Mechanical Characterization of Aluminium 8176 Metal Matrix Composite Reinforced with Boron Carbide

Mr. Praveen Kumar U B[1, a], Dr. Puneeth Kumar N[2, b *], Dr. Santhosh Kumar B M[3, c] and Dr. Manjunatha B[4, d]

[1]*Assistant Professor, JSS Academy of Technical Education, Bangalore, Karnataka, India*

[2]*Assistant Professor, Department of ME, CMR Institute of Technology, Bangalore, Karnataka, India*

[3]*Assistant Professor, JSS Academy of Technical Education, Mysore, Karnataka, India*

[4]*Assistant Professor, SJCE, JSSSTU, Department of I&P, Bangalore, Karnataka, India*

Abstract

The current study emphasizes on the characterization of Al8176 and the percentage fluctuation of boron carbide in MMC. This process necessitates via means of numerous techniques and technologies with the following goals: (i) Investigating both mechanical and physical characteristics of each constituent of the composite material for different volume fraction (ii) Recognizing how manufacturing and composition affect the composite's characteristics; and (iii) Analyzing and predicting the effectiveness of materials.These appears to be particularly significant when it comes to composite products containing extremely inhomogeneous characteristics (the line signifies the presence of inhomogeneous particle or materials will corrode faster, in this regard we concentrated on homogenous mixture to improve the corrosion resistance in the composition). The physical and mechanical characteristics in this study were looked at the microstructure research into the Aluminum-Reinforced Metal matrix composite 8176 with the boron carbide (0%, 2%, 4% and 6%). The findings show that mechanical characteristicsof the composite metal matrix, such as compression, hardness, and tensile strength, were found to increase as the weight percentage of boron carbide increased.

***Keywords**: Metal Matrix Composite, Hardness, compression strength, tensile strength.*

Introduction

Combination known as composite with metal fibers as reinforcements along with a matrix material is called as composite’s metal matrix (MMC). The selection of these reinforcements are made in such considerations that the reinforcement's tensile strength should be greater than the matrix material and there should be larger temperature difference between the melting points of matrix and reinforcements so that when added they do not burn out under high temperature [1].

Alloys with aluminium (Al) as the main metal are known as aluminium alloys, or 8176 as shown in fig. 1. Common alloying elements include copper, magnesium, manganese, silicon, tin, and zinc. Casting alloys and wrought alloys, which are further separated into heat and non-heat-treatable categories, are the two main classifications. Around 85% of aluminium is used for wrought objects including rolled plate, foils, and extrusions [2]. Due to their low melting point, cast aluminium alloys produce goods at a cheaper price [2], while having typically lower strengths than wrought alloys. While the high silicon concentration (4.0-13%) results in good casting qualities. In engineering constructions and components that are lightweight or resistant to corrosion are needed, alloys made of aluminium are widely used [3].

Fig. 1BlocksofAluminium8176ingotFig. 2 Boron Carbide Powder

Regarding hardness, boron carbide shown in fig. 2 comes in third place, just behind cubic boron nitride and diamond. The chemical that is produced in tones is the toughest thing ever. Carbon and B2O3 are reacted in an electric arc furnace to produce boron carbide powder, either through carbothermal reduction or gas phase processes.Because of its alluring attributes, such as high strength, low density, extraordinarily high hardness [4] (after diamond and boron nitride, the substance with the third-highest hardness), good chemical stability, and neutron combination capacity, boron carbide is among the most optimistic ceramic materials.Ionizing radiation doesn't damage the compound boron carbide. It is nearly as hard as a diamond. Although its low oxidation temperature of 400–500° C (750–930° F) prevents it from withstanding the heat of grinding hardened tool steels, it is employed as an abrasive in powder form in the lapping (fine abrading) of metal and ceramic products [5]. Due to its hardness and extremely low density, it has been used to reinforce aluminium in military amour and high-performance bicycles [3]. Its wear resistance has also led to its employment in pump seals and sandblasting nozzles. Boron carbide, a neutron absorber, is employed in nuclear reactors to regulate the rate of fission in powdered or solidified form.

