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Effect of Fly ash and SiC Particulates Addition on Mechanical Properties of Al - 4.5wt.% Cu Alloy Composites

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Abstract: *In the présent investigation an attempt has been made to investigate and study the mechanical properties of of Al - 4.5wt. % Cu Alloy reinforced with Fly ash and Silicon Carbide metal matrix composites produced by stir cast technique. In this study Al - 4.5wt. % Cu Alloy was considered as the base matrix to which Fly ash and SiC particulates were used as reinforcements. 3 wt. % of SiC and 3 wt. % of Fly Ash was added to the base matrix. In the preparation of the hybrid composite the reinforcements namely Fly Ash and SiC were preheated to a temperature of 400 degree Celsius and dispersed in two steps into the vortex of molten Al-4.5 wt. % Cu alloy. To improve the wettability 0.6 wt. % of Mg was added into the molten metal. The Microstructural study was carried out using optical microscopy which resulted in uniform distribution of reinforced particles in matrix alloy. The objective was to investigate the process feasibility and the resulting mechanical properties such as ultimate tensile strength and hardness. The results indicated a significant improvement in ultimate tensile strength and hardness of the composite with the addition of Fly ash and SiC particulates in Al-Cu alloy.*
Keywords - *Al - 4.5wt.% Cu Alloy, Fly ash , Hardness, Stir Cast Technique, Ultimate Tensile Strength*

I. Introduction

Metal Matrix Composites plays a very important role in Industrial applications for lighter materials. The draw backs of problems of conventional materials made an insight research into composite materials in improving properties like good wear resistance stiffness and high specific strength. Al - 4.5 wt. % Cu alloy is an aluminium alloy with copper as the primary element. It is used in applications requiring high strength to weight ratio and good fatigue resistance. Due to its high strength and fatigue resistance Al - 4.5 wt. % Cu alloy is widely used in aircraft structures especially wing and fuselage structures under tension.

Balasubramanian et al. conducted experiments and found that upon addition of SiC particles, the resistance against indentation is increased and the resistance against tensile force is initially increased and then decreased [1]. Vijay Kumar S Maga et al. observed that increase in Fly Ash gives better result when compared with Redmud [2]

Rajendra Kumar kushwaha et al. reported that the Grain size of Al-4.5wt.%Cu alloy can be reduced by addition of 0.6% Al-3Ti-.15Cu grain refiner. Hardness of alloy was observed to increased with increase grain refiner quantity, in order to further improve the mech properties[3].

Qiurong Yang et al. found that the tensile tests, the elongation of the composite shows a sharp increase from 4.5% to 13.5% due to the adding of woven carbon fibers. Meanwhile, the tensile strength of the composite is increased slightly from 168 MPa to 202 MPa compared to that of ZL205A alloy. The good ductility of the composite is ascribed to the cracks deflection, fibers pulling out, debonding and breakage mechanisms[4].

Viney Kumar et al. found that the composite with 4%Mg, 15% Fly ash found to have maximum tensile strength whereas composite of 4%Mg, 20% Fly ash was found to be of maximum hardness. Tensile strength increase with addition of fly ash. Similarly when graphite was added the decrease in tensile and hardness was observed[5].

T. Rajmohan et al. observed that the better strength and hardness are achieved with Al/10SiC−3mica composites[6]. S.B. Hassan et al. showed that using the carbonized eggshell as reinforcement in the Al–Cu– Mg alloy gives better physical and mechanical properties as compared to uncarbonized egg shell particles. Hence addition of egg shell particles upto 12 wt.% can be used as a low cost reinforcement for the production of metal matrix composites for engineering applications[7].

V.S. Aigbodion et al. conducted found that the yield strength and ultimate tensile strength increased by 49.76% and 34.25% up to a maximum of 8 wt.% bagasse ash addition, respectively. The increases in strength and hardness values are attributed to the distribution of hard and brittle ceramic phases in the ductile metal matrix. The microstructure obtained reveals a dark ceramic and white metal phases, which resulted into increase in the dislocation density at the particles–matrix interfaces. These results show that better properties are achievable by the addition of bagasse ash to Al–Cu–Mg alloy[8].

B. Vijaya Ramnath et al. inferred that the tensile strength of Aluminium alloy is marginally higher than other two samples because of its aluminium content. But, the Aluminium alloy—95% Alumina—3% Boron carbide—2% has higher tensile strength (54.60 MPa) than Aluminium alloy—95% Alumina—2% (51.7 Pa)[9].H.CAnil Kumar et al. found that the enhancement in the mechanical properties can be well attributed to the high dislocation density. However, for composites with more than 15% weight fraction of fly ash particles, the tensile strength was seen to be decreasing[10].

