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EFFECT OF RELATIVE HUMIDITY ON ADHESION WEAR OF ALUMINUM-ALUMINA COMPOSITE MATERIALS

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ABSTRACT

In this investigation the effect of relative humidity on the adhesion wear of aluminum-alumina composite was analyzed. The wear experiments were carried out at different days of year, regarding to that the natural relative humidity changed from 30 to 100%. It has been found that the adhesion wear rate decreased as the relative humidity increased. At higher relative humidity more than 80% a visible third layer of oxide iron is generated which leads to prevent metal-on-metal contact. It was found that the friction coefficient drops more than 60% at a higher relative of humidity. Also, in this investigation it has been found that as the volume fraction of alumina increased the wear rate decreased.

KEYWORDS: Dry Sliding Wear, Relative Humidity, Composite Materials, Adhesion Wear

INTRODUCTION

It is known that in practical applications, the variation on humidity affect the wear rate of metal. The ambient humidity can cover the whole range from 0-100% relative humidity. In most of published paper of unlubricated friction and wear experiments that the relative humidity of the environment is seldom controlled and often is not stated (Lankaster, 1990). Humidity measurements are a relatively simple matter, while environmental control increases the complexity of the experiment. Wear may occur as material loss and/or surface damage (Miyajima and Iwai, 2003). The large number of terms used for describing wear processes frequently complicates the discussion of wear problems. However, the wear mechanisms of these materials are still far from clear (Bing 1997). All of metals react with oxygen in air to form and oxide layer on their surfaces (Gee, 1992). The effect of these oxide layers on the wear and friction behavior has been studied extensively by many researchers. An oxide layer (Fe_3O_4 and FeO) formed by water-vapor treatment on a steel plate resulted in reduces the friction coefficient(Ito et al, 2007). The presence of water influence both the rate of oxidation and the type of the oxide form (Kubaschewski, Hopkins,1962). At low humidity, both delamination and adhesion wear occurred. At high humidity levels, both delamination and adhesion wear took place at a relative small scale and the frictional force was considerably lower than that obtained at lower humidity levels (Liew, 2006). It has been found that the wear of steel increased by a factor of 2 when the humidity was decreased from 100 to 15% RH (Klaffke, 1995). In this investigation the effect of ambient humidity on the adhesion wear of aluminum-alumina composite has been analyzed.

EXPERIMENTAL PROCEDURE

Preparation of Cast Composite

Weighed amounts of aluminum of commercial purity were taken in a clay-graphite crucible for melting in a resistance heated muffle furnace at 740^0C. The crucible has a hole of size 12 mm at the bottom plugged with graphite stopper. The schematic diagram of the experimental set-up used in this investigation is shown in Figure1. Suitable addition of magnesium was done at 710^0C so as to result in Al-4wt% Mg alloy. The surface of the melt was cleaned by skimming. A preheated turbine blade stirrer was concentrically introduced to the cleaned melt. The melt was vigorously stirred at a constant speed at 10 r.p.s. A preheated of alumina particle at 400^0C, were added at a rate of 1.5 to 2.0 gms/second to the molten. The slurry stirred continuously for four minutes. Then poured in a permanent metal mould of size 30 mm x 30 mmx 300 mm. While pouring, the remaining melt in the crucible is continuously stirred. The ingot was cooled by spraying water on it.

Wear Test

Dry sliding wear tests for aluminum-alumina composite materials were carried out using pin-on-disk machine. In this machine, the test material in the form of pins of diameter 6 mm and length 30 mm was held against the surface of 100 mm diameter rotating disk made of En-32 steel of hardness HRC 58 to 62. The pins were polished up to 4/0 grade emery paper and both, the disk and the pin cleaned with acetone and dried before carrying out the tests. The pin was loaded against the disk through a dead weight loading system. Four different loads of 14.7, 24.5, 34.3, and 44.1 N were used for each test material. The track radius had been 50 mm and the linear speed at this track radius was kept constant at 1 m/s where load was varied for tests. Each wear test was carried out for a total sliding distance of about 2199 m. Tangential force was monitored continuously during the wear test.

The wear volume at a given sliding distance was determine from the weight losses suffered by a pin were measured by interrupting the test at regular intervals of time and by recording the accumulated weight loss of the sample. The wear test were repeated three times under the same load and sliding velocity and the average results for wear volume with sliding distance are reported here. The wear test also, repeated for each samples at different days of the year, where the relative humidity measured at the time of experiment running. It has been found that the relative humidity changed from 30 to 100%. In this study the wear analyzed for three levels of relative humidity 56, 72 and 84%.

