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A study of dry sliding wear behaviour of Al6061-Al_2O_3 Nano Composites

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ABSTRACT

In the present work, the main consideration is made on the mass and strength of the mechanical engineering components. Nano composites materials have high potential for use in structural applications in which improved mechanical properties are very essential. The aluminum matrix nanocomposites are finding wider applications in the various fields of engineering and medicines like aerospace, defense, automobiles, electronics, materials, chemistry, energy, environment, information & communication, consumer goods and bio-technology. Aluminum is most suitable alternative for these purposes. In this research work, aluminum as the metal matrix composites and Al_2O_3 nano-particles as reinforcement with different weight %age as 1.0, 1.5, 2.0, 2.5, 3.0 were used and prepared by Ultrasonic assisted stir casting process. Wear behavior of prepared specimens were thoroughly studied with different type of operating parameters. In this research, the operating parameters considered are applied load, coefficient of friction and sliding velocity. The experimental results indicate that the reinforcement material Al_2O_3 present in aluminum alloy composites lowers the friction and wear rate.

Keywords – Al_2O_3 Nanoparticle, Dry Sliding, Nano Composites, Wear, Wear rate.

1. INTRODUCTION

Composite materials are engineered or naturally occurring materials made from two or more component materials with significantly dissimilar physical or chemical properties which remain separate and distinct within the finished structure. A common example of composites would be disc brake pads, which consist of hard ceramic particles embedded in soft metal matrix and are also generally used in automobiles. The most advanced examples used regularly on spacecraft body structure. Composites in day-to-day life simply refers to its application and essentiality in our life it plays a vital role in that, for example wood, bones, reinforced concrete cement, GFRP etc. Lots of object in our routine are mostly composed of composites.

1.1. Mechanism of wear

Wear can occur through five main mechanics, Adhesive wear, Abrasive wear, third body wear, fatigue wear and corrosion wear. Adhesive wear occurs when the atomic forces occurring between the materials in two surfaces under relative load are stronger than the inherent material. properties of either surface. Abrasive wear occurs between surfaces of different relative hardness. These results in the softer material being removed from the motion of harder surface. Third body wear is a form of abrasive wear that occur when hard particles becomes embedded in abrasive wear remove material in its path.

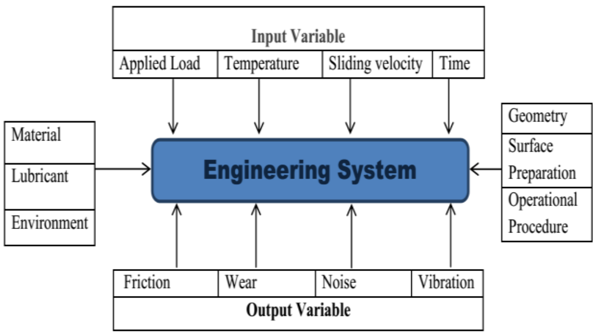

Fig.1 Input and Output of an Engineering System.

2. LITERATURE REVIEW

Number of research on wear behaviour and mechanical properties of composites material has been reported. Researchers used different type of matrix (example- Al6061, Al2024, Al356, Al6063, Al6082, Al6061-Mg-Si, Al-Zn, Al-Zn-Cu etc.) with different type of reinforcement (example- Al2O3, SiC, CeO2, TIC, Si3N4, silica sand, MgO, and B4N etc.) In most of the research work, the reinforcement particle size varies (example-7µm, 5-30 µm 60 µm, 63 µm, 90 µm, and nanometer range 400 nm, 200nm). Also, composites wear fabricated by different technique (example- powder metallurgy, stir casting, sintering, friction stir processing and liquid metallurgy route etc.). Some of researchers fabricated nano Al alloy (Yung-Chang et al, Ali Mazahery, G. B. Veeresh Kumar et al, and Mohsen Ostadshabani) have tested varies properties like hardness, tensile behaviour, compressive strength, and wear rate. The nano composites can only be fabricated by ultrasonic assisted stir casting process for better mixing of nano particles in aluminium matrix. Some researchers developed an Aluminium nano Al2O3 composite up to (Al7075 alloy with 1-2 weight percentages of Al_2O_3). None of work is reported for the wear analyses of Al6061alloy with composites up to 3.0 weight percentages.

3. EXPERIMENTAL PROCEDURE

Aluminum based MMC prepared by Ultrasonic Assisted Stir Casting Route. An ultrasonic assisted stir casting arrangement is shown in figure 3.1 which consists of a resistance Muffle Furnace, stirrer assembly and probe assembly to manufacture the composite. The stirrer assembly consists of a stirrer which was connected to a variable speed vertical drilling machine with range of 80 to 900 rpm by means of a steel shaft at the end of which the stirring blade is attached.

