The Biennial International Conference on Experimental Solid Mechanics
(X-Mech 2016)
16-17 Feb., 2016, Tehran, Iran

IUST

Center of Excellence in Experimental Solid Mechanics and Dynamics,
School of Mechanical Engineering, Iran University of Science and Technology

An experimental investigation on energy absorption behavior of thin-walled aluminum semispherical shells with and without foam

Mahmoud Shariati[1], Sara Nazarian[2], Elahe Sanati[3], Alireza shariati[4]
[1]Professor, Ferdowsi University of Mashhad, Faculty of Engineering, Mechanical Department; Tel: 05138805159,
[2]BSc student, Ferdowsi University of Mashhad, Faculty of Engineering, Mechanical Department;
[3]BSc student, Ferdowsi University of Mashhad, Faculty of Engineering, Mechanical Department; [3]BSc student, Ferdowsi University of Mashhad, Faculty of Engineering, Mechanical Department;

*(corresponding author: mshariati44@um.ac.ir)

***Abstract-* Thin-walled structural shell specimens such as cylindrical, conical and semispherical shells are commonly used as energy absorbing elements in crashworthiness applications. The load–deformation characteristics of energy-absorbing devices are a measure of their energy absorbing capacities, and they differ from one component to the other depending upon the mode of deformation and the material used. In this paper some hemispherical thin-walled aluminum shells is made by spinning metal forming process. Then some of them filled by a very light polymeric foam to increase their energy absorption capability. The specimens were tested under compression test between two flat parallel rigid plates under quasi-static loading. Results show that aluminum when filled by polymeric foam, their energy absorption capability is increased particularly.**

Keywords - energy absorption, thin-walled structures, aluminum semispherical shells, foam.

I. INTRODUCTION

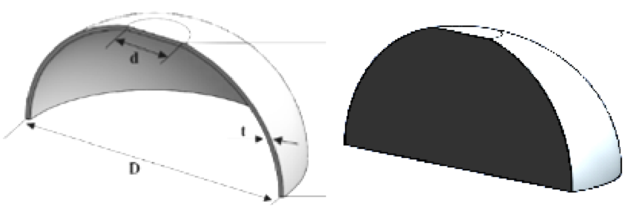
Thin-walled semi-spherical shells are often used in structures due to their energy absorbing capacity. The buckling behavior of this shells gives rise to their critical design application, including the automobile bodies, aircraft fuselages, and ship hulls. In practice, thin-walled structures have been widely adopted as main energy absorber for crashing protection attributable to their high stiffness–weight ratio, deformation pattern and energy absorption capacity. Shariati and Allahbakhsh [1] carried out an experimental and numerical study on the behavior of semi-spherical specimens under quasi-static loading with different compressive jaws. Parsapour [2] showed that increasing the number of cells increases the absorbed energy. Increasing the thickness of the quasi-hemi sphere sample in smaller diameter specimens is more effective. It was reported that foam density is of considerable influence on energy absorption of various thin-wall tubes [3]. In general, the higher the cellular or foam density, the higher the energy absorption. At the same time, various researchers attempted to increase the energy absorption of thin-walled tubes by using fillers [4–5].

This study aims to experimentally investigate the high-energy absorption of shells. The amount of energy absorbed is a function of the method of application of loads, transmission rates, deformation or displacement patterns, and material properties. Tests were performed using a Zwick/Roell servo-hydraulic machine.

II. EXPERIMENTAL TESTS

a. *Samples specification*

In this study, thin-walled semi-spherical shells with and without foam. Fig.1 and TABLE. 1 shows the geometry of the specimens. According to Fig. 1, parameters (D, d, t, h) show the upper diameter, lower diameter, thickness, and height of the semi-spherical shells, respectively. Specimens that were shown in Fig. 2 and TABLE 2, were nominated foams.



(a) (b)

Fig. 1: Cut view of specimens. (a) Aluminum semi sphere. (b) Aluminum semi sphere with foam.

TABLE 1: SPECIMEN DIMENSION.

Semi-sphere-AL	D102,5-d25-h52,7-t0,9mm

Fig. 2: deformations level of foam specimen.

TABLE 2 : DIMENSION OF FOAM SPECIMENS.

Foam specimens	Diameter	Height
P1	82 mm	33 mm

b. *Material properties*

The mechanical properties were determined according to the ASTM E8 standard. Figs. 3 shows the force-displacement curve and foams specimen. Based on the linear portion of the stress–strain curve, it was computed as E=70 GPa and σ=96.47 MPa for aluminum.

