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MECHANICAL PROPERTIES OF FLY ASH REINFORCED ALUMINIUM ALLOY (Al6061) COMPOSITES

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ABSTRACT

The results of an experimental investigation of the mechanical properties of fly ash reinforced aluminium alloy (Al 6061) composites samples, processed by stir casting route are reported in this paper. Three sets of composites with fly ash particle sizes of 4-25, 45-50 and 75-100 µm were used. The particle size ranges chosen as the said particle sizes were available more by weight fraction when sieve analysis was conducted on the sample collected for experiments and also the ones for which results are not reported. Each set had three types of composite samples with the reinforcement weight fractions of 10, 15 and 20%. The mechanical properties studied were the tensile strength, compressive strength, ductility and hardness. Unreinforced Al6061 samples were also tested for the same properties. It was found that the tensile strength, compressive strength and hardness of the aluminium alloy (Al 6061) composites decreased with the increase in particle size of reinforced fly ash. Increase in the weight fractions of the fly ash particles increases the ultimate tensile strength, compressive strength, hardness and decreases the ductility of the composite. The scanning electron micrographs of the samples indicated uniform distribution of the fly ash particles in the matrix without any voids.

Keywords: Aluminium alloy (Al6061), Fly ash, Mechanical properties.

1. INTRODUCTION

Metal matrix composites (MMCs) are the forerunners amongst different classes of composites. Over the past two decades metal matrix composites (MMCs) have been transformed from a topic of scientific and intellectual interest to a material of broad technological and commercial significance (Miracle, 2005). MMCs offer a unique balance of physical and mechanical properties. Aluminium based MMCs have received increasing attention in recent decades as engineering materials with most of them possessing the advantages of high strength, hardness and wear resistance. The stir casting method is widely used among the different processing techniques available. Stir casting usually involves prolonged liquid-reinforcement contact, which can cause substantial interface reaction (Sahin, 2003). Charles et al. (2004) studied the properties of aluminium alloy hybrid (Al-alloy/Silicon carbide (SiC)/fly ash) composites. They reported that the wear and hardness were enhanced on increasing the volume fraction of SiC. They also reported that the tensile strength was high at 10 volume fraction of SiC and decreased as the volume fraction increased. Basavarajappa et al. (2004) investigated the mechanical properties of aluminum alloy (Al2024) reinforced with SiC and graphite particles. Their results revealed that the mechanical properties such as ultimate tensile strength, yield strength, hardness and compressive strength of the composite increased predominantly with the increase in volume fraction of reinforcement. Mahendra et al. (2007) investigated the properties of Al-4.5% Cu alloy composite with fly ash as reinforcement. They reported the increase in hardness, tensile strength, compression strength and impact strength with increase in the fly ash content. Sudarshan et al. (2008) studied characterization of A356 Al - fly ash particle composites with fly ash particles of narrow range(53-106µm) and wide size range(0.5-400 µm) and reported that addition of fly ash lead to increase in hardness, elastic modulus and 0.2% proof stress. They also concluded that composites with narrow size range fly ash particle exhibit superior mechanical properties compared to composites with wide size range fly ash particles. Mahagundappa M.Benal et al. (2006) have studied the influence of reinforcement and thermal aging on the mechanical properties of Al 6061 based hybrid composites, and concluded that the ultimate tensile strength, compression strength, young’s modulus and hardness increases with increasing the reinforcement content but the ductility decreases substantially. And all these things also increase with increase in the aging duration with the marginal improvement in the ductility which may be due to the formation of precipitate in matrix alloy. Hayrettin Ahlatci et al. (2004) investigated the mechanical properties of Aluminium Silicon with 60 volume % SiC composites and concluded that as amount of Si increased up to 1%, the strength of composites increased without significant loss in toughness after which the strength showed a decline with further in crease in Si content. Hebbar et al. (2008) studied the mechanical properties of Silicon

