

Effect of Sliding Surface Temperature on the Sliding Wear Behavior of Natural Mineral Reinforced Aluminum Alloy Composite



Engineering

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ABSTRACT

In the present paper the effect of sliding surface temperature on sliding wear behavior of the cast aluminum alloy reinforced with Granite-10 wt.% particle composite has been studied at different applied loads and abrasive sizes for different sliding distances. It was noted that the wear rate decreased with sliding distance and approached to a stable value and increased with increase in abrasive size and applied load irrespective of the materials. Granite is impervious to weathering from temperature and even from the air borne chemicals. In this work a study has been carried out to observe the effect of temperature rise on the sliding surface at different speeds. In fact the test was conducted at three variable speeds of 1.93, 4.11, and 5.5 m/sec. It was analyzed that the temperature rise during sliding is dependent on magnitude of applied pressure and the duration of test.

Introduction

The natural mineral particulate reinforced composites exhibit improved wear resistance and find applications as cylinder blocks, pistons, piston insert rings, brake disks and clutch plates etc. The strength of these composites is proportional to the percentage volume and fineness of the reinforced particles [11]. The structure and the properties of these composites are controlled by the type and size of the reinforcement and also the nature of bonding [14-16].

Wear is a complex phenomenon in which real contact area between two solid surfaces compared with the apparent area of contact is invariably very small, being limiting to the points of contact between surface asperities. The load applied to the surfaces will be transferred through these points of contact and the localized forces can be very large. The material intrinsic surface properties, the surface finish, load, speed and temperature and properties of the opposing surfaces are important in determining the wear rate. Wear, the progressive loss of substance from the operating surfaces of the mechanically interacting element of a tribo-system may be measured in terms of weight loss or volume loss. Mild to severe wear occurs when friction-induced heating raises the contact surface temperature above a critical value (13) (at about 0.4 times the absolute melting temperature of the matrix). The composite transition temperature is higher than that of the unreinforced alloy thus the composite suffers lower wear volume. The higher the normal pressure, the lower is the transition temperature (14). The higher thermal conductivity of the reinforcement contributes in improving wear resistance

In most of the industrial applications a major part of the surface effects are dependent on temperatures. This is because at an atomic level all mechanical, chemical and electrical phenomena are dependent on the thermal energy. During sliding wear test the effect of operating conditions such as load and speed on friction and wear are usually the manifestations of the effect of temperature rise on the variable under study. In most of the applications the mechanical properties such as ductility and hardness and the tribological properties start to degrade due to the rise in the interface temperature (16). This degradation of the properties can cause ultimate seizure of the component having surface contact thus leading to failure of the application. Thus, it becomes important to have an estimate of the interface temperature rise for the design of industrial machinery. In most of the sliding operations, almost all the frictional energy input is used up in plastic deformation, which is directly converted to heat in the material close to the interface. This plastic deformation results in increasing the atomic lattice vibrations which is eventually transformed into heat. If the two sliding contact surfaces are not well lubricated this heat is conducted into the two contacting surfaces through contact spots. These contact spots can

be either be one or many. In the case of Pin-on-Disc system the contact point is one. Studies on the effect of temperature have shown that the wear rate increased with temperature (11). They also reported a critical temperature which marked the transition from mild to severe wear in several PRC and in the unreinforced control materials.

In this paper tests have been conducted on an aluminum LM25 matrix alloy and composite of LM25 matrix reinforced with 10% wt of the naturally occurring coarse-grained igneous rock granite. The composite was prepared by liquid metallurgy route. Granite consists of quartz, feldspar and mica in shapeless interlocking grains [13]. It is composed of at least 65% silica. It finds use as crushed granite and as dimension granite. Granite underlies much of the continents [13] and is highly stable thermally, therefore, it shows no changes with the change in temperature. It is impervious to weathering from temperature and even from the air borne chemicals. It is the high resistance to chemical erosion that makes granite useful for making tanks to store highly caustic material. In this work a study has been carried out to observe the effect of temperature rise on the sliding surface at different speeds. In fact the test was conducted at three variable speeds of 1.93, 4.11, and 5.5 m/sec.

Sliding Wear Behavior

The sliding wear behavior of materials based on dry sliding wear conditions for the matrix and the composites are characterized on the basis of the sliding surface temperature, speed, coefficient of friction and pressure. The sliding of abrasives on a solid surface results in volume removal. The mechanism of wear depends on the mechanical properties of the solid. In a ductile solid, the primary wear mechanism is related to plastic deformation; correspondingly, the hardness of the material is a key parameter in governing the amount of material removal. However, the dominant mechanism in a brittle solid depends on fracture at, or near the surface such that the governing property is the toughness of the material.