T.P.D. Rajan etal. found that the maximum hardness obtained at the outer periphery after heat treatment for

Al(356)– SiC and Al (2124) – SiC are 155 BHN and 145 BHN respectively[11]. Meftah Hrairi et al. observed that the green density increased with increasing compacting pressure and decreased with increasing weight percent of fly ash particles resulting in lightweight composites[12].

S. Kumar et al conduced inferred that the Production of bio-composite specially for manufacturing of scaffolds is another field in which RP has distinct advantages over conventional techniques[13]. G.B. Veeresh Kumar et al. found that the density of the composites increase with increased SiC content and agrees with the values obtained through the rule of mixtures. The hardness and ultimate tensile strength of Al6061–SiC composites were found to increase with increased SiC content in the matrix at the cost of reduced ductility[14]

K.V. Mahendra et al. inferred that there is an increase in hardness with increase in the particulates content. The density decreases with increase in fly ash and SiC content. The tensile strength, Compression strength, and impact strength increases with increase in fly ash and SiC[17].

In the present investigation an attempt has been made to investigate and study the mechanical properties of Al - 4.5wt,% Cu Alloy reinforced with Fly ash and Silicon carbide metal matrix composites produced by stir cast technique

II. Experimental Details

A. Materials

In the present investigation Al - 4.5 wt. % Cu alloy is used as the base matrix. Fly Ash and SiC particulates are used as the reinforcement materials. Average particle size of Fly Ash and SiC were taken as 40µm. The chemical composition of Fly Ash particulates is shown in Table 1.

Table 1: Chemical composition of Fly ash in weight percentages.

Al_2O	SiO_2	Fe_2O	TiO_2	Loss on ignition
30.40	58.41	8.44	2.75	1.43

Table 2: Chemical composition of Al-Cu Alloy

Components	Wt. Percentage
Copper	4.52
Magnesium	0.05
Silicon	0.15
Iron	0.16
Manganese	0.07
Zinc	0.01
Lead	0.01
Tin	0.01
Titanium	0.01
Chromium	0.02
Al	Bal

Al - 4.5wt% Cu alloy is an aluminium wrought alloy, which belongs to 2XXX series of aluminium alloy. It is used in applications requiring high strength to weight ratio and good fatigue resistance. Due to its high strength and fatigue resistance Al-Cu alloy is widely used in aircraft structures especially wing and fuselage structures under tension. Table 2 shows the chemical composition of base matrix used in this study.

B. Methodology

In order to achieve high level of mechanical properties in the composites, a good interfacial bonding (wetting) between the dispersed phase and the liquid matrix has to be obtained. Hence the hybrid composites Al-Cu alloy-SiC-Fly Ash used in this work were prepared by liquid metallurgy technique. This liquid metallurgy technique is also known as stir casting or vortex method. This method is most economical to fabricate composites particulates. In stir casting method before the casting reinforcements, stirrer, permanent mould preheated to 400^{o}C to remove moisture and gases from the surface of the reinforcements and equipments before casting. The Al - 4.5wt%Cu alloy was melted at a temperature of 730^{o}C in a graphite crucible in induction furnace and degassing was carried out using hexa-chloroethane degassing tablet. The tablet helps in the removal of entrapped air in the melt and thus prevents casting defects like porosity and blow holes. The reinforcements were preheated prior to their addition in the aluminium alloy melt. The preheating of the reinforcement is necessary in order to reduce the temperature gradient and to improve wetting between the molten metal and the reinforcements.

The matrix Al - 4.5wt%Cu alloy was reinforced with 3 wt. % of Fly ash and 3wt. % of SiC particulates using a mechanical stirrer at 730^{o}C with constant rigorous stirring was done for 10mins and impeller speed was kept constant at

300 rpm until a clear vortex is formed. The melt with reinforced particulates was immediately poured into dried, coated, preheated cast iron mould die. The melt was then allowed to solidify in the moulds.

C. Testing of Specimens

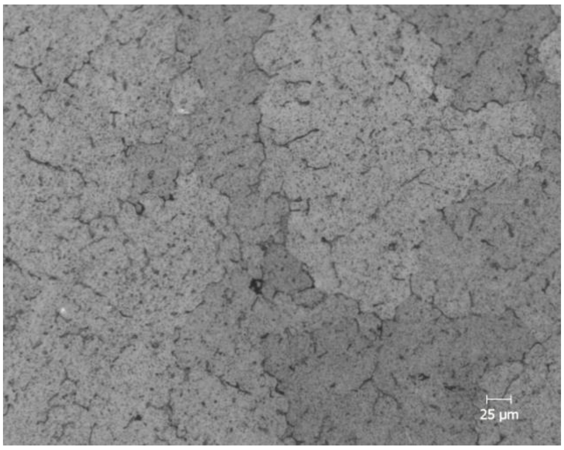
Microstructure of prepared specimen is studied by taking the central part of the composite block. The face of the specimen to be examined is prepared by polishing through 220,400, 600, 800 & 1000 grit emery papers and polished using diamond paste. The specimen is etched using Keller's reagent before it is examined using optical microscopy. Specimen for hardness test and tensile test are prepared as per ASTM standards. Hardness test is done on the polished surface of the specimen using Brinnel hardness testing machine consisting of ball indenter of 5mm and with the application of 187.5 kgf . Tensile test is done using computerized universal testing machine as per ASTM standards and four specimens are tested for each composition of composite.

