Research Article

Mechanical Characterization of B_4C-Gr Al2618 Based Composites Synthesized by Stir Casting Method

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Abstract
Aerospace and automotive industries rely heavily on aluminium alloys because of their advantageous physical and mechanical properties. This paper presents studies on the performance of stir cast B_4C (Boron carbide) and Gr (graphite) reinforced aluminium metal matrix composite (AMMC). Particulate reinforcement of B_4C and Gr is in the ratio 2:1 (wt.%). Characterization of AMMC's mechanical properties reveals that the composite has enhanced mechanical properties compared to Al2618. Through Scanning electron microscope(SEM), it is identified that microstructure of AMMC and distribution of B_4C and Gr particles in Al2618 are found to be uniform. Based on the results of the experiments, it was determined that the best AMMC mixture for improving the material's mechanical properties is a combination of B_4C and Gr, with the proportions at 8:4. As a result, the automobile sector stands to benefit greatly from the use of this AMMC in the production of engine components.

Keywords: MMCs, Ceramics, Strengthening mechanism, Mechanical properties, XRD

1 Introduction

The significance of composite materials in the field of engineering can be taken into consideration in as many as 200 composites out of 1600 engineering materials on the market today. In the beginning, these composites originated as cast iron and bronze alloys, but their applicability has been constrained by their low strength and high susceptibility to wear and seizure. Many studies have been reported and their wear behaviours have been explored in as far as possible. In the later studies, Al (Aluminium) alloy was identified as a promising material for automotive application. The hybrid aluminium metal matrix composite (AMMC) represents in modern metal matrix form has the ability to meet the requirements of evolutionary applications in engineering, for example in the fields of aerospace, vehicles, space etc. This is attributed primarily to advanced mechanical and tribological characteristics, such as stiffness, strength, abrasion and impact resistance [1]. It is difficult to have adequate strength, durability, and stability for ordinary aluminium alloys at high temperatures [2]. The use of B_4C (Boron carbide) particles as reinforcement phases could achieve significant specific property improvements for MMCs (metal matrix composites) [3]. B_4C particles are introduced as strengthening to the matrix, which possesses outstanding hardness and fracture resilience [4]. Al-B_4C composite products serve many purposes, including those of neutron absorbers in structural applications, armour plate, and substrate material for hard drives in computers [5]. Hardness and wear resistance of the alloy was increased because of the addition of B_4C-Gr particulate. Al-B_4C-Gr hybrid composite is a better replacement for Al alloy [6]. The use of a single strengthening of an Al matrix will often affect its physical characteristics. Hence, it is beneficial to incorporate self-lubricating particles such as graphite. Self-lubrication promotes antifriction properties of the matrix [7]. Adding B_4C alone in larger concentrations makes the material brittle and hard to produce, so Gr (graphite) can be used advantageously to improve the machinability of the hybrid composite [8]. The metal Al2618 is widely utilized in the production of IC engine parts. Although other alloys are strong, but Al2618 retains its strength and stability even when heated to high temperatures [9]. Therefore, potentiality of Al2618 was chosen as a matrix to furnish a genuine hybrid composite.

By reviewing the literature survey, it has been hypothesised that B_4C and Gr particle reinforced hybrid metal matrix composites have the potential to be dependable materials to substitute cast iron in automobile components. This paper explores the different compositions and types of reinforcement materials used in the manufacturing of hybrid metal matrix composites in this work and how this influences the mechanistic quality of materials.

The test specimens were subjected to tensile test, compressive test, impact test and hardness test to study the mechanical behaviour. Also, SEM and XRD techniques were used to evaluate the microstructure and phase analysis, respectively. The chemical compositions of Al2618 are depicted in Table 1.