The stirrer was made by cutting and shaping a desired shape and size manually. The stirrer consists of a four blades at an angle of 900 apart. Clay graphite crucible of 2 kg capacity was placed inside the furnace. Approximately 1.1 Kg of alloy in solid form was melted at 800oC in the resistance furnace. Preheating of reinforcement (alumina at 350oC) was done by using muffle furnace. It was used for one hour to remove moisture and gases from the surface of the particulates and to avoid high drop of temperature after addition of particulates.

Stirring is initiated to homogenize the temperature & then adding the reinforcement into molten alloy.

At every stage before and after addition of reinforcement particles, mechanical stirring is carried out for a period of 12 minutes. The stirrer is located approximately to a depth of 2/3 height of the molten metal from the bottom and rotate at a speed of 200 rpm. The speed of the stirrer is gradually raised to 800 rpm and then the preheated reinforcement particles were added into the melt. After the addition of reinforcement, stirring is continued for 15 to 20 minutes for proper mixing of the prepared particles in the matrix.

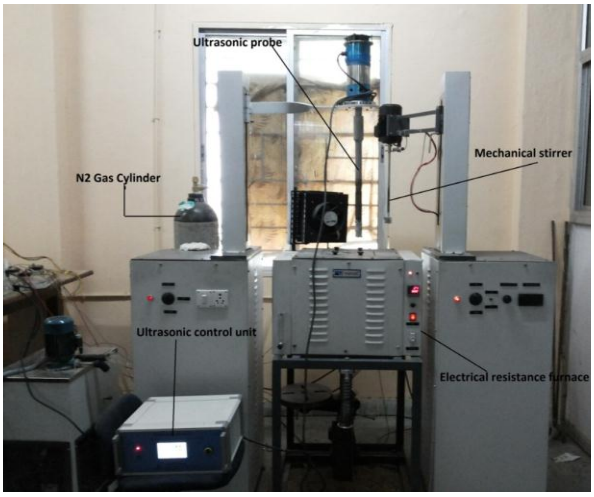

Fig.2 Ultrasonic assisted Stir Casting set up

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After this the stirer is replaced by an ultrasonic probe for the uniform distribution of nano particulates in the matrix. Before the system boot work, must make sure the horn is preheated to higher than 500˚C, the system frequency of 20.40 KHz about. The melt was kept in the crucible for approximate half minute in static condition and then it was poured in the mould. After completion of the previous procedure poured the molten metal into the die cavity.

4. RESULTS AND DISCUSSION

4.1 Density Measurement

The theoretical and experimental densities of the Al-Al_2O_3 composites were measured. Theoretical densities were obtained by rule of mixture and experimental density values obtained for the different weight% of reinforcements.

The experimental densities of Al_2O_3 have been measured by Archimedes technique. Porosities were calculated by the difference between theoretical density and experimental density. It was seen that porosity increases with increasing weight percent of Al_2O_3. This is due to the effect of low wettability and agglomeration of Al_2O_3 nano particles with high weight percentage of reinforcements. Moreover, decreasing liquid metal flow associated with the particle clusters leads to the formation of porosity.

Fig. 3 Pin-on-disc type wear testing machine

4.2 Wear Test

The wear test of the composites and unreinforced specimens under dry sliding condition. Samples from both Al 6061 alloy and the composites containing 1, 1.5, 2, 2.5, 3, weight % Al_2O_3 were prepared for the wear tests. To perform the experiment the samples were first polished, using surface polishing machine, at the end, using 1200 and 1500 grit emery paper. A pin-on-disc wear testing machine was used to perform the wear test as shown in figure 4.2. The pins were loaded against the disc by a dead weight loading system by 1:1ratio. Dry sliding wear tests were carried out using a computerized Pin-on-Disc wear testing apparatus (Model: TR20-LE) as shown in Fig. 4.2. The dry wear tests were performed at a fixed sliding distance of 1500 m and wear track diameter 100 mm for all samples. The wear rate of test specimens in mm3/m obtained from the weight loss of the specimens during sliding is plotted against sliding velocity. Al alloy were carried out under dry sliding condition under for four different applied loads of 10N, 20N, 30N and 40N.Sliding speeds (1.6, 2.5, and 4.5 m/s) were varied to study effects of particles concentration on the wear.

The wear test results of the Al6061 composites and unreinforced specimens under dry sliding. The wear rate of test specimens in mm3/m obtained from the height loss of the specimens during sliding is plotted against sliding distance in Fig. for four different applied loads: 10, 20, 30 and 40N.

