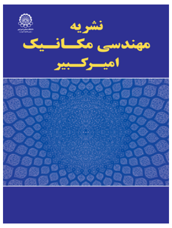

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Experimental and Numerical Investigation into the Effect of Core Density on the Energy Absorption of Sandwich Panels with Aluminum Face Sheets and Polyurethane Foam Core

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ABSTRACT: Sandwich panels with metallic face-sheets and foam core are of great importance in aerospace, naval and automotive industries due to high strength to weight ratio and high energy absorption characteristics. In this article, several aluminum sandwich panels with polyurethane foam core with different densities were designed and tested using a shock tube facility. Some of blast tests were defined in order to determine the effects of foam density on the back face-sheet displacement and energy absorption of sandwich structures. Also using the results of compression test performed on different foams, numerical simulation using Autodyn software was performed. There was a good agreement between experimental investigation and numerical results. The results show that increasing foam density can lead to reducing the back face-sheet displacement of the sandwich panel, but the energy absorption of the panel also decreases. Moreover, increasing the density of the foam, in addition to reducing the shape of the back face of the panel, leads to more uniform profile. So, if the sandwich panel is the main structure, it is advisable to use high-density foam, but if the panel is to be installed as an absorber structure on another structure, lower density foam should be used to reduce the pressure transferred to the back face of the panel. Also, the results show that the changes of the back face-sheet displacement versus impulse are linear and increasing impulse can lead to increasing the energy absorption of the core and decreasing the energy absorption of the face-sheets.

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1- Introduction

In the early 20th century, sandwich structures made from metal or Fiber Reinforced Polymer (FRP) skins separated by a core have broad significant applications in different industries, such as aerospace, building, naval, automobile, sporting goods, etc. [1]. This could be due to their attractive properties in terms of high strength and stiffness to weight ratios, aerodynamic smoothness, low thermal conductivity, impressive acoustic insulation, ease of manufacture and design ability in comparison to other structural materials. For blast loading experiments, the properties help in scattering the impulse transferred to the panel and therefore protect anything placed behind it. It is worth mentioning that the characteristic stress-strain curve of the low-density foam core controls the amount of blast energy transferred to the structure under compression. The change of the equivalent stiffness and mass of the sandwich panel play vital roles in the dynamic response of the structure while changing the core properties. Thus, it is important for engineers to find the best core configuration. Over the past few years, stepwise graded materials in which the properties of material change layer-by-layer or gradually within the material itself have been used as a core in sandwich panels. Due to design and control of the layered/graded core structure properties, these materials represent great potential to consider as an effective core materials in energy absorption systems to absorb the blast energy and improve the overall performance and blast resistance of sandwich panels where the face sheets or skins are designed for carrying the bending load and the core carries the shear load [2]. The Review of literature shows that there is a research gap in the investigations on the effects of polyurethane foam density (as the core of sandwich panels) on the sandwich panel behavior against the explosive loading. In this study, some sandwich panels with aluminum sheets and polyurethane foam cores with different densities are prepared. Then some explosive tests using shock-tube were defined and based on the experimental and numerical results, effect of foam density on the displacement of the backward surface and amount of the absorbed energy is studied.

2- Methodology

The explosive material used for explosive experimental tests is C4. The amount of explosive material in all tests was 4 g. An electric detonator was used for explosion. In this study, aluminum face-sheets and polyurethane foam core were used for manufacturing sandwich panels (Fig. 1). Aluminum face-sheets for sandwich panel samples were selected from the 6061-T6 series and had 1 mm thickness. For each sandwich panel, a circular plate of 154 mm in diameter for the front surface and a square plate of 250mm×250 mm were provided for the back panel. The core of the sandwich panels was also made of closed-cell polyurethane foam with densities of 4%, 8% and 12%. The core thickness of all panels is considered to be equal to 30 mm.

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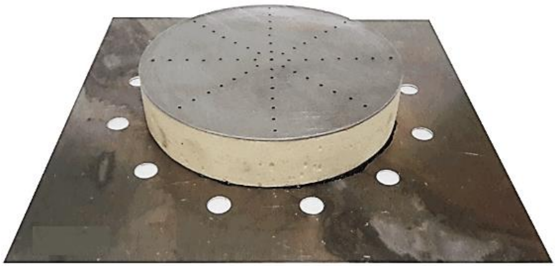

Fig. 1. An isometric view of a sandwich panel sample

Fig. 2. A view of the shock-tube

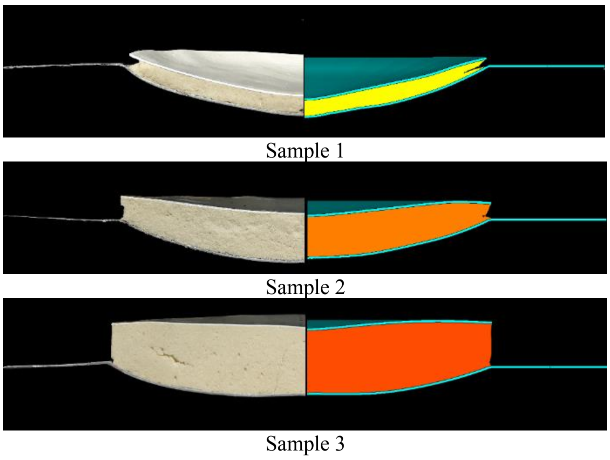

Fig. 3. Comparison of the cross-sectional area of experimental samples with numerical simulation models

