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Production of aluminum foam sandwich with various geometric shapes and investigation of their compressive properties

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In this study, various sandwich foam structures manufactured from Al/Si7 foams, by using powder metallurgy route, have been investigated. For production of Al foam, 1%wt foaming agent (TiH_2) and 7%wt Si powders were added to Al powders and mixed. Mixed powders were compacted, sintered, extruded and rolled to produce foamable precursor samples. Then these samples were applied to the foaming process to produce spherical, cylindrical and rectangular samples. Sandwich structures were produced by placing of foamable precursors in between the Al sheets and then compression test was performed. The results obtained indicate that, dimensional limitation can be overcome by using PM route. However, compressive properties and energy absorption of spherical and cylindrical layered sandwich structures were found to be lower compared to traditional sandwich foam structure.

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1. Introduction

The demand for light but high strength materials in industry is increasing ever day. Researchers are investigating materials having those properties for structural applications. Metallic foams are important materials since they providing both light weight and high strength together [1, 2]. Particularly, the developing of structural stability and production methods increases interest to aluminum sandwich foam. Aluminum sandwich foams are produced material as a result of the combination of metal plate and metallic foam. These materials include specific features such as low specific density, high impact strength, acoustic and thermal insulation. Accordingly, they have a particular importance for structural application [3, 4]. Use of such sandwich panels has been proposed for many industrial sectors including automotive, railway and aircraft industry [5-7]. Many companies perform application at commercial dimension to produce metallic foam with the method of powder metallurgy (PM). However, not being able to produce confidingly second product having the same quality makes the studies ineffective. In spite of this, it is possible to produce large quantities of aluminum sandwich foams with various applications [8]. In this study, it is predicted about overcoming dimensional limitation over production management with aluminum foam parts having different geometrical shapes and compressive strength and energy damping capacities were compared.

2. Experimental studies

2.1. Production of sandwich foams

Production of sandwich foam for the present study was carried out in two stages. The first one is the production of different geometric shapes foams by PM method and the second one is the combination of foams with plates. In the first stage, 1%wt foaming agent (TiH_2) and 7%wt Si powders were added to Al powders and mixed for 30 min in three dimensional mixer. Mixed powders were compacted at 600 MPa pressure in a die to produce PM block samples. These samples were pre-sintered to achieve a more intense structure and to facilitate extrusion process at the temperature of 550 ^oC for 180 min. The extrusion process was carried out at 450 ^oC before rolling in order to produce foamable precursor samples. Then samples were cut into various sizes to produce spherical, cylindrical and rectangular samples. The cut samples were placed into molds shown schematically in Fig. 1 and were applied to the foaming process to the temperature of 710 ^oC. Some basic data of such materials are summarized in Table 1.

Table 1. Basic data of powder materials.

Powders	Suppliers	Particle size (μm)	Purity (%)
Al	Ecka Granules	<160	99
TiH_2	Sigma-Aldrich	<44	98
Si	Atlantic Equipment Engineers	<10	99,9

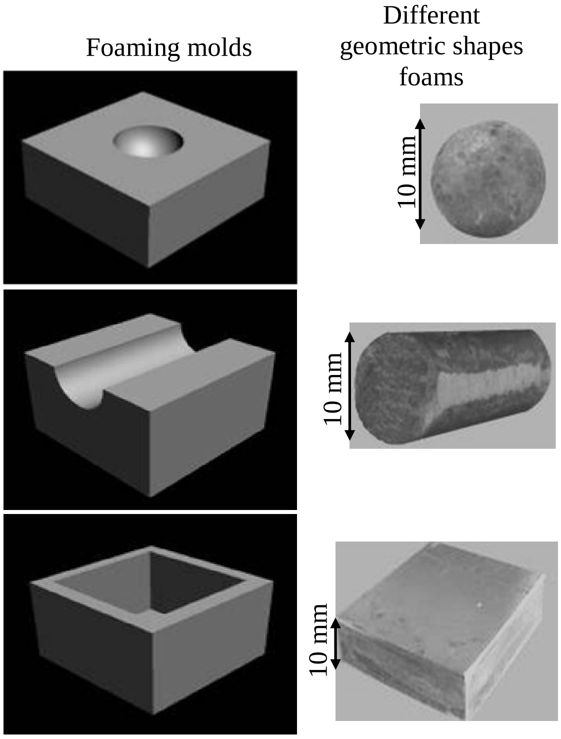

Fig. 1. Foaming molds and foam samples.

