Development and Evaluation of Various Properties of Copper - Aluminium Metal Matrix Composites

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Abstract - *Aluminium Matrix Composites (AMCs) are potential materials for various applications due to their good physical and mechanical properties. The addition of reinforcements into the metallic matrix improves the porosity, Hardness, Ultimate Tensile Strength and other mechanical properties compared to the conventional engineering materials. This paper presents the development of Al-Cu composite through Powder Metallurgy route with varying compositions and the effect of Porosity, Hardness and Ultimate Tensile Strength by addition of different compositions of copper in aluminium matrix. Different samples (Cu compositions 3, 10, 15, 20 Wt.%) of the composite were developed and Porosity, Hardness and Ultimate Tensile Strength were observed for the developed composites. Then SEM analysis of the samples were done to study the phases present and their distributions along with idea of composition.*

Keywords: Aluminium Matrix Composites, Powder Metallurgy, SEM, Hardness, Ultimate Tensile Strength.

1. INTRODUCTION

From the last few years in much industrial application the important parameter in material selection is specific strength, weight and cost. MMC (Metal matrix composites) are metals reinforced with other metal, ceramic or organic compounds. They are made by dispersing the reinforcements in the metal matrix. Reinforcements are usually done to improve the properties of the base metal like strength, stiffness, conductivity, etc. Aluminium and its alloys have attracted most attention as base metal in metal matrix composites [1]. Aluminium MMCs are widely used in aircraft, aerospace, automobiles and various other fields [2]. Aluminium based metal composite is preferable and widely used as a substitute material for making various engine parts.

2. EXPERIMENTAL PROCEDURE

In Aluminium Matrix which is in the form of powder, Copper in the form of powder is used as the reinforcing phase which is then blended and mixed with the help of mortar and pestle by varying composition of Copper (3, 10, 15, 20 Wt.%).

The blending and mixing is continued with mortar and pestle till the mixture of Aluminium and Copper becomes a fine powder having mesh size of 200µm. The mixture is then compacted with the help compact pressing machine by applying 2.5 ton pressure. Then the compacted material is sintered at 600^{o}C for 1 hour duration. After completing the sintering process the compacted Copper-Aluminium metal matrix composite becomes hard and the surface was generated for showing microstructure. For observing microstructure the surface of the compacted Copper-Aluminium metal matrix composite were polished by the emery paper 1/0 and 2/0 grade. After paper polishing the Copper-Aluminium metal matrix composite is cloth polished for fine polishing. After completing the polishing the Copper-Aluminium metal matrix composite was washed by alcohol and etched by Ferric Chloride and Kellers solution. After completing that operation the Scanning Electron Microscopy(SEM) was carried out for each Copper-Aluminium metal matrix composite using JEOL MAKE SEM model JSM 6360, operated by PCSEM software. Vicker's Micro-hardness testing is carried out on the same metallographic specimen of bead on plate sample at different positions by using 100 gf loads with 10 sec dwell time. The hardness was taken simultaneously in three different positions and finally averages them for more accuracy using Leco Micro Hardness tester (Model LM248SAT). After Vicker's Micro-hardness test Ultimate tensile strength of each Copper-Aluminium metal matrix composites is calculated by using formula

$$UTS = 3.353 \times VHN \qquad (1.1)$$

Where, *UTS* is Ultimate Tensile Strength and *VHN* is Vickers Hardness Number.
Then Apparent porosity of each of the Copper-Aluminium metal matrix composites is measured by Universal Porosity Measurement Technique by using the formula

$$\phi = \frac{W_w - W_d}{W_w - W_s} \times 100 \qquad (1.2)$$

Where, W_d = the weight of the dry sample, W_s= the weight of sample immersed in water, W_w= the weight of the saturated sample after removed from the water and ϕ is the apparent porosity.

3. RESULTS AND DISCUSSION

3.1 Porosity

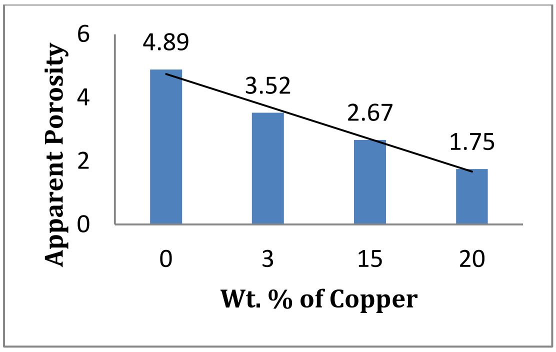

Chart-1 : Porosity due to increment of Copper into Aluminium Matrix

From Chart-1 Copper percentage increases—apparent porosity decreases. Actually, the value of apparent porosity is permissible and lies the value between 1.75% to 4.89%. Apparent porosity of Aluminium matrix composite containing 0 wt% of Copper is highest. Apparent Porosity is measured in universal porosity measurement technique.

