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Tribological study of $Al_2O_3/TiO_2/Cu$ composite by using pin-on-disc wear machine

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ABSTRACT

For all structural/functional application, tribological properties of material play most prominent role in day to day life. Tribology arises when there is relative motion between two surfaces in contact results loss of mass from surface by rubbing. To restrict this type of wear suitable lubricant can be use. This paper describes about wear behavior of three composites specimen made from constituting elements: alumina oxide, titanium dioxide and copper with the help of pin on disc machine. These three specimen pellets are made by powder metallurgy technique by increasing the furnace temperature from 100^0C to 700^0C with a rate of 3^0C/min. From wear test, wear rate graphs are plotted with respect to sliding velocity. In this study it is found that, composition of composites and sliding velocity majorly impart on wear rate. Our present aim is to test the mixture of various compositions of alumina and titanium in a copper base and test it for its different properties, to compare it with pure alumina. Among three composite it is observed that more the amount of TiO_2 percentage, lesser is the wear rate. This investigation can help to improve the tribological properties of surfaces by varying their composition.

Introduction

In this technological market, demands are for developing much new advanced material in account of suitable economic factor. Now-a-days one of an advance property of materials is coming out in demand i.e. tribological properties. Tribology generally includes wear, friction and lubrication properties of a material.

Many tribological investigations are carried out about ceramic composites to measure their metallurgical/mechanical properties [1-6]. Ceramic particles/fibers (e.g. Al_2O_3/TiO_2) reinforced composite materials are extensively used in the applications where tribological properties are important. Ceramic composite with base material metal/metallic oxide exhibits extraordinary wear resistance and are used in gears, bearings etc [7-9].

One of the considerable potential ceramic oxides is Alumina due to its excellent mechanical properties such as excellent wear resistance and hardness etc [10]. For fabrication of metal matrix composites, Aluminum alloys are being widely used as matrix material which is reinforced with alumina particles. Alumina ceramics have excellent thermal stability [11]. This composite can be used in aircraft parts, automotive parts & engine blocks, engine pistons and other part which operates under severe friction conditions [12]. Highly pure alumina ceramics is ideal for hostile environment where resistance to both wear and corrosive substances are used. Another one ceramic composite is Titanium dioxide which has poor mechanical properties. So a combination of alumina & titanium gives a better ceramic composite which can give better wear resistance than that of pure alumina. Copper matrix composites exhibits wide range of properties and are used in sliding electrical contacts of welding electrodes, transfer switches, railway overhead current systems and other electrical applications. Copper matrix composites reinforced with Alumina particles gives a better wear resistance and better refractory properties than non-reinforced copper. Copper-alumina matrix gives a better wear resistance as compared to pure copper metal or pure alumina.

In this investigation, aim is to prepare a matrix of alumina oxide, titanium dioxide and copper with varying compositions and then different test carried out to find out there wear rate.

Experimental Procedure

The ceramic composite will be prepared by mixing all powders i.e. Al_2O_3, TiO_2 & Cu. Melting point of this constituting powder are given in Table 2.1. There are three sample prepared with different weight percentage ratio. Weight of Powders was taken by help of weighing machine. Specimen-1 constitute by 50 wt % of Cu + 25 wt % of Al_2O_3 + 25 wt % of TiO_2, Specimen-2 constitute by 50 wt % of Cu + 35 wt % of Al_2O_3 + 15 wt % of TiO_2 and Specimen-3 constitute by 50 wt % of Cu + 15 wt % of Al_2O_3 + 35 wt % of TiO_2. Powders were put in a mortor which is homogenized by help of pestle. 6-10 drops of 'PVA solution' (binder) was put in the mixture for better adhesion strength. Again the stirring process continuing in the mortar till they became dry powder. In this way three specimens powder have been made and collected in a container. To give a desired shape, pressure is applied axially by the help of die and punch assembly. Die & punch are cleaned by acetone solution before use. Powder was put in to the die slowly with avoiding large vacant position inside and also for avoiding loss of powder to outside the die. Then punch was inserted in to the die. This assembles part kept inside the axial pressing machine. Pressing is carried out with dwelling time of 2 minute and with a load of 4 tons. This compressed pellet taken out from die and again

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compressed in opposite direction to form a rectangular compacted section. This green pellets cannot directly use in this experiment because it is weak and can break. So sintering carried out. Three pellets are labeled in a suitable way before sintering so that the label cannot disappear during operation. All specimens are kept in a cleaned silica disc and inserted in to the furnace. Furnace temperature gradually increases with a rate of 3°C/min from 100°C to 700°C with soaking time of 1 hour. Then furnace cools to room temperature by natural cooling. Heating & cooling are carried out slowly to avoid any damage to the specimen and for specimen strengthening [13]. Now the specimens are ready for wear experiment. The overall experimental setup is shown in figure 2.1.

