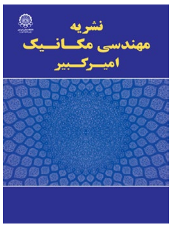

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Study on Performance of Sandwich Panel Structures with Honeycomb Core Subjected to Impulsive Loading

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ABSTRACT: In this paper, the effect of differed loading conditions, as well as structure geometries on the behavior of sandwich panel structures under uniform impulsive loading, has been investigated. For this, a full 3-Dimensional numerical model by using ABAQUS/Explicit commercial software was employed in order to simulate the dynamic response and plastic deformation of sandwich panel structures with a honeycomb core. The available experimental results were used to validate the numerical model. Afterward, in a rigorous parametric study, the influences of several effective parameters on the resistance of structure such as the front and back metallic layer thicknesses, the number of webs, and thickness of honeycomb core cell wall under three different mass weights of 0.5, 1 and 1.5 kg were studied. In the following, by using response surface methodology, an appropriate equation was developed to predict the central permanent deflection of back and front layers. The obtained results showed that there is a well-agreement between experimental and numerical results predicted by the regression model. The high correlation coefficient between the studied parameters and the structure behavior (R2 = 0.99) indicates that the proposed model has great accuracy.

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1- Introduction

Sandwich structures with a core made of porous materials (often honeycomb or aluminum foams), as an emerging protective structure, have the capability of dissipating considerable energy by large plastic deformation. The cellular microstructures offer them with the ability to undergo large plastic deformation at nearly constant nominal stress and thus can absorb a large amount of kinetic energy before collapsing into a more stable configuration or fracture [1-3]. So far, the response of sandwich structures under quasi-static loading or impact at a wide range of velocities has been extensively investigated and documented [4-7]. In recent years, increasing attention has been paid to such structures under impulsive loading due to enhanced chance of threats by an incident or terrorist attacks [8, 9]. In 2008, Dharmasena et al. [10] studied the dynamic behavior of sandwich structures with honeycomb made of stainless-steel material under free impulsive loading. Experiments were carried out at three loading levels on sandwich structures and single-layer sheets with similar surface densities. The impulse load and the dynamic load intensity were changed by varying the amount of charge load at a constant distance. At the lowest loading rate, in the center of the panel near the source of the loading, the bending of the front plate, and also the buckling of the cell wall, was observed to be remarkable and increasing, as with increasing impulse, the buckling in the cell wall and core density increased.

Despite extensive research on sandwich structures with honeycomb core under uniform impulsive loading, numerical simulations and statistical optimization of parameters that affect these structures, such as the thickness of metallic face sheets, the thickness of the honeycomb cell walls, and the number of webs in the core have not been studied. Therefore, in this paper, ABAQUS finite element commercial software was used to simulate the dynamic response and large plastic deformation of sandwich structures with honeycomb core under uniform impulsive and the experimental results of Dharmasena et al. [10] were also used to validate the numerical model. In this study, design–expert statistical software package and the response surface methodology were used to investigate the parameters affecting the resistance of the sandwich structure with the honeycomb core such as the thickness of metallic face sheets, the thickness of the honeycomb cell walls, and the number of webs in the core. This software was also applied to obtain a relationship between these factors and find optimal values of each mentioned parameter.

2- Methodology

The geometry of the sandwich structure and loading condition were modeled and based on the research paper by Dharmasena et al. [10] in ABAQUS finite element commercial software. According to Fig. 1, this sandwich structure was made of three layers. The front and back face sheets were made of a 5 mm thick plate made of super austenitic stainless steel called AL6XN. The middle layer was also made of a honeycomb core with a thickness of 0.76 mm, welded to the front and back face sheets. The sandwich structure was secured between two 19 mm thick steel supporting clamps. Then, this test fixture system is fixed with 8 bolts on two beams. The charge was placed at a distance of 100 mm above the sandwich structure. This sandwich

