Analyzing the Mechanical and Physical Properties of Aluminium – Copper Alloy Prepared By Sintering Technique

Manavalan P, Professor
Department of Automobile Engineering,
Karpaga Vinayaga college of engineering and Technology
Chennai, India

Aruljothi A[2], Assistant Professor
Department of Automobile Engineering
Karpaga Vinayaga college of engineering and Technology
Chennai, India

***Abstract*— This paper is to fabricate the Aluminium metal matrix composite reinforced with copper particle by high energy ball milling, followed by sintering techniques. The effects of Copper content and preparation methods on the microstructure and compression mechanical behaviour of Aluminium-Copper matrix composites were investigated. The micro structural characterizations revealed a homogenous distribution of Copper particles in the Aluminium matrix and also it shows fine microstructures in all sintered samples. The effect of particulate composition is studied by varying the copper concentration in the ratio of 5,10,15 wt% respectively. Hardness is increased with increasing particulate content. With increasing the reinforcement content the strength is increased and then dropped. The fabricated composites were tested for their mechanical properties such as hardness and compressive strength. Microstructure aspects were studied through SEM. The developed material of the sintered Al-Cu in this investigation could be successfully used for industrial applications due to improved mechanical properties.**

Keywords—Aluminium; Metal matrix composite; copper; sintering technique

INTRODUCTION

In powder metallurgical, Sintering is a process during which material is transformed from a dispersive (powder) state with a large specific surface to a compact state without achieving a melting point. Essential phenomenological displays of sintering are the strength increase and porosity increase. For one-component systems, sintering is carried out at a temperature of 0.6 to 0.75 of the melting point of the sintered material. Multi-component systems (powder mixtures) are generally sintered at temperatures near or slightly higher than the melting point of a component with the lowest melting point. Depending on required properties of the sintered material, the sintering process can be single-step or multistep. For example, for a manufacture of porous filters or for minimal requirements for tensile properties (self-lubricating bearings) one sintering without any further compacting operations is enough. For higher demands, an additional material compaction and additional sintering in order to enhance density, strength and ductility can come after. If needed, a technology with a combined thermo-mechanical processing is used, such as hot pressing, isostatic hot pressing and forging. Final compaction can be ensured by filling (infiltrating) a compact or pre-sintered skeleton with an element with a lower melting point. Strength and hardness can be enhanced by an additional surface or bulk heat treatment. Sintering can run without simultaneous application of an external pressure, which is a much more frequent way than sintering under pressure called as hot pressing. In the case of sintering without an external pressure the only driving force of the sintering is a reduction of the total surface energy.

MATERIALS SELECTION

Aluminium is one of the lightest engineering metals, having strength to weight ratio superior to steel. Pure aluminium doesn't have a high tensile strength.

However, the addition of alloying elements like manganese, silicon, copper and magnesium can increase the strength properties of aluminium and properties tailored to Particular applications. Here we took the alloying element as copper. The aluminium-copper alloys typically contain between 2-10%, with smaller addition of other elements. The copper provides substantial increases in strength and facilitates precipitation hardening. The introduction of copper to aluminium can also reduce ductility and corrosion resistance. The susceptibility to solidification cracking of Al-Cu alloys increased, consequently some of these alloys can be the most challenging aluminium alloys to weld. These alloys include some of the highest strength heat treatable aluminium alloys. The most common applications for these alloys are aerospace, military vehicles and rocket fins. We took Al-Cu at the following composition.

2.1 MATERIAL PREPARATION

Materials are prepared by mixing Aluminium and Copper in three different composition by Powder Metallurgy method and mass calculation are tabulated.

Set	Matrix (Aluminium) %	Reinforcement (Copper) %	Weight (G)	
			For D=10mm	For D=30mm
1	95	5	77.9	4.1
2	90	10	82.8	9.2
3	85	15	85.85	15.15

Table 2.1. Weight Calculation for samples

2.2 SPECIMEN PREPARATION

The PM preforms were prepared from pure aluminum powder and aluminium– copper mix with addition of 5%, 10% and 15% (by weight) copper in the composite to obtain dimensions of 10 mm in diameter and 10mm in height and making another component of same diameter and 30mm height. A ball mill was used for blending and mixing the powder to obtain uniformly distributed aluminum and copper powder mix. Compacts of different initial relative densities were made by using recommended compaction pressure that ranges from 250MPa-400MPa. Zinc stearate was applied for lubricating the die, punch and butt during compaction. A uniaxial compaction was employed for compacting properly poured powder in the die. The compacts were sintered in a muffle furnace at 500 ± 10^0C for holding period of 2hrs. Immediately after the completion of the sintering schedule, the specimens were allowed to cool to room temperature inside the furnace by switching off the power source of the furnace. Fig. 2.2 shows the compacted samples.

