THE EFFECT OF REINFORCEMENT RATIO AND HEAT TREATMENT ON COMPRESSIVE BEHAVIOR OF 7075 Al/SiCp COMPOSITE FOAM

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Abstract

In this study, it was achieved that closed cell 7075 Al foam and 7075 Al /SiC_p composite foam is produced by directly foaming at semi-solid temperatures. TiH_2 powder was used as blowing agent. T6 heat treatment was applied to Aluminum foam samples and behaviors under compressive loads are investigated. Heat treatment samples of composite and metal foams were compared with samples of natural aged composite and metal foams. With increasing fraction of reinforcement, compare to same density of heat treated and natural aged samples of foam yield and plateau stress was increased. Effect of heat treatment and reinforcement ratio were affected to prevent yield stress of cells walls, mergers and collapse.

Keywords: Composite metal foam, SiC, semi-solid, 7075 Al, heat treatment

1. INTRODUCTION

Along with a growing technological developments have also brought problems. To solve these problems with new technologies and new materials are needed. Metal foams keeping a combination of many advantageous properties of metals with low relative density, are cellular materials containing pores filled with gas. If pores insulated by metal walls from each other is referred to as closed cell metal foam. Metal foam offer unique physical and mechanical combinations such as, the combination of high resistance and lower specific gravities or high gas permeability and superior thermal conduction. Structurally, they are characterized by the conditions of being open or closed-cells, their specific densities, anisotropies, cell typologies, cell sizes, and cell shapes. They can be produced from different materials such as, aluminum, titanium and nickel. The field of application will eventually determine the source material of the foam [1, 2]. Two major methods are used for the metal foams productions which are liquid-phase and solid-phase methods. Their structural and resistance characteristics depend on the production method. [3, 4, 5, 6, 7]. Before the addition of blowing agent, with ceramic powders adding into liquid metal can be made a little improvement at strength [12, 13, 14]. Reinforcement powders collected on the cell wall effect to prevent over-growth of cells, mergers and collapse [8, 14]. The SiCp aluminum composite foams had higher compressive stress, but a more brittle behavior was found as compared with aluminum foams [11].

The 7xxx Al alloy series, Al-Zn-Mg and Al-Zn-Mg-Cu Al alloys are known to strengthen by precipitating hardening through heat treatment. These materials are used for automotive components such as pistons, rocker arms, brake calipers and wheels, as well as application in various fields of sports and electronic industries [9]. Effect of heat treatment of samples produced in 7075 and 6061 alloys were increased the amount of energy absorption and yield stress [10].

In this research, closed-cell composite metal foam were produced by direct foaming method using semi-solid stirring process and was investigated that effect of heat treatment and effect of reinforced of 7075Al composite foam effects on compressing behavior.

2. MATERIAL METHOD

2.1. Material Selection

AlZn5.5MgCu(EN AW 7075 was used as the matrix material, TiH_2 was used as the blowing agent, and SiCp was used as the reinforcing material for the aluminum composite foam production. Due to high yield stress and natural aged of this alloy, are frequently used in the construction of military, aeronautic, machinery and vehicle bodies in many sectors such as rail transport, shipping, automotive. Green SiC powder (GW Micro), whose chemical composition is presented in Table 1, was used as the reinforcing material. Its average grain size is 12 µm (500 Mesh), it is cheap and easy to obtain besides being high-resistant.

Table 1. Chemical composition of the reinforcing powder

Products	Grain Size		% SiC	% Free C	% Si	% SO_2	% Fe_2O_3
GW Micro	F240 F800	-	99,5	0,10	0,10	0,10	0,05

12µm average size SiCp powders were stirred into the matrix at different rates (5%, 10%, 15%, and 20%) as received. Also metal foam was produced for understanding effect of SiCp on foam structure. TiH2 (98 wt% fine powder, about 44µ in size, supplied from Merck, Germany) were used as blowing agent without any treatment.

2.2. Production of metal foam specimens

Heating EN AW 7075 alloy at semi-solid temperature and SiCp with blowing agents adding to alloy was performed into silicon carbide crucibles. Internal temperature of furnace was set 750°C and kept at this temperature during production. During production after the addition of reinforcing and foaming agents, for a straight volume progression of the formation of foam, melt which taken from crucible were transferred to the molds. Autoclave cellular concrete (ACC) molds were designed as open top face for is not limiting foaming [13]. Crucible with solid Al pieces was placed into furnace when internal temperature of furnace was 750ºC. Aluminum alloy is heated until semi-solid temperature and it were kept at semi-solid temperature by the addition of solid aluminum pieces throughout the process. Various proportions of SiCp powder was added into semi-solid material while suitable viscosity has been obtained. Until ensured that uniform distribution of SiCp, 4-6 minutes stirring process was performed. Stirring period was prolonged; stirring process was become relatively hard with increasing proportion of SiCp. 0.5 wt. % TiH2 was used as a foaming agent was added into melt and 2 minutes stirring process was performed after homogeneous distribution of reinforcement powders was established. Foamable melt was transferred into mould. For releasing H_2 gas from blowing agent and forming pores in melt moulds was kept by 9 min at 750°C then taken out of the furnace was left to cool in the open atmosphere (Figure 1).

