Manufacturing of Aluminum Alloy 6061 Composite Material using Bagasse Ash- Working Paper

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ABSTRACT

Aluminium (Al) is existing in a very large quantity found in the earth's crust and third most abundant element. Al is easily available, it has a high strength to weight ratio and it is durable. Al alloy is light weight and corrosion resistant hence used in aircraft and automobile industries. Wear is loss of material from surfaces and the life of material decreases due to wear. Al 6061 has good mechanical properties, it exhibits good weldability and it has wear resistant properties. In the literature review, information about wear resistance properties of composites containing Al 6061 as a matrix is studied for different reinforcement materials for various applications. Very few researchers studied Al 6061 is a matrix material and bagasse ash as reinforced materials. In this paper, aluminum composite material manufacturing using the stir casting method is carried out for manufacturing because of flexibility, simplicity, and having mass production capability. The problem identification about improving the wear properties of Al 6061 matrix material reinforced bagasse ash has been explored and further, research objective and methodology for the same is discussed with flowcharts. The work carried still to date is reported in this working paper.

Keywords: literature review, stir casting, Aluminum 6061 alloy, stir casting, Bagasse ash

1 Introduction

Composite is mixture of two different materials, matrix material is bind the reinforcement and merge together to use the benefits of both materials. The Use of composite is increased now a days due to increasing industrial demand for high strength and low weight material. MMCs are replacing conventional materials because of their better physical and mechanical characteristics. Presently, AMC (Aluminium Matrix composite) is used in the Automobile, military, aerospace and electrical industries. The increase in usage of these materials for automotive and aerospace application is the success of these materials. Ultimately the property of discontinuously metal matrix composites increases due to enhancing the physical and mechanical properties.

In introduction section Al 6061 as a Matrix Material, Reinforcement, Wear behaviour of Al 6061 and different reinforcement is discussed.

1.1 Al 6061 as a Matrix Material

Metal matrix composites are mostly used materials to enhance mechanical properties like hardness yield strength and tensile strength etc. because of the presence of particulate reinforcement in the matrix. Aluminium matrix composites (Al + discontinuous reinforcement) are used in the Automobile, military, aerospace and electricity industries increases due to enhancing their physical and mechanical properties.

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Hasim et al. [1] has suggested stir casting method for manufacturing of Al6061 composite and challenges associated with it. Author also pointed that process parameters such as stir casting speed, impeller diameter and its positions impacts on improvement in mechanical properties. Apart from that process having advantages such as simplicity, cost effective, control of microstructure. Noguchi and Fukizawa [2] suggested AMC and others composite as alternative materials which will reduce weight, improve efficiency and reduce cost in automobiles and also used in various applications due to properties like high specific strength, stiffness, wear resistance and dimensional stability[3-5] and in specific Al6061 widely used because of having excellent formability and ability to modify the strength [6].

Table 1: *Chemical Composition of Al6061 alloy* [5]

Element	Wt. %
Cr	0.25
Ni	0.05
Sn	0.001
Pb	0.24
Cu	0.24
Mg	0.802
Zn	0.25
Fe	0.7
Mn	0.139
Si	0.43
Ti	0.15
Al	Balanced

Table 1 provides the Chemical Composition of Al6061 alloy. Now a day's industrial growth is at high so technology is also growing hence there is a need to find out new materials. To find out new materials particulate reinforced play a major role. On the other hand hybrid metal matrix composite term introduced in which materials reinforced by mixing of two or more different reinforcements to get the advantage of both. Researchers also show that AMC, reinforced with particulate used in automotive engines, pistons, bearing materials, wear is one of the most common term which affect the industry in terms of various component like bearing. In industry due to wear frequently components used to change, wear performance AMC is reported better than unreinforced matrix material [6-7].

