

Experimental Research on Effect of Friction Reducing Agent Added to Lubricant Oil

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Abstract—In order to improve friction reducing effect of the lubricant oil used in automobile engines, taking a type of lubricant oil as the blank sample and eight kinds of test oils were prepared by adding in seven types of friction reducing agent. By doing friction-wear tests, SEM detections and 3-dimensional profile tests, friction reducing effect of the seven friction reducing agent were analyzed. The friction-wear test results show that, lubricant oil added molybdenum can significantly reduce friction. The SEM detection results show that, organic lipid had little effect on friction reducing. The 3-dimensional profile test results show that, lubricant oil added stearic acid nanometer Ti can significantly reduce friction. The research results provide guidance for preparing high performance lubricant oil.

Keywords—lubricant oil; friction reducing agent; SEM; 3-dimensional profile

I. INTRODUCTION

The negative impact of automobile exhaust is increasingly standing out with the rapid increase of automobile quantity in China [1]. Improving structure of the engine is a kind of common method for improving fuel efficiency of the automobile [2, 3]. However, performance of engine lubricant oil needs to be improved with the structure improvement of the engine [4]. Friction and wear properties of the lubricant are the most important indexes to evaluate application effect of the lubricant [5]. By adding in reducing agent, application effect of the lubricant can be improved significantly [6]. Thus, application effect of the engine can be improved.

Taking a kind of lubricant as the blank sample, seven kinds of reducing agents were added. Friction-wear tests, SEM tests and 3-dimensional profile tests were conducted for the lubricant oils. Meanwhile, friction reducing effect of the seven kinds of reducing agent was analyzed.

II. EXPERIMENTAL CONDITION

A. The Blank Lubricant Oil

Taking a kind of lubricant oil as the blank sample, parameters of the lubricant oil are shown in Table I.

TABLE I. PARAMETERS OF THE LUBRICANT OIL

Parameters	GB11121-2006	Experimental method
Kinematic viscosity (mm ² /s)	10.17	GB/T265
CCS (mpa·s)	5533	GB/T6538
Low-temperature pumping viscosity (mpa·s)	18320	GB/T0562
High shear viscosity (mpa·s)	2.99	GB/T0618
Flash point (°C)	226	GB/T3536
Pour point (°C)	-45	GB/T3535
Evaporation loss (%)	11.0	GB/T0059
Mechanical impurity (%)	0.007	GB/T511
Water (%)	trace	GB/T260

B. Reducing Agents

Seven kinds of reducing agents were added to the blank lubricant oil, i.e. molybdenum dithiocarbamate with the proportion of Mo is 8.839%, oleic acid-modified nanometer TiO₂ with the proportion of Ti is 8.58%, stearic acid-modified nanometer TiO₂ with the proportion of Ti is 10.49%, organic borate with the proportion of B is 1.67%, organic borate with the proportion of B is 0.49%, thio-phosphoric acid-modified nano-Cu with the proportion of Cu is 13.2% and organic lipid whose density is 980 kg/m³.

C. Experimental Instruments

SRV-4 friction-wear tester was used for the experiment. Material, diameter, hardness and surface roughness of the test ball are AISI 52100 steel, 10 mm, 60±2 HRC and 0.025±0.005 μm, respectively. Material, diameter, thickness, hardness and surface roughness of the test disk are AISI 52100 steel, 24±0.5 μm, 7.8±0.1 mm, 60±1 HRC and 0.035~0.050 μm, respectively.

D. Lubricant Oil Samples Preparation

The seven kinds of reducing agents were added to the blank samples and proportion of the reducing agents was 0.5%. The eight kinds of lubricant oil samples were heated to 75 °C and efficient stirring for at least half an hour. The friction-wear tests

were conducted on the SRV-4 tester and the controlled parameters are shown in Table II.

TABLE II. THE CONTROLLED PARAMETERS

Parameters	Running in stage	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
Frequency (Hz)	1	1	1	1	1	1
Load (N)	1	6	6	4	12	10
Temperature (°C)	50	50	70	70	105	125
Time (min)	0.5	12	12	12	15	15

III. ANALYSIS OF THE RESULTS

A. The Friction-Wear Tests

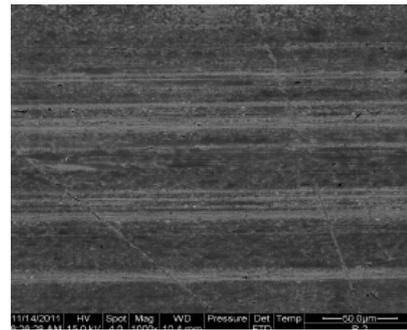
By conducting friction-wear tests for the eight kinds of lubricant oil samples, friction coefficients of the samples under different stages are shown in Table III. The results show that, sample 2 by adding in Mo was significantly effective than the other samples. Owing to strict friction parameters and less amount of the lubricant oil samples, friction-wear phenomenon was happened at the boundary area. Temperature of the lubricant oil rise rapidly and the other seven kinds of lubricant oil samples cannot form friction reducing layer. Thus, the lubricant oil sample with organic molybdenum can inhibit temperature increment and has good friction reducing effect.

