Hardness and wear behavior of b4c particulates reinforced al-7si-1mg alloy composites

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Abstract--- The work is carried out to investigate and study the hardness and wear properties of b_4c reinforced al-7si-1mg alloy metal matrix composites. in the present work al-7si-1mg alloy is taken as the base matrix and b_4c particulates as reinforcement material to prepare metal matrix composites by stir casting method. for metal matrix composites the reinforcement material was taken 5 wt. %. the reinforcement particulates were preheated to a temperature of 600ºc and dispersed into a vortex of molten al-7si-1mg alloy. the microstructural characterization was done using scanning electron microscope. properties like hardnessand wear were evaluated as per astm standards. further, scanning electron microphotographs revealed that there was uniform distribution of b_4c particulates in al-7si-1mg alloy matrix. hardness and wear resistance of al-7si-1mg and b_4c composites were increased as compared to base alloy.

Keywords--- Al-7Si-1Mg alloy; B_4C; hardness; stir casting; metal matrix composites.

I. INTRODUCTION

Metal matrix composites are increasingly becoming attractive materials for advanced aerospace, automobile industries due to light weight, low cost, easy fabrication and ever increasing demands of modern technology. Metal matrix composites are the combination of soft base metal with hard refinement material and have recently found special interest because of their specific strength and specific stiffness at room or elevated temperature. With the advancement of modern technology, there is a everlasting demand for an economical, light weight harder, stronger and energy saving material in the area of space, aircraft, advanced defense fighter jets and automobile application, aluminum matrix composites(AMC) found application in these areas[1,2].Many modern fabrication techniques where in use for the manufacture of MMC materials according to the type of base material and the type of reinforcement used like stir casting, squeeze casting, liquid metal infiltration and spray co-deposition. Among the above, stir casting technique is the simplest and most economical used technique is known as 'vortex technique' or stir casting technique' it is attractive because of simplicity, low cost of processing, flexibility, most economically for large sized components to be prepared as well as production of near net shaped components.

Due to advancement in technology, there is enlarged demand for an economical, light weight, harder, stronger and energy saving material in the area of space, aircraft, defence and automotive application and aluminum matrix found applications in these areas[3].Aluminum alloy reinforced with hard ceramic particles of WC,,SiC,Al_2O_3,B_4C and graphite for forming a composite to realize improvements in mechanical properties such as hardness, young's modulus, yield strength and ultimate tensile strength of the MMCs, The composites finds application in aerospace and automobile industries [4].Though stir casting is the most commonly methods employed for the MMCs, wettability is the main problem associated with stir casting. To overcome the wettability problem occurring commonly, wetting agent namely magnesium has been found out by several researchers.

AMCs with SiC as the reinforcement particle, SiC has a tremendous advantage of improving the properties like low density, high strength, low thermal expansion, high thermal conductivity, high hardness, high elastic modulus, excellent thermal shock, resistance and superior chemical inertness. Priority has been emphasized for developing affordable Al-based MMCs with various hard and soft reinforcements like SiC, Al_2O_3, zircon, graphite and mica [5].Qiurong yang et al. analyzed that the tensile test, elongation of the composites shows a sharp increase from 4.5% to 13.5% due to woven carbon fibers .Meanwhile the tensile strength of the composite is increased slightly from 168Mpa to 202MPa compared to that of ZL205A alloy. The good conductivity of the composite is ascribed to the cracks deflection, fibers pulling out, debonding and breakage mechanism [6].

There has been tremendous research work carried for the mechanical behavior and for the wear. As per the research carried out so far, it was revealed that the reinforcement particulate graphite increases the wear resistance and with another reinforcement of Al_2O_3 in a hybrid matrix, mechanical properties where improved and also at elevated temperatures [7].Even for the Al alloy A356 and reinforcement of SiC composites, it has been investigated for dry sliding wear studies, shows better mechanical behavior compared to those without coating [8, 9].

From the literature survey, there is a lack of data available for mechanical behavior of A-7Si-1Mg reinforced with B_4C particulates. The present work "Hardness and Wear Behavior of Al-7Si-1Mg- B_4C metal matrix properties" has been fabricated and characterized. The microstructure, hardness and the wear behavior of Al-7Si-1Mg alloy matrix with reinforced B_4C particulates have been studied.

II. EXPERIMENTAL DETAILS

Materials Used

For the metal matrix composite the base alloy Al-7Si-1Mg is reinforced with boron carbide powder of 60-80 microns in size and is fabricated as Al-7Si-1Mg-B_4C metal matrix composites. Density of Al-7Si-1Mg is 2.80 g/cc and that of the reinforcement particle is 2.52/cc. The chemical composition of Al-7Si-1Mg base alloy is shown in Table1.

