CRIMSON PUBLISHERS
Wings to the Research

Research & Development in Material Science

ISSN: 2576-8840

Short Communication

Quasi-Statics Compressive Deformation Behavior of Aluminium Alloy ($AlSi_7Mg$) Foam under Axial Loading

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Submission: May 01, 2018; **Published:** May 11, 2018

Abstract

In this experiment, Al-Si_7Mg Al-alloy and Al-Si_7Mg Al-alloy 10wt% SiCp foams are prepared by melt stir processing route. The numerous parameters specifically cell size, cell wall, and shape of cell is found out of the square foam samples. The results concluded that the cell wall thickness is more in Al-Si_7Mg Al-alloy 10wt% SiCp foam than that of Al-Si_7Mg Al-alloy foam. It is noted from compression test curve at 0.1/s that Al-Si_7Mg Al-alloy 10wt% SiCp foam samples exits high plateau stress. Meanwhile the compression test reveals the energy absorption rate per unit volume of Al-Si_7Mg 10wt% SiCp foam is more than Al-Si_7Mg Al-alloy foam and energy absorbed efficiency is found out of Al-Si_7Mg and Al-Si_7Mg 10wt% SiCp foam. The microstructure of foam samples is characterized by field emission scanning electron microscopy. The energy absorbing test efficiency is verified using the Universal Testing Machine that works on variable strain rates. Compression is performed on 0.1/s strain rate to obtain the results.

Keywords: Energy absorption; Deformation; Relative density; Porous materials

Introduction

TIn recent years of research, aluminium foam has drawn attention towards it, due to their amazing mechanical, thermal, acoustic, electrical and physical properties. Aluminium foams are characterised for having low relative density, higher stiffness to weight ratio, high vibration and energy absorption, higher specific strength and better insulation properties. Aluminium alloy matrix syntactic foam using pressure infiltration process and studied it dynamic mechanical behaviour by SPHB system [1]. Experimental investigations on two aluminium foams, fabricated by molten body transitional foaming method, for studying the impact behaviour, deformation mechanism and energy absorption characteristics [2]. It was also inferred that during the impact, with increase in foam density there is an increase in peak load and energy absorption capacity and the compressive properties and energy absorption for aluminium foams for different cellular geometry [3]. They used two different foams, namely, uniform cell structure and dual-size cell structure foams for the research and found that the dual-size cell structure foam has enhanced stiffness and crash-energy absorption characteristics than the uniform cell structure foam. Experimented on aluminium/copper hybrid foam, fabricated from Al 6101-T6 alloy and copper deposited on the foam using electro-deposition method, and studied its behaviour during compression at high strain rate loading [4]. Aluminium alloy foam by decomposition of TiH_2 in a stabilized melt with different microstructures of cell walls, which is obtained by solutionizing and quenching prior to thermal ageing treatment [5]. The compressive behaviour of aluminium alloy syntactic foams of four metal matrix materials, Al99.5, $AlSi_{12}$, AlMgSi1 and $AlCu_5$, with hollow iron spheres as reinforcing material [6]. These four-metal matrix syntactic foams are prepared by infiltration technique assisted with low pressured inert gas. Also, aluminium foam reinforced with *in-situ* generated $MgAl_2O_4$ spinel whiskers and studied its energy absorption and compressive behaviour [7]. An investigation on expanded perlite/aluminium (EP/A_{356}) syntactic foams for dynamic loading [8] and mechanical behaviour and energy absorption efficiency of $AlSi_7$ foams for both static and dynamic loadings [9]. The results also inferred that strain rate has a great influence on foam strength when the loading is changed from static to dynamic.