TABLE III. FRICTION COEFFICIENTS OF THE SAMPLES UNDER DIFFERENT STAGES

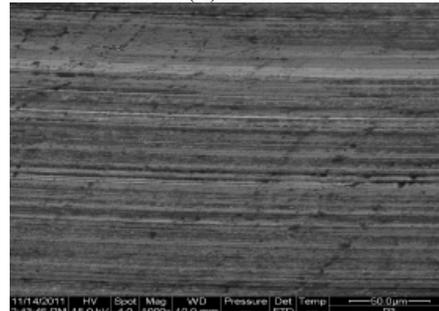
No.	Friction reducer	Stage 1	Stage 2	Stage 3	Stage 4	Stage 5
1	Blank sample	0.119	0.121	0.137	0.133	0.129
2	Organic molybdenum	0.039	0.038	0.039	0.046	0.066
3	Oleic acid nanometer Ti	0.124	0.125	0.129	0.127	0.128
4	Stearic acid nanometer Ti	0.126	0.122	0.133	0.130	0.129
5	Organic borate 1	0.128	0.128	0.134	0.133	0.134
6	Organic borate 2	0.125	0.127	0.131	0.131	0.131
7	Thio-phosphoric acid nanometer Cu	0.126	0.126	0.137	0.133	0.134
8	Organic lipid	0.116	0.131	0.135	0.138	0.120

B. SEM Analysis

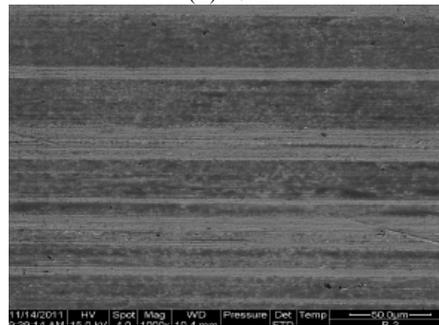
The test disk was taken out after SRV test and energy spectrum analysis was conducted for the spot-size using SEM. By conducting SEM analysis for the worn-out surface and amplify 1000 times, test results of the eight kinds of lubricant oil samples are shown in Fig. I.



