

# **The Effect of Boron Carbide Reinforcement on the Dry Sliding Wear Behaviour of Gravity cast Al-7Si-0.45Mg**

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**ABSTRACT:** In this research paper, the alloy Al-7Si-0.45Mg A356 grain refined and modified using Al-5Ti-1B and Al-10Sr respectively was cast in pre-heated permanent mold using liquid metallurgy route. They were further reinforced with varied percentage of Boron Carbide and tested for Microstructure, and wear resistance. The results indicated improvement in wear resistance which may be attributed to the refined microstructure, grain refinement and modification of alloy and improved hardness due to reinforcement of hard particles of B<sub>4</sub>C.

**KEYWORDS:** Heat treatment, Boron Carbide, Dry sliding wear behaviour.

## **I. INTRODUCTION**

Aluminium-Silicon alloys and their composites are known for their excellent combination of characteristics namely, low density, excellent castability, formability, good mechanical properties, cryogenic properties and good machinability. They have wide range of applications particularly in Automobile, Aerospace and Marine sectors on account of their light weight, good surface finish, resistance to wear and corrosion and high strength-to-weight ratio. As components with complex geometries can be produced cost effectively, they find enhanced application particularly in Automobile and Aerospace sectors. Reduction in weight due to low density leads to increased load capacity, increased mileage, reduced pollution of environment and higher profits to the manufacturers. The low melting temperature, ease of handling, easy formability, easy recycling has led to increased demand for aluminium alloy/composite components.

## **II. MATERIALS**

Grain refined and modified Al-7Si-0.45Mg were cast in pre- heated permanent mold in the form of cylindrical rods of diameter 25 mm and length 300 mm. They were further reinforced with varied percentage of B<sub>4</sub>C. Test specimens for hardness and wear were obtained by machining the rods and tested as per ASTM standards.

# International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Vol. 5, Issue 3, March 2016

**Table 1: Chemical Composition of Al-7Si-0.45Mg**

Element	Weight %
Si	7.25
Mg	0.45
Fe	0.086
Cu	0.010
Mn	0.018
Ni	0.025
Zinc	0.005
Others	0.028
Al	Balance

### III. METHODOLOGY

- a. **Microstructure:** The specimens for microstructure were prepared as per standard metallurgical procedures, etched in etchant prepared using 90 ml water, 4 ml HF, 4 ml H<sub>2</sub>SO<sub>4</sub> and 2g C<sub>r</sub>O<sub>3</sub> and photographed using Optical Microscope.
- b. **Hardness test:** The hardness tests were conducted as per ASTM E10 norms using Rockwell Hardness Tester. The tests were performed at randomly selected points on the polished surface of samples by providing sufficient space between indentations and distance from the edge of specimen. The hardness values of gravity cast Al-7Si-0.45Mg, grain refined and modified Al-7Si-0.45Mg and B<sub>4</sub>C reinforced and grain refined and modified Al-7Si-0.45Mg are shown in Table 2.
- c. **Wear test:** Dry sliding Wear tests were carried out at room temperature using Pin-on-Disc apparatus for varied loads and sliding distances. The wear rates were evaluated using weight loss method by dividing the loss of weight of specimen by the sliding distance for a known sliding time. The loss of weight was measured using an Electronic balance to the accuracy of 0.0001gm. The wear rate was based on the average value of 5 test results. During test, the load was increased gradually till seizure, indicated by high temperature rise; abnormal wear and vibration in Pin-disc assembly were observed. The disc was thoroughly cleaned using acetone after every test. The worn surfaces were further analysed for type of wear.

### IV. RESULTS AND DISCUSSION

- a. **Microstructure: (200X):**

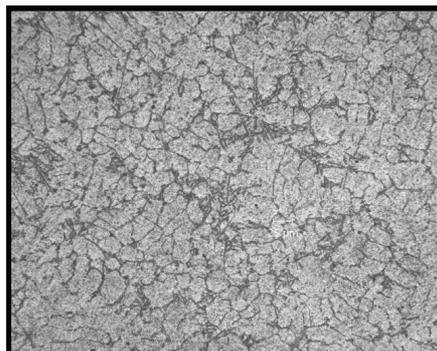


Plate 1: Microstructure of As-cast A356

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Plate 1 shows the distribution of the primary dendrite alpha phase (aluminum rich phase) in as-cast alloy which is predominant in the matrix. Grey coloured needle shaped silicon particles seen in and around the inter dendrite regions resulted in increased aspect ratio.