The present study includes the synthesis of Al-Si_7Mg Al foam with 10wt% SiC particles by melt stir route manufacturing process and investigation on compression and energy absorption characteristics of Al-Si_7Mg Al foam with 10wt% SiC particles. The mechanical properties of the foam are calculated and also validated with the experimental data obtained and also a detailed study of the microstructure of Al-Si_7Mg Al foam with 10wt% SiC particles is conducted, for studying the pore structure and cell wall thickness of the foam. The energy absorbing test efficiency is verified using the Universal Testing Machine (UTM) that works on various strain rates. A comparative study is also conducted between Al-Si_7Mg Al foam and Al-Si_7Mg Al foam with 10wt% SiC particles for a better understanding of implicational areas of the synthesized foam.

Experimentation

The foam of Al-Si_7Mg Al alloy with 10wt% SiC particles is fabricated by melt stir processing method. Firstly, the pieces of Al-Si_7Mg alloy and SiC particles are placed in a cast iron mold, having dimensions of 80mm diameter and 120mm length. The cast iron mold is then placed inside an electrical resistance furnace for melting the materials placed in it. After the molten melt is formed, it is stirred with the help of a mechanical stirrer at a speed of 1000rpm. The SiC particles present in the melt act as thickening agents and no further addition of thickening agents. The stirring process is performed at 670-690 °C and is performed for 30 seconds. After the completion of the stirring process, the mechanical stirrer is removed from the mold for allowing the formation of foam [10,11]. Finally, the cast iron mold is removed from the furnace and cooled the foam formed with the help of compressed air. The Al-Si_7Mg Al alloy foam used for comparative study is also prepared using the same melt stir fabrication process, just by taking Al-Si_7Mg Al alloy as raw material for foam manufacturing and also by adding 10wt% SiCp for the thickening of the melt formed. 12 samples were cut in to square shape using the Electrical Discharge Machining (EDM) wire cut machine with outmost accuracy and macrostructure from the billet of each shown in Figure 1.

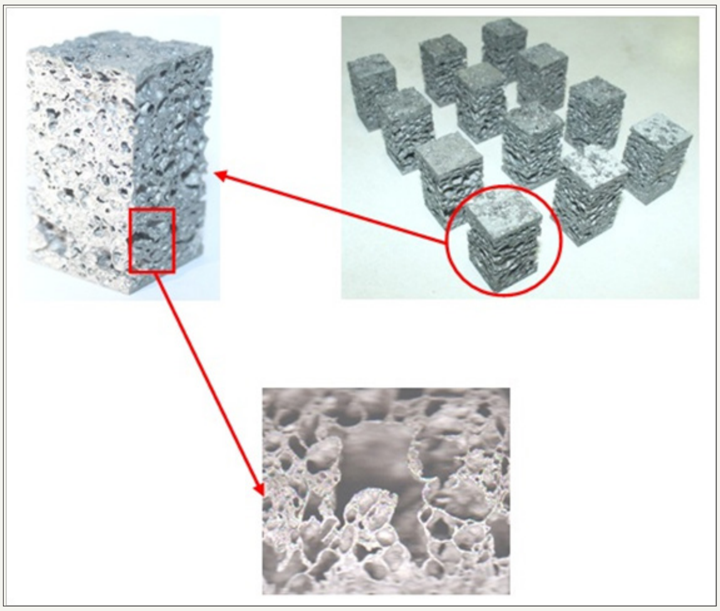

Figure 1: The macrostructure of square sample.