Table 2.1 Materials used in specimen and their melting points

Materials	Chemical formula	Melting Point (°C)
Alumina	Al_2O_3	2072
Titanium oxide	TiO_3	1843
copper	Cu	1083

Fig 2.1 Pin-on-disc setup

Testing for wear rate

Initial weight of the specimen was masured by using weighing machine. The specimen was clamped to the flat. Load of 20 N was applied on the flat. The specimen was kept in contact with disc. The disc was rotated by help of motor at a given speed for 5 minutes. After 5 minutes, the disc was stopped. The specimen was removed from the clamp. Final weight of the specimen was taken. Weight loss was calculated by using the following formula:

$\Delta W = IW - FW$

Where ΔW is weight loss, IW is initial weight, FW is final weight. Wear rate in N/m was calculated by using the following formula:

$WR = \Delta W/d_{sd}$

Where WR is wear rate, d_{sd} is sliding distance. Sliding distance was calculated by using the following formula:

$d_{sd} = 2\pi rNt$

Where r is radius of wear track, N is sliding speed in RPM (revolutions per minute) of disc, t is time for which disc rotates. Sliding speed (v) in m/s is calculated by using the following formula:

$v = 2\pi rN/60$

Wear track radius was measured and its value was 5.25 cm. Wear rate was calculated for three

Specimens at three different sliding speeds for 500, 750 and 1000 RPM. Graphs were plotted between wear rate and sliding speed for three specimens.

Results and Discussion

Figure 4.1, 4.2 and 4.3 shows the wear rate vs. sliding speed of specimen-1. In figure 3.1, it is observed that wear rate decreases from 3.089 X 10^{-6} N/m to 0.362X 10^{-6} N/m as there is increase in sliding speed from 2.75m/s to 5.50m/s and sliding distance from 824.67 m to 1649 m (shown in Figure 4.1). In figure 4.2, it is observed that wear rate decreases from 10.267 X 10^{-6} N/m to 1.872 X 10^{-6} N/m as there is increase in sliding speed and sliding distance in the same way as that of specimen-1. (Shown in Figure 4.2). In figure 4.3, it is observed that wear rate decreases from 5.133X 10^{-6} N/m to 0.909X 10^{-6} N/m as there is increase in sliding speed and sliding distance in the same way as that of specimen-1. (shown in Figure 4.3).

Table 4.1 Wear rate of specimen 1

Sl. No.	Sliding Speed (m/s)	Initial Weight (gm)	Final Weight (gm)	Weight Loss (ΔW)	Sliding Distance (d_{sd}) (m)	Wear Rate X 10^{-6} (N/m)
1	2.75	8.532	8.272	0.260	824.67	3.089
2	4.12	8.111	7.965	0.146	1237	1.156
3	5.50	7.965	7.904	0.061	1649	0.362

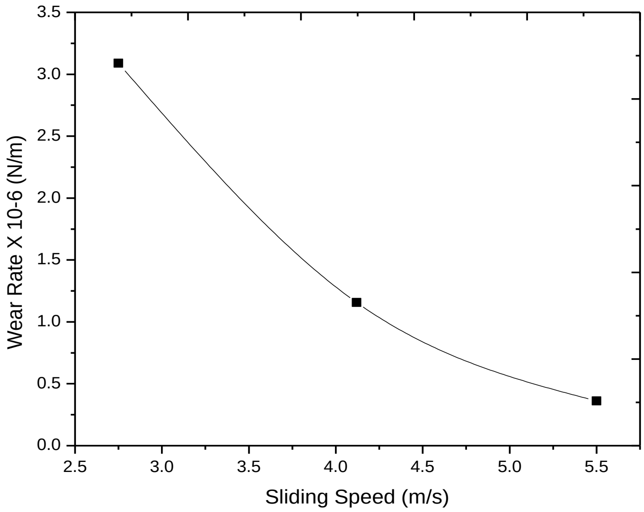

Fig 4.1 Graph between wear rate and sliding speed for specimen 1

Table 4.2 Wear rate of specimen 2

Sl. No.	Sliding Speed (m/s)	Initial Weight (gm)	Final Weight (gm)	Weight Loss (ΔW)	Sliding Distance (d_{sd}) (m)	Wear Rate X 10^{-6} (N/m)
1	2.75	8.194	7.330	0.864	824.67	10.267
2	4.12	7.217	6.626	0.591	1237	4.682
3	5.50	6.626	6.311	0.315	1649	1.872