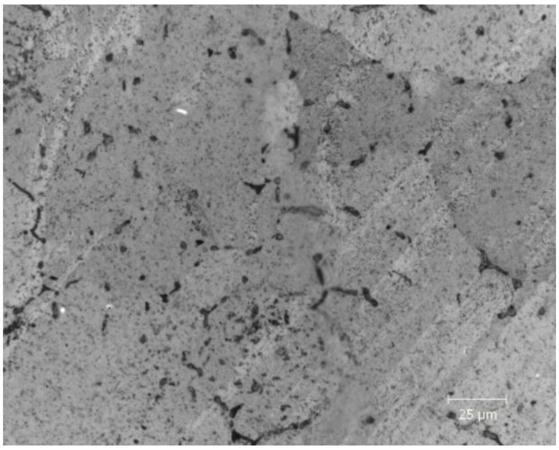
III. Results And Discussion

A. Microstructural Analysis

For the microstructure examine of the composites, the casted samples were ground using abrasive silicon carbide paper of different grit sizes. After every polishing the samples were thoroughly washed, dried and polished on velvet cloth. The polished specimen is electro-etched with recommended etching reagents called Keller's reagent. This highly polished surface was observed and microstructure viewed under optical microscope and captured for micro photographs.

Fig. 1 (a-b) shows the optical microphotographs of Al - 4.5wt%Cu as cast alloy and Al - 4.5wt% with 3 wt. % of Fly ash and 3wt. % of SiC particulate composites. This reveals the uniform distribution of SiC and Fly ash particles and very low agglomeration and segregation of particles, and porosity. The vortex generated in the stirring process breaks solid dendrites due to higher friction between particles and Al matrix alloy, which further induces a uniform distribution of particles.





(a) **(b)**

Fig. 1: Optical microphotographs of (a) as cast Al - 4.5wt%Cu alloy (b) Al - 4.5wt%Cu-Fly ash and SiC Composite

A. Hardness

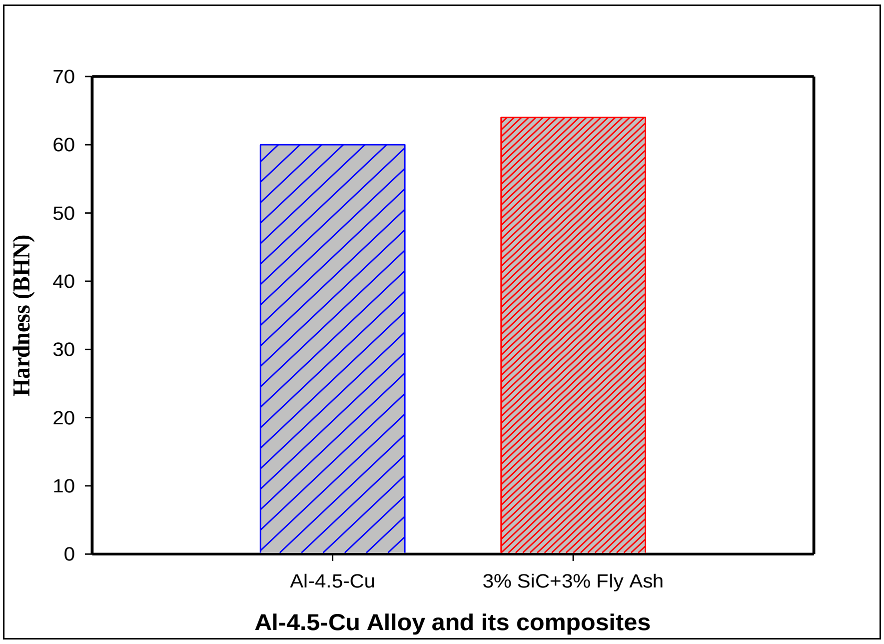


Fig. 2: Shows hardness of as cast Al - 4.5wt%Cu alloy and its composites

The hardness measurements on Al - 4.5wt%Cu-SiC-Fly ash hybrid composites are shown in fig. 2. The hardness of cast Al - 4.5wt%alloy and Al - 4.5wt%Cu -SiC-Fly ash composites containing 3 wt. % each are evaluated using ball indenter at an applied load of 187.5 kgf with dwell time 15 secs for each sample at different locations. It can be observed that the hardness of the composite is greater than that of its cast matrix.. since the SiC particles being hard dispersoids contribute positively to the hardness of the composite. The increase in hardness is attributed to the hard SiC particles which act as a barrier to the movement of dislocation within the matrix. This dispersion-strengthening effect is expected to be retained even at elevated temperatures and for extended time periods because the particles are not reactive with the matrix phase. The results obtained and the observations made are consistent with the results of other workers. Increased in the hardness of composites reinforced with hard particles has been reported by several workers [15,16].