Results and Discussion

Micro-structure investigation

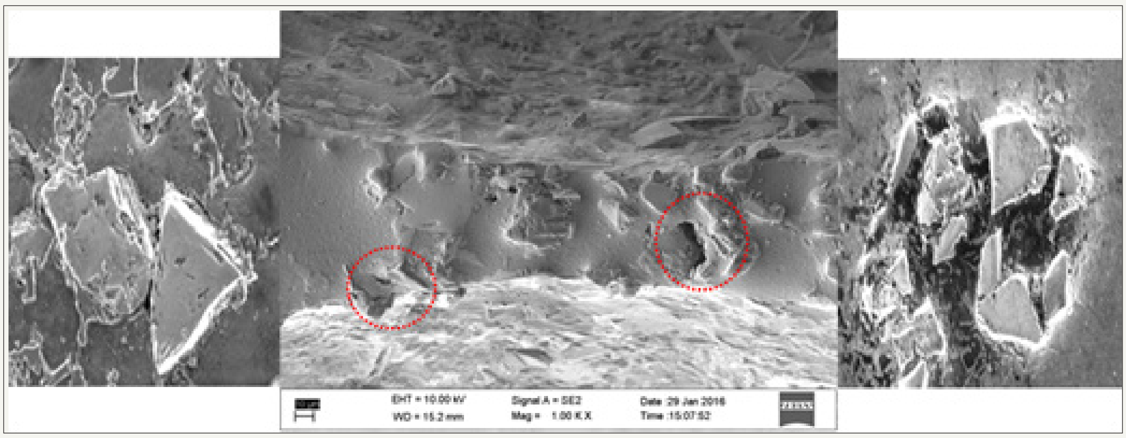

Figure 2: Al-Si_7Mg Al alloy foam with 10wt% SiC particles.

How to cite this article: Dipen K R. Quasi-Statics Compressive Deformation Behavior of Aluminium Alloy (AiSi7Mg) Foam under Axial Loading . Res Dev Material Sci . 6(1). RDMS.000628.2018. DOI: 10.31031/RDMS.2018.06.000628

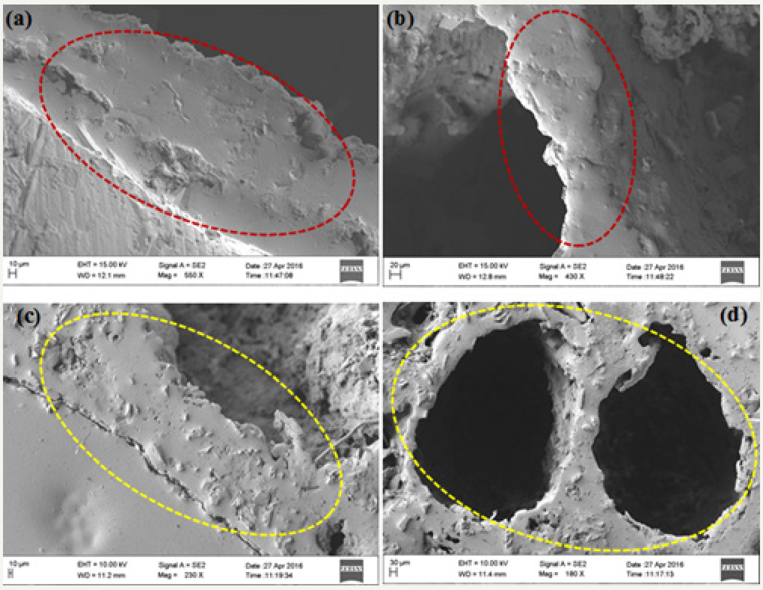

Figure 3: FE-SEM micrographs of

3a & 3b: Al-Si7Mg Al alloy foam

3c & 3d: Al-Si7Mg Al alloy foam with 10wt% SiCp.

Digital Image Analysis of Al-Si_7Mg Al alloy and with 10wt% SiC particles composite foam sample is performed for the characterization of the cell structure properties like wall thickness, cell size etc. Later the foam samples are analyzed by the Field Emission Scanning Electron Microscope (FE-SEM) at Center for Research, Indian Institute of Technology (ISM) Dhanbad, using Mean Intercept Length Method (MILM). The micrographs Al-Si_7Mg Al alloy composite foam cell wall obtained by the FE-SEM is as shown in Figure 2. The micrographs clearly illustrate the pores, cell structure and cell walls of both foams, i.e. Al-Si_7Mg Al alloy foam (Figure 3a & 3b). The thickness of cell wall of Al-Si_7Mg Al alloy composite foam is clearly 3-4 times that of the Al-Si_7Mg Al alloy foam. The increase in the cell wall thickness of Al-Si_7Mg Al alloy composite foam is due to the presence of SiC particles, as it retards the flow of melt during the stirring process. The highly magnified view of the Al-Si_7Mg Al alloy foam with 10wt% SiC particles shows the presence of SiC particles in it and is shown in Figure 3c & 3d.