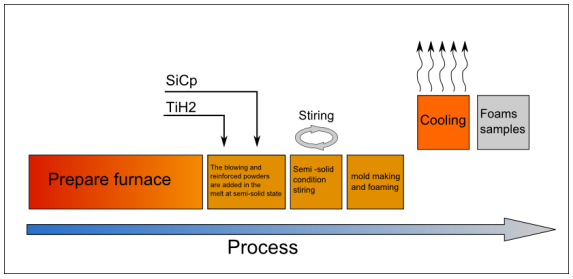


Fig. 1. Composite foam material production by using semi-solid stirring

2.3. Experimental procedure

Specimens were prepared with a precision cutting machine (figure 2). All the specimens had a square base section (15x15mm) and were 30 mm height. Their size and shape were established according to common compression standards.

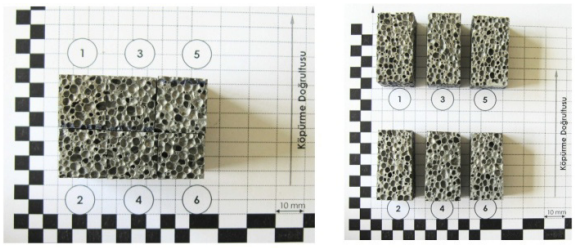


Fig. 2. Composite foam specimens

The heat treatment procedure for aluminum foams was derived from known parameter sets for conventional AW 7075. After machining, the specimens were processed by heat treatments, and thus the foams ready to use can be classified as two categories:

- T6-strenghening, solution treatment at 480^0C for 1.7h, prior to water quenching and aging at 120^0C for 24 h.
- Natural aging, room temperature at 20^oC for 20 day.

The furnace was used for heat treatment. The furnace characterization was decided K-type thermocouples at four points measurements and working conditions are suitable for heat treatment was decided. Heat treatment process of composite foam specimens was shown at figure 3.

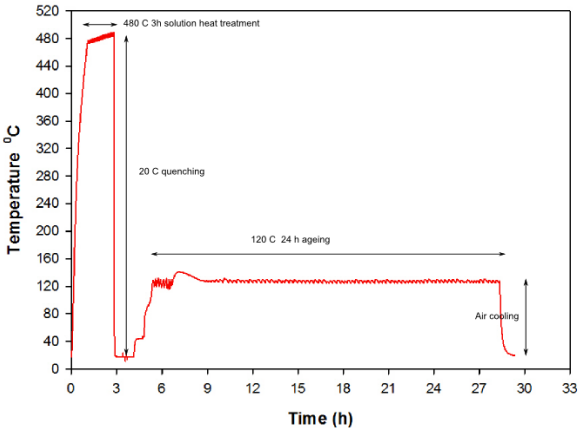


Fig. 3. Heat treatment process of composite foam specimens

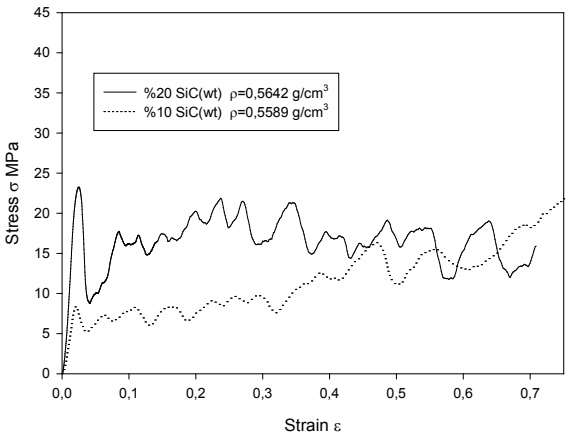
Uniaxial compression tests were performed on an Instron testing machine. Tests were conducted under displacement control with a cross-head speed of 0.5 mm/s.

