EFFECT OF ADDITION OF FLY ASH AND GRAPHITE PARTICULATES ON THE MECHANICAL BEHAVIOR OF Al-7Si ALLOY HYBRID COMPOSITES

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ABSTRACT

Hybrid metal matrix composites are considered as advanced materials in the field of automotive, marine and several industrial applications. In the present work, investigations have been made on effect of dual particulates addition on the mechanical behaviour of Al-7Si alloy. Fly ash and graphite particulates were used as the reinforcements in the Al-7Si alloy base matrix. Hybrid composites were prepared by using liquid melt method, keeping 3 wt. % of fly ash constant and varying graphite in steps of 3, 5 and 7 wt. % in the Al-7Si alloy. Samples were tested for microstructural characterization by using scanning electron microscope, energy dispersive spectroscope and X-Ray diffraction. Mechanical behaviour like hardness, ultimate tensile strength and yield strength were evaluated as per ASTM standards. Scanning electron micro photographs revealed the uniform distribution of fly ash and graphite particulates in the Al-7Si alloy and confirmed by EDS analysis and XRD patterns. Further, hardness and tensile properties of base matrix Al-7Si alloy was enhanced with the addition of fly ash and graphite particulates.

KEYWORDS: Al-7Si Alloy, Fly Ash, Graphite, Melt Stirring & Mechanical Behaviour

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INTRODUCTION

In recent years, micro particle fortified metal matrix composites (MMC's) have increased wide acknowledgment on account of their fascinating properties [1]. The concentration of innovative work in the (MMC) zone has as of late moved towards minimal effort strengthened composites which are focused for automotive and aviation applications [2]. MMC are one of the vital and broadly known composites in light of their extensive assortment of properties offered in joining numerous conceivable materials and fortifications, which enables changing material properties to meet particular prerequisites [3]. All things considered and contrasted with un-strengthened materials, hybrid composites have fundamentally enhanced properties including high specific strength, specific modulus, damping limit, hardness, great wear protection, low co-productive of warm extension, high warm protection, erosion protection and furthermore high quality to weight ratio, light weight, ease of fabrication [4]. Mainstream fortification materials for these composites are silicon carbide, alumina, boron carbide, titanium carbide, and graphite particles; while, aluminium, titanium and magnesium are the most widely recognized matrix materials.

Among MMCs, aluminium metal matrix composites (AMMCs) have got specific consideration in the previous three decades, because of their high strength quality and stiffness and prevalent wear protection [5]. There are a few fabrication strategies accessible to deliver AMC materials yet there is no one of a kind course in this.

Because of the decision of material and types of fortifications, creation procedures can change. For the most part there are two types of manufacture strategies accessible

- Solid stage creation technique incorporates dispersion holding, extrusion, drawing, hot rolling, powdered metallurgy course.
- Liquid stage manufacture technique incorporates fluid metal penetration, stir casting, compo process, and pressure casting [6].

Stir casting is generally accepted promising route because of its simplicity, flexibility, and applicability to large quantity production.

A few looks into assessed the different properties of aluminium metal composites to know the impact of particles on base matrix. Babu Rao et al. [7] found that there was a uniform appropriation of fly ash particles in the matrix phase and furthermore great bonding amongst lattice and fly ash particles. The hardness of the composites increased whereas the density of the composites decreased with increasing the amount of fly ash than the aluminium. Upgraded mechanical properties were seen with increasing amount of fly ash under pressure.

Mahendra et al. [8] inferred that AMMC's containing up to 15% fly ash and SiC particles could be easily created. Uniform distribution of fly ash was seen in the composite. The fluidity and density of AMMC's decreases, and hardness enhanced with increment in level of particulates. The rigidity, compression strength, and impact strength increases with increase in percentage of particulates. Venkat Prasat et al. [9] observed that the adding fly ash particles in aluminium compound have the potential for preserving vitality soft aluminium. As closed from numerous past research examines, the reinforcing of aluminium combinations with a dispersion of fine ceramic particulates, (for example, fly ash particles) firmly enhanced their potential in wear protection and auxiliary applications.

Jinfeng Leng et al. [10] reported the machinability of SiC-graphite hybrid composites and their results revealed that the presence of graphite particle acted as solid lubrication and promoted chip formation during cutting resulting in improved machinability. Swami et al. [11] conducted by varying particulate from 0 to 4 wt. % and found that when the graphite content was increased there were significant reduction in hardness and monotonic increase in the ductility, ultimate tensile strength.

