Key Engineering Materials *Online: 2007-02-15*
ISSN: 1662-9795, Vols. 280-283, pp 1319-1322
doi:10.4028/www.scientific.net/KEM.280-283.1319

Friction and Wear Characteristics of SiC and Si_3N_4 Ceramics Against ZrO_2 Ceramic Under Dry Friction

X. Tian[1,2], B. Lin [2] and W.L. Zhang[1]

[1] The College of Quality and Technical Supervision of Hebei University, P.R. China, 071000

[2] The State Education Ministry Key Laboratory of Advanced Ceramics & Machining Technology, Tianjin University, Tianjin, P.R. China, 300072

Keywords: Dry friction, Wear, Ceramics

Abstract. The friction and wear of the silicon carbide (SiC) and hot pressed silicon nitride (Si_3N_4) against zirconia (Y–TZP) sliding under dry friction and room temperature conditions were investigated with pin-on-disk tribometer at sliding speed of 0.56 $m{\cdot}s^{-1}$ and normal load of 50 N, 80 N and 120 N, respectively. It was found that, the coefficient of friction and wear rate are dependent on the test duration as well as the normal load. Through analyzing and comparing, the wear rates of the two frictional couples both are in the 10^{-6} mm^3 $(N{\cdot}m)^{-1}$. Based on the variety regulation of the wear maps, the wear mechanisms of the two couples were analyzed. Between the two couples, the friction and wear characteristics of the SiC/ZrO_2 couple are better than the Si_3N_4/ZrO_2 couple's.

Introduction

Ceramics materials are increasingly being used in a variety engineering application for ideal wear–resistance material, because of their excellent physical and chemical properties such as low density, high strength, high hardness, good fracture toughness, high resistance to chemical corrosion, as well as their ability to retain these properties at elevated temperature, they are often used as wear–resistance components [1,2]. Recently, Gahr [3] and Guatier [4] et al. have studied properties of friction and wear of zirconia ceramics and revealed different wear mechanisms such as brittle fracture, materials transfer, plastic deformation and tribochemical reaction on the friction pairs, depending on the various friction pairs and experiment conditions.

However, up to now, we haven't formed a system that people studied the friction and wear characteristic of ceramics, so restricted the use of ceramics widely. This paper discussed the response of the SiC/ZrO_2, Si_3N_4 /ZrO_2 friction couples with load changed and compare the friction and wear characteristics of the couples.

Table 1 Mechanical and physical properties of ceramic samples

Materials	Density [g/cm^3]	Hardness [GPa]	Flexural Strength [Mpa]	Fracture toughness [$Mpa.m^{1/2}$]	Elastic modulus [GPa]	Diameter [mm]
SiC	3.086	25	443	4.81	430	13.2
Si_3N_4	3.24	18	900	6.3	300	10.36
ZrO_2		12.9	419	8.98	216	

Experiment Equipment and Sample

The tribological tests were carried out using MG-200 high speed and high temperature tribometer by disk–on–pin. The disks tested wear prepared by zirconia (Y–TZP) ceramic. The pins were prepared by silicon carbide (SiC) and silicon nitride (Si_3N_4). The disks and pins all were ground. Their physical-mechanical properties and size of the materials used are given in Table 1.

