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WEAR AND HARDNESS CHARACTERIZATION OF AA6061/ALB_2 METAL MATRIX COMPOSITES

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ABSTRACT

Aluminium- alloys and Aluminium-based metal matrix composites have found application in the manufacture of various automotive engine components such as cylinder blocks, pistons and piston insert rings where adhesive wear (or dry sliding wear) is a predominant process. Further, their hardness property plays a role for applications in high abrasive conditions. In this present investigation composites were prepared with aluminium alloy reinforced with 2%, 4% and 6% of potassium tetrafluoroborate (KBF_4) in order to obtain aluminium boride (AlB_2) by In-Situ chemical reaction between KBF_4 and aluminium alloy.. The properties investigated were wear rate and hardness, For wear, the influence of applied load, sliding speed and wearing time were critical parameters in relation to the wear regime encountered by the material. The casting was produced by stir casting technique and specimens were machined as per the ASTM standards. It was observed that wear rate is less and hardness improved when compared with the base alloy proving the fact that the formed AlB_2 due to In situ reaction with KBF_4 has a remarkable effect on wear resistance of the composites.. The X-ray Diffractometer test was performed to determine the intensity of reinforcement in the matrix. The (SEM) image confirms the formation of ALB_2 with uniform distribution in to the matrix.

Keywords: Metal Matrix Composites, AA6061, Wear, Hardness, AlB_2

1. INTRODUCTION

Metal Matrix Composites are being increasingly used in aerospace and automobile industries owing to their enhanced properties such as elastic modulus, hardness, tensile strength at room and elevated temperatures, wear resistance combined with significant weight savings over unreinforced alloys. The commonly used metallic matrices include Al, Mg, Ti, Cu and their alloys. These alloys are preferred matrix materials for the production of MMCs [1-4]. MMCs attracted researchers due to the availability of reinforcements at competitive cost, suitable processing technique and the availability of standard working method to fabricate them. The composite prepared by ex-situ method suffers thermodynamic instability between matrix and reinforcements, thus limiting their ambient and high temperature mechanical properties. The major challenges in processing of ex-situ MMC is thermodynamic instability of ceramic reinforcing phases with the matrix. This

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is due to poor wetting between matrix and reinforcement. Ex-situ process possesses drawbacks like agglomeration, poor wetting and heterogeneity in microstructure. Also, ex-situ composite fabrication method comprises of many stages, like sorting, alignment infiltration and sintering. In order to overcome the above limitations, in situ processes have received much attention because of their interesting characteristics. In-situ composite is material in which the ceramic phase is formed within the parent phase by controlled melt growth, chemical reaction, transformation and deformation. By the in-situ formation of metal matrix composites (MMCs), a better homogenous microstructure can be achieved. Moreover, the reinforcements made by in-situ reactions show a clean interface of reinforcement matrix and small size of particles resulting in better mechanical properties [5, 6]. In-situ production of reinforcing particles in the metal matrix appears to be a promising route to fabricate composites in terms of both technical and economic considerations. The in-situ formation of a ceramic second phase provides greater control of size and level of reinforcements, as well as the matrix reinforcement interface, yielding better tailor ability of the composites. Among the various reinforcing particles, AlB_2 is particularly attractive because it exhibits high specific modulus, strength, hardness and stiffness, excellent wear resistance, low-heat expansion coefficient, stability of properties at elevated temperatures and reduced density. These unique properties make them attractive in aerospace, automotive and marine industries for both nano structural and structural applications [8]
The alloy AA 6061 is widely used in numerous engineering applications including transport and construction where superior mechanical properties such as tensile strength, hardness etc., are essentially required. The superior corrosion resistance property with mechanical flexibility makes it a suitable candidate material for various marine and other structural applications [9-11].

2. Materials Used

2.1 Aluminium AA6061 (Matrix)

Aluminium is an abundant, light and strong metal which has found many uses. Like all composites, aluminium-matrix composites are not a single material but a family of materials whose stiffness, strength, density, and thermal and electrical properties can be tailored. The matrix alloy, reinforcement material, volume and shape of reinforcement, location of the reinforcement, and the fabrication method can be varied to achieve required properties. Regardless of the variations, however, Al composites offer excellent thermal conductivity, high shear strength, excellent abrasion resistance, high temperature operation, inflammability, minimal attacks by fuels and solvents. AA6061 alloy was produced form M/s Fenfee metallurgical, Bangalore. India.