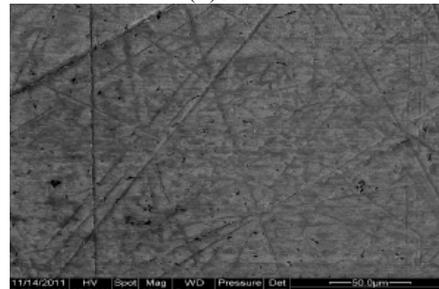
(A) No. 1



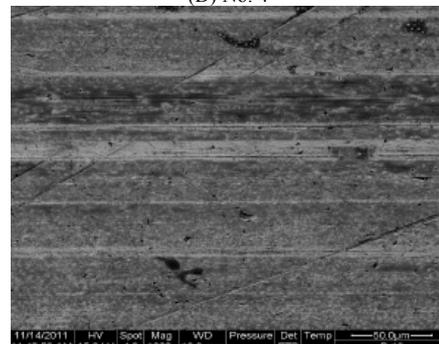
(B) No. 2



(C) No. 3



(D) No. 4



(E) No. 5

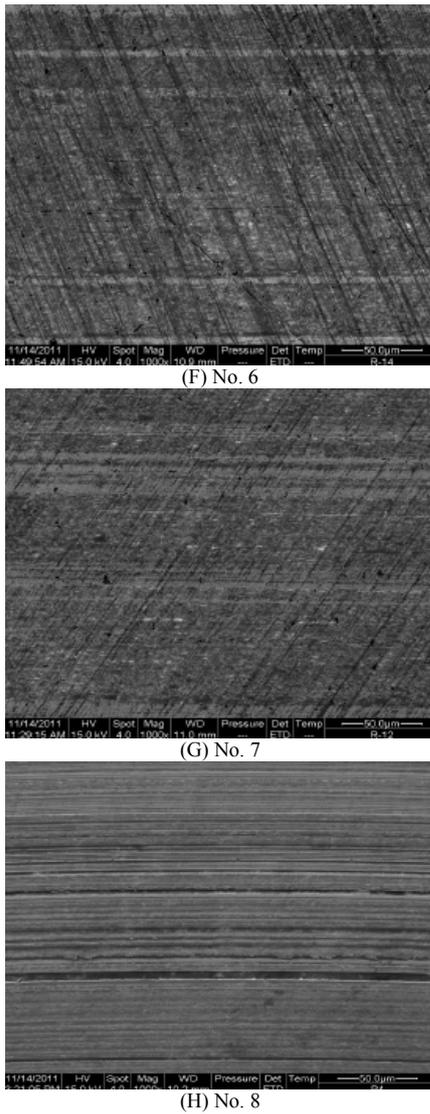


FIGURE I. SEM IMAGES OF THE SAMPLES

From Fig. I (A), we can see that friction-wear of the blank lubricant oil sample is relatively regular. However, the furrows are relatively deep. From Fig. I (B), we cannot see regular friction-wear scratches and the irregular lines were caused by rough surfaces of the test ball. From Fig. I (C) and Fig. I (D), we can see that the friction-wear scratches are relatively wide but not deep enough, and friction reducing effect of oleic acid nanometer Ti is better than stearic acid nanometer Ti. From Fig. I (E), we can see that the friction area is large, the furrows are deep and adhesive-wear phenomenon was happened. From Fig. I (F), we can see deep linear frictions. From Fig. I (G), we can see that the effect of thio-phosphoric acid nanometer Cu and oleic acid nanometer Ti is similar. From Fig. I (H), we can see that the effect of organic lipid and blank lubricant oil is similar. Thus, organic lipid had little effect on friction reducing.

C. 3-Dimensional Profile Analysis

According to the SEM testing results, four typically test disks were selected and the surface topographies were observed. 3-dimensional profiles of No. 2, 3, 4 and 7 are shown in Fig. II.

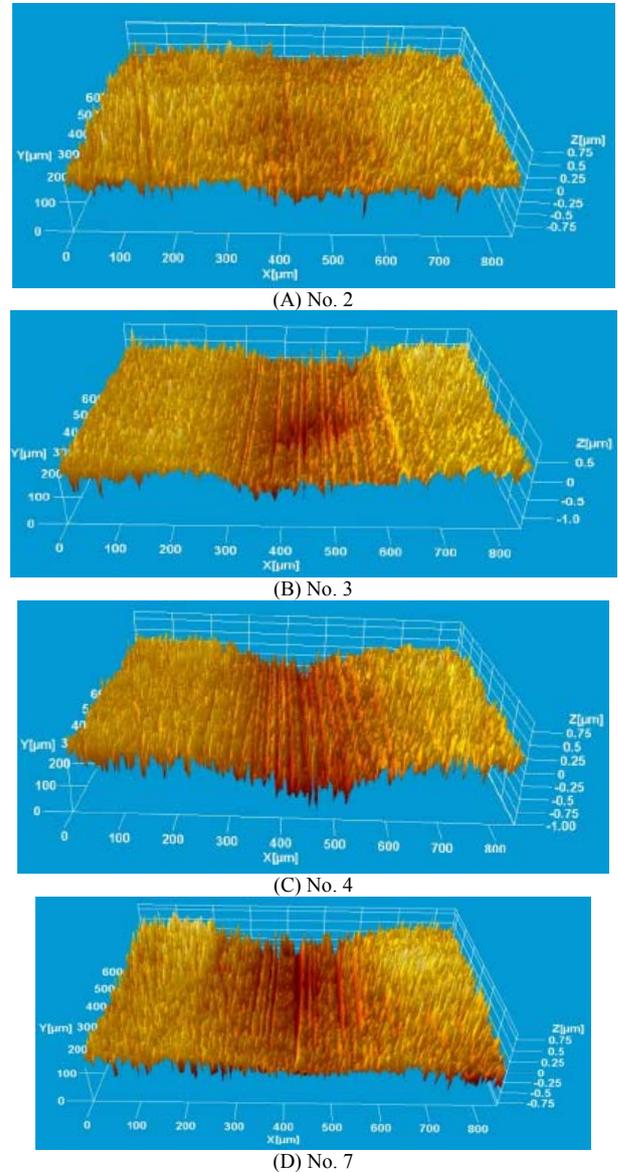


FIGURE II. 3-DIMENSIONAL PROFILES

From Fig. II (A), we can see that there are almost no scratches on surface of the test ball. From Fig. II (B), we can see that little scratches appeared on surface of the test ball and depth of the scratches is shallow. From Fig. II (C), we can see that many deep scratches appeared on surface of the test ball. From Fig. II (D), we can see that the scratches are more than Fig. II (B), but less than Fig. II (C). The 3-dimensional profile results are in accordance with the SEM testing results.

IV. CONCLUSIONS

(1) From the SRV friction-wear tests, we can see that lubricant oil added molybdenum can significantly reduce friction, and the average reduction rate of friction coefficient is 63.6%. The other additive agents have a common effect on friction reduction.

(2) From the SEM detections, we can see that organic lipid had little effect on friction reducing, and the other additive agents have their own unique characteristics.

(3) From the 3-dimensional profile tests, we can see that many deep scratches appeared on surface of the test ball smeared stearic acid nanometer Ti. Thus, lubricant oil added stearic acid nanometer Ti has positive effect on friction surfaces.

ACKNOWLEDGMENTS

This work was supported by Technological Innovation Project of Scientific and Technological Development Fund of China Coal Research Institute (2017CX01).

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