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DRY SAND ABRASIVE WEAR BEHAVIOR OF CHILL CAST ALUMINUM BORON CARBIDE COMPOSITES

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ABSTRACT

Aluminum metal matrix composite (Pure Aluminum / Boron Carbide) was cast through stir casting technique. The processing of the casting was achieved with the influence of different metallic chill materials (Stainless Steel 304, Cast iron and Copper). Three body sand abrasive wear tests were performed at the chill side of the casting to analyze the chilling effect on the abrasive wear behavior of the composites. The experiments were conducted at room temperature using sand abrasive wear testing machine as per ASTM G 65-81 standards using silica sand of 312 microns as an abrasive medium. Speed of 200 rpm was kept constant for all the tests and the parameters such as load (10, 20, 30 N) and time (15, 30, 45 min) were varied for three levels. From the obtained results, it is observed that the wear rate is mainly affected by the use of end chills and also by the applied load and time. Copper chilled composites show lower wear rate than the stainless steel and cast iron chilled composites. The optical microscope was used to analyze the worn surfaces and wear mechanism.

Keywords: sand abrasive wear, metal matrix composites, end chills, stir casting.

INTRODUCTION

In most of the engineering and structural applications, the metal matrix composites play a vital role in providing better wear resistance and longer life due to its attractive tailored properties. The aluminum matrix composites are in great demand in sectors like aircraft, automotive and military due to their high strength, stiffness, hardness, better wear and corrosion resistance. The addition of hard ceramic particulates like boron carbide, silicon carbide, aluminum oxide etc., into aluminum matrix composites has increased its potential towards the application in the field of wear and tear [1-2]. A sound casting with the superior properties can be obtained by using metallic materials as end chills which has a deciding effect on the microstructure, mechanical and tribological properties [2-3]. The stir casting method is the most economic and commonly used for the fabrication of metal matrix composites [4-5]. Ajit Kumar Senapati et al. [6] reported the detailed review on the abrasive wear behavior of the aluminum alloys treated with various reinforcements. D. Ramesh *et al*. [7] studied the abrasive wear behavior of the frit particles reinforced with Al6061 alloy and observed that the composites have more abrasive wear resistance than the alloy in both heat treated and as-cast conditions. N. Radika and R, Raghu [8] investigated the dry sand abrasive wear behavior of functionally graded aluminum boron carbide composites and reported that the abrasive wear rate decreases with the increasing speed and increases with the increasing load.

From the support of the literature, it is confirmed that no attempts have been made to study the effect of chill on the dry sand abrasive wear behavior of aluminum boron carbide composites. Hence, the present paper aims to investigate the effect of various factors like chill, applied load and time on the dry sand abrasive wear behavior of chill cast aluminum boron carbide composites.

EXPERIMENTAL PROCEDURE

Composite preparation

The mold was prepared by using Autoclave aerated concrete (AAC) bricks of lower thermal conductivity with chill on one side. Thus, the chill side of the mold extracts the overall heat. Cast iron, stainless steel, and copper plates are used as end chills because of the large difference in their thermal conductivity. The final dimension of the mold cavity was 50 mm x 100 mm x 200 mm. The arrangement of the mold with end chills is as shown in Figure 1 (a) and 1 (b).

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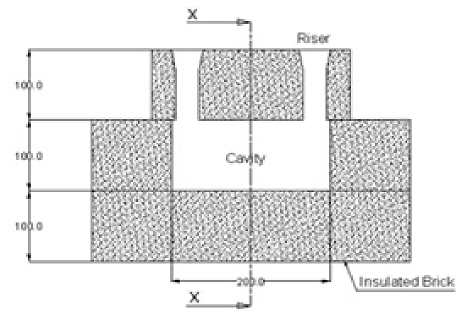

Figure-1(a). Front view of the mold assembly [2, 9].

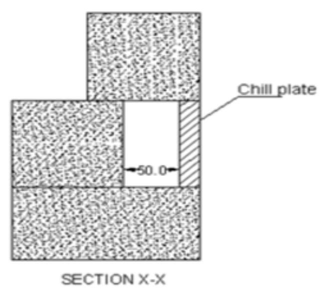

Figure-1(b). Side view of the mold assembly showing the location of the end chill [2, 9].