Materials and Procedures

Selection of Materials

There are important factors that are to be considered during the selection of the reinforcement. Thereinforcement must be helping to the enhance the performance of base metal and must be of easeduring fabrication process. Procurement of an ingot and then getting it powdered is not a good ideawhenreadilyavailablepowdercanpurchase.ConsideringtheprojectworkbeingaparticulateAluminium metal matrix composite, the kind of reinforcement to procure must be in powder form.The project demands the quality of the reinforcement, boron carbide to be of a superior quality whichhelps in obtaining better results [6]. Boron carbide being the 3rd hardest ceramic material will help inenhancingthehardnesspropertyofthebasemetal,Aluminium8176.Thebasemetal,Aluminium8176 was selected due to its peculiar characteristics. Material composition of selected material listed below in table 1 and 2.

Procedures

Samples were prepared by fabrication process with 4 different % of boron carbide in addition to Al8176. i.e., AL+ 0% Boron carbide, AL+ 2% Boron carbide, AL+ 4% Boron carbide and AL+ 6% Boron carbide.For different % of AL+ % Boron carbide samples were prepared according to ASTM for tensile and compression test [7]. Tensile and compression samples were studied for all 4 variations using tensile testing machine, universal testing machine according to ASTME8-16a at 24°C. All samples were tested for hardness using Micro Vickers Hardness Tester.After tensile and compression test, all the values and results were observed and tabulated.

Table1MaterialPropertyofAluminium8176Alloy

ALUMINIUM8176ALLOY	
CHEMICALCOMPOSITION	
Element	**Content(%)**
Aluminium,Al	≤ 98.5
Iron,Fe	0.40 – 1
Zinc,Zn	≤ 0.10
Silicon,Si	0.030 -0.15
Gallium,Ga	≤ 0.030
Other(each)	≤ 0.050
Other(total)	≤ 0.15

Table 2 Material Property of Boron Carbide

BORONCARBIDE(B4C)	
TYPICALPROPERTIESOFBORONCARBIDE.	
Property	**Value**
Density(g.cm-3)	2.52
MeltingPoint(°C)	2445
Hardness(Knoop100g) (kg.mm-2)	2900 – 3580
FractureToughness(Mpa.m-½)	2.9 – 3.7
Young'sModulus(Gpa)	450 – 470
ElectricalConductivity(at25°C)(S)	140
ThermalConductivity(at25°C)(W/m.K)	30 – 42
ThermalExpansionCo-eff.X10-6(°C)	5
Thermalneutron capturescrosssection(barn)	600

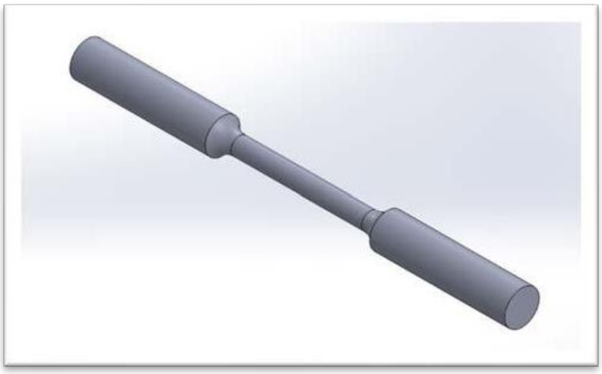
Mechanical Tests

Hardness Test

Almost every type of material can be tested using the microhardness procedures, including metals, ceramics, composites, and others.Vickers Hardness Tester (HBW 2.5/62.5) sample hardness measurement. The weight applied is 62.5kg, per Standard Test Reference ASTM E10:2018 Ball Diameter -2.5mm. Although "Macro" Vickers loads can be up to 30 kg or more, most loads are quite light, ranging from 10gm to 1kgf.

Tensile Test

Samples were prepared according to ASTM standards for tensile as shown in fig. 3a &3b and compression test followed by series of turning operations. Figure 3c shows the fractured samples after tensile test.



