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Studies on Mechanical Behavior of A356 Alloy - 4 Wt. % Graphite And 8 Wt. % B_4C Hybrid Composites

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Abstract: In the present examination the A356 alloy hybrid composites containing 4 wt. % of Graphite and 8 wt.% B_4C particulates were created for the investigation. The microstructure of the composite was analyzed by scanning electron microscopy, micrographs were taken to recognize the nearness of graphite and B_4C molecule in aluminum lattice. Further, tensile behavior of as cast A356 alloy and A356-4 wt. % Graphite and 8 wt. % of B_4C composites were examined. Mechanical properties like UTS, yield strength and ductility were assessed according to ASTM benchmarks. Microstructural perception uncovered the uniform dissemination of particles in the A356 composite framework. From the investigation, it was discovered that a ultimate and yield values of composite was expanded due to Graphite and B_4C particles in the composite. Further, from the investigation ductility of the composite abatements with the expansion of B_4C particulates.

Keywords: A356 Alloy, Graphite, B_4C, Ultimate Tensile Strength, Yield Strength, Stir casting, Percentage Elongation.

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I. INTRODUCTION

Metal matrix composites (MMC's) are playing pivotal role in almost all of the engineered & non engineered sectors today because of its most important property high strength to weight ratio. MMC's impart good thermal & corrosion resistance with high potential applications especially in automotive & aerospace sectors [1, 2]. Usually MMC's are developed using less dense material like Aluminium, Magnesium or Titanium; which are reinforced with stiffer ceramic material in the form of either particulates or fibers. Aluminium alloys are exceptional in their properties as they exhibit density as low as 2.7 g/cc with magnificent malleability & thermal conductivity [3]. The Aluminium alloy also has good strength with melting point as low as 660^{o}C. Aluminium alloy matrices find applications almost everywhere because of its sublime physical as well as mechanical properties. Previous research show overall enhanced properties with addition of reinforcements within Aluminium alloy matix. Several reinforcing ceramics like Aluminium oxide, Silicon Carbide, Boron Carbide, Titanium Carbide etc., are being used by researchers continuously to develop better and better optimized composite material [4].

Intense work has been carried to develop composites with various combinations of matrix & reinforcements. Hybrid composites are being developed in recent times to furthermore balance the overall properties. The Hybrid composition comprises of a base alloy combined with more than one reinforcing phase, the combination of additional reinforcement is done to compensate the properties which other reinforcing material lack. There are several techniques of developing composites via both solid & liquid metallurgical route, the most common being Powder metallurgy and stir casting route. When compared to stir casting technique, powder metallurgy route has few drawbacks like difficulty in producing complex structures, time consuming process and most importantly expensive technique. Hence, stir casting or liquid metallurgy technique is used in current study to develop Aluminium based hybrid composite [5].

When it comes to real time applications one has to keep in mind that materials undergo lot of stress in various environmental conditions. Researchers have put in lot of effort to develop composites with improved strength & hardness using different combinations of reinforcing phases with Aluminium matrix alloys. Dinesh Patidar et al., [6] has proved there is improvement in mechanical properties of B_4C reinforced Aluminium alloy

MMC. There has been increase in tensile & compression strength along with hardness with increase in B_4C particulates. S. A. Sajjadi et al. [7] developed composite comprising of 5 wt% of Al_2O_3 micro particulates reinforced within Aluminium alloy & shown us improved Strength & Hardness of composite when compared with its base alloy. A. Bardeswaran et al. [8] has carried out research on effect of Graphite particulates in A7075. It can be seen that increase in Graphite particulates in Aluminium alloy decreases the overall hardness & tensile strength of the composite.

In the present work, an attempt is made to develop A356 - 4 wt. % Graphite-8 wt. % B_4C hybrid composites by liquid stir casting technique. Further, a comparative study on mechanical behavior of A356 alloy and A356 - 4 wt. % Graphite-8 wt. % B_4C hybrid composites has been made.

