Evaluation of Microstructure and Compression Behaviour of Aluminium-Alloy Foams

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Abstract: *Aluminium alloy foam (AAF) is a kind of engineering material which has relatively high stiffness and strength achievable at low density. AAF was fabricated by melt route process using* TiH_2 *as a foaming agent. The fabricated AAF was characterized by Energy-dispersive X-ray (EDX), scanning electron microscope (SEM) and Material pro. The compressive deformation behaviour of AAF of varying densities and pore sizes have been studied at different strain rates (0.0001 /s to 10 /s). The result indicates that the foaming agent (*TiH_2*) is suitable for the preparation of small aperture aluminium foams with normal pore diameter in between 1 to 1.5 mm. The energy absorption characteristics of the AAF were found to be appreciable.*

Keywords: *AAF, Compression deformation, Microstructure and Strain-rate, EDX, SEM*

1. Introduction

The method of producing aluminium alloy foams has been widely studied [1-3]. These foams are a usually invented with only 2 to 20% of the density of the parent metal and yet still retain significant levels of strength and stiffness [4]. The inimitable properties of metallic foams make them desirable for an extensive variety of applications, such as thermal barriers and as a core material for sandwich structural. Aluminium alloy foams also have the potential for use in a crash absorber [5-8]. Increasing demands of regarding for passenger safety in automobiles sector and materials recycling make constructors now think of using metal foams. On the other hand, the manufacturing cost of closed cell aluminium foams (CCAFs) are lower than of open cell aluminium foam (OCAFs) and with the use of foaming agent from powder compact method, and it can be also possible to make a parts in the final shape, doesn't matter any shape and size with a dense aluminium casing on it. Recently several author reported that the aluminium foams with SiC particle showing metal matrix composite structure for improved the performance of crash absorber. During last 5 years the similar material have been ruled out for technically or economic reasons [9-10]. Nowadays several companies have recently developed processes and capable of manufacturing larger numbers of metal foams using molten metal processing systems.

Therefore, this study is aimed at determining on the energy absorption characteristics of AAF. The compression behaviour and energy absorption capacity under compressive were studied. The study shows the energy absorption capacity of AAF and made by the melt route process at Advanced Materials and Processes Research Institute (CSIR) Bhopal, India.

1.1 Aluminium Foams

LM 25+10% SiCp foam models were manufacture through the melt route method by CSIR-AMPRI Bhopal. The porosity of aluminium foam varied from 76% to 88% shows in Figure 1 and the cell sizes of aluminium foam varied from 0.8 to 1 mm. The aluminium foams with the dimension of 20x20x30 mm were prepared using a wire-cutting machine as the filling cores the data were the average value of six samples (i.e. rectangular shape).

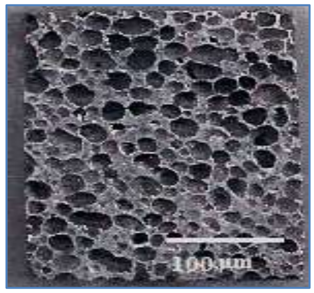


Figure 1: porosity varied from 76 to 88% of AAF

2. Material and Experimental Techniques

1.2 Sample Preparation and Pore Size

Aluminium alloys (LM25) were foamed by melt route process using metal hydride as a foaming agent and silicon carbide (SiC) as a thickening agent respectively. Titanium hydride releases hydrogen gas (H_2) when added in liquid metal. Large volume of hydrogen (H_2) gas is released, which creates bubbles that lead to foam structure. When foaming process is completed, the foam structure is cooled by compressed air. In the present study we have taken LM25 with 10wt% SiC particle foam and foam sample is cutting by using a slow speed cutter. The advantage of aluminium alloy foam becomes observable when energy absorption capacities are measured as a utility of weight in lightweight structures and relatively high stiffness.

Pore size distribution is calculated using material pro software. One face of the sample is scan and uploaded to the material pro software and calculated the pore size.

1.3 Density Measurement

The average density of the LM25+10%SiCp foam is 0.548 g/cm^3.The relative density of Al (2.7g/mm^3) alloy foam is also calculated. The average relative density of LM25+10%SiCp foam is 0.198 g/mm^3.

3. Results and Discussion

3.1 Compression Test

Compression test of LM25+10%SiCp foam is performed on a UTM machine at different strain rate (0.0001/s to 10/s) for compression test, sample of 20mm×20mm×30mm are used. Figure 2 shows the compressive-stress versus compressive-strain response of the AAF was found to be sensitive to the applied strain rate between 0.0001/s to 10/s. The plateau stresses were found to be similar with a small average increase in level for increasing strain rate.

