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Microstructure and Dry Sliding Wear Behavior of Al7475 Alloy – 37 Micron Sized B_4C particulates Reinforced Composites

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Abstract

This paper deals with the fabrication and evaluation of wear properties by introducing 37 micron size B_4C particulates into Al7475 alloy matrix. Al7475 alloy based metal matrix composites were prepared by stir casting method. 2, 4, 6, 8 and 10 wt. % of 37 micron sized B_4C particulates were added to the base matrix. For each composite, the reinforcement particles were pre-heated to a temperature of 500 degree Celsius and then dispersed in steps of two into the vortex of molten Al7475 alloy to improve wettability. The Micostructural study was done by using Scanning Electron Microscope (SEM), which revealed the uniform distribution of B_4C particles in matrix alloy, EDS analysis confirmed the presence of B_4C particles in the Al7475 alloy matrix. A pin-on-disc wear testing machine was used to evaluate the wear loss of prepared specimens, in which a hardened EN32 steel disc was used as the counter face. The results revealed that the wear loss was increased with increase in normal load and sliding speed for all the specimens. The results also indicated that the wear loss of the Al7475-B_4C composites were lesser than that of the Al7475 matrix. The worn surfaces were characterized by SEM microanalysis.

Keywords: Al7475 alloy, B_4C, Stir Casting, Microstructure, Wear, Worn Morphology, Wear Debris

INTRODUCTION

Aluminium and its alloys have continued to maintain their mark as the matrix material most in demand for the development of Metal Matrix Composites (MMCs) [1-3]. This is primarily due to the broad spectrum of unique properties it offers at relatively low processing cost. Some of the attractive property combinations of Al based matrix composites are: high specific stiffness and strength, better high temperature properties, thermal conductivity, and low thermal expansion [4-5].

As a result of this, these materials are found to be used in mechanical components such as gears, cams, wheels, impellers, brakes, clutches conveyors, transmission belts, bushes and bearings [6]. In most of these services the components are subjected to tribological loading conditions.

There are several fabrication techniques available to manufacture MMC materials but there is no unique route in this respect. Due to the choice of material and reinforcement and types of reinforcement, the fabrication techniques can vary considerably. There are two types of fabrication methods available i) solid phase fabrication method includes diffusion bonding, hot rolling, extrusion, drawing, explosive welding, powder metallurgy route, and pneumatic impaction ii) liquid phase fabrication method includes liquid metal infiltration, squeeze casting, compo casting, pressure casting and spray co-deposition [7] The preparation of such Al based composites by melting and casting routes i.e. stir casting is by far the most economical one, but is associated with some inherent problems arising mainly from both the apparent non wettability of Al_2O_3 and graphite by liquid aluminium alloys [8] and the density differences between the two materials. Therefore, the introduction and retention of hard ceramic particles like Al_2O_3 and soft particles like graphite in the molten aluminium is extremely difficult. Poor wettability and density differences also results in poor recovery of graphite particles in aluminium melt. Good wetting is an essential condition for the generation of a satisfactory bond between particulate reinforcements and liquid metal during casting to allow transfer and distribution of load from the matrix to the reinforcements without failure. In the present work an attempt has been made to improve the wettability of reinforcement particles with aluminium by adding particles in two steps into the matrix.

Hard ceramic particulates such as zirconia, alumina, B_4C and SiC have been introduced into aluminium based matrix in order to increase the strength, stiffness, wear resistance, fatigue resistance. Among these reinforcements B_4C is compatible with aluminium and forms good bond with the matrix.

Previous researchers revealed, at small amount of graphite contents poor lubrication and small matrix weakening occur. With increasing graphite content, the created graphite film completely separates the wear couple and at the same time protects the matrix, still resistant to plastic deformation. When graphite content exceeds a certain threshold level, weakening of the matrix is so much advanced that the lubricant film is no longer able to protect it effectively, so deformation and cracking are the prevailing phenomena. This graphite content plays an important role to determine the properties of composite.

