COMPARATIVE STUDY OF THE FRICTION AND WEAR BEHAVIOR OF SEVERAL FUNCTIONAL COATINGSAT HIGH TEMPERATURE

ZHANG RUIJUN [1,2], LI SHENGHUA[1], JIN YUANSHENG[1]

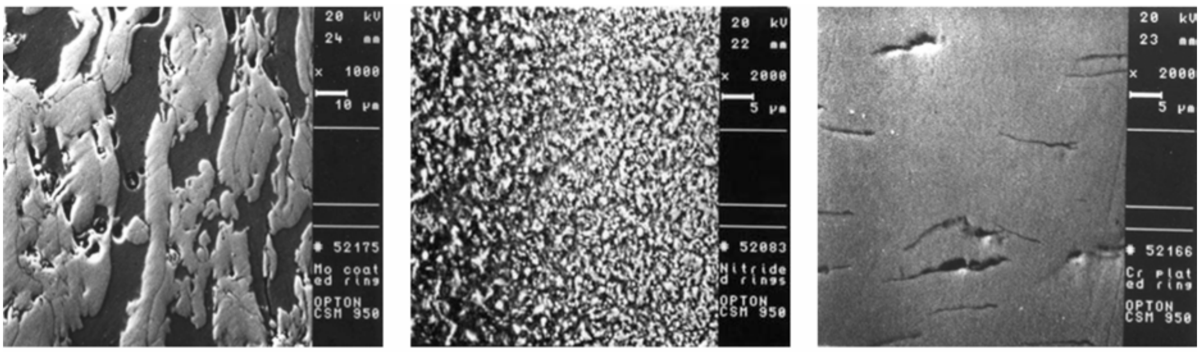
The friction and wear behavior of several functional coatings, Mo-sprayed, nitrided and Cr-plated, in-sliding against grey cast iron at high temperature (320°C) was investigated with an Optimol-SRV test rig. The worn surfaces of the three coatings were observed and analyzed by means of scanning electron microscopy (SEM) and X-ray photoelectron spectroscopy (XPS). It was observed that, when lubricated with lubrication oil (SJ/CF/5W-30) containing molybdenum dithiocarbomate (MoDTC), The nitrided coating shows better friction and wear performances than those of Mo-sprayed and Cr-plated. SEM observations of worn surfaces show that both the wear severity and the wear mechanisms in the contact surface are quite different for the three coatings. XPS analysis of worn cast iron surface indicates that the proportion and kinds of chemical species depend heavily on the coatings types. It is supposed that the better friction and wear behavior for the nitrided coating at 320°C is attributed to the higher content of MoS_2 and other wear-resistant compounds generated on the worn cast iron surfaces.

1. Introduction

The friction and wear behavior of tribomate materials is highly effected by temperature - an important parameter for a tribological system [1, 2]. Mo-sprayed coating, nitrided coating and Cr-plated coating are three kinds of typical piston ring materials in IC engine. In previous works, the tribological behavior of the three coatings at lower temperature (lower than 100°C) were studied [3-5]. In practice, the working temperature for the piston ring is higher and can even reach a temperature of 320°C for the top ring. Therefore, in this paper, the tribological behavior of the coatings of Mo-sprayed, nitrided and Cr-plated at 320°C is investigated.

2. Experimental

Tribological test was carried out with an Optimol-SRV high temperature test rig, wherein the upper specimen is Mo-sprayed coating, nitrided coating and Cr-plated coating, respectively, and their microstructure and property(hardness) are shown in Fig.1 and Table 1, respectively. The lower specimen sliding against the three coatings is made of plain grey cast iron, which has a microstructure of P+F+graphite and hardness of 210Hv.



a) Mo-spayed b) nitrided c) Cr-plated

Fig.1. Microstructural morphologies for three functional coatings

Table 1

Hardness for the three functional coatings

Coating type	Hardness(Hv)
Mo-sprayed	634(Mo region), 972(Ni region)
Nitrided	645
Cr-plated	1259

The test was performed under lubricated condition, and the lubricant used is a fully formulated mineral engine oil(SJ/CF/5W-30) containing molybdenum dithiocarbomate (MoDTC) of 3 wt%. The test temperature was chosen to be 320°C so as to investigate the tribological behaviors of the three coatings at high temperature.

