a flat-spherical indenter by analytical and numerical model.

The objective of this paper is to develop a new simple analytical model for perforation process of aluminum sandwich panels with the hexagonal honeycomb core subjected to the high-velocity impact of blunt projectile. The results of ballistic limit and residual velocity of striker have been computed by experimental results.

2- Analytical Model

In this paper, energy absorption of aluminum skins and honeycomb core of sandwich panels have been calculated separately.

2-1- Penetration of aluminum skins

In the quasi-static loading, by using the springs-mass model, energy absorption of aluminum skins with considering difference energy absorption mechanisms are calculated. In the quasi-static loading, the energy absorption of skins is presented in Eq. (1) [4].:

$$E_{def} = \frac{(K_{bs}W_{0f} + K_d W_{0f}^3)^2}{2K_c} + \frac{1}{2}K_{bs}W_{0f}^2 + \frac{1}{4}K_d W_{0f}^4 \quad (1)$$

Where W_{0f}, K_c, K_{bs} and K_d are critical transverse deflection of the mid-plane, contact stiffness, effective bending and shear stiffness and dishing stiffness, respectively.

Finally, for getting the impact perforation energy (E_{dAL}), dynamic enhancement factor (φ) is used. The impact perforation energy can be expressed by following equation:

$$E_{dAL} = \varphi_{AL} E_{sAL} \quad (2)$$

2-2- Penetration of honeycomb

Wierzbicki model [5] for perforation of honeycomb cells has been used in this paper. According to experimental observation [6], energy absorption at dynamic loading (E_{Dh}) equal to:

$$E_{Dh} = 1.3E'_{sh} \quad (3)$$

Where (E'_{sh}) is energy absorption at quasi-static loading.

2-3- Ballistic Limit and Residual Velocity of Sandwich Panel

An approximate value for the ballistic limit velocity (V_b) is obtained by combining the energy balance ($E_p = M_p V_b^2/2$) and energy absorption of sandwich panel (E_T). The ballistic limit velocity (V_b) is obtained from following equation:

$$V_b = \sqrt{\frac{2E_T}{M_p}} \quad (4)$$

where (M_p) is projectile mass. Also, residual velocity (V_r) is equal to:

$$V_r = (V_i^2 - V_b^2)^{0.5} \quad (5)$$

In Eq. (5) V_i is the initial velocity.

3- Results and Discussion

In this study, the analytical model predictions are compared with the experimental results reported in Goldsmith et al. study [7] and analytical results of Hoo Fatt and Park model [1]. Comparison of the results with Goldsmith et al. study [7] is presented in Table 1.

Figure 1 shows that ballistic limit velocity versus projectile diameter (D_p) for different projectile masses, while sandwich panel size is fixed.

It is evident form Figure 2 that when the projectile's mass increases, while the diameter of the projectile is constant, the ballistic limit decreases. Also when the diameter of the projectile increases the ballistic limit velocity increases.

Table 1. Comparison between the ballistic limits velocity of present analytical model and the experimental result [7]

Ballistic Limit (m/s)			
Test No.	Experimental [7]	Analytical model	Error%
1	50	50.93	1.86
2	53	51.31	3.18
3	85	93.66	10.1

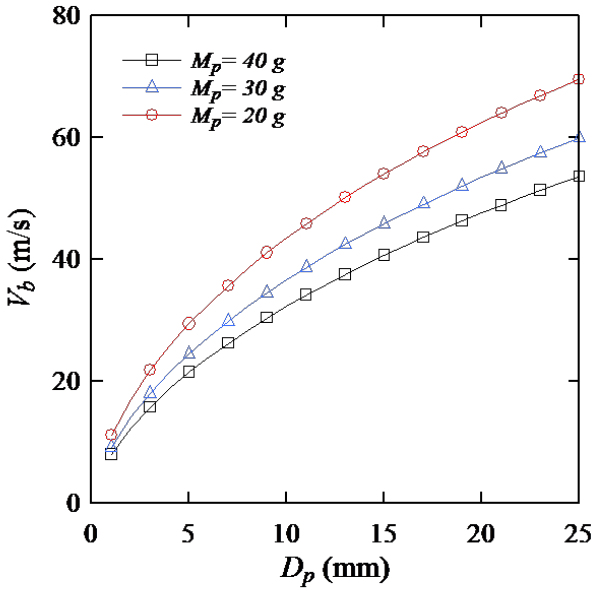

Figure 1. Ballistic limit vs. (D_p) for different projectile masses, at constant sandwich panel size and projectile density

Figure 2 shows that ballistic limit velocity versus (S), while $D_p=1.5S$. It is clear that, when the honeycomb cell size increases, the ballistic limit velocity increases.

4- Conclusion

-In this paper, a new analytical model has been presented for energy absorption of aluminum-honeycomb sandwich panels under ballistic impact. Energy absorption of aluminum skins with considering difference energy absorption mechanisms is calculated. In addition, energy absorption of honeycomb has been determined by the Wierzbicki model.

-It is shown that the ballistic limits and residual velocity of projectile predicted by new have good agreement with available experimental results.

-According to the analytical model, at constant diameter of the projectile, the ballistic limit velocity increases, when the honeycomb cell size increases.

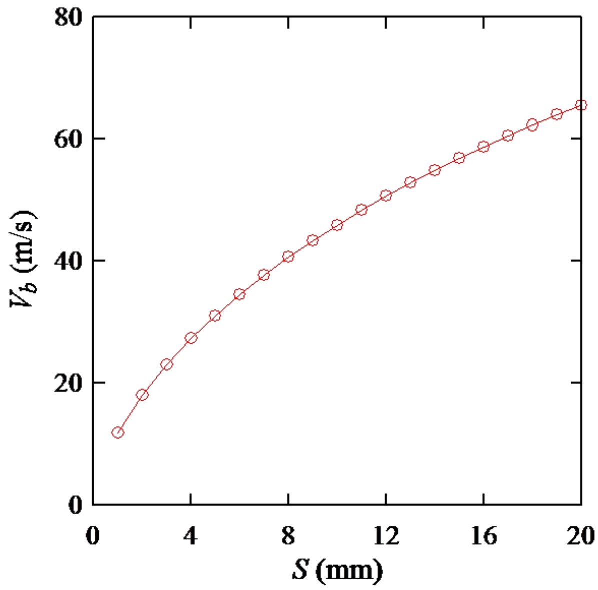

Figure 2. Ballistic limit versus cell size of aluminum-honeycomb sandwich panel

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