Fig. 2.2 shows the compacted Samples

3. TESTING

After successful fabrication of composite material, they are undergone various tests to find out mechanical properties. We have done following tests.

- Compression test
- Brinell hardness test
- Microstructure Analysis
- Scanning Electron Microscope

3.1 COMPRESSION TEST

The experiment was conducted for Al–Cu PM composite with different content of copper (5%, 10% and 15%) in the composite. Standard compression specimens of diameter 30±0.5 mm and of height 33±2 mm of three different sets of composition of matrix were prepared by machining from sintered compacts. Upset tests were performed at room temperature between two flat platens on computer controlled servo hydraulic universal testing machine at a constant cross head speed. Specimens are subjected to plastic deformation by upsetting to 50% or the fracture initiation, whichever happens earlier. The values of the compression test is listed below table 3.1

Test parameters	Set-I (95%Al-5%Cu)	Set-II (90%Al-10%Cu)	Set-III (85%Al-15%Cu)
Compression load in KN	53.18	67.97	64.20
Compression strength in N/mm^2	75.00	96.00	90.00

Table 3.1. Compression test

3.2. HARDNESS TEST

The experiment was conducted for Al–Cu PM composite with different content of copper (5%, 10% and 15%) in the composite. Standard compression specimens of diameter 30±0.5 mm and of height 33±2 mm of three different sets of composition of matrix were prepared by machining from sintered compacts. Then these components were tested for hardness. Brinell hardness number is obtained using a perfectly spherical hardened steel ball of 5 mm pressed against the test surface using a static force of 250 kg for at least 10 seconds and measuring the diameters of the indentation left on the surface by means of a graduated low power microscope. The values of the hardness test are listed below.

Test parameters	Set-I (95%Al-5%Cu)	Set-II (90%Al-10%Cu)	Set-III (85%Al-15%Cu)
BHN – (5mm Ball /250kg load)	40.2,42.6, 42.2	44.0,43.3, 42.9	46.7,45.6, 45.9

Table 3.2. Hardness test

3. 3.3. MICROSTRUCTURE

Samples from each set are taken and kept in a Optical Trinocular Metallurgical microscope to find out microstructure using with the magnification of 100X and 500X lenses and the microstructure given below

Set I [Al = 95%, Cu = 5%]

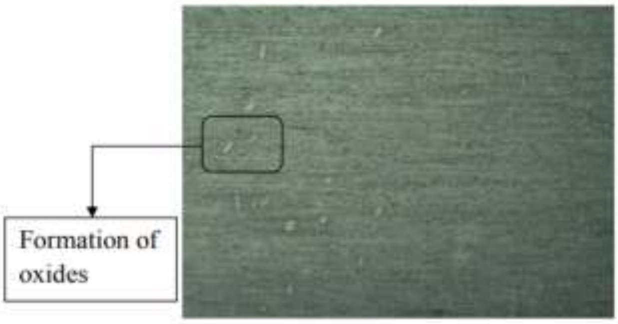

Fig.3.3.1a.Microstructure of Al-5%Cu (100X)

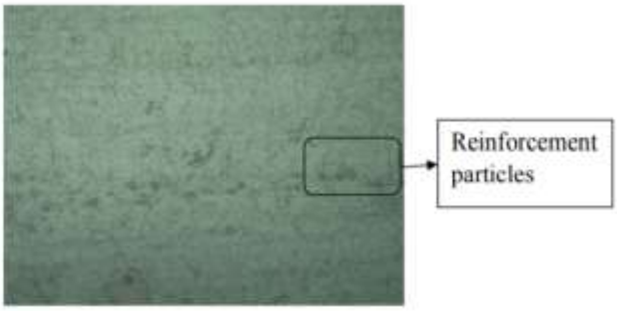

Fig.3.3.1b.Microstructure of Al-5%C (500X)

The microstructure shows about blending of matrix and reinforcement particles in samples fig.3.3.1a and 3.3.1b shows the presence of pores in the sample. The white layer surface found in the microstructure (fig. 3.3.1b) indicates the prescence of Al and the black porous indicates the presence of copper particles and a few traces of Al2O 3, this is due to high temperature oxidation.

