

# Anti-wear Mechanism Analysis of Nano-CaCO<sub>3</sub> Additives

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**Abstract:** In this paper, the wear test was carried on with cylinder piston by the wear test device, receiving the results of the piston ring wear and abrasive characteristics by monitoring the wear process, the thesis analysis and put forward the nano-CaCO<sub>3</sub> lubricating oil additive anti wear mechanism by the ferrography analysis technology, and provide the technical reference for the relevant measures to reduce wear and the friction, and provide reference value for further study on the related theories of reducing wear and reducing friction.

## 1 Preface

Internal combustion engine is the most important power machinery, which is widely used in all walks of life, such as aviation, railways, machinery[1]. With the rapid development of production practice, the wear of internal combustion engines is diversified and the degree of wear is getting deeper and deeper. with the rapid development of nanotechnology, nonmaterial have the characteristics of small size, large specific surface area, quantum effect, quantum tunneling effect and interface effect[2]. The application of nonmaterial in tribology has become an important research topic of nanoscale tribology[3]. And we can analyze the characteristics of abrasive grain by the ferrography analysis technology. It has strong explanatory for the fault diagnosis of lubrication and wear. It is an important method for the study of lubrication theory [4].

## 2 The Wear Test

Taking the piston-cylinder produced by a combustion engine factory as the test object (hereinafter referred to as piston-cylinder, model 4100QB). The domestic Kunlun lubricating oil was used as the lubricating condition, we can analyze the characteristics of abrasive grain and the wear of piston in the three wear period by the ferrography analysis technology and analyze the influence of nano-CaCO<sub>3</sub> lubricant additive on wear from macroscopic and microscopic perspectives.

## 3 The Analysis of Wear

### 3.1 The Wear Test without Adding Nano-CaCO<sub>3</sub> Additive

The specifications of the lubricant oil used in the test are shown in Table 1.

**Table 1** the condition during the wear of cylinder

Load and speed 1Kg and 270r/min	Lubricant oil CD 20W-50	the type of lubricant oil CD 20W-50
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In the case of fixed test conditions, the changes of the wear of piston changing with time are shown in Table 2.

**Table 2** the Wear of Piston

time (min)	30	60	100	200	300	400	600	800	1000	1200
piston(mg)	2.0	4.0	8.7	11.4	11.1	11.6	19.3	23.2	30.0	38.0

The specifications of the lubricant oil used in the test are shown in Table 3.

### 3.2 The Wear Test with Adding Nano-CaCO<sub>3</sub> Additive

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**Table 3** the Condition during the Wear of Cylinder

Load and speed 1Kg and 270r/min	Lubricant oil CD 20W-50+1%CaCO <sub>3</sub>	the type of lubricant oil CD 20W-50
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In the case of fixed test conditions, the changes of the wear of piston changing with time are shown in Table 4.

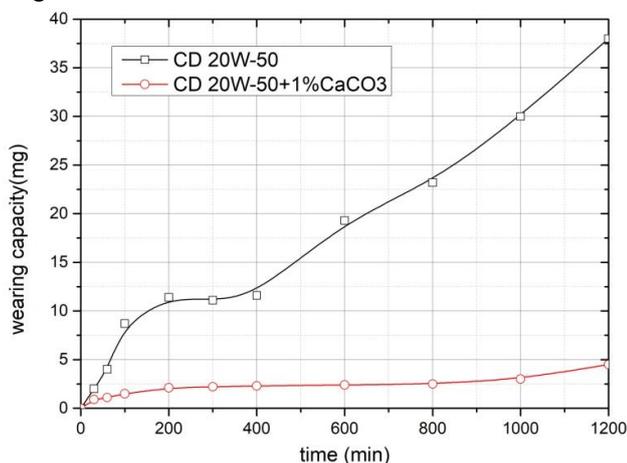
**Table 4** the Wear of Piston

time (min)	30	60	100	200	300	400	600	800	1000	1200
piston(mg)	0.9	1.1	1.5	2.1	2.2	2.3	2.4	2.5	3.0	4.5

### 3.3 Comparatively analyze the curve of wear under two kinds of lubrication conditions

Figure 1 shows the time-wear curve under the Kunlun engine oil without adding additive and adding CaCO<sub>3</sub>. From the figure 1, the two curves far away, the wear station is far difference. From the wear period, the first 60 minutes is the run-in stage under the condition

with adding CaCO<sub>3</sub>, froming 100 minutes is the stable wear period, and after 1000 minutes is the serious wear period. Under without additive, the first 100 minutes is the run-in period, stable wear period is shorter from 200 minutes to 600 minutes. From the analysis of the amount of wear, the addition of nano-CaCO<sub>3</sub> greatly changes the amount of wear, which is about 1/6 of that of the non-additive.



