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Comparative Investigation on Mechanical and Tribological Performance between E-Glass Fiber and Boron Carbide (B4c) Reinforced Aluminum 8176 MMC

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Abstract

Because of its high strength to weight ratio and high corrosion resistance features, hybrid reinforcement of aluminium is a technology developed in response to the constantly growing demand in areas of the service industries such as aircraft, automobile, marine, and transportation. The two types of aluminium metal matrix composites (MMCs) used in this study—one reinforced with B4C fibre and the other with E-glass fiber—are examined for their mechanical and tribological properties. Both composites, Al8176, were made utilising the Stir Casting technique, and the reinforcement percentage varied in 2 wt.% increments (that is 0, 2, 4 and 6 wt.%). After solidification, the tests on specimen were conducted according to ASTM standards. The results of the tensile test show that both Al8176/B4C and Al8176/E-Glass fiber composites achieved their highest tensile strength at 4 wt.% reinforcement, reaching 72.5 N/mm^2 and 103.5 N/mm^2, respectively. Similarly, the compression strength of the composites reached its peak at 6 wt.% reinforcement, measuring 319.6 N/mm^2 and 292.2 N/mm^2 for Al8176/B4C and Al8176/E-Glass fiber respectively. The Al8176/B4C and Al8176/E-Glass fibre composites' the highest hardness ratings were observed to be 26.8 HV1 and 38.0 HV1 respectively at 6 weight percent reinforcement, according to the Micro Vickers hardness test. The wear tests wear conducted on test specimen using pin on disc method in which, the disk was running at a speed of 2000 rpm and the load was varied at intervals of 2,4,6 kg. SEM analyses were performed at 100x, 200x, and 500x magnifications.

Keywords: *Metal Matrix Composite, E-Glass Fiber, Boron Carbide, Hardness, Tensile strength.*

Introduction

Aluminium Metal Matrix Composites (AMMCs) have seen a substantial increase in demand recently. They can be machined more easily, have a less thermal expansion coefficient, are lighter, and have better mechanical characteristics. The other properties that make Aluminium rule the lightweight industry are its low density, hardness, alloying capacity, non-corrosive property in its Pure form, high thermal conductivity, availability, and low cost.

Al 8176

Aluminium 8176 is an 8000 series Aluminium which means that the primary alloying element is iron (Fe). The second digit denotes a unique modification to one of the alloying elements. The specific alloy is indicated by the third and fourth numbers 7 and 6 respectively.Aerospace and avionics applications for aluminium composites are improved by their special thermal characteristics, such as metallic conductivity and a coefficient of expansion that can be reduced to zero.

E-Glass fibre

Glass fibres are typically used to reinforce polymers. E-glass, corrosion-resistant -glass, and high-strength -glass are the most common forms of glass fibres. E-glass fibres were the first important synthetic composite reinforcement to be produced for electrical insulation applications, therefore the term "E". E-glass fibres are by far the most typical kind of fibrous support. They are less priced, which is the key justification and were developed earlier than other fibres. Glass fibres are made up of multifilament bundles. The diameters of the filaments range from 3 to 20µm. When compared to other fibre reinforcements, E-glass fibres have exceptionally low elastic moduli. E-glass fibres are also subject to creep and tension.

Boron carbide

Carbon and boron combine to form the crystalline substance known as boron carbide (B4C). It is a very tough, synthetic material used in control rods for nuclear power plants, lightweight composite materials, abrasive and wear-resistant items. Boron carbide is one which ranks third in the term of hardness behind cubic boron nitride and diamond. BC4 is the most durable artificial materials ever created. It is used as an abrasive in powder form to lap metal and ceramic materials. Although it is vulnerable to the heat of grinding hardened tools due to its low oxidation temperature of 400–500°C. Due to its extreme hardness and low density, it is used as reinforcement for aluminium in military armour and rough terrain vehicles.

