



Influence on Lubricant Properties of Anti-wear Agent Containing Nitrogen, Boron and Molybdenum

Xuguo Huai & Shihai Zhao

School of Mechanical and Electronic Engineering, Tianjin Polytechnic University

Tianjin 300160, China

E-mail: xuguo.huai@163.com

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Abstract

The lubricant property of composite lubrication oils was studied through the friction and wear experiment of the A3 steel-GCr15 steel pairs on the ring-block wear testing machine. The composite lubrication oils were prepared from base oil added various content (0, 2%, 3%, and 4%) of organic anti-wear agent, which contains Nitrogen, Boron and Molybdenum. In order to research the influence of the base oil, the non-brand base oil was selected to compare with the brand one. The results show that adding the anti-wear agent can enhance lubricant property and improve the frictional and wear resistance of materials. When the anti-wear agent content reached 3% in the composite lubrication, the A3 steel-GCr15 steel pairs possess the lowest friction coefficient and wear rate. The lubricant property of the non-brand base oil can be enhanced by adding anti-wear agent, even better than that of the brand with the same concentration (3%).

Keywords: Anti-wear agent, Lubricant property, Friction and wear

1. Introduction

Friction-wear failure of mechanical components is among the most common problems that limit productivity. Frequently repairing or replacing worn parts costs businesses both time and money. Therefore, the reduction of surface wear is a common goal in many industries. Generally there are two ways to solve this problem. The first is surface improvement of material. So, protective coatings have been used against friction and wear, such as plasma nitriding (Xia Yanqiu, 2006, pp.145), Al₂O₃-TiO₂ coating (Narulkar VV, 2008, pp.582) and Al/Al₂O₃ Composite Coatings (Yin ZJ, 2007, pp.1430-1437). Adding anti-wear agent has become the other popular way and the most successful techniques for reducing the wear of materials and equipments. There are two kinds of anti-wear agents, that is, organic anti-wear agent and inorganic anti-wear agent. The organic anti-wear agents contain metal 8-hydroxyquinolines (M.W Sulek, 2003, pp.301-307) and Nitrogen-containing compound (Qiao Yulin, 1998, pp.165-169). And the inorganic anti-wear agents contain nanocopper (Yu Helong, 2006, pp.433-438), nanometer Titanium (Hu Zeshan, 2000, pp.292-295), and so on. In this experiment, the new organic anti-wear agent contains Nitrogen, Boron and Molybdenum, simultaneously.

In the present work, the composite lubrications were prepared from vary base oil with various concentrations (0~4%) of the anti-wear agent, which contains Nitrogen, Boron and Molybdenum. And the friction and wear properties of the A3 steel- GCr15 steel pairs were studied under oil lubrication on M-2000 wear testing machine. The friction coefficient and wear rate were researched to demonstrate the influence of the anti-wear agent and the base oil.

2. Experimental

2.1 Preparation

The specimen preparation of A3 steel process is as follows: Firstly, the samples of A3 steel were prepared though polishing to bright specular surface with emery paper and fabric. Then, those samples were ultrasonic cleaning with anhydrous alcohol for 0.5h. Lastly, the specimens were dried at 85°C for an hour.

2.2 Experimental measurement and characterization

The friction and wear properties were studied on M-2000 ring-block wear testing machine under oil lubrication. The A3 steel is bonding on the metal fixture as the upper sample and the counterpart ring is GCr15 steel, which inner bore is 16mm and external diameter 40mm. The counterpart is sliding friction at a load of 200N and 0.42 m/s for 40 minutes.

The lubrications were prepared from brand base oil (named B lubrication) added the anti-wear agent of 0%, 2%, 3%, 4%, respectively, which were signed by the symbol 0-B, 2-B, 3-B and 4-B. In order to demonstrate the influence of the base oil, the non-brand base oil with the anti-wear agent (named N lubrication) was selected to compare with the brand oil.

The friction coefficient was calculated by the formula (1):

$$\mu = \frac{T}{RP} \times \frac{\alpha + \sin\alpha \cos\alpha}{2\sin\alpha} \quad (1)$$

Where T is the friction torque (N/m), which was recorded every five minutes, P is the load of pressing the surfaces (N), R is radius of lower sample (m), 2α is the contact angle of the upper sample with the counterpart and μ is the friction coefficient of A3 steel/ GCr15 pairs as a function.

The wear rate of A3 steel sample, which is the rate of weight loss, was calculated by comparing its mass with an electronic balance (sensitivity 0.1mg) before and after friction. Prior to weighing, the samples were ultrasonic cleaned with anhydrous alcohol and dried half an hour, respectively. Thus the wear rate can be calculated.

The worn surface morphology was observed by OLYMPUS BX51 System Microscope.

