Effect of EUP Injection Parameters on the Combustion Characteristics of Diesel Engine

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Abstract. With the increasingly stringent requirements for energy conservation and emission reduction of diesel engine, electronic control of diesel fuel injection system is necessary. EUP (electronic unit pump) can precisely control the fuel injection process which can reduce the exhaust emission and fuel consumption effectively. In this paper a EUP diesel engine is used as the research object. Through the combination of simulation and experiment, the effect of injector diameter and injection timing on the combustion of the engine is studied. The results show that the above parameters have an important effect on the gas mixture formation and combustion process of the diesel engine in the cylinder. By selecting the appropriate parameters, the optimized diesel engine can meet the non-road national stage III emission regulation.

Instruction

With the increase of environmental pollutants, more stringent emission regulations are enacted in many countries. Injection parameters affect the combustion performance characteristics of the engine greatly. The use of advanced injection timing can reduce CO₂ and HC emissions and increase NOₓ emissions[1-3]. Optimizing the spray characteristics by changing the nozzle geometry is a good way to improve combustion [4-6]. In this study, a EUP diesel engine is used as the research object to investigate the effect of injector diameter, injection timing on the combustion characteristics.

The Description of Simulation Model

Calculation Target

In this study, a non-road four-cylinder turbocharged intercooled diesel engine is researched, and the main parameters are shown in Tab. 1.

Calculation Model

According to the practical parameters of the diesel engine, the combustion chamber calculation grid model of the diesel engine is built by FIRE software[7-9].

In order to verify the accuracy of the model, the comparison of the indicator diagram is an effective method. Figure 1 is the comparison of simulation and measured indicator diagram at the maximum torque speed 1800 r/min, 100% load. The simulation results and the measured results are basically consistent. This shows that the model can be used to simulate the combustion process of diesel engine cylinder.
Table 1. Main parameters of diesel engine.

<table>
<thead>
<tr>
<th>Program</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Four-stroke, DI, Turbocharged intercooled</td>
</tr>
<tr>
<td>Bore (mm)×Stroke (mm)</td>
<td>108×118</td>
</tr>
<tr>
<td>Total displacement(L)</td>
<td>4.324</td>
</tr>
<tr>
<td>Rated Power (kW)/Rated speed(r/min)</td>
<td>73/2400</td>
</tr>
<tr>
<td>maximum torque (N·m)/Speed(r/min)</td>
<td>360/1800</td>
</tr>
</tbody>
</table>

![Figure 1. Comparison of calculated and measured indicator diagram.](image)

**Simulation Results and Analysis**

**Effect of Injector Diameter on the Combustion Performance**

Figure 2 shows the effect of different injector diameters on the fuel/air equivalence ratio distribution at 364 °CA, from left to right is 0.22 mm, 0.24 mm and 0.26 mm. A larger area of fuel mist appeared at the depth of the combustion chamber at 0.26 mm. This is because that with the injector diameter becoming larger, the jet distance would be longer, which may cause more fuel to spray to the combustion chamber sidewall.

![Figure 2. Fuel/air equivalence ratio distribution of different injector diameters.](image)

As can be seen from Figure 3 (a), the peak value of the in-cylinder pressure gradually increases as the injector diameter decreases. This is because the smaller the diameter of the injector, the smaller the droplet diameter of the injector, which is conducive to the mixing of fuel and air. Figure 3 (b) shows that with the decrease of injector diameter, the peak of the cylinder temperature increases. After considering, the injector diameter selected for the further bench test is around 0.24 mm.

![Figure 3. Comparison of in-cylinder pressure and mean temperature with different injector diameters.](image)
Effect of Injection Timing on the Combustion Performance

The combustion process is simulated at 1800 r/min, 75% load and SOI (start of injection) timing is selected as 6°CA, 10°CA and 14°CA BTDC, respectively.

Figure 4 shows the effect of injection timing on the average turbulent kinetic energy in the cylinder. With the increase of the injection advanced angle, the turbulent kinetic energy in the cylinder increases and the turbulence energy reaches the peak earlier. As the fuel spray changes the mixing state of the fuel and air in the cylinder, the ignition timing changes. When the fuel SOI timing is 6°CA BTDC, the time that the average turbulence energy reach the peak is delayed, which may cause the post-combustion.

As can be seen from Figure 5 (a), the peak value of the in-cylinder pressure increases with the advancing injection timing. When the SOI timing is 14°CA BTDC, the peak value of in-cylinder pressure is 11.6 MPa, and the peak value of the in-cylinder pressure at SOI timing 6°CA BTDC has a significant drop of only 9.3 MPa. From the Figure 5 (b), the peak value of the cylinder mean temperature increases with the advancing injection timing. After considering, we select the injection timing varying from 10 to 14°CA BTDC for further bench test study.

Emission Test with Optimized Engine

A steady-state cycle test under eight work conditions was carried out in a national certification emission laboratory. The test results are shown in Tab. 2.

The emission performance had been significantly improved after optimization of diesel engine. Emission values measured by steady-state cycle test under eight work conditions were less than emission restriction of national stage III emission standard.

<table>
<thead>
<tr>
<th>Contaminants</th>
<th>CO</th>
<th>HC+NOX</th>
<th>PM</th>
</tr>
</thead>
<tbody>
<tr>
<td>national stage III emission limit [g/kW·h]</td>
<td>5.0</td>
<td>4.7</td>
<td>0.4</td>
</tr>
<tr>
<td>Test results [g/kW·h]</td>
<td>0.494</td>
<td>4.417</td>
<td>0.159</td>
</tr>
</tbody>
</table>

Conclusions

(1) With the decrease of the injector diameter, the average turbulent kinetic energy in the cylinder gradually increased, which improved the mixing of fuel and air. The combustion was more sufficient, which caused the peak value of the in-cylinder pressure and the cylinder temperature increasing.
(2) The average turbulence energy in the cylinder rose with the increase of the injection advanced angle, and the peak value was also advanced. The mixing of the fuel and air was more homogeneous and the combustion process was optimized. The peak value of the in-cylinder pressure and the cylinder temperature also increased. But the fuel consumption was increased and the power was reduced.

(3) The steady-state cyclic discharge test was carried out on the optimized and improved diesel engine. The measured emission values were in accordance with the non-road emission standards.

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Reference