2.2 Potassium Tetrafluoroborate KBF_4 (Reinforcement)

Potassium tetrafluoroborate was used in order to react with molten aluminium alloy and form aluminium diboride (ALB_2) which is well known for its relatively high strength and durability as characterized by the relatively high values of its melting point, hardness, strength to density ratio, and wear resistance.

3. Experimental Details

The metal matrix composites were fabricated using, aluminium alloy is reinforced with 2%, 4% and 6% of fluoride salt (KBF_4) salt to produce ALB_2 by a method involving the reaction of KBF_4 with molten aluminium with an attempt to improve its wear resistance and hardness property. For wear, the influence of applied load,

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sliding speed and time were critical parameters in relation to the wear regime encountered by the material. The casting were done by stir casting technique and specimens are machined as per the ASTM standards. The wear and hardness tests were performed. The wear test showed the maximum improvement of 93.65 % in the wear resistance for 6% reinforced KBF_4 MMC while the Brinell hardness test showed a maximum improvement of 76.10% for 6% reinforced KBF_4 MMC, both values obtained with the analyzed uncertainty. Scanning Electron Microscope (SEM) image shows the grain refinement and uniform distribution of grains in the matrix alloy

4. Results and Discussions

4.1 Adhesive Wear

Wear test was performed on pin on disk wear testing machine. The specimens were prepared as per ASTM G99 with varying speed ranging from 720 rpm to 1120 rpm.

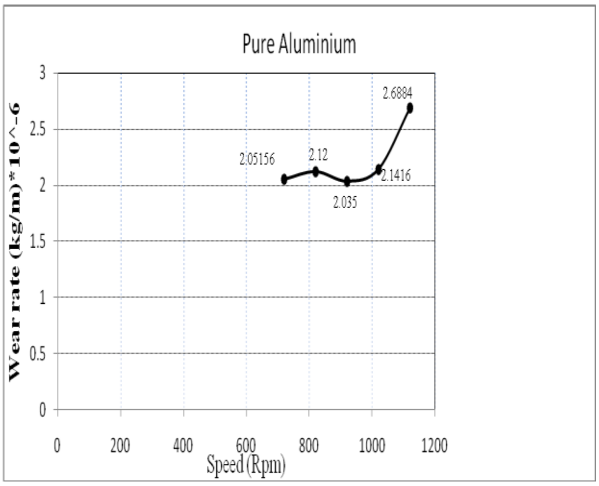

Fig 1: Variation of Wear Rate of Aluminium >= 95% Purity with Varying Speed

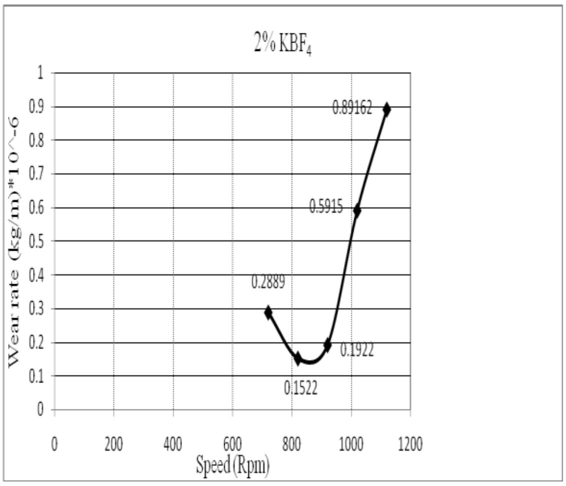

Fig 2: Variation of Wear Rate of AA6061 - 2% KBF_4 Composite with Varying Speed

Fig 1 show the dependency of wear rate with speed, as the speed increases wear rate is steadily increased upto 1010 rpm then it increases drastically.

