Characterization of Boron Carbide Particulate Reinforced AA6061 Aluminium Alloy Composites by Stir Casting Process

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Abstract - *Stir casting is an economical method to produce Aluminium matrix composites (AMCs). In the present work, Aluminium alloy AA6061 reinforced with various amounts (1, 2 & 3 wt. %) of Boron Carbide particles were prepared. The matrix alloy was melted in a casting furnace and with the help of the automatic stirrer, a vortex is formed. Boron Carbide particles were added to the periphery of the vortex and the composite melt was solidified in a permanent mold. The microstructures of the AMCs were studied using and scanning electron microscopy. Boron Carbide particles were observed to refine the grains and were distributed homogenously in the Aluminium matrix. Boron Carbide particle clusters were also seen in a few places. Boron Carbide particles were properly bonded to the Aluminium matrix. The reinforcement of Boron Carbide particles improved the hardness, wear, and Microstructure analysis of the AMCs.*

***Key Words*: Metal Removal Rate (MMR), Wear Resistance Test, Hardness Test, Inverted Microscope, AA6061, Boron Carbide.**

1. INTRODUCTION

Casting is a manufacturing technique where the solid metal is melted and heated to the right temperature (occasionally handled to alter its chemical composition), and is then poured right into a hollow space or mildew, which incorporates it with inside the right form for the duration of solidification. Thus, in a one step, easy or complicated shapes may be crafted from any steel that may be melted. The ensuing product could have genuinely any configuration the clothier desires. In addition, the resistance to operating stresses may be optimized, directional characteristics may be controlled, and a nice look may be produced. Cast elements variety in length from a fragment of an inch and a fragment of an ounce, to over 30 ft and plenty of tons. Casting has marked benefits with inside the manufacturing of complicated shapes, elements having hollow sections or inner cavities, elements that comprise abnormal curved surfaces, very massive elements, and elements crafted from metals which might be hard to machine. Because of those apparent benefits, casting is one of the maximum essential of the producing processes. In metalworking and jewelry making, casting is a technique wherein a liquid steel is in some way added right into a mildew additionally it is added via way of means of a crucible that carries a hole form a third-dimensional negative picture of the supposed form. The steel is poured into the mildew thru a hole channel known as a sprue. The steel and mildew are then cooled, and the steel a part of the casting is extracted. Casting is most usually used for making complicated shapes that might be hard or uneconomical to make via way of means of different methods.

2. METHODOLOGY

The literature review has given an insight of the alloy research work and the gaps found in it enabled to identify problem areas find solution through the experimental methodology fulfilling the objective. The initial step is to select the material for the castings and also focus on the application of the material. And then proceed for the stir casting process we need to prepare the material in the calculation of weight material and weight percentage of the composite material. After completion of stir casting process, we collect the ingot and move for the machining process as per our standard size for the wear and hardness process.

3. EXPERIMENTAL DETAILS

The Aluminium alloy AA6061 bricks were cut in power hacksaw machine to the small pieces to feed the materials in to the crucible. The required proportion of the pieces as per experimental plan is fed in to crucible and melted by heating in the induction furnace at the temperature of 700-750°C for 1 to 2 hours and melt the AA6061 pieces above its liquid temperature to make it in the form of semi liquid state around 800°C.

The Boron Carbide (B_4C) particles in the right proportion as per the experimental plan are preheated to a temperature of 700-750°C to make their surface oxidized. The preheated mold is heated to 200°C to fully harden. During the reheating process of AA6061 aluminium alloy at 750°C stirring is done by means of a mechanical stirrer, which rotates at a speed of 500 rpm. Then the reinforcing powder is added to the semi-liquid aluminum alloy in the furnace. Argon gas is passed in to the molten metal to remove the soluble gases present in the liquid state metal. The molten metal stirring is carried out for upto 3 minute's duration.

The aluminium composite material reaches completely liquid state at the temperature of about 900°C and the completely melted aluminium composite is poured into a cast iron die, then solidified to form the desired cast samples. The samples casted are shown in figure 1. Thus, all specimens are casted according to the experimental plan.

3.1 Sample Fabrication

The AA6061 aluminium alloy is introduced to the melt furnace and it is melted. After melting of actual, the molten metal is made to pour on the cylindrical die. After casting sample is solidified, die end is removed. Finally collect the casted samples.

Figure -1: Casted samples

3.2 Microstructural Analysis

An inverted microscope was used to analyze the dispersion of the reinforcing particles in the base alloy. An inverted microscope is a microscope with a light source and a condenser on the top, above the stage, while the target and tower are below the stage. The stage of an inverted microscope is generally fixed, and focus is corrected by moving The objective lens zooms in or out of the sample along the vertical axis from the samples. The focusing mechanism usually has a double concentric knob for coarse and fine adjustment. The focusing mechanism usually has a double concentric knob for coarse and fine adjustment. Depending on the size of the microscope, four to six different magnifications can be connected to a rotatable revolver, the so-called is nosepiece. These microscopes can also be equipped with accessories for fixed cameras, fluorescent lamps, confocal scanning and many other applications. Samples prepared is creating flat surfaces by facing, well-polished with the help of fine grade emery paper, clean and tested as per test reference.