Literature Review

Dr. Sanjay Kumar S M, et al. [1] the investigation focuses on the fabrication process of an Aluminum Metal Matrix Composite (Al/B4C/WC), emphasizing the selection of materials for its production. For the purpose of evaluating the mechanical and tribological characteristics of the hybrid aluminium metal matrix composite, the weight proportion of reinforcing particles such as tungsten and boron carbides (B4C and WC) is chosen. According to the study, increasing in the amount of boron carbide (B4C) in aluminium matrix composite results in better mechanical and tribological capabilities. Additionally, using a hybrid metal matrix composite rather than monolithic metal matrix composite results in less weight this improves fuel efficiency in cars.T Vishnu Vardhan et al. [2] thesis on the stir casting process used in the manufacture of MMCs and experimentally investigated the mechanical parameters of Aluminium alloy-alumina boron carbide metal matrix Composites. MMC composition varies for alumina (1%, 4%) and boron carbide (4%, 1%) while remaining 95% aluminium alloy. Using pictures created by a scanning electron microscope, the produced samples are additionally carefully inspected for their internal structure and random orientation of particles. Sandeep D. et al. [3] have conducted a review of the literature on Hybrid metal matrix composites made of Al7075, Al2O3, and MICA particles are studied and evaluated for their mechanical properties. Taking into account the review, current research aims to learn more about the mechanical characteristics of AA7075 Hybrid composites reinforced with short E-glass fibres and as-cast micro particles. These composites are made of 200 micron-sized micro particles and short, variable-composition E-glass fibres, which range in length from 2 to 3 mm. The extent of improvement in the mechanical characteristics of these Metal Matrix Composites (MMCs), as determined through thorough mechanical testing, is predominantly influenced by the choice of reinforcement type and its respective volume fractions. Sp. G. Pantelakis et al. [4] have conducted an assessment of the literature on "Assessment of the ability of conventional and innovative wrought Al alloys for mechanical performance in light weight applications." The ability of advanced wrought Al alloys for mechanical performance in light weight structures by involving quality indices is included in this article. An experimental examination is being conducted on a range of aeroplane structures made of wrought Al alloy. The results reveal that when using quality indices to pick materials for aeroplane constructions, ignoring the scatter in alloy characteristics and alloy density might lead to errors.

Experimental Work

Both the metal matrix composites were fabricated using stir casting process, the filler material (B4C and E-Glass fibre) was added to the metal matrix at 0, 2, 4 and 6 wt.%. The Al8176 was stir cast with B4C to fabricate Al8176 / B4C composites. The furnace's temperature must be precisely measured and controlled (±1ºC). There were two thermocouples and one PID controller used. The stirrer was powered at various speeds by a 1HP motor. The rotary blades were immersed in the composite material using a screw-operated raising mechanism.3 kg of Al 8176 was placed in a graphite crucible and cooked to approximately 750°C in an electric furnace, the percentage of B4C was calculated using a digital electronic weighing equipment and stored in a furnace. The temperature was raised to approximately 480°C and Impurities were removed using degasifires. The molten metal Al8176 was removed from the furnace and preheated B4C was added. The Al8176/B4C composite is placed in a furnace and heated to around 800°C.Following that, the melt was swirled at 300 rpm with a graphite impeller coupled to a variable speed motor. For 10 minutes, the furnace temperature was held constant at 750°C. The molten metal was then poured into the mould, yielding an Al8176 / B4C composite. The same process was used to create the various weight percentages of other mixtures. The casted Al 8176 / B4C composite specimen was machined for various tests. The Al8176/E-Glass fibre metal matrix composite was made in the same manner.

Result and Discussion

Comparison of Tensile test between Al8176/E-glass fibre and Al8176/B4C

The samples were prepared following the guidelines of the ASTM standard E8/E8M. Subsequently, the tests were performed using a universal testing machine. Al8176/E-Glass fibre performs better in tensile test compared to Al8176/B4C. Al81761/E-Glass Fibre reaches a maximum of 103.5 N/mm^2 at 6 wt.% and Al8176/B4C reaches a maximum of 72.5 N/mm^2 at 4 wt.%. Figure 1 and Figure 2 describes loads vs CHT of different weight percentages of filler.Comparison of Tensile test between Al8176/E-glass fibre and Al8176/B4C is shown in table 1 and 2 respectively.

