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Research Article

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Tribological properties of titanium dioxide powders as lubricant additives

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Abstract

The effect of far infrared nano-sized titanium dioxide powders as lubricant additives on tribological properties was studied by adding the surface modification treatment nano -sized ceramic powders into base oil. The tribological properties were studied by a four-ball friction tester. The friction coefficient and wear scar diameters of lubricants in the presence or absence of TiO_2powders were analyzed. The mechanism of friction and wear was also explored in the present paper. The results show that the friction coefficients of base oil and nano-sized ceramic powders lubricant have little difference at initial stage, however the friction coefficient of TiO_2 nano-sized ceramic powders lubricant decreased greatly in the late stage of friction tests, which is far less than the friction coefficient of base oil. The average friction coefficient of far infrared nano -sized ceramic powders lubricant decreases first and then increases with the increase of additive amount of far-infrared nano-ceramic powders. When the additive mass fraction of far-infrared nano-sized ceramic powders is 1.0%, the average friction coefficient of the lubricant achieves the minimum, and correspondingly its change rate relative to the base oil reaches -31.6%. The wear scar diameters ofTiO_2 nano-sized ceramic powders lubricant are much less than those of the base oil, the wear scar diameter achieves the minimum when the additive mass fraction of far-infrared nano-sized ceramic powders is 1.0%.

Keywords: TiO_2 nano-sized ceramic powder; surface modification; base oil; additive; tribological property.

Introduction

Lubricant is used in various types of machinery to reduce the friction of the liquid lubricant, mainly from the lubrication, cooling, rust, cleaning and sealing effect [1]. With the in-depth study of nanomaterials and technologies, it was found that nano-particles made of nano-lubricating oil additives can greatly improve the friction and wear resistance of lubricating oil, but the small particle size of nanoparticles with large specific surface area, large surface energy and high surface activity make it easy to agglomerate, so the formation of a large number of aggregates with a large number of weak connection interface.

In this paper, surface modificated TiO_2 nano partilces were added into base oil. When the TiO_2 powder were as additives, the properties of lubricating oil were measured by four ball friction testing machine. In the presence or absence of TiO_2 powder the factors on lubricating oil change of friction coefficient and wear scar diameter were studied. The friction and wear mechanism were also explored.

1. Experimental

1.1 Surface modification

Due to the surface of TiO_2 contains hydroxyl groups, and silane coupling agents that modification effect of nano particles containing hydroxyl group is the best were choose to modificateTiO_2.Therefore using the silance coupling agent KH550,KH570,and both the composite modifier of mass ratio of 1:1were used to modify the TiO_2 particles.

0.1 g surface modification agent were dissolved in a mixture of de ionized water and anhydrous alcohol. The modified agent solution was pH=4 prepared by using hydrochloric acid to adjust. At room temperature, the solutions were ultrasonic dispersed for 10 min, and then hydrolyzed in 60 ℃ water bath for 30 min. The 10 g ball-mill,dried far red nanometer ceramic powder were added to the solution of the modified agent after hydrolysis, continue to ultrasonic dispersion 30 min in 50 ℃water bath. Then by drying, cooling, grinding, the modified TiO_2 nano ceramic powder were obtained [2].

The nano ceramic powders modified by different modifiers were added into the base oil. The compatibility between nano ceramic particles and the lubricating oil, dispersion stability and surface modification effect are evaluated by the centrifugal method.

The experiments showed that the compound mixed with the 6 wings synchronous rotor had the better dispersion of carbon black than that mixed with the 4 wings rotor at the same experiment condition. The high speed centrifugal sedimentation experiment showed that, the better dispersion of modificated TiO_2 nano particles with composite modifier than that modificated with other modifiers at the same experiment condition. This modificated TiO_2 nano particles with composite modifier began to appear precipitation at 6 h,nano powder is completely precipitated at 24h, which elapsed time is far more than the other modifie. Placed in the base oil, the modificated TiO_2 nano powder precipitate appeared after 60 d, after 140 d, powder not yet fully precipitated. The reason for this arrangement: the surface free hydroxyl groups of modified nanoparticles form a new stable chemical bond with groups of modifier after hydrolysis process.

1.2 Four ball friction and wear

The far-infrared nano-ceramic powders modified by the composite modifier were dubbed 0.5%, 1.0%, 1.5% and 2.0% nano-far-infrared ceramic powder lubricating oil, respectively, and compared with 150SN The friction and wear properties of the nano-ceramic powder lubricating oil were measured by a four-ball friction tester. The experiment condition: the speed is 1200 r/min , the temperature is 75 ℃ , the load is 392 N, and the test time is 60 min. The variation of friction coefficient with time and the wear scar diameter of 3 experimental steel ball were measured. The properties of the the TiO_2 ceramic powder of nano lubricating oil was evaluated by wear resistance, friction coefficient and 3 averaged wear spot diameter.150SN base oil mainly contains carbon atoms with a relatively small number of double or triple bond of unsaturated hydrocarbons, the basic physical and chemical properties is shown in Table 1 .