Spherical-shaped aluminum foam samples were obtained by means of free-form foaming in previous studies. The precusor samples were put into spherical shape using the surface tension in the foaming process. However, the samples are not exactly spherical as a result of the melting foam which is deformed due to the effect of gravity [9, 10]. This problem was solved with the foaming process in the mold shown schematically in Fig. 1. Thus, the foams with more spherical shapes were obtained and the size control could be done easily. In addition, the surface roughness was found to be lower than that of the free-foaming. In this way, the notch effect can be reduced during the deformation (Fig. 2). The production of complex-shaped foams is possible through PM [11]. However, the production of large-scale structures is very difficult. Thus, the production of large size sandwich structures is also difficult by PM route. Spherical and cylindrical-shaped foams were utilized for the solution of this problem.

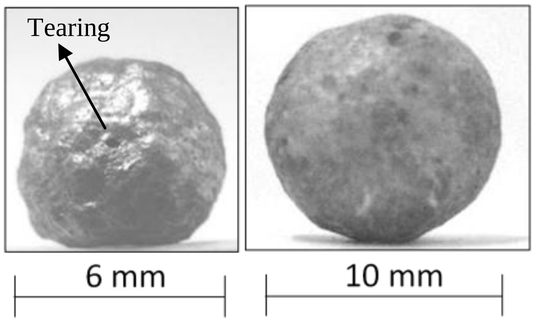

Fig. 2. The appearance of spherical Al foams produced with free form and in a spherical mold.

In the second stage, the produced foams were placed between the sheets with 2 mm in thickness and bonded. Loctite Al-1 type epoxy resin and hardener were used for the bonding process. Resin and hardener were mixed in a 1:1 ratio for a period of about 1 hour and then applied to the surfaces of aluminum plates. The sandwich foam structures produced in the current study with various geometric shapes layers with dimensions of 40×40×14 mm^3 is shown in Fig. 3.

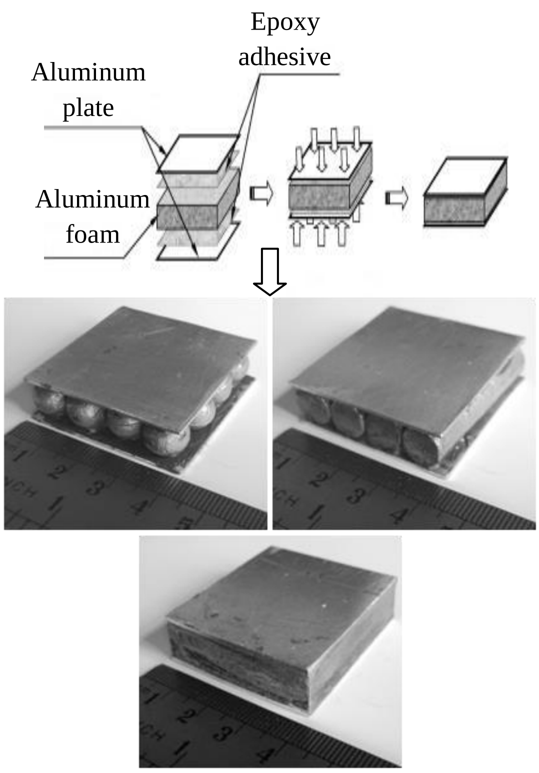

Fig. 3. Sandwich structures with different geometric layers.

3. Results of compression test and discussion

Compression tests of samples were made using Instron 3369 test machine. Deformation control was obtained with a loading rate of 2 mm/min. The average stress-strain curves of sandwich structures are given in Fig. 4. As seen in the graph all samples exhibited similar slopes. Every three foam sandwich structure during the deformation exhibited linear elastic behavior below the yield point of the foam. In this region the yield strengths of spherical, cylindrical, and the traditional sandwich structures were determined as 6 MPa, 8 MPa and 22 MPa respectively. The gradual deformation behavior of sandwich foams under the compressive strength is shown in Fig. 5. The response area of the foam against the applied force consists of a single point in the sandwich structure with spherical layer, but the response area increased with increasing force. Whereas the applied force was absorbed by a wider area in normal sandwich structure which caused the yield strength of the traditional sandwich structures to be more than spherical and cylindrical-layered sandwich structures. Stöber et al investigated the mechanic properties of aluminum foam-polymer hybrid structures and emphasized the similar results [12]. There were some cracks thought to be caused by strain hardening the outer surface of the foam with the increase in the rate of deformation. The structure was increasingly concentrated as a result of the folding of the pore walls over one another and this decreased capacity of energy absorption.