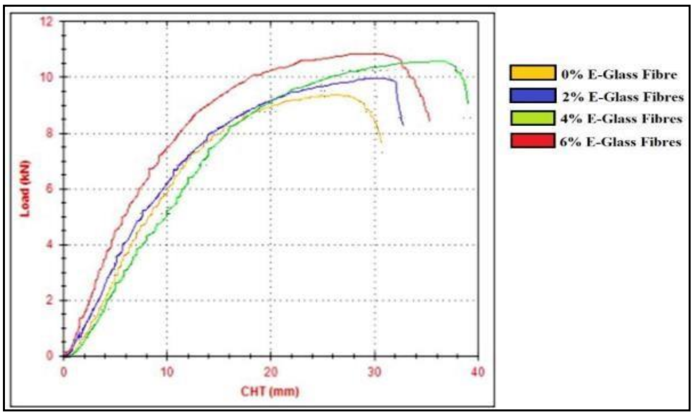


Fig.1 Al8176/E-Glass fibre

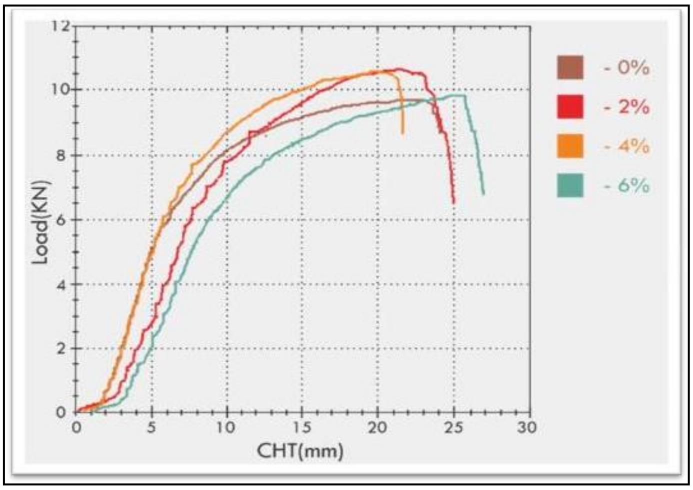


Fig. 2 Al8176/B4C

Table 1 Comparison of Tensile test between Al8176/E-glassfibre.

Properties/Material	Al + 0% EGlass Fibre	Al + 2% EGlass Fibre	Al + 4% EGlass Fibre	Al + 6% EGlass Fibre
Load at Yield	7.19 kN	7.8 kN	9.64 kN	9.95 kN
Yield Stress	59.0 N/mm^2	63.6 N/mm^2	78.4 N/mm^2	80.4 N/mm^2
Load at Peak	10.810 kN	11.640 kN	12.350 kN	12.800 kN
Tensile Strength	88.6 N/mm^2	94.8 N/mm^2	100.5 N/mm^2	103.5 N/mm^2
% Elongation	39.1%	32.7 %	32.1 %	30.2 %

Properties/Material	Al+0%EGlassFibre	Al+2%EGlassFibre	Al+4%EGlassFibre	Al+6%EGlass Fibre
Load at Peak	35.250kN	38.790kN	35.400kN	35.470kN
C.H.Travel at Peak	13.700 mm	15.220 mm	13.030 mm	15.340 mm
Comp. Strength	265.6 N/mm^2	292.2 N/mm^2	266.7 N/mm^2	267.2 N/mm^2

Table 2 Comparison of Tensile test between Al8176/B4C

Table 3 Comparison of compression test between Al8176/B4C

Properties/Material	Al+0%B4C	Al+2%B4C	Al+4%B4C	Al+6%B4C
Load at Peak	40.640kN	41.930kN	42.290kN	42.420kN
C.H.TravelatPeak	15.950 mm	15.490 mm	15.970 mm	15.350 mm
Comp.Strength	306.3 N/mm^2	315.9 N/mm^2	318.6 N/mm^2	319.6 N/mm^2