Tab .1 Basic physical and chemical properties of base oil with brand of 150SN

Viscosity at 40 ℃ ($mm^2 \cdot s^{-1}$)	Viscosity at 100 ℃($mm^2 \cdot s^{-1}$)	viscosity index	flash(ing) point ℃	Pour point℃	Density at 20 ℃ ($kg \cdot m^{-3}$)
40	**6.11**	**98**	**202**	**-12**	**0.8559**

2. Results and Discussion

Fig. 1 is the friction coefficient/time curve of the far-infrared TiO_2 powder indifferent amounts of base oil and far-infrared nano-ceramic powder. It can be seen from the figure, the initial friction of the amount of oiladded to the friction coefficient have a small range of fluctuations, there was an increasing trend in general. The friction coefficient of base oil increased with time, on the contrary, the friction coefficient of nanometer lubricating oil decreased with the increase of time. When the content of nano-ceramic powder was 1.0%, the friction coefficient is maintained at about 0.06 and reached the minimum, and the rate of change of the initial coefficient of friction was -20%, indicating the addition of a small amount of nanoparticles will improve the lubricating properties of lubricating oil remarkably.

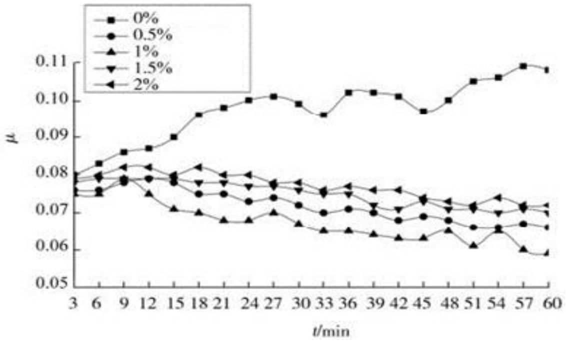


Fig. 1 Variation of friction coefficients with time in different additive amounts of TiO_2nano-sized ceramic powder

Up to minmize,the change rate of the relative initial friction coefficient is -20%, which shows that the addition of a small amount of nanoparticles makes the lubrication characteristics of lubricating oil significantly improved.

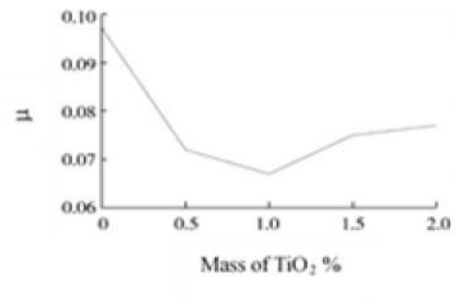


Fig. 2 Average friction coefficient with different additive amounts of TiO_2 nano-sized ceramic powders

Fig. 2 shows average friction coefficient variation with different additive amounts of TiO_2 nano-sized ceramic powders. With the increasing amount of nano - ceramic powder, the average friction coefficient of lubricating oil decreases firstly and then increases gradually. When the mass fraction of far - infrared nano - ceramic powder is 1.0%, the average coefficient of friction is the smallest.

Table 2 shows the average friction coefficient of nanometer lubricating oil change with different addition amount of TiO_2nano ceramic powder the relative decline of nano particles into the average friction coefficient of lubricating oil is obviously reduced, showing strong anti-wear properties. When the TiO_2 ceramic powder mass fraction was 1%, the average coefficient of variation nano lubricating oil base oil relative rate of -30.9%.

Table 2 the average friction coefficient of nanometer lubricating oil with different addition amount of TiO_2 nano ceramic powder

Nano ceramic powder mass fraction	0.5	1.0	1.5	2.0
Change rate%	-25.8	-30.9	-22.7	-20.6

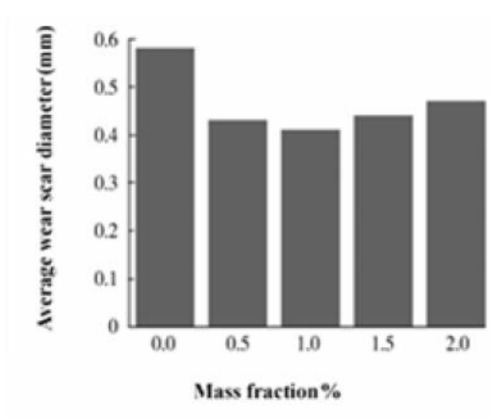


Fig. 3 Average wear scar diameter of ball in different amounts of TiO_2 nano-sized ceramic powders in oil lubrication

Fig.3 shows the average spot grinding lubricant TiO_2 ceramic powder with different mass fraction of ball diameter. Seen from the Figure, with the continuous increasing of the amount of wear scar diameter decreases first, then increases gradually, when the mass fraction of the TiO_2 ceramic powder is 1%, the diameter of wear scar is minimum.