1.2 Reinforcement

Reinforcement is done for enhancing the properties of the base material. Small particles of one material are introduced in another material. Particulate reinforcement is the same in all directions it is spherical, cubic, rectangular or irregular in shape. It is in micron or nano size. The main advantage of particulate reinforcement is available easily, is less in cost, having great wear resistance. In the present study there are Al_2O_3, fly ash, Bagasse ash, SiCp, TiCp, Garnet particles, Red mud, Rock dust, TiB_2 and some hybrid reinforcement are taken. Adding these reinforcement in Al 6061 enhance the properties of AMC.
Section 2 describes the Literature review followed by the research gap, Section 3 describes a methodology for the identified research objectives, Section 4 materials and manufacturing Al6061 matrix reinforced bagasse ash, Section 5 is about Conclusion and future work.

2 Literature Review

In the literature review, the wear behaviour of Al 6061 and different reinforcement is reported. These studies are classified based on the type of reinforcement used such as Silicon Carbide, Titanium Diboride, and Red Mud Reinforced, reinforced with hybrid composites. Also, different researchers varied reinforcement percentages and understand wear behaviour (abrasive, dry sliding, sliding) by wear test considering parameters load, sliding speed, time and data analysis for predicting wear behaviour using statistical methods is also reported in the literature.

2.1 Silicon Carbide Reinforced AMC

Ashok Kumar Mishra *et.al,* [7] Studied the effect of parameters such as applied load (10, 20, 30 N) and weight fraction of SiC (5-40%). Wear behaviour of composite tested on a pin on disc machine having sliding velocity 2 m/s and sliding distance 2000 m. wear is increasing as load and sliding velocity increases and the coefficient of friction decreases with increasing reinforcement. The best result got at 35% of reinforcement i.e. wear rate reduces. Y. Sachin [8] The Factorial design of the experiment was used to explain the abrasive wear behaviour of Al alloy and its composites and to create linear equations for wear rate prediction. It is apparent from equations and experiments that composite has greater wear resistance than base alloy. When the SiC abrasive paper was created, the applied load and sliding distance wear rate of both increased as the abrasive size increased. A 24 m sliding distance, a 20 N load, and a 17 mm abrasive size. Yogesh Kumar Singla *et.al,* [9] Dry sliding wear behaviour of Al 6061 with different reinforcement is tested. Wear test parameters are sliding distance (up to 3000 m) and applied load (20 N). Under applied load conditions two different types of wear behaviour were observed: a) wear rate increase initially then decreased by increasing sliding distance, it is because the initial stage of sliding composite is softer than the later stage. b) In this stage constant wear rate was observed. Manish Roy [10] Dry sliding wear test carried out on pin on disc wear machine. Parameters used for tests are loads and type of reinforcement as well as the size of reinforcement. The type and size of reinforcement have a negligible effect on the wear rate of composite (Al + SiC). The wear rate of composite material is lower than that of pure material. A Vencl et.al [11] In automobile industries mostly used material is Al-based alloy reinforced with SiC. This main focus is on the improvement of material and production cost as low as possible with better material properties. The use of Al in automotive industries is increasing because of reduced wear rate also high wear resistance comparing to traditional materials. Ashok Kr. Mishra *et.al,* [12] Taguchi method is used for planning of method, L9 orthogonal array used to analyse the data. ANOVA and regression are used for developing the response of 10% and 15% SiC reinforced in Al. In case 10% Sic AMC sliding distance is 62.2% has the highest wear rate, in the case of 15% AMC applied load 57.2% has the highest wear rate. L. Natrayan *et.al,* [13] At three distinct levels, fractional factorial experimentation was conducted out with four parameters: volume fraction of reinforcement, solutionizing time, ageing temperature, and ageing duration. The findings reveal that abrasive wear loss values were virtually identical to experimental results. In calculating volumetric wear loss, the volume percentage of reinforcing particles had a substantial impact.

2.2 Titanium Diboride Reinforced AMC

Ch. Mohana Rao *et.al,* [14] Abrasive wear behaviour of Al6061 composite performed on machine pin-on-disc. The parameter which they vary are temperature, reinforcement percentage, applied load, sliding speed. Wear rate increases in case of increasing reinforcement percentage reason behind that are improper mixing, clustering of reinforcement particle. Al/ TiB_2 10% shows better abrasive wear result than Al/TiB_2 5% and Al/ TiB_2 15%. S. Suresh *et.al,* [15] Dry sliding wear test obtained on a pin on disc wear machine. EN31 disc was rubbed against the composite sample, before testing pins and disc surface were cleaned with acetone.