II. EXPERIMENTAL STUDY

Table 1. Chemical composition of A356 Alloy

Element	Element
Magnesium	0.29
Silicon	7.20
Iron	0.18
Copper	0.02
Zinc	0.01
Manganese	0.01
Titanium	0.11
Nickel	0.01
Aluminium	Bal

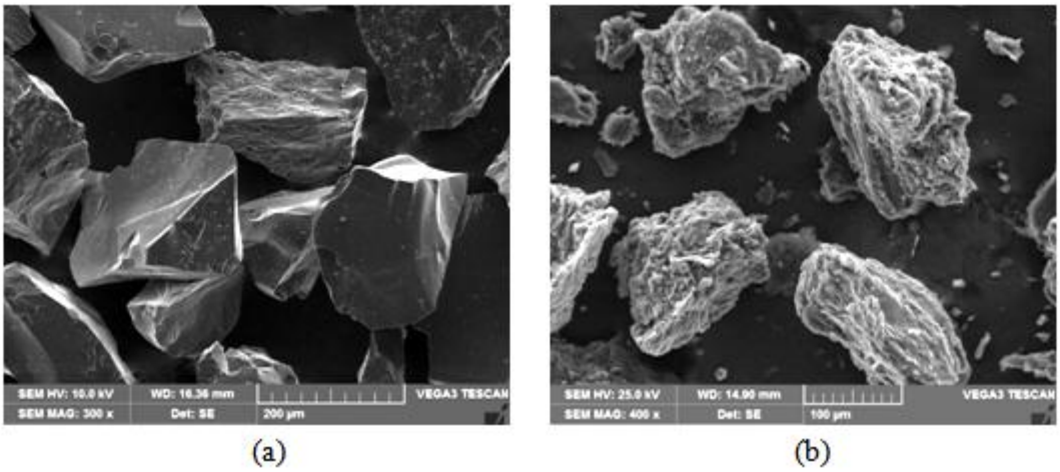


Fig. 1. Showing the scanning electron microphotographs of (a) B_4C (b) graphite particles.

In the present study, A356 alloy with the theoretical density of 2700 kg/m3 was used as a matrix material. The chemical composition of the matrix material is given in Table1. B4C with theoretical density of 2520 kg/m3 and graphite particles with 2200 kg/m3 were used as reinforcements. Figure 1 show the B4C and graphite particles of size 80-100 microns used in the study.

The fabrication of A356r-Graphite- B4C composites was carried out by liquid metallurgy route via stir casting technique. The major components of the casting process consist of electrical resistance furnace; zirconium coated steel impeller and cast iron permanent mould. The power rating of electrical furnace utilized was 60kw and greatest temperature confine was 1200 degree Celsius. The mechanical stirrer utilized for blending the liquid amalgam amid the planning of composites was covered by zirconium to withstand high temperature and to keep movement of ferrous particles from the stirrer material into copper compound liquefy. The permanent type of mould made of cast iron used in fabrication is shown in Fig. 2.

Figure 2: Cast iron die used to prepare the samples

Ascertained measure of the A356 amalgam ingots were surged into the furnace for liquefying. The melting point of Al compound is 660˚C. The melt superheated to a temperature of 730˚C. The temperature was recorded utilizing achrome-alumel thermocouple. The liquid metal was then degassed utilizing strong hexachloroethane (C_2Cl_6) for 3 min [9]. A stainless steel impeller covered with zirconium was utilized to mix the liquid metal to make a vortex. The stirrer was pivoted at a speed of 300rpm and the profundity of drenching of the impeller was 60 percent of the tallness of the liquid metal from the surface of the liquefy. Further, the graphite and B_4C particulates were preheated in a heater upto 500˚C were brought into the vortex. Mixing was proceeded until interface cooperation between the fortification particulates and the network advances wetting. At that point, A356 alloy combination 4 wt. % of graphite and 8 wt.% of B_4C composite was filled permanent die having measurements 125mm length and 15mm breadth.