Set II [Al = 90%, Cu = 10%]

Figure.3.3.1c. Microstructure of Al-10%Cu (100X)

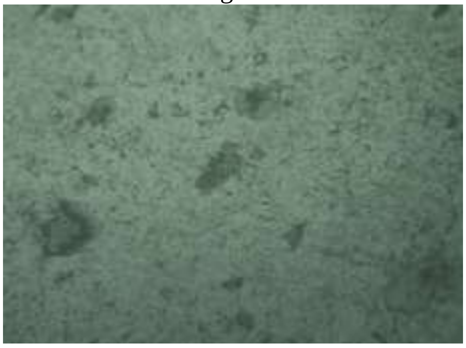

Figure.3.3.1d.Microstructure of Al-10%Cu (500X)

The agglomeration of copper particles is found in this sample. Similar to the previous proportion of reinforcement particle, in this sample also there is a presence of copper particles (black layer), the white layer in fig.3.3.1d.indicates the presence of Al particles and a few traces of Al2O 3 are present.

Set III [Al = 85%, Cu = 15%]

Figure.3.3.1e. Microstructure of Al-15%Cu (100X)

Figure.3.3.1f. Microstructure of Al-15%Cu (500X)

In this fig. 3.3.1e and 3.3.1f shows the blending of matrix and reinforcement particles. Among all the samples this sample shows higher number of oxides which in turn reacts with Al and forms Al2O 3. The increased number of pores will results in decreased ductility and hardness of the material.

3.4. SCANNING ELECTRON MICROSCOPE

Samples from each set are taken and kept in Scanning Electron Microscope to find out the elemental analysis of the samples using magnification of 500X and 1000X lenses.

Set I [Al = 95%, Cu = 5%]

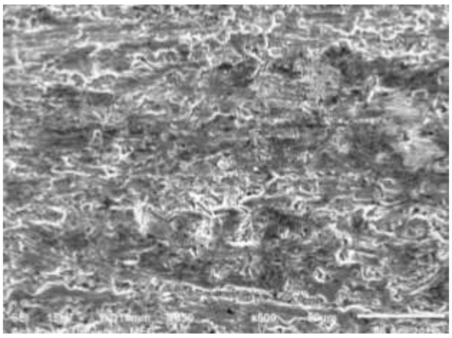

Figure.3.4.1a.SEM photograph of AL-5%Cu (500X)

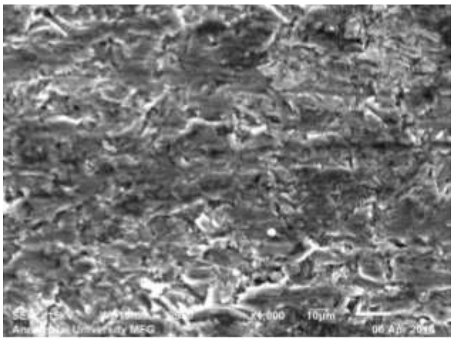

Figure.3.4.1b.SEM photograph of AL-5%Cu (1000X)

In this fig.3.4.1a and 3.4.1b shows the morphology of Matrix (Aluminium-95%) and the Reinforcement (Copper-5%). During manufacturing and other processes pores may produce, due to this oxidation occurs. Due to oxidation the material Aluminium is reacted with oxygen and becomes Aluminium oxide. The white colour in the fig.3. 4.1a and 3.4.1b are the oxidized areas. Due to oxidation the ductility of the material is decreased and the brittleness of the material is increased. Al is used for its ductile property by adding 5% of reinforcement (copper), this property is decreased.