Fig 2 show the dependency of wear rate with speed, as the speed increases wear rate is steadily decreased upto 800 rpm then abnormal increase in wear rate

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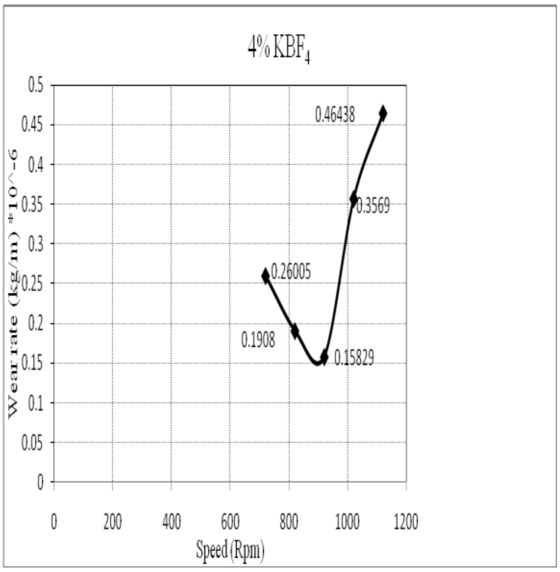

Fig 3: Variation of Wear Rate of AA6061 - 4% KBF_4 Composite with Varying Speed

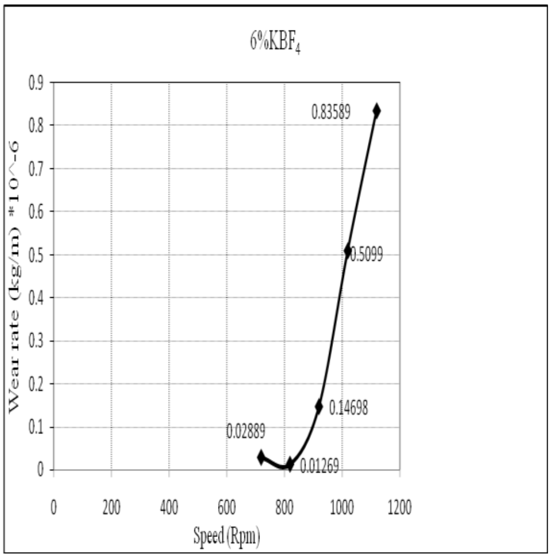

Fig 4: Variation of Wear Rate of AA6061 - 6% KBF_4 Composite with Varying Speed

Fig 3 show the variation of wear rate with speed, as the speed increases wear rate is steadily decreased up to 910 rpm then it increases drastically.

Fig 4 show the variation of wear rate with speed, as the speed increases wear rate is slightly decreased up to 805 rpm then it increases drastically.

So it is concluded that the optimum speed of 800 – 900 rpm is feasible for the developed composites beyond that wear rate is higher.

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4.2 Comparison of Wear Rate and Hardness for Different Percentage Reinforcement of KBF_4 Reinforced MMC

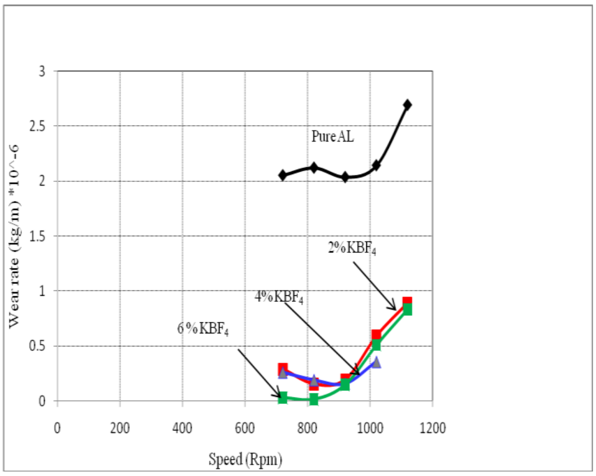

Fig 5: Graphical Representation of Wear Rate for Base Alloy and Al - KBF_4 MMC

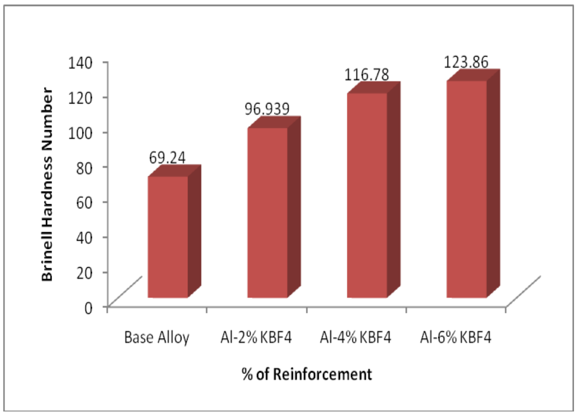

Fig 6: Graphical Representation of Hardness Test for Base Alloy and Al - KBF_4 MMC

Fig 5 show the graphical comparison of wear rate for base alloy and Al-2%,4%,6% KBF_4 metal matrix composites. From the above fig it can be clearly seen that the wear rate for 6% KBF_4 composite is less as compared with 2% and 6% Al-KBF_4 composites. When compared with the base alloy wear rate of developed composites has remarkable effect that is wear rate decreases to a large extent on the addition of the reinforcement.