Table 1: Chemical compositions (%) of Al2618 [2]

Si	Fe	Cu	Mn	Mg	Cr	Ni	Zn	Ti	B	Ca
0.24	1.30	2.52	0.004	1.46	0.02	1.14	0.01	0.07	0.003	0.002

2 Materials and Methods

2.1 *Fabrication of AMMCs by using stir casting method*

This method involves the integration of reinforcement particles and matrix material, which causes the composite mixture to solidify. In this technique, the matrix material was melted, and an uninterrupted stirring motion was used to create a vortex at the surface

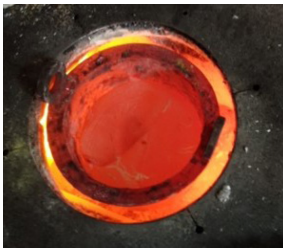

Figure 1: Molten metal.

Figure 2: Stirring.

Figure 3: Pouring molten metal.

Figure 4: Poured metallic die.

of the melted substance. The vortex technique entails the incorporation of ceramic particles that have been pre-treated into the swirling mass of molten alloy that is produced by the revolving impeller. The stir casting technique was used in this research to manufacture Al2618 alloy with B_4C and Gr.

The AMMCs cast procedure depicts in Figure 1–4. The crucible used was made up of graphite. Melting is kept for 60 min at a temperature range of 650–700 °C. Molten metal is supplemented with 1.5 wt% of magnesium to promote particle dispersion in the alloy during the melting process and to increase wet potential of the molten metal. Reinforcements made of B_4C and Gr that had been weighed were preheated to a temperature that had been predetermined to be 500 °C to eliminate any moisture or other gases. As soon as the primary reinforcement B_4C is added, it necessitates uninterrupted stirring at 150 rpm for optimal mixing. Supplementary reinforcement (Gr) has been heated up in advance of use. Then Gr was added, and the mixture was stirred vigorously for approximately ten to fifteen minutes [8]. Hex-chloroethanol (C_2Cl_6), a degassing agent, was added since the molten metal had the potential to create gas. At a temperature of 700 °C, molten metal is poured into the mould while the pouring temperature remains constant. After that, the liquid might congeal into a solid in the mould when subjected to atmospheric pressure, thereafter, cast specimens were taken out. Table 2 depicts the wt% of particulate reinforcements in Al2618 investigated in this study.

Table 2: %Wt. of particulate reinforcement in Al2618 in the ratio 2:1

Sample Designations	Composition	Al2618 %	B_4C %	Gr %	Total Particulate B_4C and Gr Reinforcement %
Al 2618	Al 2618	100	0	0	0
HC1	Al 2618+2 % B_4C–1 % Gr	97	2	1	3
HC2	Al 2618+4 % B_4C–2 % Gr	90	4	2	6
HC3	Al 2618+6 % B_4C–3 % Gr	85	6	3	9
HC4	Al 2618+8 % B_4C–4 % Gr	80	8	4	12
HC5	Al 2618+10 % B_4C–5 % Gr	75	10	5	15

2.2 *X-ray diffraction microstructural study*

The fabricated AMMCs were subjected to X-ray diffraction to study the phase of the alloy and composites. The Bruker ASX D8 X-ray diffractometer was used to scan the samples and record the corresponding intensities at a speed of 1.50 θ/min through 10–800 for diffraction angle (2θ) [10]. A microstructural analysis was carried out using SEM to make sure particle distribution in the matrix. The sample was made with the diameter of 10 mm and the thickness of 5 mm. Specimen's surface preparation for microscopic study is carried out with abrasive papers of grit size order (1000, 1500, 2000, and 4000). Later polished samples were brushed and engraved with Keller's reagent, accompanied by acetone washing.

2.3 *Tensile test and compression test*

The tensile and compression test specimens were prepared according to ASTM E8 and E9 standards, respectively [11]. The tensile test of the specimens was conducted with UTM (Universal testing machine) (Maximum Capacity 50 KN: Measuring Range 0-50 KN: UTM with computer interface (Make: BISS).

