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Effect of with and without cryogenic treatment on Tensile, hardness and impact on hybrid Aluminium-6061 metal matrix composites

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Abstract— The metal matrix composite (MMC) have become the leading material in aerospace and automobile industries and particle reinforced aluminum MMC`s have received a considerable attention due to their excellent mechanical properties like hardness, high tensile strength etc. Aluminum matrix composites refer to the class of light weight high performance aluminum ceramic material systems. The purpose is to study above mechanical properties of Al-6061 with boron carbide and graphite in cryogenic condition by varying boron carbide with 0, 3, 6, 9 and 12% particulate using stir casting process. An improved mechanical property of composites makes them very useful for various applications in many areas from technological point of view. The microstructure and hardness of the fabricated composites were analyzed and reported.

Keywords— Tensile, hardness, Impact, Boron carbide, graphite, Al 6061, cryogenic condition, stir Casting, Metal matrix composites, Scanning Electron Microscopy

1. INTRODUCTION

Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. These properties have made particle-reinforced metal matrix composites (MMCs) an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, Transportation and industrial sectors. Corrosion behavior is very important parameter for assessing the application potential of composites as structural materials. Aluminum alloys reinforced with ceramic particulates have significant potential for structural applications due to their high specific strength and stiffness as well as low density. These properties have made particle-reinforced metal matrix composites (MMCs) an attractive candidate for the use in weight-sensitive and stiffness-critical components in aerospace, Transportation and industrial sectors. Corrosion behavior is very important parameter for assessing the application potential of composites as structural materials. Table 1 shows the composition of aluminum 6061.

Aluminum	95.85–98.56%
Silicon	0.4% - 0.8%
Iron	0% - 0.7%
Copper	0.15% - 0.4%
Manganese	0% - 0.15%
Magnesium	0.8% - 1.2%
Chromium	0.04% - 0.35%
Zinc	0% - 0.25%
Titanium	0% - 0.15%
Other elements	0.15%

Table.1 Composition of Al-6061 alloy

2. OBJECTIVE

The main objective of this work is to fabricate Al6061-B_4C-Gr metal matrix composite by stir casting process, to prepare specimens according to ASTM standards. To investigate tensile, hardness and impact properties with and without cryogenic condition.

3. MATERIAL AND METHODS

From literature survey it was cleared that, there is wide scope to studies on corrosion behavior of Al-B_4C-Gr hybrid metal matrix composites, so aluminium-6061 is chosen as matrix material, silicon carbide and graphite as reinforcement materials.

Table.2 shows Composition of Al 6061, B_4C and Gr for specimen preparation. The quantities of boron carbide and graphite were taken in a pan and were pre heated by placing the pan on crucible for 15 mins. Al 6061 was heated in the furnace at a temperature of 800^{o}C.The molten material was stirred with a stirrer speed of 220 rpm to create vortex, then the heated reinforcements were added and stirred. The composites were cast using conventional methods. The specimens are casted in 4 different combinations and it is shown below in table 2. Fig 1 shows the stir casting apparatus required to fabricate specimens.

Sl.No	Reinforcement %
Specimen 1	0%
Specimen 1	3%
Specimen 2	6%
Specimen 3	9%
Specimen 4	12%

Table.2 Composition of Al 6061 & Sic and Gr for specimen preparation


Fig.1 Stir Casting Apparatus

4. TESTING

Tensile Test was carried out on a computerized UTM according to ASTM E8. Fig 2 shows the tensile test specimens details

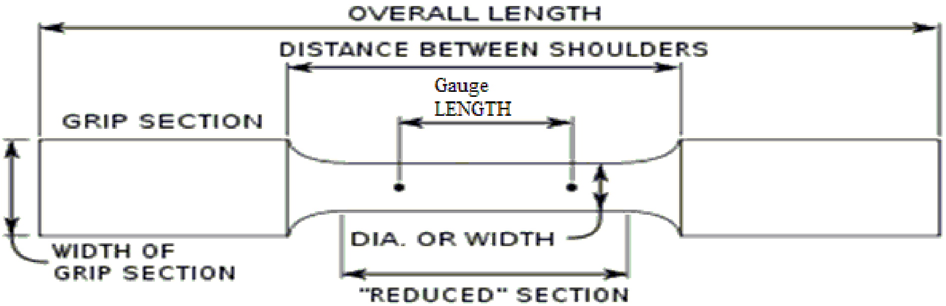

Fig.2 Tensile Test Specimens details

HARDNESS TEST

Hardness test was done with standard Rockwell Hardness Testing Machine. Test was performed according to ASTM E18.

