Investigation of the Effect of Pore Size on Mechanical Properties of Open Cell Aluminium Foam Structure

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***Abstract*— *Al foams with different pore size were developed through infiltration process by foundry technology and characterization of the developed Al foams for their density, porosity and compression strength. Al foams were produced through infiltration process by open metal die casting using soil granules of different diameter as space holder particles (SHP). The SHP balls were removed from the Al foam by water jet along with vibration. The density and porosity were measured by theoretically and experimentally. The compression tests were conducted on developed Al foams of different densities using universal testing machine. Developed Al foam density varies from 0.9g/cc to 1.2g/cc, the porosity varies from 54% to 65% and compressive behaviour showed the plateaus stress was directly proportional to SHP ball size in Al foams.*

***Keywords*— Al foam, compressive strength, density, SHP and porosity.**

I. INTRODUCTION

Aluminium foam structures are high specific strength porous solids which have a highly complex interconnecting microstructure and are large deformation materials. The properties of foamed and highly porous metals are of interest both for practical applications and for the study of the fundamental behaviour of the class of materials as a whole. Many methods exist for the production of metallic-foams [1,2]. Foam materials engage research interest because they are hybrid in structure and behaviour, not exclusively solids, liquids, or gases. These materials have a solid or liquid cellular structure that entraps a gas within it, therefore they exhibit properties and characteristics of multiple states of matter [3].

Foams are usually produced by injecting a gas, such as air, into a material in the liquid state. The formation process can be seen in the common place nucleation and self-organization of bubbles whenever someone pours a glass of beer or brews a cappuccino [4]. The vast field of natural and man-made foam materials is divided into liquid and solid cellular materials. Solid cellular materials are further categorized as open- or closed-cell foams depending on the shape of the cells. A cellular material with cells that are completely closed, such as foams composed of hollow spherical cells, is considered closed-cell foam because the fluid trapped in each cell is restricted to that cell. In closed-cell foams, there is no fluid flow across the foam's cellular structure without breakage of the cell walls. On the other hand, open-cell foams allow fluid flow throughout the cellular structure. The cellular architecture of these open-cell foams looks like a network of small, interconnected ligaments. Many cellular solids have cellular structures in between open- and closed-cell where many of the cells show characteristics of both types [5].

Though many researches [6-8] went on the fabrication of Al foam, no research work was presented on fabrication of Al foams by gravity die casting, prediction of density and porosity with SHP ball size. So, the aim of this project was to fabricate the aluminium foams through infiltration process by gravity metal die casting technology, characterization of Al foam for its density and porosity and testing of Al foams for compressive behavior.

II. EXPERIMENTAL STUDY

Al 6061 alloy was selected as a material for foams, Al is known for its low density, ductility and thermal conductivity. Due to these interesting properties they have been used in wide variety of applications. Chemical Composition of Al 6061 alloy is given in TABLE.1 and has a conductivity of 218 W/m K.

The aluminium foams production was carried out by considering the pore sizes of 6, 8 and 10 mm diameter. Poly vinyl alcohol powder of 4 grams is mixed in 50 ml of water then heated till the PVA powder get completely dissolved in water. 100 gram of Alumina (Al_2O_3) (1 to 5 µm) is mixed with 22 ml of PVA solution to form a dough. This dough is extruded and cut into equal parts; these are rolled in empty ball mill apparatus which results in solid spheres. The spherical shape was desirable to the regular packing of these ceramic balls in the mould. These ceramic balls were then stored in a sealed bag to prevent any loss of moisture content.

Table 1. Chemical Composition of Al6061 alloy

Mg	Si	Fe	Cu	Ti
0.92	0.76	0.28	0.22	0.10
Cr	Zn	Mn	Be	Al
0.07	0.06	0.04	0.003	Bal

Fig. 1: Steps for preparation of Aluminium foams

Green sand mould of a dimension of 100 X 95 X 30mm was prepared shown in Fig. 1(a). Mould sand was dried in room temperature for 24 hours. Pre-heating of the mould box to 500ºC, placing the solid spheres in the hot mould cavity and allowing it for 5 minutes were done as shown in Fig. 1(b).