3.3 Rockwell Hardness Test

A standard load (depending on the type of material) is applied by a standard indenter (cone or ball) for a standard time. The hardness number is determined directly in the test. Hardness is the property of the material that is offered a Scratch and split resistance. This is the most important property as the material is subject to friction and scratches. Through this experiment we can determine the hardness of the given material.

Figure -2: Morphological microstructure image analysis sample

4. MATERIALS AND EQUIPMENTS REQUIRED

Rockwell hardness testing machine is used as the tip is Diamond cone and ball indentor. Specimens (Hardened steel, Mild steel, Brass, Copper, and Aluminium). Hardness of a material is commonly defined as Resistance to the permanent indentation under static and dynamic load. If the material is to be used under direct static or dynamic loading, only the indentation hardness test can be used to determine the indentation resistance. In this test indentor is forced into the surface of a test piece in two operations, measuring the permanent increase in depth of an indentation from the depth.

4.1 Specification

The Rockwell hardness tester displays the hardness number directly on the dial attached to the machine. The casted specimens may be cylinder, cube, thick or thin metallic sheets. The Ability to determine hardness upto = 100 RHN, Maximum application of load = 150 Kgf Method of load application, Lever type Least measuring hardness number= 1RHN.

4.2 Procedure

Keep loading and the unloading lever of the point A, which is unloading condition. Select the acceptable indentor & weights in keeping with the dimensions. Place the test sample on testing table anvil. Turn the hand wheel to lift the workpiece until it makes contact with indentor & continue turning till the longer pointer at the dial gauge makes 2 ½ rotations. Then it stops at zero continue turning slowly till the little pointer reaches the red spot at this is often automatic zero setting dial gauge. Turn the lever position A to B i.e. from unloading to loading position in order that the whole load will act. When the dial gauge of the longer pointer reaches steady position and move the lever to the unloading position A. [Avoid sudden release at the lever] Now note the reading within the last dial indicator by notifying the big pointer Turn back the hand wheel and takeaway the workpiece. Similarly repeat the step from 1-8 for various trials and for various metals.

4.3 Wear Testing

Wear is erosion displacements of material from its derivative and the original position on a solid surfaces carry out by the action of another surface. Wear of metals occurs by the plastic displacement of surface and near-surface material and by the detachment of particles that from wear debris. The generated particle size may vary from millimeter range up to an ion range.

The Wear test is done to find the wear performance and also to investigate the wear mechanism of the casted samples. Wear test is done by the pin-on-disc machine. Pin-on-disc wear testing is a commonly used technique for abrasive wear of the material. As the name implies that the apparatus consists of a "pin" is contact with the rotating disc. Either the pin may be flat, spherical or indeed if any convenient geometry, including that of actual wear components.

In the pin-on-disc test, the coefficient of friction is continuously studied as wear occurs, and the metal material removed is weighed by weighing and measuring the profile of the resulting wear track. The Changes in coefficient of friction are frequently indicative of a change in wear tests as equilibrium conditions become established. Figure 6 shows the pin-on-disc apparatus and the Figure 3 shows the wear test samples.

Figure 3. Wear Test Samples

5. EXPERIMENTATION

According to ASTM G99-95, the pin-disc testing machine is used to check the dry sliding wear properties of aluminum alloys and their compounds. The wear specimen size of 10 mm diameter and height of 30 mm was cut from cast samples, machined and then polished metallographically. The test was conducted with constant load at constant speed and time. All these tests were conducted at room temperature. The initial weight of the sample's measurements taken in a single pan electronic weighing apparatus with a least count of 0.0001 g, when the testing, pin was pressed against the counterpart rotating against EN32 steel disc with hardness 65HRC by applying the weight. An approximately strain-gauged friction detecting arm holds and loads the pin specimen vertically in to a rotating hardened steel disc. After the specified sliding distance has passed for the specified time, the sample is taken out, cleaned and weighed to determine the weight loss due to wear. The difference in weight measured before and after the test gives the wear the specimen. The wear rates were resolved to utilize the weight reduction strategy.

The wear value is obtained directly from the computerized wear testing machine. The graph gives the wear values. The coefficient of friction value can also be obtained from the graph. The most common method of calculating the coefficient of friction is from the normal load and frictional force. Normal force can be calculated from the load applied. The frictional force value is obtained directly from the graphs.

Coefficient of friction μ = frictional force/ normal force

6. RESULTS AND DISCUSSION

This Project deals mechanical properties of 6061 Aluminium Alloy. By Varying the Reinforcement weight percentage Boron Carbide (1%, 2%, and 3%).

