Investigations on Mechanical Behaviour of Micro Graphite Particulates Reinforced Al-7Si Alloy Composites

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Abstract. Micro particulates reinforced metal matrix composites are finding wide range of applications in automotive and sports equipment manufacturing industries. In the present study, an attempt has been made to develop Al-7Si-micro graphite particulates reinforced composites by using liquid melt method. 3 and 6 wt. % of micro graphite particulates were added to the Al-7Si base matrix. Microstructural characterization was done by using scanning electron microscope and energy dispersive spectroscope. Mechanical behaviour of Al-7Si-3 and 6 wt. % composites were evaluated as per ASTM standards. Scanning electron micrographs revealed the uniform distribution of micro graphite particulates in the Al-7Si alloy matrix. EDS analysis confirmed the presence of B and C elements in graphite reinforced composites. Further, it was noted that ultimate tensile and yield strength of Al-7Si alloy increased with the addition of 3 and 6wt. % of graphite particulates. Hardness of graphite reinforced composites was lesser than the base matrix.

1. Introduction
A composite material is a material framework made out of an appropriately orchestrated blend or mix of at least two nano, miniaturized scale or full scale constituents with an interface isolating them that contrast in shape and synthetic structure and are basically insoluble in each other [1]. The discrete constituents are known as the support and the persistent stage is known as the framework. As per the substance idea of the lattice stage, composites are named Metal Matrix (MMC), Polymer Matrix (PMC) and Ceramic Matrix Composites (CMC). MMCs when all is said in done comprise of no less than two segments, to be specific lattice and the support. The lattice is normally a composite, and the support is typically earthenware. The point required in outlining MMC materials is to consolidate the alluring qualities of metals and pottery [2]. Among MMC aluminum grid composites (AMCs) have gotten specific consideration in the previous three decades because of their high particular quality and firmness and prevalent were resistances [3].

These days the primary concentration is given to aluminum as framework material as a result of its extraordinary mix of good consumption resistance, low electrical resistance and brilliant mechanical properties [4]. Points of interest of AMCs have many favourable circumstances over solid materials including-higher particular quality, great wear resistance, higher warm conductivity, bring down coefficient of warm development, and have been utilized as a part of airplane, space, protection and car businesses. Mix throwing is one of the minimal effort prepare out of accessible assembling strategies for AMCs, with preferred standpoint of ease; it additionally offers an extensive variety of material and handling conditions and can produce composites with up to 30% volume portion of support with better holding of metal network with fortification particles in view of mixing activity. Because of every one of these favourable circumstances blend throwing process is utilized in the present research for the assembling of composites [5].

Mahendra et al. [6] presumed that HMMCs containing up to 15% fly fiery debris and SiC particles could be effectively created. Uniform appropriation of fly powder was seen in the grid. The ease and
thickness of HMMCs diminishes, while hardness increments with increment in rate of particulates. The elasticity, pressure quality, and the effect quality increments with increment in rate of particulates. Madeva Nagaral et al. [7] arranged composites by utilizing Liquid Metallurgy Route (Stir Casting Technique), despite the fact that powder metallurgy creates better mechanical properties in MMCs, fluid state has some vital focal points, for example, better network molecule holding, simpler control of framework structure, straightforwardness, minimal effort of handling, closer to net shape and wide determination of material. Al6061 combination is taken as the base framework to which Al2O3 and graphite particulates are utilized as fortifications. 6 wt.% of Al2O3 is added to the base grid, while, the graphite is differed from 2, 4 and 6 wt. % into the base framework. For every composite, support particles are pre-warmed to a temperature of 200°C and after that scattered in ventures of 3 into the vortex of liquid Al6061 combination to enhance wettability and appropriation. The hardness and tractable properties of arranged composites were inspected. Mechanical properties like hardness and elasticity of Al6061 amalgam was expanded by expansion Al2O3 particles. The Micro-Vickers hardness of the Al6061-6wt. % Al2O3 was found to diminish with expansion of graphite content in the composite yet the impact of graphite content on elasticity of the composite was less.

Viney Kumar et al. [8] found that elasticity increment with expansion of fly ash. So also when graphite was included then abatement in ductile and hardness was watched. The composite with 4% Mg, 15% Fly ash remains observed to be most extreme elastic while composite of 4% Mg, 20% Fly ash was observed to be of greatest hardness. Particular wear rate diminishes with expansion of fly ash up to a specific volume while with graphite expansion it likewise diminishes. Hiroki Kurita et al. [9] watched that, because of thermal mismatch amongst Al and Gr, an inward structure of Gr was harmed in vicinity to the Al/Gr interface, while the one of a kind spanning of the sticky graphite sheets scarcely associated the Al grid and Gr. This outcome proposes that the Gr inter laminar quality is weaker than the Al/Gr interfacial quality; the Gr between laminar quality is hence the overwhelming determinant of the thermo mechanical and mechanical properties of the Al-Gr composite. While the warm conductivity of the Al-Gr composite was steady with that hypothetically anticipated, the exceptional warm development coefficient (TEC) of the graphite was not reflected in the delivered Al-Gr composites. The harmed internal structure of Gr in closeness to the Al/Gr interface adds to warm exchange however does not shoulder the heap coming about because of warm anxiety.