RESULTS AND DISCUSSIONS

The cumulative weight loss with increasing sliding distance have been measured and converted into cumulative volume loss on the basis of density of the tested sample. The variation of cumulative volume loss with a sliding distance at a normal load of 14.7 N and 44.1 N , and sliding speed of 1 m/s for aluminum- alumina composite material has 3.1 wt% of alumina particles at different levels of relative humidity of 56, 72 and 84% are shown in Figure 2(a) and 2(b) respectively. The cumulative volume loss increases linearly with increasing sliding distance. The line obtained by linear least square fit for all the value of relative is indicated in Figure 2.

These lines at different relative humidity converge at low sliding distance, where the differences in wear volume at different relative humidity are relatively small. One may observe that at higher relative humidity these linear least square fit lines do not pass through the origin and have negative intercepts. The negative intercept are common at higher humidity where the transfer layer containing oxide from the counterface readily form on the sliding surface of the test samples and effectively protect it from wear particularly at lower loads. These transfer layer on the sliding surface of the test pins are visible with naked eyes when test pin sliding at higher relative humidity and low load. At higher loads these transfer layer are not visible possibly because the transfer layers are continuously removed as they formed.

Increasing the alumina particles content on the aluminum-alumina composite materials from 3.1 wt% to 10.25 wt% decreased the cumulative volume loss about 50% as shown in Figure 3(a) and 3(b). The wear resistance of the composites material is improved by increasing the reinforced alumina particles content on the composite. The presence of more hard particles in the composite materials, more new fresh surfaces formed on the counterface during sliding, encouraged more oxidation especially at higher relative humidity (Ito, 2006). Rosenberg et al(2005) found that the formation of mixed layer of oxidations preventing direct metallic contacts and reduces the wear rate of the composites.

The wear rate has been determined from the slope of cumulative volume loss with sliding distance as estimated by the linear least square fit. Figure 4 shows the variation of the wear rate with normal load of the aluminum-alumina composite has 3.1 wt% of alumina. The wear rate increases linearly with the normal load, at all the levels of relative humidity. However, at higher humidity more oxidation occurred at the counter face of steel. These hard iron particles stick on the worn surface of the tested pin and may work as a separate layer between the worn surface and the steel counter face leads to reduction in mass loss from the pin. The effect of alumina content on the wear rate of the composite materials is shown in Figure 5. As the alumina content increasing in the composite leads to increase the hardness of the composite, which regarding to Archard's law decreases the wear of the composite from one side, in the other hand increasing the alumina particles, reducing the ductility of the composite.

Figure 6 shows the wear debris under a load of 14.7 and 44.1N as observed under stereo optical microscope at the magnification of X32 of a composite materials has 3.1 wt% of alumina. There are scoring marks and craters on the wear surface which have resulted in fine oxide particles and large metallic particles in the wear debris. The mechanism of the wear is primarily oxidative inspite of some crates resulting possibly due to galling under the prevailing test conditions. The crates are sometimes filled with fine oxide debris. At higher load of 44.1 N, some alumina particles pulled out as shown in Figure 6.

The variation of friction coefficient with sliding distance has been recorded at intervals of a minute during dry sliding wear under different loads. The coefficient of friction rises during the initial period of sliding when the surface are evolving towards better conformation and with further sliding fluctuates about mean value. Figure 7 shows the variation of the mean value of the friction coefficient with the applied normal load, for composites have 3.1, 7.2 and 10.25 wt% of alumina particles at a relative humidity of 84%. The friction coefficient a tending to decrease with increasing load and the effect is more pronounced at higher load.

At higher load the extent of frictional heating is high and the increased temperature could increase the extent of formation of oxide at the asperity contact thereby reducing the coefficient of friction. Increasing the present of hard ceramic particles in the composite materials lead to increase oxidation at the steel of counter face, result more reduction of friction coefficients. However, increasing the environmental humidity encourage the formation of oxide layer which play a main rule of friction reduction as shown in Figure 8. For a composite having 3.1 wt% of alumina particles, the friction reduces by 30% when the relative humidity changed from 56 to 84%.

CONCLUSIONS

The present investigation has led to the following conclusions:

- The relative humidity enhancing the formation of oxide layer which preventing metal on metal contact during dry sliding wear, which reducing the wear rate and the friction coefficient of the composite materials.
- The hard alumina particles reducing the wear rate of the composite materials during dry sliding wear by two ways, first by increasing the hardness of the composite materials, the second by producing more new fresh iron surfaces which becomes more candidates to oxide especially at higher relative humidity.
- At higher normal loads the oxide layer continuously removed as it formed, also some particles alumina pulled out from the matrix, leads to increase the volume loss during dry sliding wear.