Fig 6 shows that the hardness of composite material increases as the amount of reinforcement increases. This is attributed due to the higher hardness of reinforcement.

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5. Morphological Studies

The cristalographic structures of the compounds that could appear in the microstructure of the composite are: hexagonal (AlB_2) and tetragonal (AlB_{12}) as shown in the Fig 13 below.

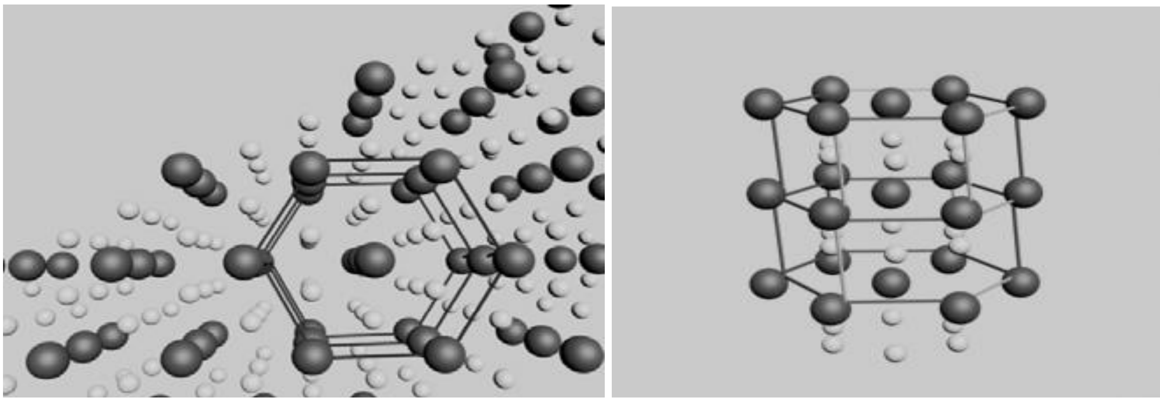

Fig 7: 3d Structure of Alb_2 Represents the Aluminium Atoms, and the Boron Atom

Fig 7 below shows the results of the optical analysis of the in- situ AA6061/AlB_2 composite. It is noted that AlB_2 type structure formed, the hexagonal form of the particles being clearly noticed. Since the exothermic reaction between aluminium (AA6061 alloy) and KBF_4 took place entirely in the molten alloy, no oxidation layer on the surface of the AlB_2 particles was formed.

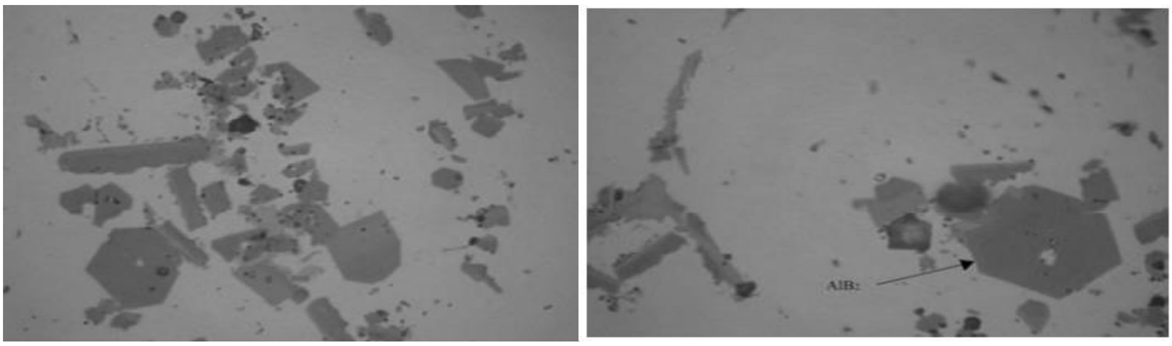

Fig 8: Morphology of AlB_2 Particles in AA6061/AlB_2 In Situ Composite

The X-ray diffraction measurements were carried out with the help of an advance Rigaku model using X-ray radiation at an accelerating voltage of 40 kV and a current of 20 mA. In this test the sample was in stationary condition, only the arms of the X- ray tube was rotating in the opposite direction from 300 to 700 of 2θ during the test. The samples were scanned with a scan rate of 2^o / minute. After the data for intensity was obtained for 0.02o angle (2Θ), origin pro 8.5 was used to plot the graphs for intensity v/s Bragg's angle.