Set II [Al = 90%, Cu = 10%]

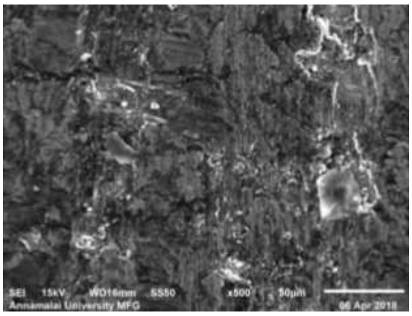

Figure.3.4.1c SEM photograph of AL-10%Cu (500X)

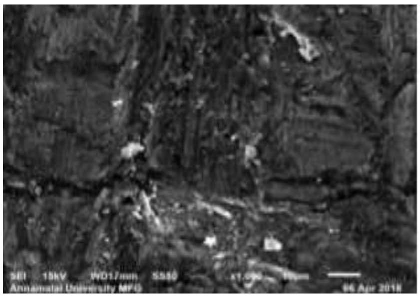

Figure.3.4.1d SEM photograph of AL-10%Cu (1000X)

In this fig.3.4.1c and 3.4.1d shows the morphology of Matrix (Aluminium-90%) and the Reinforcement (Copper-10%). The agglomeration of copper particles occurs in this proportion of reinforcement. Here there is less number of pores present. The formation of Aluminum oxide is less in this proportion. Therefore, the ductility of the material remains same. Comparing to the above reinforcement (copper-5%) this shows decreased brittleness.

Set III [Al = 85%, Cu = 15%]

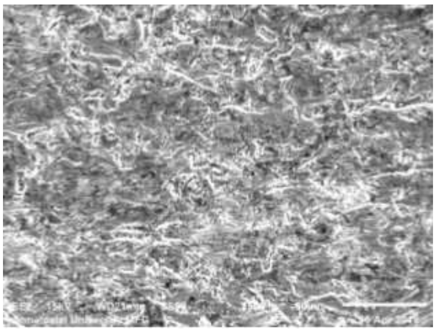

Figure.3.4.1e SEM photograph of AL-15%Cu (500X)

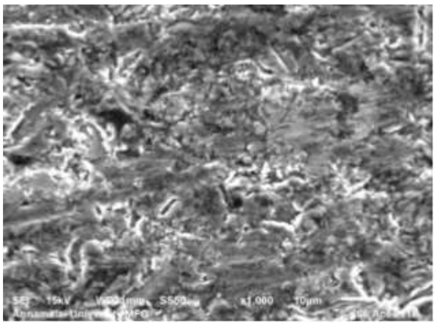

Figure.3.4.1f SEM photograph of AL-15%Cu (1000X)

In this fig.3.4.1e and 3.4.1f shows the morphology of Matrix (Aluminium-85%) and the Reinforcement (Copper-15%). Similar to the Al-5%Cu in this material also oxidation occurs. Due to oxidation the material Aluminium is reacted with oxygen and becomes Aluminium oxide. The white colour in the fig.3.4.1e and 3.4.1f are the oxidized areas. Due to oxidation the ductility of the material is decreased and the brittleness of the material is increased. Al is used for its ductile property by adding 5% of reinforcement (copper), this property is decreased.

4. **RESULT**

4.1. COMPRESSIVE STRENGTH

The compressive strength of the composites was tested in the Universal testing machine (UTM). The compressive strength is depicted in the graph. The effect of Al and Cu in each volume fraction is evaluated and shown in fig.4.1. The compressed samples are shown in fig. 4.2.

- The compressive strength shows high value in the Set II (Al-10%Cu)
- The compressive strength varies due to the variation in the weight percentage. Ductile materials show less compressive strength than the brittle, when ductile material is compressed it began bulge on the sides and become barrel shapes.

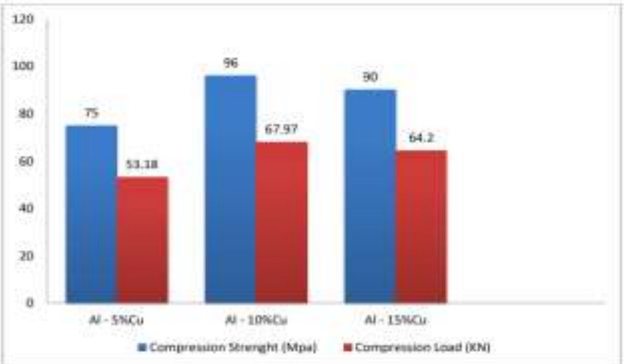

Figure 4.1 Graph for comparison of compression tests values of different sets

4.2 BRINELL HARDNESS

The hardness test were carried out on the prepared composite samples in Brinell hardness tester, the test were conducted at constant loading 250Kg and 5mm ball. Each sample from the sets is subjected to hardness test, and mean value is taken to avoid the higher deviation of the result. The Mean hardness of the each set is depicted in the graph (fig.4.3), the effect of reinforcement also evaluated.