Wear Rate of Composites calculated, by using following formula

- Weight Loss = Initial weight- Final weight
- Volume Loss= Weight Loss / Density
- Wear Rate = Volume Loss / Sliding Distance
- Coefficient of Friction (µ) = Average Friction Force/Applied Load = Ff / Fn

4.2.1. Variation of Wear rate with weight % of Reinforcement of composites

The results indicate that the variation of weight percentage of the Al_2O_3 reinforcement with applied load has a clear effect on the wear rate. The wear resistance of the composite specimens increase with increasing weight percentage of nano Al_2O_3 reinforcement and decrease wear resistance with applied load. It is seen that the wear resistance of a composite specimen with a fixed weight percentage of reinforcement decreases with increasing applied load (Fig.4.1- 4.3). At constant applied load, the composite specimens show a lower wear rate as compared to unreinforced alloy. In figure Shows the variation in wear rate with load for both the Al alloy 6061 and Al 6061- with 1%, 1.5%, 2%, 2.5%,and 3weight % Al_2O_3 composites. It can observe that the wear rate of the unreinforced alloy is lower than that of the composite.

4.2.2. Variation of wear rate with the variation of sliding speed

Figure (4-9) shows the wear rate on ordinate and sliding speed on abscissa for Al6061 and its composites having 1% Al_2O_3, (in fig. 4.4) 2% Al_2O_3, (in fig. 4.5) and 3% Al_2O_3 (in fig. 4.6) under sliding speeds 1.5 m/s, 2.5 m/s and 4.5 m/s and various applied load of 10N, 20N, 30N, and 40N respectively. As expected, the wear rate of the unreinforced and composite specimens increases with increasing sliding velocity. It is seen from the figure (4.4-4.6) that the wear rate of the unreinforced alloy specimens increases more rapidly with applied load compared with the composite alloy specimens. The graphs show that the wear rate increased very rapidly with increasing sliding velocity.

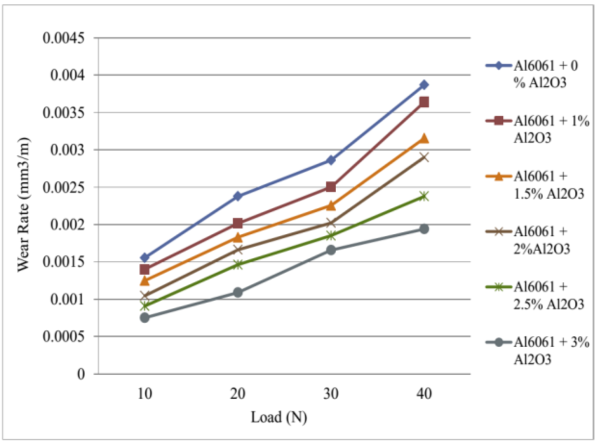

Fig 4 Variation of Wear rate with weight % of Reinforcement of composites at sliding velocity 1.6 m/s

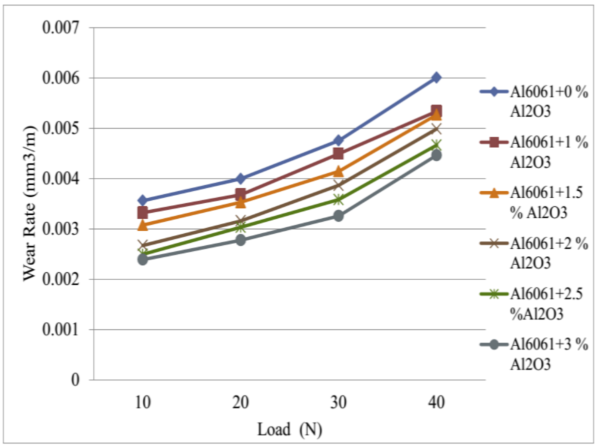

Fig 5 Variation of Wear rate with weight % of Reinforcement of composites at sliding velocity 2.5 m/s

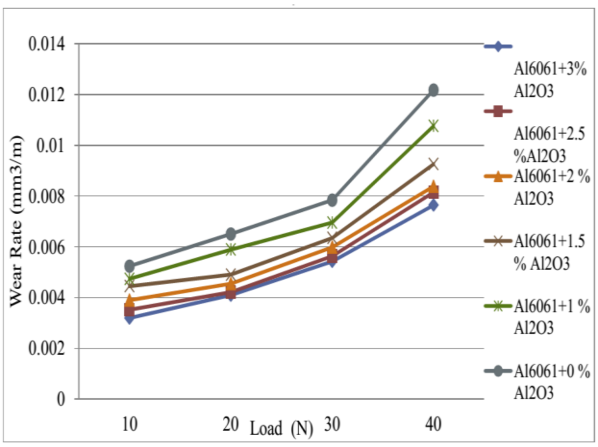

Fig 6 Variation of Wear rate with weight % of Reinforcement of composites at sliding velocity 4.5 m/s