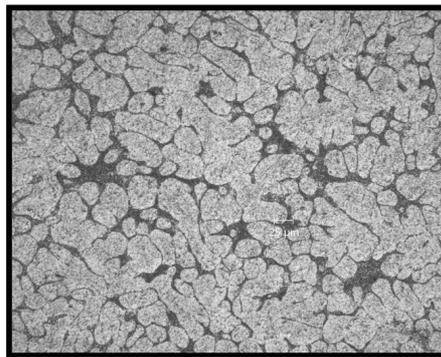
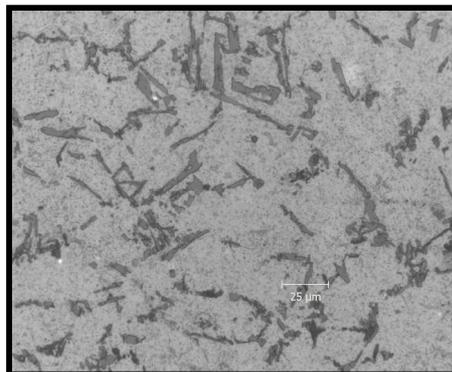
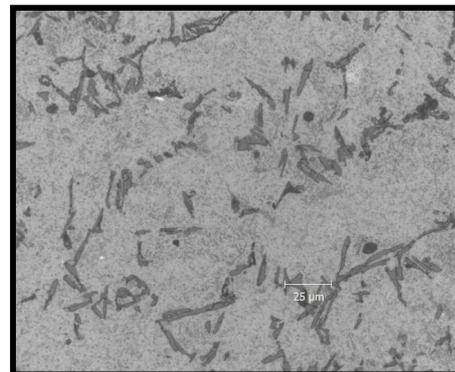


Plate 2: Microstructure of Grain refined and Modified A356 ( $A_{GRM}$ )

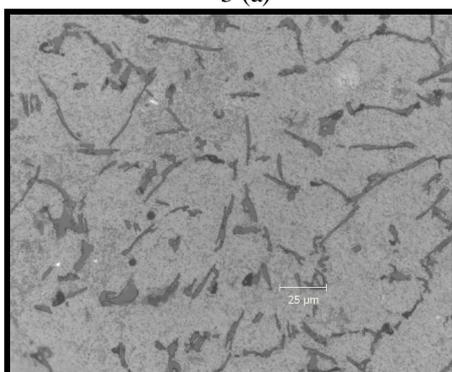
Plate 2 shows the Microstructure of combined Grain refined and modified alloy  $A_{GRM}$ . Grain refinement resulted in fine grain structure and reduction in size of primary aluminium grains. Grain modification produced fibrous and finely dispersed Si and promoted the formation of finer particles of Iron-rich inter-metallic compounds which are hard compared with as-cast material. Further, it led to refined porosity dispersion leading to increased hardness and wear resistance.



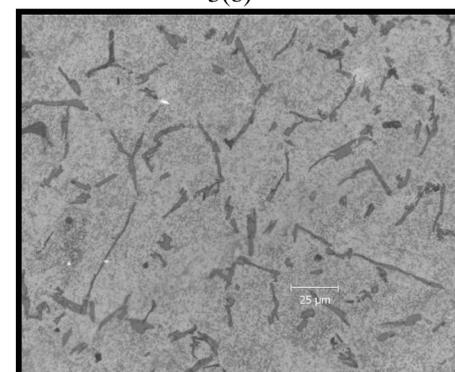
3 (a)



3(b)



3(c)



3(d)

Plate 3: Microstructures of  $A_{GRM}$  reinforced with 1%, 3%, 5% and 7%  $B_4C$

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Plate 3(a), 3(b), 3(c) and 3(d) show the microstructure of  $A_{GRM}$  reinforced with 1%, 3%, 5% and 7%  $B_4C$  indicating uniform distribution of  $B_4C$  in the matrix.