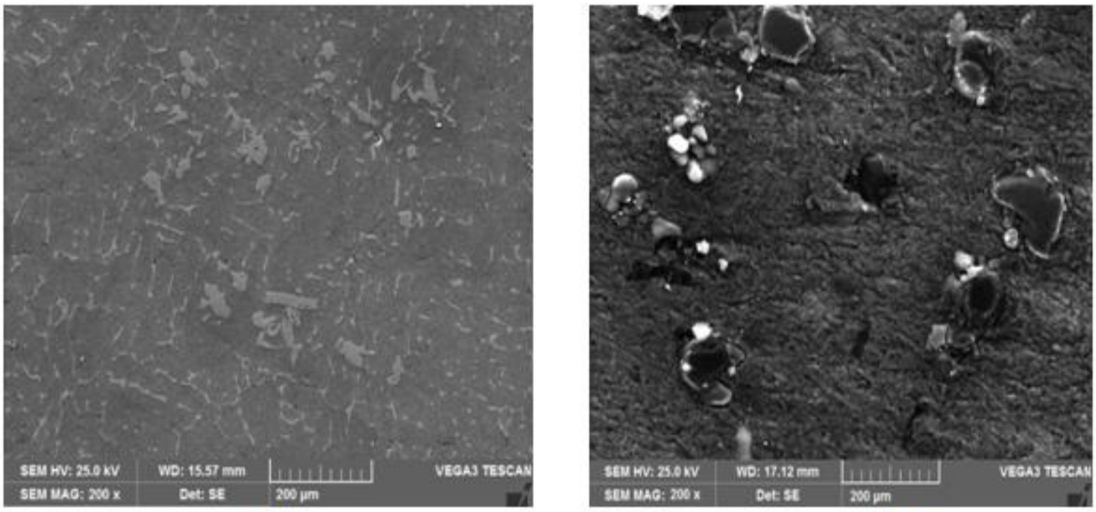
The microstructural study was carried out on the investigating composites using scanning electron microscope. Samples around 5 mm diameter cut from the castings and were polished properly. Keller's reagent was used to etch the samples. Tensile specimens were machined from the cast samples. Hardness of as cast A356 alloy and graphite-B_4C amalgam composites were directed to know the impact of small scale particles in the network material ASTM E 10 standard [10]. The cleaned illustrations were striven for their hardness, using Brinell hardness testing machine having ball indenter for 250 kg load and stand time of 30 sec., three readings were taken at better places of the case and a typical regard was used for figuring.

The tensile specimens of circular cross section with a diameter of 9 mm and gauge length of 45mm were prepared according to the ASTM E8 standard testing procedure [11]. The tests were conducted on a universal testing machine. All the tests were conducted in a displacement control mode at a rate of 0.1 mm/min. Multiple tests were conducted and the best results were averaged. Various tensile properties like ultimate tensile strength, yield strength and percentage elongation were evaluated for both as cast A356 alloy and A356 alloy-4 wt. % Graphite-8 wt. % B_4C hybrid composites.

III. RESULTS AND DISCUSSION

3.1 Micro structural Analysis

The SEM investigations are valuable in deciding the grain measure, grain shape and conveyance of fortification particulates inside the base matrix, which greater affects the mechanical properties. The SEM micrographs of as cast A356 amalgam and A356-4 wt. % Graphite-8 wt. % B_4C hybrid composites are appeared in Fig. 3 (a-b) individually. The micrographs of A356-graphite-B_4C composites uncover the uniform appropriation of graphite-B_4C particulates all through the grid. Consistently appropriated fortifications increment the hardness and diminish the porosity of the metal framework composites.