In this study, an attempt has been made to prepare Al7475 alloy composites by adding 2, 4, 6, 8 and 10 wt. % of B_4C particulates with 37 micron size into matrix by using a novel two stage reinforcement addition method. Further, the prepared Al7475-B_4C composites were studied for effect of load and sliding speed on the wear properties by using pin-on-disc wear testing machine.

EXPERIMENTAL DETAILS

Materials Used

Metal matrix composites containing 2, 4, 6, 8 and 10 weight percentages of B_4C particulates with 37 micron size were produced by liquid metallurgy route. For the production of MMCs, Al7475 alloy was used as the matrix material while B_4C particles with an average size of 37 μm were used as the reinforcements as shown in the fig.1. The chemical composition of the alloy used in the present investigation is given in Table 1.

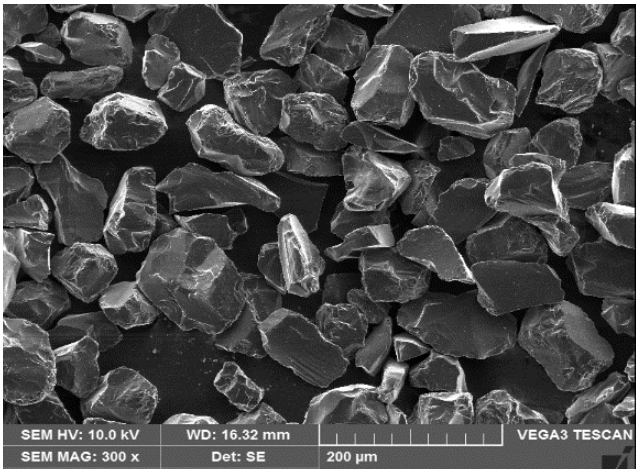


Fig.1 Showing the SEM micro-photograph of 37 micron sized B4C particles used in the study

Table 1: Chemical composition of Al7475 alloy

Elements	Symbol	Wt. %
Zinc	Zn	6.0
Magnesium	Mg	2.40
Silicon	Si	0.10
Iron	Fe	0.12
Copper	Cu	1.80
Titanium	Ti	0.06
Manganeese	Mn	0.06
Chromium	Cr	0.25
Aluminium	Al	Balance

Preparation of Composites

The fabrication of Al7475-B_4C composites will be carried out by liquid metallurgy route via stir casting technique. Calculated amount of the Al7475 alloy ingots are charged into the furnace for melting. The melting point of Aluminium alloy is 660 °C. The melt superheated to a temperature of 750 °C. The temperature will be recorded using achrome-alumel thermocouple. The molten metal is then degassed using solid hexachloroethane (C2Cl6) for 3 min. A stainless-steel impeller coated with zirconium is used to stir the molten metal to create a vortex. The stirrer will be rotated at a speed of 300rpm and the depth of immersion of the impeller was 60 percent of the height of the molten metal from the surface of the melt. Further, the B_4C particulates are preheated in a furnace upto 500 °C will be introduced into the vortex. Stirring is continued until interface interactions between the reinforcement particulates and the matrix promotes wetting. Then, Al7475- 2, 4, 6, 8 and 10wt. % B_4C mixture are poured into permanent cast iron mold having dimensions 125mm length and 15mm diameter. Similarly, composites are prepared for varying particle size composites. Further, based on the microstructal study, wear properties evaluation conducted as per ASTM G99 standards at varying loads, sliding velocities and sliding distances.

Wear Test

Dry sliding wear tests were carried out on Al7475 alloy and Al7475-B_4C composites using a pin-on-disc wear test apparatus. Cylindrical pin specimens of 8 mm diameter and 30 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 with acetone. Test conditions included load-speed settings of 100, 200, 300 and 400 rpm under a 4kg normal load, and 1, 2, 3 and 4kg loads at 400rpm speed. The initial weight of the specimen was measured in an electronic weighing machine with ± 0.01mg accuracy. Data collected and analyzed for wear rates in the form of weight loss.

RESULTS AND DISCUSSION

Microstructural Analysis

Fig. 2 (a) shows microstructure of as cast Al7475 aluminium alloy, fig. 2(b-f) represents Al7475-2, 4, 6, 8 and 10 wt. % of B_4C. The SEM micrographs reveal almost uniform distribution of B_4C particulates throughout the matrix as observed in the fig. 2(b-f) below. Uniformly distributed particulates increase the overall strength and other properties reducing the porosity of the MMC.