The cell size distribution of both foams is a little uniform up to a maximum percentage and remaining is a mixture of cells of different sizes. It is noted that the Al-Si_7Mg Al alloy foam has a cell size of about 1-2mm, about 70% of the foam and the remaining is comprised of cells of sizes 0.5-0.8mm and 2-3mm. In the case of Al-Si_7Mg Al alloy foam with 10wt% SiC particles, it is observed that the 55% of the foam is comprised of cells having size 4-10mm, 30% have cell sizes of 2-3.5mm and remaining is comprised of cells having sizes of 0.5-1mm.

Deformation characteristics

The samples of size 30mm x 30mm x 30mm and having relative density ≥0.20 of Al-Si_7Mg Al alloy foam and sample size: 30mm x 30mm x 30mm having relative density ≤0.20 of Al-Si_7Mg Al alloy with 10wt% SiCp composite foam, were used for compression testing. While the sample preparation, precautions were taken so that each surface in linear direction should accommodate at least seven cells. The density of Al-Si_7Mg Al alloy foam and with 10wt% SiCp composite foam is found out by mass and volume measurement. The test for determining the deformation characteristics and energy absorption of Al-Si_7Mg Al alloy foam with 10wt% SiC particles and Al-Si_7Mg Al alloy foam are performed on UTM at Indian Institute of Technology, Bombay, at a strain rate of 0.1/s. The stress-strain curves developed using the obtained experimental data is utilised for predicting the yield stress, plateau stress and densification strain of both foams. The data obtained from the deformation tests is used for the determination of stress-strain characteristics of Al-Si_7Mg Al alloy foam and Al-Si_7Mg Al alloy foam with 10wt% SiC particles. The deformation behaviour of foams, i.e. Al-Si_7Mg Al alloy foam with 10wt% SiC particles are as shown in Figure 4. The stress-strain curves of both foams, i.e. Al-Si_7Mg Al alloy foam with 10wt% SiC particles and Al-Si_7Mg Al alloy foam, are as shown in Figure 5a & 5b and 30% deformation after compression test (Figure 5c). Also, clearly show three distinct regions of deformation, namely linear plastic region, plateau region and densification region. The stress-strain curves of the foams clearly show that the plateau stress of Al-Si_7Mg Al alloy composite foam is higher than that of Al-Si_7Mg Al alloy foam, in turn indicates that the energy absorption capacity is higher for Al-Si_7Mg Al alloy composite foam. The data indicates that the plateau stress of the Al-Si_7Mg Al alloy composite foam is 3.5 times that of the ordinary Al-Si_7Mg Al alloy foam. The maximum plateau stress of Al-Si_7Mg Al alloy composite foam is 7.50MPa and the maximum plateau stress of ordinary Al-Si_7Mg Al alloy foam is 2.60MPa respectively. The presence of SiC particles in the composite foam altered and enhanced the properties of cell wall and pore size and also changed the failure mechanism of the foam.

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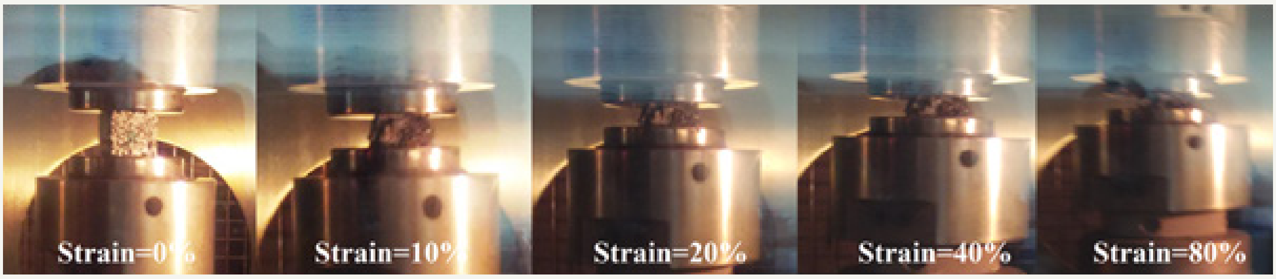

Figure 4: Deformation mechanise of Al-Si7Mg Al alloy foam with 10wt% SiC particles.