Test Procedures

Two body sliding wear tests were carried out on prepared specimen of LM25 alloy and granite composite on Pin-on-disc wear testing system. Force and wear in microns were monitored with the help of electronic sensors. For each type of material, tests were conducted at three different speeds (1.93, 4.11 and 5.5 m/s). All the tests were conducted for a maximum sliding distance of 5000m under varying load upto 8 Kg in steps of 0.5 Kg. A cylindrical pin of size 10 mm diameter and 40 mm length prepared from composite casting was loaded through a vertical specimen holder against horizontal rotating EN32 disc of steel with hardness 65 HRC and diameter 50 mm for testing. The flat surface of the specimen was abraded by using 2000 grit paper. Wear tests

were carried out at room temperature without lubrication for about 2Hrs and 20 min.

Temperature rise near the mating surface of the specimen was measured as a function of test duration using a Chromel Alumel thermocouple. Inserted in the hole of the pin specimen 1.5 mm away from the sliding surface. The seizure of the specimen was indicated by a relatively higher rate of temperature rise of test pin and followed by vibrational and abnormal noise from the mating surface. Both the alloy matrix and the two set of composites were tested under identical conditions. The specimens were cleaned thoroughly by acetone before and after the test for measuring the weight loss. The wear rate was calculated as the volume loss per unit sliding distance. Each test was conducted as long as the thermal condition or the wear rate reached a steady state condition unless the wear rate was too high causing seizure.

Sliding Surface Temperature

According to the available data [3] a great part of the frictional heat is supplied to the moving specimen at high sliding speeds. However for the Pin-on-Disc Test setup this does not hold true since the bulk temperature of the disc is much lower than that of the pin and most of the frictional heat is supplied to the stationary disc. Contrary to this if temperature measurements are made at the stationary pin and the rotating disc it is observed that both the temperatures increase with increasing test duration. It is also seen that the temperature of the stationary pin is always higher than that of the rotating disc, Moreover the mean temperature at the apparent contact surface is found to be different than that predicted by literature [4-5]. The difference in temperature is due to the contrast in bulk temperature between the pin and the disc.

During the sliding of the specimen against the counter surface the temperature of the mating surface increases with in the test duration. The temperature rise is plotted as a function of test duration for different sliding speeds and pressures.

Fig 1.1(a) compares temperature rise in the composite containing granite particles with respect to that of the LM25 matrix alloy with test duration at sliding speed of 1.93 m/sec for different applied pressures. It is noted that at lower pressures (0.2 Mpa) irrespective of materials the temperature rises initially with test duration and after a test duration of 20 minutes it reaches to the stable value where as at higher pressures (0.6 Mpa) the temperature of the alloy initially increases at a slower rate and after test duration of 27 minutes, it rises very sharply and reaches to seizure. The very sharp increase in temperature in alloy may be an indication of initialization of seizure in it. It may also be noted from the figure that the temperature rise in case of the composite is significantly lower than that of the alloy and the composite does not seize even at the pressure of 0.6 Mpa. Figure 1.1(b) compares the variation of temperature rise in case of the composite is slightly lower than that of the alloy and the composite does not seize even at the pressure of 0.6 Mpa. Figure 1.1(b) compares the variation of temperature rise of composite at the sliding speed of 1.93 m/sec. for the whole range of applied pressure used in the present study. Here also it is noted that the temperature rise increases with increasing pressure and test duration. In general after a specific test duration the temperature rise reaches almost a stable value. But when the applied pressure is more than 1.0 Mpa the temperature starts rising again after a certain test duration of (for 1.4 Mpa, 40 minutes; and for 1.6 Mpa 32 minutes). It also indicates the initialization of seizure in the composite. It may also be noted that the composite seized only at the applied pressure of 1.6 Mpa.

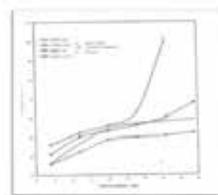


Figure: 1.1(a) Temperature near the mating surface

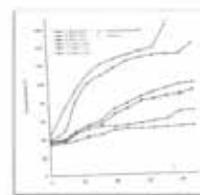


Figure: 1.1(b) Temperature near the mating surface

of specimen as a function of test duration at sliding of specimen as a function of test duration at sliding speed of 1.93 m/sec for different applied pressures for the matrix alloy and the granite composite for the granite composite

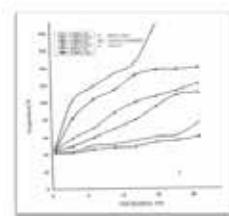


Figure 2.1(a) Temperature near the mating surface
Figure 2.1(b) Temperature near the mating surface of the

of the Specimen of LM25 and Granite reinforced Specimen of Granite reinforced composite as a

composite As a function of test duration at the sliding function of test duration at the sliding speed of 4.11 m/s at speed of 4.11 m/s at different applied pressures different applied pressures

