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EVALUATION ON SYNERGISTIC ANTIWEAR PROPERTIES OF ORGANIC ANTIMONY COMPOUNDS AS LUBRICANT ADDITIVE

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Summary :
Four ball tester was used to evaluate the antiwear and extreme pressure properties of antimony dialkyldithiophosphates (SbDDP),organic tin friction reducer (SnSO), chlorinated paraffin (T 301), sulfurized isobutylene (T 321), and their synergistic effects. The synergistic scuffing resistance of SbDDP with T 301 and T 321 was also evaluated. The results show that SbDDP exhibit better antiwear synergism with SnSO, T 301 and T 321 respectively, especially, synergistic effect of SbDDP with T 301 is the best. Moreover, data from scuffing resistance show SbDDP with T 321 exhibits good synergistic effect, but SbDDP with T 321 exhibits antagonistic effect. However, the combination of SbDDP with T 301 and T 321 exhibits good synergistic antiwear effect and scuffing resistance, especially, the synergistic effect was very obvious when the concentration of active elements attains optimal proportion.

Key words: *antiwear properties, antimony dialkyldithiophosphates, organic tin friction reducer, chlorinated paraffin, sulfurized isobutylene*

1 INTRODUCTION

The addition of extreme pressure (EP) and antewear (AW) additives was used to improve the friction and wear behaviors of lubricant, thus, avoiding surface damage. In the boundary lubrication regime, the formation of a surface chemical reaction film is the determining factor in minimizing the friction and wear. This depends on the nature and chemistry of additives or tribological effects of their active elements (sulphur, phosphorus, nitrogen, chlorine, etc) [1,2].

Metalic dialkyldithiocarbamates of zinc, lead, molybdenum, etc have been widely utilized as a multifunctional lubricant additive to provide antiwear protection as well as to inhibit the oxidation of petroleum lubricants [3-5].

The effect of a particular additive depends on its chemical nature, and its concentration. However, they don't exhibit better antiwear and extreme pressure properties under different operational conditions. The wide variety of positive effects demonstrated by the combination of different types of additives[6-9].

The required functional action is achieved by appropriate balance. Investigations that can optimize the composition and expand the areas of application of additive packages, are of considerable scientific and practical interest.

The present work aims to investigate the antiwear and extreme pressure properties of oils containing antimony dipropyldithiophosphate (SbDDP) and organic tin friction reducer (SnSO), chlorinated paraffin (T301) and sulfurized isobutylene (T321) respectively, and subsequent exploitation of the results for the development of synergistic antiwear engine oil composition.

2 EXPERIMENTAL

2.1 Oil samples and additives

Additive antimony dipropyldithiophosphate (SbDDP) was synthesized in the authors' laboratory. Organic tin friction reducer (SnSO), chlorinated paraffin (T 301) and sulfurized isobutylene (T 321) were commercial. The type and contents of active elements for all additives are shown in Table 1.

Table 1 Type and content of active elements in the additives

Additive	Content of active elements wt, %				
	Sb	S	P	Cl	Sn
SbDDP	11.3	17.6	8.5	-	
SnSO	-	14.8	-	-	7.1
T301	-	-		42	
T321	-	41	-	-	

All concentrations of additives used in the investigation are expressed in percentages by weight if not stated otherwise. The model additives in different proportions were weighed, mixed and dissolved in industrial sample of liquid paraffin or mineral base oil 500 SN with viscosity 28.1 mm^2/s at 100°C.

In the different compositions studied, the original additive, i.e. antimony dialkyldithiophosphate with other additives, always keeping the sum of the two additive concentrations at the initial level-2.0% in the particular example. This experimental approach allows for a clear assessment of the synergetic and antagonistic interactions.

2.2 Tribological Tests

Tribological properties of base oils containing additives were evaluated with a four-ball machine at a rotating speed 1450 rpm, room temperature about 25 °C. The balls used in the tests were made of GCr15bearing steel (AISI52100) at a diameter of 12.7mm with HRC of 59 to 61.

The antiwear properties were evaluated under loads of 392, 490 and 588N respectively for 30 min according to ASTM D4172-82, they were characterized by average wear scar diameters (WSD). The load-carrying capacities of additive was characterized as maximum non-seizure load (P_B value) which was evaluated by a short (10 s) extreme pressure test according to ASTM D2783-88. The relationships between its performances and the concentrations are also given.