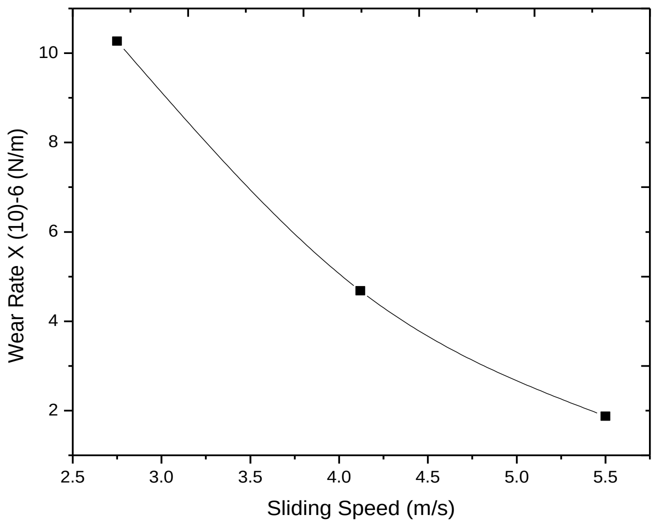

Fig 4.2 Graph between wear rate and sliding speed for specimen 2

Table 4.3 Wear rate of specimen 3

Sl. No.	Sliding Speed (m/s)	Initial Weight (gm)	Final Weight (gm)	Weight Loss (ΔW)	Sliding Distance (d_{sd}) (m)	Wear Rate X 10^{-6} (N/m)
1	2.75	8.552	8.120	0.432	824.67	5.133
2	4.12	8.120	7.883	0.237	1237	1.878
3	5.50	7.883	7.730	0.153	1649	0.909

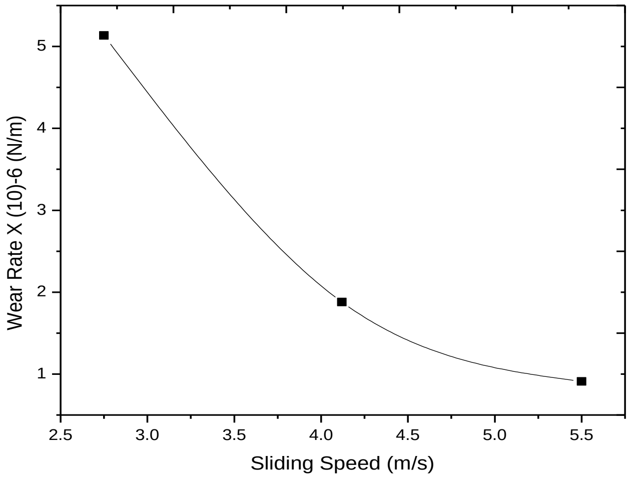

Fig 4.3 Graph between wear rate and sliding speed for specimen 3

From the above graphs, we find that as the sliding velocity is increasing, the wear rate is decreasing. Wear rate is inversely proportional to the sliding velocity, which is supporting the theory, i.e. as the sliding speed increased, the coefficient of friction decreased [20]. In specimen 2, the wear rate of was found to be very high. This is due to very high alumina content (35%) which is more than the optimum amount. Due to very high alumina content, there is lack of proper binding and fusion in preparation of composites. Wear rate of specimen 1 was found to be very low as it contained proper combination of alumina (25%) and titanium dioxide (25%). Wear rate of specimen 3 was more than specimen 1 but much less than specimen 2 because the percentage of alumina (15%) is low as compared to optimum amount. Due to very low alumina content, strength of the composite reduces which results in higher wear as compared to specimen 1.

Conclusions

The present investigation aimed at comparison of wear rates of three composites made from different percentage of copper, alumina and titanium dioxide. The analysis was carried out by fabricating the experimental setup, preparing the three composites and performing the wear test on the specimens. Graphs between wear rate and sliding velocity were plotted for the three specimens and wear rates of three specimens were compared.

It draws the following conclusions:

a) Wear rates of all three specimens decreased with increase in sliding velocity.

b) Specimen 2 having alumina content higher than the optimum amount showed higher wear. Specimen 1 having proper combination of alumina and titanium dioxide showed very low wear rate. Specimen 3 having alumina content lower than optimum amount showed higher wear rate.

c) Amount of alumina and titanium dioxide content affects the wear rate. Proper combination of alumina and titanium dioxide results in high wear resistance of the composite.

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