**Figure 1** the time-wear curves under the conditions of CD 20W-50 and CD 20W-50+1%CaCO<sub>3</sub>

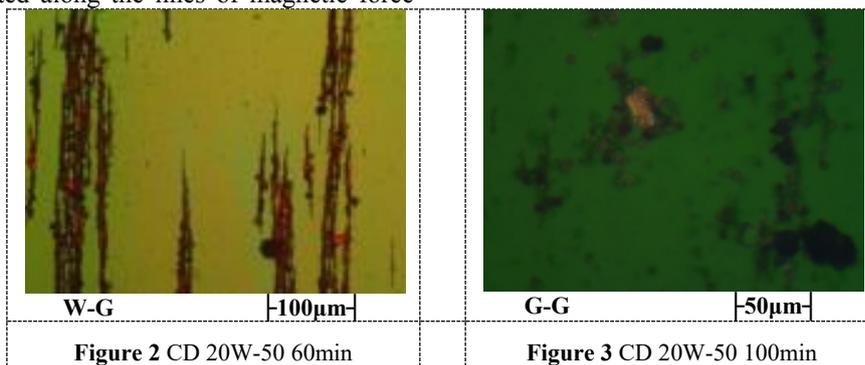
## 4 Ferrography analysis of adding Nano-CaCO<sub>3</sub>

### 4.1 The ferrography analysis in run-in period

The following figures are the fields of abrasive grains in run-in period which under the condition of adding nano-CaCO<sub>3</sub>. In the following figures, the abrasive grains are evenly distributed along the lines of magnetic force

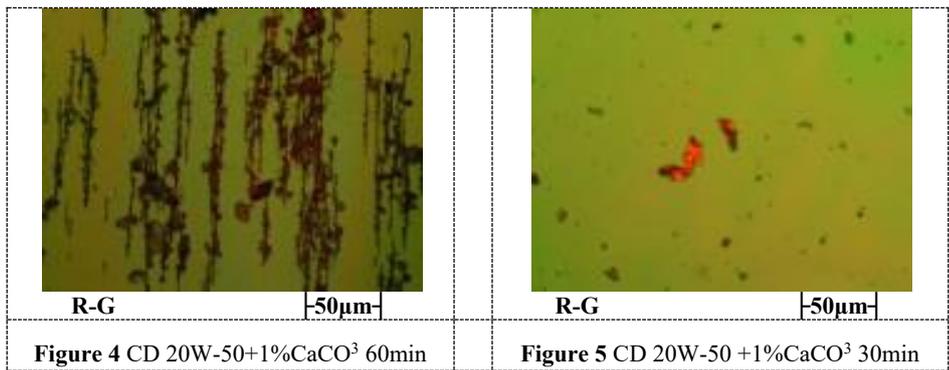
and catenary, and the red pellets Fe<sub>2</sub>O<sub>3</sub> and the black abrasive grains Fe<sub>3</sub>O<sub>4</sub> appear.

By comparing the characteristics of wear particles without adding additive and adding CaCO<sub>3</sub> additive, it can be seen that the magnetic lines of force with CaCO<sub>3</sub> additive are less than those without additive, as shown in Figure 2 and Figure 4. The typical grain size is also about 5μm smaller than the typical grain size without CaCO<sub>3</sub> additive.



**Figure 2** CD 20W-50 60min

**Figure 3** CD 20W-50 100min

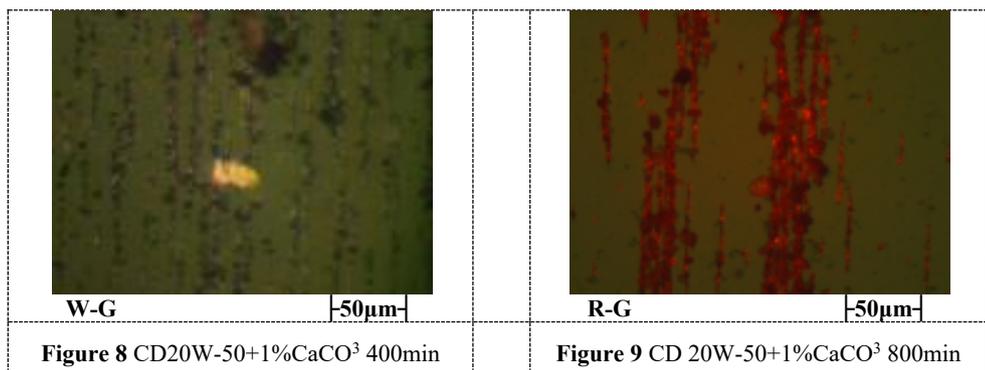
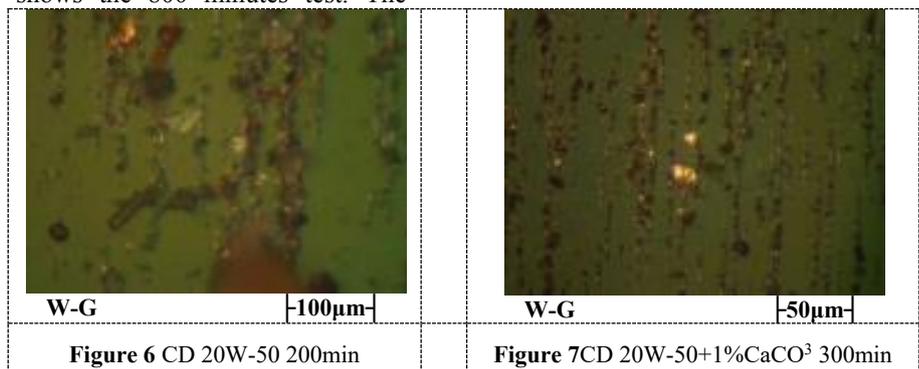