Compared with base oil, it can be found, the wear scar diameter of lubricating oils with TiO_2 ceramic powder additive is far less than the base oil, which shows the wear resistance of base oil has been greatly improved by the that nano TiO_2 powder.

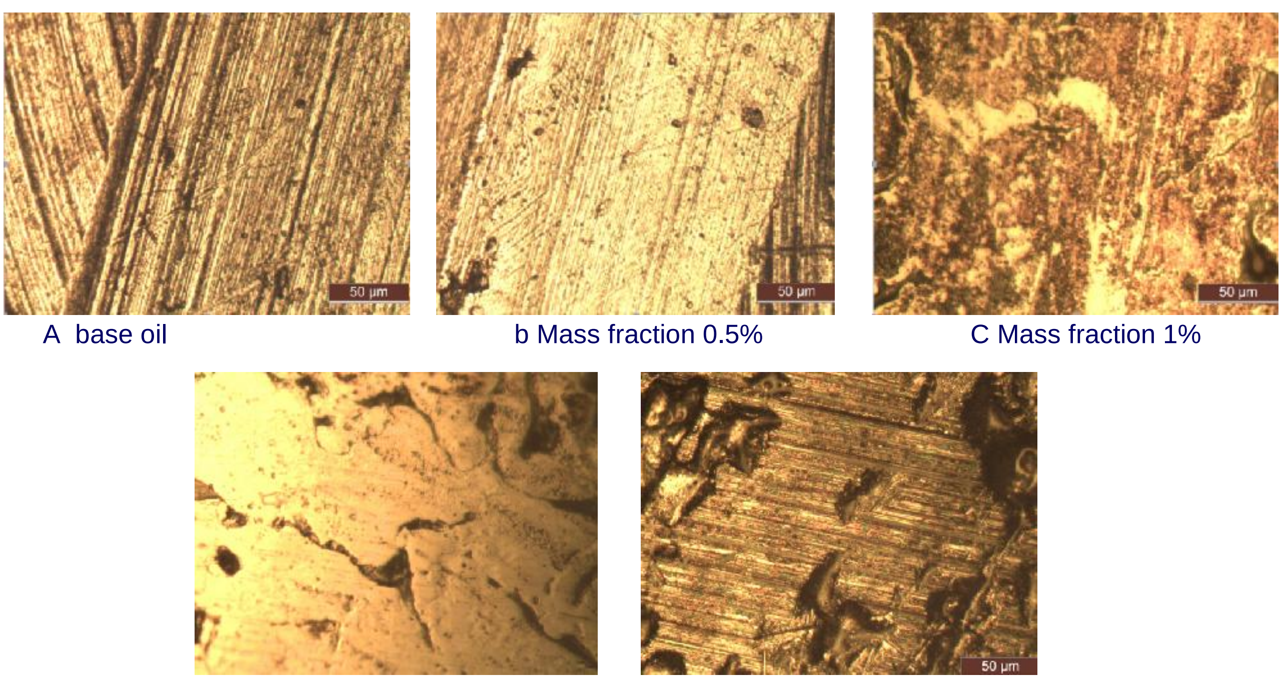
3 Wear mechanism analysis

In the four-ball test, the lubrication type of the oil sample begins with the boundary lubrication, which is the critical state before the transition from the fluid lubrication to the unlubricated state. The formation of a boundary lubricating film is the most important feature of boundary lubrication, which separates two contact surfaces, and its favorable shear properties reduce friction and wear. If the wear of the contact surface increases with time, the surface roughness is too large, or even a large furrow, which will lead to the occurrence of oil film piercing phenomenon, that occurs asperities between the direct contact, resulting in Friction and wear increase, and then a more serious abrasive wear [3]. In this study, the friction coefficient of base oil in the latter part of the sharp increase is caused by this reason.

In the initial stage, the abrasion between asperities leads to a small increase in the coefficient of friction. When the valleys of the asperities are polished, the boundary lubricating films adsorbed on the surfaces of the friction surfaces begin to exhibit lubrication properties.Although a small amount of nano-particles in the lubricating oil adsorbed to the surface of the friction pair or filled to the asperity valley [4], the smooth surface of the friction and lubricating oil itself good lubrication performance makes this effect is not obviously. There is not much difference between the performance of the base oil and lubricating oil friction coefficient.

After a period of time, when the lubricating film of the base oil is punctured by the surface of the rubbing pair with increasing roughness, the friction coefficient of the nano-ceramic powder base oil at this time decreases Instead of increasing. The reason is that the surface of the friction pair due to wear and the emergence of large asperities and furrow, the nanoparticles can quickly fill these small gully, the actual contact surface is smoother, and formed a new film by adsorption of large amounts of nanoparticles on surface. At the same time, the sliding friction change into numerous small rolling friction, thereby the friction coefficient reduced[4].