Carbide particle reinforced Alluminium alloy (AA2024) composites and found that tensile strength, tensile modulus, hardness, impact strength decreased with the reinforcement of SiCp. Wu et al. (1996) studied the mechanical properties of monolithic Alluminium with 12 weight % of silicon and found that ultimate tensile strength is improved considerably by the addition of low volume fraction (3-7%) of aluminosilicate short fibres. Veereshkumar et al. (2009) investigated the mechanical properties of Al6061-Al_2O_3 and Al7075- SiC composites and reported that brinnel hardness of the composites were found to be increased with increase in filler content in the composites, the dispersion of Al_2O_3 in Al6061 and SiC in Al7075 alloy confirmed enhancement of the mechanical properties. Unlu, (2008) studied the properties of Al based Al_2O_3 and SiC particle reinforced composite materials and found that mechanical properties like hardness of the composites significantly improved by the use of reinforcements. Wahab, et al. (2009) studied the characterization of aluminum metal matrix composites reinforced with aluminum nitride and found that hardness was 44 Hv for Al-Si matrix and increased to 89 Hv for an Al-Si composite reinforced with 5% wt.% AlN powder. The higher values in hardness indicated that the AlN particles contributed to the increase of hardness of the matrix (Wahab et al., 2009).

From the above literature review, it can be concluded that in order to study the influence of the particle size of fly ash as reinforcement on the aluminium alloy (Al6061) composite and to study its effect on mechanical properties different sizes of fly ash have been selected in the present study. Even though some of earlier investigations showed that the mechanical properties will be enhanced with increase in particle size, but a systematic study has not been carried out. Hence an attempt is made to the influence of these parameters on the various properties so as to explore it as an interesting and useful engineering material.

2. EXPERIMENTAL PROCEDURE

2.1. Specimen Preparation

Fly ash reinforced Aluminium alloy (Al6061) composites, processed by stir casting route was used in this work. The three types of stir cast composites had a reinforcement particle size of 4-25, 45-50 and 75-100 µm each. The required quantities of fly ash (10, 15 and 20 Wt. %) were taken in powder containers. Then the fly ash was heated to 450°C and maintained at that temperature for about 20 min. then weighed quantity of Al (6061) alloy was melted in a crucible at 800°C which is more than 100°C above liquidus temperature of the matrix alloy. The molten metal was stirred to create a vortex and the weighed quantity of preheated fly ash particles were slowly added to the molten alloy. A small amount of Mg (0.5 wt. %) was added to ensure good wettability of particles with molten metal. After mixing the melt was poured into a prepared mould for the preparation of specimen.

Table 1 shows the chemical composition of the Al (6061) and Table 2 shows the major chemical composition of the Fly ash particle.

Table 1 Chemical compositions of Al (6061) alloy (Weight Percentage)

Mg	Si	Fe	Cu	Ti	Cr	Zn	Mn	Al
.90	.75	.25	.22	.09	.10	.05	.04	Bal

Table 2 Chemical composition of Fly ash (Weight Percentage)

Al_2O_3	SiO_2	Fe_2O_3	TiO_2	Loss of Ignition
28.44	59.96	8.85	2.75	1.43

2.2. Testing for Mechanical Properties

The tensile tests were conducted on these samples according to ASTM E8-95 at room temperature, using a universal testing machine (INSTRON). The specimens used were of diameter 12.5mm and Gauge length 62.5 mm, machined from the cast composites with the gauge length of the specimen parallel to the longitudinal axis of the castings. The compression tests were conducted as per ASTM-E9-95.The specimens used were of diameter 15mm and length 20 mm machined from cast composites. The Brinnel hardness tests were conducted in accordance with the ASTM E10.

3. RESULTS AND DISCUSSION

As the microstructure plays an important role in the overall performance of a composite and the physical properties depend on the microstructure, reinforcement particle size, shape and distribution in the alloy, prepared samples were examined using a Scanning Electron Microscope (SEM) to study the distribution pattern of fly ash in the matrix. The micrographs shown in Figure 1 (a) and (b) depict the microstructure of as cast Al6061 and fly ash reinforced Al6061.

