Journal of Mines, Metals and Fuels, *71(12D): 59-64; 2023. DOI: 10.18311/jmmf/2023/47985*

Print ISSN : 0022-2755

Journal of Mines, Metals and Fuels

Contents available at: *www.informaticsjournals.com/index.php/jmmf*

Investigation of Mechanical Properties of AL-7SI With 6 WT% of 40- and 90-Micron Size Boron Carbide Metal Matrix Composite

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Abstract

To create and evaluate the mechanical behaviour of B4C-reinforced A356 alloy metal composites that are 6 wt. % and range in size from 40 to 90 microns. Method: By using the liquid melt stir cast process, an alloy called A356 with 6 wt. % B4C reinforced composites was created. SEM and EDS were used to characterise the microstructure of these produced composites. According to ASTM standards, mechanical characteristics such as hardness and tensile strength were assessed. Findings: The extensive dispersion of B4C particles in the A356 matrix was demonstrated by a SEM of A356 alloy with 6 wt. % of B4C composites. The A356 alloy matrix's EDS signals verified the presence of B4C particles. The hardness increased by 28.6%, ultimate strength by 26%, and yield strength by 44.4 percent with a little loss in ductility with the addition of 6 wt. % of B4C particles. Novelty: Aerospace-grade aluminium alloy A356 is often utilised in industrials. B4C particles with a size range of 40 to 90 microns were included into advanced metal composites to assist reduce weight. The choice of A356 alloy and B4C reinforcement was made strategically to meet the demanding conditions of mining operations. The results indicate a clear potential for improving the efficiency and overall performance of mining equipment.

Keywords: *Boron Carbide, Hardness, Metal Matrix Composites, Tensile*

1.0 Introduction

Al–Si alloy is used to make a large number of castings each year. This alloy is one of the most often used alloys in industries due to its low density, good castability, high fluidity and specific strength[1]. The Aluminium alloys, on the other hand, have low hardness and poor wear resistance, limiting its usage in many tribological applications. When high-modulus refractory particles are mixed with a ductile metal matrix, a material is created that has mechanical and tribological qualities somewhere between matrix alloy and ceramic reinforcement[2]. Aluminium, magnesium, titanium, and alloys of these metals are often utilised as metallic matrices. Since AMCs have a lower coefficient of thermal expansion than conventional Al alloys, they are the basis for 69% of all MMCs produced annually in large quantities[3,4]. The fact that AMCs supplemented with ceramic whiskers/fibers/particles added to them have better wear resistance, they are good candidates for materials in a range of tribological applications is one of the key driving reasons for their technical development. The addition of ceramic fibres or particles, which function as a load bearing and abrasive

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component, improves the tensile, hardness strength and wear resistance of aluminium alloys. Ceramic particles such as SiC, B_4C, Al_2O_3 and TiC, have been successfully introduced into AMCs to improve their tribological characteristics[5]. B_4C powder was used as reinforcement in this research because it has a greater hardness than other commonly used reinforcements like SiC and Al_2O_3[6]. Furthermore, its density is quite similar to that of the Al alloy matrix. This attribute is combined with others that are appealing, such as strong impact and wear resistance and great chemical resistance[7]. Fabrication procedures vary greatly depending on the kind of reinforcement used. It is possible to use traditional stir casting procedures, which are also known as compo casting. Faster process cycles and the suppression of segregation, settlement, or agglomeration are only a few advantages.

The wettability of B_4C particles is a major concern, since it is poor at the melting point of aluminium (660°C)[8]. The reinforcement is mixed with a semisolid matrix alloy. On undispersed reinforcement, the solid phase in viscous semisolid acts as an abrasive, assisting in the absorption of the ceramic particles into the semisolid medium. In comparison to a totally molten alloy, non-metallics are prevented from settling, floating, or aggregating by the hardened metallic particles, resulting in a more uniform particle distribution. Finally, the composites' microstructure tensile strength and hardness were studied experimentally.

2.0 Experimental Procedure

The investigation's matrix material was a commercial casting-grade aluminium alloy (A356)[1]. Because of its superior fluidity and the inclusion of silicon and magnesium. Because the silicon percentage of A356 alloy is high, it may be kept in a liquid condition for extended periods of time at conventional casting temperatures without considerable Al_4C_3 formation. This alloy's liquidus temperature is 615.8 degrees Celsius, and it is suitable for semisolid processing due to its wide semisolid interval[10]. The inclusion of Si in this alloy is meant to make it easier for the liquid alloy to wet the reinforcing. SiC and Al_2O_3 are the most used reinforcing materials for A356. Because B_4C powder is more expensive than SiC and Al_2O_3, there has been little study on B_4C reinforced MMCs. Specific amounts of B_4C with particle sizes of 40 and 90 micron size were introduced to the matrix alloy in this investigation.