It has been found that in many previous researches, aluminium alloys dispersed with graphite particles are known as potential materials for many applications such as bearings, bushings, pistons, etc., because they offer good resistance to wear [12]

The primary aim of the present work is to fabricate Al-7Si aluminium based matrix composites reinforced with fly ash and graphite particulate, obtained by stir casting method at a temperature of 760°C. During composites preparation, magnesium added to enhance the wetting property and better bonding. The composites thus obtained were characterized for their microstructural and mechanical properties.

EXPERIMENTAL DETAILS

Matrix Material

In the present study, Al-7Si is used as the matrix material; most of the applications in areas such as aerospace, automobile, marine make use of A300 series, aluminium silicon series alloys, and particularly hypoeutectic alloys. A356 normally has 7% silicon, 0.35% magnesium. The silicon gives good fluidity when casting and reduce overall weight of the cast. The magnesium provides strength (through heat treatment) while maintaining reasonable ductility. The theoretical density of Al-7Si is taken as 2.67 g/cm^3 .

Table 1: Chemical Composition of Al-7 Si Alloy

Element	Si	Cu	Mg	Mn	Fe	Zn	Ni	Ti	Al
Wt. (%)	7.20	0.02	0.29	0.01	0.18	0.01	0.02	0.11	Balance

Reinforcement Material

In the present work, Fly ash and graphite particulates are used as the reinforcement materials. In present work, 1-10 μm Fly ash particulates (power station Fly ash) were used procured from (NTPC, Raichur). Here, Fly ash is a precipitator with density 2.3 g/cm^3 .

Table 2: Primary Components of PSFA

Elements	SiO ₂	SO ₃	Al ₂ O ₃	Fe ₂ O ₃	MgO	CaO	Na ₂ O	K ₂ O	TiO ₂
Concentration %	56.60	2.22	22.26	8.14	1.17	12.14	1.00	0.90	1.61

Graphite is a mineral made of the element 'carbon.' Graphite has the same chemical composition as diamond which is also a pure carbon. Graphite density is low 2.16 g/cm^3 and is lower than the base matrix Al-7Si alloy 2.67 g/cm^3 . In the present work, 5-15 μm graphite particulates were used, procured from S D Fine Chemical Ltd., Mumbai, India.

Preparation of Hybrid Composites

Hybrid metal matrix composites are considered as advanced materials in the field of automotive, marine, and several industrial applications. In the present work, investigations have been made on effect of dual particulates addition on the mechanical behaviour of Al-7 Si alloy. Fly ash and graphite particulates were used as the reinforcement in the Al-7 Si alloy base matrix. Hybrid composites were produced by simplest and most economical used technique known as stir casting technique or Vortex technique. As per ASTM standards casting procedure, Al-7Si is heated to the temperature of 760°C in electrical resistance furnace. Thermocouple is used to check the temperature of the melt in the graphite crucible. At around 750°C , powder of hexa-chloroethane (C_2Cl_6) is added to the melt to remove all the unwanted trapped gasses and thus prevents casting defects like blow holes and porosity. Next, magnesium was added to decrease the surface tension and viscosity of the melt. The required quantities of preheated Fly ash (3 wt.% fixed) and graphite (3, 5, and 7 wt.%) were taken in separate containers and added to Al-7 Si melt with continuous stirring for about 10 minutes at 250-300 rpm. by Zirconium-coated stirrer until a clear Vortex is formed leading to good bonding, increase in the wettability between matrix and reinforced particles and to avoid agglomeration aimed at obtaining uniform homogenous distribution of reinforced particulates in the melt.

After mixing of the reinforcement particulates, the temperature of the melt reduced and started to solidify, following which the melt was superheated above the liquid temperature with continued stirring and finally poured into permanent mould made of cast iron and allowed to solidify. After complete solidification, the casting is removed from the

mould. Composites thus prepared were machined according to the ASTM standards. Now, the hybrid composite samples were subjected to various tests. Samples were tested for microstructural characterization by using Scanning Electron Microscope (SEM), Energy Dispersive Spectroscopy (EDS) and X-ray Diffraction (XRD). Mechanical behaviour like hardness, ultimate tensile strength and yield strength were evaluated as per ASTM standards.

RESULTS AND DISCUSSIONS

Microstructural Studies

Figure 1 (a) - (d) shows the SEM micrographs of Al-7Si alloy, Al-7Si-3% Fly ash - 3% graphite (Figure 1b), Al-7Si-3% Fly ash - 5% graphite (Figure 1c) and Al-7Si-3% Fly ash - 7% graphite (Figure 1d) composites. This reveals the uniform distribution of fly ash and graphite particles in Al-7Si base matrix and very low agglomeration and segregation of particles. The vortex generated in the stirring process breaks solid dendrites due to higher friction between particles and Al matrix alloy, which further induces uniform distribution of particles.