It is observed from the fig.2 (d) as the weight percentage of B_4C particulates increases in the Al7475 alloy matrix, the presence of number of particles are more in the Al alloy matrix. Also, it is visible that, there is strong interfacial bonding between the

B_4C particles and Al7475 alloy matrix, which makes the composites strong.

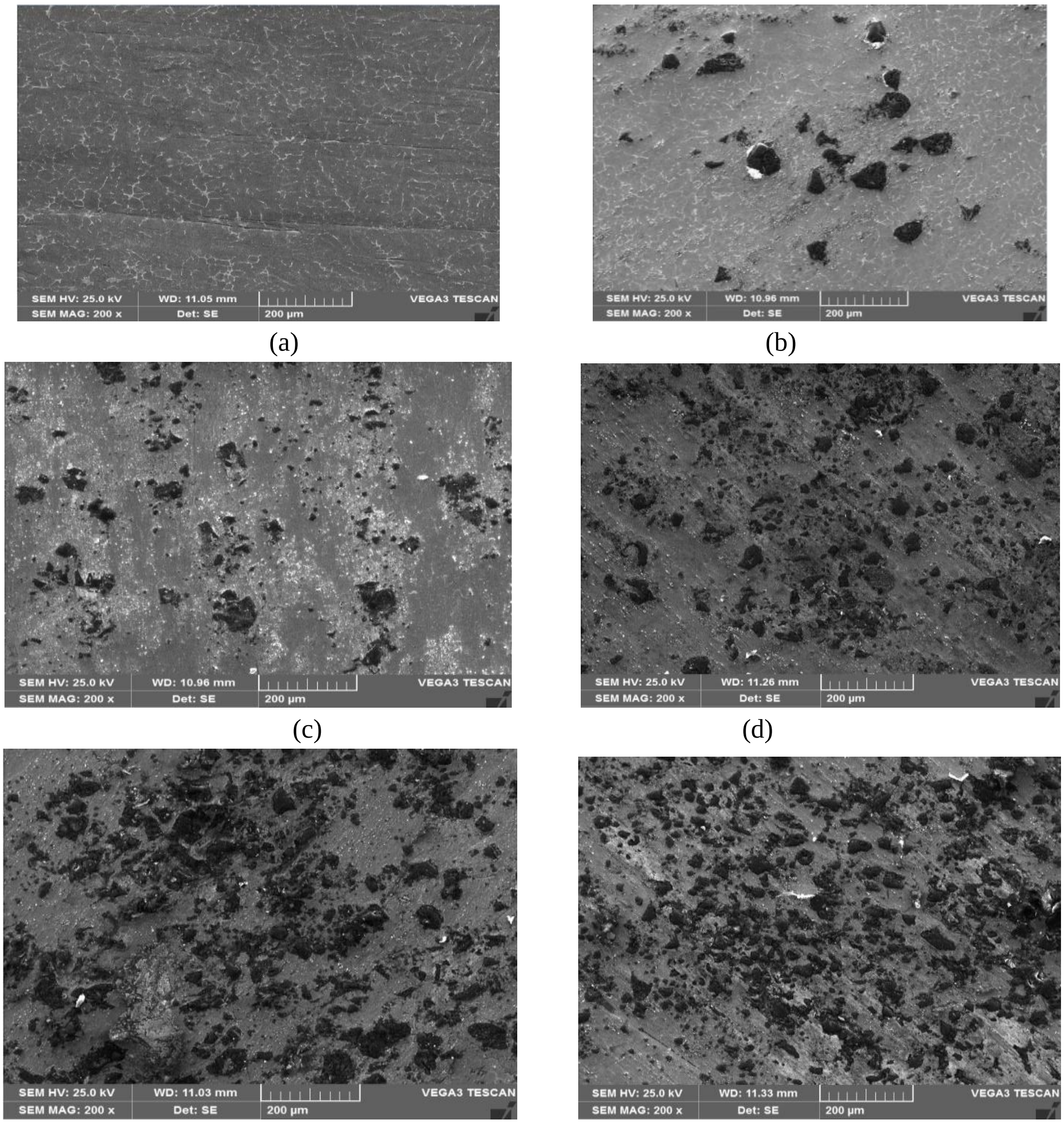
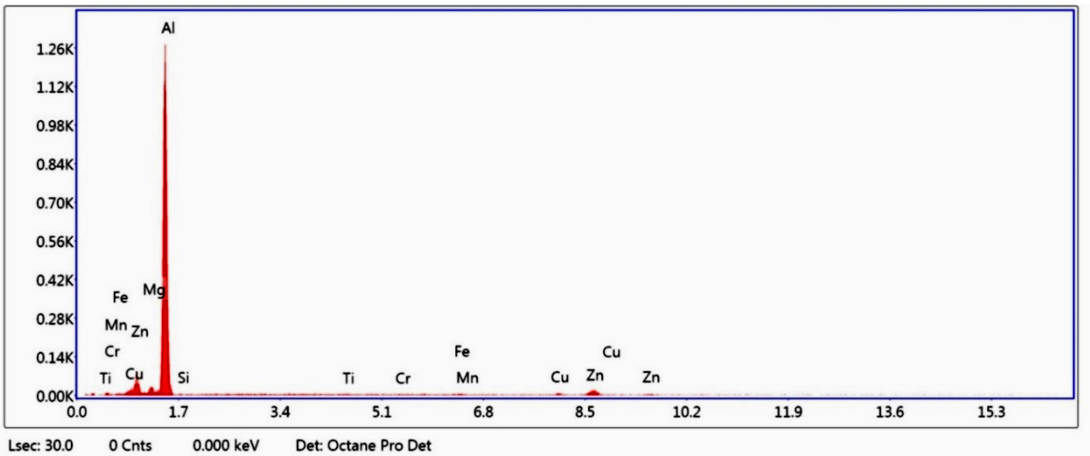
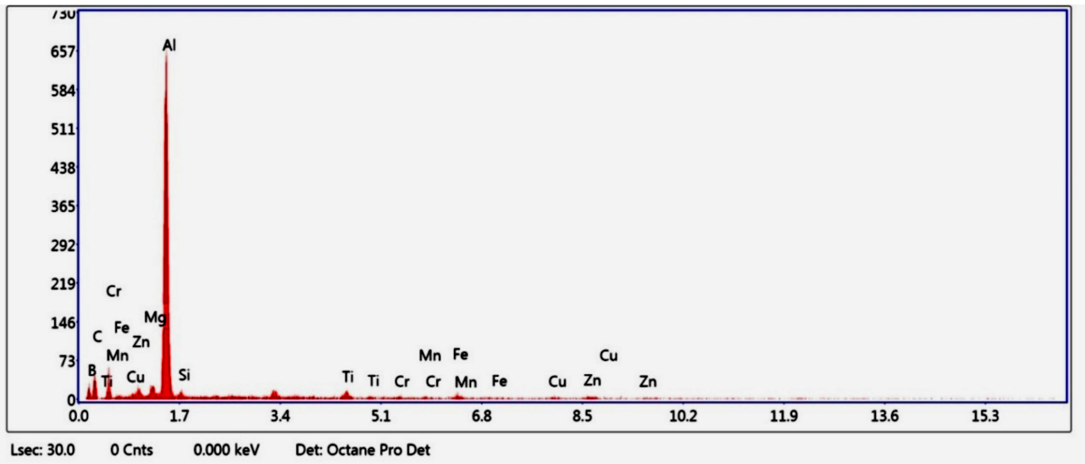


Fig. 2 Scanning electron micrographs of (a) as cast Al7475 alloy (b) Al7475-2 wt. % B_4C (c) Al7475-4 wt. % B_4C (d) Al7475-6 wt. % B_4C (e) Al7475-8 wt. % B_4C (f) Al7475-10wt. % B_4C with 37 micron size particles



(a)



(b)

Fig. 3 Energy Dispersive Spectrographs of (a) as cast Al7475 alloy (b) Al7475-10wt. % B_4C with 37-micron size particles

Al7475 alloy with 37 micron sized B4C particulates reinforced composites were analysed by EDS to know the elements like B and C in Al7475 alloy matrix as shown fig. 3. From the EDS spectrums, it is revealed the presence of B and C elements in Al7475 alloy along with Al.

