Development of Al-Cu Metal Matrix Composite through Hot Compaction

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Abstract: ***Metal Matrix Composites significantly enhanced mechanical properties- like higher stiffness, strength& light in weight. Development, Hardness and microstructure were carried out on hot forged and annealed treated Al4.2%Cu metal matrix composites to understand their fabrication process and their mechanical properties. Al4.2%Cu was prepared by warm forging using suitable die assembly on a 150 ton capacity hydraulic press. The Al4.2%Cu powder was well blended in the container and then they are poured into the Die assembly at three different temperatures- 400°C, 450°C and 500°C to make the three different samples successfully. All the three developed samples are cut into two halves, the one half as the forged part and the other half for annealed treated. This paper captures the salient features of development, hardness and microstructure of Al4.2%Cu Metal Matrix Composites.***

Keywords: Metal Matrix Composites, Hardness, Microstructure

1. Introduction

Conventional monolithic materials have limitations in achieving good combination of strength, stiffness, toughness and density. To overcome these shortcomings and to meet the ever increasing demand of modern day technology, composites are most promising materials of recent interest. There has been an increasing interest in composites containing low density and low cost reinforcements [1-3]. Now a days the particulate reinforced aluminium matrix composite, a gaining importance because of their low cost with advantages like isotropic properties and the possibility of secondary processing facilitating fabrication of secondary components. Among the entire liquid state production routes, stir casting is the simplest and cheapest one. But the main problem associated with this process is the non-uniform distribution of the particulate due to poor wet ability and gravity regulated segregation [4]. Mechanical properties of composites are affected by the size, shape and volume fraction of the reinforcement, matrix material and reaction at the interface.

Powder Metallurgy is popular because it is reliable compared with alternative methods [5], but it also has some disadvantages. The blending step is a time-consuming, expensive and potentially dangerous operation. In addition, it is difficult to achieve an even distribution of particulate throughout the product, and the use of powders requires a high level of cleanliness [6] otherwise inclusions will be incorporated into the product with a deleterious effect on fracture toughness and fatigue life.If proper care is taken during blending operation and compaction process makes the sample defect free and more enhanced mechanical properties like grain size, microstructure, hardness, toughness, density, strength, stiffness and less porosity in the final product[7-8].

Objective of the present work
1) To develop Al4.2%Cu matrix composite through Hot Compaction.
2) To measure the hardness of the above as forged composite and the annealed treated composite.

2. Experimental Details

2.1Material and Chemical Composition of Die

The material used for die making for our experimental work and study is HCHCR-D2 grade steel, the chemical composition of the die is given in Table 1.1.

Table 1.1: Chemical composition of Die

Fe	C	Si	Mn	Cr	Mo	V
84.13	1.54	0.32	0.34	12.00	0.76	0.91

Figure 1.1: Die, Top & Bottom punch

2.2 Methodology

In our experiment, we have selected the HCHCR Die because it has the quality with high wear resistant and toughness properties due to Vanadium addition of 0.91%. Normally, it supplies an annealed condition and will offer hardness to reach 57-59 HRC. It can be machined in the annealed condition. D2 is the superior steels than D3 due to high alloys properties. As a first step, we have designed the die in catia file(igsformatt) and then framed as shown in Fig 1.1. The selected die is given heat treatments i.e. hardening is followed by tempering in the Muffle Furnace.

2.3 Weighing of Al-Cu alloys under Digital Weighing Machine

The weighing machine is properly checked whether it shows zero reading in its weightless condition or not. Firstly, the weighing machine is reset to zero. Then the container is kept onto the machine and again reset it to zero. The copper powder is taken into the container and weighed to 4.2 gand then the atomized Al powder is taken into the same container till it weighed to 100g. Now the container has Al (95.8%) and Cu (4.2%) alloy and is ready for further Milling Process for blendingthem homogeneously.

2.4 Blending of Al- Cu Powder Alloys

The atomized Aluminium powder mesh size-150µm and Copper mesh size-200µm are blended properly to obtain a homogeneous powder blend in the Ball- Milling container for 2 hours.

2.5 Furnace Used for Heat Treatment of Die and sample

Muffle furnace is a furnace in which the sample is isolated from the fuel and all of the products of combustion including gases, flames and flying ash. The furnace is a front-loading box type with an externally heated chamber. In our experiment, we heated the top punch, the die, and the bottom punch at 400°C so that our die can withstand the applied load. The specification of the furnace used in the experimental work is as follows-

- Temperature Range 30- 700 °C
- Power – 230V, 50 Hz, single phase

2.5.1 Preparation of samples

The blended homogeneous mixture of Al-Cu powder alloys are poured into the die cavity. Then the top punch is kept over the die before placing into the Muffle Furnace. The whole die set up is then clamped and kept into the furnace. The furnace should be given 400°C, 450°C and 500°C to make three different samples. They may drop their temperature from bringing out of the furnace to the press. Therefore, we add +20°C so that the temperature drop should be least as much as possible. Now the whole die set up (top punch is lubricated with oil for nonstick onto its surface) is kept under the press. And the press is applied slowly and given 500 lbs- 1100 lbs to make the test sample.