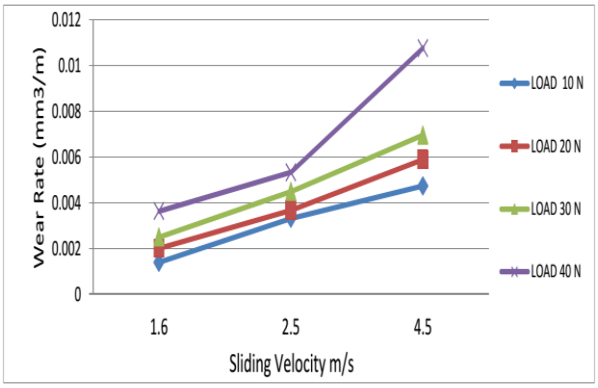

Fig 7 Variation of wear rate with the variation of sliding speed of 1 % of Al_2O_3

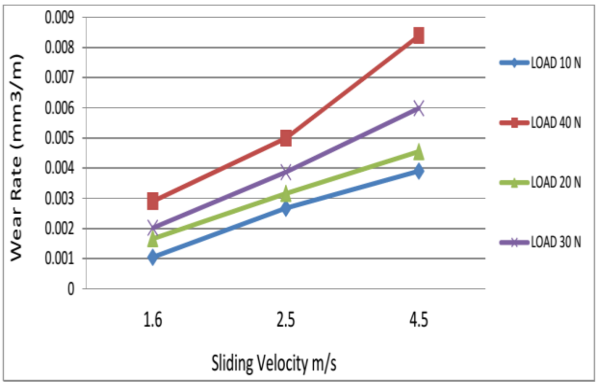

Fig. 8 Variation of wear rate with the variation of sliding speed of 2 % of Al_2O_3

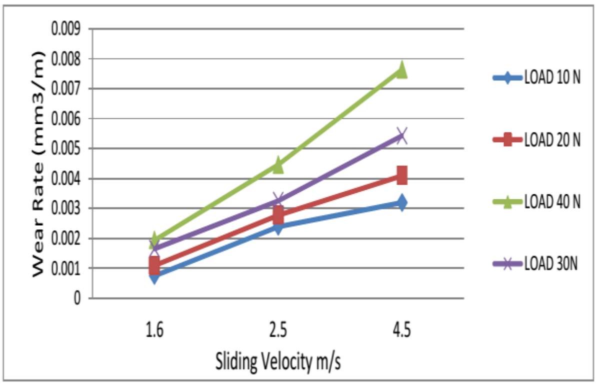

Fig. 9 Variation of wear rate with the variation of sliding speed of 3 % of Al_2O_3

Result of Hardness of Sample shows the hardness of AMCs reinforced with Al_2O_3 by the ultrasonic stir casting route. It is observed that the hardness of AMCs was increased by increasing weight % of Nano Al_2O_3 Hardness of composite depends on the weight % of reinforcement and the matrix. Coefficient of thermal expansion of Al_2O_3 is less than that of aluminium alloy 6061, an enormous amount of dislocations are generated at the particle- matrix interface during solidification process, which further increases the matrix hardness.

Table 1 Hardness Mesurement Table

SAMPLE	1	2	3	4	5	6	AVERAGE
1% Al_2O_3	48.2	47.5	50.25	43.78	45.6	47.27	47.1
1.5% Al_2O_3	59.4	58.45	54.47	52.9	60.1	53.5	56.42
2% Al_2O_3	65.6	64.84	63.5	62.87	60.9	65.09	63.8
2.5% Al_2O_3	69.5	62.8	68.5	70.28	65.8	68.0	67.48
3% Al_2O_3	70.2	68.4	67.8	72.4	65.5	71.38	69.28

Smaller ceramic particle reinforced composite have more particle matrix interface as in case of alumina reinforcement compared to larger particle reinforced composite for same amount. Hence, the hardness of the composite increases with decrease in particle size and increase the weight % of reinforcement. The use of Ultrasonic Transducer which generates the vibration at the 20 KHz frequency helps to break the cluster which is formed during the stirring process and the particle is dispersed in a matrix. Hardness tests were carried out to observe the effects of wt. % of Aluminium oxide on aluminium alloy matrix.

5. CONCLUSIONS

- Aluminium matrix nano (1, 1.5, 2, 2.5, and 3 weight %) Al_2O_3 Composites have been successfully fabricated by ultrasonic assisted stir casting technique.
- The experimental density is closer to the theoretical density of composites. Porosity of composites could be decreased considerably due to the ultrasonic treatment and nitrogen degassing.
- The hardness of the composites is higher as compared to un-reinforced alloy and hardness of the composites increases with increasing weight percent of the Al_2O_3 nano particles.
- At constant sliding distance, and same sliding velocity, wear rate of composites increases with increasing applied load for alloy and composites and decrease with increasing percentage of the Al_2O_3 nano particle in the composite.
- At constant sliding distance, it is observed that an increase in sliding velocity results in increased wear rates of all the composites. It is maximum for load 40 N and minimum for load 10 N.

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