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The test was done by varying the load (5, 10, 15 N) at a constant speed of 500 rpm with a sliding speed of 2.61 m/s and a sliding distance of 2000 mm. Study shows that the wear resistance of composites increases with increasing the reinforcement percentage also coefficient increase with increasing the load. S. Suresh *et.al,* [16] Sliding Wear test is done on the pin on disc wear, dry sliding wear test was carried out under different parameters like load (5, 10, 15 N) at constant speed 500 rpm, sliding speed of 2.61 m/s weight percentage of TiB_2 (0%, 2%, 4%, 6%, 8%, and 10%), sliding distance (2000 m). A regression model is developed also Response surface methodology is used for developing mathematical model also to minimize the experimental condition. Analysis of variance is used for checking the accuracy of the mathematical model. RSM is used for analysing the experimental result. Specific wear rate is calculated by using the final model, forgetting the final model all the coefficients test under a confidence level of 99.5%. Findings: a) wear resistance of Al 6061 decrease with an increasing percentage of reinforcement TiB_2 b) second-order polynomial regression equation is developed using response, also RSM box Behnken design method is successively used to develop the model. A. Sreenivasan *et.al,* [17] composite (Al + TiB_2) slide against EN24 steel on the pin on disc machine. Parameters used for the study are load and speed. Effect of load on composite as load increase wear rate is decreasing on another hand as reinforcement percentage increases wear rate increases. In this case of sliding speed, at the initial stage wear rate increase as speed increases after that it decreases with increasing speed. Manish Roy *et.al,* [18] Dry sliding wear test carried out on pin on disc wear machine. Parameters used for tests are loads and type of reinforcement as well as the size of reinforcement. The type and size of reinforcement have a negligible effect on the wear rate of composite (Al + TiB_2). The wear rate of composite material is lower than that of pure material. S. Suresh *et.al,* [19] wear rate is observed at a load of 5, 10 & 15N for AA 6061 & 0,3,6,9 & 12% of TiB_2 composite. Wear resistance is increases with an increasing percentage of TiB_2 reinforcement. Under low applied load, a low wear rate exists and it is because of the regime. At high loading, condition wear is also high. The wear of AA 6061 is higher than the AMC. Suresh Suresh *et.al,* [20] Parameters used for load, percentage of reinforcement, sliding speed and sliding distance. During the test sliding speed of 2.61 m/s and the sliding distance of 2000 mm are kept constant. The wear rate increases with increasing load, at 10N wear, is moderate and at 15N wear is high. Wear rate is minimum in case of high reinforcement percentage this is because of the hard nature of the reinforcement.

2.3 Red Mud Reinforced AMC

Selvam. M *et.al,* [21] At minimum applied load on AMC, maximum 20% red mud reinforced for getting a better result. For maximum load application, 10% red mud is reinforced to get better wear resistance. The wear resistance of reinforced material is better compared to unreinforced material. Yogesh Kumar Singla *et.al,* [22] Parameters choose for experiments are load, sliding speed and sliding distance. Among three parameters two-parameter make constant which are load 20 N, sliding speed 1.6 m/s. The result of Al composite is better than base Al alloy in comparison to microhardness. Wear resistance improves with the addition of red mud in Al. wear rate decreased with increasing particulate weight from 2.5-7.5%, also beyond 7.5% wear rate increases because of poor interfacial bonding. Gangadharappa M *et.al,* [23] wear rate decreases with increasing velocity. Taguchi method used to conduct the experiments also ANOVA is used for the significance of factors. According to results, among all four factors (% wt.), sliding distance, sliding velocity, and load) load is the most significant factor. Narender Panwar *et.al,* [24] Red mud is used as reinforcements in composite material. Mechanical as well as tribological properties of Al are improved by introducing red mud in it. AMC is used in marine components, camera lenses, Electrical parts and equipment, fittings, aircraft industry, bicycle industry, driveshafts, Brakes etc. Red mud is a waste product and hazardous to the environment also so it can be utilized in composite, due to this it can be disposed of.