2.4 *Hardness and impact test*

The hardness and impact test specimens were prepared

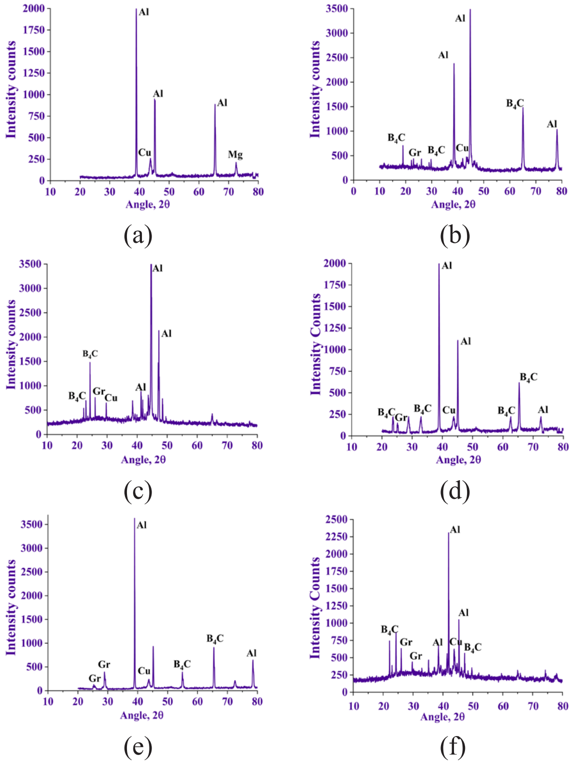

Figure 5: XRD of the samples: (a) Al2618; (b) HC1; (c) HC2; (d) HC3; (e) HC4; (f) HC5.

according to ASTM E10 and E23 standards, respectively [11]. The hardness test of the specimen was conducted at a load of 250 kgf with a dwell time of 30 s. The sample was mounted on an anvil, striking the opposite side of the notch with the hammer. The energy consumed by the specimen has been adequately documented and reported as the material's impact energy.

3 Results and Discussions

3.1 *X-ray analysis and microstructural study*

The matrix alloy Al 2618 and hybrid composite X-ray diffraction (XRD) pattern and SEM are shown in Figures 5 and 6. The outcome of the XRD result reveals that the solid peaks representing Al, B_4C and Gr occur at smaller peaks in the HMMCs (hybrid metal matrix composites). The existence of Mg and Cu is also seen in all hybrid composites, but with very small proportion. Angles of 10–80° for diffraction angle (2θ) were held for XRD study [12].

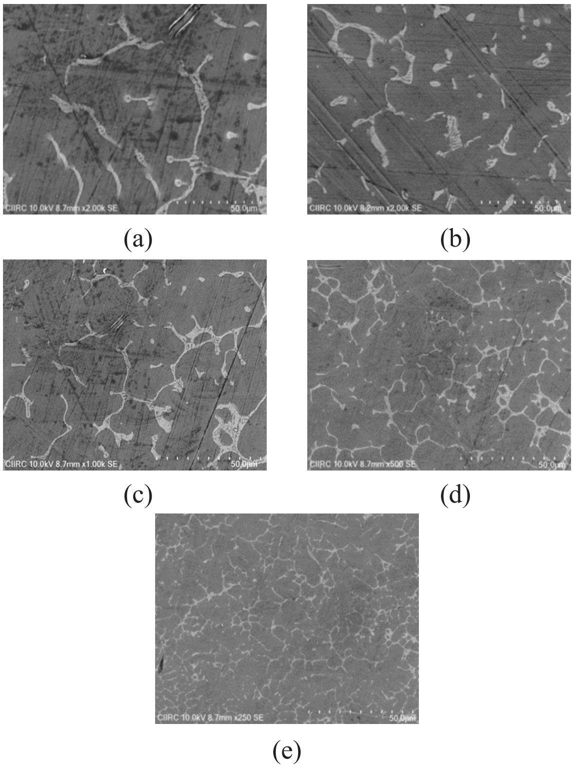

Figure 6: Microstructure of HMMCs. (a) HC1; (b) HC2; (c) HC3; (d) HC4; (e) HC5.

The observation of the microstructure reveals strong dispersion, and uniform distribution of B_4C and Gr as shown in Figure 6(a)–(e). The development of α-Al is primarily due to the thermal imbalance of strengthened particles and Al 2618. There has been a reasonably strong interfacial bond between the particles and Al 2618 since no voids are seen on the interface. The magnitude of clustered reinforcement coalescence also increases with an increase in reinforcement wt% [13].