Aluminum of 99.9% purity was chosen as the matrix material and boron carbide of particle size of 105 microns as reinforcement. Melting of the matrix material was done in resistance furnace. Boron carbide was preheated to 250˚C. After degassing and slag removal the melt was stirred continuously to get a fine vortex. 2 wt. % preheated reinforcement material was added into the vortex of the melt which was at 725˚C and stirred for 15 minutes at 250 rpm. The procedure adopted by Sanman *et al.* [9] was followed for obtaining the pure aluminum casting with cast iron chill and Al-B_4C composites with different chill materials.

Dry sand abrasive wear test

Three body abrasive wear test was conducted at room temperature using sand abrasive wear testing machine as per ASTM G65-81 standards. Test samples of size 75 x 25 x 8 mm were cut from as-cast samples and machined. The specimens were polished, cleaned with the acetone and initial weight was noted using digital weighing balance. 312 Microns grain size of silica sand was used as the abrasive media. Speed of 200 rpm was kept constant for all the tests. Load and testing time were varied from 10 N to 30 N in steps of 10 N and 15 minutes to 45 minutes in steps of 15 minutes respectively. After the test, the specimens were cleaned with acetone and final weight was noted down and the difference in the weights was considered for weight loss.

RESULTS AND DISCUSSIONS

The studies on dry sand abrasive wear behavior of composites cast with different chills with respect to applied load, test time and analysis of its worn surfaces using optical microscope are discussed below.

Dry sand abrasive wear behavior

Effect of chill plate

Figure-2 shows the variation in dry sand abrasive wear in terms of weight loss of the samples for cast iron chilled matrix material and different chilled composites at a constant speed of 200 rpm with an applied load of 10 N and testing time of 30 minutes. The cast iron chilled matrix material was cast for comparison with the different chilled boron carbide reinforced aluminum matrix composites. It is clear from these figures that the wear resistance of Al-B_4C composite is better than that of pure aluminum cast with cast iron chill. The results also indicate that the copper chill induces maximum wear resistance compared to cast iron and stainless steel chills.

As the thermal conductivity of the copper chill is much higher than the cast iron and stainless steel, the extraction of heat during solidification through copper chill is maximum leading to faster cooling rating which results in fine grains followed by the medium grains of cast iron and coarse grains of stainless steel chill. Because of the fine grains and the incorporation of boron carbide particles into the matrix material, the hardness of the copper chilled composite increases resulting in very good abrasion wear resistance [2].

Effect of applied load

Figure-3 shows the variation in dry sand abrasive wear in terms of weight loss of the samples for cast iron chilled matrix material and different chilled composites for a testing time of 30 minutes with an applied load of 10, 20 and 30 N at a constant speed of 200 rpm. It is clear from the obtained results that the wear loss increases with the increase in applied load for both the pure aluminum and the composites cast using various chill materials. The highest wear mass loss was for cast iron chilled pure aluminum and the lowest was for copper chilled composites. Silica sand is the main reason for the abrasion of the specimen as it falls in between the rotating rubber wheel and the specimen. As the load increases, the contact between the abrasive medium and the specimen will be more and thus the exposed surface of the specimen gets highly penetrated by the silica sand which results in more wear and thus the loss of the material will be high. The same trend in the variation of the wear rate is reported by the other investigators [7, 8].

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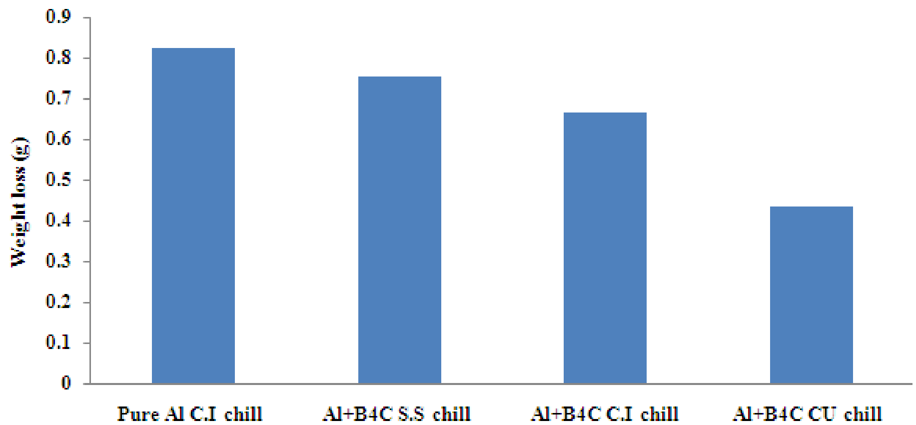

Figure-2. Variation of abrasive weight loss of Pure Al (C.I Chill) and Al-B_4C composites with different chill materials.