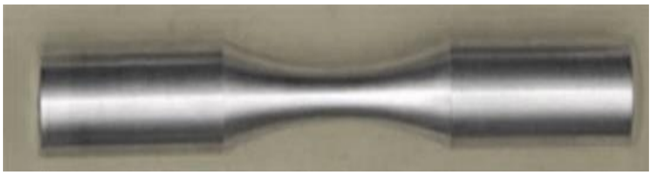


Fig.3aTensileTestSpecimen–IsometricViewFig. 3b.Tensile specimen

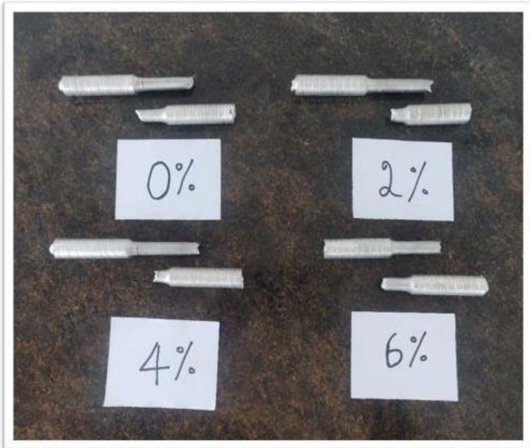


Fig. 3c Tensile samples aftertest

Compression Test

Compression tests are performed to investigate the behaviour of a material under crushing stresses and samples as shown in fig. 4. In this experiment maximum load selected was 400 kN with maximum elongation of 250mm.

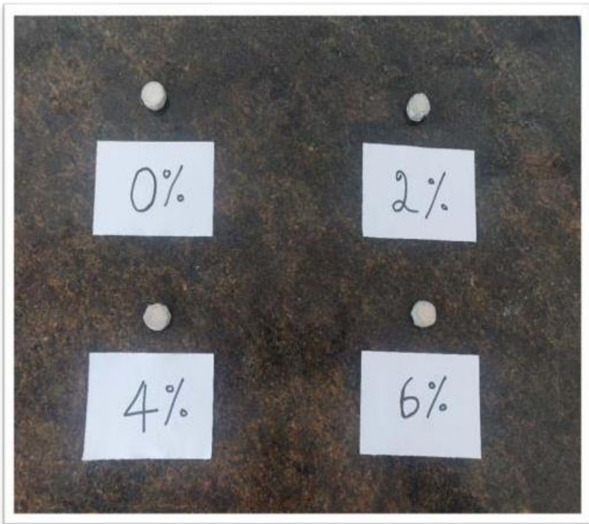


Fig. 4 Compression samples after test

Results and Discussion

Hardness

Properties/Material	Al+0%BoronCarbide	Al+2%BoronCarbide	Al+4%BoronCarbide	Al+6%BoronCarbide
HardnessTest1	22.5	22.5	23.9	26.5
HardnessTest2	22.6	22.9	25.2	27.1
HardnessTest3	22.6	22.7	25.5	26.8
AverageHardness	22.5	22.7	24.8	26.8

Table3ComparisonofMicro-VickersHardnesstestresults

The hardness of sample with lower percentage of sulphur and phosphorous and higher percentage of sulphur and phosphorous are determined using Brinell hardness testing machine (HWB) and tabulated in table 3. The object of this test is to compare the properties of hardness of medium carbon steel specimens that contain trace elements of sulphur and phosphorous.According to Fig. 5, the weight % of boron carbide reinforcement particles has been shown to increase along with the Micro Vickers Hardness of the aluminium metal matrix composite.

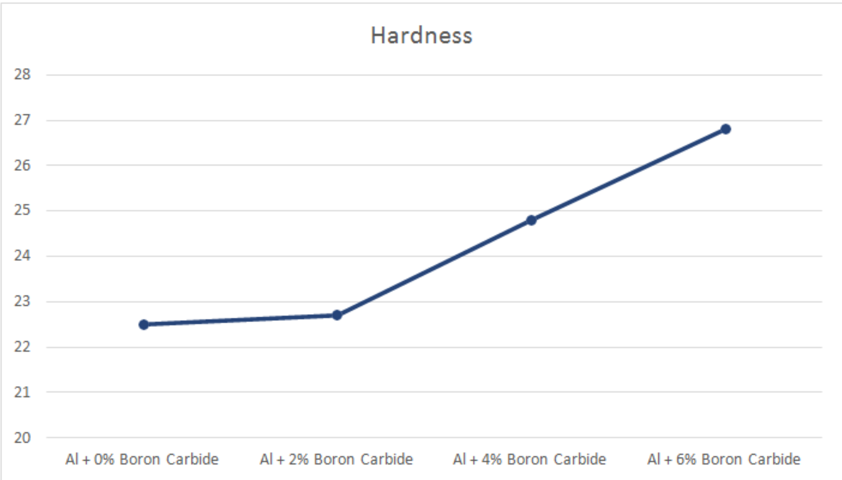


Fig. 5Avg. hardnessvswt.%boroncarbide

Compression test:

Table4ComparisonofCompressiontestresults

Properties/Material	Al+0%BoronCarbide	Al+2%BoronCarbide	Al+4%BoronCarbide	Al+6%BoronCarbide
LoadatPeak	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	306.3N/mm^2	315.9N/mm^2	318.6N/mm^2	319.6N/mm^2

The matrix alloy Aluminium8176's mechanical properties have improved with the addition of boron carbide.We can see that the increase in the compression strength a composite's property with increasing percentages of reinforcement added, and it is determined to be at its highest for 6% wt Boron Carbide in the Compression strength of fabricated composites. Thisindicatesthatincreasingthereinforcementpercentagewillresult in morebrittleness in thecomposite as shown in table 4 and fig. 6.

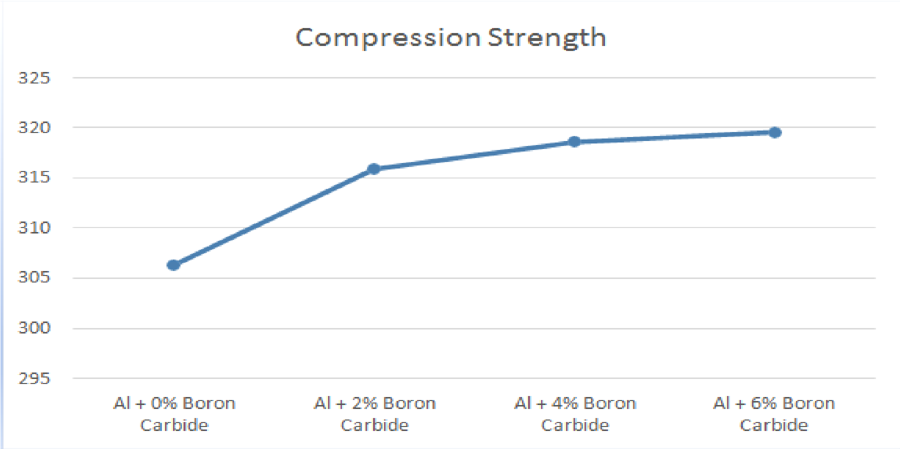


Fig. 6 ComparisonofCompressionStrength

Tensile Test

Table5ComparisonofTensileProperties

Properties/Material	Al+0%BoronCarbide	Al+2%BoronCarbide	Al+4%BoronCarbide	Al+6%BoronCarbide
LoadatYield	6.31kN	4.72kN	6.55kN	5.35kN
YieldStress	51.7N/mm^2	38.9N/mm^2	53.2N/mm^2	43.9N/mm^2
LoadatPeak	9.670kN	7.090kN	8.930kN	8.220kN
TensileStrength	59.2N/mm^2	58.4N/mm^2	72.5N/mm^2	67.4N/mm^2
%Elongation	33.7%	13.5 %	23.7 %	21.3 %

The inclusion of boron carbide, the mechanical specifications of matrix alloy Aluminium8176 have enhanced. Fig. 7 shows the relation between Tensile power of fabricated composites andvarying % by weight of boron carbide. We can observe that there is an increment in tensilestrength property of the composite. Additionally, we can see that 6% weight percentage Boron Carbide no longer has the same tensile strength. This suggests that increasing the reinforcing % further will make the composite more fragile as tabulated in table 5.