**4.2 The ferrography analysis in stable wear period**

Figure 6 shows the field of abrasive grains without additive at 200 minutes. In Figure 7 and Figure 8, typical large abrasive grains can be clearly seen along the lines of magnetic force. The abrasive grain surface is smooth. In Figure 7, the large abrasive grain size is about 10µm and the edge of the abrasive grain is irregular. Figure 8 shows the test results for 400 minutes. In the Figure 8, the large abrasive grain size is about 15µm. The large abrasive grain has a straight edge and the other edges are irregular. Figure 9 shows the 800 minutes test. The

abrasive grains accumulate more chains, and the amount of friction polymer increases.

The entire stable wear period, uniform and slender magnetic lines, abrasive grains sizes range are not large, there are only a few large abrasive grains. By comparison, it can be found that the abrasive grains with adding additive all need to be more than 200 times in order to observe the large clear field of abrasive grains. And the typical large abrasive grains can be observed after 500 times the field. During this period, the large abrasive grains sizes with additive were about 10µm-15µm while the typical large abrasive grains with no additive were about 15µm.



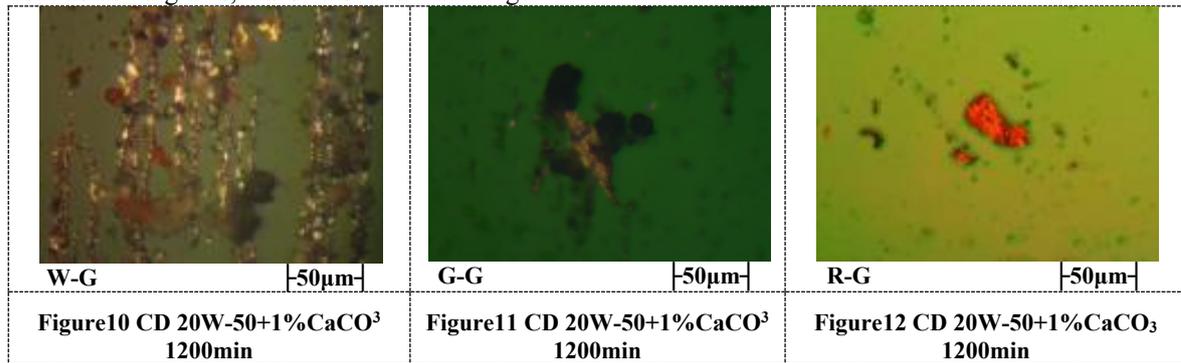
**4.3 The ferrography analysis in serious wear period**

Figure 10 is a spectrogram of 200 times field of adding nano-CaCO<sup>3</sup> additive to Kunlun oil. It can be clearly seen that there are many friction polymers, and there are many chains of abrasive grains, their surfaces are smooth. And large abrasive grains appear more.

At 1200 minutes of testing, as shown in Figure 10, a 200x field clearly shows that the chains of abrasive grains grow larger and larger, the sizes of the larger abrasive grains increase, and the presence of friction polymer occurs. Fatigue spalling grains appear in the magnetic flux as shown in Figure 11. The surface of the abrasive grains is relatively flat and thick. Fatigue spalling grains are mainly caused by pitting corrosion on the friction surface, causing the metal material to be spalled. Initially, only the microscopic peeling, with the

continuance of wear, one after another macroscopic peeling until the wear failure. Figure 12 is the serious sliding wear abrasive grains, the size of them are larger

than 15 $\mu\text{m}$ , the surfaces of abrasive grains have serious scratches, and have temper stain.