Table 4 Comparison of compression test between Al8176/B4C

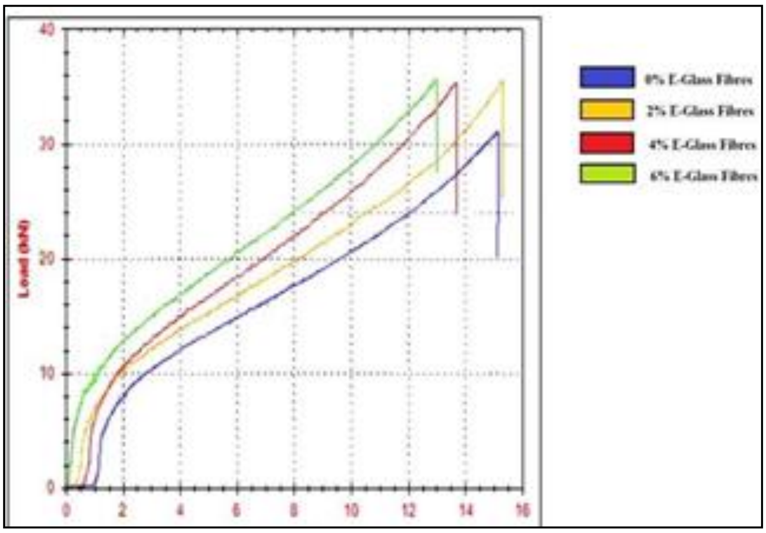
Properties/Material	Al+0%B4C	Al+2%B4C	Al+4%B4C	Al+6%B4C

Load at Peak	40.640kN	41.930kN	42.290kN	42.420kN
C.H.TravelatPeak	15.950 mm	15.490 mm	15.970 mm	15.350 mm
Comp.Strength	306.3 N/mm^2	315.9 N/mm^2	318.6 N/mm^2	319.6 N/mm^2

Comparison of Compression test between Al8176/E-glass fibre and Al8176/B4C

The samples were prepared following the specifications of the ASTM E9/E9M standard. Subsequently, the tests were performed using a universal testing machine. It was observed that Al8176/B4C exhibited a higher compression strength compared to Al8176/E-Glass Fiber. Al8176/B4C reached a maximum compression strength of 319.6 N/mm^2 at 6 wt.%, while Al8176/E-Glass Fiber reached a maximum compression strength of 292.2 N/mm^2 at 2 wt.%. The Fig 3 and Fig. 4 represents the different wt.% of filler added and their Loads vs CHT curves. Comparison of compression test between Al8176/E-glass fibre and Al8176/B4C is shown in table 3 and 4 respectively.