6.1 Rockwell Hardness Test

Table -1: Rockwell Hardness Test Sample Result

S.No	SAMPLE 1	SAMPLE 2	SAMPLE 3
1.	49.8	60.7	80.6
2.	43.2	63.7	107
3.	43.5	56.7	69.4
4.	46.8	47.3	66.5
5.	36.3	64.6	65.8
RESULT	**43.92**	**58.6**	**77.86**

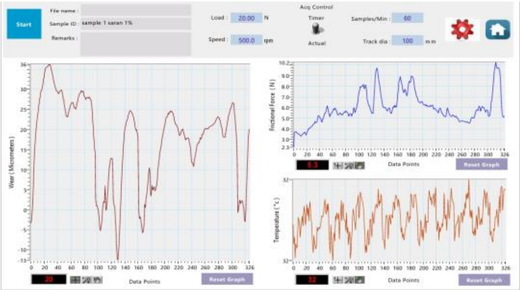
Through the investigation of the samples, sample 3 can obtained the maximum hardness of 77.86 RHN. Test result shows that by increasing the Boron carbide then the hardness also gradually increased.

6.2 Pin-On-Disc Reading

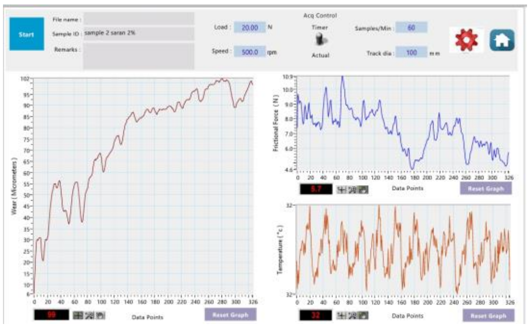
Table -2: Wear Test Sample Result

s.no	Reinforce (%)	Initial mass(gm)	Final mass(gm)	Wear rate(μ)	Friction force(N)
1	1	5.872	5.870	20	5.3
2	2	4.656	4.651	99	5.7
3	3	5.366	5.350	315	10.2

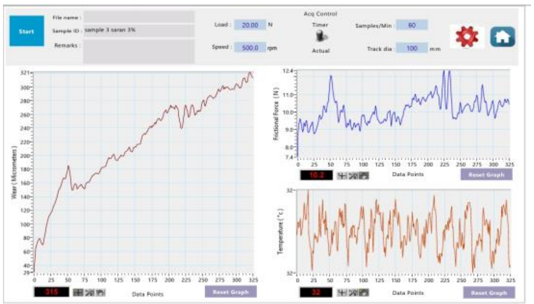
The load, speed and time is maintained as constant. The Load is 20N, the speed is 500rpm and time is 5 min. According to the wear test readings, the sample 2 has the moderate wear, the sample 3 has the highest wear rate.



a) Variation of wear rate sample 1



b) Variation of wear rate sample 2



c) Variation of wear rate sample 3

6.3 WEAR MORPHOLOGY

A morphological feature worm surface is an important quantitative aspect of wear surface analysis. The wear measurement depends on the tribiological properties of the gap. Image analysis technique with microscope is the best way to recognize the main causes of the particles generation. A figure shows the micrograph of the worn surface of the samples studied. It shows the presence of reinforcement particles over the worn surface which acts as a resistant to the materials wear figure 6 shows the micrograph of the worm surface sample 3 is shown.

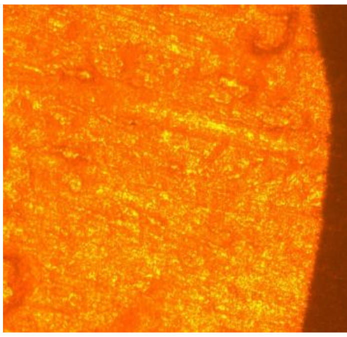


Figure -4: SAMPLE -1

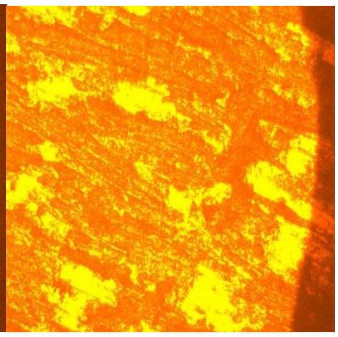


Figure -5: SAMPLE -2

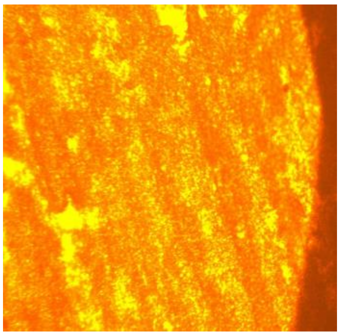


Figure -6: SAMPLE -3

7. CONCLUSIONS

The composite sample of Aluminium Alloy AA 6061 as matrix, Boron Carbide Particulates as reinforcement were fabricated using stir casting process. The mechanical properties such as hardness, wear test and microstructure were investigated from the fabricated samples. The microstructure analysis shows fairly even distribution of particles and some agglomeration of Boron Carbide. The composite exhibited superior wear resistance when compared with base aluminium AA 6061 matrix alloy and the wear resistance get increased. It is clear from the S/N ratio that Load is the most significant factor followed by speed and time. From the comparison charts we can have concluded that when the load increased the wear rate increases tremendously at low speed. And also the wear rate decreases with increases in the speed.

ACKNOWLEDGEMENT

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