3.2 *Hardness test*

Primary and supplementary reinforcements' impact on the hybrid composite's (Al2618 + B_4C-Gr) hardness is seen in Figure 7. The hardness of the HMMCs increases by a large amount monotonously as the B_4C and Gr content increases. In particular, the hardness rises by about 42% when B_4C and Gr contents are increased (2:1). The enhanced hardness can be attributed to the fact that the strong B_4C and Gr

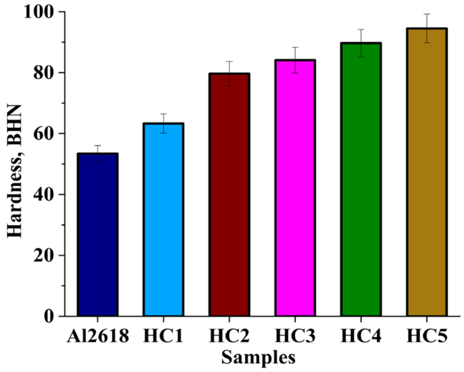

Figure 7: Hardness test results.

particles serve as inhibitor to dislocation movement in Al2618 [14]. The particulate content of B_4C and Gr is increased from 0 to 10 wt% and 0 to 5 wt%, the HMMCs achieve a hardness that is substantially higher than their initial value, reaching almost twice as high as they were before.

3.3 *Tensile test*

The rise in UTS (ultimate tensile strength) is due to supplementary reinforcement (Gr) particles serving as obstacles to dislocation in the microstructure. A big benefit of this dispersion-strengthening effect is that it can continue to function adequately at temperatures above the average and for extended periods of time because the particles are not insensitive to the matrix [15]. When B_4C and Gr contents are raised (2:1 wt%), the UTS rises monotonically by over 16.42%. because of the existence of strong B_4C particles that transmit strength to the matrix. Increased UTS may be attributable to strong B_4C particles that transmit strength to the matrix alloy and thus improve tensile stress resistance as seen in Figure 8 [14]. The interspace gap between B_4C and Gr hard particles is decreased, which increases the dislocation pile-up with growing particulate content. The spontaneous accumulation of particulate in the matrix contributes to a constraint in the plastic flow. This provides the composites with a greater tensile strength. Also, the increase in UTS may be attributed to a strengthening of the matrix as the composite grain size has been decreased and difference between thermal expansion coefficient of the matrix and reinforcement particulates generates substantial dislocation density throughout the matrix

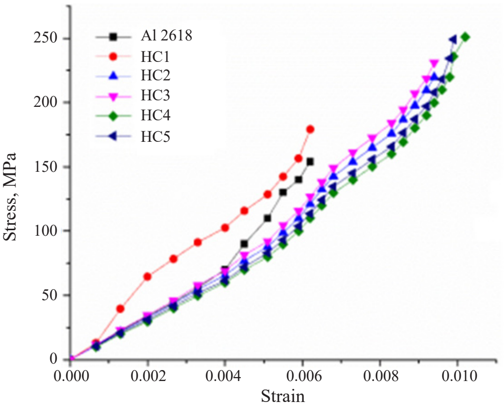

Figure 8: Stress v/s strain plot.

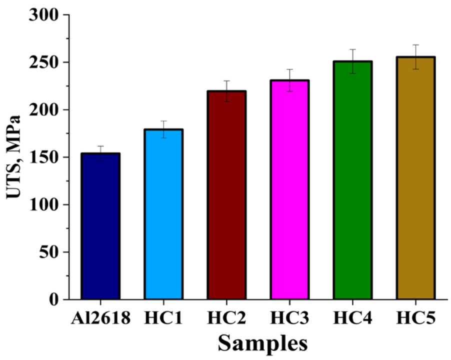

Figure 9: Ultimate tensile strength plot.

[16]. B_4C and Gr particles do not react to Al2618 thus dispersion- strengthening is maintained for long periods of time even at elevated temperatures [17]. The most impressive rise in UTS is over 30.6% when the particle content of B_4C and Gr is raised (8:4 wt%) as shown in Figure 9.