Fig. 3 Al8176/E-Glassfibre



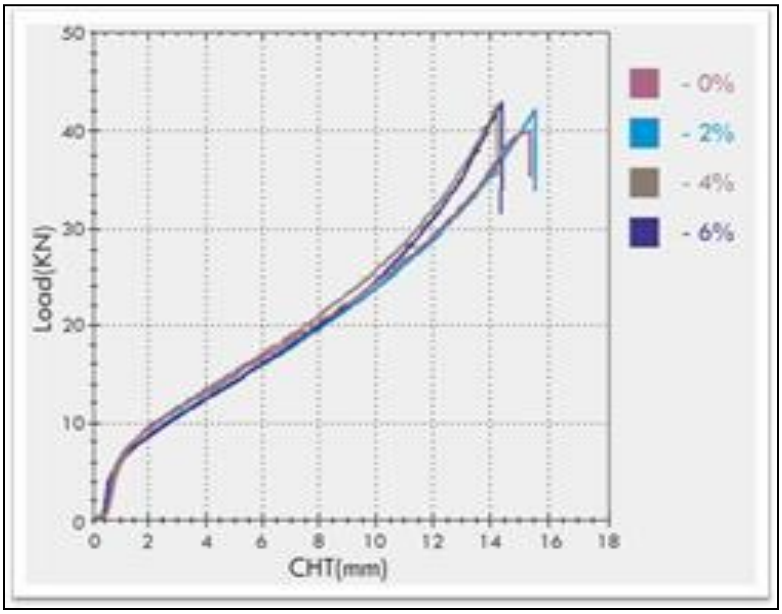
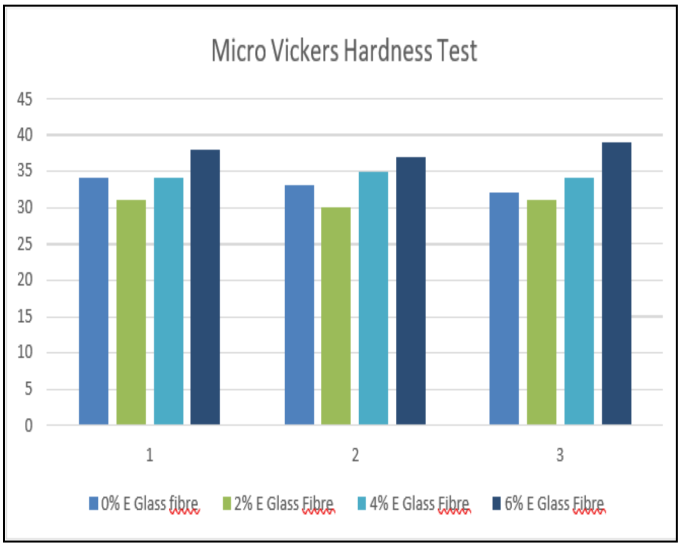


Fig.4.Al8176/B4C

Comparison of Hardness test between Al8176/E-glassfibre and Al8176/B4C

The specimens were machined according to ASTM standard E18. The tests were conducted by using Vickers hardness Tester. Al8176/E-Glass Fibre has higher Hardness value than Al8176/B4C. Al8176/B4C reaches a max Hardness value of 28.6HV1 at 6 wt. % and l8176/E-glass Fibre reaches a max Hardness value of 38 HV1 at 6wt. %. The Fig. 5 and Fig. 6 represent the different wt. % of filler added and their Hardness.Comparison of



hardness test between Al8176/E-glass fibre and Al8176/B4C is shown in table 5 and 6 respectively.

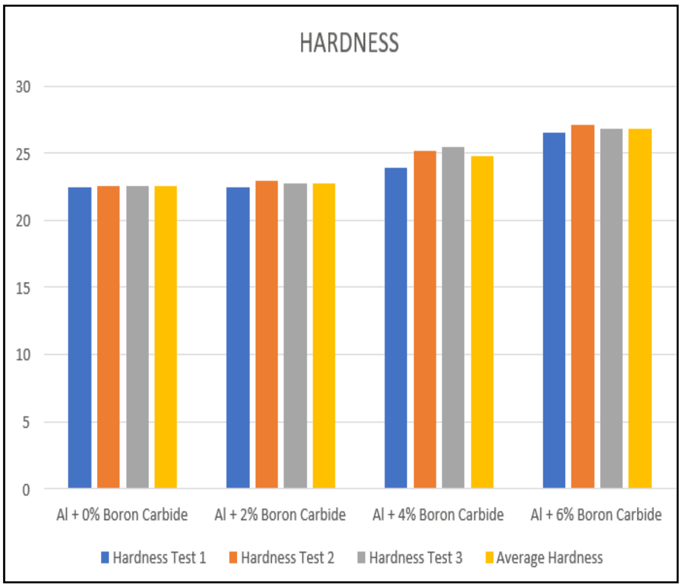


Fig.5 Al8176/E-Glass fibre

Fig6 Al8176/B4C

Comparison of Wear test between Al8176/E-glass fibre and Al8176/B4C

The wear test was conducted according to ASTM standard G-99 by using “pin on disk” apparatus. The disk was rotating at 1500 rpm with varying load of 2, 4, 6Kg load was applied on the specimens. The friction and Co-efficient of Friction (μ) of Al8176 / E-Glass Fibre and Al8176/B4C are tabulated in table 7 and 8 respectively.