2.4 AA6061 reinforced with hybrid composites:

K. Umanath *et.al,* [25] Al 6061 reinforced with hybrid reinforcement (SiC & Al_2O_3). Wear test is carried out on pin on disc machine, from test it is clear that 15% reinforcement has better wear resistance. RSM is used to estimate imperical relation, also the regression equation is developed for calculating the wear. Analysis of variance is used for checking the accuracy of the mathematical model. The mathematical model is giving the relation between wear and influencing parameters. Influencing parameters are volume fraction, applied Load, rotational speed. Findings: a) In this case of reinforcement if reinforcement volume fraction is less than 5% then the wear of composite is equal to the wear of unreinforced material. b) In the case of rotational speed, less than 200 rpm wear rate is negligible. If the rotational speed is more than 400 rpm then wear occurred. C) If the applied load is more than 58.86 N then wear occurred. Mahagundappa M. Bena *et.al,* [3] Investigated Al 6061- hybrid reinforcement makes composite by stir casting method. Preheat the reinforcement at 300 0C. Wear test carried out in the pin-on-disc machine by rubbing hybrid composite against C-Cr steel. Tested composite artificially aged at T61h, T63h, T65h, and T67h. Before wear test samples polished 400, 600 800 1000 emery grit paper. Sliding distance from 500- 1500 m, sliding velocity 1.832 m/s, load 20N, humidity 30%. Increasing in reinforcement percentage wear rate decreases and 1h aged hybrid composite has low resistance on the other hand maximum wear resistance is found in 5h aged composite. Viney Kumar *et.al,* [26] has manufacture a hybrid metal matrix composite consist of fly ash (10-20 wt. %) and graphite fixed weight 4% reinforced with Al alloy 6061.. A dry sliding velocity test was done on a pin-on-disc wear machine. The sample size for testing was ø10×35mm and samples were polished with abrasive paper and the rotating disc was EN31 against composite samples. The load applied for the test is 30N and r.p.m. is 1000, 1500, 2000. Findings (a) specific wear rate decreases with increasing the percentage of fly ash but up to 15%. (b) Specific wear rate increases with the addition of 4% graphite with fly ash but it makes machining smooth. (c) As rpm increases, a specific wear rate also increases by 20% fly ash and 4% graphite. (d) At 1500 rpm specific wear rate decreases in the case of 10% fly ash and 4% graphite, 15% fly ash, and 4% graphite. Shankar Subramanian *et.al,* [27] The stir casting process was used to create an Al-Si10-Mg alloy strengthened with 9wt% treated sugarcane bagasse ash. Wear test carried out on pin on disc wear machine, parameters used are load, sliding speed and time which is kept constant 20 min. minimum wear rate observed in (Al-Si10-Mg+9% SiC+9% SBA) with 10 N load.

Based on the findings of the literature review, it is reasonable to conclude that reinforcing the reinforcement improves the parent material's physical and mechanical qualities. When compared to unreinforced alloy, AMCs offer greater strength, wear resistance, and weight savings. Reinforcement like SiC, Al_2O_3, and fly ash-based composites have received more attention than bagasse ash. Wear is a common industrial problem in which the material is primarily influenced by speed and environmental factors. Optimization of the parameters like stirring time, temperature, mould heating etc. are needed in the case of the stir casting technique.

3 Research Objective and Methodology

Based on detailed literature review following research objectives for further study purpose

1) To study the effect of various parameters on the wear of the material.
2) To study the wear behaviour of particulate reinforced composite material.
3) To manufactured bagasse ash reinforced aluminium alloy 6061 matrix composite.
4) To study the wear characteristics of manufactured composite by varying parameters.
5) To generate regression equation for wear behaviour of bagasse ash reinforced aluminium alloy 6061 matrix composite.
6) To use response surface methodology for prediction of wear behaviour of aluminium alloy 6061.