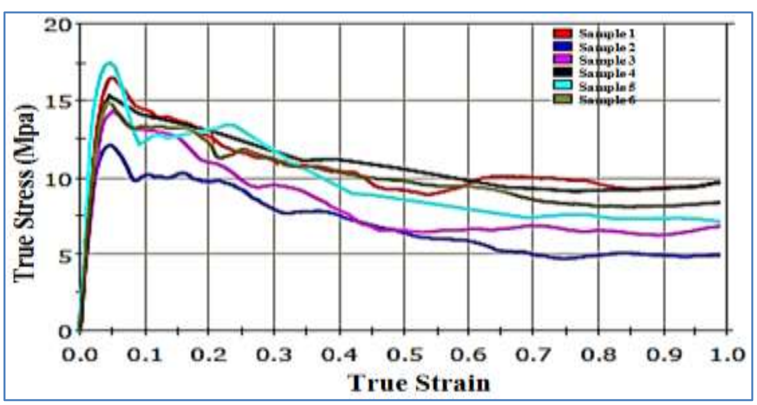


Figure 2: strain stress curve at various strain rate of AAF

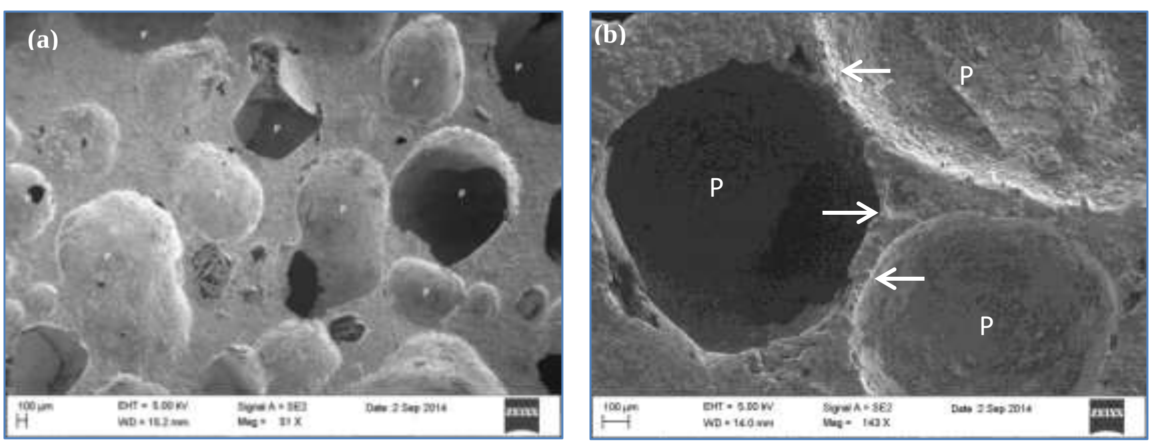
The plateau strength of the foam at 0.0001/s to 10/s, increased from 3.51 MPa for strain rates in between 0.0001/s to 6.25 MPa at 10/s. The absorbed energy ranged from 2.43 to 4.01 MJ/m^3 for strain rates in between 0.0001/s and 10/s (Table 1) respectively.

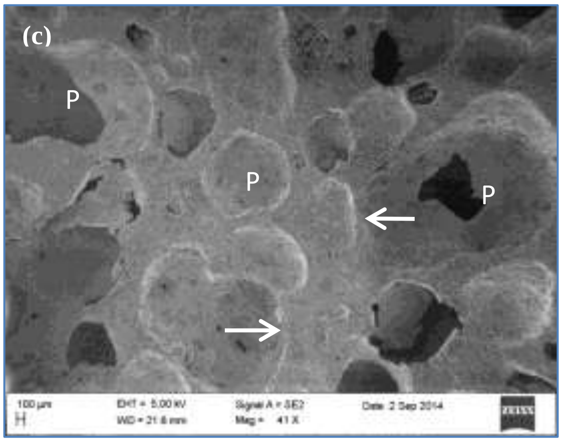
TABLE 1: Plateau stress and energy absorption with different strain rate

S.No.	Strain Rate (/sec)	Plateau Stress (Mpa)	Energy Absorption (MJ/m^3)
1	0.0001	3.51	2.43
2	0.001	3.75	2.41
3	0.01	3.38	1.76
4	0.1	3.39	3.37
5	1.0	6.25	4.07
6	10	6.25	4.01