Table1. Chemical composition of Al-7Si-1Mg alloy

Elements	Wt. Percentage
Si	7.0
Mg	1.0
Zn	0.10
Ti	0.10
Al	Bal

Composite Preparation

The metal matrix composites of Al-7Si-1Mg –B_4C have been produced by simplest and most economical used technique known as vortex technique or stir casting technique. As per the ASTM standards of casting procedure Al-7Si-1Mg is heated to the temperatures of 730ºC in the electrical resistance furnace. 5 wt. % of B_4C reinforcement particulates were added to the base alloy. Due to the increase in the weight percentage of reinforcement particulates B_4C porosity defect may occur during metal matrix composite [10] where as increasing the stirring time reduces the porosity level [11].The temperature of the electric furnace was controlled to an accuracy of ±50ºC using a digital temperature controller. Degassing agent solid hexachloroethane (C_2Cl_6) is added to expel all absorbed gases from the molten metal once the temperature have been reached. Before the addition of B_4C particulates, mechanical stirring process is carried out with the help of zirconia coated stirrer to form a fine vortex. The speed of the stirrer is rotated for 5-8 mins at a spindle speed of 300 rpm. The B_4C particulate is preheated to a temperature of 600ºC in a preheater to increase the wettability. The stirrer was immersed into the molten metal in the crucible at a depth of 2/3 from the bottom. The addition of the B_4C particulates to the molten metal is divided into two equal weights rather adding all at once to avoid agglomeration of the matrix. At every stage, stirring is carried out before and after introduction of reinforcement particulate B_4C to the molten metal. Before pouring the molten metal into the mould die, the molten metal is heated for about 5 mins. The melt is poured into a preheated cast iron mould dimension of 125mm X 15mm diameter.

Testing

Microstructure and mechanical behavior of the Al-7Si-1Mg alloy and its composites were carried out. A metallographic examination was carried out by using scanning electron microscope. The sample preparation for microstructural study was carried out first by polishing the sliced samples with emery paper up to 1000 grit size, followed by polishing with Al_2O_3 suspension on a grinding machine using velvet cloth. Finally, the samples were polished by using 0.3 microns diamond paste. The polished surface was etched with Keller's reagent and examined with a scanning electron microscope. Hardness tests were performed on as cast Al-7Si-1Mg alloy and Al-7Si-1Mg -TiC composites to know the effect of B_4C particles in the matrix material. The polished specimens were tested for their hardness, using Brinell hardness testing machine having ball indenter for 250 kg load and dwell time of 30 sec. Five sets of readings were taken at different places of the specimen and an average value was used for calculation.

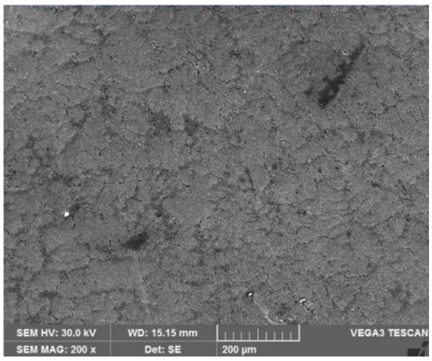
Dry sliding wear tests were carried out on Al-7Si-1Mg alloy and Al-7Si-1Mg -B_4C composites using a pin-on-disc wear test apparatus. Cylindrical pin specimens of 8 mm diameter and 25 mm length were mounted vertically on a pin holder. The end of specimens were polished with abrasive paper of grit size 600 and followed by grade 1000. During the test the pin was pressed against the counterpart EN32 steel disc with hardness of 60 HRC. Prior to each run, the steel counter-face was ground with 320grit and then 600grit SiC abrasive for few minutes followed by cleaning

ISSN: 2319-6890)(online),2347-5013(print)
20 May 2016

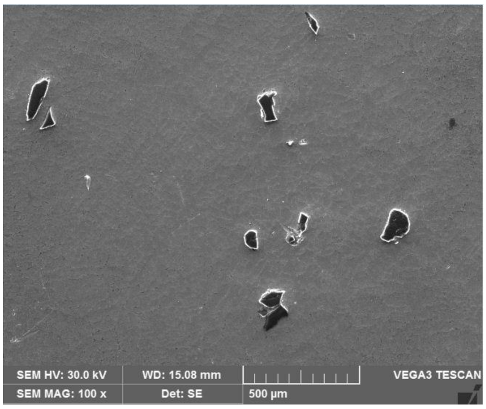
with acetone. Wear tests were conducted at constant 280rpm and varying loads for sliding distance of 6000m. Wear in terms of height loss was measured and same has been plotted.

III. RESULTS AND DISCUSSION

MIcrostructural Analysis



(a)



(b)

Fig.1: Showing the SEM microphotographs of (a) as cast Al-7Si-1Mg alloy (b) Al-7Si-1Mg-5wt.% B_4C Composites

Figure 1 (a) - (b) shows the Scanning Electron Microscope micrographs of as cast Al-7Si-1Mg alloy and its composites. Figure 1b shows the SEM micrograph of 5wt. % of B_4C particulate composites. This reveals the uniform distribution of B_4C particles and very low agglomeration and segregation of particles. The vortex generated in the stirring process breaks solid dendrites due to higher friction between particles and Al matrix alloy, which further induces a uniform distribution of particles.