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To achieve the research objectives methodology as shown in figure 1.

The project's initial stage is to melt the aluminium alloy 6061 until it becomes liquid. Because we're constructing a composite material, reinforcement must be added to the basic material, which is 6061 aluminium alloy. Let 30 minutes for the reinforcement to heat up. Stir the mixture at 250 rpm for 5 to 10 minutes after introducing reinforcement. The liquid is injected into the mould, after cooling the liquid form of aluminium is transformed into the rod. Following the fabrication of the composite, the machining procedure should be completed. Then, different tests will be done on composite materials. In case of composite wear testing, the pin on disc wear apparatus will be used. On the basis of wear results, a regression equation will generate for explaining the effect of independent on dependent parameters. Response surface method will be used for prediction of wear behaviour of manufactured composite. ANOVA statistical analysis can be used to further validating the model. The methodology and process of manufacturing composite is shown in figure 1.

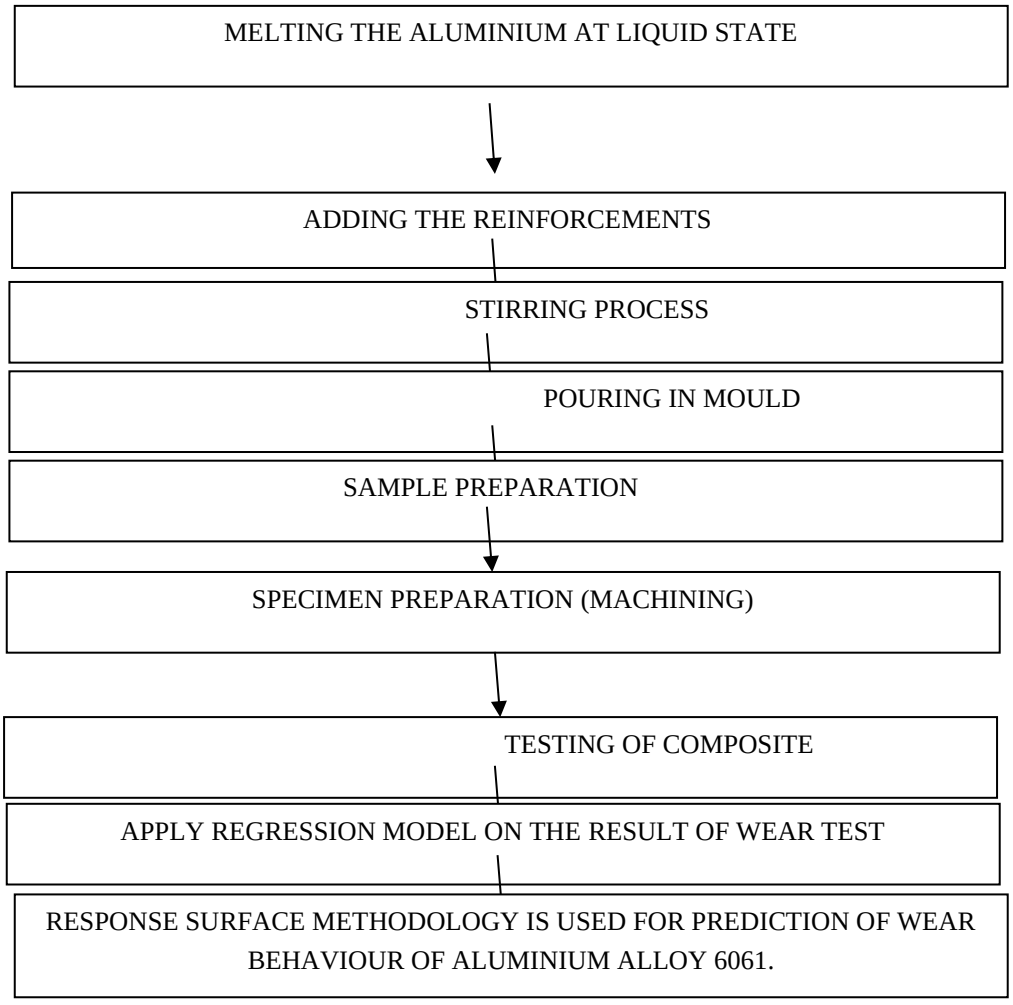

Figure 1 *Methodology*

In this work, bagasse ash as reinforcement the ash comes from the sugar sector, where sugar cane is burned to create electricity for the processing machinery. The purpose of using ash because its availability in very large quantity, cost of bagasse ash is low, by utilizing as reinforcement reduce the generation of greenhouse gases it also improves maintainability, coefficient of friction.

4 Manufacturing of material

The initial stage in manufacturing is to clean and weigh the aluminium alloy 6061 to remove any dust. Then the clean the crucible and put it into the furnace. The crucible of an induction furnace is made of cast iron, and a temperature controller, which is actually a thermocouple, is linked to it, which senses the temperature of the furnace by inserting a sensor into it. The induction furnace is shown in Figure 2

Figure 2 *Induction furnace*

Because the aluminium material was uneven in size, it was chopped into smaller pieces and weighed before being put into a crucible. As the temperature of the furnace increased aluminium starts melting and at 650 – 750 0C it converted into a liquid state. Further, In order to eliminate pollutants from liquid, scum powder is added. Different kinds of gases fill the crucible throughout the stir casting process, necessitating the injection of hexachloroethane to eliminate them. After that, the addition of magnesium improves the wettability of the mixture. However, increasing the amount over 1 wt. percent causes the slurry to become viscous, making uniform particle dispersion problematic. At last, the bagasse ash, which acts as a reinforcing agent, is heated for 30 minutes before being progressively added to the sample. While doing this, for 5-10 minutes, the liquid is stirred with a stirrer at 250 RPM. Because of the stirring, a vortex is produced in the liquid and homogeneous distribution of bagasse ash takes place. The setup of stir casting is shown in figure 3 below.