3. CONCLUSION

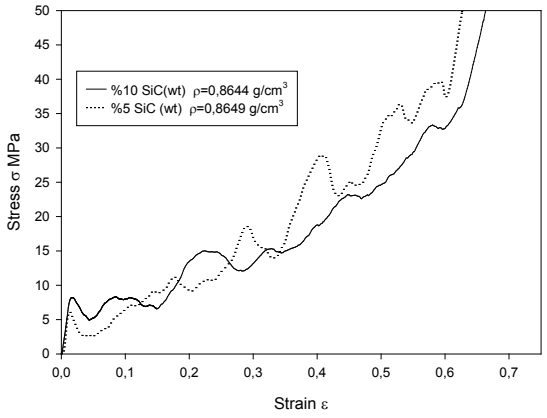
In this study, 7075 Al alloy reinforced with SiCp composite metal foam was produced. Effect of reinforcement ratio and heat treatment on the foam was investigated. At the same time the temperature and foaming time of production, is very effective on the foam density. With increasing fraction of reinforcement, density of composite metal foam decreased and porosity was increased. Depending on the fraction of reinforcement, relative density of foams was varied between 0.5-0.7 g/cm^3. 60-80 % porosity was achieved. It's known that in composite materials production reinforcement ratio increases with increasing density of the material [10]. A reinforcement increase of matrix material was caused within viscosity and a more organized cells comprised homogeneous cells of structure. Densification region, collapse region and liner region of compressive result of the specimen was observed.

3.1. The effect of reinforcement ratio on compressive behavior of composite foam

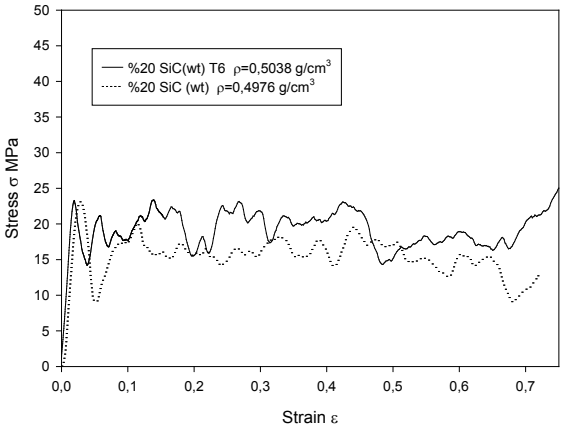
Compressive properties of the foam material of the most important parameters are the foam density. The stress of composite foam increases with increasing density. Similar density foam samples were selecting and different reinforcement ratios were compared graphic of compressive. Linear region of strain rate was low and collapse region of cell wall layers began to crumble were observed. The increases in the amount of reinforcing materials were increased resistance to collapse. For two foams with the same density, the yield stress of %20 reinforced composite foams is greater than of %10 reinforced composite foams because the cell wall material of the former has higher yield stress than that of the later. Compressive strength results of different reinforcement ratios are shown in the following figure 4a-b.



(a)



(b)



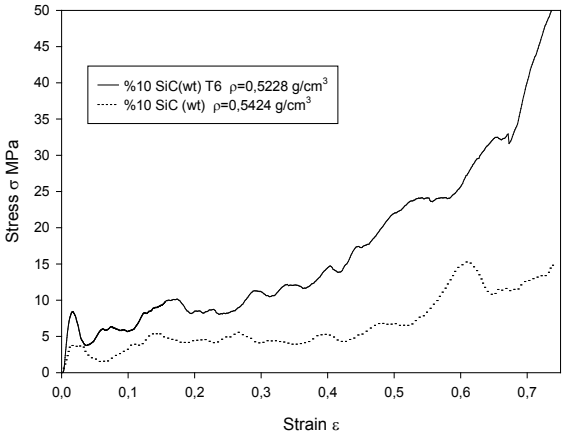
(a)

Fig. 4. Stress-strain graph of composite foam a) 20 %wt. SiCp reinforced composite foam b) 10 %wt. SiCp reinforced composite foam

The energy absorption of compressive test was considered up to %50. It is noted that compared with the %20 of heat treatment foam, the absorption energy of T6 heat treatment foam of 10 % reinforced specimens exhibits a 45.62 % increase, due to the heat treatment.

3.2. The effect of heat treatment on compressive behavior of composite foam

Yield strain rate of specimens which applied heat treatment have low value. Same reinforced rate with the density were chosen with the properties of heat treatment condition different specimens were compared. The increase in energy absorption of sample is approximately 20.36% for 20% reinforced for heat treatment than no heat treatment of 20 % reinforced sample (figure 5a). The increase in energy absorption of sample is approximately 58.12% for 10 % reinforced for heat treatment than no heat treatment of 10 % reinforced sample(figure 5b) and sample of no reinforced of heat treatment are compared due (figure 6).