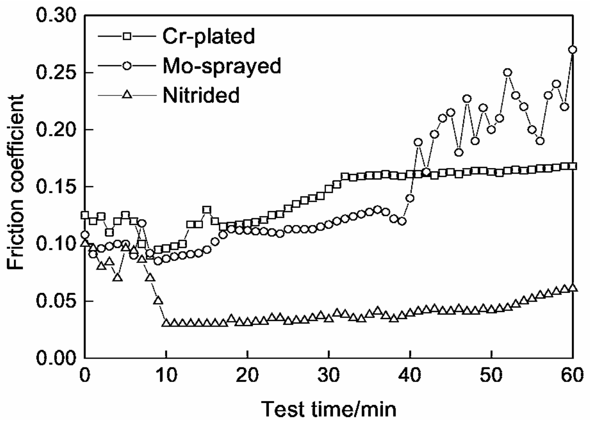


Fig.2. Variation of friction coefficient for the coatings of Mo-sprayed, nitrided and Cr-plated with test duration

During the experiment, the friction coefficient and wear rate are determined. In addition, the morphologies of worn surfaces are observed by means of Opton CSM950 type scanning electron microscopy(SEM) and chemical states of typical elements on the worn surface are analyzed by means of PHI-5300 ESCA type X ray photoelectron spectroscopy (XPS).

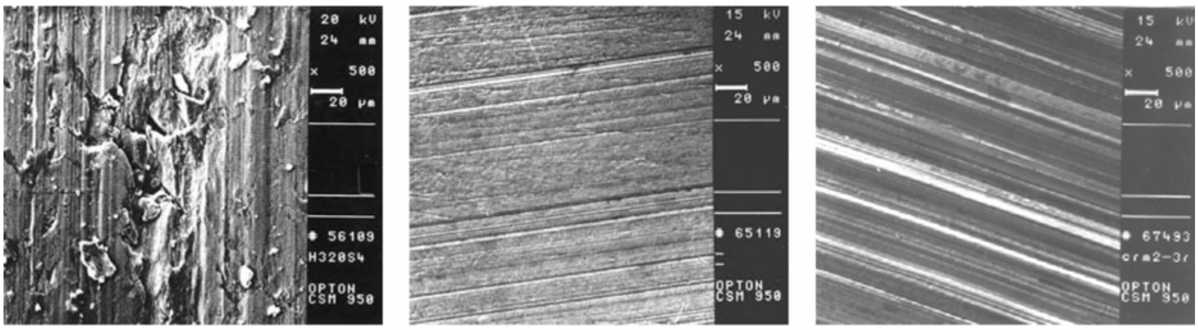
3. Results and discussion

3.1 Tribological results

Fig.2 shows the variation of friction coefficient for the coatings of Mo-sprayed, nitrided and Cr-plated with test duration

It can be seen that, for the different coatings, the variation of friction coefficients with test duration is different. During the whole test duration, the friction coefficient of nitrided coating can be maintained at lower level (0.04-0.05), while the friction coefficient of Cr-plated coating is higher (ca.0.12) and increases gradually with the test time. As for the Mo-sprayed coating, the friction coefficient is also higher and increases with the test time, and begins to fluctuate after 40 min. The results indicate the superior frictional behavior for nitrided coating at 320°C.

In Table 2 is presented the wear rates of the three coatings as well as their tribomates-the lower cast iron specimens.



a) Mo-sprayed b) nitrided c) Cr-plated

Fig.3. Morphologies of the worn surfaces for the three different coatings

Table 2

Wear rates of the three coatings as well as their tribomates-the lower cast iron specimens

Coating types	Wear rate for upper specimen (10^{-4}mm/min.)	Wear rate for lower specimen (10^{-3}mm^3/min.)
Mo-sprayed	4.3	3.4
Nitrided	1.8	1.2
Cr-plated	3.9	3.2

Comparatively, when the nitrided coating is used as the upper specimen, the wear rates of the coating itself and its tribomate are much lower than the coatings of Mo-sprayed and Cr-plated as well as their tribomates, which indicates the better antiwear performance for the nitrided coating.