Figure 3 *Stir casting set up*

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Then the all mixture is poured into the mould without wasting a time so that the reinforcing agent doesn't situate at the bottom of the furnace. Before that, the mould is heated for 60 minutes to maintain the temperature of the liquid and the mould, as well as to ensure that no gases are trapped inside. To avoid casting flaws, maintain a consistent spacing between the crucible and the mould. Following the stirring, the melted composite is poured into a warmed metal mould to create rod specimens. Figure 4 shows rod formed after casting was made in a circular mould having a diameter of 20 mm and a length of 320 mm.

Figure 4 *Rod formed after casting*

In current work aluminium alloy 6061 is used as a matrix material reinforcement used is 0, 1, 2, 3, 4 wt. % of bagasse ash.

5 Conclusion and Future work

The following conclusions have been drawn with the assistance of the current work.

The stir casting method is used for manufacturing of Al alloy 6061 matrix composite. In comparison to other processes, stir casting is easy and inexpensive, and the cost is further lowered by employing mass manufacturing. From the literature review, the wear property of the base material is enhanced by the addition of different reinforcement materials. The effect of the different parameters during experiments like applied, sliding velocity and distances, reinforcement percentage etc. explained. The use of red mud, fly ash, and bagasse ash as reinforcing materials will consume a waste product that would otherwise generate recycling issues and environmental risks.

A test should be carried out on manufactured composite material are as follows:

1. Tensile test: The greatest stress that a material can bear while being stretched or pushed before breaking is known as tensile strength.
2. Compression test: Some materials fracture at their compressive strength limit; while others deform permanently, so a given amount of deformation may be considered as the limit for a compressive load. Compressive strength is an important factor to consider while the design of structures.
3. Wear test: Wear testing can help you evaluate materials and predict how long your product will last.
4. Microstructure test: In order to analyze the microstructure of a metal alloy, a microstructure test is conducted. The microstructure of material provides for the assessment of supply and the possibility of faults.

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