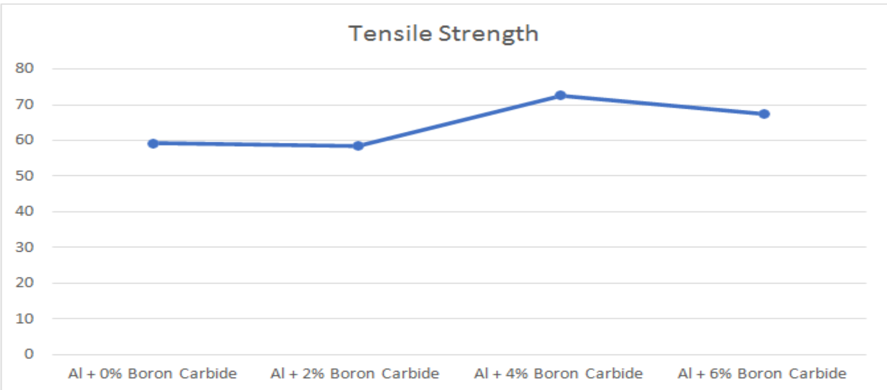


Fig.7ComparisonofTensileStrength

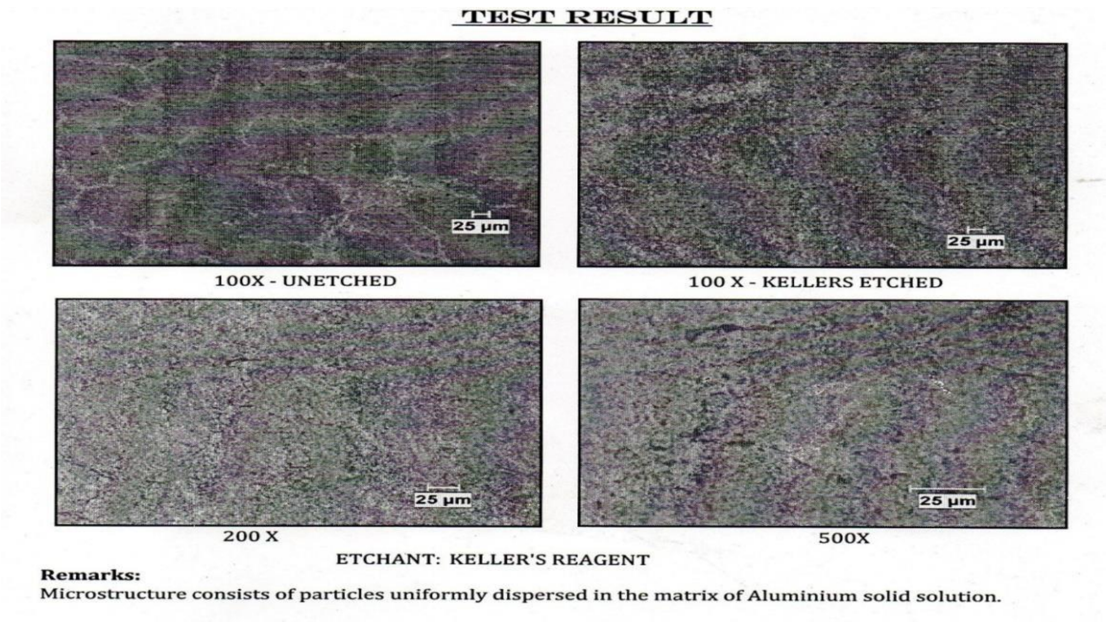


Fig.8SEM Image of Al8176+ 0% Boron carbide

Micro-StructureTest

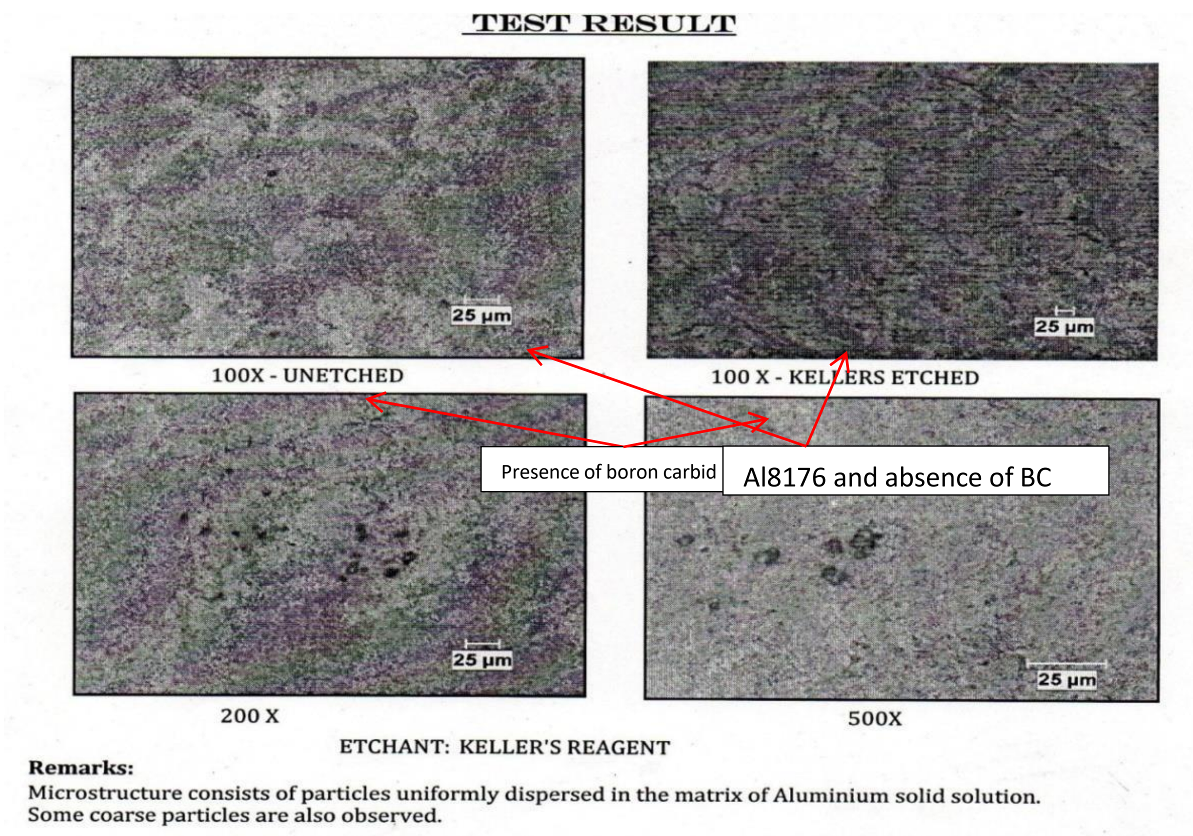


Fig.

Fig.

9SEM Image of Al8176+ 2 % Boron carbide

Fig.8 shows the microstructure of Al8176 with 0% boron carbide metal matrix composite in which SEM image shows absence of Boron carbide in it.

In fig. 9 the SEManalysis shows the clear presence of small amount of boron carbide for the 2% volume fraction which is highlighted and showed in the image above.