An optical microscope was used to determine the wear scar diameters of the three lower balls with an accurate reading to 0.01 mm. Then, the average of the three wear scar diameters was calculated and cited as the wear scar diameter reported in this paper.

In addition, the scuffing resistance of additive in oils was also evaluated by commercial instrument from JB corporation, as illustrated in Fig. 1. It was were characterized by numbers of weights and relative levels of wear scar for upper cylinder tested. The more numbers of weights and lower relative levels of wear scar, the better scuffing resistance of oils.

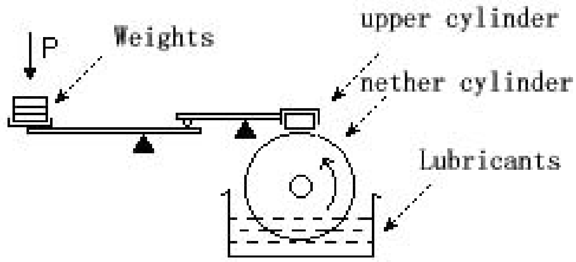

Fig.1 Schematic view of the specimen area commercial instrument

3 RESULTS AND DISCUSSION

3.1 Antiwear and load-carrying properties of SbDDP with SnSO

Antimony dipropyldithiophosphate (SbDDP) and Organic tin friction reducer (SnSO) were added to 500SN oil, the wear scar diameters (WSD) of tested balls and maximum non-seizure load (P_B value) are list in Table 2. It can be see clearly that SbDDP possesses better antiwear and load carrying properties than SnSO at the same conditions evidently, and they were improved with the increase of its concentration. When SbDDP is combined with SnSO, the antiwear properties of oils are improved to different degrees compare with each alone. For instance, at constant total concentration of the package, the WSD of the mixtures (at 1.0% SbDDP and 1.0% SnSO) is lower than that of 1.0% SbDDP or SnSO alone, the antiwear properties of SbDDP can be improved by 31% at load of 588 N. Even the complex exhibit better performances than 2.0% SbDDP. However, After the combination SbDDP with SnSO, P_B values of oils were not improved compare with 1.0% SbDDP, even obviously lower than 2.0% SbDDP.

Table 2 Evaluation on antiwear and load-carrying properties of SbDDP with SnSO

Additive composition, %		Wear scar diameter (WSD), mm			Maximum non seizure load P_B, N
SbDDP	SnSO	392 N	588 N	784 N	
0	0	0.632	0.873	failure	559
1.0	0	0.428	0.773	0.927	882
2.0	0	0.390	0.573	0.875	1108
0	1.0	0.607	-	-	588
0	2.0	0.553	-	-	618
0.5	0.5	0.518	0.857	-	-
0.5	1.5	0.543	0.840	-	-
1.0	1.0	0.480	0.533	0.858	784
1.5	0.5	0.460	0.542	-	834

3.2 Antiwear and load-carrying properties of SbDDP with T 301

Antimony dipropyldithiophosphate (SbDDP) and chlorinated paraffin (T301) were added to 500SN oil, the wear scar diameters (WSD) of tested balls and maximum non-seizure load (P_B value) are list in Table 3. The results show that the anti wear and load-carrying properties of base oil containing T301 only are not improved. However, when SbDDP is combined with T301, the WSD of tested ball are improved by 20-35% under same experimental loads, while the P_B values are not reduced. Therefore, the complexes of SbDDP with T301 all exhibit good antiwear synergism without impairing the load carrying abilities.

Table 3 Evaluation on antiwear and load-carrying properties of SbDDP with T 301

Additive composition, %		Wear scar diameter (WSD), mm			Maximum non seizure load P_B, N
SbDDP	T 301	392 N	588 N	784 N	
0	0	0.632	0.873	failure	559
1.0	0	0.428	0.773	0.927	882
2.0	0	0.390	0.573	0.858	1108
0	1.0	0.68	-	-	618
0	2.0	0.645	-	-	618
1.0	1.0	-	0.495	0.535	981
2.0	1.0	0.392	0.45	0.520	1108
2.0	2.0	0.385	0.472	0.563	1069

3.3 Antiwear and load-carrying properties SbDDP with T 321

Antimony dipropyldithiophosphate (SbDDP) and chlorinated paraffin (T321) were added to 500SN oil, the wear scar diameters (WSD) of tested balls and maximum non-seizure load (P_B value) are list in Table 4. The results show that the addition of T321can improve load carrying properties of base oil. When SbDDP is combined with T321, the WSD of tested ball are improved to different degrees compare with each alone, while the P_B values are not improved. Therefore, the complexes of SbDDP with T321 posses good synergistic antiwear properties.