IMPACT TEST

Impact test was done with Izod Testing Machine. Test was performed according to ASTM E23. Fig 3 shows the specimens prepared for hardness test.

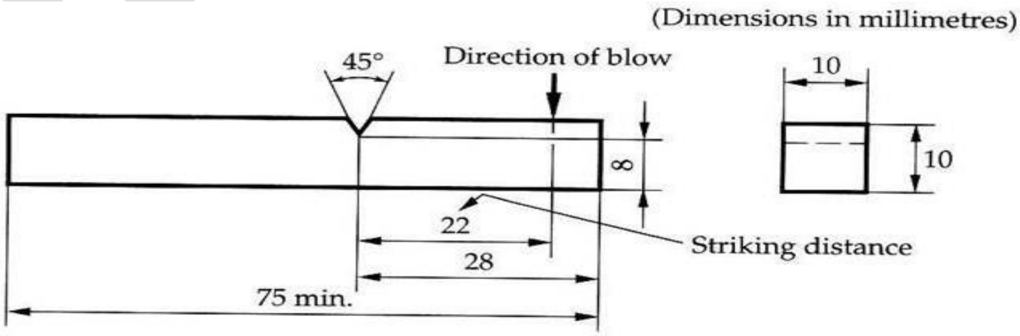

Fig.3 Impact Test Specimens details

5. RESULTS AND DISCUSSION

1. TENSILE TEST RESULTS

a. Before Cryogenic Treatment

Specimen	Tensile Strength in N/mm^2
0%	80.265
3%	85.324
6%	93.168
9%	127.924
12%	121.131

Table.3 output data after tensile test

b. After Cryogenic Treatment

Specimen	Tensile Strength in N/mm^2
0%	89.458
3%	96.739
6%	105.042
9%	138.97
12%	126.131

Table.4 output data after tensile test

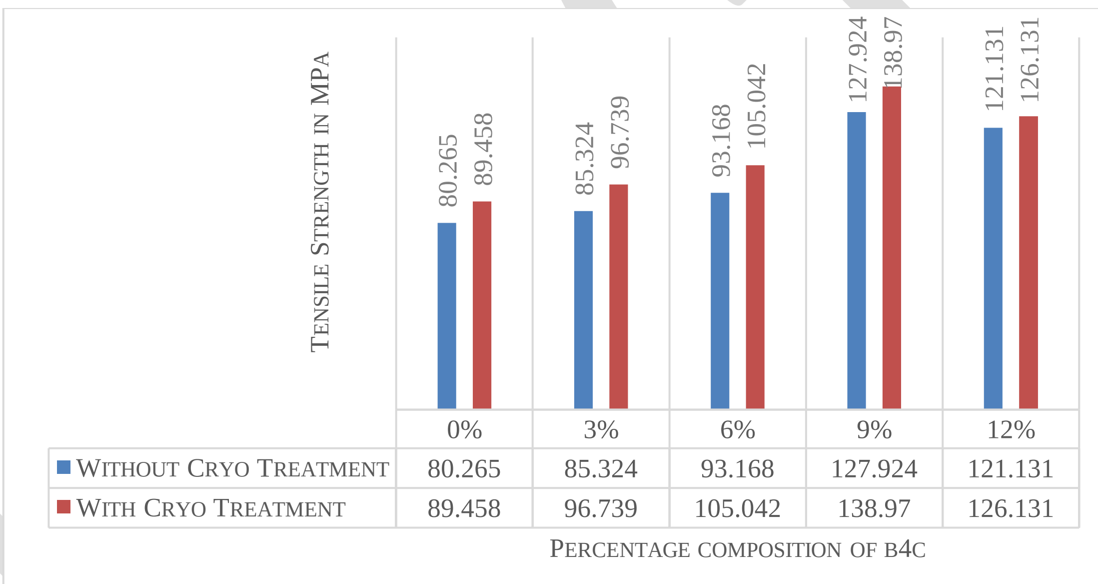

Fig.4 Variation of Tensile Strength and Peak load for different composition of B_4C