2.5.2 Heat Treatment of the sample

In the present investigation, the prepared test samples were heated in the furnace up to 400°C, 450°C and 500°C holding at these higher temperature for 60 minutes followed by furnace cooling (at 30°C temp) for 1 day. After furnace cooling, the samples are cooled to room temp for further prediction of different deformation behaviors under 500 kg prescribed load. The values of the different deformation under prescribed load.

2.6 Hardness Test

The hardness of the annealed treated and without annealed i.e. as forged samples were measured in BrinellHardness Numbermeasuring machine with a load of 500Kg. The load was applied for 30 seconds in order to eliminate the possible segregation effect, a minimum of three hardness readings were taken for each specimen at three different locations of the test samples and then taken average value data.

2.7Microstructure

Microstructure and mechanical characterization of Al-Cu matrix composites are carried out by using metallographic examinations with O/M and Brinell Hardness Number (BHN). The sample preparation for microstructural study have been carried out first by polishing the sliced samples with emery paper up to 1200 grit size, followed by polishing with Al_2O_3 suspension on a grinding machine by using velvet cloth. Metallographic specimens are prepared for microstructural observation by grinding 80 to 1200 grits with SiC abrasive paper and then they are consecutively polished by Al_2O_3 suspension pastes of various sizes. The polished surface of the sample is etched with10% NaOH solution and examined on Optical Microscopy (O/M).

3. Results & Discussion

3.1 %Deformation under Hydraulic Press

The three samples produced, explained in the Experimental procedure section 2.1 are taken altogether to tabulate the different % of deformation under prescribed press before going to the first crack formed in the samples.

Table 3.1: %Deformation under hydraulic press (psi)

Deformation% Under Press psi	Sample 1	Sample 2	Sample 3
0%	14	15	13
5% at 600 psi	13.3	14.25	12.35
10%at 600 psi	12.6	13.5	11.7
20%at 1000 psi	11.2	12.0	10.4
30% at 800 psi	9.8	10.5	9.1
40% at 1000 psi	8.4	9.0*	7.8*
50% at 1100 psi	7.0*	7.5	6.5

Note 1 :- (*) Crack formed on the sample surface thus further deformation is stopped.

3.2 Hardness

The hardness of the heat treated samples and as forged samples are measured in BrinellHardness Number and explained in the Experimental procedure section 2.1. The values of the hardness number for different test samples are given in the Table 3.2.

Table 3.2: Sample showing Different hardness

S.No.	Sample Name	Load (Kg)	Average Hardness (BHN)
1	Annealed 1	500	53.4
2	Annealed 2	500	66.1
3	Annealed 3	500	56
4	Without Annealed 1	500	56.8
5	Without Annealed 2	500	69.1
6	Without Annealed 3	500	56.8

3.3 Microstructure

The sliced samples are taken for the microstructural study in transverse axis and on forgedaxis are well explained in the 2.7 microstructure sectionas shown in Fig3.1.

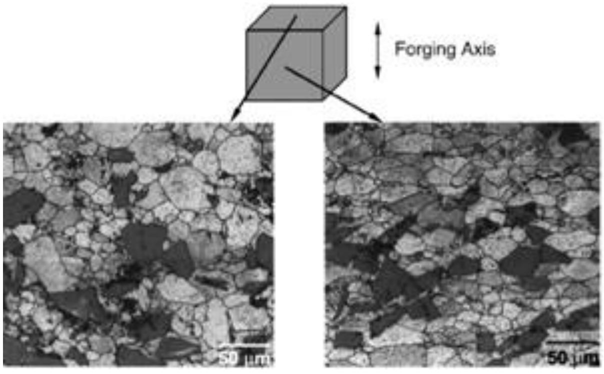

Figure 3.1: Microstructure along Transverse and Forging axis using O/M

4. Conclusions

In the present investigation, the Al-Cu matrix composite alloys were successfully synthesized through powder metallurgy method and hot compression technique. Following conclusions can be withdrawn from the microstructural and mechanical investigations. The conclusions drawn from the results can be summarized as follows:

- Microstructural investigations revealed a uniform distribution of Cu particles in the Al matrix which make them successful work of the Al-Cu matrix composites.
- The powder forged samples gets absolutely uniform microstructure.
- The bonding between the layers gets improved by increasing the warm forging i.e. maximum for sample 3 in both as forged and annealed condition.
- The hardness of the Al4.2%Cu composite were increased with the number strain hardening in the press and reached a maximum value of 69 BHN at 1100 lbs load.
- The annealed samples give less hardness value as compared to their parent samples under 500Kgfload.
- The warm forging at 500°C for sample 3, the samples compacts better and make bonding stronger in relative to higher strength, hardness and pore size becomes smaller.

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