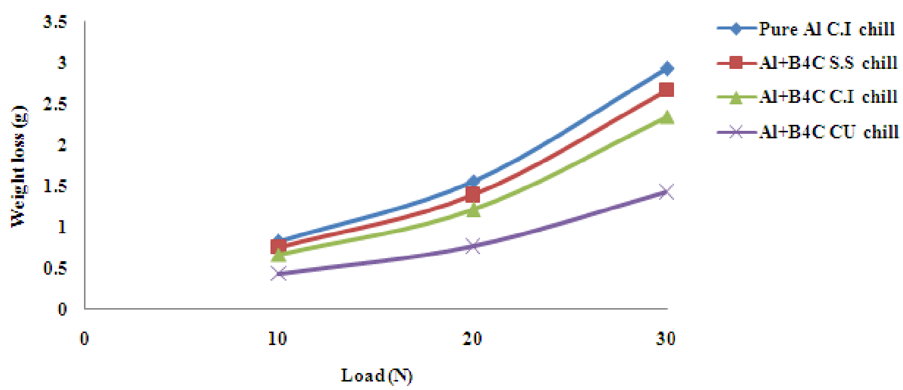

Figure-3. Variation of abrasive weight loss of Pure Al (C.I Chill) and Al-B_4C composites with different chill materials with respect to load.

Effect of testing time

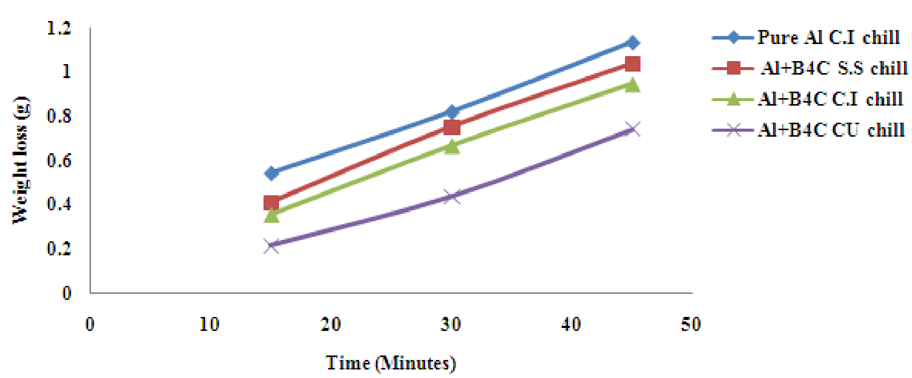

Figure-4. Variation of abrasive weight loss of Pure Al (C.I Chill) and Al-B4C composites with different chill materials with respect to time.

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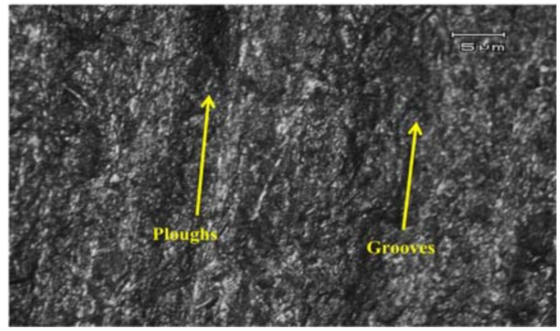
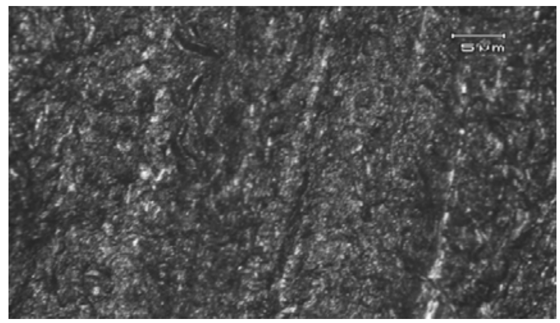
Figure-4 shows the variation in dry sand abrasive wear in terms of weight loss of the samples for cast iron chilled matrix material and different chilled composites for a testing time of 15, 30 and 45 minutes with an applied load of 10 N at a constant speed of 200 rpm. The highest wear mass loss was for cast iron chilled pure aluminum because of its softer surface and less hardness and the lowest was for copper chilled composites because of its high hardness which is due to the fine grain structure and incorporation of boron carbide particulates. In these figures, for cast iron chilled matrix material and copper, cast iron and stainless steel chilled composites the wear increases as the testing time increases for a given load and speed. The cause for the increase in wear with the increase in the testing time is due to the more exposition time of the specimen surface with the inverse face, which makes the abrasive particles to easily abrade the exposed surface resulting in more wear and high material loss.

