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Investigation on wear properties of Aluminum reinforced with ZrO_2 and Rice Husk Ash

[1]S Hari Chealvan[*], [2]V Krishnaraj, [3]K Anand, [4]R Naveen Anthuvan

[1,2,3,4] Faculty, Department of Production Engineering, PSG College of Technology, Coimbatore - 641004
[*] shc.prod@psgtech.ac.in

Abstract

Al 6061 is one of the most important light weight material used in industries. But its application is limited due to its restriction in mechanical properties like hardness and yield strength. The main problem existing in the industries is to develop components of less weight with good mechanical characteristics. So, an Metal Matrix hybrid composite was developed with Aluminium 6061 using Zirconium dioxide and rich husk ash as the reinforcements through stir casting method. These were added in the proportions to the weight% of 1%, 2%, 3% and 4% respectively. To evaluate the wear properties the obtained casting component was machined to get the standard pins of diameter 10 mm and the wear test was performed. The result shows that decrease in wear rate is achieved without affecting the density of the material.

INTRODUCTION

High strength to weight ratio of Aluminum alloys makes it suitable for various applications like automobile, pneumatic cylinders, pistons etc. Though it has good properties it has its drawbacks in wear characteristics. Thus by enhancing its wear properties it could use widely in many applications. So due to the demand for improving wear properties in aluminum, an Aluminum composite with a suitable reinforcement should be made. A composite material is made up of two or more separate constituents. The material with higher weight proportion is called as the matrix and acts as a base material in which the less weight proportion material is added. The material with less weight proportion is called as the reinforcement. The matrix and the reinforcements are physically and chemically distinct with in the final material. The properties of the composites are superior when compared to its constituents. When there are three materials in the composite then it is called as a hybrid composite.

Hybrid composite contains more than one reinforcements in a single matrix material in order to obtain desired properties. Hybrid composites are one of the low cost methods to attain the required material properties with additional unique features. Some of the advantages are balanced strength and stiffness, reduced weight and cost, improved fracture toughness and improved wear resistance. Manufacturing industries are struggling nowadays to produce parts that are of less weight at the same time possess good mechanical properties such as hardness, tensile strength etc. in order to overcome this problem two different materials are combined to achieve the requirement.

Manivannan et al[1], investigated the heat transfer rate of aluminium metal matrix composite with micro sized cubic boron nitride manufactured using bottom tapping stir casting method. Magnesium was used upto 2% as the wetting agent to ensure the uniform dispersion of CBN in the composite. The result shows the significant enhancement in heat transfer rate due to the addition of CBN particles in Aluminium alloy (AA6061 T6). Ramachandra et al[2], stated that hardness and wear resistance was improved by the incorporation of Nano ZrO_2 particles in the aluminium matrix making it suitable for automotive applications such as pistons, cylinder liners and connecting rods. Using urea as the fuel, nano Zirconium dioxide particles (n-ZrO_2) are reinforced into the aluminium matrix in different percentages by weight using powder metallurgy technique. Wear test using pin on disc apparatus and micro structural study on sintered specimens reveals the uniform distribution of n-ZrO_2 particles with slight agglomeration and good interfacial bond between matrix and n-ZrO_2 particles.

Patoliya et al [3], investigates the Zirconium Dioxide Reinforced Aluminium (AL6061 Alloy) Metal Matrix Composites developed by varying weight fraction of the reinforced particles as 0wt. %, 2.5wt. %, 5wt. % and 7.5wt. % by keeping all the other parameters constant. The mechanical properties like hardness, tensile strength were improved with the increase in weight fraction of zirconium dioxide particles in the aluminium matrix. Koli [4], stated that superior mechanical and physical properties are provided by Al_2O_3 reinforcements resulting in Aluminium metal matrix composites. Reinforcing submicron or nano particles plays the major role in providing composites with high performance and superior mechanical properties. Utilization of high energy ball milling gives out high class blending of Al with Al_2O_3. It improves the hardness by 92% and tensile strength by 57%. Reddy et al[5], investigated the mechanical properties of Aluminium hybrid composite reinforced with SiC and fly ash using stir casting. Use of fly ash as secondary reinforcement is to reduce the weight of the composite since the density of SiC is greater than aluminium. It also increases strength, hardness and compressive strength. The results showed that as the percentage of reinforcement's increases hardness, wear resistance and tensile strength also increases. Suryakumari et al[6], investigated the mechanical properties of hybrid MMC fabricated using the stir casting method and heat treating to T6 condition. High impact strength, fine grained microstructure and high microhardness was obtained under various microstructural and impact tests carried out for combination of 2.5% Al_2O_3 and 5% SiC.