Table 1 shows the chemical make-up of A356 alloy. A mechanical stirrer is used to integrate B_4C particles into the A356 alloy. This treatment aids particle integration while decreasing undesirable interfacial reactions.

Table 1. Chemical composition of A356 alloy

Symbol	Wt %
Si	6.98
Mg	0.35
Fe	0.10
Ti	0.15
Cu	0.01
Ni	0.013
Zn	<0.015
Sn	<0.005
Mn	<0.005
Al	Balance

In this experiment, a very basic experimental set-up was utilised. The primary section of the device can attain temperatures of up to 1000°C. Inside the heating band is a 2-kilogramme capacity graphite crucible with a cover for keeping the ingredients. An electrical resistance-heated furnace was used to melt batches of matrix alloy crucibled in graphite**.** The alloy was heated to roughly 700 degrees Celsius before being swirled at 800 revolutions per minute using a graphite impeller powered by a variable AC motor. While stirring, the furnace's temperature was progressively reduced until the melt had achieved a temperature in the region between liquid and solid. (i.e. 590°C). The particles were then added evenly at a rate of 50 g/min for a time span of roughly 1–3 minutes, with the stirrer positioned just under the slurry's surface. It is allowed to mix isothermally in

the semisolid condition for another 30 minutes after charging. The composites were made with 40 and 90 micron size of B_4C particles at a concentration of 6%. To prevent molten aluminium and graphite pieces from oxidising

3.0 Surface Analysis

SEM images of the as-cast A356 combination and the A356 compound with a 6 weight-percent addition of 40 and 90 micron-sized B_4C composites are shown in Figures 1, 2 and 3. The SEM images of the A356 compound and the A356 compound with the addition of 40 and 90 micron-sized tiny B_4C composites, respectively, are shown in Figures 1,2 and 3. The micrograph of the A356 combination with tiny grains and no holes is shown in Figure 1. Additionally, Figure 2 and 3 demonstrates the existence of B_4C in the A356 combination. The A356 matrix and B_4C particles are strongly bound by this combination. The two-phase support expansion technique was effective in spreading the A356 combination's particles. In this way, using suited particles aids in improving the composites' qualities.

The EDS ranges of composites made with A356 and a 6 weight-percent addition of B_4C particles with sizes

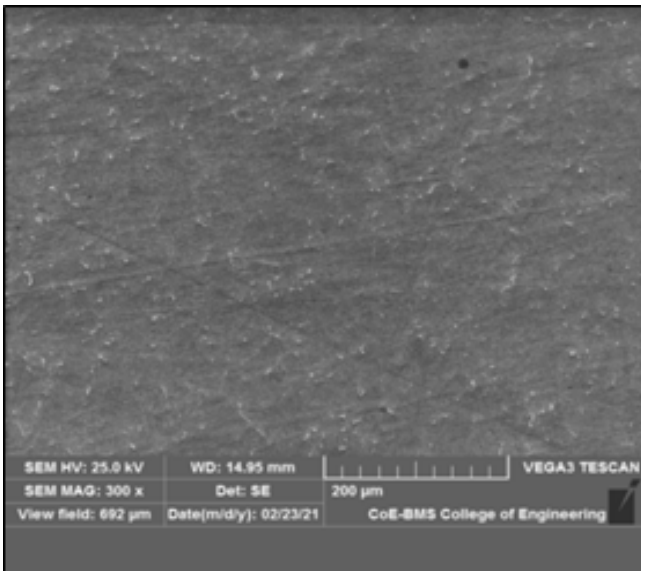


Figure 1. SEM image of A356 alloy.

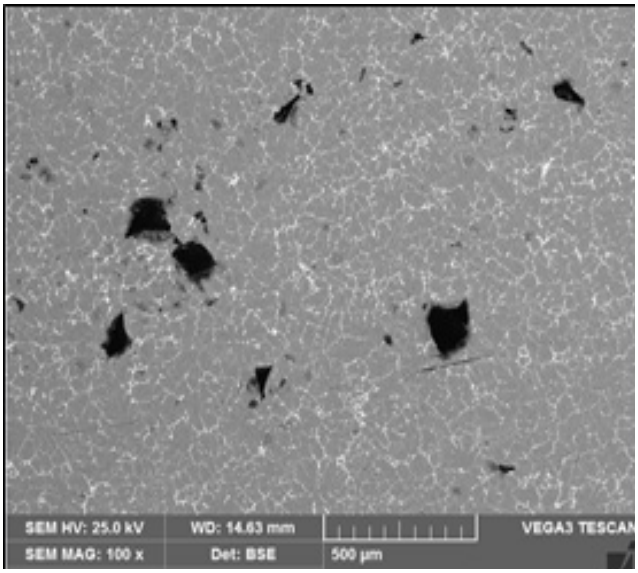


Figure 2. SEM image of A356 alloy +40µm B_4C.