3.2 Microstructure Characterization

Microstructure analysis, aluminium foam models is cut from top to bottom portion of the rectangular casting, prior to the microstructure analysis, the sample are mechanically polished using standard metallographic practices [5]. The metallographically polished Al foamed sample are etched with Keller's reagent, sputtered with gold shown in Figure 3 (a) and (b). The microstructure of foam samples is analysed using Scanning Electron Microscope (SEM) (Supra 55, Carl Zeiss, Germany) at ISM Laboratory. It shows the pores (marked P) and cell wall (arrow marked) and higher magnification micrographs of the cell wall shown in Figure 3 (c). The thickness of the cell wall is measured to be around 100 µm. Figure 3 (d) shows a SEM micrograph the wall thickness measured to be around 100 µm and higher magnification micrograph of cell wall clearly shows SiCp.





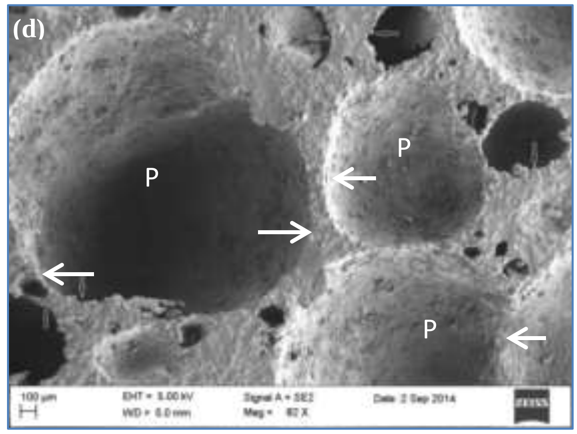


Figure 3: (a) and (b) SEM micrograph of aluminium alloy foam showing pores (c) higher magnification micrograph showing cell wall (d) higher magnification micrograph of the cell wall showing distribution of 10% SiCp in the aluminium alloy matrix.

Energy dispersive X-ray analyses (EDX) investigation was also performed on AAF with the trade name LM25. LM 25 Al-alloy (NALCO, INDIA) have chemical composition 0.15 wt.% Cu, 0.57 wt.% Mg, 0.48 wt.% C, 7.20 wt.% Si, and rest is aluminium also satisfied (Figure 4).

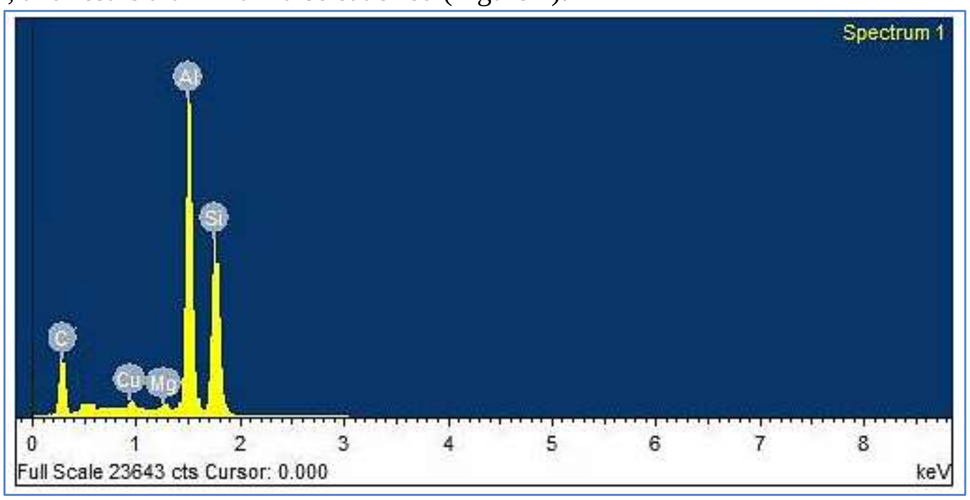


Figure 4: energy dispersive X-ray analyses (EDX) of AAF

4. Conclusion

The strength property of the AAF has been characterized and its response to quasi-static at various strain rates presented. The initial pore collapse, plateau stress, and densification regions have been defined and along with the energy absorption capacity calculated form the resultant stress strain curves. A significant influence on the strength of the AAF material when exposed to low strain rate was observed. The quasi-static loading of the AAF material showed the maximum strength increase of all situations. Based upon the study of the influence of strain rate constitutive response of AAF, the following conclusions can be

1. The compressive stress strain response of an AAF was found to depend on the applied the strain rate 0.0001 to 10/s.
2. The deformation of the AAF was found to be diverse in nature.
3. The AAF failed at 0.01/s strain rate via deformation band collapse.

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