

# Study of Mechanical and Tribological Properties of Al7178 Alloy Reinforced with Boron Carbide and Fly Ash.

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**Abstract** - The Aluminum based Matrix Metal Composites (MMCs) having vast diversity of applications in aerospace, automation, conveyance and submerged domain. This is fundamentally owing to its extraordinary and enduring properties namely as light in weight, low in density, higher hardness, higher resistance in temperature and corrosion resistance. Matrix metal composites (MMCs) are molded by fusing materials (at least one among them materials are metallic) having variable characteristics. In this current study Aluminum 7178 as matrix metal as base metal, boron carbide (B<sub>4</sub>C) and fly ash as reinforcements of Al7178 alloy. Aluminum MMCs are widely formulate by stir-casting process. The boron Carbide as reinforcement was summing in consignment of 2%, 4%, 6%, and 8% and Fly ash was added constant in sum of 4% on weight selection basis into the liquidize metal matrix. The heterogeneous organize pop of composites were marshal to study Mechanical characteristics behavior like tensile strength, compression strength, hardness strength. Tensile strength, Hardness strength and compression strength of the formulate metal matrix composites are increased with increase of 4% boron carbide weight and 4% Fly ash weight at given test specimens and hence obtained optimistic results.

**Key Words:** AL7178, Boron Carbide, Fly Ash, Hardness Test, Compression Test, Tensile Test, Mechanical Properties and Stir Cast Method.

## 1. INTRODUCTION

In today's modern world the composites are in huge demand as well as necessary in the development of life style of the generation that we linked centuries ago. The utilization of steel and iron exist, the tougher and harder material which has exceptional results in ancient wars were begins in 1300 BC. Most of the modern technologies and processes requires different type of materials with different combination of mechanical and physical properties were not in considered to be compared to the traditional materials. These type of upgraded materials are enormously used in aerospace field, automotive and also in space research operations applications. The source of material availability for the engineers mainly includes metals, ceramics, fibers, and plastics as composite materials, the combination of either two or more metals, ceramics, fibers and polymers is another

classification of materials which are rapidly increasing and demand too.

## 2. LITERATURE SURVEY

Siddra Maryam and Farooq Bashir [1] investigated the effect of irradiation of laser on structural parameters and harness surface of Al 7178 alloy and mechanical properties like are studied using Vickers hardness test and XRD. XRD represents an increasing in grain size and laser shots. Finally, the increase in linear distance of boundary heat affected area of laser.

Ramindar Singh Bhatia et.al [2] investigated the results of Alumina oxide, Graphite, boron carbide Particles with Aluminium alloy Al-12%Si by Stir Casting method. So, he operated and researched by adjust the Alumina of (0%, 5%, 10%, 15%, 20%, 25%), Boron Carbide of (0%, 1%, 2%, 3%, 4%, 5%), and also graphite (0%, 1%, 3%, 5%, 8%, 11%) in MMCs.

M.Shankar, A.Gnanavel babu, M.Mariyappan [3] - They examined the Silicon carbide and Fly ash intensify along Aluminum 6061 amalgam. Forming variety of examples utilizing and the mix propelling techniques and orthodox for supporting substance squander in the lattice material, the hardness of composite material additionally explores. Rigidity shrink with enlarge rate of support. The rate of wear of composites minimized along enlarged loading rates for consolidation.

## 3. MATERIALS USED FOR MANUFACTURING METAL MATRIX COMPOSITE Al ALLOY 7178 AS A MATRIX

Aluminum alloys gains strength when they are in low range of temperature and becomes to sub-zero range temperature due to exposure in nature. Temperature range between 210° C to 260° C these alloys becomes high to sensitive and has high corrosion resistance properties and good conductor of electricity. Al 7178 alloy widely used in aircrafts structure.

**Table -1:** Mechanical Properties of Aluminum Alloy7178 [4]

properties	values
Ultimate strength of tensile	605 MPa
yield strength of tensile	535 MPa
Modulus of elasticity	72 MPa
Poisson's ratio	0.34
Strength of shear	355 MPa
Specific heat capacity	857 J/gm°C
Machinability	70%
Compressive yield strength	525 MPa

### 3.1 Boron carbide as Reinforcement

Boron carbide with chemical formulae as ( $B_4C$ ) remarkably solid carbon –boron ceramic material, chemical material used in shield tank, bullet proof bestows, engine ecotage talc and also various commercial applications. Along a Vickers hardness testing is  $> 35GPa$ , also known one of these hard materials present in the present world, beyond Diamond and cubic Boron Nitride material[6].