B. Ultimate Tensile Strength

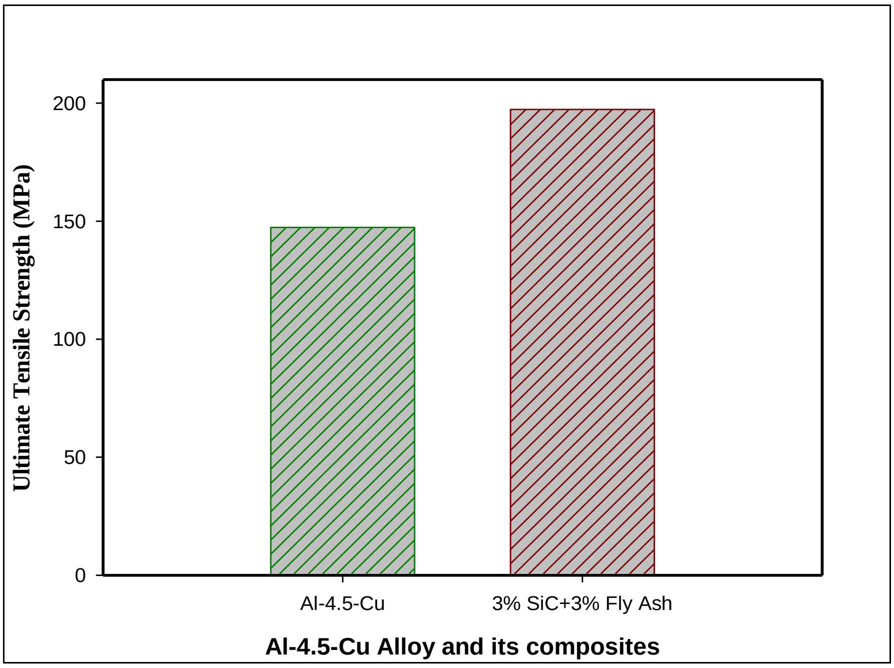


Fig. 3: Shows ultimate tensile strength of as cast Al - 4.5wt%Cu alloy and its composites

Fig. 3 shows the ultimate tensile strength (UTS) of the composite is higher than that of the matrix alloy. The improvement in tensile strength of the composites may be attributed to the fact that the filler SiC and Fly ash possesses higher strength due to the better bonding and uniform dispersion of SiC and Fly ash particulates in base matrix. In the present case, the increase in UTS of the composites specimen is obviously due to the presence of hard SiC particles which impart strength to the matrix alloy, imparting more resistance to the composite against the applied tensile stresses. The strength properties of the metallic materials primarily depend on the microstructural ability of the alloy to resist displacement motion. The observed improvement in tensile strength of the composite is attributed to the fact that the reinforcement fly ash possess higher strength Increased in the hardness of composites reinforced with hard particles has been reported by several workers [10]. Increase in strength by a resisting displacement can be achieved by various mechanisms like inclusion or dispersion of reinforcing particles in the alloy. Further the effect of SiC on tensile strength in the present work also shows the increase in the ultimate tensile strength. This increase in UTS may be due to the SiC particles acting as barriers to dislocation in the microstructure.

IV. Conclusions

The existing work on Fly ash and SiC particulates reinforced Al - 4.5wt% Cu Alloy by two step addition using Stir Cast technique has led to the following conclusions.

- Fly ash and SiC particulate reinforced Al - 4.5wt% Cu alloy by 3wt. % of Fly ash and SiC were successfully produced by two stage additions.
- Two stage reinforcements addition method adopted for Fly ash and SiC particulates during melt stirring produced in uniform distribution of Fly ash and SiC with no agglomeration as shown in optical micro photographs.
- The hardness of the composite was found to be higher than the base matrix Al - 4.5wt% Cu alloy.
- Ultimate Tensile Strength (UTS) of Al - 4.5wt%Cu -3 wt. % Fly ash -3 wt. SiC composites were found to be higher than base matrix Al - 4.5wt%Cu alloy.
- The improvement obtained in UTS of Al - 4.5wt%Cu alloy after insertion of 3 wt. % Fly ash and 3wt. % SiC particulates were 25.33% as compared to the base alloy.

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