REFERENCES

1. Bing k. Yen,(1997) "The effect of humidity on friction and wear of an aluminum-silicon eutectic alloy", Journal of material science, vol.32, pp 821-828.
2. Gee M. G.(1992) “ The formation of aluminum hydroxide in the sliding wear of alumina”, Wear, Vol.153, pp. 201-227.
3. Ito K., Martin, J. M., Minfray C., Kato K.,(2007) " Formation Mechanism of a Low Friction ZDDP Tribofilm on Iron Oxide", Tribology Transaction.
4. Klaffke, D.,(1995) " On the repeatability of friction and wear results and on influence of humidity in oscillating sliding test of steel-steel pairings", Wear, vol. 189, pp 117-121.
5. Kubaschewski O. and Hopkins B.E.,(19620 "Oxidations of metals and alloys.", Second edition, Butterworths.
6. Lankaster J.K.,(1990) "A review of the influence of environmental humidity and water on friction, lubrication and wear”, Tribology international, 371-389.
7. Liew, Willey Yun Hsien, (2006) “Effect of relative humidity on the unlubricted wear of metals”. Wear,260(7-8), pp 720-727.
8. Miyajima T. Iwai Y. (2003) “Effect of reinforcement on sliding wear behavior of aluminum matrix composites”, wear 255 pp 606-616.
9. Rosenberger M. R.,Schvezov C.E, Forler E., (2005) “Wear of aluminum matrix composites under condition that generates a mechanically mixed layer”, Wear,vol. 259(1-6), pp 590-600.
10. Yen B.K, Ishihara T., (1996) “Effect of humidity on friction and wear of Al-Si eutectic alloy and Al-Si-alloy-graphite composites”, Wear, vol. 198(1-2), pp. 169-175.

APPENDICES

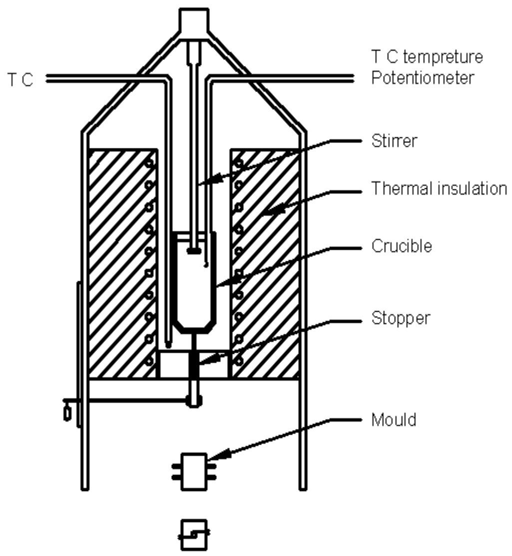
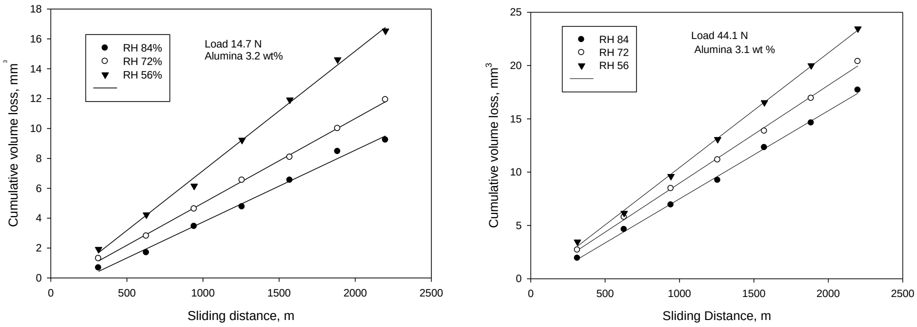
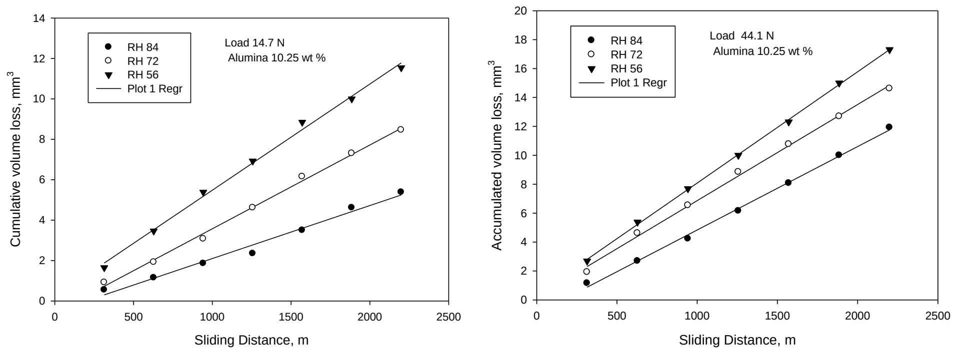


