Dry Sliding Wear Behavior of B$_4$C Particulates Reinforced Al7020 Alloy Composites

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Abstract

The work is carried out to investigate the dry sliding wear behavior of B$_4$C reinforced Al7020 alloy metal matrix composites. In the present work Al7020 alloy was taken as the base matrix and B$_4$C particulates as reinforcement material to prepare metal matrix composites by stir casting method. For metal matrix composites the reinforcement material was varied from 0 to 4 wt. % in steps of 2 wt. %. The wear resistance of metal matrix composites was studied by performing dry sliding wear test using a pin on disc apparatus. The experiments were conducted at a constant sliding speed of 300rpm and sliding distance of 4000m over a varying load of 1, 2 and 3Kg. Similarly, experiments were conducted at a constant load of 3Kg and sliding distance of 4000m over a varying sliding speed of 200, 300 and 400rpm. The results showed that the wear resistance of Al7020-2% B$_4$C and 4% B$_4$C composites were better than the unreinforced alloy. The wear in terms of height loss found to increase with the load and sliding speed. To study the dominant sliding wear mechanism for various test conditions, the worn surfaces were analyzed using scanning electron microscopy.

Keywords: Al7020 Alloy, B$_4$C Particulates, Microstructure, Wear, Worn Surface

INTRODUCTION

Metal matrix composites (MMCs) have been accepting extraordinary consideration because of their high rigidity, hardness and modulus, and also their high wear resistance contrasted with the framework. The tribological properties of aluminum compounds can be altogether upgraded by the addition of a dispersed ceramic particle phase [1, 2]. The subsequent material is all around known as aluminum matrix composites (AMCs). The improved properties of AMCs, for example, high particular quality, lessened wear rate and lower warm expansion has pulled in the consideration of the materials designing group. AMCs are replacing regular aluminum alloys in a few applications including aviation, car, ship building and atomic designing [3]. Among different ceramic particles B$_4$C is progressively favored as support for AMCs because of its thermodynamic dependability, high dissolving point, high hardness, high flexible modulus and remarkable wear resistance.

AMCs could be delivered either by solid state or fluid (liquid) state preparing [4, 5]. Liquid state systems are for the most part utilized in light of the fact that these are economically viable, simple and applicable in large quantity production. Melt stirring techniques are of two sorts in particular ex situ and in-situ. In ‘ex-situ’ procedure artistic fortifications are added remotely to the liquid metal though ‘in-situ’ handle the generation of support happens inside the network accordingly of compound response. The in-situ composites represent a few focal points over ex-situ, for example, uniform dispersion of fortification particles, grain refinement, clear interface, improved warm steadiness and prudent preparing [6-8].

Al-Zn based Al7020 alloy is heat treatable aluminum composite, which offers high quality at low particular weight and are broadly utilized as basic segments, especially in the aerospace industry. B$_4$C strengthened Al7020 composites are therefore be considered to have more application potential. It is however a testing undertaking to create homogeneous Al/B$_4$C AMCs utilizing these strategies. Regular imperfections, for example, porosity, agglomeration, isolation and slag consideration are for the most part unavoidable. A homogeneous dispersion of B$_4$C particles is fundamental to accomplish upgraded properties and execution.

Over the last decade, a lot of studies have been carried out to overcome these insufficiencies and plenty of experimental preparations have been performed. Several efforts have been made to improve the interface bonding between aluminium and ceramic particles by exploring surface coating of the ceramic particles. In the present study Al7020-B$_4$C composites have been fabricated by using novel two step mixing process of reinforcements, to improve the wettability of B$_4$C particulates with Al alloy matrix.

In this study, an attempt has been made to prepare Al7020 alloy composites by adding 2 & 4 wt. % of B$_4$C particulates into matrix by using a novel two stage reinforcement addition method. Further, the prepared Al7020 – B$_4$C composites were studied for effect of load and sliding speed on the wear properties by using pin-on-disc wear testing machine.

EXPERIMENTAL DETAILS

Metal matrix composites containing 2 and 4 weight rates of B$_4$C particles were created by liquid metallurgy course. For
the generation of MMCs, an Al7020 alloy was utilized as the framework material while B₄C were utilized as the fortifications. The theoretical density of grid material Al7020 amalgam is 2.80g/cm³ and support particulates B₄C is 2.52g/cm³. The chemical substance of Al7020 composite utilized as a part of the work is given in the table 1.

<table>
<thead>
<tr>
<th>Element (symbol)</th>
<th>Wt. percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zn</td>
<td>0.5</td>
</tr>
<tr>
<td>Cu</td>
<td>0.2</td>
</tr>
<tr>
<td>Mn</td>
<td>0.5</td>
</tr>
<tr>
<td>Mg</td>
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<tr>
<td>Fe</td>
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<td>Si</td>
<td>0.35</td>
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<td>Ti</td>
<td>0.1</td>
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<td>Al</td>
<td>Bal</td>
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The B₄C particle reinforced Al7020 alloy metal matrix composites have been produced by using a vortex method. Initially calculated amount of Al7020 alloy was charged into SiC crucible and superheated to a temperature 730°C in an electrical resistance furnace. The furnace temperature was controlled to an accuracy of ±10 degree Celsius using a digital temperature controller. Once the required temperature is achieved, degassing is carried out using solid hexachloroethane (C₂Cl₆) to expel all the absorbed gases. The melt was agitated with the help of a zirconia coated mechanical stirrer to form a fine vortex. A spindle speed of 300 rpm and stirring time 3-5 min. were adopted. The B₄C particulates were preheated to a temperature of 500 degree Celsius in a pre-heater to increase the wettability. The pre-heated B₄C particles introduced into melt in steps of two at constant feed rate of 1.2-1.4 g/sec. After holding the melt for a period of 5 min., the melt was poured from 710 degree Celsius into a preheated cast iron mould having dimensions of 120mm length x 15mm diameter.