- It seems that hardness of the specimen varies significantly with the variation in the volume fraction of the composite
- From the graph we can find that Set II and Set III having 43.40 and 46.06· while the Set I shows only 41.66

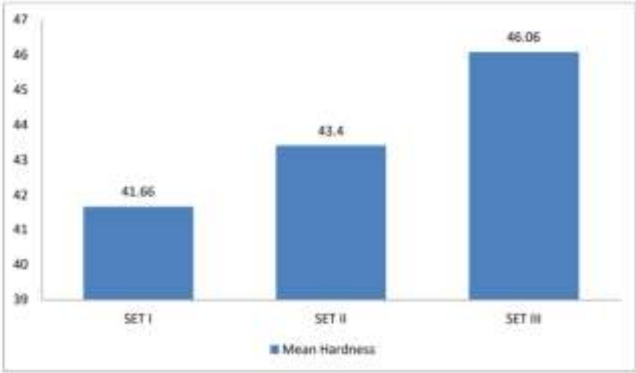

Figure 4.3 Comparison of hardness values of different sets

5. CONCLUSION

The following conclusions can be drawn from the results and discussions

1. The compressive strength increases gradually with increase in copper content and starts decreasing after a particular level.
2. The hardness increases with increase in reinforcement (copper) content.
3. With increase in copper content in the composite, the proportion of Al-15%Cu shows higher hardness among the other two proportions.
4. Compressive strength is higher in the proportion of Al-10%Cu, therefore this proportion could be used in compressive applications.
5. The SEM image shows that the proportion of Al-10%Cu will have less porosity and the ductility remains same.

6. REFERENCES

[1] Azim Gökçe, Fehim Fındık, Ali Osman Kurt (2011). Microstructural examination and properties of premixed Al–Cu–Mg powder metallurgy alloy.

[2] Jean-François Silvain, Amélie Veillère, Yongfeng Lu (2014). CopperCarbon and Aluminum-Carbon Composites Fabricated by Powder Metallurgy Processes Journal of Physics.: Conf. Ser. 525 012015.

[3] Katerina Sfontnicova, Miroslav Kursa, Ivo Szurman (2014). Powder Metallurgy-A Textbook.

[4] Liu Z.Y., Q.Z. Wang, B.L. Xiao∗ , Z.Y. Ma, Y. Liu (2010). Experimental and modeling investigation on SiCp distribution in powder metallurgy processed SiCp/2024 Al composites. Materials Science and engineering A 257:5582-559.

[5] Moustafa S.F, Z. Abdel-Hamid, A.M. Abd-Elhay (2002). Copper matrix SiC and Al2O3 particulate composites by powder metallurgy technique. Materials letters 53:244-249.

[6] Muhammad Rashada, Fusheng Pana, Zhengwen Yua, Muhammad Asif, Han Lina, Rongjian Pana(2015). Investigation on microstructural, mechanical and electrochemical properties of aluminum composites reinforced with graphene nanoplatelets. Materials International 25:460-470.

[7] Pickens J.R. (1981). Aluminium Powder Metallurgy Technology for HighStrength applications. Journal of Material Science 16:1437-1457.

[8] Radha Raman Mishra1, Rajesha S2 and A.K. Sharma3 (2014). Microwave Sintering of Pure Metal Powders – A Review. International Journal of 43 Advanced Mechanical Engineering. ISSN 2250-3234 Volume 4, Number 3, pp. 315-322.

[9] Rajkumar. K, S. Aravindan (2011). Tribological studies on microwave sintered copper–carbon nanotube composites. Wear 270:613-621.

[10] Venugopal P, R.Venkatraman, R.Vasudevan, K.A. Padmanabhan (1988). Journal Mechanical Working Technology, 16:51-64.

[11] Wilbert D. Wong- Angel a, Lucia Tellez-Juradoa,Jose.F.Chavez-Alcalaa, Elizabeth Chavira-Martınez b, Vıctor F. Verduzco-Cede no c (2014). Materials and Design 58:12-18.