3. Results and discussion

3.1 The influence of the content of the anti-wear agent

The friction coefficient curves of A3 steel/ GCr15 pairs, as a function of sliding time, are shown in Fig.1. It can be seen that the friction coefficient decreases more rapidly early and is relatively steady after about 30min of sliding time. Under the lubrication of 3-B, the friction coefficient A3 steel/ GCr15 steel pairs was the lowest.

Fig.2 shows the wear rate of A3 steel samples under the lubrication of 0-B, 2-B, 3-B and 4-B, respectively. It clearly indicates that the wear rate of sample under 0-B was the highest, and the wear rates of A3 steel under B lubrication with anti-wear agent were lower than that under B lubrication, so the anti-wear agent can enhance the lubrication performance of the base oil. When the anti-wear agent content is 3% in the composite lubrication, the A3 steel-GCr15 steel pairs possess the lowest friction coefficient and the least wear rate.

Corresponding worn surfaces of A3 steel are shown in Fig.3, which the magnification used for indentation measurement is 1500. For under base oil (as shown in Fig.3a) alone, the friction surface fracture shedding and ploughing were evident. Local delamination was observed and the damage region was more extensive. All the other three had less fracture shedding and ploughing than under base oil. And under the lubrication of 3-B, the friction surface had the least scratched lines and ploughings.

So, as is said above, the anti-wear agent can reduce the depth of subsurface plastic deformation and prevent the development of long subsurface ploughing, which led to surface spalling. And under the lubrication oil, the A3 Steel sample possesses of lower friction coefficient and wear rate. It can conjecture that the surface of A3 steel maybe form the ceramic film in the process of sliding friction.

3.2 The influence of the base oil

As discussed above, the lubricant property of base oil with 3% anti-wear agent is the best. So we choose the 3-N lubrication (N lubrication added 3% anti-wear agent), for comparison with the 3-B lubrication.

Fig.4 shows the friction coefficient of A3 steel/ GCr15 pairs as a function of sliding time. In evidence, the friction coefficient under 3-N was lower than 3-B. At the same, the friction coefficient of two samples decreased and was relatively steady after about 30min of sliding time.

Fig.5 shows the wear rate of two samples under B and N lubrication with the same content anti-wear agent. Under the 3-N lubrication, the wear rate was much lower than 3-B lubrication.

Fig.6 shows the worn surfaces of A3 steel under the lubrication of 3-B and 3-N. For Fig.6a, the friction surface fracture shedding and ploughing were evident. The surface of A3 steel under the 3-N lubrication was generally smooth, although some scratched lines were seen.

Through the above analysis, under the non-brand base oil added this anti-wear agent, the A3 Steel expresses lower friction coefficient and wear rate. And the lubricant property of the composite lubrication based the non-brand oil is even better than the brand one added the same concentration. The reason may be that the anti-wear agent can have a

synergic potentiation with one additive of the non-brand base oil. And the Synergetic enhancement mechanism will try to be analyzed in another project.

4. Conclusions

The following conclusions can be drawn from the present study:

- (1) Adding the anti-wear agent can enhance lubricant property and improve the frictional and wear resistance of A3 steel.
- (2) When the anti-wear agent content reached 3wt% in the composite lubrication, the A3 steel-GCr15 steel pairs possess the lowest friction coefficient and wear rate.
- (3) The non-brand base oil, added the same content (3%) anti-wear agent, can show the better lubricant property than that of the brand one.

References

- Hu, Zeshan., Wang, Liguang., and Huang, Ling. (2000). Preparation and Tribological Properties of Nanometer Copper Borate as Lubricating Oil Additive. *Tribology*, 20, 292-295
- Ksenija Topolovec, Miklozic., Jocelyn, Graham., and Hugh, Spikes. (2001). Chemical and Physical Analysis of Reaction Films Formed by Molybdenum Dialkyl-Dithiocarbamate Friction Modifier Additive Using Raman and Atomic Force Microscopy. *Tribology Letters*, 11, 71-81
- M.W, Sulek., and A, Bocho-Janiszewska. (2003). the Effect of Metal 8-Hydroxyquinolines as Lubrication Additives on the Friction Process. *Tribology Letters*, 15, 301-307
- Narulkar, VV., Prakash, S., and Chandra, K. (2008). Effects of Temperature on Tribological Properties of Al₂O₃-TiO₂ Coating. *Defence Science Journal*, 58, 582-587
- Qiao, Yulin., Liu, Weimin., and Qi, Shangkui. (1998). The Tribochemical Mechanism of the Borate Modified by N-Containing Compound as Oil Additive. *Wear*, 215, 165-169
- Xia, Yanqiu., Zhou, Feng., and Lin Yimin. (2006). Study on Friction and Wear Properties of Plasma Nitriding 45# Steel under Different Lubrication. *Tribology*, 26, 145-149
- Yin, ZJ., Tao, SY., and Zhou, XM. (2007). Tribological Properties of Plasma Sprayed Al/Al₂O₃ Composite Coatings, *Wear*, 263.1430-1437
- Yu, Helong., Xu, Binshi., and Xu, Yi. (2006). Friction and Sliding-wear Behavior of Steel-Aluminum Tribopair Improved by Nanocopper Additive. *Tribology*, 26, 433-438