3.2 Micro-Hardness

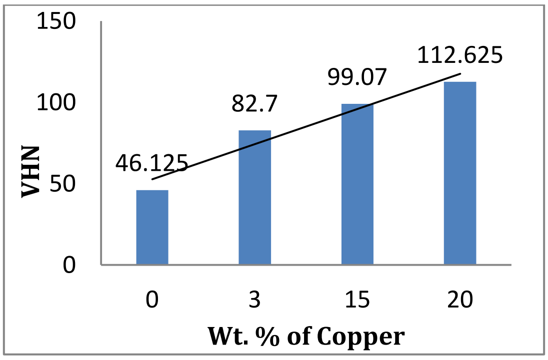

Chart-2 : Variation of MicroHardness due to increment of Copper into Aluminium Matrix

Chart-2 shows that hardness increases with copper percentage increases. Hence, maximum hardness occurs at 80 wt% Al -20 wt% Cu. Copper is a metal with very good hardness . Aluminium is metal, means low hardness. Combination of Al and Cu gives improved hardness than pure aluminium.

3.3 Ultimate Tensile Strength

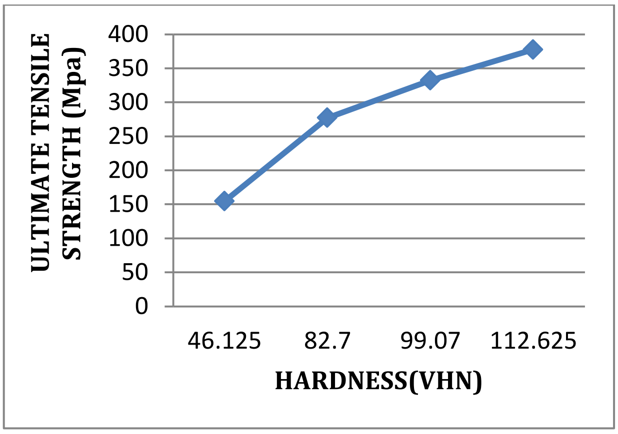

Chart-3 : Variation of Ultimate Tensile Strength

As it is mentioned above that hardness increases with Copper percentage increases. Hence, maximum hardness occurs at 80 wt% Al -20 wt% Cu. So Chart-3 shows as the hardness increases the ultimate tensile strength also increases. Hence maximum ultimate tensile strength is found in 80 wt% Al -20 wt% Cu. So it can be said that increase in Copper percentage in Copper-Aluminium metal matrix composite will increase the ultimate tensile strength of the composite.

3.4 SEM analysis

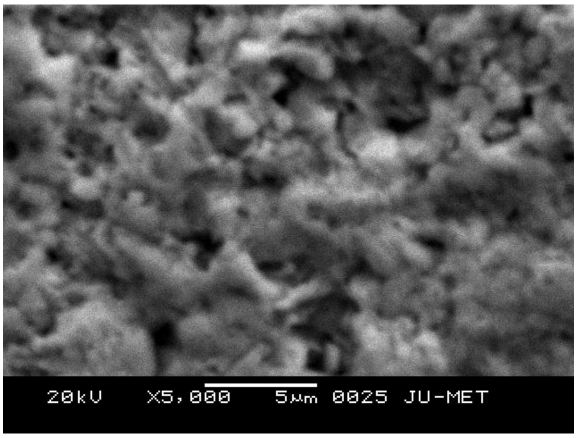

Fig-1(a): : SEM analysis of Copper-Aluminium Composites

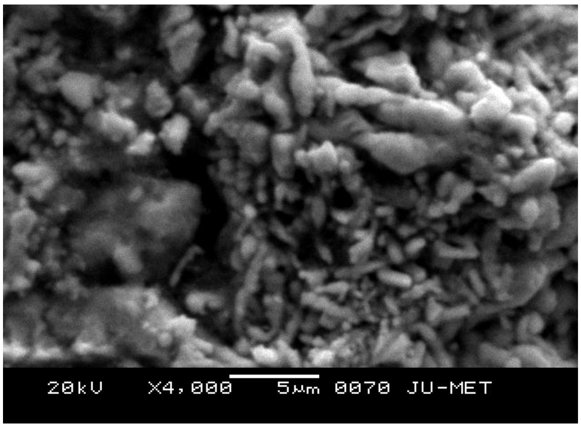

Fig-1(b) : SEM analysis of Copper-Aluminium Composites

Fig-1(a) and Fig-1(b) SEM image indicates fine grain aluminium structure is produced and make matrix phase. Melting point of aluminium is 660°C. But here sintering was done at 600°C in 1 hour duration on box furnace.

As temperature increases simultaneously in box furnace, aluminium melts at 600°C and produce fine grain structure. Copper is well distributed through out entire composite and play as second phase.

4. CONCLUSIONS

The significant conclusions on Al- Cu composites are as follows:

- Al-Cu composites were developed successfully by powder metallurgy technique.
- Hardness is increased with incorporating Cu into Al matrix. Hardness is increased significantly up to 20 Wt. % Cu content.
- Porosity also decreases with increment of Cu percentage. Hence, maximum porosity observed in 0% weight fraction of Cu.
- The results of study suggest that the hardness value of Cu-Al increases with the Cu content. The best esult has been obtained at 20% weight fraction of Cu particles. Maximum Hardness = 112.625 VHN.

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