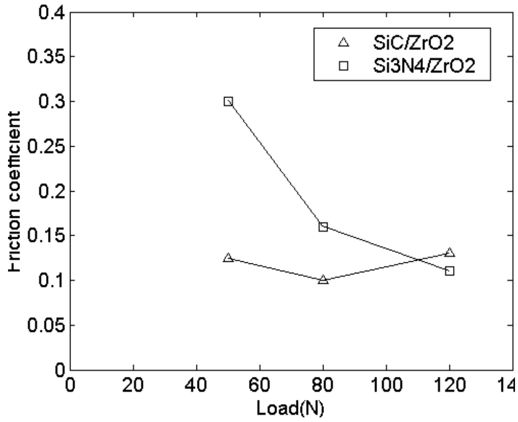

Fig.1 Friction coefficient

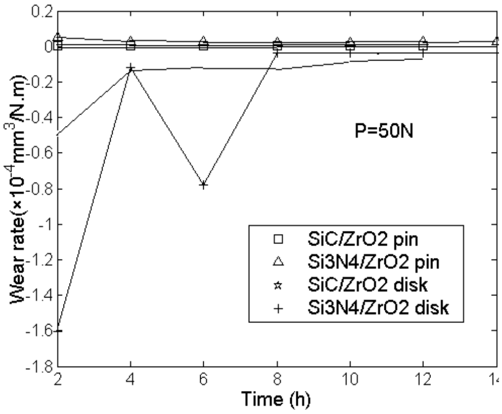

Fig.2 Wear rates of two friction couples at 50 N

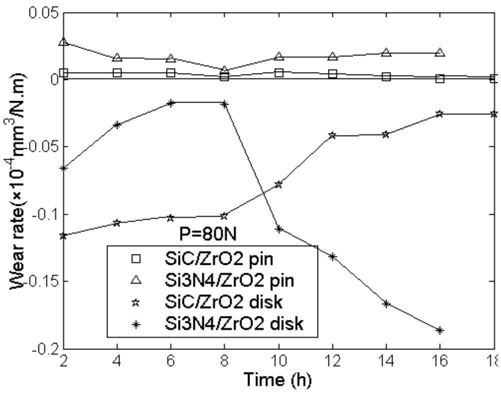

Fig.3 Wear rates of two friction couples at 80 N

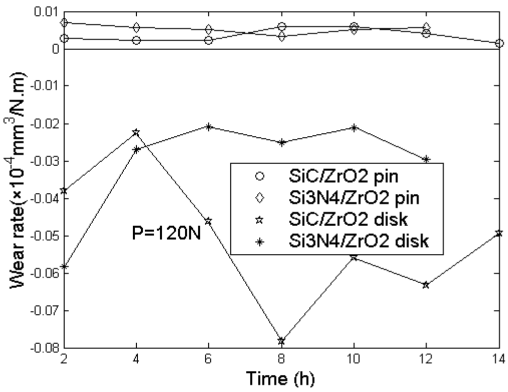

Fig.4 Wear rate of two friction couples at 120 N

Test Method

Dry–sliding experiments took place in laboratory air, room temperature and unlubrication. SiC and Si_3N_4 ceramic pins slid against rotating disks on the tribometer. The normal loads applied on the pin were 50 N, 80 N and 120 N, respectively. The sliding speed was fixed at 0.56 m/s. Before and after test, all samples were cleaned by acetone. Friction moment was transmitted to a recorder by a transducer continuously during the test and the friction coefficient was determined. The weight losses of the pin were weighed by using a light electricity analysis weighing balance, accuracy within $\pm 10^{-4}$ g. Before and after each wear test at every two hours, wear scare depth of the disks were measured by using a lever comparison apparatus with an accuracy of $\pm 10^{-3}$ mm. In order to have balanced measurements for disk sample, an average of sixteen measurements along radial was considered for subsequent computations. The volume loss and wear rate (mm^3/ N·m) was calculated. In order to wipe away the wear debris, wiped the wear place with absorbent cotton during test.

The Test Results

Friction coefficient. Friction coefficient of the same material repetition measured took mathematic average value. The friction coefficient of each material is shown in Fig. 1.

Maps of wear rate of pin and disk. As plotting maps of wear rate, for putting together the maps of the pin and disk, the wear rate of the pin takes positive value and the disk's takes negative value.

Discussion

SiC/ZrO₂ couple. Fig.1 shows that the friction coefficient of the SiC/ZrO_2 couple changes at 0.1 or so, Figs. 2, 3 and 4 show that the wear rates of the SiC pin are reduced, as load change from 50 N to

120 N. This is the result that more easily sheared film on the friction surface of silicon carbide ceramic formed in frictional chemical reaction. Our testing condition accorded with literature [5]. At the loads are 50 N, 80 N and 120 N, the quantity of wear loss is all small. Because the film formed, sheared force reduced, so wear rate lower. But the plotted has a wave from up to down, because after the lubricous film on the pin had formed, it was broken at later, therefore wear loss increases. This film formed again next running, the plotted has the descent again.

The Figs. 2, 3 and 4 show, the wear rate of the disk gradually decreases as applied load is 50 N, has a little undulate. As applied load is 80 N, the trend is down. As applied load is 120 N, sometime it is up and down, wave is larger, but total trend gradually decrease. Through analyzing the reason, we know there was the change of the tetragonal to monocline (t $\rightarrow$ m) during friction, the toughness was enhanced, and wear–resistance increased [8].

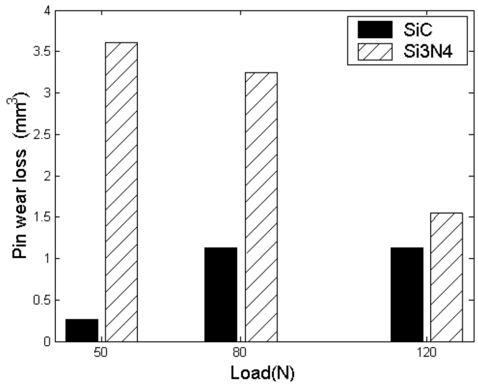

Fig.5 Wear loss of the pin

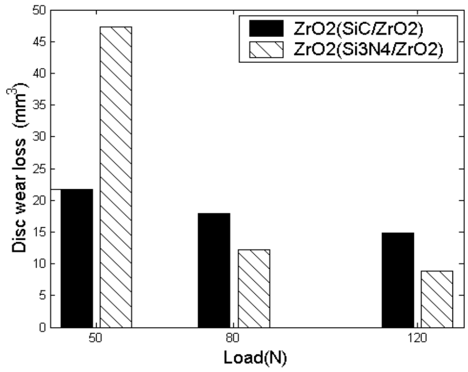

Fig.6 Wear loss of the disk

Si_3N_4/ZrO_2 couple. Fig.1 shows that the friction coefficient of the Si_3N_4/ ZrO_2 couple changes from 0.3 to 0.11 while load changes from 50 N to 120 N.