Optical microscope analysis

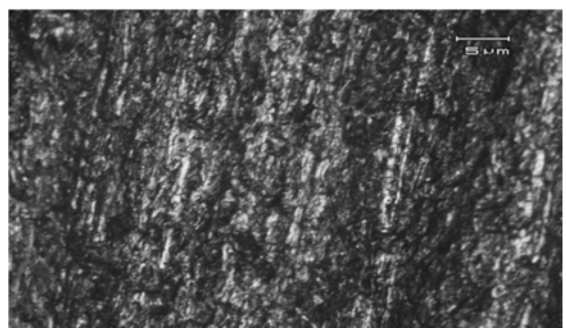
Figure-5 shows the optical microscope images of the worn surfaces. The worn surfaces shown are abraded with abrasive particle size of 312μm, applied load of 10 N at the speed of 200 rpm for a period of 30 minutes. Massive ploughs and deep grooves were observed in case of cast iron chilled matrix alloy as shown in Figure-5 (a). This is due to the softer surface and low hardness of the matrix material which allows the silica sand to easily penetrate on the surface of the specimen and abrade it through the cutting action, forming large ploughs and deeper grooves resulting in severe wear. Stainless steel and cast iron chilled Al-B_4C composites exhibits better wear resistance than the pure aluminum cast with cast iron chill. Thus, the amount of ploughing and grooving is minimum as shown in Figure-5 (b) and 5 (c) respectively. It is also noticed that more amount of scratches have been made than the ploughs and grooves in copper chilled composites as shown in Figure-5 (d). This may be due to the amount of penetration of the abrasive medium on the surface will be less in case of copper chilled composites due to its fine grain structure and high hardness resulting in less ploughs and the loss of the material is also low.



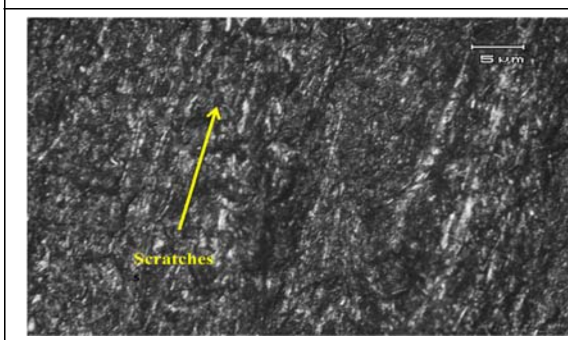
Cast iron chilled matrix alloy



Stainless steel chilled Al-B_4C composite



Cast iron chilled Al-B_4C composite



Copper chilled Al-B_4C composite

Figure-5. Optical microscope images of worn surfaces of Pure Al (C.I Chill) and Al-B_4C composites cast using different chill materials

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CONCLUSIONS

Aluminum matrix composites with boron carbide particulates as reinforcing material was fabricated successfully by means of stir casting technique using different metallic chill materials. Dry sand abrasive wear tests were performed at the chill side of the casting to analyze the chilling effect on the abrasive wear behavior of the composites. Based on the obtained results, the following conclusions can be made:

1. The cast iron chilled matrix material has the highest wear mass loss due to its softer surface and low hardness.
2. The copper chilled Al-B_4C composite exhibits good wear resistance among stainless steel and cast iron chilled Al-B_4C composites because of its fine grain structure
3. The hardness of the copper chilled composite increases resulting in very good abrasion wear resistance.
4. The abrasive wear loss increases with the increase in applied load and also with the increase in testing time for both the pure aluminum and the composites cast using various chill materials.
5. The worn surface reveals that the copper chill induces maximum wear resistance compared to cast iron and stainless steel chills.

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