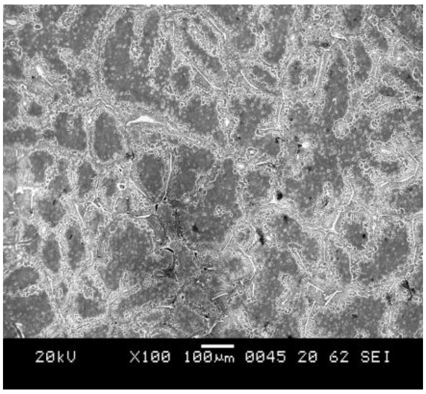

Figure 1(a) Microstructure of Al 6061

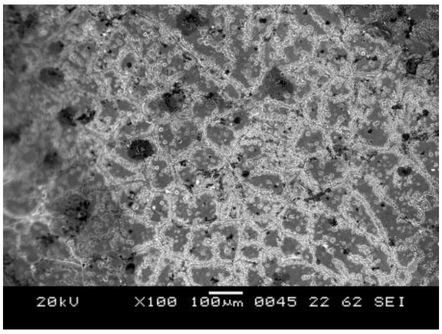

Figure1 (b) i. Microstructure of Al 6061 with 10% weight fraction of fly ash (4-25 micron)

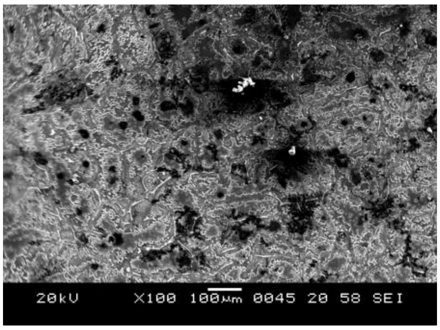

Figure 1(b) ii. Microstructure of Al 6061 with 15% weight fraction of fly ash (4-25 micron)

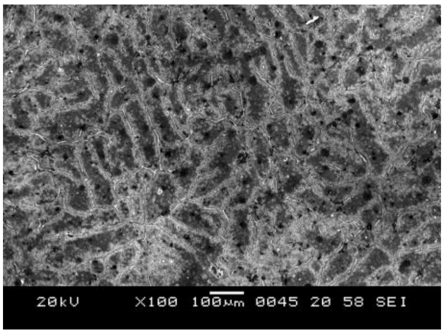

Figure 1(b) iii. Microstructure of Al 6061 with 20% weight fraction of fly ash (4-25 micron)

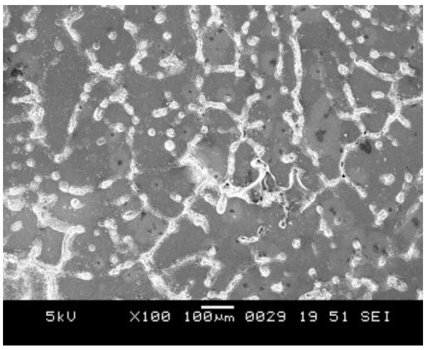

Figure1 (b) iv. Microstructure of Al 6061 with 10% weight fraction of fly ash (45-50 micron)

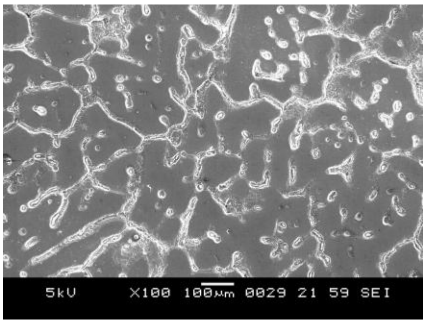

Figure 1(b) v. Microstructure of Al 6061 with 15% weight fraction of fly ash (45-50 micron)