Wear Behaviour

The variation of wear loss is as shown in fig. 4. Applied load affects the wear rate of Al-Alloy and the composites significantly and is the most dominating factor controlling the wear behaviour. The wear loss varies with the normal load which is an indicative of (Archardi's law) and is significantly lower in case of composites.

With increase in loads there is higher volumetric wear loss for matrix alloy and the composites. However, at all the loads considering wear resistance of the composites is superior to the matrix alloy. Several researchers [9, 10] indicated that under different applied load conditions identified different wear mechanisms, at lower loads the particles support the applied load in which the wear resistance of MMC's are in the order of magnitude, better than Al7475 alloy. 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 reinforced and unreinforced composite materials. The variation of wear loss of the matrix alloy Al7475 and its composites with 2, 4, 6, 8 and 10 wt. % of B_4C content is shown in fig. 4. The improvement in the wear resistance of the composites with B_4C reinforcements can be attributed to the improvement in the hardness of the composites and improved hardness results in the decrease in the volumetric wear loss of the composites

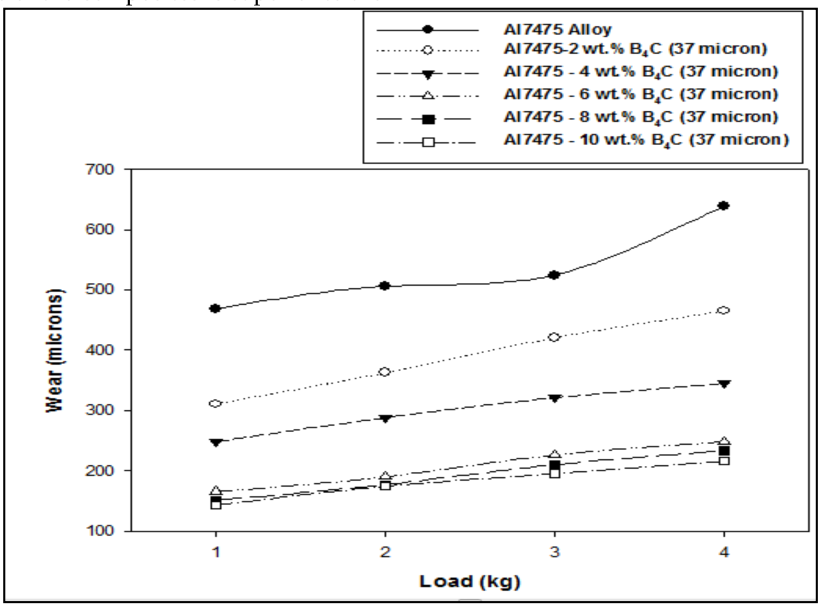


Fig.4 Shows wear loss of Al7475 Alloy and its composites at varying loads and 400rpm constant speed for 37 micron B_4C particulate composites