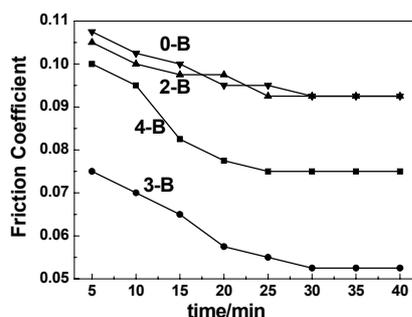


Figure 1. The friction coefficient of A3 steel/ GCr15 steel pairs as a function of sliding time under B lubrication with different content anti-wear agent

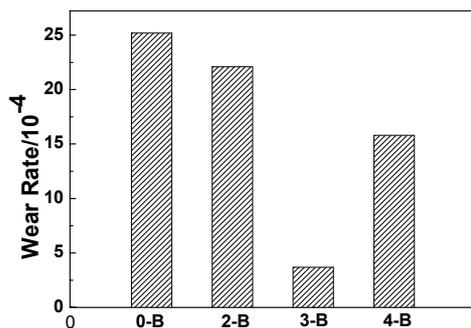


Figure 2. The wear rate of A3 steel samples under B lubrication with different content anti-wear agent

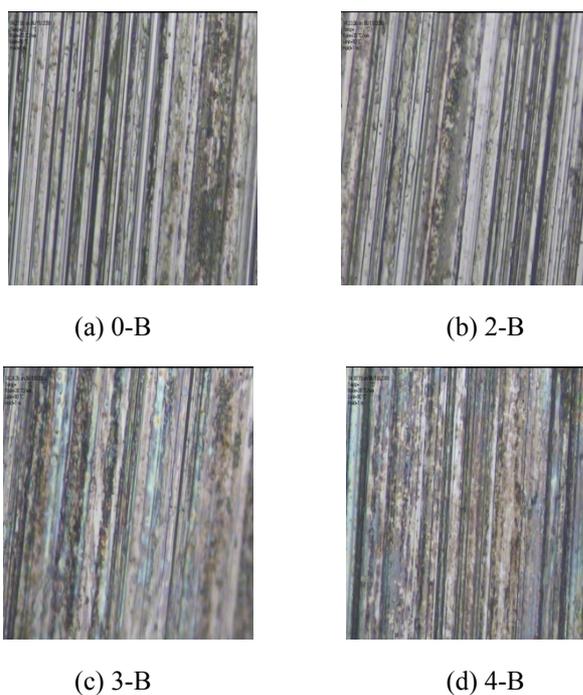


Figure 3. Micrographs of A3 steel worn surface under B lubrication with different content anti-wear agent

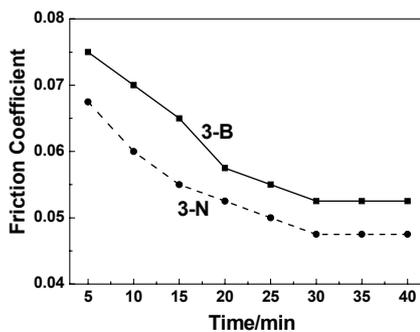


Figure 4. The friction coefficient of A3 steel/ GCr15 steel pairs as a function of sliding time

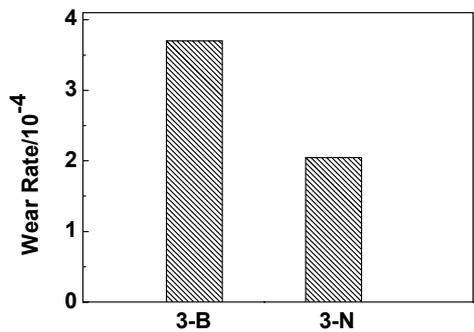


Figure 5. The wear rate of A3 steel samples under B and N lubrication with the same content anti-wear agent

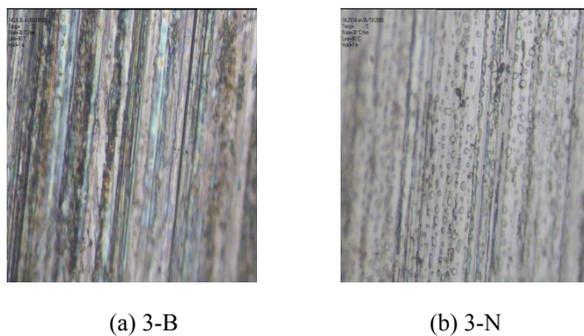


Figure 6. Micrographs of A3 steel worn surface under B and N lubrication with the same content anti-wear agent