Fig.10SEM Image of Al8176+ 4% Boron carbide

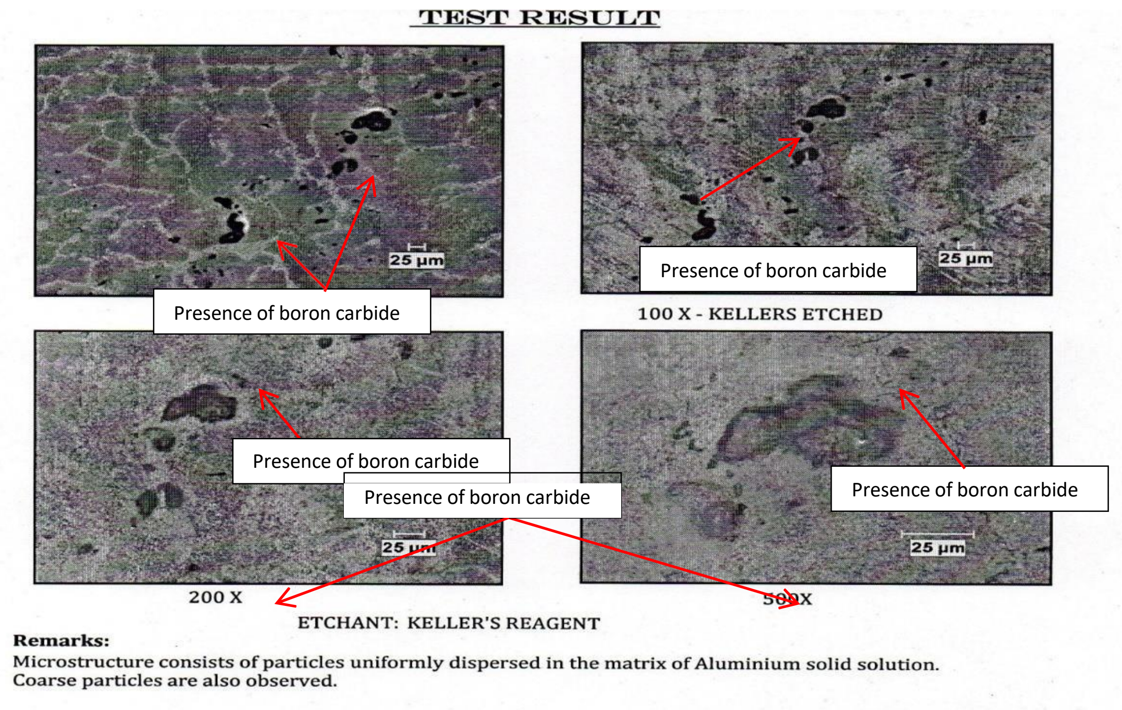
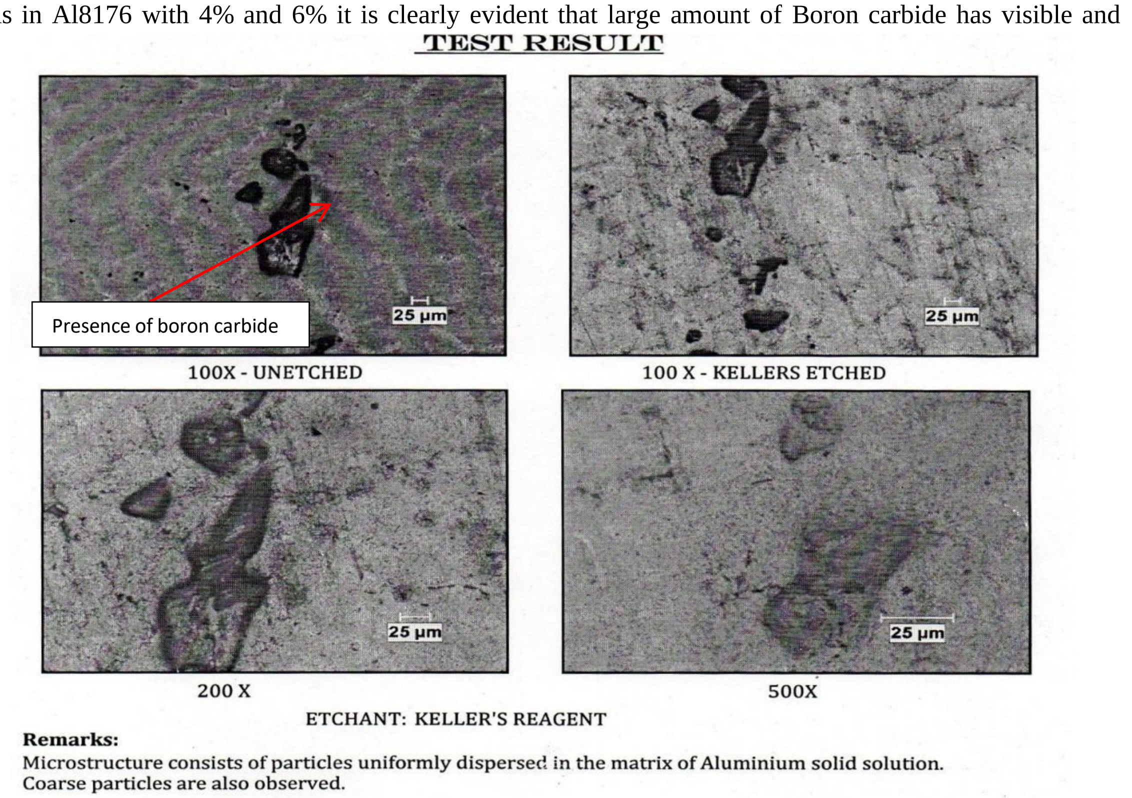


Fig.11SEM Image of Al8176+ 6% Boron carbide

Whereas in Al8176 with 4% and 6% it is clearly evident that large amount of Boron carbide has visible and



evenly distrusted along the surface as shown in fig. 10 and 11 respectively.

Conclusion

The microstructure and mechanical characteristics of composites made of metal matrix and aluminium were assessed after they had been stir cast with different weight percentages of boron carbide reinforcement particles. The study's findings lead to the following interpretations:

- The composite had homogenous depending on the microstructure, the Boron Carbide reinforcement particles disperse.
- It was demonstrated that the metal matrix composite's tensile strength rose up to 4% weight of boron carbide before dropping.Indicating that adding more reinforcement would make the composite brittle. The composite material has a 22.46% improvement in tensile strength.
- The metal matrix composite's compressive strength has grown throughout the weight percentage of the reinforcement. The composite material has a 4.34% increase in compression strength.
- The metal matrix composite's hardness quality has improved across the weight percentage of the reinforcement. The composite material has a 19.11% improvement in hardness.

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