**Table -2:** Properties of Boron Carbide ( $B_4C$ )

Properties	Values	And Nature
Molar Mass	55.25 G/Mol	
Density	2.50 G/Cm <sup>3</sup>	
Melting Point	2760 °C	
Boiling Point	3505 °C	
Solubility In Water	Insoluble	



**Figure :- 1** Boron Carbide

### 3.2 Fly ash as Another Reinforcement

Fly burning residual particles (as of size 0.6 - 99 microns) are with drawl from pulverized coal consuming procurement. Fly ash powderhave a remarkable thickness which is low and wettability linking fly scorching particles are maintained constant. It attains different fortifications properties which are tends to isotropic behavior and the percentage of discrete particles generated simultaneously. Electric resistance is high and less heat conductivity. Due to

the blazing thickness of fly ash are used in making composite light in weight.



**Figure :- 2** Fly Ash

## 4. METHODOLOGY

Following are the methodology for achieving objectives of this study;

- Procurement of raw materials.
- Casting the composite specimen.
- Machining the specimens.
- Testing the specimens.
- Calculation of properties.

The Matrix material is Aluminium alloy 7178 and Reinforcements as fly ash, Boron carbide are procured. In order to fabricate specimens for complete research work the quantity of matrix material and reinforcements are computed.

From earlier estimation,  $B_4C$  is summing as reinforcement to 0% to 8% with addition of 2% and constant 4% of Fly ash with respect to Aluminium alloy 7178 weight.

**Table -3:** ASTM E8 Dimensions [5]

Symbol	Dimension (mm)	Description
G	50 (+,-0.1)	Gauge Length
D	12.5	Diameter
B	20	Length of End Section
A	100	Length of Reduced Section
R	002	Radius of Fillet
L	155	Overall Length
C	20	Diameter of End Section



Figure:- 3 Methodology Of Casting



Figure:- 4 Pouring Hot Mixture in Mould



Figure:- 5 Specimens after casting

#### 4.1 Calculation of Specimen for Machining

The above prepared specimen by casting is now machined on the lathe as per the ASTM E8 procedure. The lathe uses the HSS (High Speed Steel) tool for the machining process. The ASTM E8/E8M specimen is as shown in figure below [6].

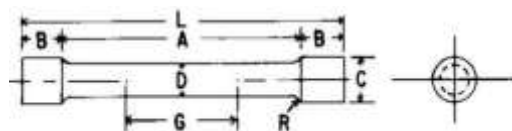


Figure:- 6 ASTM E8 Specimen [5]

**Table -4:** Represents Characteristics Of Boron Carbide And Fly Ash as Reinforcements and Al7178 of base metal matrix Of Tensile, Compression, Hardness tests.

S.No	Composition Of Materials	Designation		Fly Ash
		Alloy	Wt (%) Of B <sub>4</sub> C	
1	Al7178 (100%) of Tensile	1	0	0
2	Al7178 + 2% B <sub>4</sub> C + 4 %Fly Ash	2	2	4
3	Al7178 + 4% B <sub>4</sub> C + 4 %Fly Ash	3	4	4
4	Al7178 + 6% B <sub>4</sub> C + 4 %Fly Ash	4	6	4
5	Al7178 + 8% B <sub>4</sub> C + 4 %Fly Ash	5	8	4
6	Al7178 (100%) of Compression	6	0	0
7	Al7178 + 2% B <sub>4</sub> C + 4 %Fly Ash	7	2	4
8	Al7178 + 4% B <sub>4</sub> C + 4 %Fly Ash	8	4	4
9	Al7178 + 6% B <sub>4</sub> C + 4 %Fly Ash	9	6	4
10	Al7178 + 8% B <sub>4</sub> C + 4 %Fly Ash	10	8	4
11	Al7178 (100%) of Hardness	11	0	0
12	Al7178 + 2% B <sub>4</sub> C + 4 %Fly Ash	12	2	4
13	Al7178 + 4% B <sub>4</sub> C + 4 %Fly Ash	13	4	4
14	Al7178 + 6% B <sub>4</sub> C + 4 %Fly Ash	14	6	4
15	Al7178 + 8% B <sub>4</sub> C + 4 %Fly Ash	15	8	4

### 5. MECHANICAL TESTS

#### 5.1 Tensile tests

Tensile tests conducting in computerized universal testing machine (UTM) as per E9 ASTM Standards for the examining the mechanical characteristics, properties and its behavior.