Comparison of wear test between Al8176/E-glass fibre and Al8176/B4C is shown in table 7 and 8 respectively.

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Table 5 Comparison of Hardness test between Al8176/E-glass fibre

Properties/Material	Al+0%E-GlassFibre	Al+2%E-GlassFibre	Al+4%E-GlassFibre	Al+6%E-Glass Fibre
Hardness Test1	34HV1	31HV1	34HV1	38HV1
Hardness Test2	33HV1	30HV1	35HV1	37HV1
Hardness Test3	32HV1	31HV1	34HV1	39HV1
Average Hardness	33HV1	30.67HV1	34.3HV1	38 HV1

Table 6 Comparison of hardness test between Al8176/B4C

Properties/Material	Al+0%B4C	Al+2%B4C	Al+4%B4C	Al+6%B4C
Hardness Test1	22.5HV1	22.5HV1	23.9HV1	26.5HV1
Hardness Test2	22.6HV1	22.9HV1	25.2HV1	27.1HV1
Hardness Test3	22.6HV1	22.7HV1	25.5HV1	26.8HV1
Average Hardness	22.5HV1	22.7HV1	24.8HV1	26.8 HV1

Table 7 Comparison of wear test between Al8176/E-glassfibre.

Wt.added/Material	Al + 0% E Glass Fibre		Al + 2% E Glass Fibre		Al + 4% E Glass Fibre		Al + 6% E Glass Fibre	
	Friction	μ	Friction	μ	Friction	μ	Friction	μ
2kg	11.5N	0.586	15.8N	0.805	14.4N	0.734	12.4N	0.632
4kg	15.6N	0.397	16.4N	0.417	18.9N	0.481	28.2N	0.718
6kg	19.8N	0.504	24.5N	0.624	30.3N	0.772	34.3N	0.874

Table 8 Comparison of wear test between Al8176/B4C

Wt.added/Material	Al + 0% B4C		Al + 2% B4C		Al + 4% B4C		Al + 6% B4C	
	Friction	*μ*	*Friction*	*μ*	*Friction*	*μ*	*Friction*	*μ*
2kg	9.3 N	0.47	13.4 N	0.68	12.6 N	0.64	10.2 N	0.51
4kg	13.8 N	0.35	14.5 N	0.36	16.8 N	0.42	26.4 N	0.67
6kg	17.5 N	0.29	22.8 N	0.38	28.7 N	0.48	32.6 N	0.55

Comparison of Microstructure test between Al8176/E-glass fibre and Al8176/B4CAluminium 8176+E Glass Fibre 6%