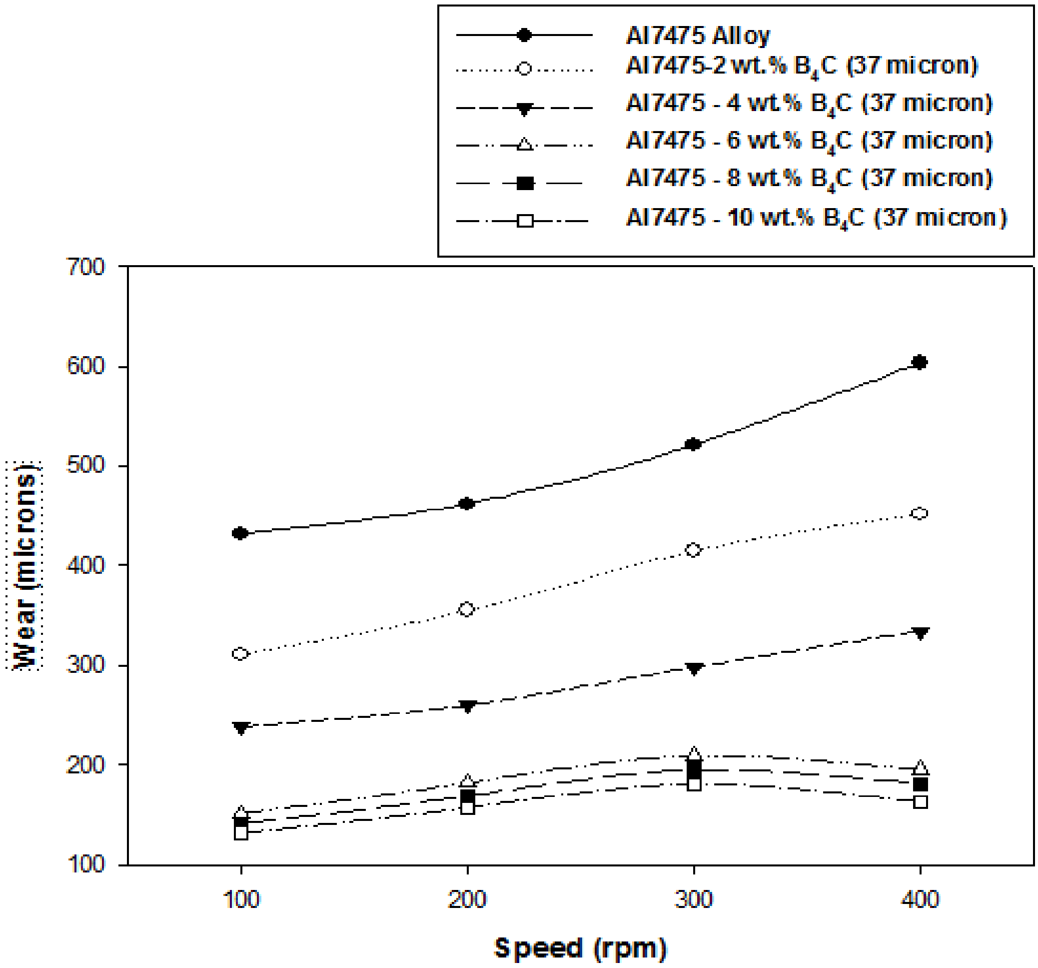


Fig. 5 Shows wear loss of Al7475 Alloy and its composites at varying speeds and 4 kg constant load for 37 micron B_4C particulate composites

Fig. 5 shows the variation of wear loss of Al7475 matrix alloy and Al7475-2, 4, 6, 8 and 10 wt. % of B_4C composites at constant 4kg load and varying sliding speeds. With an increasing speed i.e. 100, 200, 300, and 400 rpm, there is an increase in the volumetric wear loss for both matrix alloy and its composites. However at all the sliding speeds studied, the volumetric wear loss of the composite was much lower when compared with the matrix alloy. Further increased wear rate with increased sliding speed is due to thermal softening of the composite [11, 12]. On the other hand, the increased temperature at higher sliding speeds can cause severe plastic deformation of the mating surfaces leading to form high strain rate sub-surface deformation. The increased rate of sub-surface deformation increases the contact area by fracture, and fragmentation of asperities. Therefore, this leads to enhanced delamination contributing to enhance wear rate.

CONCLUSIONS

The present work on processing and evaluation of Al7475-B_4C metal matrix composite by melt stirring has led to following conclusions. Al7475 alloy based composites have been successfully fabricated by melt stirring method using two stage addition method of reinforcement combined with preheating of particles. The SEM microphotographs of composites revealed uniform distribution of reinforcement particulates in the Al7475 alloy metal matrix. The addition of B_4C particles to Al7475 alloy matrix improves the wear resistance of the composite. The wear loss is dominated by load factor and sliding speed. The increase of loads and sliding speeds leads to a significant increase in the wear loss. The Al7475-B_4C composites have shown lower rate of volumetric wear loss as compared to that observed in as cast Al7475 alloy matrix.

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