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The Impact of Common Rail System's Control Parameters on the Performance of High-power Diesel

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Abstract

The effect of common rail system's injection timing and rail pressure on high-power diesel's fuel economy and emission characteristics has been studied through tests. The experimental results show that with the rail pressure increasing, fuel economy and smoke are improving, while NO_x is deteriorating. However, as rail pressure very high, the improving trends of smoke and fuel economy are not obvious terribly, and even at low load condition, the economy will decline instead. With injection timing delayed, NO_x is reducing while smoke and fuel economy are augmenting at the conditions of high load. However, at the low load conditions, with injection timing lagging, smoke and NO_x will decline simultaneously.

Keywords: diesel;Diesel;high pressure common-rail; emission; timing; pressure

1. Introduction

Electronic control high pressure common rail system has the advantages of high injection pressure and flexible injection parameters (pressure, timing, and fuel quantity). It becomes the preferred choice for the advanced diesel engine with low noise, low emission and low fuel consumption [1].

When the fuel enters into the cylinder with different injection timings and injection rates, the combustion results will vary widely [2-3]. Comparing with traditional inline pump system, high pressure common rail fuel system has higher injection pressure and smaller nozzle diameter, so spray diameters become smaller and the interface between air and fuel is expanded significantly. Due to spray's entrainment effect on its surrounding air caused by high-speed fuel beam, the mixing is accelerated greatly and more uniform. Hence, ignition delay is shortened and ignition location transfers to the front of the spray, so the combustion process is different from the traditional direct injection diesel engines[4].When

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high-power diesel matches with common rail system, the single injection time is mainly used, thus the rail pressure and injection angle are the major control parameters. This work will discuss the influence of the two parameters on the high-power diesel with common rail system.

2. Test Equipment

The tests are carried out in a 6-cylinder turbocharged diesel engine. Its parameters are shown in Table Ⅰ.

Exhaust gas is measured by adopting Horiba MEXA-7100DEGR and AVL415 smoke meter. Fuel consumption meter is AVL735 and dynamometer is CAC450. Through the calibration software of ETAS, the parameters in ECU are adjusted.

TABLE I. The Parameters of The Diesel

Rated speed	1900rpm
Rated power	276kW
Maximum torque/Speed	1630Nm/1200-1500rpm
Idle speed	600rpm
Bore/stroke	126/155mm
Compression ratio	17：1
Number of valves	4
Number of nozzles	8
nozzle diameter	0.19mm
Injection angle	145°
Injection system	BOSCH CR system

3. Experimental Results and Discussion

3.1 The Affection of Rail Pressure

Maintain the engine speed at 1000 r/min, injection angle at 0 °, and output torques at 400Nm, 1000Nm and 1500Nm respectively. Fig. 1 to Fig. 3 show the corresponding test results of fuel consumption, smoke and NOx at different rail pressures.

As shown in Fig. 1, when loads are 1000Nm and 1500Nm, brake specific fuel consumption (BSFC) firstly has a rapid drop with rail pressure augmenting. It is due to that high rail pressure is benefit to atomize fuel and form high-quality combustible mixture, which can reduce diffusion combustion duration. Hence, the thermal efficiency enhances and the economy improves significantly. When the rail pressure exceeds 1200bar, the drop trend of BSFC is slowly. It indicates that as the rail pressure increasing, the improvement of the BSFC is no longer distinct. Under 400Nm the influence of rail pressure on BSFC is more complex. When rail pressure more than 800bar, the BSFC is deteriorated on the contrary. It is because exorbitant fuel injection pressure is over the match scope of combustion chamber, and mural fuel is so much that economy becomes worse instead at low load condition.

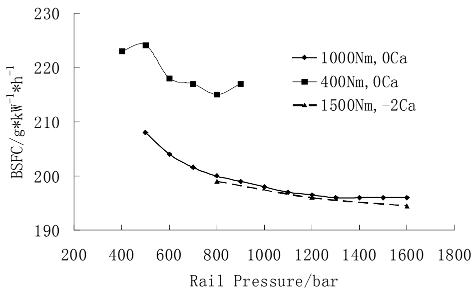

Figure 1. BSFC at different rail pressures

With rail pressure increased, a continuous decline of smoke appears in Fig. 2. Higher injection pressure makes spray particles more exiguous, enlarges the interface between fuel and air, and shortens the evaporation time. Besides due to spray's entrainment effect on its surrounding air caused by high-speed fuel beam, the formation of mixture is accelerated greatly and its distribution is more uniform. Thereby the particulate matter is reduced. But when the injection pressure is too high, the soot emission doesn't improving significantly.