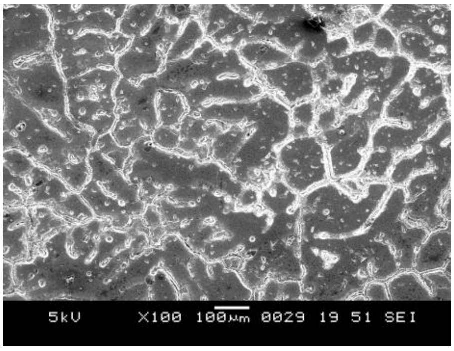

Figure 1(b) vi. Microstructure of Al 6061 with 20% weight fraction of fly ash (45-50 micron)

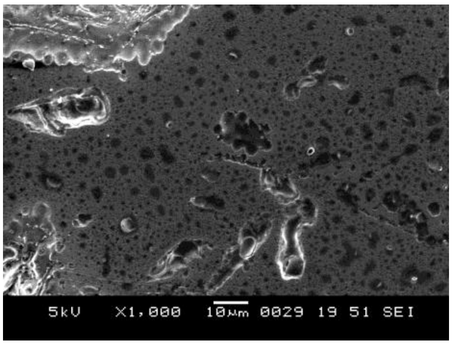

Figure 1(b) vii. Microstructure of Al 6061 with 10% weight fraction of fly ash (75-100 micron)

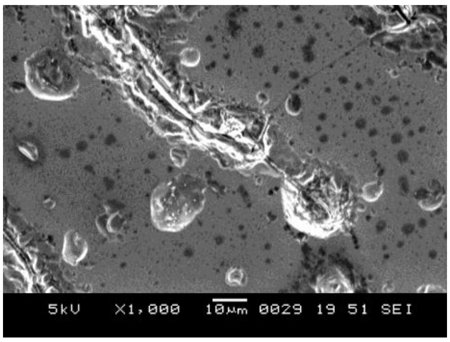

Figure 1(b) viii. Microstructure of Al 6061with 15% weight fraction of fly ash (75-100 micron)

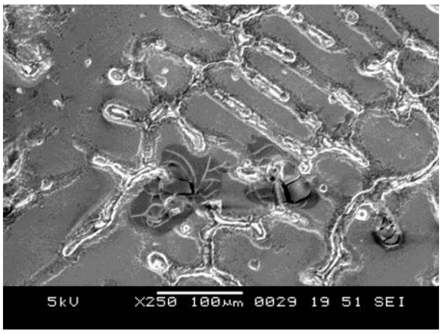

Figure 1(b) ix. Microstructure of Al 6061 with 20% weight fraction of fly ash (75-100 micron)

A uniform distribution of fly ash particles without voids and discontinuities can be observed from these micrographs. It was also found that there was good bonding between matrix material and fly ash particles; however no gap is observed between the particle and matrix.

3.1. Tensile Properties

Figure 2 shows the variation of tensile strength of the composites with the different weight fractions of fly ash particles. It can be noted that the tensile strength increased with an increase in the weight percentage of fly ash. Therefore the fly ash particles act as barriers to the dislocations when taking up the load applied (Basavarajappa et al., 2004; Seah et al. 1995). The hard fly ash particles obstruct the advancing dislocation front, thereby strengthening the matrix (Suresh et al., 2003). However, as the size of the fly ash particles increased, there was decrease in tensile strength. Good bonding of smaller size fly ash particles with the matrix is the reason for this behavior. The observed improvement in tensile strength of the composite is attributed to the fact that the filler fly ash posses higher strength. The decrease in the tensile strength of the samples with fly ash weight fraction beyond 15 % is due to the poor wettability of the reinforcement with the matrix.

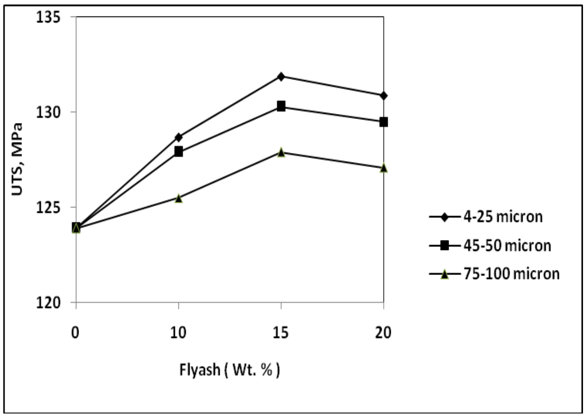

Figure 2 Variation of tensile strength with the weight fraction of fly ash.