3.4 *Compression test*

Figure 10 illustrates the UCS (ultimate compressive strength) of a hybrid composite (Al2618+B_4C-Gr). It has been demonstrated that there is an unbroken upward trend in the compressive strength of the HMMC material with increasing content of B_4C and Gr. Indeed, the compressive strength increases by about 10.24% when the B_4C and Gr contents are raised (2:1). B_4C and Gr that serve as inhibitors for microstructure dislocation increase in compressive strength. Dispersion-strengthening plays a vital role to increase in UCS because it can continue to function

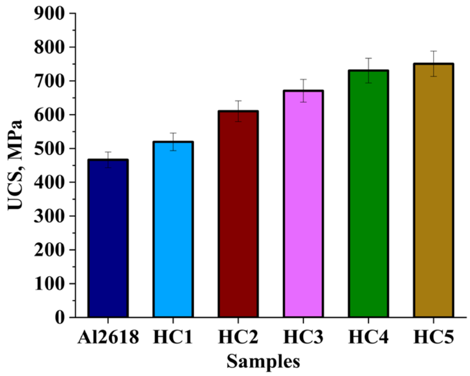

Figure 8: Stress v/s strain plot.

adequately at temperatures above the average and for extended periods of time. In addition, the reinforcement particles do not react with the matrix phase (Al2618) [18]. The growth in compressive strength is primarily due to the reduction in the inter-particle distance between the particles of B_4C and Gr and they resist deforming stress. The increase in the UTS is more impressive than the increase in compressive strength because the compressive strength of Al2618 is very high, in fact, multiple times the UTS. Reinforced alloy shows slight increase in compressive strength (10.24%). The incorporation of primary and supplementary (B_4C & Gr) particles has enabled hybrid metal matrix composites to appear as brittle instead of ductile materials, as is noticeable from the findings presented above [12]. The Figure 10 depicts the comparative increases in UCS, by changing the amount of B_4C and Gr within the matrix, there seem to be substantially modified compressive strength of the HMMCs. There must be a balance in choosing how much graphite can be used to improve the mechanical and physical properties without losing its hardness. The mechanical characteristics of HMMCs are greatly changed by variating the wt% of B_4C and Gr particulates [14].

3.5 *Impact test*

Figure 11 depicts effect of B_4C and Gr on impact strength of composite. The impact strength of the HMMCs increases (65%) as the wt% particles rise (2% B_4C: 1% Gr) in Al2618. By adding 8 wt% of B_4C and 5 wt% of Gr, which creates a minor transition from the ductile to brittle in matrix. The significant improvements in impact strength of HMMCs was

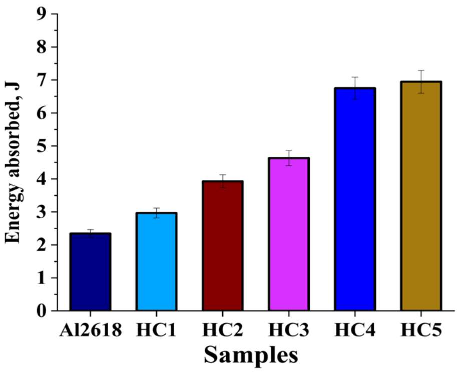

Figure 11: Impact energy plot.

not observed (S4 and S5). Crack and decohesion can reduce the impact strength of the material due to intrinsic defects in composites [13].

4 Conclusions

The casting of Al2618 with B_4C and Gr reinforcement composites has been fabricated and the following findings were reached as a result:

- The stir-casting technology was effectively utilized in the fabrication of hybridized composites.
- The SEM reveals that the B_4C and Gr particles in Al2618 are distributed uniformly.
- XRD confirms the presence of B_4C and graphite in Al2618.
- Dispersion-strengthening effect of B_4C and Gr particles in HMMCs improves the hardness of Al2618.
- The ultimate tensile strength, compressive strength, and impact strength of HMMCs, all have a tendency to improve along with an increase in the wt% of B_4C and Gr particles in Al2618.
- It is found that the mechanical properties of Al2618 with 8 wt% B_4C and 4 wt% Gr particulate reinforcement are significantly improved.

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