When the addition amount is small, the resulting lubricating film is thinner, and the shear strength is small. In addition, the valleys of a large number of asperities and the newly formed furrows [5] may not be filled, resulting in a larger friction coefficient. When the added amount is large, even though the nanoparticles have been modified by surface modification, their particle size is still very small with large specific surface area and specific surface energy [6]. When the nanoparticle concentration is so large that the surface particles contact each other and the probability of collision greatlyIncreased.In addition, due to the external friction pairs of itsextrusion and shear, it is easy to aggregate into larger particles, resulted in poor dispersion, degrading the friction and wear resistance of lubricating oil. On the other hand, since toomany nanoparticles can not all to form a lubricating film and fill into the valleys of the asperities, a large number of nanoparticles that do not participate in the formation of the lubricating film are free in the lubricating oil, which reduces coefficient of friction first decreases, and then gradually increased.



A base oil b Mass fraction 0.5% C Mass fraction 1%

d Mass fraction 1.5% e Mass fraction 2%

Fig. 4 Effect of different additive amounts of TiO_2nano-sized ceramic powders on morphology of friction pair surface

Fig. 4 shows the effect of the amount of far-infrared nanoceramics powder on the surface morphology of the friction pair when the magnification is 100. It can be seen from Figure 4a, base oil lubrication of the friction surface of the largest wear surface diameter and has a more obvious Furrow wear marks. At the later stage of the friction experiment, the increasing of the surface roughness leads to the abrupt increase of the wear amount. The boundary lubricating film in the boundary lubrication is getting smaller and smaller, which leads to the abrasive wear. From Fig. 4b and Fig. 4c, it can be seen that the surface of the friction pair is only slightly scratched, the surface is smooth and the diameter of the wear spot is the smallest. The results show that under the action of a small amount of nanoparticles, the new asperities and furrows generated by the friction process are quickly filled with the nanoparticles and a new lubricating film is formed, which is a good antifriction and antifriction effect. From Fig. 4d and Fig. 4e, it can be seen that the smaller furrows appear on the surface of the friction pairs, which are more serious than those in Fig. 4b and 4c. Compared with the deeper furrows in the base oil, grinding performance has greatly improved. This shows that excessive nanoparticles will not continue to improve the anti-wear properties of lubricating oil, but to make it worse, which is a short time by the intervention of nanoparticles and lubricants caused by a combination of fluidity deterioration

4. Conclusion

1) The friction coefficient of base oil and nanometer far-infrared ceramic powder lubricating oil are not very different in the initial stage. When the surface of the friction pair has large asperities orfurrows due to abrasion, the filling effect of nano-particles reduces the friction coefficient The friction coefficient of nano-lubricating oil at the late stage is even smaller than that at the initial stage.The friction coefficient of the nano-lubricating oil with the mass fraction of 1.0% is far less than that ofthe initial nano-ceramic powder.

2) The average coefficient of friction of nanometer lubricating oil decreased with increasing dosage, and the average friction coefficient of nanometer lubricating oil was the smallest when adding mass fraction of 1.0% The base oil rate of change reached -31.6%.

3) The wear resistance of the nano-ceramic powder was much better than that of the base oil, and the wear resistance of the nano-ceramic powder was improved greatly with the increase of the additive amount. And the wear spot diameter was the smallest when the massfraction was 1.0%.

4) The anti-wear performance of nano-lubricating oil is deteriorated due to the increase of agglomeration probability, the short time of nanoparticle intercalation and the deterioration of lubricating oil flow.

References

[1]Qiao Hongbin, Guo Qiang. Research status of nano - wear additives for lubricating oils [J]. mechanical engineering materials,2005,29（4）：4-6.

[2]Huo Yuqiu, Yan Yu Tao, Zhai Yu Chun [J]. materials review. Study on the tribological properties of nano lubricating oil additive SiO2, 2004,18 (4): 101-103.

[3]Wang Heng, Yang Qiaoli, Wang Yumin. Study on Tribological Properties of nano ceramic additives in lubricating oils [J]. lubrication and seal, 2008,33 (3): 48-50.

[4]Wang Yingzi, Zhao Hong, Wei Caiye, et al. [J]. technology China powder preparation far infrared nanometer titanium oxide powder, 2004,10 (1): 21-23.

[5]Zhou Huidi, Yue Meie. Study on the application of nano particles in tribology [J]. lubrication and sealing,2003（2）：32-35.

[6]Wang Xiaoli, Xu Binshi, Xu a, et al. The friction and wear properties and mechanism of [J]. tribology of Nano Cu Additive in lubricating oil, 2007,27 (3): 235-240.

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