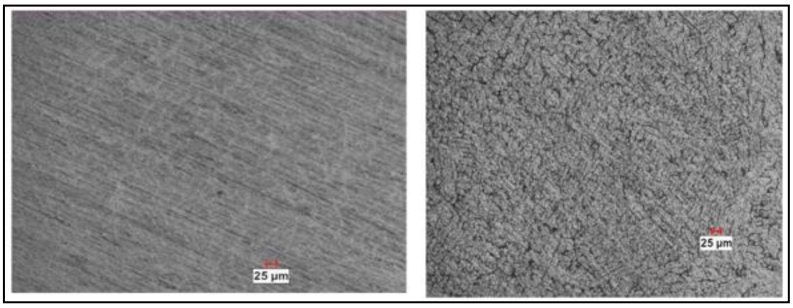


Fig.7 100X–UNETCHED and100X–KellersEtched

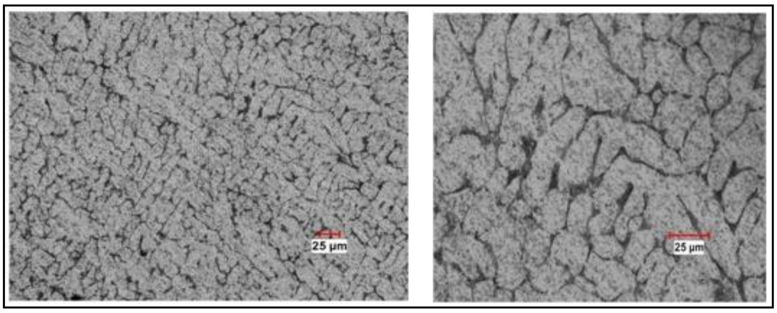
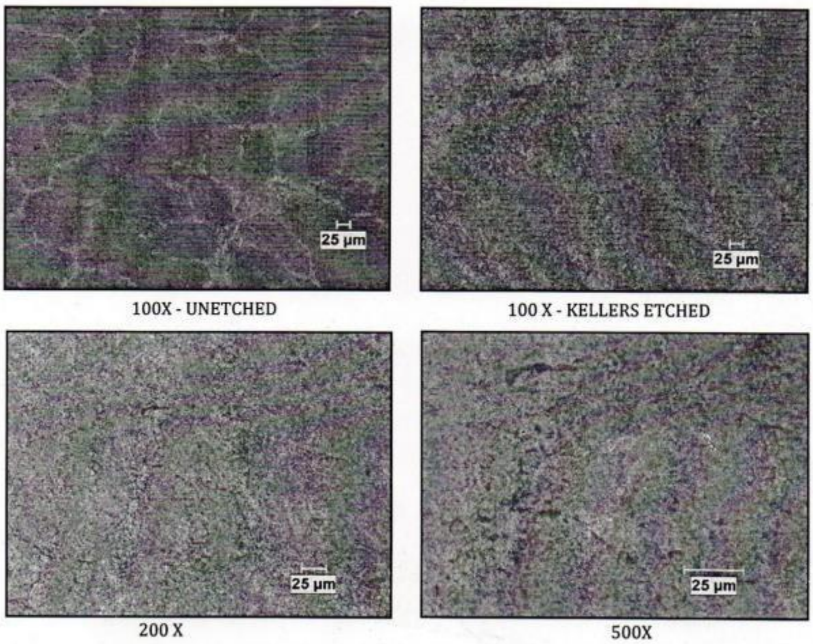


Fig.8 200X & 500X

Aluminium 8176+Boron Carbide 6%

The specimens were tested for microstructure according to ASTME407. The microstructure was analyzed for 100X, 200X and 500X times zoom. The above images fig. 7 and 8 are 6 wt. % of filler added to metal matrix. The matrix of the aluminium solid solution contains fine precipitates of alloying elements, which are scattered in the dendrite area of the microstructure.

Fig. 9 100X–Unetched, 100X–KellersEtched, 200X & 500X



Conclusion

We finally obtained a composite material, one made from mixing Aluminium 8176 and E Glass Fibres and the other from mixing Aluminium 8176 and Boron Carbide, with homogeneously distributed reinforcements. During stir casting methodology, mould with fewer defects is obtained, and is concluding during microstructure analysis.

From the mechanical tests and wear tests that were performed on the specimen, thefollowingpoints are concluded:

- Al8176/E-Glass Fibre tensile strength improved by 25%, while Al8176/B4C tensile strength went up by 22.46 percent.
- Al8176/E-Glass Fibre compressive strength rose by 10%, while Al8176/B4C compressive strength increased by 4.34%.
- The Al8176/E-Glass Fibre's hardness improved by 25%, and the Al8176/B4C Fibre's hardness increased by 19.11%.
- Due to the roughness produced by E Glass and Boron carbide, the material's wear characteristics also significantly enhance. The wear property increases by nearly 10% in both the composites leading to various applications in industry.

Further studies via microstructure analysis suggested that these increase in properties are impacted and a result of the orientation and homogeneity of the E-Glass fibre in Aluminium 8176 as well as the consistent distribution of B4C.

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