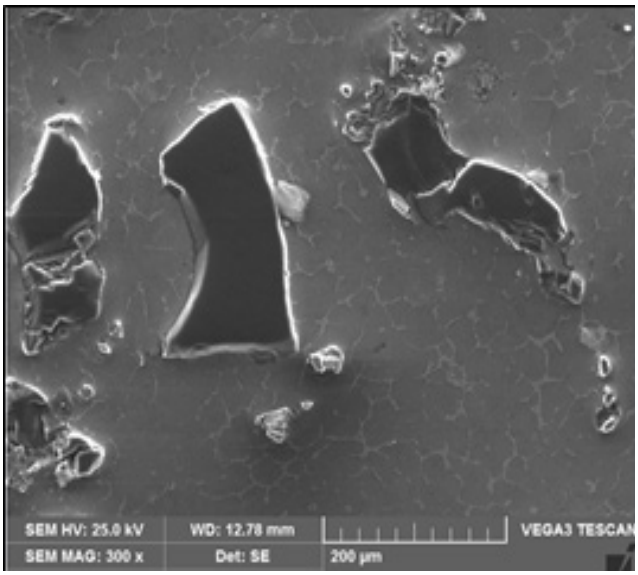


Figure 3. SEM image of A356 alloy +90µm B_4C.

of 40 and 90 microns are shown in Figure 4,5 and 6. The alloying components of the A356 compound are shown in Figure 4, with Mg and Si serving as the primary alloying segments. The range confirms the B_4C particles as B and C components in the generated composites in Figure 5 and 6 which shows the results of an EDS study of A356-6 weight percent of 40 and 90 micron size B_4C composites.

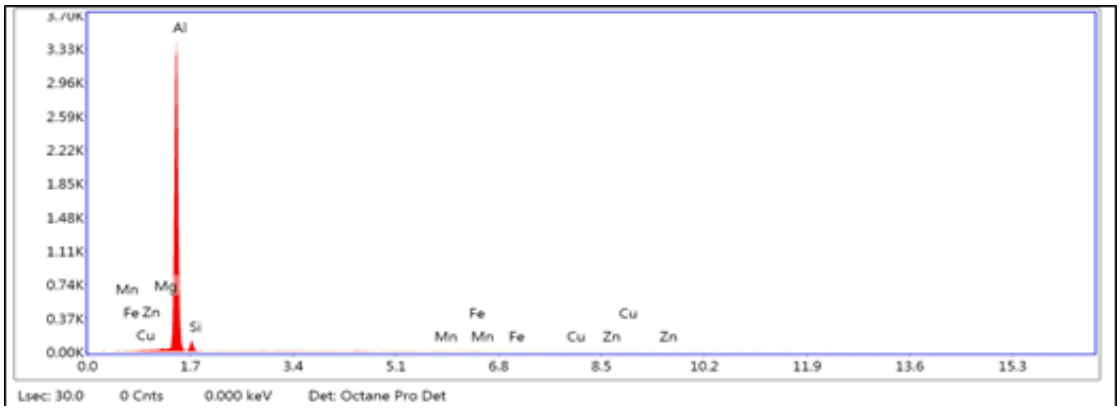


Figure 4. EDS image of A356 alloy.

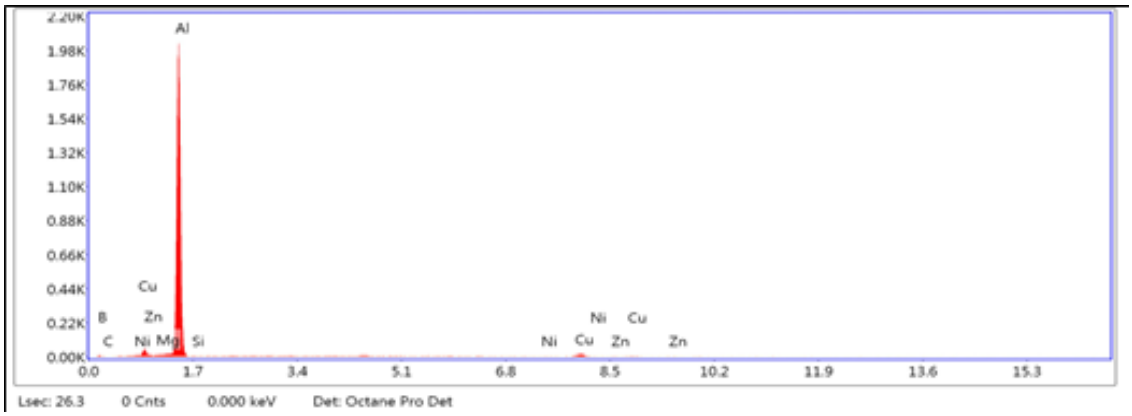


Figure 5. EDS image of A356 alloy +40µm B_4C.