### b. Hardness Test Results:

SI No.	Alloy	Designation	Hardness ( $R_B$ )
1	Al-7Si-0.45Mg	A356	60
2	Al-7Si-0.45Mg with Grain refinement and modification	$A_{GRM}$	65
3	$A_{GRM} + 1\% B_4C$	A1	63
4	$A_{GRM} + 3\% B_4C$	A3	78
5	$A_{GRM} + 5\% B_4C$	A5	74
6	$A_{GRM} + 7\% B_4C$	A7	72

**Table 2: Hardness values of As-cast and Grain refined and Modified Al-7Si-0.45Mg ( $A_{GRM}$ ) and  $B_4C$  reinforced A356**

Table 2 shows hardness values of A356,  $A_{GRM}$  and alloys reinforced with  $B_4C$ . It is clear from the graph that hardness increases with Grain Refined and Modification and further with  $B_4C$  reinforcement. The optimum value of reinforcement is 3%  $B_4C$  giving hardness values of 78 indicates 20% increase in hardness compared to  $A_{GRM}$ . Beyond 3% (i.e 5% & 7%), a decreased value of hardness observed. The decreased hardness beyond 3% may be attributed to the decreased solubility of  $B_4C$  in the matrix.

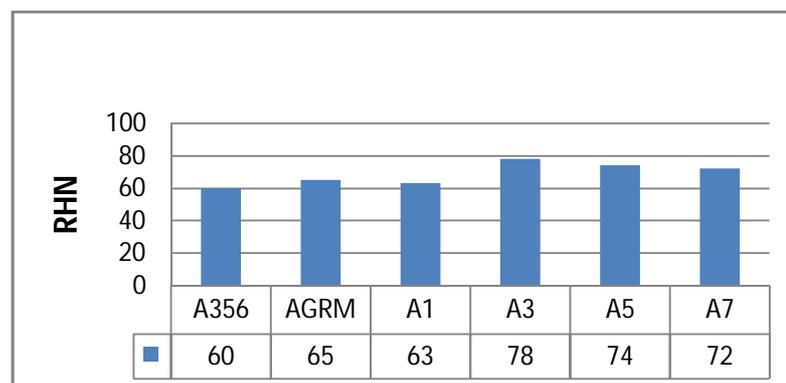


Fig 1: hardness values of Al-7Si-0.45Mg,  $A_{GRM}$  and  $B_4C$  reinforced  $A_{GRM}$  and A1-A7

Fig 1 shows the hardness values of Al-7Si-0.45Mg,  $A_{GRM}$  and  $B_4C$  reinforced  $A_{GRM}$  and A1-A7. It is clear from figure that hardness increases with grain refinement and modification and A3 indicating maximum hardness compared to A1, A5 and A7 which may be attributed to the optimum percentage and uniform distribution of  $B_4C$  in A3.

**c. Wear test Results**

**i. Effect of sliding distance on wear rate**

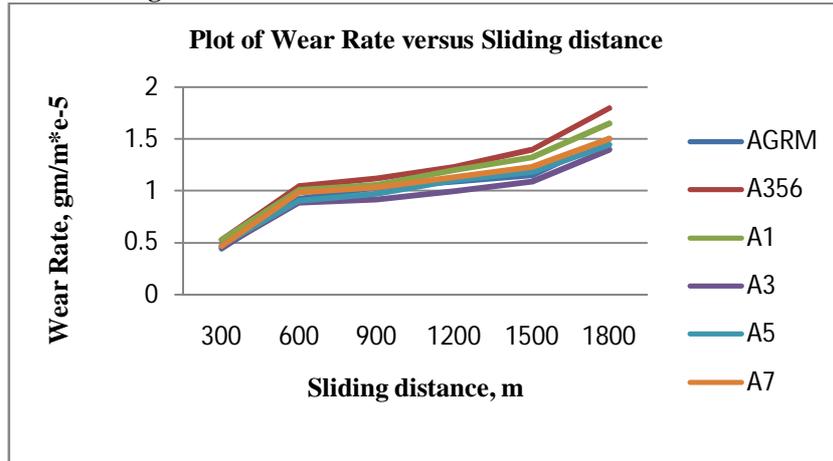


Fig 2: The effect of sliding distance on the wear rate of gravity cast Al-7Si-0.45Mg, Grain Refined and Modified alloy A<sub>GRM</sub>, and B<sub>4</sub>C reinforced composites