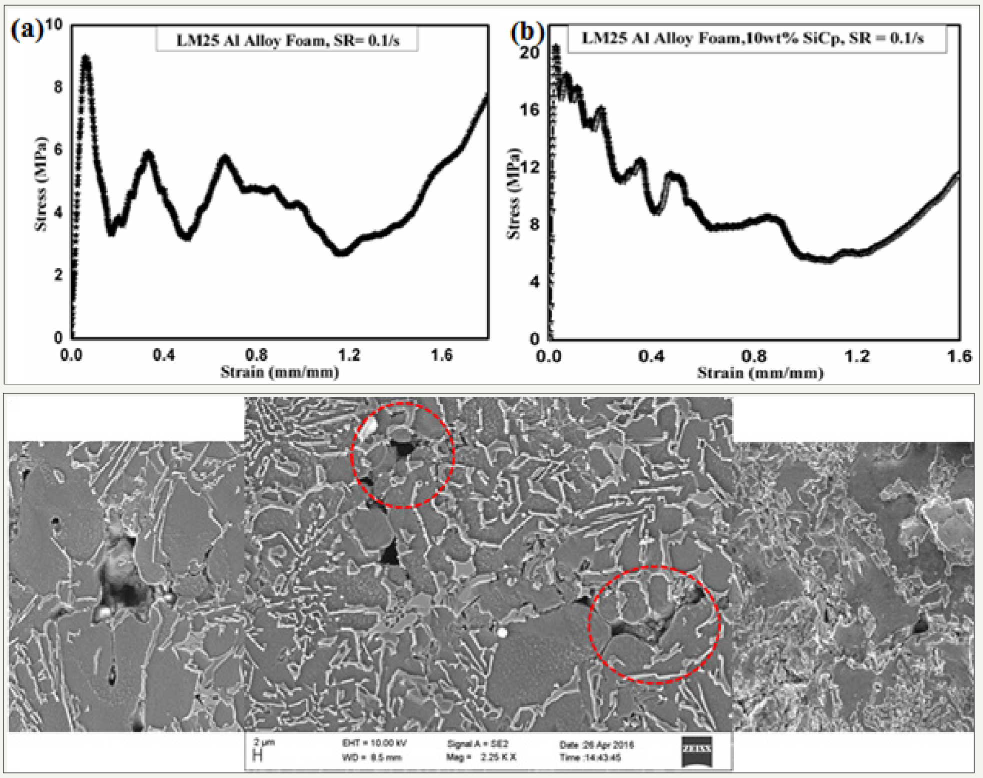

Figure 5: Stress-strain diagram of

5a: Al-Si7Mg Al alloy foam

5b: Al-Si7Mg 10wt% foam

5c: Deformation (30%) of Al-Si7Mg with 10wt% SiC particles.

Conclusion

Higher cell wall thickness is observed with micro-structure of Al-Si_7Mg Al alloy with 10wt% SiC particles, which is almost 3-4 times that of Al-Si_7Mg Al alloy foam. In case of pore size also the same appears is 4-10mm whereas the maximum pore size for ordinary foam is 2-3mm, which is about 4-5 times. The SiC particles present in the composite foam enhanced its strength and micro-structure leading to the higher plateau stress of the composite foam than the ordinary foam. The plateau stress of Al-Si_7Mg Al alloy with 10wt% SiC foam is 7.50MPa and for Al-Si_7Mg Al alloy foam 2.60MPa. Due to the higher plateau stress exhibited by the Al-Si_7Mg Al alloy 10wt% SiC foam, the energy absorption capabilities are also higher for the composite foam.

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