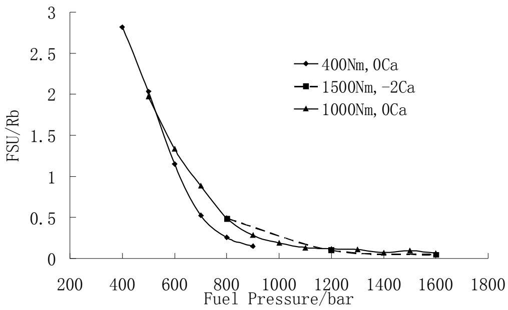

Figure 2. FSU at different rail pressures

NOx always increases markedly with pressure increasing in Fig. 3. Because higher rail pressure can bring about that pre-mixture during ignition delay increases, oxygen-rich region is expanded and pre-mixed combustion is promoted. Burning is improved further. Both the peak of heat release rate and the in-cylinder temperature go up that conduces a corresponding increase in NOx emissions.

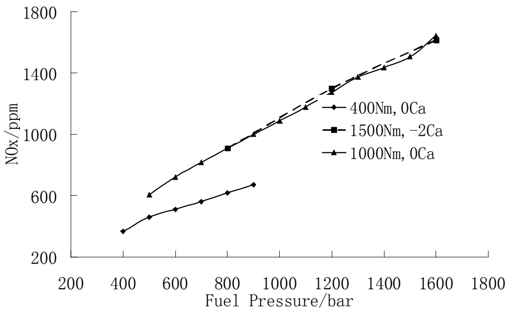

Figure 3. NOx at different rail pressures

The experimental results of rail pressure show that in a certain area high injection pressure can make smoke emission and thermal efficiency improved observably, but for specific combustion chamber, it is not genuine that the higher pressure will lead to the better impaction. So it needs a full-scale balance among various indicators in order to confirm the injection pressure.

3.2 The Affection of Injection Angle

The tests are performed at 1000r/min, 1000Nm and maintaining rail pressure 500bar and 800bar respectively. Fig. 4 to Fig. 7 show the experimental results with different injection angles.

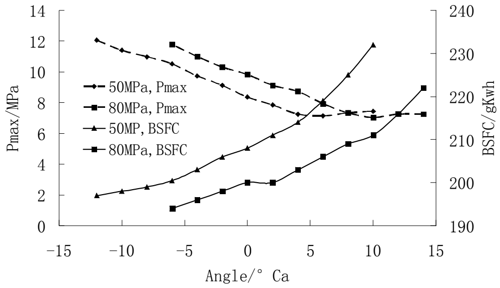

Figure 4. BSFC and peak pressure at different advanced angles

As shown in Fig. 4, with injection angle lagging, BSFC augments and explosive pressure reduces. It suggests that the combustion energy can not be intensively released near the top dead center (TDC).Thus the efficiency drops and the economy becomes worse.

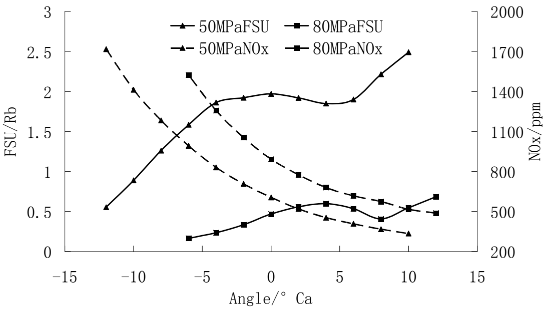

Figure 5. PM and NOx at different advanced angles

The results in Fig. 5 show that with advancing injection, NOx goes up monotonously. This is because fuel is injected into the cylinder under a lower initial temperature and pressure condition which extends ignition delay. Thereby fuel increases during premixed combustion period and pre-mixture keeps rich-oxygen state. So temperature inside the cylinder rises promptly at the stage of rapid combustion and combustion efficiency is enhanced. At this time the conditions of high-temperature and oxygen-rich that are obligatory for the generation of NOx is strengthened and NOx increases.