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The pattern reveals the presence of Al and AlB_2 peaks, indicating that AlB_2 is formed in the composite, at high cooling rate. As it is known the adhesion mechanical work of the in situ composites is higher than of the ex situ composites, this fact presenting an advantage of the in situ composites.

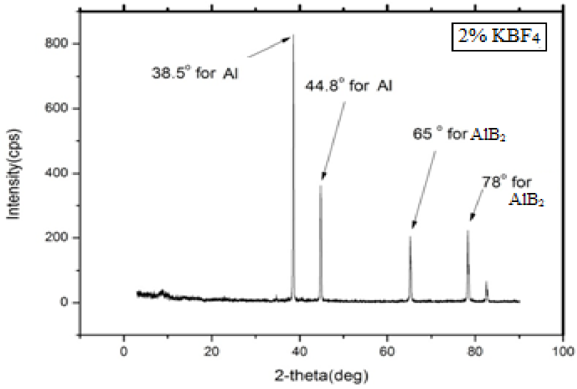

Fig 9: XRD Pattern for 2% Al-KBF_4 Showing its Presence in the form of AlB_2 At 65° And 78°.

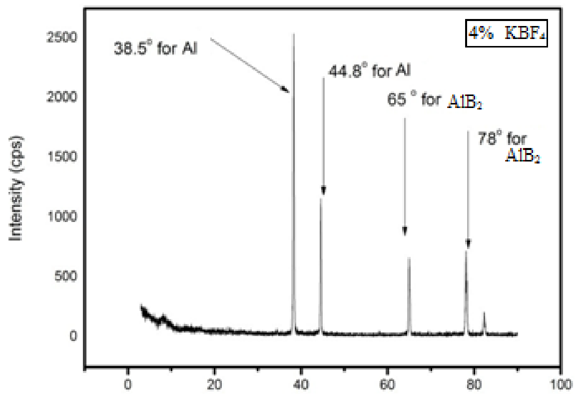

Fig 10: XRD Pattern for 4% Al-KBF_4 Showing its Presence in the form of AlB_2 At 65° And 78°

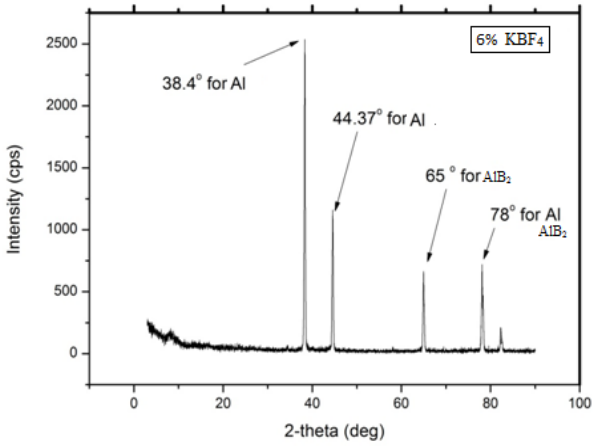

Fig 11: XRD Pattern for 6% Al-KBF_4 Showing its Presence in the form of AlB_2 At 65° and 78°.