From above table/graph it shows that the B4C particles are very effective in improving the tensile strength of the composites. Tensile strength of the composite increases with increasing in particle size. The tensile strength of Aluminum metal matrix Composite was found to be maximum for the weight percentage of 9 and decreasing the strength gradually with the increase in weight percentage of the reinforcement. This is because the addition of B4C particles induces more strength to the matrix alloy by offering more resistance to the tensile strength.

When the material is cryogenically treated then the ultimate tensile strength and the yield strength increases with decrease in temperature. This is because the ultimate and yield strength of the material largely depends on the movement of the dislocation. At low temperature the internal energy of the atom is low. As a result, the atoms of the material vibrate less vigorously with less thermal agitation. When these agitations are low the movement of the dislocation is hampered. It requires very large stress to tear the dislocation from their equilibrium position. Therefore, the material exhibits increasing in ultimate and yield strength.

2. HARDNESS TEST RESULTS

a. Before Cryogenic Treatment

Specimen	Hardness Number (HB)
0%	26.87
3%	28.25
6%	32.75
9%	34.25
12%	36.58

Table.5 output data after hardness test

b. After Cryogenic Treatment

Specimen	Hardness Number (HB)
0%	28.62
3%	31.75
6%	35.73
9%	37.34
12%	39.84

Table.6 output data after hardness test

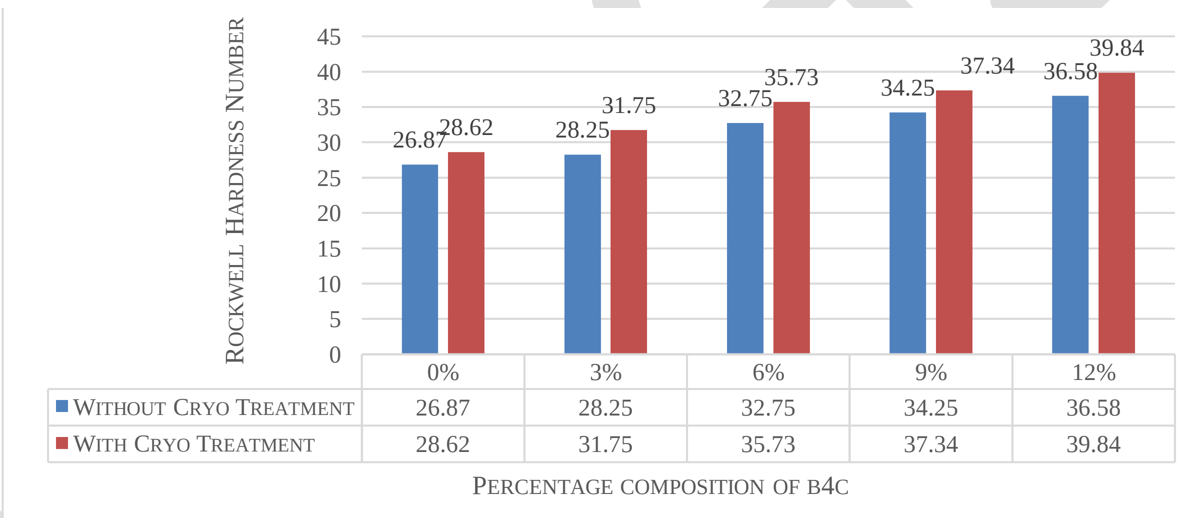

Fig.5 Variation of Rockwell Hardness Number for different composition of B_4C

The hardness of the AMC is increased with the increase in the particle size. The addition of the reinforcement particles in melt provides additional substrate from solidification to trigger, thereby increasing the nucleation rate and decreasing the grain size. For 12% of B4C the hardness was found to be maximum. With the presence of such hard surface, area of the particles offers more resistance to the plastic deformation which leads to increase in the hardness of composites. When the material is cryogenically treated, since the hardness is directly proportional to the ultimate tensile strength. It also follows the same trend as ultimate tensile strength.