(a) (b)

Figure 3: Showing the SEM micrographs of (a) as cast A356 alloy (b) A356-4 wt. % Graphite-8 wt.% B_4C hybrid composite

3.2 Hardness Measurements

Hardness is a property of a material that indicates the ability of the material to resist local plastic deformation. Fig. 4 shows the influence of the graphite and B_4C particle contents on the hardness of the A356 alloy. The hardness values are positively correlated with the weight percentage of graphite and B_4C particles, because particles strengthened the matrix. Furthermore, the results show that B_4C particles reinforced MMCs harder than A356 alloy due to Hall-Petch and Orowan strengthening mechanisms as well as the good interface between the reinforcement and matrix [12]. A356-4 wt. % graphite – 8 wt. % B_4C composites show more hardness, the increase in hardness of these composites can be attributed to the dispersion strengthening effect [13]. By adding 8 wt. % B_4C particulates into the A356 alloy, the hardness of A356 alloy increased to 63.1 BHN from 90.8 BHN.

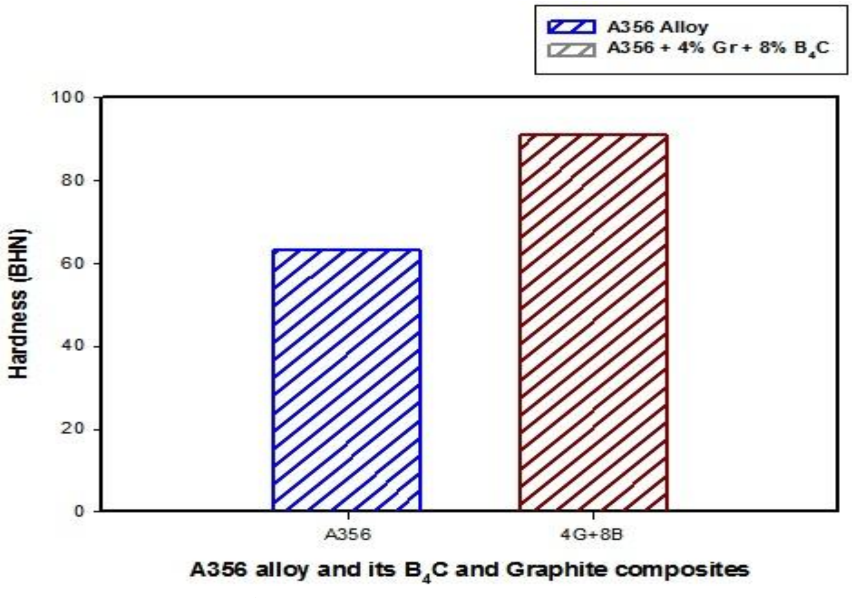


Figure 4: Showing the hardness of as cast A356 alloy and A356-4wt. % Graphite – 8 wt.% B_4C hybrid composite

3.2 Tensile Properties

Fig. 5, 6 and 7 showing the tensile properties of as cast A356 alloy and A356-4 wt. % Graphite-8 wt.% B_4C hybrid composite. Fig. 5 showing the ultimate tensile strength (UTS) of A356 alloy and it's composite. From the figure, it is evident that UTS of A356-graphite-B_4C hybrid composite is higher than the base matrix alloy. By adding 4 wt. % of Graphite – 8 wt.% B_4C particles to the base alloy, UTS has been increased from 164.5 MPa to 245.7MPa.

From the fig. 6 it was found that yield strength (YS) of the as cast A356 base alloy is 130.1 MPa and in A356-4 wt. % of Graphite – 8 wt.% B_4C hybrid composite is 172.7 MPa. It showed an improvement of 32.7% in yield strength as compared with as cast base matrix.

