

Optimizing the hot compaction parameters of Al-Mg-Cu foams processed through elemental powder route

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Abstract. Aluminium foam is most commonly used in automobiles, so a closed-cell foam is going to be prepared. This is prepared by the powder metallurgy process using aluminium in addition to Copper and Magnesium, along with Titanium Hydride as a blowing agent. The composition of the powder used vary with weight%, Aluminium of purity 99.7%, Copper of purity 99.8%, Mg of purity 98.3% along with this TiH₂ is used as a blowing agent. Copper is used in this method because it has higher melting temperature and higher strength, and also to add strength to aluminium while compacting. The composition of Al-Mg-Cu produces foam with properties of corrosion resistance, and also reduce the weight of the foam. Since Mg gives better result than the Cu, Mg is used as an alloying element because it can increase the oxidation rate, improve the structure of the pore developed in foam, can produce less coarse and more homogeneous foams, and also obtain the maximum expansion of the foam. Thus by varying the parameters like varying the composition of the powder, temperature, time and the pressure given during compaction we will be able obtain a better result for producing a good precursor.

Keywords: Aluminium foam, Powder Metallurgy, TiH₂.

1. Introduction

Powder metallurgy route is one of the most attractive method for producing metallic foams because it allows us to make a wide range of components and near-net shaped geometries foams and as well as the foams with an integral sandwich structure. Still now extensive researches have been carried out to develop Al alloy foams through powder metallurgy route [1, 2]. The Powder Metallurgy process can produce smaller pore net-sized structure. The composition used in this process is Al-Mg-Cu along with TiH₂. Aluminum foams have high strength, low weight, can control noise, acts as a heat exchanger thus they have been mostly used in automobile industry, aerospace industry, medical industry widely [3]. The powder metallurgy process is



used because it helps us by reducing the need for machining and even complex shapes can be easily made by using this method [4].

Aluminium, Copper powders are used because it has good mechanical properties and can be used in variety of applications along with some alloying elements [5 - 7]. Research on Mg alloys showed better pore structure because it showed good wettability where Mg and Al alloys combined together while compacting forms MgAl_2O_4 [8]. To reduce the weight and corrosion problems of the foam magnesium helped in giving better result [9]. The TiH_2 is heat treated to delay the hydrogen evolution that is the hydrogen will evolve only at a higher temperature thus helping in foaming and producing of pores [10]. So this heat treatment is done by heating TiH_2 at 480°C constantly for a period of 3 hours [11, 12]. High amount of Mg content can change the pores formation in early stage, due to which the pores grow and nucleate in a pool of liquid in a fairly spherical way, thus a high expansion rate and good pore structures can be obtained from magnesium [13]. The related research on Mg alloy foam fabrication by PM route is still limited. Mg alloy foams are definitely expected to be particular advantageous due to the lower densities of their 4 metal matrix, which are approximately two-thirds that of Al and good mechanical properties, and also it helps in developing a good pore size and structure [14]. So in this paper we are going experiment the compaction of powder at different temperature, pressure, and composition to obtain a better pore structure and better foaming expansion.

2. Materials and Experimental Procedure

The powders are obtained from a dealers of size Aluminium 325 mesh, Copper 325 mesh, Magnesium 80 mesh, and purity of Aluminium 98.3%, Copper 98.3%, Magnesium 98.3%, TiH_2 99.3%. The TiH_2 used for experimenting is heat treated in a hot furnace at 480°C for about 3 hours. The composition is Aluminium 44 grams, Copper 4 grams, Magnesium 2 grams, TiH_2 0.5-1% , for a 50 gram specimen. The powders of required composition are mixed together through a pot mixer, for about 20 minutes. To compact the obtained powder we use die and the hydraulic machine. Firstly it is cold compacted at the room temperature for about 30 sec, and then heat is supplied to the die through a ceramic heater, and then it is compacted at different pressure for about 5min. Table 1 shows the compaction temperature, pressure, weight for the sample to be compacted.

Table 1. Compaction Temperature, Pressure and Weight of the sample

Specimens	Compaction Temperature	Compaction Pressure	Weight of the sample after compaction	Density
	($^\circ\text{C}$)	(MPa)	(gm)	(g/cc)
Specimen1	353	320	26	0.932
Specimen2	280	367	20.64	1.044
Specimen3	300	467	21	1.231
Specimen4	410	300	30	0.771



Figure 1. The specimen obtained after compaction.

Figure1 shows the compacted sample after compaction is done. The obtained four samples after compaction are cut into a square shape of size 12X12(mm) and thickness of 5mm as shown in Figure2.