3.2 SEM observation and XPS analysis of the worn surface

The SEM observations of the worn surfaces for the Mo-sprayed coating, nitrided coating and Cr-plated coating are shown in Fig.3. It can be understood that wear mechanism and wear severity are dependent on the coating types. The wear mechanism for nitrided coating and Cr-plated coating belongs to abrasion. However, the plowings on the worn nitrided coating surface are fine and shallow, while the plowings on the worn Cr-plated coating surface are wide and deep. As for Mo-sprayed coating, the wear mechanism includes abrasion and adhesion.

According to the XPS analysis of the worn surfaces of the cast iron specimens sliding against the coatings of Mo-sprayed, nitrided and Cr-plated. It can be found that there exist XPS spectrum peaks for Fe3p, Mo3d, S2p and P2p on the worn surfaces, and the constituent species include mainly Fe_2O_3, FeO, MoO_3, MoS_2, $FeSO_4$, FeS as well as phosphates, etc.

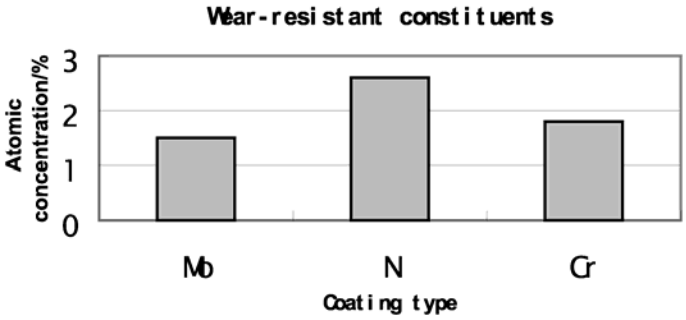


Fig.4. Wear-resistant constituents for three coatings

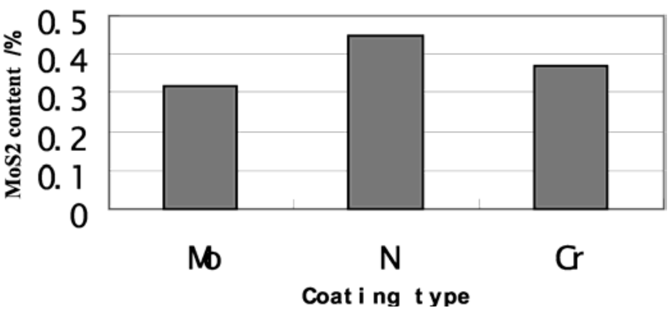


Fig.5 MoS_2 contents on the worn iron surfaces for three coatings

In Fig.4 are presented the comparison of content of MoO_3, FeS and phosphates of superior wear resistance on the worn surfaces of cast iron specimens sliding against the coatings of Mo-sprayed, nitrided and Cr-plated [6, 7]. It can be seen that the higher the content of the MoO_3, FeS and phosphates, the better the wear resistance of the coating (Table 2).

In Fig.5 is presented the content comparison of MoS_2 of excellent antifriction property on the worn surfaces of the cast iron specimens sliding the coatings of Mo-sprayed, nitrided and Cr-plated. According to the comparative results of MoS_2 content and the friction coefficient, it can be deduced that the superior antifriction for the nitrided coating is much related to the more MoS_2 generated on the worn surface of cast iron specimen sliding against the coating.

4. Conclusions

1 Comparatively, the nitrided coating exhibits superior tribological behavior.

2 At 320°C, wear mechanism for nitrided coating and Cr-plated coating are abrasion. However, the wear for Cr-plated coating is much more serious. As for Mo-sprayed coating, wear mechanism including abrasion and adhesion can be observed.

3 The proportion of the main substance species on the worn surface is dependent on the coating types. The superior tribological behavior for the nitrided coating is attributed to the higher content of MoS_2 as well as MoO_3, FeS and phosphates generated on the worn surfaces.

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1- State Key Laboratory of Tribology, Tsinghua University, Beijing 100084
2- School of Materials Science and Engineering, Yanshan University, Qinhuangdao 06604

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