### 5 Anti-wear Mechanism Analysis of Nano-CaCO<sub>3</sub> Additive

During the process of friction, the nano-CaCO<sub>3</sub> in the lubricating oil are affected by two factors resulting in their migration of the frictional contact surface [5]. First, the local high temperature generated in the process of friction makes the molecular weight greater than that of the bulk phase, and these strong molecular fluctuations occur non-directional migration, thus they increase the chances of nano-CaCO<sub>3</sub> migrating to the frictional contact surface. Second, the frictional contact surface produces an interfacial electric field such as an escape electron that enhances the frictional surface, and the enhanced interface electric field produce enhanced magnetic field. Due to the presence of weak electromagnetic field and the adsorption of nano-CaCO<sub>3</sub> surface extremely strong, so the nano-CaCO<sub>3</sub> more easily

enriched in the bad contact surface of liner - piston, shown in Figure 13. Due to its small particle size and high surface energy [6], nano-CaCO<sub>3</sub> form a layer of physical adsorption film on the frictional contact surface just before the friction begins. The adsorption layer is oriented perpendicularly to the frictional contact surface, and has strong adhesion.

As the local friction temperature increases slowly, due to the nano-CaCO<sub>3</sub> has a very high pressure, even if aboving adsorption temperature of the adsorption layer will not be destroyed. When the temperature continues to rise to a certain temperature, the elements in the nano-CaCO<sub>3</sub> penetrate into the friction surface or the friction sub-surface and form a solid solution with the liner of the liner-piston, and at the same time chemical reaction forms a thin wear-resistant chemical reaction layer, Figure 14. Thus they improve the anti-wear and anti-wear lubricating oil performance.

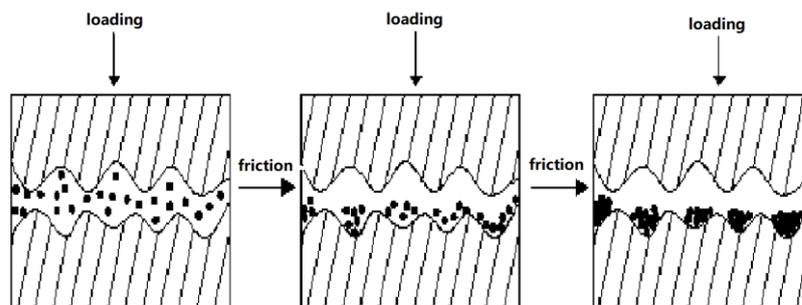


Figure13 an example of enrichment effect of nano-CaCO<sub>3</sub> on the friction surface

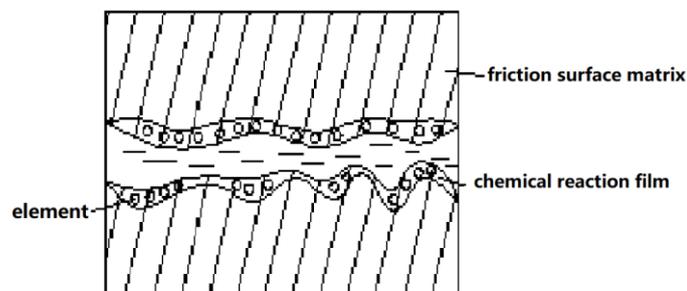


Figure14 an example of the effect of nano-CaCO<sub>3</sub> formation chemical reaction membrane

## 6 Conclusion

Based on the wear test of nano-CaCO<sub>3</sub> as a lubricating oil additive, based on the nano-material science and tribology, the anti-wear mechanism of the nano-CaCO<sub>3</sub> lubricant additive was studied and analyzed based on the characteristics of the abrasive particles. The results show that compared with the lubricating oil without nano-CaCO<sub>3</sub>, the lubricity of nano-CaCO<sub>3</sub> is greatly improved and the wear loss is significantly reduced, which greatly improves the lubrication condition of the cylinder-piston ring.

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## References

1. ZL Cui, ZK Zhang. *Nanostenet. Mater.* 1996.7 (3):355-361
2. Kaufman R E. Remaining Useful Life Measurements of Diesel Engine Oils, Automotive Engine Oils, Hydraulic Fluids, and Greases Using Cyclic Vohammetrie Methods[J]. *Lub Eng*, 995:51(3)
3. Kaufman R E, Rhine W E. Assessment of a Remaining Lubricant Life[R]. Report No. AFWALTR-86-2024, November, 1986
4. Xiaohan Liang et al. *Ferrography and its application in mechanical monitoring and diagnosis*. Beijing: China Communications Press, 1993.10
5. Zhang E et al. *Ferrography and its industrial application*. Xi'an: Xi'an Jiaotong University Press, 2001.10
6. L Rapoport, M Lvovsky, I Lapsker, et al. Friction and wear of bronze powder composites including fullerene-like WS<sub>2</sub> nanoparticles. *Wear*, 2001, 249:150-15706. (in Chinese)