Saravanakumar et al. [10] aluminum grid composite was made for various mixes of Alumina and graphite by utilizing melt stirring strategy. Hybrid AMCs uncovered that mechanical properties were enhanced when AA 6063 composite was strengthened with alumina and graphite particles. Mechanical portrayal demonstrates that the nearness of 6% of alumina particles in the framework enhanced mechanical properties than other blend of alumina with lattice material. Rajesha et al. [11] explores the dry sliding wear conduct of graphite strengthened aluminum composites created by the liquid metal blending strategy by methods for a pin on disc wear set up. Dry sliding wear tests were completed on graphite fortified metal matrix composites (MMCs) and its framework compound sliding against a steel counter face. The outcomes demonstrated that the sliding separation for (Wear Volume Loss) WVL, sliding separation and fortification rate for COF was observed to be best component among the other control parameters on dry sliding wear. Based on the literature survey, work related to Al7-Si as base matrix and Graphite as reinforcements not had been done, but much work is done by using Al6082, Al6061, Al6063, LM25, Al2024 as matrix material and other alloys. In this context an attempt has been made to carry out experiments on Graphite reinforced Al7-Si composites fabricated by stir casting method.

Al7-Si and Micro Graphite particulate composites were fabricated in steps of 3 and 6 wt. %. Microstructural study was finished by utilizing checking electron micrographs and EDS. Mechanical properties like hardness, extreme rigidity and yield quality were assessed according to ASTM measures. Graphite and graphite powders are generally utilized as a part of modern applications for their amazing dry greasing up properties. Along these lines, if strong grease like graphite is contained in the aluminum combination, it can be discharged consequently amid the wear procedure.
Graphite is a standout amongst the most generally utilized strong oil materials. The main constraint included is that, utilizing graphite as a strong oil cause's loss of quality of the composites. To beat the above issue, one increasingly extra reasonable fortification material ought to be added to shape a mixture composite which can enhance mechanical and tribological properties.

2. Experimental Details

2.1 Materials Used

In the present work Al7-Si alloy with the theoretical density of 2710 kg/m³ was used as a matrix material. Graphite micro particulates with theoretical density of 2200 kg/m³ were used as reinforcements. The chemical compositions of the graphite are mainly carbon.

2.2 Preparation of composites

The metal matrix composites of Al-7Si and micro graphite particulates have been produced by easier and most economical used technique known as stir casting technique or vortex method. As per the ASTM standards of casting procedure Al-7Si is heated to the temperatures of 750ºC in the electrical resistance furnace. The addition of reinforcement particulate graphite varied from 3 to 6 wt % in-steps by mechanical stirring. Digital temperature controller having an accuracy of ±20ºC was used to control the temperature of the melt in an electrical resistance furnace. Degassing agent solid hexa-chloroethane (C2Cl6) is added to remove all unwanted absorbed gases from the molten metal. Before the addition of graphite micro particulates, mechanical stirring process was carried out to form a fine vortex with the zirconia covered stirrer. The stirrer is rotated for 5-8 minutes at a speed of 250 rpm. To increase the wettability of graphite particulates, pre-heating was done in a pre-heater at a temperature of 300 degree Celsius. The stirrer was dipped into the molten Al-7Si matrix at a depth of 2/3 from the bottom of the crucible. The pouring of the graphite particulates to the molten Al-7Si is divided into three equal weights rather than adding all at once to avoid agglomeration of the matrix. At each stage, stirring was done before and after addition of micro-graphite reinforcement particulates to the molten metal. Before pouring the Al-7Si-Graphite melt into the mould die, the molten metal is heated for about 5 minutes. The melt is poured into a cast iron preheated permanent die of dimensions 200mm length and 25mm diameter.