Figure 1: Scanning Electron Micrographs of (a) Al-7Si Alloy (b) Al-7Si -3% Fly Ash - 3% Graphite (c) Al-7Si -3% Fly Ash - 5% Graphite (d) Al-7Si -3% Fly Ash - 7% Graphite Composites

Figure 2 (a) – (c) are energy dispersive X-Ray spectrographs of Al-7Si-3% Fly ash - 3% graphite (Figure 2a), Al-7Si-3% Fly ash - 5% graphite (Figure 2b) and Al-7Si-3% Fly ash - 7% graphite (Figure 2c) composites respectively.

(a)

(b)

(c)

Figure 2: Energy Dispersive Spectrographs of (a) Al-7Si -3% Fly Ash - 3% Graphite (b)Al-7Si -3% Fly Ash - 5% Graphite (c) Al-7Si -3% Fly Ash - 7% Graphite Composite

The EDS analysis confirmed the presence of Al, Si, O, Fe and C in the Al matrix alloy. Fly ash contents O, Fe, K and C as the major elements, which is confirmed. Further, graphite is an allotropic form of carbon (C), which is confirmed by EDS analysis from the Figure 2 a-c.

Hardness Measurements

Figure 3: Hardness of Al-7Si-Fly Ash and Graphite Reinforced Hybrid Composites

Figure 3 shows the effect of fly ash and graphite particulates on the hardness of Al-7Si alloy. From the graphs, it is noted that Fly ash and graphite reinforced composites showed more hardness strength as compared to the Al-7Si base matrix. Further, as weight percentage of graphite increases from 3 to 7 %, in Al-7Si-3% Fly ash composites, it is observed that hardness increased from 62 BHN to 71BHN. This increase in hardness is mainly due to the presence of Fly ash and graphite particulates in the matrix. These particulates act as the barrier for dislocations.

From the plots, it is also revealed the specimens prepared from 25mm diameter castings shown more hardness values as compared to 50 and 75 mm diameter castings. This strength increase in 25 mm diameter castings is mainly due to the solidification process. Specimens prepared from the smaller diameter dies shown more rapid cooling as compared to the bigger diameter dies. So, this cooling effect plays major role to enhance the strength of the composites.

Ultimate Tensile and Yield Strength

Figure 4: UTS of Al-7Si-Fly Ash and Graphite Reinforced Hybrid Composites

Figure 5: YS of Al-7Si-Fly Ash and Graphite Reinforced Hybrid Composites

Figure 5 showing the effect of fly ash and graphite particulates on the tensile behaviour of Al-7Si alloy. From the graphs, it is noted that Fly ash and graphite reinforced composites showed more ultimate and yield strength as compared to the Al-7Si base matrix. Further, as weight percentage of graphite increases from 3 to 7 %, in Al-7Si-3% Fly ash composites, it is observed that UTS increased from 167 MPa to 181.5 MPa, for base alloy it is found that 161 MPa. This increase in UTS and YS is mainly due to the presence of Fly ash and graphite particulates in the matrix. These particulates act as the barrier for dislocations [13].

From the plots, it is also revealed the specimens prepared from 25mm diameter castings shown more UTS and YS values as compared to 50 and 75 mm diameter castings. This strength increase in 25 mm diameter castings is mainly due to the solidification process. Specimens prepared from the smaller diameter dies shown more rapid cooling as compared to the bigger diameter dies. So, this cooling effect plays major role to enhance the strength of the composites.

CONCLUSIONS

The present work entitled, “Investigations on Mechanical Behaviour of Fly ash and Graphite Particulates reinforced Al7Si alloy hybrid composites.” has led to the following conclusions:

- The liquid metallurgy technique was successfully adopted in the preparation of hybrid composites by taking 3 wt. % of Fly ash constant and varying graphite content in steps of 3, 5 and 7 wt. %.
- The micro structural studies from scanning micro photographs revealed the uniform distribution of the Fly ash and graphite particulates in the Al-7Si alloy matrix.
- The Energy Dispersive (EDS) analysis revealed the presence of Fly ash particles in Al-7Si-Fly ash and graphite composites.
- Further, in the case of hybrid composites i.e. Al-7Si-3% Fly ash & 3% graphite composites shown more hardness as compared to the Al-7Si-3% Fly ash & 5% graphite and Al-7Si-3% Fly ash & 7% graphite reinforced composites.

- Both UTS and YS values are increased as the weight percentage of graphite increased in steps of 3, 5 and 7 wt. % in Al-7Si-3% Fly ash composites.
- Further, it is observed that specimens prepared from 25mm diameter castings shown more UTS and YS as compared to the 50mm and 75mm diameter castings.

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