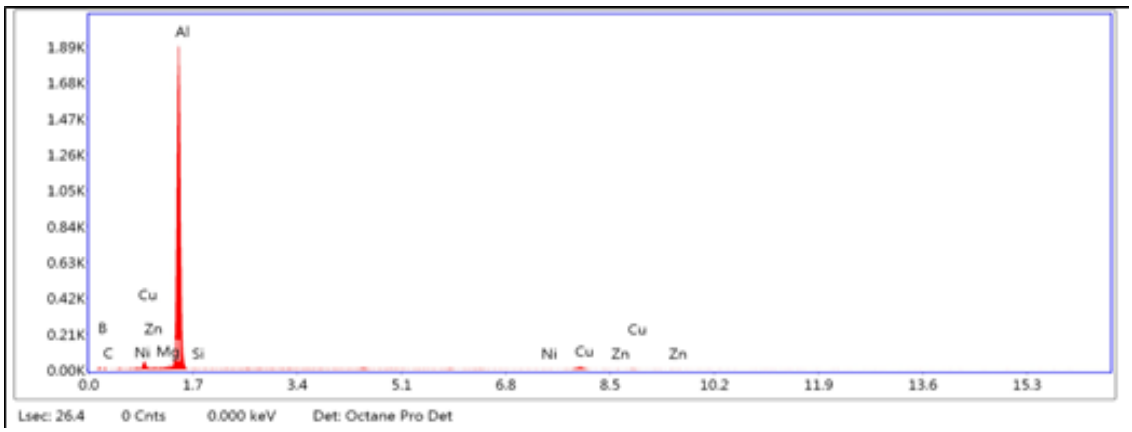


Figure 6. EDS image of A356 alloy + 90µm B_4C.

4.0 Hardness

Figure 7 shows the composite's hardness value for the matching wt-percentage of reinforcement. It can be seen that when the weight percent of ceramic reinforcements increases, the hardness value of the base alloy increases as well. The improvement in hardness is due to the application of reinforcement. The specimen was produced in accordance with ASTM guidelines. The test was carried out on the specimen by applying

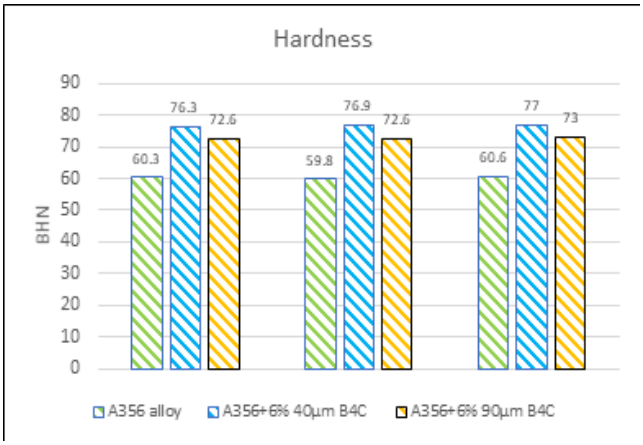


Figure 7. The hardness of A356 alloy and its composites.

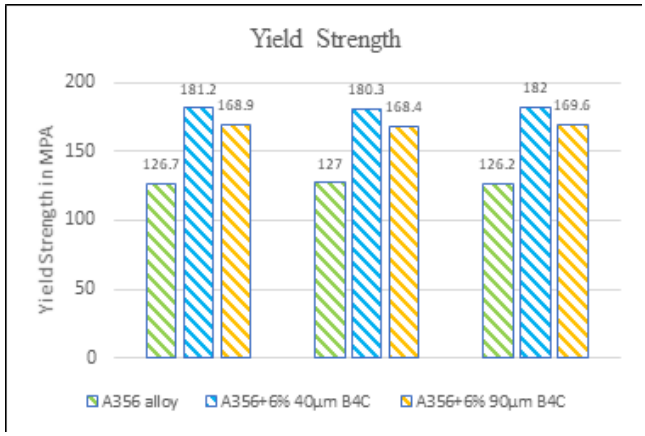


Figure 9. YS of A356 alloy and its composites.

a weight of 100 grammes on it for 15 seconds. The hardness of the ceramic reinforcements is higher than that of the underlying metal, and the base alloy and reinforcement surfaces would have a strong interfacial connection. An increase in dislocation density brought on by more reinforcement adds to the material's enhanced hardness[11]. To accommodate the ceramic reinforcements, the matrix expands in volume and deforms plastically.

