STUDY ON TRIBOLOGICAL MODIFICATION APPLIED ULTRA-DISPERSED DIAMOND AS AN OIL ADDITIVE WITHIN PROCESS RUNNING-IN FOR IC ENGINE

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SUMMARY
In this paper, focus on the EQ6100 engine (a kind of Chinese engine), the whole process of running-in has been respectively conducted on the KT-300 tests rig making use of a special running-in oil (coded as MR-oil) applied ultra-dispersed diamond (UDD) and normal 15W/40 oil. The properties of the surface of cylinder-piston ring were determined by Talyurf-6, scanning electron microscopy (SEM) and energy dispersive analysis X-ray (EDAX) in order to investigate the mechanism of running-in and modification. The results of testing indicate that UDD can take effect to accelerate running-in process, divide and reduce bulk of iron filings in running-in oil and prevent big hard particles from scratching cylinder bore into oil. Owing to nanoscale of UDD particles in MR-oil, the ball-bearing effect of diamond nanoparticles existed between the rubbing faces to polish surface of cylinder, ant-wear and reduce friction.

Keywords: Tribological modification, Solid Lubricant, Engine, Running-in

1 INTRODUCTION
Running-in is an necessary process before starting the normal operation of new engine. A number of papers concerning running-in have been published in recent decades [1-3]. In recent years, there has been considerable concerning on the effectiveness of solid powdered as an additive in oil [4-6]. The ultra-dispersed diamond (UDD) particles synthesized by the detonation of explosives with negative oxygen balance constitute a new nano-materials with practical value [7-8]. Figure 1 is a transmission electron microscopy (TEM) picture of ultra-dispersed nanoparticles synthesized by the detonation of explosives.

Figure 1. A TEM picture of diamond nanoparticles

It can be found that these nanoparticles have an average size of 5 nm, commonly exhibiting spherical or polyhedral shape.

In this paper, focus on the EQ6100 engine, the process of running-in has been respectively conducted on test rig of engine making use of a special two-phase lubricant oil (coded as MR-oil) applied UDD and normal 15W/40 oil as running-in oil. The tribological properties of UDD particles as an oil additive were investigated with Talyurf-6, scanning electron microscopy (SEM) and energy dispersive analysis X-ray (EDAX). The mechanism of modification and reduction of wear and friction by UDD particles was discussed.

2 EXPERIMENTAL DETAILS
For the sake of contrast, two groups of running-in experiment for EQ6100 engine were conducted on KT-300 test rig. 15W/40 oil and MR-oil was respectively used as lubricant for the engine’s running-in. The properties of the surface of cylinder-piston ring were determined by Talyurf-6, scanning electron microscopy (SEM) and energy dispersive analysis X-ray (EDAX) in order to analyze and investigate the mechanism of running-in and modification for the tribo-pair of cylinder-piston ring.

3 RESULTS AND DISCUSSION

3.1 Variation in Surface Roughness of Cylinder
The variation in the cylinder surface roughness ($R_a$) during running-in process is given in table 1. It can be found that the roughness in the cylinder surface applied MR-oil as running-in oil is improved more significantly than the other.

<table>
<thead>
<tr>
<th>Oil sample</th>
<th>Survey position</th>
<th>Roughness $R_a$ in cylinder/$\mu$m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Before running-in</td>
<td>After running-in</td>
</tr>
<tr>
<td>15W/40 TDC</td>
<td>1.01</td>
<td>0.95</td>
</tr>
<tr>
<td>BDC</td>
<td>0.98</td>
<td>0.94</td>
</tr>
<tr>
<td>MR-oil TDC</td>
<td>0.99</td>
<td>0.78</td>
</tr>
<tr>
<td>BDC</td>
<td>1.02</td>
<td>0.85</td>
</tr>
</tbody>
</table>

Table 1:

3.2 Variation in Cylinder Pressure and friction power consumption
The variation in the cylinder pressure ($P$) and friction power consumption ($W$) during running-in process is
given in table 2. These results indicate that UDD particles as an additive in MR-oil can polish the cylinder bore to strengthen cylinder pressure and reduce friction between rubbing surfaces.

<table>
<thead>
<tr>
<th>Oil sample</th>
<th>Cylinder pressure ( P ) / kPa</th>
<th>Friction power consumption ( W/N \cdot m )</th>
</tr>
</thead>
<tbody>
<tr>
<td>15W/40</td>
<td>Before running-in: 827</td>
<td>After running-in: 856</td>
</tr>
<tr>
<td></td>
<td>Before running-in: 38.81</td>
<td>After running-in: 37.93</td>
</tr>
</tbody>
</table>

3.3 SEM Image of Cylinder Surface

Figure 2 and figure 3 presents the SEM images of cylinder surface during the running-in process. The SEM results indicates that MR-oil exhibit a beneficial effect by reducing the time of running-in and making a high quality of cylinder surface. This result is in line with the variation in surface roughness \( R_a \) of cylinder, cylinder pressure \( (P) \) and friction power consumption.

3.4 EDAX Profile of Cylinder Surface

Figures 4 ~ 6 show that EDAX profile of specimen surface of cylinder during the running-in process. From figure 5, it can be found that carbon element in surface of cylinder after 45 min running-in by MR-oil was expanded significantly, implying that UDD particles in MR-oil can penetrate into the cylinder surface owing to their nanoscale to ameliorates the composition of surface of cylinder and improves the tribological property of cylinder surface.
4 CONCLUSION

UDD particles in MR-oil can penetrate into the rubbing surface of cylinder to improve the tribological property of cylinder surface within running-in process owing to their nanoscale. Under boundary lubricating condition, the particles not only possesses excellent load-carrying capacity, anti-wear and friction-reduction properties but also polish and inlaid into the surface of cylinder and form a thin boundary lubricating film of UDD particles to prevent the rubbing faces from direct contact. MR-oil also plays a notable role in accelerating running-in process, improving running-in quality and tribological properties of the surface of cylinder. However owing to nanoscale of spherical or polyhedral shape UDD particles, the ball-bearing effect of diamond nanoparticles existed between the rubbing faces.

5 REFERENCE