Table 4 Evaluation on antiwear and load-carrying properties of SbDDP with T 321

Additive composition, %		Wear scar diameter (WSD), mm			Maximum non seizure load P_B, N
SbDDP	T 321	392 N	588 N	784 N	
0	0	0.632	0.873	failure	559
1.0	0	0.428	0.773	0.927	882
2.0	0	0.390	0.573	0.858	1108
0	1.0	0.717	-	-	696
0	2.0	0.625	-	-	784
1.0	1.0	0.425	0.79	-	882
2.0	1.0	0.395	0.50	0.663	1069
2.0	2.0	0.407	0.508	0.642	1108

3.4 Antiwear property and scuffing resistance of SbDDP with T 301 and T 321

Antimony dipropyldithiophosphate (SbDDP), chlorinated paraffin (T301) and chlorinated paraffin (T321) were added to 500SN oil, the wear scar diameters (WSD) of tested balls are list in Table 4, the data from resultant scuffing resistance are list in Table 6. As regard to antiwear properties, the combination of SbDDP with T301 and T321, have positive effects to different degree. Moreover, the results form Table 6 show that numbers of weights are increased significantly and relative levels of wear scar are lower after the combination of SbDDP with T321 or with T301 and T321. These complexes exhibit good antiwear capacity and scuffing resistance. Especially, the synergistic effects are obvious when the concentration of active elements attains optimal proportion.

Therefore, binary systems of borate SbDDP with other additives undergo complex concentration dependent interactions with antiwear and load carrying properties. The concentrations of the active elements in the bulk oil samples before the tests provides useful information for the consumption of the additives in the competition for the rubbing surfaces, and the formation of surface films. But the decomposition products of additives package out of the contacts and action mechanism should also be investigated further.

Table 5 Wear scar diameter for 500 SN oils containing SbDDP, T 321and T 321

Additive composition, %			Wear scar diameter (WSD), mm		
SbDDP	T 301	T321	392 N	588 N	784 N
0	0	0	0.632	0.873	failure
1.0	0	0	0.428	0.773	0.927
2.0	0	0	0.390	0.573	0.858
2.0	1.0	1.0	-	0.482	0.670
2.0	1.0	2.0	-	0.475	0.972
1.0	1.0	2.0	-	0.605	0.841

Table 6 Evaluation on scuffing resistance of SbDDP, T 321and T 321

Additive composition, %			Numbers of weights	Relative levels of wear scar
SbDDP	T 301	T321		
0	0	0	4	Heavy
0	1.0	0	7	Moderate
0	0	1.0	8	Moderate
2.0	0	0	10	heavy
2.0	1.0	0	6	Moderate
1.0	0	2.0	>12	Light to moderate
2.0	0	1.0	>12	Light to moderate
2.0	1.0	1.0	11	Light
1.0	1.0	1.0	12	Light
2.0	1.0	2.0	>12	Light to moderate
1.0	1.0	2.0	>12	Light to moderate
1.0	0.5	1.0	>12	Light

4 CONCLUSION

(1) Antimony diisopropyldithiophosphate (SbDDP) possessed better antiwear and load carrying capacities in base oil. When it was combined with organic tin friction reducer (SnNO), the complex exhibit good synergistic antiwar properties. However, they exhibits antagonistic effect as regard load carrying capacities.

(2) Antimony diisopropyldithiophosphate (SbDDP) exhibit better antiwear synergism with T 301 and T 321 respectively, the synergistic effect of SbDDP with T 301 is better than with T 321.

(3) The complex of antimony diisopropyldithiophosphate SbDDP, T 301 and T 321 exhibits good synergistic antiwear effect and scuffing resistance

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