Rasidhar et al[7], stated that aluminium matrix composites were fabricated using Stir casting technique. Ilmenite nano particles were synthesized using ball milling process. Weight percentage of (1%, 2%, 3%, 4%, and 5%) Ilmenite was added to the composite in the form of powders at 750°C in the form of packets formed using aluminium foils. Even and fine distribution of nano particles was confirmed under SEM analysis study. Also superior properties were achieved on hardness and tensile strength without compromising the ductility and nature of matrix material. Kumar et al [8], investigated the effect of adding fly ash and graphite with aluminium under different conditions and stated the effect of rpm on wear properties and comparison of mechanical properties. Sieved fly ash up to 100µm and Graphite powder with a particle size less than 50 µm was used. With upto 15% addition of fly ash, the tensile strength increases and further addition reduces the former. Addition of graphite smoothened the machining but decreases the specific wear rate. Karthikeyan et al.[9] analyzes the LM25/ZrO_2 composite material casted using stir casting method. Aluminium (LM25) alloy was chosen as a base matrix metal. 0, 3, 6, 9, and 12% weight fraction of Zirconium dioxide (ZrO_2) particulates are reinforced with the base metal. The tensile, hardness, compression and impact strength and weldability increases with increase in the percentage of ZrO_2 in LM25 alloy. Mohammed Usman et al.[10], investigated the effect and properties of using high silica content Rice husk ash as matrix for aluminium reinforcement by varying 5% interval volume from 0 to 30%. The result shows the decrease in density of composite with increase in reinforcement making it suitable for high class automobile applications.

Hence from the literatures, it is found that investigation on aluminium reinforced with zirconium dioxide and rice husk ash was done separately for the achieving the required properties. Hence the present work focuses on the development of hybrid composite of aluminium reinforced with zirconium dioxide and rice husk ash for the improvement of properties.

METHODOLOGY

The methodology shown in Figure 1 is followed to identify the wear property of the composite.

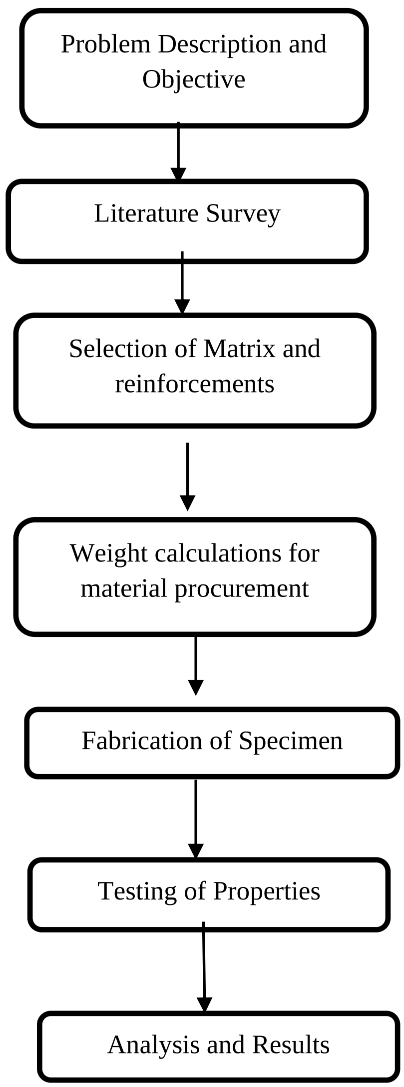

Fig. 1 Methodology

Materials and Methods

Aluminium 6061

Aluminium 6061 is the most widely used aluminium alloy, the material was selected for the work. It can be used for producing heat treatable alloys from medium to high strength capabilities. Al 6061 rods are shown in the figure 2. Al 6061 has its applications in many automotive and marine sectors. The chemical composition of Al 6061 is shown in the Table 1.