Figure:- 7 Specimens Before Tensile Test



Figure:- 8 Specimens After Tensile Test

#### 5.2 Compression tests

Compression test specimen is prepared by machining operations like facing and turning on the lathe, where it is done as per ASTM Standards. Specifications of compression test specimen is, The height and diameter of compression test specimen is 20 mm each.

Then these test specimens conduct a experiment on computerized universal testing machine (UTM) where specimen subjected to compressive pull or load. The

mechanical properties like compressive load, yield load, Ultimate compressive strength are obtained from Data Acquisition System (DAS) of the UTM machine.



Figure:- 9 Specimens Before Compression Test



Figure:- 10 Specimens After Compression Test

### 5.3 Hardness tests

Hardness indentation test commonly used in applications of mechanical field of engineering to examine the deformation and hardness of particular specimen. The Brinell hardness test indenter of 5mm is used and load applied is 250 KGs. Hardness tests assists in reading the impermeable properties of different materials and surface approach and cause surface defacement. For brinell hardness for each 10 sec the load of 25 KGs is applied on the surface and polished specimens by using of 1/16" red ball indenter.



Figure:- 11 Specimens Before Hardness Test



Figure:- 12 Specimens After Hardness Test

## 6. TEST RESULTS AND DISCUSSION

### 6.1 Tensile test results

By using UTM (Universal Testing Machine) tensile tests were performed as discussed below in table 6.01 then after tensile test is conducted for well dimensioned prepared specimens. So, Tensile test are practiced according to ASTM E8-16a.

Table -5: Represents The Results of Tensile Test Specimen on (UTM) Of AL 7178 Alloy And Its composites

Alloy Designation Tensile specimen	Ultimate Tensile Strength (UTS)in N/mm <sup>2</sup>	Yield load in kN	Elongation in (%)
1	92.365	11.160	3.400
2	89.267	10.680	1.660
3	106.584	12.940	0.680
4	95.085	10.880	1.240
5	93.352	11.400	1.060

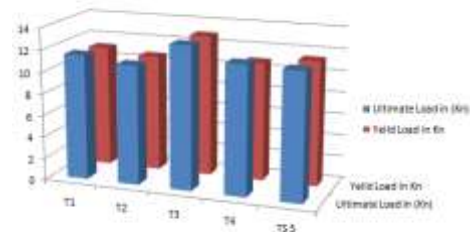
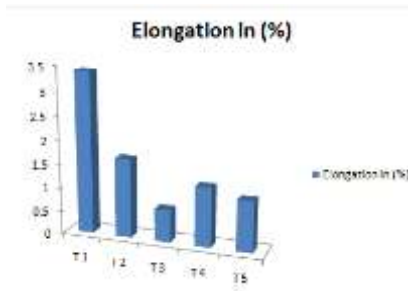


Chart -1: Represents Ultimate load and yield load of Tensile test specimens

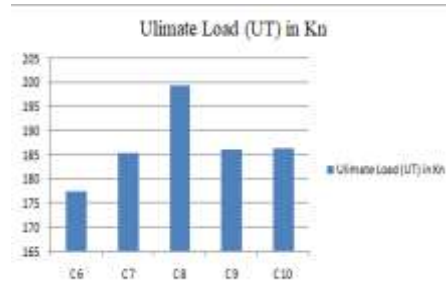
From the above table and chart tensile specimen (T3) UTS ultimate tensile strength and YS yield stress value are maximum at 4% B<sub>4</sub>C and 4 % Fly ash comparatively to all different tensile specimens.

It is clear from the above figure that % of elongation is increased and maximum at (T1) Al 7178 cast 100% is about 3.400%. whereas increase in reinforcement the elongation % decreases up to 1.660% and 0.680% of 2% B<sub>4</sub>C and 4% Fly ash by adding and 4% B<sub>4</sub>C and 4% Fly ash of (T2) and (T3) specimens respectively. The minimum % of elongation is of specimen (T3) whereas (T4) and (T5) increased by 1% each that is of 1.240% and 1.060%.so, we consider maximum % of elongation of (T3) specimen in research case.





**Chart -2:** Represents Elongation in percentage of Tensile test specimens



**Chart -3:** Represents Ultimate load of Compression test specimens

### 6.2 Compression test results

Compression tests were carried out on specimens Al 7178 alloy and its composites, with the help of (UTM) universal tensile machine. Ultimate load and displacement v/s load graph is observed and noted the and values from the (UTM) and finally calculated the values in below table.