Similarly, Figure 2.1 (a) compares the temperature rise near the mating surface of the specimen at different applied pressures for the matrix alloy with respect to that of the granite composite at sliding speed of 4.11 m/sec. It is evident from the figure that the temperature rise in the alloy is more than that in the composite. It may also be noted that the temperature near the mating surface of the specimen increases slowly at lower applied pressure (0.2 Mpa) with test duration both for the matrix alloy and the granite composite. In general rate of increase in the temperature of the mating surface rises with the increase in the applied pressure. It may be noted that in most of the cases the temperature reaches a stable value after a specific test duration as can be observed from Figures 1.1(a) and (b) at the sliding speed of 1.93. It is further noted that there is a fast increase in the temperature of the mating surface before the seizure that is for alloy specimen beyond test duration of 20 minutes at the applied pressure of 0.4 Mpa. Figure 1.1(b) compares the temperature rise of composite specimen at a speed of 4.11 m/sec under different applied pressures. It is noted that at the lower applied pressures the temperature rises very slowly with the test duration. At higher applied pressure the rise in temperature is very high. However after a specific test duration the temperature reaches to the saturation. It may further be noted that the composite does not seize when the applied pressure is less than 1.0 Mpa. When the applied pressure is 1.2 Mpa the rise in temperature is very fast and finally reaches to the onset of seizure after a test duration of around 5 minutes.

Figure 3.1(a) represents the variation of temperature near the mating surface of the composite with respect to that of the al-

loy with the test duration under different applied pressures at the sliding speed of 5.55 m/sec. It has been noticed that the rise in temperature in case of the composite is lower as compared to that of the alloy irrespective of the applied pressures as was observed in the earlier cases. The temperature rise of the matrix alloy and the composite containing granite particles at lower applied pressures increases gradually with the test duration and ultimately acquires a saturation value. It was also noticed that the alloy specimen did not seize upto a period of 15 minutes at the low pressure of 0.2 Mpa but as the pressure increased to 0.3 Mpa and the temperature to 185°C the alloy specimen reached to the onset of seizure within 12 minutes. Figure 3.1(b) represents the variation of temperature rise with test duration time at different applied pressures at the same speed for composite reinforced with granite. It is quite obvious from the figure that the temperature rises with the increase in pressure. It is also noted from the figure that the temperature rise tends to acquire a saturation limit at the intermediate values of the applied pressure (0.4-0.6) Mpa. It is also noted that for a higher value of pressure of 0.8 Mpa, seizure is reached at 205°C within a duration of 6 minutes. Thus, temperature rise during sliding is dependent on magnitude of applied pressure and the duration of test.



Figure 3.1(a) Temperature near the mating surface of Specimen of LM25 and Granite reinforced

Figure 3.1(b) Temperature near the mating surface of Specimen of Granite reinforced composite As a function of test duration at the sliding speed of 5.5 m/s at different applied pressures

Conclusion

In case of the LM25 matrix alloy the maximum temperature is 183°C at a speed of 3.96 m/sec as compared to 185°C at the speed of 4.11 m/sec. It was observed that the granite composite also shows similar characteristics with the maximum temperature being 205°C at 5.55 m/sec as compared to 209°C at 3.96 m/sec. The granite particles reduced the wear rate in the mild wear regime and increased the transition temperature by about 40-50°C. However, they did not provide any substantial benefit above this temperature, and the micro-structural analyses shows that the granite particles below the contact surfaces were comminuted. Posterior studies confirmed these results and found that the transition temperature decreased as the contact load increased

The rapid rise in temperature of mating surface in the beginning could be attributed to the breaking of sharp asperities and their possible oxidation (Figs. 1.1-3.1). Such broken asperities provide abrasive action leading to the higher localized heating. After a certain period, the number of such asperities reduces and the possibility of the formation of oxide layers on the surface increases. This helps in increasing the extent of matching of the specimen surface with the disc, leading to a reduction in heating and a lower temperature rise. After a certain period of time temperature rises rapidly depending on the applied load. This may be due to breaking of the oxide layers which leads to higher abrasive action and localized heating [16]. During this period

the material may be partially fused and causes brazing with the disc. This increases frictional force on the contact surface and finally leads to steep rise in temperature. This is the case prior to seizure of the material. The rise in temperature increases with increase in applied load. This may be attributed to the fact that extent of deformation and fracture of sharp asperities increases with increase in load. As stated earlier the fragmented asperities cause abrasive action and get oxidized and finally leading to localized heating.