When load changes, Figs.2, 3 and 4 show the wear rates of pin increase with time (sliding distance) prolonged. As applied load is 50 N, the value is very low, but it is higher than the silicon carbide pin's. The wear rates of pin gradually decrease to a minimum value at beginning and then go up a stabilization value as load is 80 N, 120 N, respectively.

Through analyzing, the reason of the curves changing was that during friction the flash temperature was 300°C or so, the heat was not easily dissipated. It made the surface of the pin oxidized and formed SiO_2 film [6], sheared forces reduced, induced plotted to go down. During friction followed, with along time, the thickness of the film added, so the wear rate stabilized with a certain value. When load increases, the thickness of the SiO_2 film doesn't balanced the wear loss, so the wear rate of pin first decrease then increase as load is 80 N, 120 N, respectively.

Figs. 2, 3 and 5 show the wear rate of the disk of the Si_3N_4/ZrO_2 couple decreases is like waves first as applied load is 50 N, after the wear rate reduces to a certain value with time prolonged. As the applied load is 120 N, curve likes wave decreases too. The curve altitude increased is very great as the applied load is 80 N. At first there is decreasing trend, but with time prolonged, there is increasing trend. Through analyzing the reason, we know that fine particles are generated as a result of adhesion forces and raising frictional heat rapidly. There was the change of the tetragonal to monocline (t$\rightarrow$m) during friction like the SiC/ZrO_2 friction couple, the wear rate is very low. When at high load applied, the color of the wear track changed into black, it was evidence that some materials transferred to the disk surface, the structure of the surface became brittle, inducing the increase in the amount of microcracks and debris [7,8,9]. The presence of the debris enhanced the friction and wear. Ultimately wear rate increases.

Total wear loss of two couples. Fig. 5 shows the wear loss of the pin increases with loads after running 12 h, SiC pin's is very close as load is 80 N and 120 N. While load is 50 N, the wear loss of the pin is the lowest. Si_3N_4 pin's decreases as the load increased, Fig.6 shows that the total wear losses of the two disks decrease with the loads increased. the reason may be that the stress and temperature of the contact area increased with loads, This induced the change of the tetragonal to monocline ($t \rightarrow m$) and increased the toughness, wear rates go down.

Conclusions

Based on the tribological test for silicon carbide and silicon nitride ceramics pin sliding against zirconia disk under unlubricated and room temperature conditions, the following conclusions can be drawn.

The friction coefficient of the SiC/ZrO_2 couple changes a little and one of the Si_3N_4/ZrO_2 couple decreases with loads increased. The wear rate of two couples both is in the scale of $10^{-6}\ mm^3(N\cdot m)^{-1}$, especially the disk's of SiC is in the scale of $10^{-7}\ mm^3\ (N\cdot m)^{-1}$. It is regarded as microabrasion /microploughing. The total wear loss of the pin of SiC/ZrO_2 couple increases and the Si_3N_4/ZrO_2 couple's decreases with loads increased. But the total wear loss of the pin of Si_3N_4/ZrO_2 couple is higher than the SiC/ZrO_2 couple's at the same conditions. The total wear losses of the disk of two couples decrease with loads increased. But the total wear loss of the disk of the Si_3N_4/ZrO_2 couple is the largest at 50 N. There is little decreasing with loads increased at 80 N, 120 N.

The result is that friction and wear properties of the SiC/ZrO_2 couple are better than the Si_3N_4/ZrO_2 couple's.

Acknowledgments

The Author acknowledges gratefully the help given by Mr. Y.G. Shen and Mr. J.H. Han et al. at Tianjin University.

References

[1] K. Kato: Wear Vol. 258 (1990), pp. 117.
[2] Y.F. Kong, Z.F. Yang, G.Y. Zhang and Q.M. Yuan: Wear Vol. 218 (1998), pp. 159.
[3] K.H.Zum Gahr, W. Bundschuh and B. Zimmerlin: Wear Vol. 269 (1993), pp,162.
[4] P. Guatier and K. Kato: Wear Vol. 305 (1993), pp. 162.
[5] S.Q. Zhou and H.N. Xiao: China Ceramic Industry Vol. 9 (2002), pp. 17.
[6] J.J. Wei and Q.J. Xue: J. Chinese Ceram. Soc. Vol. 21 (1991), pp. 149.
[7] M. Terheci, J. Nanos, H. Giannakoudaris and S. Abanteriba: Wear Vol. 201 (1996), pp. 26.
[8] H.W. Liu, Q.J. Xue and L. Lin: Tribibol. Vol. 16 (1996), pp. 16.
[9] A. Tucci and L. Esposito: Wear Vol. 172 (1994), pp. 111.