3.2. Compressive Strength

From the Fig. 3, it can be observed that the compressive strength increased with an increase in the weight percentage of fly ash particles. This is due to the hardening of the base alloy by fly ash particles (Mahendra and Radhakrishna, 2007). The decrease in compressive strength was observed as the size of the fly ash particles increased.

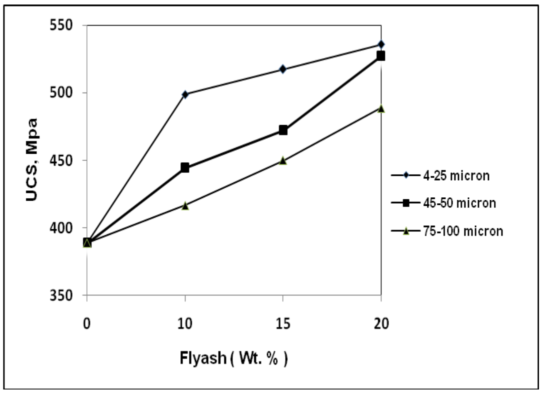

Figure 3 Variation of compressive strength with the weight fraction of fly ash.

3.3. Hardness

From Fig. 4, it can be noted that the hardness of the composite increased with the increase in weight fraction of the fly ash particles. Thus the hard fly ash particles help in increasing the hardness of the aluminium alloy (Al6061) matrix (Mahendra and Radhakrishna, 2007).

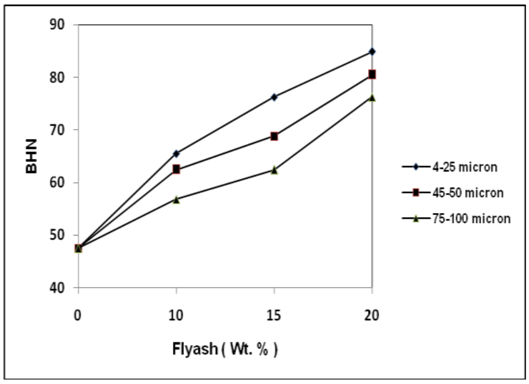

Figure 4 Variation of hardness with the weight fraction of fly ash.

3.4. Ductility

Fig.5 shows that the ductility of the composite decreased with the increase in weight fraction of the fly ash. This is due to the hardness of the fly ash particles or clustering of the particles. The various factors including particle size, weight percent of reinforcement affect the percent elongation of the composites even in defect free composites (Sudarshan and Surappa, 2008).

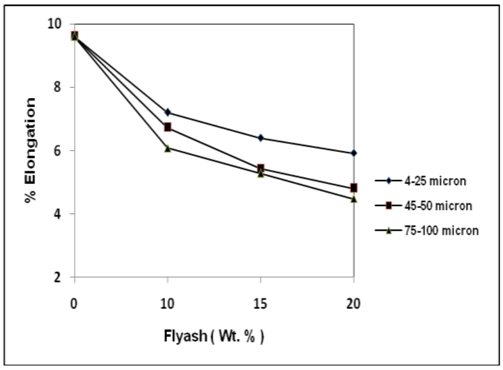

Figure 5 Effect of the weight fraction of fly ash on Hardness

4. CONCLUSIONS

The stir casting method used to prepare the composites could produce uniform distribution of the reinforced fly ash particles. The Tensile Strength, Compression Strength and Hardness increased with the increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. The ductility of the composite decreased with increase in the weight fraction of reinforced fly ash and decreased with increase in particle size of the fly ash. 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.

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