Melting of Al 6061 alloy using muffle furnace up to 800 °C, adding degas agent into the liquid aluminium and pouring the molten aluminium (>800 ºC) in the mould cavity filled with solid spheres and cooling it were done as shown in Fig. 1(c-e). Finally the solidified casting was removed and cleaned. After removing the cast from the mould, it was then put in a water bath. The ceramic balls were removed with the aid of ultrasonic vibration. Open-cell aluminium foam was therefore obtained. After development of varying density cylindrical aluminium foam specimen, next work was to characterize them for its porosity and density, that was calculating the theoretical density and percentage porosity values and compare with that of experimental values.

For analysing the compressive behaviour of Aluminium foams we were in need of flat specimens. Then flat specimens were developed by using the required metaldies of different sizes. Compression testing on Aluminium foams was done by using ASTM C365-05 for specimen having the standard specimen size 40mm x 40mm x15mm. Compression testing on Aluminium foams was done on the universal testing machine (UTM) of 20Ton capacity and 100kg least count.

III. RESULTS AND DISCUSSION

The effect of SHP ball size on density and SHP Ball size on porosity of Al foam are shown in Fig. 2(a) and (b). Fig. 2(a) shows SHP ball size varying from 6mm to 10mm taken on X axis and density from 0.9g/cc to 1.2g/cc taken on Y axis. The observation gave good evidence that in the present investigation, the relative density is increasing with increasing pore cell size (SHP) due to variation in volume. Increase in density leads to increase in cell wall of the Al foam. Hence the decrease in porosity as shown in Fig. 2 (b).

The behaviour of the compressive stress and strain of Al foam is as shown in Fig. 3 and 4. The main feature of the stress-strain response during loading condition is that the foam exhibits three distinct regimes such as an elastic regime at beginning of the compression, followed by a long stress-strain nearly plateau during the localised collapse due to plasticity of each cell [9-10]. The layer by layer foam cells are collapsed during this regime. After all foam cells are collapsed, this will lead to the densification of the foam and finally act as a solid structure. Finally a rapid rise in stress along with the compressive strain could be seen.

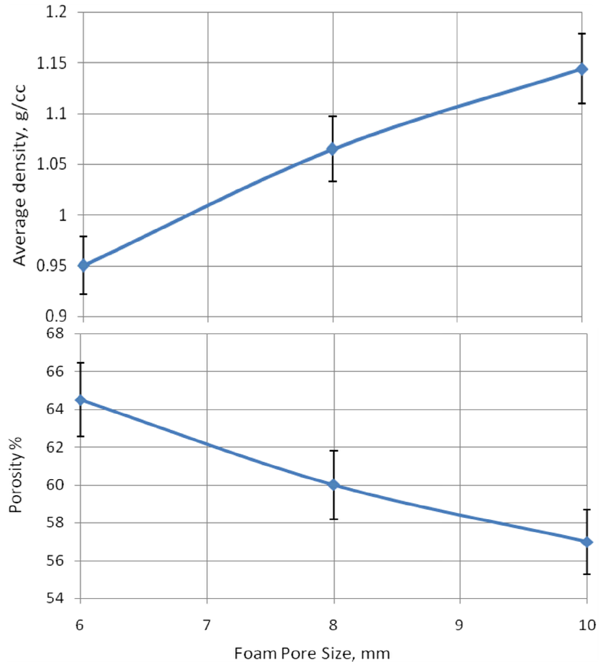

Fig.2 Effect of SHP diameter on a) average density and (b) porosity of the Al foam

From the Fig.3 that plateau load and plateau stress are increasing with size of SHP Ball. It means that Al foam with SHP of size 10mm is taking more load to cross the plateau region. All the Al foam specimens have their own characteristics and finally it depends on the applications where we want to use the metal foam. But in other hand the % strain decrease with increasing the foam pore size.