2.3 Testing

Microstructure and mechanical conduct of the Al-7Si-graphite composites were completed. A metallographic examination was led by utilizing checking electron magnifying instrument. The example arrangement for microstructural consider was completed first by cleaning the readied examples with SiC scraped area paper up to 1000 coarseness estimate, additionally cleaned with Al2O3 suspension utilizing velvet material on a pounding machine. At long last, the examples were cleaned by utilizing 0.3 microns diamond paste. The cleaned surface was scratched with Keller's reagent and inspected with a filtering electron magnifying instrument. The tensile properties of the example were measured by utilizing an electronic malleable testing machine at room temperature in light of ASTM standard. Hardness of as cast Al-7Si amalgam and Al-7Si-graphite composites were directed to know the impact of small scale graphite particles in the network material. The cleaned examples were tried for their hardness, utilizing Brinell hardness testing machine having ball indenter for 250 kg stack and abide time of 30 sec., five arrangements of readings were taken at better places of the example and a normal esteem was utilized for figuring. Fig. 3 demonstrates the distinctive examples utilized as a part of the examination.

3. Results and Discussion

3.1 Microstructural Studies

Fig. 1 (a) - (c) demonstrates the SEM micrographs of Al-7Si amalgam, Al-7Si-3% graphite and Al-7Si-6% graphite composites separately. This uncovers the uniform conveyance of graphite particles in Al-7Si
base lattice and low agglomeration and isolation of particles. The vortex created in the blending procedure breaks strong dendrites because of higher contact amongst particles and Al grid combination, which additionally initiates a uniform circulation of particles.

Figure 1. Scanning electron micrographs of as cast (a) Al-7Si (b) Al-7Si-3 wt. % (c) Al-7Si-6 wt. % Micro-Graphite composites

Fig. 2 shows energy dispersive X-Ray spectrographs of Al-7Si alloy (fig.2a) and 6 wt. % of graphite composites (fig. 2b). The EDS analysis confirmed the presence of Al, Si, Mg and C in the Al matrix alloy. Graphite contents C as the major element, which is confirmed by EDS analysis.
Figure 2. Showing the Energy Dispersive Spectrographs of (a) Al-7Si alloy and (b) Al-7Si-6wt. % graphite composite

3.2 Hardness

The hardness of as cast Al-7Si, Al-7Si-3wt. % Graphite and Al-7Si-6wt. % Graphite composites are evaluated using ball indenter of diameter 5mm at an applied load of 250kg with dwell time 30 seconds for each sample at different locations. The hardness variation of samples for as cast Al-7Si with 3 and 6 wt. % of Graphite is illustrated in Fig. 3. The hardness of Al-7Si-Graphite composites is less than the Al-7Si alloy (62 BHN), due to content of micro-Graphite reinforcement. The Soft Graphite content contributes decrease in the hardness of Al-Si matrix. This decrease in hardness is mainly due the softness and for their excellent dry lubricating properties of the micro-graphite particles to that of aluminium alloy [12].
Figure 3. Hardness of Al-7Si and graphite reinforced composites

3.3 Ultimate Tensile and Yield Strength

Figure 4. Ultimate tensile strength of Al-7Si and graphite reinforced composites
The tensile conduct of all the readied tests of composites is resolved to look at the ductile properties like extreme rigidity and yield quality. The examples were stacked using pressurized water in the mechanized general testing machine. The heaps at which the example has achieved the yield point and separated were noted.

Fig. 4and 5 demonstrates the variety of ultimate strength (UTS) and yield quality of base compound, when fortified with 3 and 6 wt. % of graphite particulates. The microstructure and properties of graphite particulates contributes in the upgrade of properties of composites. Because of the solid interface holding, stack from the network exchanges to the support bringing about expanded extreme elasticity. This expansion in extreme elasticity chiefly is because of nearness of graphite particles which are going about as hindrance to separations in the microstructure [13, 14]. A definitive elasticity of as cast Al-7Si amalgam was found around 164 MPa, advance after expansion of 6wt. % graphite particulates it has expanded to 191 MPa. The change in yield quality of Al-7Si amalgam has been seen after expansion of graphite content, which is about around 15.4%.

4. Conclusions
The present work entitled, “Investigations on Mechanical Behaviour of Micro Graphite particulates Reinforced Al-7Si Alloy Composites” has led to the following conclusions:

- The liquid metallurgy technique was successfully adopted in the preparation of Al-7Si alloy reinforced with 3 and 6 wt. % graphite particulates.
- The micro structural studies from scanning micro photographs revealed the uniform distribution of the graphite particulates in the Al-7Si alloy matrix.
- The Energy Dispersive (EDS) analysis revealed the presence of graphite particles in Al-7Si alloy composites.
- Hardness of the Al-7Si-graphite composite was found to be lesser than base Al matrix.
• The ultimate tensile strength of the composites was found to be higher than that of base matrix. The improvements in UTS by adding 6 wt. % of graphite was increased by 16.4 %.
• The yield strength of the composites found to be higher than that of base matrix. The yield strength of base matrix Al-7Si is increased from 142 MPa to 164 MPa after addition of 6 wt. % of graphite particulates.

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