



# Evaluation of mechanical characteristics for Aluminum-copper Metal matrix composite

Velugula Mani Kumar and Chinta Neelima Devi

Department of Mechanical Engineering, University college of Engineering, JNTUK, Vizianagaram, AP, INDIA

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Received 18<sup>th</sup> December 2013, revised 28<sup>th</sup> February 2014, accepted 21<sup>st</sup> March 2014

## Abstract

*The use of high performance materials in both the airframe and propulsion systems enables the modern aircraft to rotate larger degree while retaining its strength. To obtain continual performance, designers are constantly searching for lighter and stronger materials. The attractiveness of aluminum is that it is relatively low cost, light weight metal that can be heat treated to fairly high strength levels and it is one of the most easily fabricated high performance materials, which usually correlates with lower costs. The aluminum-copper and aluminum-zinc alloys are the primary alloys used in airframe structural applications. The aluminum-copper metal matrix composites are used in damage tolerance applications such as the lower wing skins and fuselage structure of commercial aircraft. In the present study, aluminum alloy specimens (6061) will be developed with variations of % of copper in the composition viz., 4%, 6%, 8%, 10% using die casting process. The mechanical properties like tensile strength, hardness, % elongation, impact strength and micro structures analysis will be carried out.*

**Keywords:** Aluminum, casting, metal matrix composites, tensile strength, impact strength, micro structure.

## Introduction

Aluminum is the familiar matrix for the metal matrix composites (MMCs)<sup>1,2</sup>. The Al alloys are quite useful due to their low density, good corrosion resistance, high thermal and electrical conductivity, and high damping capacity. They offer a large variety of mechanical properties depending on the chemical composition of the Al-matrix. There are two principal classifications, namely casting alloys and wrought alloys. About 85% of aluminium is used for wrought products. Aluminum alloys are used extensively in aircraft due to their high strength-to-weight ratio. On the other hand, pure aluminum metal is much too soft for such uses, and it does not have the high tensile strength that is needed for airplanes and helicopters<sup>3,4</sup>. Copper is one of the best alloying element since the beginning of the aluminum metal matrix composites. In the cast alloys the basic structure consists of dendritic in nature and possess aluminum solid solution, with a variety of particles at the grain boundaries or interdendritic spaces, forming a brittle components with eutectics in nature. Most alloying elements can improve the modulus of elasticity of aluminum, but the increase is not remarkable for the aluminum-copper alloys<sup>5</sup>. The modulus of elasticity at room temperature is of the order of 70-75 GPa and practically the same in tension and in compression. It changes regularly with temperature from a value of 76-78 GPa at 70 K to a value of the order of 60 GPa at 500 K. The Poisson ratio is of the order of 0.32-0.34. The Poisson ratio increases with increasing temperature<sup>6-8</sup>. Many of the cast alloys and of the aluminum-copper-nickel alloys are used for high-temperature applications, where creep resistance is important<sup>9-11</sup>.

## Methodology

Casting is a probably one of the most ancient processes of manufacturing metallic components. Also with few exceptions, it is the first step in the manufacture of metallic components. The process involves in melting the metal, pouring it into a previously made mould or cavity which conforms to the shape of the desired component. Allowing the molten metal to cool and solidify in the mould and finally removing the solidified component from the mould, cleaning it and subjecting it to further treatment, if necessary. The casting technique used is die casting.

**Die casting:** It is a metal casting process that is characterized by forcing molten metal under high pressure into a mould cavity. The mould cavity is created using two hardened tool steel dies which have been machined into shape and work similarly to an injection mould during the process, most die castings are made from non ferrous metals specifically zinc, copper, aluminium, magnesium, lead, and tin based alloys<sup>12-13</sup>. Depending on the type of metal being cast, a hot- or cold-chamber machine is used. Die casting produces more castings than any other casting process. Die castings are characterized by a very good surface finish and dimensional consistency.

**Process:** Die preparation, filling, ejection, and shakeout are the four steps in traditional die casting, also known as high-pressure die casting. The dies are prepared by spraying the mould cavity with lubricant. The lubricant can helps in control the temperature of the die and it also assists in the removal of the casting. The dies are then closed and molten metal is

injected into the dies under high pressure between 10 and 175 MPa (1,500 and 25,400 psi). Once the mould cavity is filled, the pressure is maintained until the casting solidifies<sup>14-15</sup>. The dies are then opened and the shot is ejected by the ejector pins with proper lubrication. The Prepared inspected Al-Cu samples are shown in Figure 1 and 2 for conducting tensile strength, hardness and analysis of micro structures.



**Figure-1**

**Al-Cu Samples for testing of Tensile Strength**



**Figure-2**

**Al-Cu samples for Micro structure analysis**

**Results and Discussion**

The samples of Al-Cu metal matrix composite are tested and the values of tensile strength, Hardness, and % of elongation are showing in the table-1. The experimental results of Impact strength by using Izod and Charpy tests are shown in table-2.