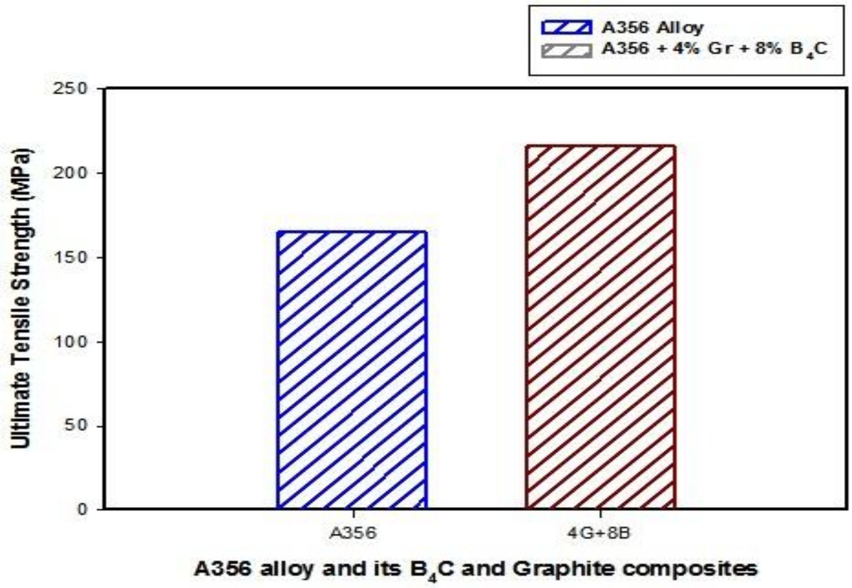


Figure 5: Showing the ultimate tensile strength of as cast A356 alloy and A356-4wt. % Graphite – 8 wt.% B_4C hybrid composite

The expansion in UTS and YS is essentially because of solid holding between support particles and copper lattice, assumes an imperative part on the load exchanging from network to fortification. This is a result of grain refinement and molecule reinforcing [14]. The upgrade of quality is influenced by the higher load bearing and crisscross reinforcing caused by graphite-B_4C particles. It is relied upon that because of the distinction in the coefficients of warm development amongst framework and graphite-B_4C fortification and consequently thermal mismatch stress, there is a probability of expanded disengagement thickness inside the network amid cooling from hardening temperature [15]. In contrast with the base A356, the considerable improvement in the quality saw in the composites is because of the nearness of the particles as obstructions that limit the movement of disengagements caught by graphite-B_4C particulates. This will prompt expand the rigidity of the micro composites amid pliable tests.

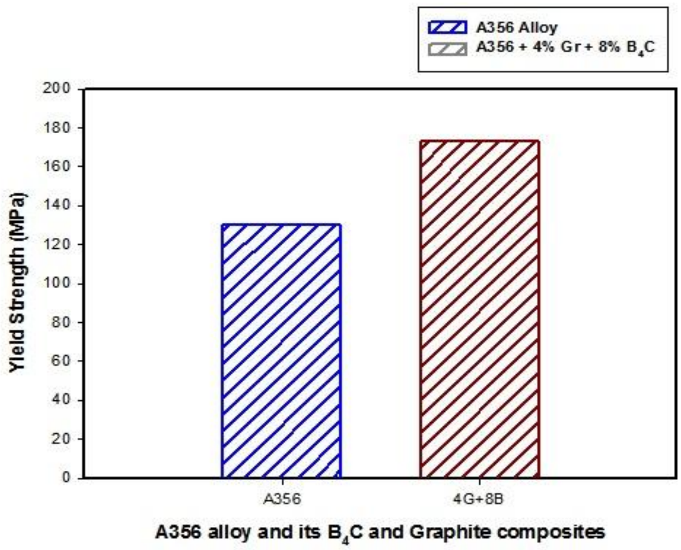


Figure 6: Showing the yield strength of as cast A356 alloy and A356-4wt. % Graphite – 8 wt.% B_4C hybrid composite