Table 1 Chemical composition of Al 6061[10]

Element	**Weight %**
Aluminum	95.8 - 98.6
Chromium	0.04 - 0.35
Copper	0.15 - 0.4
Iron	Max 0.7
Magnesium	0.8 - 1.2
Manganese	Max 0.15
Silicon	0.4 - 0.8
Titanium	Max 0.15
Zinc	Max 0.25

Fig. 2 Aluminium 6061

Zirconium Dioxide

From the literature survey it was found that on adding zirconium dioxide to Al 6061 the wear properties, tensile properties and hardness increased. As the hardness is increased the level of ductility eventually reduced. When zirconium dioxide was added the density of the composite was more than that of Al 6061.

Rice Husk Ash

Rice husk ash is the second reinforcement for the fabrication of hybrid composite. It is identified from the literature survey that on adding rice husk ash the wear properties, tensile properties and hardness increases. When rice husk ash was reinforced with Al 6061 it was found that the density of the composite was less than that of Al 6061. Rice husk ash was shown in the Figure 2.

Fig. 3 Rice Husk

Experimentation and Testing

Weight calculation

Diameter of die used= 30mm

Height of the die= 260mm

$V=\pi r^2 h$

$= \pi (15)^2 260$

= 0.0001838 cubic meter

Then, mass of the material (Aluminium 6061) can be filled =density* volume

Density of Aluminium 6061 is 2700 kg/m^3

Mass of the aluminium= 0.496 kg

The amount of matrix and reinforcement used for the process is shown in the Table 2.

Table 2 Composition table

% by weight each	Aluminium (gm)	Zirconium dioxide (gm)	Rice Husk Ash (gm)
1%	490	5	5
2%	480	10	10
3%	470	15	15
4%	460	20	20
Total weight	1900	50	50

Reinforcement pretreatment

Preparation of Rice Husk Ash (RHA)

Rice husk Ash particulates were first thoroughly washed with water to remove the dust and then dried in room temperature for 24hrs. It was then heated to the temperature of 200° C for one hour to obtain moisture free product. Again it was heated to 600°C for about twelve hours to remove the carbonaceous matter.

This process will change the colour of the rice husk ash from black to grayish white. The silica rich ash, thus obtained was used as the reinforcement material in the preparation of composite. The rice husk ash was prepared using the furnace shown in Figure 4.

Fig. 4 Pretreatment of Rice husk

Preheating of reinforcement

Rice husk ash and zirconium dioxide is mixed and preheated in the oven at a temperature of 500°C for 30 minutes. The same procedure is repeated for all other compositions. The preheating of reinforcement is done for mainly two reasons one is to remove the moisture content in it and other reason is to make compatible with the molten aluminium. So care must be taken while selecting the preheating temperature. The preheating of the mixture was placed as shown in the Figure 5.

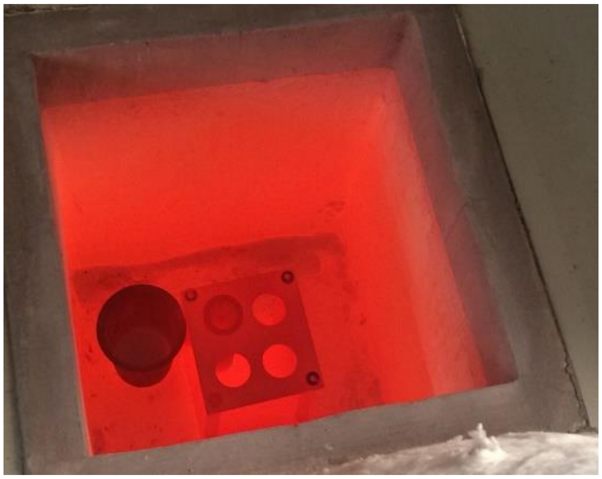

Fig. 5 Preheating of mixture (RHA and ZrO2)

Stir casting

Fig. 6 Stir casting setup

Aluminium bars are cut to get the required weight to be placed inside the furnace. After the aluminium is melted inside the furnace, reinforcement is added in to the furnace with the help of silver container using tongs in the gradual manner.