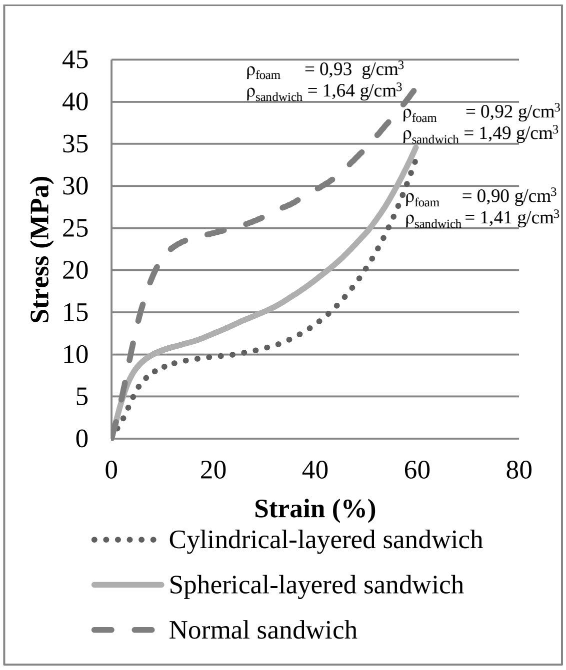

Fig. 4. Average stress-strain curves of sandwich structures.

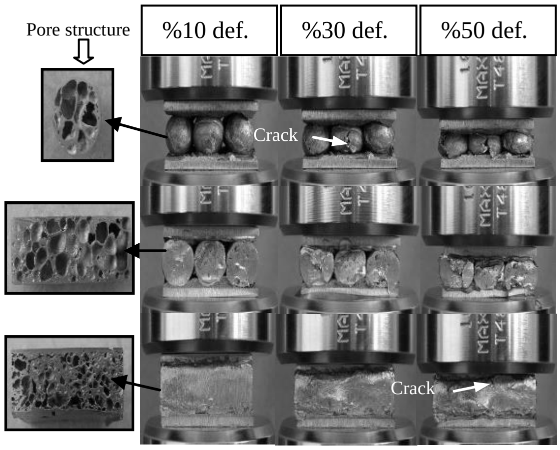

Fig. 5. The gradual deformation behavior of sandwich structures.

The plane of the curve was determined by the average slope line adding to stress - strain curves in the diagram of Fig. 4. The integral of the compression strength was taken according to the strain range by making use of these planes and the area under the curve was calculated. Thus, the energy absorption rates of the sandwich structures were determined (Fig. 6). It was observed that the energy absorption capacity of traditional sandwich structures was higher than the other structures. This ratio in total energy change was 57% and 42% higher than those of spherical and cylindrical-layered sandwich structures respectively. The energy absorption capacity was increased depending on the relative density and yield strength [13].

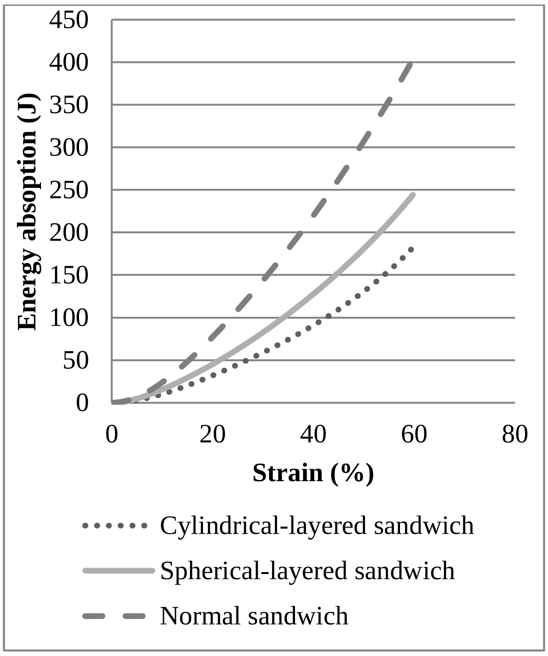

Fig. 6. Energy absorption-strain curves of sandwich structures.

4. Conclusion

In this study, sandwich foam structures with different geometric shapes were produced by using PM method. The easy of production and compressive properties of sandwich foam structures were discussed. Accordingly, dimensional limitations of the manufacturing process (for the production of large sandwich structures) can be overcome with spherical and cylindrical-layered sandwich structures. However, the compressive strength was found to be lower than the traditional sandwich structures because the contact points between the plates with the foams at the beginning and continuation of the deformation were different. Moreover, this situation was due to the difference in density. The total amount of energy absorption of the traditional sandwich structures was 57% and 42% higher than those of spherical and cylindrical-layered sandwich structures respectively.

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