In this study, an explosive shock tube device was used to create the explosive loading (Fig. 6). The specimens are fastened to the shock-tube opening by means of fixtures and screws so that the boundary conditions are fully clamped at the back edges of the sandwich structure. The explosive material is also placed behind the shock-tube using a Teflon holder.

The numerical simulation of the problem is made using ANSYS Autodyn software. Correct selection of the material model and the equation of state, as well as the correct application

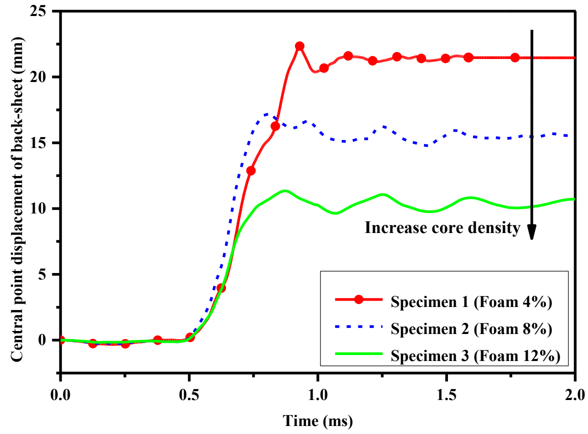

Fig. 4. Time history of backward displacement of structures intended to investigate the effect of the core density

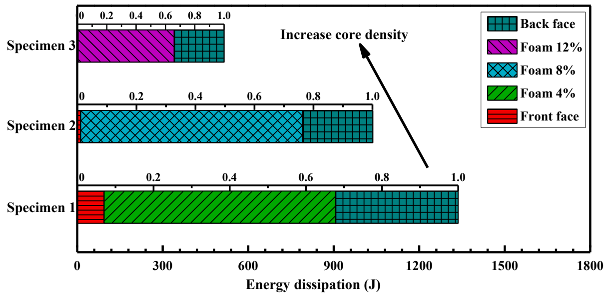

Fig. 5. The amount of energy absorbed in the components of structures to investigate the effect of the core density

of the physical conditions of the problem, such as boundary conditions, and the use of contact surfaces and elements appropriate to the type of problem, allow the correct simulation to be performed.

3- Results and Discussion

In order to check the correlation between the numerical and experimental results in terms of deformation modes, the crosscut deformation profiles for all sandwich panels with different configurations obtained from numerical simulations were compared to the experiments and are illustrated in Fig. 3. As shown in Fig. 3, there is good agreement between the numerical and experimental results.

Fig. 4 shows the timing history of the back-displacement of the desired sandwich panels. As can be seen, as the density of the core increases, both the maximum amount of displacement and residual displacement of the back surface decrease. For example, the maximum displacement and rear displacement of the sandwich panel 3 are both about 49 percent lower than the corresponding values for the sandwich panel 1. Also, as seen in this figure, the oscillations of the surfaces increase with increasing core density, which is due to the increase in the foam modulus of elasticity and its damping effect.

Fig. 5 reports the amount of energy absorbed in the components of the investigated panels. According to the figure, as the density of the cores increases, the amount of energy absorbed by the face-sheets and cores decreases, as well as the total amount of energy absorbed. The results show that by increasing foam density, the back-surface displacement decreases due to the increased flexural rigidity of the foam (and thus the panel), while the same density reduces the foam porosity and its ability to absorb the energy of the blasting.

4- Conclusions

In this paper, by defining a number of explosive tests on some sandwich panels with aluminum face-sheets and polyurethane foam cores, the effect of foam density on the of displacement of the back surface of the sandwich panels, has been studied. Also, the mechanical properties of the foam have been extracted using axial pressure tests on the foam and numerical parametric studies have been done which show that the numerical results are in good agreement with the experimental data. Using numerical simulations, the energy absorption in the sandwich panels was calculated. The results are as follows:

1. The polyurethane foam core has a significant effect on the amount of back face-sheet displacement and energy absorption.

2. Increasing the density of the polyurethane foam core in the sandwich structure reduces the maximum displacement of the back face-sheet, but also decreases the amount of absorbed energy. This indicates that if the sandwich panel is used as the main structure, increasing the density will be positive, but if the panel is to be installed as an absorber on the main structure and play as a sacrificial structure role, it would be better to use lower density foams. If it is necessary to balance the goals (displacement of the back face-sheets and energy absorption), polyurethane foam with a density of 8.3% is the best choice.

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