Metallographic test specimens of 5mm thickness were prepared by cutting the as cast and B₄C strengthened Al7020 combination composites. Test samples were polished according to the standard metallographic methodology and etched with Keller’s reagent. The microstructure was viewed utilizing scanning electron microscope instrument.

The dry sliding wear behavior of as cast Al7020 alloy and Al7020-B₄C composites were evaluated using a pin-on-disc wear apparatus at room temperature according to ASTM G99 standard. Pins of length 25 mm and diameter 8mm were prepared from the cast samples. The experiments were conducted at a constant sliding speed of 300rpm and sliding distance of 4000m over a varying load of 1Kg, 2Kg, and 3Kg. Similarly experiments were conducted at a constant load of 3Kg and sliding distance of 4000m over a varying sliding speed of 200, 300 and 400rpm. The polished surface of the pin was slide on a hardened chromium steel disc. A computer aided data acquisition system was used to monitor the loss of height. Wear value is presented in terms of height loss.

**RESULTS AND DISCUSSION**

**Microstructure study**

**Table 1.** Chemical composition of Al7020 alloy

![Fig. 1](a-c) Showing the scanning electron microphotographs of (a) as cast Al7020 alloy (b) with 2 wt.% of B₄C & (c) with 4 wt.% of B₄C
Figure 1 (a-c) shows the SEM microphotographs of Al7020 alloy as cast and Al7020 with 2 and 4 wt. % of B₄C particulate composites. This reveals the uniform distribution of B₄C particles and very low agglomeration and segregation of particles, and porosity.

Fig. 1 b-c clearly show and even distribution of B₄C particles in the Al7020 alloy matrix. In other words, no clustering of B₄C particle is evident. There is no evidence of casting defects such as porosity, shrinkages, slag inclusion and cracks which is indicative of sound castings. In this, wetting effect between particles and molten Al7020 alloy matrix also retards the movement of the B₄C particles, thus, the particles can remain suspended for a long time in the melt leading to uniform distribution.

**Effect Load on Wear**

The variation of wear loss at steady 300rpm sliding speed and changing loads of 1Kg, 2Kg and 3Kg is as appeared in fig. 3. Applied load influences the wear of Al7020 compound and the composites fundamentally and is the most overwhelming component controlling the wear conduct. The wear misfortune changes with the typical load and is altogether lower if there should arise an occurrence of composites. With increment in loads there is higher wear misfortune for matrix alloy and the composites. However at all the loads considering wear resistance of the composites is better than the framework combination. At higher loads and the transition to severe 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 and its composites with 2 and 4 wt. % of B₄C content is shown in fig. 3.

The improvement in the wear resistance of the composites with B₄C reinforcement can be attributed to the improvement in the hardness of the composites and improved hardness results in the decrease in the wear loss of the composites [9, 10].

**Effect Sliding Speed on Wear**

Fig. 4 shows the variation of wear loss of Al7020 matrix alloy and Al7020-2% & 4% B₄C composites at constant 3Kg load and varying sliding speeds. With an increasing speed i.e. 200, 300, and 400 rpm, there is an increase in the wear loss for both matrix alloy and its composites. However at all the sliding speeds studied, the 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. 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 [11, 12].
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. Further, 4wt. % of B$_4$C particulates reinforced Al7020 alloy composites shown more resistance to wear.

**Fig. 4:** Showing wear of Al7020 alloy and its composites at varying sliding speed, constant load of 3Kg and 4000m sliding distance

**Worn Surface Morphology**

**Fig. 5:** Shows the SEM microphotographs of worn surfaces of (a) as cast Al7020 alloy (b) Al7020 – 2wt. % B$_4$C (c) Al7020 – 4wt. % B$_4$C composites at 3Kg load and 300rpm sliding speed.

Wear surface analysis of composites were examined by scanning electron microscope. Fig.5a-c represents the wear surface of as cast Al7020 alloy and specimens containing 2 & 4 wt. % of B$_4$C particles reinforced composite at 3Kg load and 300rpm sliding speed. The examination of worn surface as appeared in figure 4a, that the worn surfaces of base combination are considerably rougher than composites. Cavities and extensive furrowed surfaces are found on worn surface of Al7020 amalgam. The sign of pits and scores underpins the way that delicate Al composite disfigured at higher load of 3kg and at 300rpm speed and hauled out from the surface. The wear track perception demonstrates that grip and delamination are prevailing wear instruments seen at higher loads. This is supported by the large sized delamination flakes and severe adhesion resulting in bulk removal of material at higher loads [13].

Fig. 5b & c shows the SEM image of the worn surface of Al7020-2 & 4 wt. % of B$_4$C composite tested at applied load of 3kg and 300rpm speed. The grooves are very small due to the hard nature of B$_4$C reinforcement and poor wear losses. As the ceramic particles resist the delamination process, composites are found to have greater wear resistance [14]. Worn surface shows less cracks and grooves mainly due to the presence of hard particulates.

**CONCLUSIONS**

The present work on processing and evaluation of Al7020-B$_4$C metal matrix composite by melt stirring has led to following conclusions. Al7020 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 fairly uniform distribution of reinforcement particulates in the Al7020 metal matrix and EDS spectrographs confirmed the presence of B$_4$C particles. The addition of B$_4$C particles to Al 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 Al7020-4% B4C composites have shown lower wear loss as compared to that observed in as cast Al7020 alloy and 2 wt. % B4C reinforced composites matrix. Worn morphology showed the effect of hard ceramic particulates addition on wear behavior of Al alloy and its composites.

REFERENCES