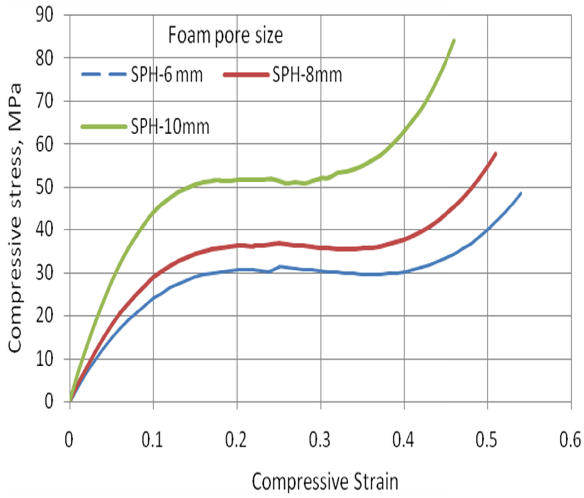

Fig.3 Compressive stress strain behaviour of different foam pore size of the Al foam materials

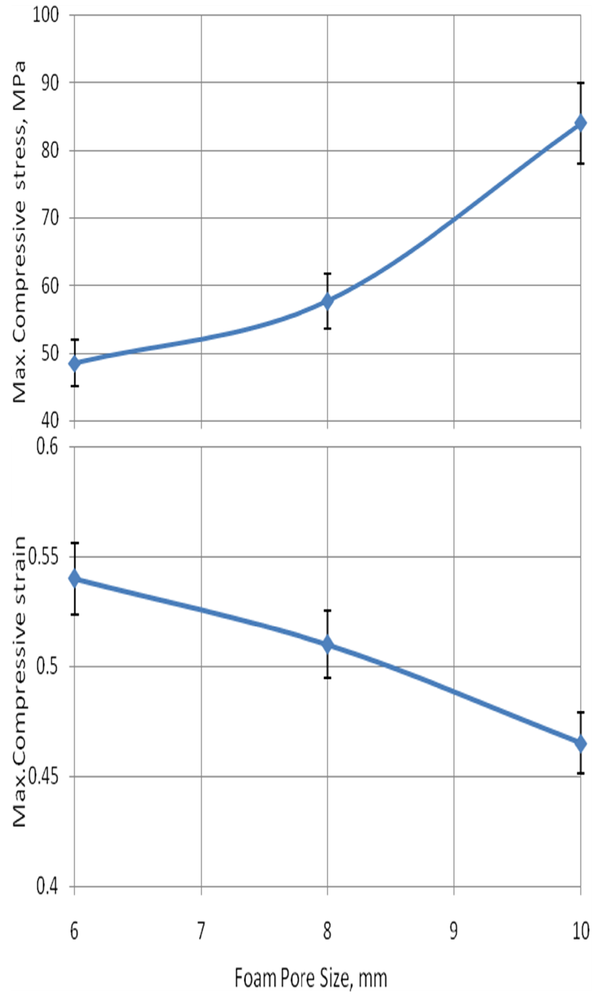

Fig.4 Effect of SHP diameter on Maximum (a) Compressive stress and (b) Compressive strain of the Al foam materials

IV. CONCLUSIONS

Different density Al foams were developed and tested for physical and compressive properties. Characterization of Al foams showed that density was directly proportional to SHP ball size and it was varied from 0.9 to 1.2 g/cc. Al foam with 6 mm SHP ball was having 0.95g/cc. Characterization of Al foams showed that porosity was inversely proportional to SHP ball size and it was varied from 54% to 66%. Al foam with 6 mm SHP ball was having 64.5% porosity. Comparison between the compressive behaviour of all the three different specimens was done and it shows that plateau stress was directly proportional to SHP ball size (soil granules).

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