Application of Metal Self-Repairing Additives on Cylinder-Piston Ring Rubbing Pairs

Lei Wang[1] , X.C. Zhou[1]* , Q.Q. Li[1],C.Q. Yuan[1], X.P. Yan[1] ,Y.H. Chen[2]

[1] *Reliability Engineering Institute, Wuhan University of Technology, Wuhan 430063, PR China*
[2] *Yangtze River Waterway Bureau*

ABSTRACT

The metal self-repairing additives can be used in situ auto-repair worn surface of the long-term running machine parts. The basic composition of the metal self-repairing additives was magnesium silicate hydroxide of empirical formula [$Mg_6(Si_4O_{10})(OH)_8$]. The auxiliary components were metallurgical activator and deoxidizer. And this metal self-repairing was applied to a dredger named "HJ18". The effects of the application were analyzed by spectra analysis. The spectral data showed that the running conditions which included running time and lubrication volume, etc had great impact on the formation of the auto-restoration layer. Laboratory experiment showed that there were a series of chemical and physical changes occurred when the magnesium silicate hydroxide of empirical formula [$Mg_6(Si_4O_{10})(OH)_8$] was added into the oil in given conditions, then a certain thickness smooth layer was formed on abrasion surface.

Keywords: Lubrication, metal self-repairing additive, magnesium silicate hydrate, dredger

INTRODUCTION

Lubricant and additive manufacturers were facing many challenges in order to satisfy all requirements both for high performances of fluid-depended machinery and in bionomics and environment friendship[1]. These requirements address creative developments of lubricant formulation technology for achieving both advanced lubrication regimes and positive compatibility with the full fluid-depended system[2,3]. Academia and industry had devoted concentrated effort to develop triboadditives chemistry to enable the targets. Traditional triboadditive family members included oiliness agents, antiwear additives, extreme pressure additives, and friction modifiers. They were integral parts of fully formulated lubricating oils for reduced friction coefficient, lowered wear rate and increased load-carrying capacity[4,5]. To extend the reconditionable damage wear region and avoid the system runs in non-reconditionable region, some metal self-repairing additives as special wear reconditioning additives were needed to develop, so that surface damage wear could be effectively and efficiently reconditioned[6,7], the metal self-repairing additives main constituent was magnesium silicate hydroxide of empirical formula [$Mg_6(Si_4O_{10})(OH)_8$]. And the technique which can be initiated by the tribosystem itself in a real-time manner and in situ in presence of a proprietary worn-damage reconditioner should be nominated as auto-reconditioning technology of worn metal surfaces [8,9].

Presently, the metal self-repairing additives was mainly used in trains, cars and construction machinery. But in ship, especially which with complex and harsh conditions such as dredger, the research and the use of this additives were absent. However, the loss caused by wear and tear in dredger was extremely serious. If the metal self-repairing additives can be added to the lubrication cycle system of dredger's diesel engine efficiently, great significance will be made in the facet of lowering wear, reducing failures and improving the efficiency of the dredger .

EXPERIMENTS

1. Study on dredger

On commission of the Yangtze River Waterway Bureau, the metal self-repairing additives have been added to the dredger named"HJ18" which was being serviced in Qingdao. Table 1 showed the case of all the diesel engine of this dredger.

Table 1 The case of all the diesel engine of the "HJ18"

Item	Propulsion Diesel Engine	Dredging Pump Diesel	Generator
number of cylinders	6	8	12
cylinder bore	240	160	128
power (Kw)	1200	640	329
speed (rpm)	600-1000	930	1500
lubrication volume (L)	950	310	55
lubrication brand	CD40	CD40	SAE40
lubrication consumption (kg/h)	≤0.8+10%	0.55-0.60	0.50-0.60
exhaust temperature (℃)	340-360	430-450	390-410

The lubrication brand of the propulsion diesel engine and the dredging pump diesel were CD40 which was manufactured by GW Co. Correspondingly, and that of the generator was Castrol SAE40. The metal self-repairing additives which produced by OS Co. have been blended in a traditional lubricant with a 1‰ dose according to the manual. The used lubrication in the dredger has been replaced by new lubrication in order to avoid other factors (such as water and the failure lubricants and so on) influencing the result before the experiment. The new lubricant brand shown in table 1.

* Corresponding Author

The used lubrication was analyzed by spectral analysis, the contents of Fe, Cr, Mg, Al can be easily quantified in 30 seconds. The spectral data of port engine oil (added the metal self-repairing additives) and starboard engine oil (not added) were recorded automatically during analysis course. The difference between the two engines' oil can be easily seen according to the spectral data. In the same way, the difference between the oil of generator 2(added) and generator3[#] (not added) can be obtained. More over, this additive also had been added in dredging pump diesel lubrication in order to study its effect under harsh conditions. The oil had been sampled by professionals every 15 days , and there were eight times in all.

2. laboratory experiment

In order to study the influence of operating conditions on formation of the reconditioned layer, the pin-on-disk tester (MMW-1) was used to do the friction and wear experiment in Lab, The results showed that a certain thickness smooth layer was formed on abrasion surface in given conditions, but the micro-crack and the micro-pores still exist.

The experimental materials were Cast Iron(for disk) and 35 $^{\#}$Steel(for pin). The disk was 10 mm thick, with external diameter of 54 mm and inner diameter of 38 mm, with hardness of 42~52.8 HRC and surface roughness of 0.76~1.07 μm. The pin was ϕ4.8×12.7 mm and with surface roughness of 0.8~1.02 μm. The lubrication brand was SAE40 with a flash point of 232℃and a pour point of -20℃.