Fig 2 shows the plot of the effect of sliding distance on the wear rate of as cast A356, A<sub>GRM</sub> and B<sub>4</sub>C reinforced A1, A3, A5 and A7 with A3 indicating maximum wear resistance compared to A1, A5 and A7 which may be attributed to the increased hardness resulting from optimum reinforcement and uniform distribution of B<sub>4</sub>C in the matrix.

**ii. Effect of load on wear rate**

Fig.3 shows the effect of load on wear rate of As-cast Al-7Si-0.45Mg, Grain Refined and Modified Al-7Si-0.45Mg where, an increase in wear rate is observed for both As-cast Al-7Si-0.45Mg and Grain Refined and Modified Al-7Si-0.45Mg.

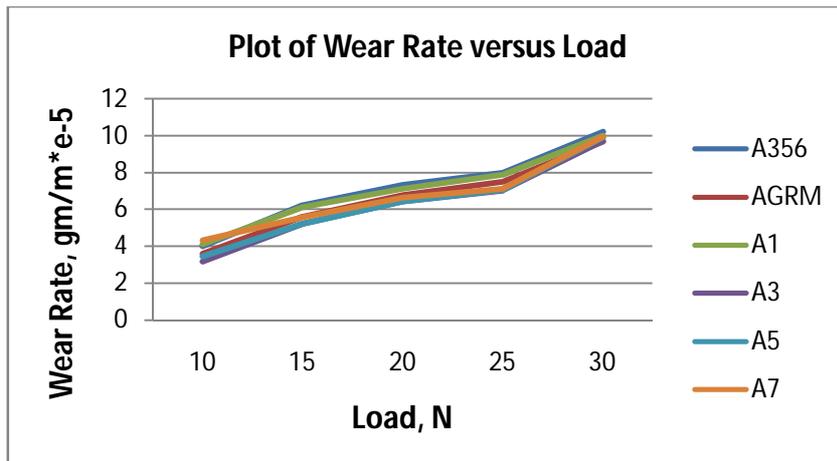


Fig 3: The effect of load on wear rate of gravity cast Al-7Si-0.45Mg, A<sub>GRM</sub> and composites reinforced with B<sub>4</sub>C

An increased wear resistance is observed for Grain Refined and Modified Al-7Si-0.45Mg compared to As-cast A356. In the plot A1, A3, A5 and A7 exhibit better wear resistance compared to A356 and A<sub>GRM</sub> with A3 exhibiting least wear or maximum wear resistance.

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## d. Analysis of Worn surfaces of gravity cast Al-7Si-0.45Mg, A<sub>GRM</sub> and A1 to A7

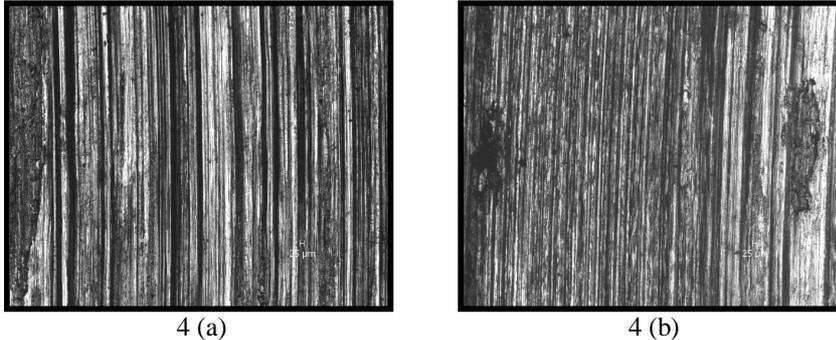


Plate 4: Optical micrographs of worn surfaces of gravity cast Al-7Si-0.45Mg (4 a) and A<sub>GRM</sub> (4 b)