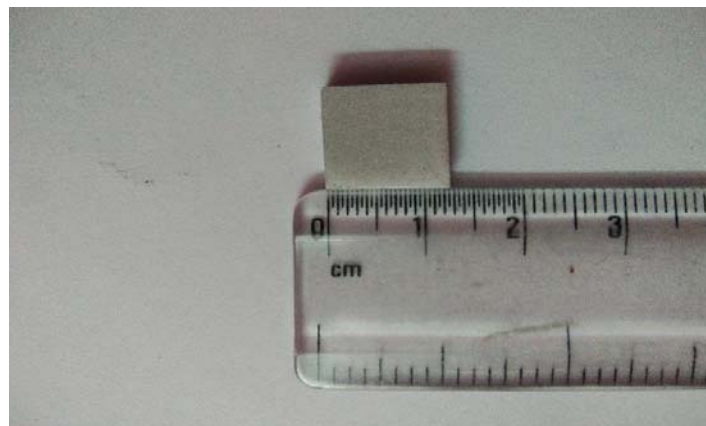


Figure 2. Square shaped sample 12X12 (mm).

Then the samples are foamed using an Electric Induction Plate at different temperature and time by varying the heating rate as mentioned in the Table2.

Table 2. Foaming temperature, time and heating rate

Samples	Foaming Temperature (⁰ C)	Time taken to foam (min)	Heating rate (⁰ C/min)
1	650	10	72
2	630	10	72
3	630	20	31.5
4	610	20	30
5	640	15	42.6
6	630	10	63
7	650	20	32
8	640	5	128

3. Results and Discussion

The samples obtained were foamed at different temperature, and heating rate as shown in table2, these samples showed different foaming expansion at different temperature. Among that sample 6 which was heated 630°C at a heating rate of $63^{\circ}\text{C}/\text{Min}$ showed better expansion when compared to other experiment result.

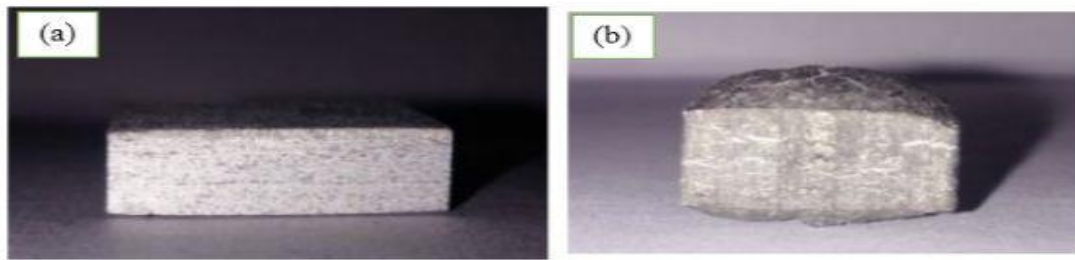


Figure 3. (a) Before heating, (b) After heating of the compacted sample.

The above figure 3(a) shows the image of sample6 before foaming and figure 3(b) shows the image of sample sample6 after foaming is done using the electric induction plate, which gave better foaming expansion than the other samples. Thus the best heating rate to foam the sample is $63^{\circ}\text{C}/\text{Min}$ for about 10 Min.



Figure 4. Sample with burnt magnesium after foaming is done.

The figure 4 shows a blackish layer on top of the foamed sample, these blackish layers are Magnesium used in the composition while compacting, which burnt completely during foaming expansion. This is probably Mg has not properly mixed along with the Al because of the low pressure applied during compaction, thus on increasing the pressure Mg will completely mix with Al to form a homogeneous mixture by giving us a better result.



Figure 5. Cross-sectional view of a foamed sample.

The above figure5 shows the cross sectional view of the foamed sample in which the pore structure is not in a uniform shape, and also there is some crack formation because the Mg in the sample has completely burnt while foaming resulting in poor pore structure and crack formation. This happened because the pressure was less while compacting the powders as mentioned earlier.

4. Conclusions

1. The samples which were foamed after the compaction produced a blackish layer on top of the sample as shown in figure4, the blackish layer so obtained were the burnt Mg were it did not bind properly with the Al because of lack in pressure during compaction. So, on increasing the compaction pressure the Mg will bind properly with the Al.
2. As the Mg alloy did not mix properly with the Al the foaming expansion was less, crack began to develop in the foam and also the pore structure were not uniform, resulting in poor pore structure as shown in Figure5.
3. To foam the sample the best heating rate is at $63^{\circ}\text{C}/\text{min}$ for about 10 Min, where it showed higher expansion than the other samples.
4. All the samples started showing some changes at the point of 450°C while heating. And the expansion started to begin at the temperature 480°C - 500°C .

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