3. IMPACT TEST RESULTS

a. Before Cryogenic Treatment

Specimen	Impact Value (Joules)
0%	2
3%	6
6%	4
9%	6
12%	12

Table.7 output data after impact test

b. After Cryogenic Treatment

Specimen	Hardness Number (HB)
0%	1
3%	6
6%	4
9%	5
12%	11

Table.8 output data after impact test

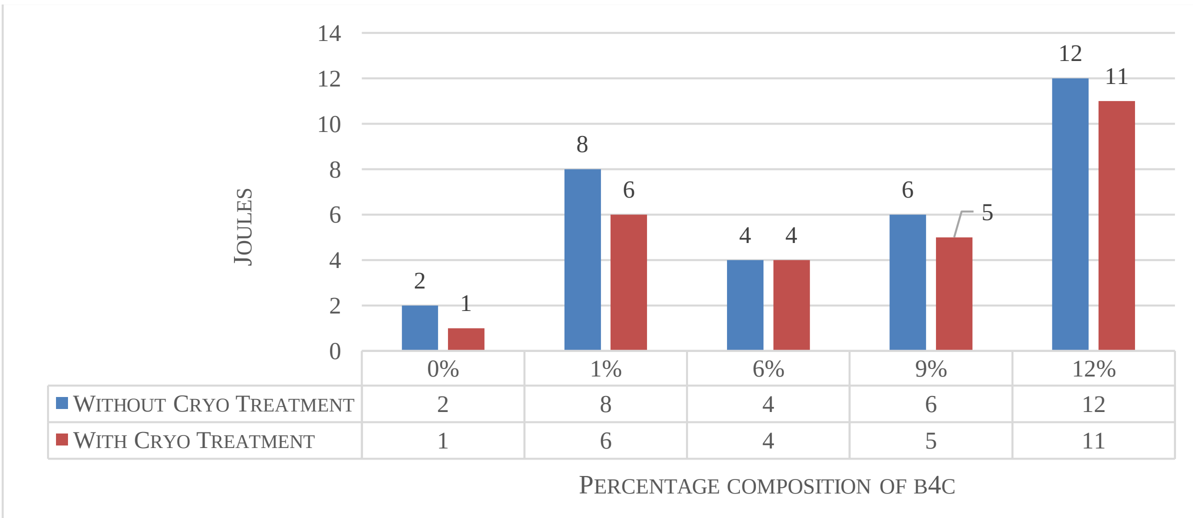

Fig.6 Variation of Impact test for different composition of B_4C

From the above graph it can be seen that the impact value is decreased and then increased with the increase in the percentage of reinforcement and the impact strength is less for cryogenically treated material because when the specimens are cryogenically treated the impact strength of material decreases with decreasing in temperature. This is because the material exhibits the ductile to brittle transition at low temperature.

6. CONCLUSION

a) The results from tensile test shows, the tensile strength increases have the percentage reinforcement increases and reaches the maximum at 9 wt% of reinforcement and then decreases gradually with increasing the reinforcement weight percentage.

b) When the specimens are cryogenically treated the tensile strength increases with decreasing the temperature. It is found that the tensile strength is higher in case of cryogenically treated specimens on compared with non-cryogenically treated specimens.

c) The results from the Rockwell hardness shows, hardness of the composites increases with increase in the percentage composition. For 12% composition hardness found to be maximum.

d) In case of cryogenically treated specimens' hardness increases as the temperature decreases. On comparing with and without cryogenic condition, it is found that hardness increases for all wt% of reinforcement for cryogenic condition.

e) The results from the Izod impact shows, the impact strength of the composite decreases with increase in the percentage composition but for 12% composition impact strength increases may because of presence of non-uniform distribution

f) When the specimens are cryogenically treated, the impact strength decreases. This is because at low temperature the material exhibits ductile to brittle transition.

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