The disk and pin were cleaned by propanone firstly, then labeled, dried and weighed. Its surface feature can be obtained by Optical Microscope. The samples were divided into two groups, observation group(added the self-repairing additives) and control group(not added), and the total wear time was 3h. After completed the experiments, Optical Microscope was used to observe the surface feature again and find the differences.

DISCUSSION

1. The results of the real ship test

New lubricant's spectral data were shown in Table 2. All the contents of elements were low(Fe≤1.8ppm, Cr≤0.5ppm, Al ≤1.4ppm,Mg≤4.9ppm) except the content of Mg in Castrol SAE40 lubricant (257ppm).

Table 2 The spectral data of the new lubricant

ITEM \ ELEMENT	Fe	Cr	Mg	Al
Great Wall CD40	1.8	0.1	4.9	1.4
Castrol SAE40	0.6	0.5	257	0.8

Figure 1 was the test data comparison between port engine(added the self-repairing additives)oil and starboard engine(not added)oil , the results displayed that the wear rates rose gradually, but the port engine oil had higher contents of Fe, Cr, Mg, Al than the starboard oil. In port engine oil ,the contents of Fe, Al rose from 20ppm to 43.2ppm and from 6.9ppm to 11.4ppm gradually; respectively, in starboard engine oil ,the two elements rose from 12.7ppm to 32.5ppm and from 4.6ppm to 9.3ppm. The rising curve of two elements in the port engine oil was consistent with the starboard engine oil. However, the contents of Cr, Mg changed differently: in the port engine oil, the Cr content increased rapidly up to 9.2ppm on the fourth sample then changed smoothly, and the Mg content presented vertical line ascending and up to 315ppm; in the starboard engine oil, the contents of the Cr, Mg were showed an steady increasing tendency, and at the eighth sample reached their maximum(Cr≤5.3ppm,Mg≤127ppm). This difference was caused by adding of the self-repairing additives into the oil.

From table 1, the conclusion was reached that the metal self-repairing additive didn't function obviously in the port engine oil. Because the lubrication volume size was too large and the effective composition of the additives couldn't circulate sufficiently in the lubricant cycle system, the self-repairing additives were too low to work effectively.

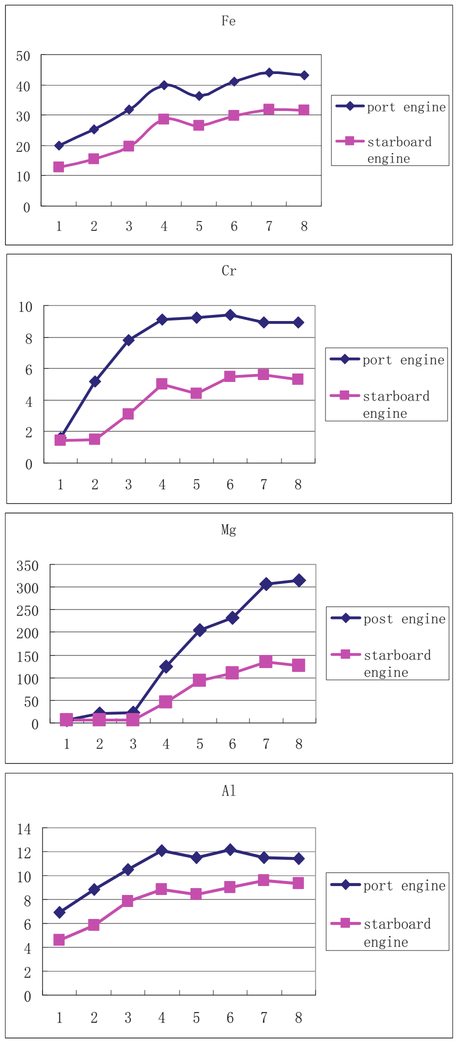

Fig. 1 The spectral data comparison between port engine oil and starboard engine oil

Figure 2 was the spectral data comparison between generator2$^{\#}$ oil(added) and generator3$^{\#}$ oil(not added), and the content curves was quit irregularly, especially in the generator3$^{\#}$ oil which did not add the self-repairing additives. In the generator3$^{\#}$ oil, the contents of the Fe, Cr, Al rose steeply, and at the fifth sample reached their maximum(Fe≤129ppm, Cr≤8.6ppm, Al≤22.2ppm); on the contrary, in the generator2$^{\#}$ oil, the Fe, Cr, Al contents were low and changed little(Fe ≤ 33.4ppm, Cr ≤ 4.1ppm, Al ≤ 10.6ppm), which means that the wear of the generator2$^{\#}$ changed smoothly. However, these elements contents decrease sharply at the sixth and seventh sample separately in the 2$^{\#}$ and 3$^{\#}$generator's oil . The major cause was that new lubricants had been added into the two lubrication systems separately before the two samples.

The content of Mg were not significantly changed, and stayed in a range of 233~276ppm, according to the table 1 and table 2,the content of Mg came from Castrol SAE40 lubricant.

It was easy to see the element contents in the oil of generator2$^{\#}$ (added) were lower than generator3$^{\#}$ (not added),because the contents of self-repairing additives were enough to exhibit restorative effects and came to the conclusion that the metal self-repairing additives showed better function on the generator.