Hardness Measurements

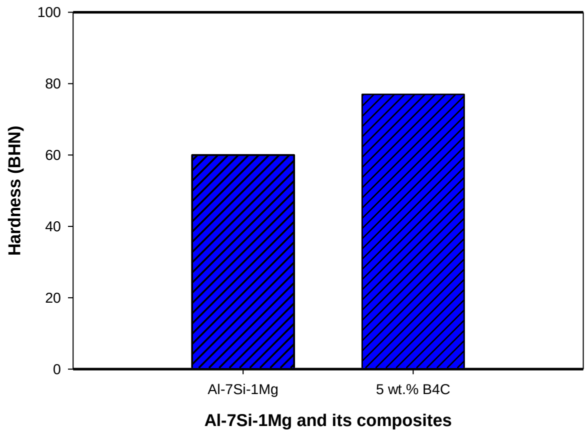
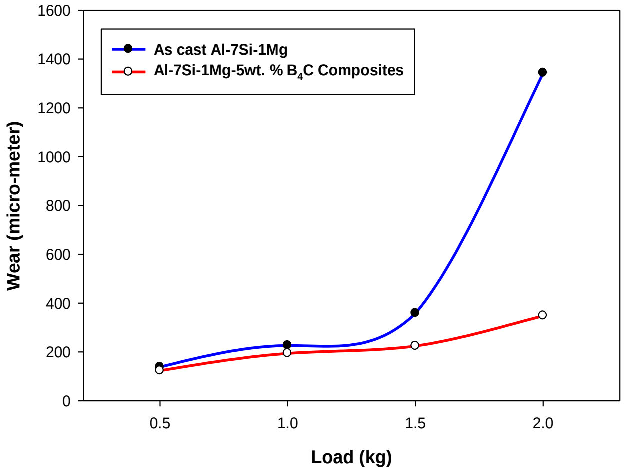


Fig.2: Variation of Al-7Si-1Mg with 5wt. % of B_4C particulates in Hardness before and after addition

From the figure 2, it is observed that there is an increase in the hardness of Al-7Si-1Mg with addition 5 wt % of B_4C particulate. The graph shows the variation of hardness of Al-7Si-1Mg alloy with B_4C reinforcement particulate. It can be concluded that the addition of 5 wt. % of B_4C particulate results in increasing the hardness. The hardness of a soft material such as Aluminum matrix is increased when it is reinforced with a hard particulate [12].

Wear Studies

Figure. 3 shows the wear in terms of height loss for as cast Al-7Si-1Mg alloy and also Al-7Si-1Mg and 5wt. % B_4C composites. Wear test conducted by using pin-on-disc ear testing machine. Wear tests are carried at varying laods from 05 kg to 2 kg in steps of 0.5 kg for 6000m sliding distance and at constant 280 rpm sliding speed. Wear in terms of height loss is measured for both alloy and composites. Wear resistance increases by adding 5 wt. % of B_4C particulates in the Al alloy matrix.



 doi: 10.17950/ijer/v5i6/018

Fig.3: Showing wear in height loss of as cast Al-7Si-1Mg and its composites at varying loads

The results clearly indicate that the increase of load increases wear loss. Also the maximum wear is observed for unreinforced alloy. From the results, it has been asserted that the addition of B_4C particulates to the matrix has a marked effect on the wear. The wear loss of the composite specimen decreases with the increasing weight percentage of particulate reinforcement. At higher loads and the transition to sever wear the surface temperature exceeds a critical value. So as applied load increases ultimately there is an increase in the wear loss for both the unreinforced and reinforced composite materials. It is observed that the wear loss of the composites decrease with 5wt. % B_4C reinforcements in the matrix alloy. The improvement in the wear resistance of the composites with 5 wt. % of B_4C reinforcements can be attributed to the improvement in the hardness of the composites and improved hardness results the decrease in the wear loss of the composites

IV. CONCLUSIONS

The present work entitled, "Hardness and Wear Behavior ofAl-7Si-1Mg-B_4C Metal Matrix Composites",has led to following conclusions:

- Of Al-7Si-1Mg-B_4C particulate composites were successfully produced by liquid stir casting route with 5 wt. % of B_4C reinforcement.
- Aluminum based metal matrix composites have been successfully fabricated by liquid stir casting method by two step addition of reinforcement combined with preheating of particulates.
- The hardness of Al-7Si-1Mg alloy composites increased with the addition of 5 wt. % B_4C particulates.
- The wear in terms of height loss decreases by adding 5 wt. % of B_4C particulates in Al-7Si-1Mg alloy composites.
- The applied load has more impact on wear behavior of both as cast Al-7Si-1Mg alloy and its composites. As load increases there was increase in wear loss for both materials. Al-7Si-1Mg-5wt. % B_4C composites shown more resistance to wear as compared to base alloy.

V. REFERENCES

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