The above XRD graphs confirm the presence of reinforcement in the matrix. The XRD patterns obtained for Al-$KBF_4$with high peaks at 38.5° or 44.8° showed the corresponding intensity to be 800 counts per second (cps) for 2% KBF_4 reinforced aluminium. For 4% Al- KBF_4 the peaks as at 38.5° or 44.8° and corresponding intensity to be 2500 cps 6% Al- KBF_4 the peaks were at 38.5° or 44.37° which showed the corresponding intensity to be around 2500 cps

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5.1. Optical and SEM Studies on the Material Systems Studies

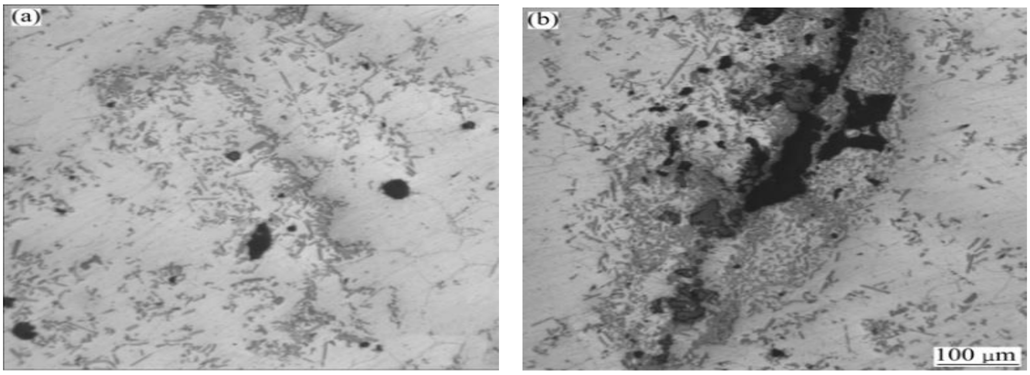

Fig 12: (a) and (b) Optical Micrographs of two Typical Large Agglomerations of Boride Particles in AA6061 2% KBF_4 Prepared Composites

The chain-like agglomerations, as shown in Fig 12 (a), consist of only AlB_2 phase. This kind of agglomeration is also found composites prepared by the addition of KBF_4 salt directly to the aluminium melt. They are probably formed at the interface between molten aluminium and the floating molten salt.
The other typical ones are characterized by the aggregated boride particles of both AlB_2 and AlB_{12} surrounded with some residual salt as shown in Fig 12 (b). Agglomerations formed at the interface between molten aluminium and salt droplets during addition KBF_4 into molten aluminium.

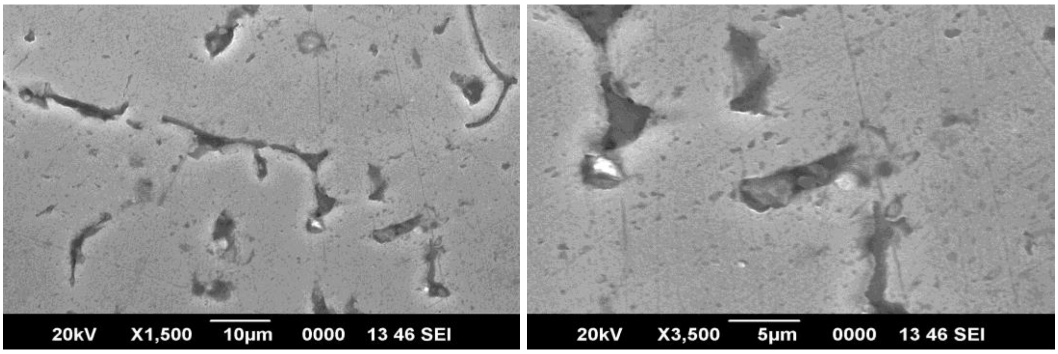

Fig 13: Scanning Electron Micrographs of Etchied AA6061 Base Alloy

The SEM analysis of the aluminium base alloy with etching shows that, some elements like Fe, Si and SiO2 were observed as small granular structure as shown in Fig 13.
Fig 20, 21, 22 shows the Scanning electron micrographs images of composites prepared by the addition of 2%, 4%, 6% of KBF_4 with etching. The images clearly revels the formation of AlB_2 into the prepared composites.