5.0 Tensile and Yield Strength

Figure 8 and 9 show that the value of tensile and yield strength increases as the quantity of reinforcing increases. The inclusion of reinforcements causes a rise in dislocation density. may be ascribed to the rise in tensile and yield strength. When an aluminium matrix is reinforced with hard reinforcements, thermal mismatch causes dislocations, which increases the dislocation density. By impeding the movement of the dislocations, this increase in dislocation density improves tensile and yield strength The specimen was produced in accordance with ASTM E-8. In the UTM, the test was carried out. There is a rapid rise in tensile strength at 6 wt-percent of 40 µm the reinforcement, this might be a result of the matrix dispersing the ceramic reinforcements.

6.0 Percentage Elongation

Figure 10 shows the effect of increasing the weight-percentage of reinforcement on the composite material's

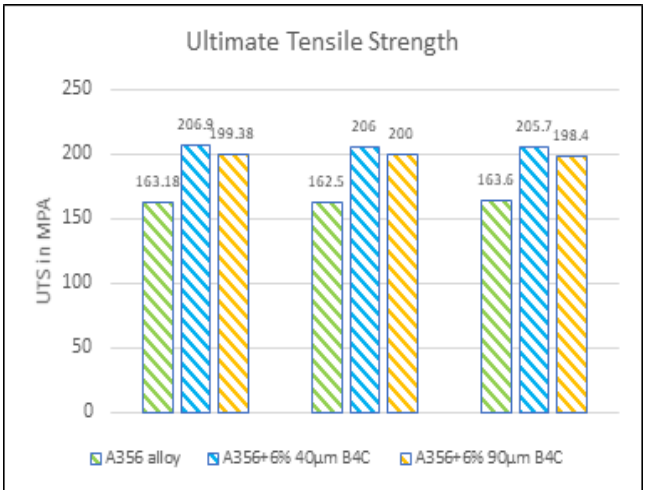


Figure 8. UTS of A356 alloy and its composites.

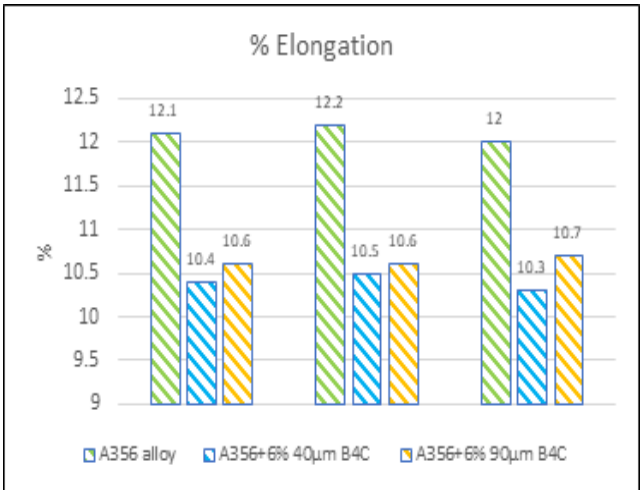


Figure 10. % elongation of A356 alloy and its composites

% elongation. It can be seen that as the quantity of reinforcement added increases, the % elongation decreases. The dispersion hardening occurring in the composite material is responsible for the decrease in percentage elongation.

7.0 Conclusion

In the present study, A356-B_4C composites were successfully made utilising the stir cast method and 6 weight percent B_4C particles that were 40 and 90 microns in size. To examine different mechanical qualities including hardness, UTS, and YS, ASTM standards were used. The network was largely devoid of holes, much like in SEM micrographs, as cast-combination and similarly adopted small B_4C composite. The A356 combination network contains B_4C particles, according to the EDS study. When compared to unreinforced A356 as-projected amalgam, the characteristics of A356 and 6 weight percent B_4C composites were more prominent. The present study uses 6 weight percent of 40 and 90 m B_4C particles to create composites; future research is possible to determine the effects of adding more particles at higher weight percents on the mechanical behavior of A356 alloy. The results indicate a clear potential for improving the efficiency, durability, and overall performance of mining equipment.

8.0 References

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