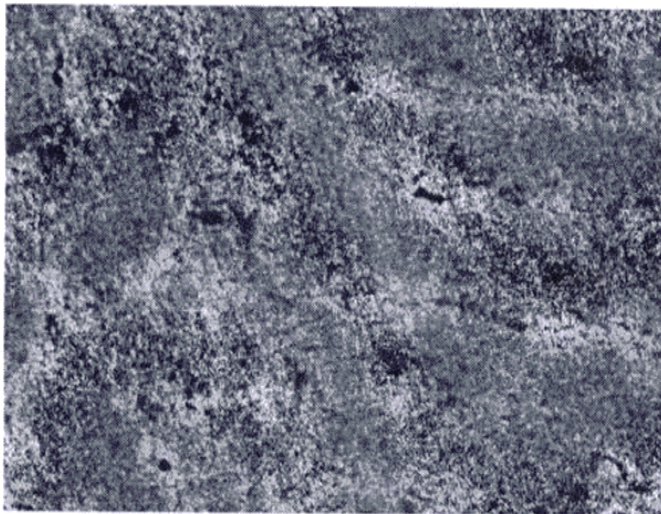
**Table-1**  
**Experimental results of samples of Al-Cu metal matrix composite**

% of aluminium	% of copper	Tensile strength N/mm <sup>2</sup>	Hardness number	% of elongation
96	4	121.45	147	10.26
94	6	129	152	14.56
92	8	131.37	157	6.02
90	10	86.57	144	4.86

**Table-2**  
**Experimental results of samples of Al-Cu metal matrix composite**

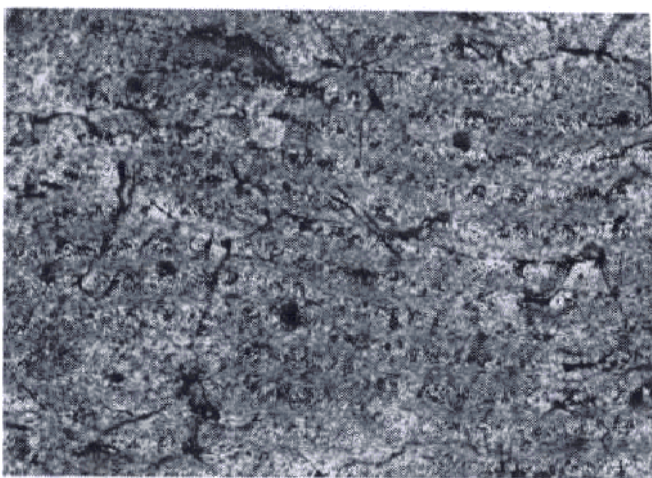
% of aluminium	% of copper	Izod impact energy joules	Charpy impact energy joules
96	4	6	3
94	6	3	8
92	8	8	10
90	10	2	4

The microstructures of Al-Cu MMC material are shown in Figures 3,4,5 and 6 and can strongly influence physical properties such as strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior, wear resistance, and so on, which in turn govern the application of these materials in industrial practice. For analysis of microstructures of Al-Cu samples, the Keller's reagent is used<sup>16, 17</sup>. The composition of Keller's reagent is 92% Distilled water 6% nitric acid and 2% hydrofluoric acid<sup>18</sup>. The graphs between varying composition with tensile strength, % elongation, impact strength by using izod and charpy tests are shown in figure 7, 8, 9 and 10.



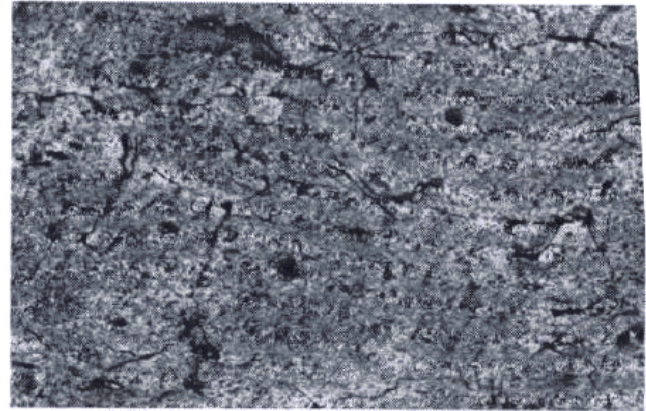
100X Keller's reagent

**Figure-3**  
 Microstructure of sample containing 4% Cu



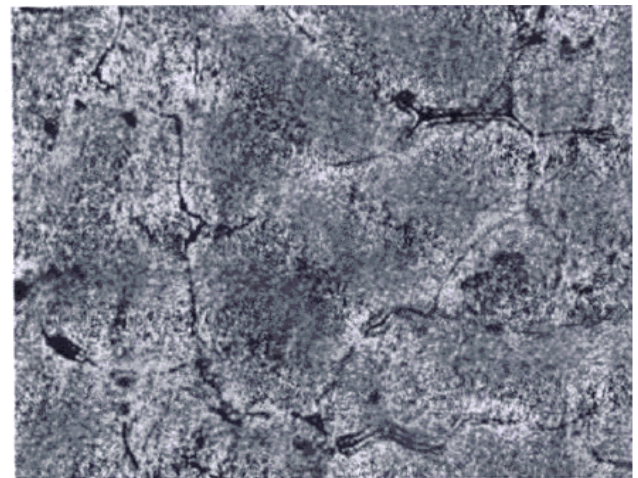
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**Figure-4**  
 Microstructure of sample containing 6% Cu