Figure 1: Schematic Diagram Showing Experimental Set-up for Stir-Casting



(a) **(b)**

Figure 2: Effect of Relative Humidity on Cumulative Volume Loss of a Composite has 3.1 wt% of Alumina, at Normal Loads of (a) 14.7 N and (b) 44.1N



(a) **(b)**

Figure 3: Cumulative Volume Loss with Sliding Distance of a Composite Material has a 31 wt% of Alumina at Different Relative Humidity at Normal Loads of (a) 14.7 N and (b) 44.1N

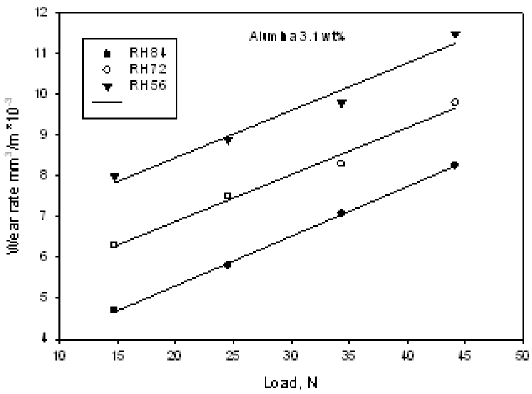


Figure 4: The Effect of Humidity on the Wear Rate of the Composite has 3.1 wt% of Alumina

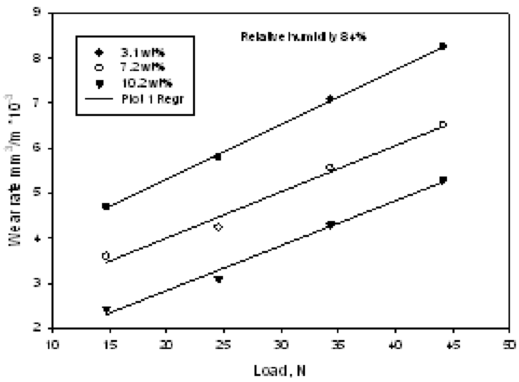
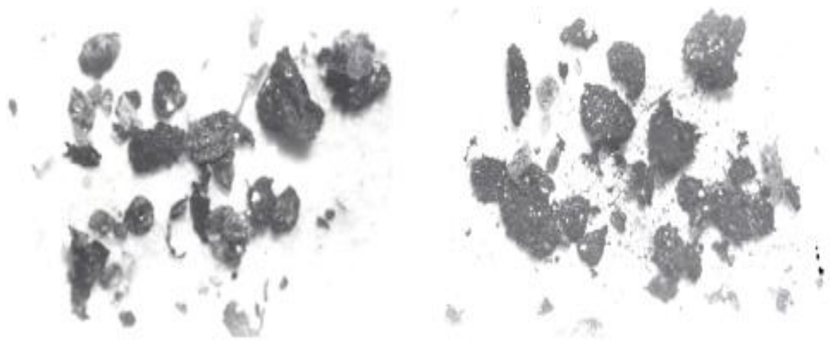


Figure 5: The Effect of Particle Contents on the Wear Rate of a Composites



(a) (b)

Figure 6: Optical Micrograph of the Wear Debris of a Composite Materials at Load of (a) 14.7 N and (b) 441 N

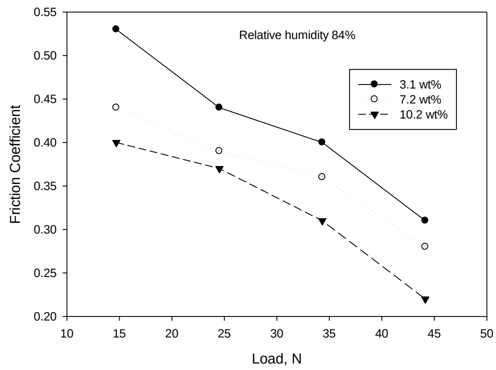


Figure 7: The Effect of Alumina Contents on the Friction Coefficients of the Composites Materials

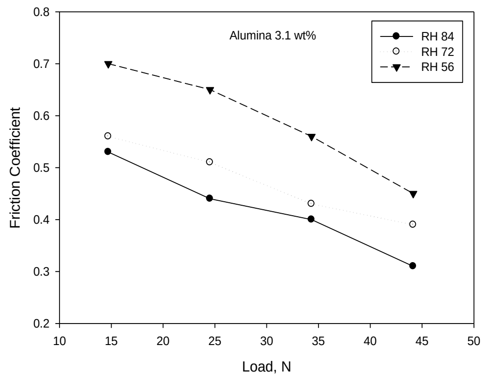


Figure 8: The Effect of Humidity on the Friction Coefficient of a Composite has 3.1wt% of Alumina