Fig. 7 Stir casted rod

In order to increase the homogeneity stirring is used. Effective stirring action is based on the stirrer profile, stirring speed and stirring time. At the first trail reinforcement of 1% combination is added without preheating and casting is made by the mould. Here, most of the reinforcement particles are obtained as the slag. This shows the wettability between the reinforcement and matrix is poor. In order to increase that property reinforcement is preheated and then added. The stir casting setup is shown in the figure 6. Stir casted hybrid composite rod was shown in the figure 7.

Wear Testing

Another parameter of interest is wear rate of the materials. Wear rate is found by using pin on disc apparatus. The parameters of pin on disc are the weight loaded, speed and the distance travelled. The wear testing setup on the pin on disc tester is shown in the figure 8.

Fig. 8 Pin on Disk Apparatus

Fig. 9 Pin for wear test

The pin for wear test is shown in the figure 9. The disc was polished using the emery sheet before the process was started. The pin was placed between the fixed and the movable dies and was tightened using the Allen screws. It is to be ensured that the pin touches the disc properly. The parameters loaded before the experiments are as follows: 3 Kg of load is applied with the sliding velocity as 3 m/s. The speed for testing is 573 rpm and the sliding time of 16minutes 40 seconds was set and the process was carried out. The wear rate is calculated by taking weight of the specimen before and after the wear test. From the change in weight the percentage of wear is calculated. The wear test was done for all the four specimens and the process was carried out for all the specimens without changing the parameters.

Results and Discussions

Density

The Diameter of the pin used is as follows: Diameter=10mm and Height=30mm.
The density calculations were done with the weights measured for wear test

1. For pure Al 6061, Density= 6.2126/ ($3.14*5^2*30$) =0.00264 grams/cc
2. For 1%, Density= 6.2074/ ($3.14*5^2*30$) =0.00264 grams/cc
3. For 2%, Density=6.1938/ ($3.14*5^2*30$) =0.00263 grams/cc
4. For 3%, Density=6.1781/ ($3.14*5^2*30$) =0.00260 grams/cc
5. For 4%, Density=6.0731/ ($3.14*5^2*30$) =0.00257 grams/cc

From the above density calculations it is clearly seen that on adding the reinforcements there isn't much change in the density values. From the previous studies it was found that on adding zirconium dioxide, the density was more than that of pure aluminium and on adding rice husk ash, the density was less than that of pure aluminium. Thus we can conclude that density has not increased than the pure aluminium and addition of rice husk ash along with zirconium dioxide will prevent it from increasing the overall density of aluminium resulting in a composite with light weight.

Wear

The wear test was carried out and the following readings were obtained. The readings are tabulated as shown in the Table 3

Table 3 Wear percentage

Material	Weight before wear (g)	Weight after wear (g)	Percentage wear (%)
Pure Al 6061	6.2126	6.2015	0.111
1%	6.2074	6.2037	0.059
2%	6.1938	6.1912	0.041
3%	6.1781	6.1765	0.025
4%	6.0731	6.0722	0.014

The result shows that with the increase in wt % of reinforcement the percentage of wear keeps reducing. Hence it can be concluded that increasing the percentage of reinforcement will increase the wear resistance of the material.

Addition of reinforcement

The reinforcements mixing were made proper by preheating it and then they were mixed in little quantities for each stir. While mixing the reinforcements with aluminium matrix the following observations were made

1. For 1% of reinforcement each there was a thorough mix-up and there weren't any slag in the form of powder rather there was material slag.
2. For 2% of reinforcement each there was a better mix-up and there were only little quantities of powder and material slag
3. For 3% of reinforcement each there was a good mix-up but there were a handful of powder and material slag
4. For 4% of reinforcement each there was a good mix-up but had more quantities of powder and material slag

From the above observations we can clearly find that on adding more reinforcements the mixing was not good and impurities were out as slag.

Conclusion

Aluminium metal matrix hybrid composite reinforced with zirconium dioxide and rice husk ash was fabricated using stir casting. The composite was fabricated for four different weight percentages for mechanical and micro structural study. The results of density calculations showed that with addition of rice husk ash with zirconium dioxide prevented the increase of density of aluminium composite. The results from wear test showed that wear resistance increases with increase in weight percentage of reinforcements. But during the fabrication of composites it was seen that at higher weight percentage the amount of slag formed also increased. Hence it can be concluded that zirconium dioxide with rice husk ash can be used for application where there is less weight as well as high wear resistance is required.

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