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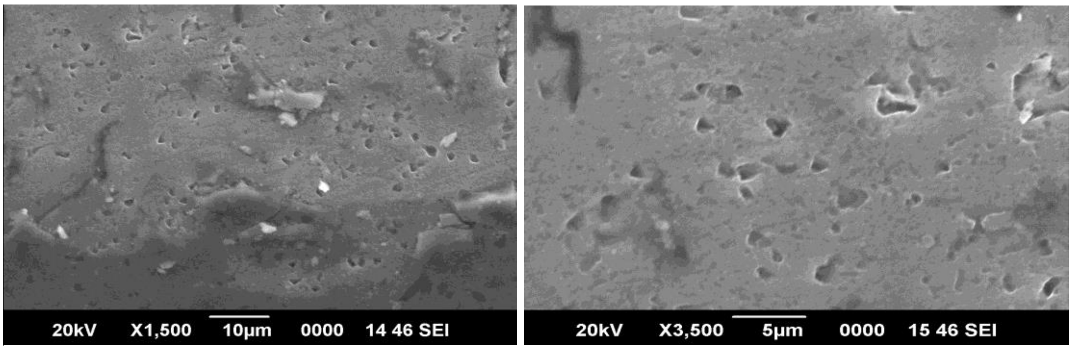

Fig 14: Scanning Electron Micrographs for 2% KBF4 with Etching

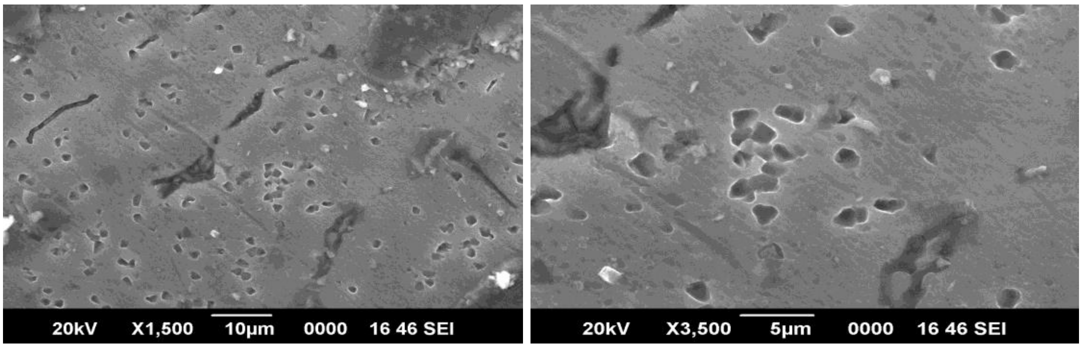

Fig 15: Scanning Electron Micrographs for 4% KBF_4 with Etching

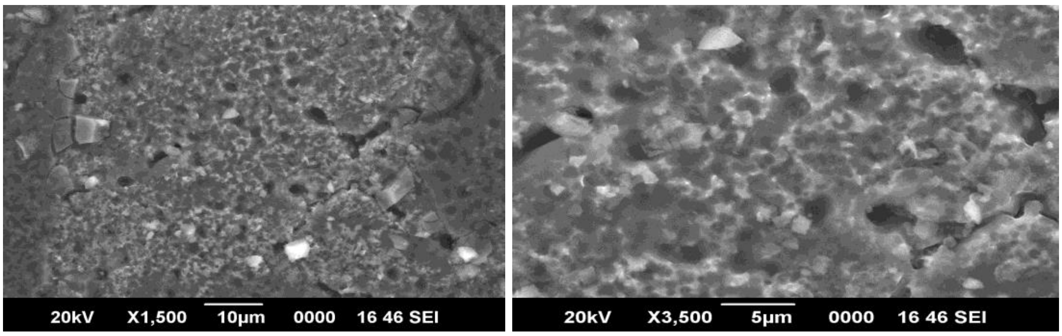

Fig 16: Scanning Electron Micrographs for 6% KBF_4 with Etching

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7. Conclusion

1. The AA6061 Composites were prepared successfully by In-situ technique.
2. It is observed that AlB_2 is formed by chemical reaction between KBF_4 and aluminium alloy.
3. Optical micrographs show the formation and uniform distribution of AlB_2 with good bonding between the matrix and reinforcement.
4. SEM images confirm the presence of AlB_2 particles which are cubic, pentagonal and hexagonal shaped formed by In-situ reaction between matrix alloy and KBF_4
5. XRD studies conforms the presence of AlB_2 within the matrix.
6. At 6% weight of KBF_4 reinforcement, the improvement in wear resistance is maximum due to the higher dispersion of the KBF_4 matrix.
7. The improvement in the hardness value was maximum for the 6% KBF_4 reinforced MMCs which is due to greater resistance to permanent indentation for the applied load and smaller value of indentation diameter compared to the other which attributes due to higher hardness of reinforcement.

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