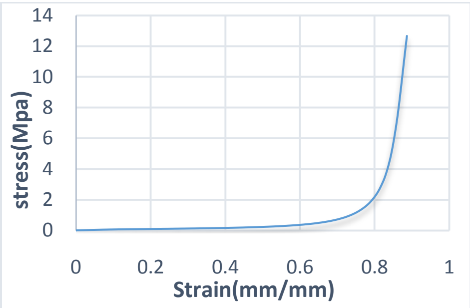


Fig. 3 : stress-strain curve of Polymer foam specimen.

c. *Investigated parameters*

Parameters which are used for comparison and could be obtained from load-displacement curve are as follow.

Maximum crushing load – maximum crushing load, P_{max}, is the maximum force during loading process and often occurs at the initial stage of loading when the first folding happens. This parameter is important in optimum design of energy absorbers and attempt is to reduce its value.

Total absorbed energy – this parameter shows the total energy consumed during structure deformation and is equal to area under load–displacement curve which is obtained from the following equation:

$$E_{absorbed} = \int P d\delta \quad (1)$$

Where P and δ are crushing load and crushing distance, respectively.

Average crushing load – average load, P_m, is obtained by dividing the measured absorbed energy to the total crushing distance δ_t:

$$P_m = \frac{1}{\delta_t} \int P d\delta \quad (2)$$

Crush force efficiency – this parameter, CFE, is used to compare efficiencies of energy absorbers and is defined as the ratio of average/maximum crushing loads:

$$CFE = \frac{P_m}{P_{max}} \quad (3)$$

Specific absorbed energy – this parameter, SAE, is absorbed energy, $E_{absorbed}$, per unit mass of structure, M:

$$SAE = \frac{E_{absorbed}}{M} \quad (4)$$

III. DISCUSSION

In this paper, the energy absorption behavior of hemi-sphere thin-walled structures under quasi-static loading was studied by experimental tests. Also Table. 3 was computed all of parameters, and it was compared together. Fig. 4 were demonstrated force-displacement curves of two codes. In addition Fig. 5 is shown deformations steps of sample.

Semi sphere	M (gr)	P_{max}	$E_{absorbed}$(J)	P_m	CFE	SAE
AL with foam	110.1	13.4	383.1890	10.36	0.77	3.48
AL without foam	40.8	10.5	250.8999	6.81	0.65	6.15

TABLE 3 : RESULT OF SPECIMENS.

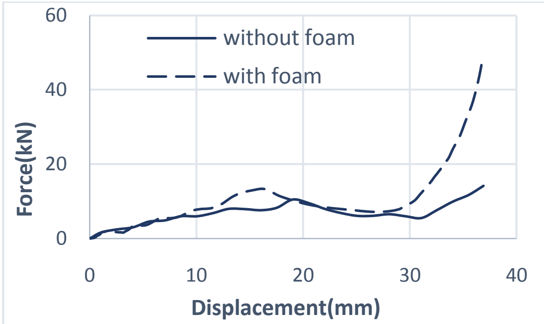


Fig. 4: comparing force-displacement behavior of aluminum semi sphere with and without foam.

Fig. 5: Deformations step of specimen.

IV. CONCLUSION

Results show that changing aluminum semi sphere into aluminum semi sphere with foam, were increased the number of maximum crushing load, total absorbed energy, average crushing load and crush force efficiency. But it decrease specific absorbed energy %41, because of increasing weight.

V. REFERENCES

1- Shariati, M. and Allahbakhsh, H., Numerical and experimental investigations on the buckling of steel semi-spherical shells under various loadings, *Thin-Walled Structures*, Vol. 48, No.8, (2010), 620-628.

2- Parsapour, M. Experimental and Numerical Studies on the Energy Absorption Characteristics of Simple and Multi-cell Shapes of Quasi-hemisphere Thin-walled Structures, *International Journal of Engineering*, Vol. 27, No. 8, (2014), 1307-1316.

3- Sun GY, Li GY, Hou SJ, Zhou SW, Li W, Li Q. Crashworthiness design for functionally graded foam filled thin-walled structures. Mater Sci Eng A 2010; 527:1911–9.

4- A. Ghamarian, H. R. Zarei, M. A. Farsi, N. Ariaeifar, Crashworthiness investigation of the empty and foam-filled conical tube with shallow spherical caps, Strain49 (2013) 199–211.

5- H.R. Zarei, A. Ghamarian, Experimental and numerical crashworthiness investigation of empty and foam-filled thin-walled circular tubes with shallow spherical caps, Exp. Mech. 54 (2014) 115–126.