FSU and injection angle does not retain the monotonic relationship, and the course can divide into three stages. The first stage occurs at the time of larger injection advance angle and there appears the traditional trade-off relationship between NOx and smoke emissions in diesel engines, namely reducing one kind of emissions will induce the other increasing. The third stage takes place when the angle is very lag. During this stage, it’s in the expansion process and the cylinder volume gradually augments, equivalent compression ratio is reduced, combustion efficiency plays down, and the combustion in cylinder has no longer been normal, so the emission is deteriorated and fuel consumption mounts up. The second stage places between the two ones in which it appears that smoke and NOx lessening simultaneously. The impact of injection angles on smoke is shown in Fig. 6 on the conditions of 1000rpm, different rail pressures and loads.

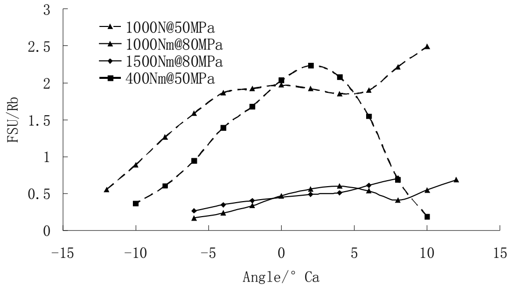

Figure 6. The effect of advance angle on FSU on different operating conditions

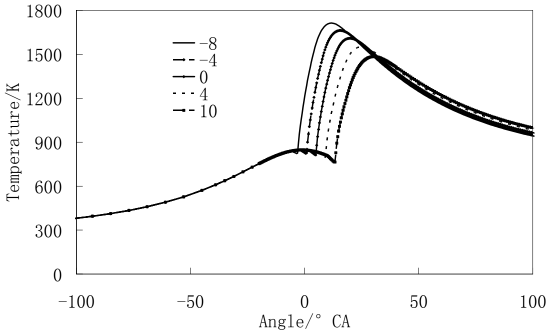

Figure 7. Simulation results of combustion temperature in Cylinder at 1000r/min-400N-50Mpa

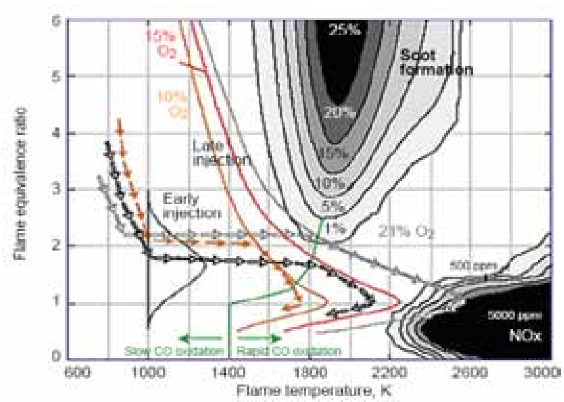

Figure 8. Regimes of soot and NOx formation expressed in terms of flame equivalence ratio and combustion temperature [5]

As can be seen from Fig. 6, smoke corresponding to 400Nm has an obvious drop, while with the load of 1500Nm its change has already been completely monotone, which shows that there is an inconsistent relationship between NOx and smoke on the high load condition, while both appears reduction under the small load condition. Fig. 7 shows the computational cylinder temperatures with different injection angles on the conditions of speed of 1000rpm, torque of 400Nm and rail pressure of 50Mpa. Fig. 8 displays the relationship among the emissions of diesels, in-cylinder temperature and air-fuel ratio [5]. It can be observed from Fig. 7 that combustion temperature falls with injection angle's delay and the temperature has already been close to the region of the low-temperature combustion state, so NOx and smoke are depressed in the meantime.

4. Conclusions

Tests on rail pressure and injection timing are carried out with a high-power diesel engine. The study has the following conclusions:

(1)Rising rail pressure in the appropriate range, smoke and economy can be improved effectively. However, NOx will increase.

(2) Under the heavy load condition if the rail pressure is too high, the improvement of smoke and economy are not remarkably, while NOx will be enhanced obviously. Under the light load condition, too high rail pressure will make BSFC worse instead.

(3) On the condition of heavy load, with the delay of injection angle, NOx decreases and smoke increases monotonously.

(4) Under the low and middle load, if injection pressure is high enough, NOx and smoke will reduce at the same time due to the decline of combustion temperature with the delay of injection angle.

Acknowledgment

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