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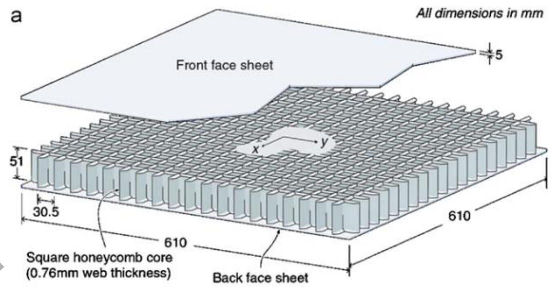

Fig. 1. A view of the sandwich structure examined [10]

Table 1. Optimum conditions

Independent parameters	Desirability
The thickness of metallic face sheets (mm)	3.82
Number of the web in the core	7
The thickness of honeycomb core (mm)	0.8
Charge mass (kg)	0.5

structure is shown in Fig. 1.

To validate numerical simulation results, the results were compared with the experimental results reported by Dharmasena et al. [10]. In Fig. 2, a comparison between the actual and simulated models is shown. The comparison of the deformation profile shows that a satisfactory agreement between the simulated model and the experimental values is established; therefore, the proposed model can be used for further studies.

3- Results and Discussion

Due to the high number of effective parameters on the permanent and transient deformations of structures under extreme dynamic loading, it is very difficult and time consuming to study the effect of each of them individually. Using simple methods, such as changing a parameter at any time cannot illustrate the interaction between the mentioned parameters and its effect well. To this end, the design-expert statistical software package is suggested. In this method, by performing a number of experiments or numerical simulations, the effect of the effective parameters on the final output is determined. Among the test design methods, the response surface method for high performance is more commonly used by researchers. In this paper, the response function is the central permanent transverse deflections of front and back face sheets, and the independent variables affecting them which include the thickness of metallic face sheets, the thickness of the honeycomb cell walls, the number of webs in the core, and the mass of charge.

Based on the results obtained from the statistical software and analysis of the variance of the results of the regression model, the optimal sandwich panel construction conditions with the purpose of achieving the highest resistance and the least deflections in the front and back face sheets of the sandwich structure were determined as Table 1 with a desirability of 0.96.

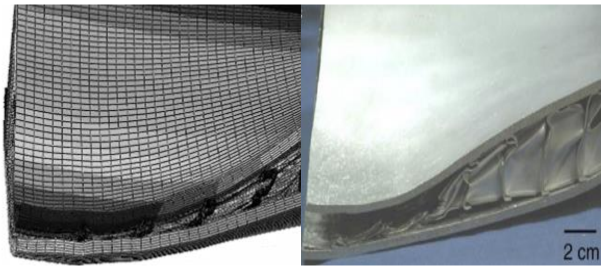

Fig. 2. Comparison between the results of experiments and the simulated model

4- Conclusions

In this paper, the dynamic plastic response of sandwich structures with honeycomb core under uniform impulsive loading was studied numerically. In the numerical section, in order to reduce the computations, a Three-Dimensional (3D) quarter symmetry model was generated due to the symmetry of the problem. The CONWEP model was used to exert pressure and shock of the uniform impulsive loading. Also, Johnson-Cook plasticity material model was applied to model behavior of metallic materials, with its damage criterion. The design-expert software was used to analyze the results obtained from numerical simulations. In order to examine the significance of the regression models from the software, the confidence level was considered 95%, which means that if the p-value for the model is less than 0.05, then the considered model is meaningful. Using the variance analysis of the numerical values of the coefficients of variables, p-value, as well as R2 and Radj2 were obtained. A comparison of numerical simulation results with the corresponding experimental results showed that the simulated numerical model has very good accuracy. Regarding the high correlation coefficient (R2=0.99) obtained from the response surface methodology method, it can be concluded that the results of the regression model are very consistent with the experimental results related to the deformation of the front and back face sheets of the sandwich structure under the impulsive loading. Also, the results of optimization of the studied parameters showed that the sandwich structure with the highest resistance should have 3.82 mm thick face seven webs in the core, a honeycomb core with a thickness of 0.8 mm and a charge mass of 0.5 kg.

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