(b)

Fig. 5. Comparison with heat treatment and no treatment of composite foam a) 20 %wt. SiCp composite foam b) 10 %wt. SiCp reinforced composite foam

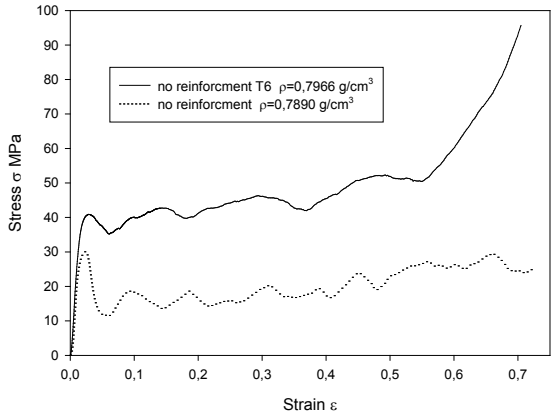


Fig. 6. Two specimens of metal foams of different heat treatment

1) 7075 Al foams and 7075Al/SiCp composite foams were prepared successfully by semi-solid condition of direct foaming of melt using TiH2 blowing agent.

2) The plastic collapse stress of 7075 foams increases with increasing density

3) The compressive stress–strain curve of 7075 Al foams is smooth. Whereas the compressive stress–strain curve of 7075 Al /SiCp composite foams and heat treatment of 7075 Al/SiCp is not smooth and exhibits some serrations.

4) At the same density, the yield stress and collapse stress of 7075 Al/SiCp composite foams increase with increasing SiCp volume fraction and heat treatment of 7075 Al/SiCp foams.

5) Particularly, T6 heat treatment can significantly raise the dynamic strength and energy absorption of the7075 Al and 7075 Al/SiCp foams.

6) The experimental results highlighted that heat treatment performed on both 7075 Al/SiC foam and 7075 Al foams increased the elastic limit and plateau stress level and consequently the absorbed energy during crushing.

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REFERENCES

[1] H.P. Degischer, Handbook of Cellular Materials - Production, Processing, Applications,H.P. Degischer y B. Kriszt (Eds.), Wiley-VCH, Weinheim, pp. 5-7.,2000

[2] Banhart, J., Fleck, N. and Mortensen, A., "Cellular Metals: Manufacture, Properties, Applications", Verlag Metall Innovation Technologie MIT Berlin, Germany,ISBN 3-935538-12-X,2003

[3] F.Behrendt,J.Banhart,H.Schubert,"Characterisation and Opt. of Blowing Agent For Making Improved Metal Foams"

[4] F. Simancik, L. Lucan And J.Jerz, "Reinforced Aluminium Foams" Institute Of Materials And Machine Mechanics, Sas, Bratislava, Slovak Republic

[5] John Banhart, Manufacture, "Characterisation And Application Of Cellular Metals And Metal Foams", Progress In Materials Science, 46, 559–632, 2001

[6] Yu, S., Luo, Y., Liu, J., "Effects of Strain Rate and SiC Particle on the Compressive Property of SiCp/AlSi9Mg Composite Foams", Materials Science and Engineering, 487, 394-399,2008

[7] Yu, C.J., Banhart, J., "Mechanical Properties of Metallic Foams", Fraunhofer USA Metal Foam Symposium, 37-48,1997

[8] S. Elbir, S. Yılmaz, A. K. Toksoy, M. Guden "SiC-Particulate Aluminum Composite Foams Produced By Powder Compacts: Foaming And Compression Behavior" Journal Of Materials Science 38,4745–4755,2003

[9] Demirhan, P.A., 2010, Investigation of Mechanical Properties of Composite Metal Foam, Master of Science Thesis, Trakya University, Turkey

[10] S.W, Kim., D.Y., Kim , W.G., Kim, K.D. Woo, "The study on characteristics of heat treatment of the direct squeeze cast 7075 wrought Al alloy" Materials Science and Engineering, 487, 304-306,2001

[11] Campana, F., Pilone, D., 2009, "Effect of heatt treatments on the mechanical behaviour of aluminium alloy foams" Scripta Materialia, 60 :679-689

[12] Luo, Y., Yu, S., Li, W., Liu J., Wei ,M.,"Compressive behavior of SiCp/AlSi9Mg composite foams" Journal of Alloys and Compounds, 2007

[13] Deqing, W., Xiangjun, M., Weiwei, X., Ziyuan, S., 2006, "Effect of Processing Parameters on Cell Structure of an Aluminum Foam", Materials Science and Engineering, A420, 235–239

[14] Esmaeelzadeh,S., Simchi, A., Lehmhus, D., 2006, "Effect of Ceramic Particle Addition on the Foaming Behavior, Cell Structure and Mechanical Properties of P/M AlSi7 Foam", Materials Science and Engineering, A424, 290–299