Plate 4 shows the optical micrographs of the worn surfaces of Al-7Si-0.45Mg and Grain Refined and Modified Al-7Si-0.45Mg (i.e A<sub>GRM</sub>) slid through 1500m under the normal load of 30N and velocity of 1m/s. It is obvious from plate 4 that wear grooves are wider and deeper in Al-7Si-0.45Mg compared to that of A<sub>GRM</sub> which may be attributed to higher hardness in A<sub>GRM</sub>.

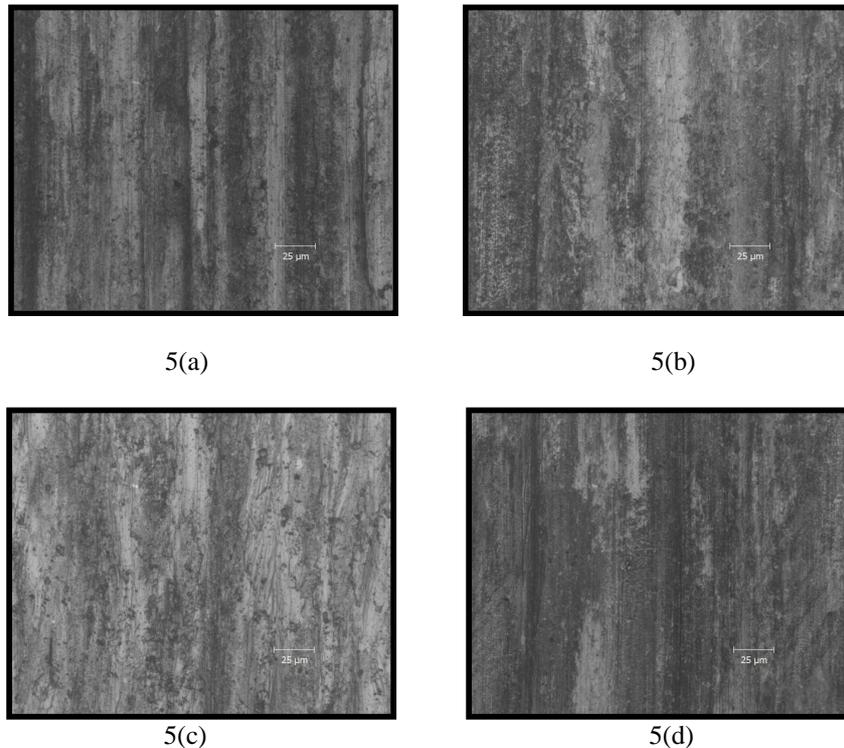


Plate 5: Optical micrographs of worn surfaces of A<sub>GRM</sub> reinforced with 1%, 3%, 5% and 7% B<sub>4</sub>C

Plate 5a, 5b, 5c and 5d shows the Optical micrographs of worn surfaces of A<sub>GRM</sub> reinforced with 1%, 3%, 5% and 7% B<sub>4</sub>C respectively with A3 showing shining worn surface, indicating a hard surface with least wear compared to A1, A5 and A7.

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## V. CONCLUSION

1. Sound and dense castings were produced by Gravity casting using pre-heated permanent mold.
2. The addition of Grain refiner resulted in fine grain structure and reduction in size of primary aluminium grains. Grain modification resulted in fibrous and finely dispersed Si and promoted the formation of finer particles of Iron-rich inter-metallic compounds which are hard compared with as-cast material.
3. Addition of B<sub>4</sub>C in Al-7Si-0.45Mg has resulted in improved hardness and wear resistance. The maximum Hardness and hence the wear resistance was obtained for alloy reinforced with 3%(weight) of B<sub>4</sub>C in Al-7Si-0.45Mg alloy.

## VI. ACKNOWLEDGEMENT

We thank Principal and Management of Sahyadri College of Engineering and Management, Adyar, Mangalore-575007 for motivating and providing facilities for research.

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