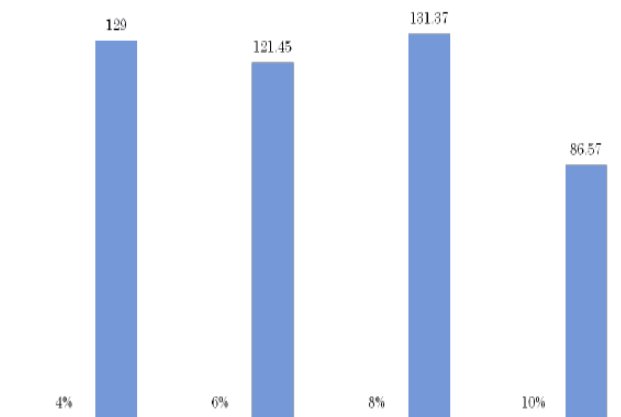
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**Figure-5**  
 Microstructure of sample containing 8% Cu

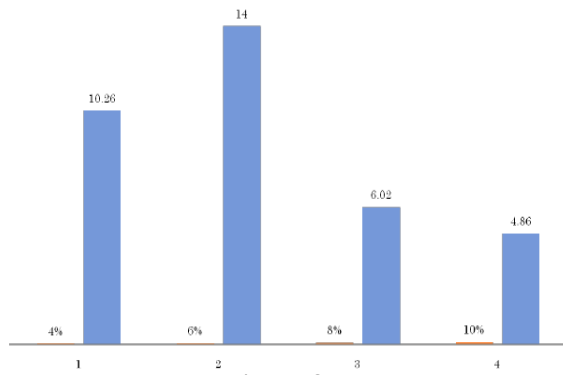


100X Keller's reagent

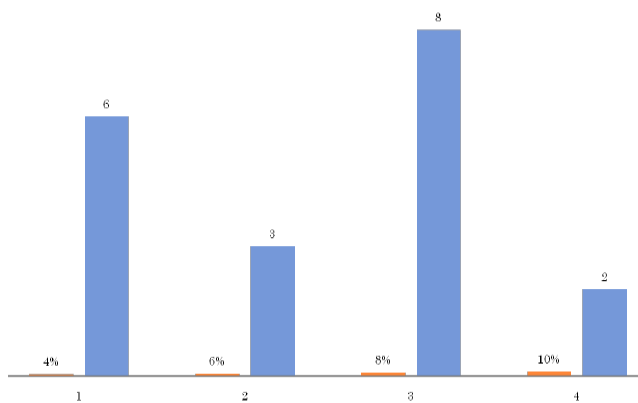
**Figure-6**  
 Microstructure of sample containing 10% Cu



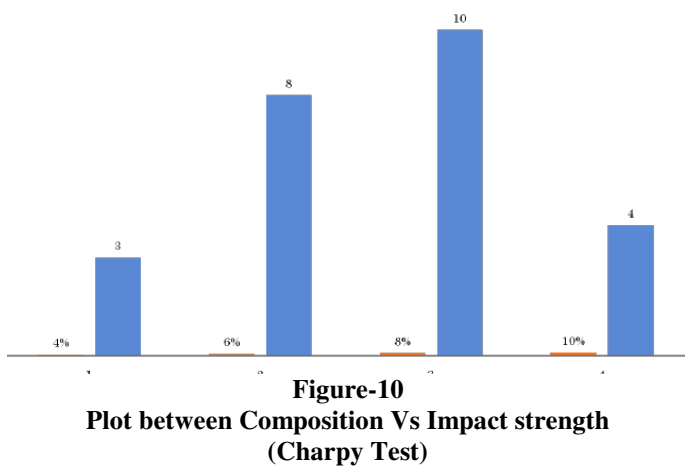
**Figure-7**  
 Plot between Composition Vs Tensile strength



**Figure-8**  
Plot between Composition Vs % Elongation



**Figure-9**  
Plot between Composition Vs Impact strength (Izod Test)



**Figure-10**  
Plot between Composition Vs Impact strength (Charpy Test)

## Conclusion

Aluminum-copper particulate composite was successfully synthesized by the Die-casting method. This may be attributed to the fact that Cu particles greatly interact with each other leading to clustering of particles and consequently settling

down. The micro structural behavior of aluminium with copper has been studied by varying mass fractions of 4%, 6%, 8%, and 10%. Micro structural observations show that the copper particulates are uniformly distributed in the Al6061 matrix. In all microstructures consist of coarse grains of aluminium solid solution with copper inter metallic particles in the grain boundaries are observed and this can influence the fracture behavior. It is observed from results that the hardness of Al alloy (6061) with Cu MMC increases with increasing wt% of copper particulate upto 8 wt% and then decreases with increasing wt% of Copper particles. The tensile strength and impact strength (by using Charpy test) of the composite increased with increase in wt% of copper particulates up to 8%.

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