Alloy Designation of Compression Test Specimen	Ultimate Load (UT) in kN
6	177.312
7	185.678
8	199.909
9	186.456
10	186.450

**Table -6:** Represents Ultimate load of Compression test specimens.

According to the above mentioned graph it is clearly mentioned that the ultimate load of C6 (Al7178 100%) is 177.580 KN, But the ultimate load of C7 (Al7178+2%B<sub>4</sub>C +4% Fly ash) is 185.460 KN then, ultimate load of C8 (Al7178+ 4%B<sub>4</sub>C +4% Fly ash) is 199.340 KN and C9 (Al7178+ 6%B<sub>4</sub>C +4% Fly ash) is 186.100 KN and finally C 10 (Al7178+ 8%B<sub>4</sub>C +4% Fly ash) is 186.540 KN respectively.

From the above mentioned compression tests specimen the ultimate load values, we concluded that the C8 represents the maximum ultimate load comparatively remaining 4 compression specimens. So, C8 has optimistic values for the alloy AL7178 with 4% B<sub>4</sub>C and constant 4% Of Fly Ash as its composites. Hence the maximum ultimate load value should be taken in consideration for the best results in research.

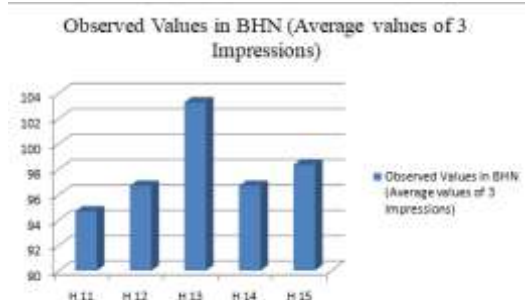
### 6.3 Hardness test results

Brinell hardness tests are conducted on the Al 7178 alloy and its composites for different specimens, by using Brinell hardness tester as per ASTM E10 standard test method. Hardness is observed in a hardness tester and values noted and calculated average value in below table.

**Table -7:** Represents The Hardness Test Specimen Results On Brinell Hardness Test Machine Of AL 7178 Alloy And Its composites.

Alloy Designation Of Hardness Test Specimen	Observed Values in BHN			
	Impression 1	Impression 2	Impression 3	Average
11	106	104	99.8	94.67
12	97.3	93.9	92.8	96.67
13	98.3	95.9	97.2	103.27
14	98.3	94.3	97.2	96.67
15	99.3	98.3	97.2	98.33

From the above graph it is clearly mentioned that the hardness of H 11 (Al7178 100%) is 94.67, But the hardness of H 12 (Al7178+2%B<sub>4</sub>C +4% Fly ash) is 96.67 and the hardness of H 13 (Al7178+ 4%B<sub>4</sub>C +4%Fly ash) is 103.27 and H 14 (Al7178+ 6%B<sub>4</sub>C +4%Fly ash) is 96.67 and finally H 15 (Al7178+ 8%B<sub>4</sub>C +4% Fly ash) is 98.33 respectively.



**Chart -4:** Represents Brinell Hardness Value (BHN) test specimens

From the above mentioned BHN average values we concluded that the H 13 represents the maximum hardness value comparatively remaining 4 values are nearer. So, H 13 has optimistic values for the alloy AL7178 with 4% B<sub>4</sub>C and constant 4% Of Fly Ash as its composites. Hence the maximum BHN value should be taken in consideration for the best results in research.

## 6. CONCLUSIONS

Aluminum (MMCs) have been in expansive ultimatum due to their optimistic properties in space, aerospace and automobile applications. In the current analysis of research work Al7178 reinforced along Boron Carbide as well as fly ash by traditional stir casting technique with volume fraction of boron carbide at 2%, 4%, 6% and 8% where as fly ash kept constant at 4%. The main target of this project to achieve the mechanical properties of aluminum alloy and its composites. The following conclusions are mentioned below and as follow.

- Aluminium alloy (7178) reinforced along Boron carbide (B<sub>4</sub>C) as well as Fly Ash have mould in stir cast method.
- The (UTS) ultimate tensile strength value of tensile test specimens is observed and calculated, where tensile test specimen with Al7178+ 4 %B<sub>4</sub>C+ 4 % Fly Ash found a maximum (UTS) ultimate tensile strength is increases of 6 % with respect to other test specimens and % of elongation, yield stress and ultimate load calculated.
- Compression test is conducted by (UTM) universal testing machine and hence observed and calculated maximum ultimate load, where Al7178+ 4 %B<sub>4</sub>C+ 4 % Fly Ash found maximum with increase of 4% of other test specimens.
- Hardness test is conducted on (BHN) Brinell hardness number and obtained optimistic value.

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