Fig. 7 demonstrates the elongation of as cast A356 alloy compound and its composites. The rate prolongation was diminished in hybrid composite when contrasted with the base amalgam. It can be seen from the diagram that the flexibility of the composites diminishes altogether with the 4 wt. % graphite and 8 wt.% B_4C strengthened composites. This abatement in rate extension in correlation with the base compounds is a most regularly happening drawback in particulate fortified metal framework composites. The diminished malleability in A356-4 wt. % graphite and 8 wt.% B_4C composites can be ascribed to the nearness of B_4C particulates which may get broke and have sharp corners that make the composites inclined to restricted split start and spread. The embrittlement impact that happens because of the nearness of the hard artistic particles causing expanded nearby pressure fixation destinations may likewise be the reason [16, 17].

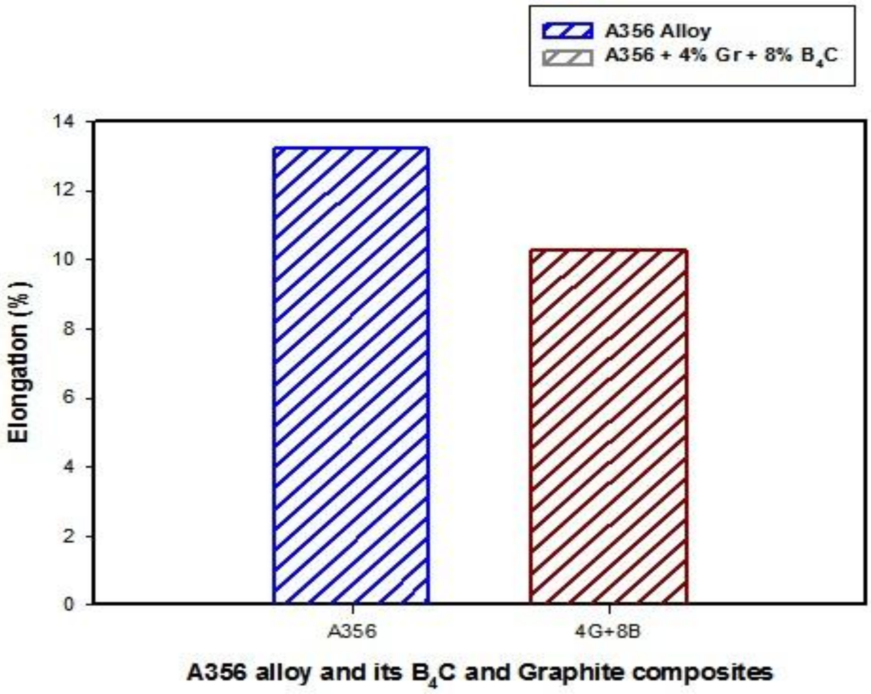


Figure 7: Showing the percentage elongation of as cast A356 alloy and A356-4wt. % Graphite – 8 wt.% B_4C hybrid composite

IV. CONCLUSIONS

This present research is centered on the development and characterization of the microstructure and mechanical behavior of A356 alloy and its hybrid composites containing 4 wt. % of graphite and 8 wt.% of B_4C particles. From the above results and discussion the following conclusions are made:

1. From the liquid metallurgy techniques A356-graphite-B_4C hybrid composites were prepared successfully.
2. The scanning electron micrographs revealed the uniform distribution of graphite and B_4C particulates in A356 base alloy.
3. The hardness of A356 base alloy increased with the addition of 4 wt. % of graphite and 8 wt. % of B_4C particulates.
3. The ultimate tensile strength of A356 base alloy and 4 wt. % of graphite and 8 wt. % of B_4C composites were 164.5 MPa to 245.7MPa respectively.
4. A356 base alloy and 4 wt. % of graphite and 8 wt. % of B_4C composites were 130.1 MPa to 172.7MPa respectively. This shown an improvement of 32.7 %, when compared with the base alloy A356.
5. The ductility of base alloy A356 reduced with the addition of 4% graphite and 8% B_4C particulates.

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