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Development of Fuel Injection System for Non-Road Single-Cylinder Diesel Engine

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ABSTRACT: Several important factors such as the fuel injection pump, the nozzle and the high-pressure fuel pipe on a single cylinder diesel engine were optimized. The comparison tests results of injection character and the diesel engine emission showed that the pressure of the fuel injection system was increased by the optimal scheme. The highest pressure increased to 63.6 MPa, improved 44.5%. The fuel atomization performance and combustion process were improved. The emission performance with optimal scheme obviously improved which meets China-III non-road diesel engine emission standards and has a large margin.

Keywords: single cylinder diesel engine; China-III emission standards; fuel injection system; injection character; optimal design

I. INTRODUCTION

With the increasing shortage of oil resources and the increasing environmental pollution, Chinese government for diesel engine emissions of pollutants controls are becoming increasingly strict. China as the world's largest single-cylinder diesel engine production for the single-cylinder diesel engine energy saving and environmental protection requirements are also rising, especially with the GB 20891-2014 <non-road mobile machinery diesel exhaust pollutant emission limits and measurement methods' (China's third and fourth stage)> implementation, higher requirements for single-cylinder diesel engine emissions level are put forward.

Because single-cylinder diesel engine's structure and the use of objects, it's use is restricted, so that pressurization system, exhaust gas recirculation (EGR) system, post-processing systems and other advanced technology in the single-cylinder diesel engine to promote more difficult. Therefore, for single-cylinder diesel engine, to achieve the focus of the three emission technology research is to do a good job of diesel engine structure optimization and machine purification[1]. Fuel injection system as the most critical diesel system, to improve the performance of diesel engines, reduce fuel consumption and emissions of pollutants play a vital role.

In this paper, the fuel injection system of a single-cylinder diesel engine with direct injection single-cylinder diesel engine is optimized and tested by fuel injection characteristic test and diesel engine discharge test.

II. THE BASIC SITUATION OF THE PROTOTYPE

The main technical parameters of the prototype are shown in Table 1.

Table 1. The main technical parameters of the prototype

Type	Displacement / L	Bore × travel/ mm× mm
Single cylinder, horizontal, water cooled, four strokes	1.194	115 × 115

rated power / kw	rated speed / r·min^{-1}	maximum torque / N·m	maximum torque speed / r·min^{-1}
14.7	2200	74	1650

III. OPTIMIZATION DESIGN OF FUEL INJECTION SYSTEM

The key to improving the overall level of the diesel engine is to improve the combustion process. To achieve this goal, the fuel injection system must be improved[2]. A large number of experiments show that China's single-cylinder direct injection diesel engine maximum injection pressure of 40 MPa or so[3]. In order to meet the three-way requirements of the non-road country, it is necessary to increase the injection pressure of the fuel system while improving the atomization quality and no abnormal injection at higher injection pressure conditions.

A. Optimal design of the fuel injection pump

Appropriate increase in the plunger lift of the fuel injection pump, optimize the cam profile, is to improve the fuel injection pressure, improve the law of an effective fuel injection[4]. The effective lifting of the plunger is

increased, the reflection of the pressure wave is enhanced, the injection pressure is effectively increased, and the plunger diameter is increased, the oil supply rate is increased, and the injection pressure is further improved. After the optimization Of the cam program movement rate relative to the original cam raised about 20%, two kinds of cam parameters shown in Figure 1.

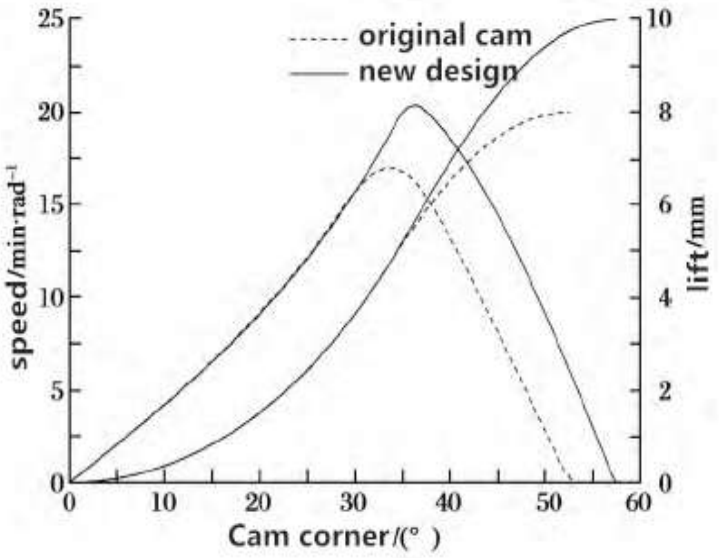

Figure 1. Two kinds of cam parameters

B. Optimal design of the nozzle

Fuel injectors are an important part of the fuel injection system, the diesel engine power, fuel economy, emission indicators play a very important role. With the continuous progress of diesel engine technology, the requirements of the nozzle continuously improved, the nozzle has been toward the porous, small aperture direction[5]. To improve the fuel injection pressure, not only need to have a higher pump pressure, the nozzle should also be optimized to get better fuel atomization quality. The original machine is a 5-hole nozzle, in order to improve the jet pressure and get better atomization quality, need to reduce the nozzle diameter and flow, according to the standard point of fuel consumption, fueling duration and other parameters to calculate, respectively Three kinds of 6-hole injector program A, B, C, its relative to the original program D, high pressure flow were reduced by 33.9%, 19.8%, 15.4%.

C. Optimal design of the high-pressure fuel pipe

The choice of high-pressure tubing geometry (mainly inner diameter and length) has a significant effect on fuel injection and diesel engine work. If improper selection may occur abnormal jet, resulting in increased fuel consumption, exhaust smoke and other undesirable phenomena. Shortening the length and inner diameter of the high-pressure tubing, reducing the high-pressure volume, reducing the loss of the high-pressure fuel along the way, thereby increasing the injection pressure. And the length of the structure by the diesel engine to determine the size, not easy to shorten. Therefore, in fact, only the inner diameter can be changed[6]. So to maintain the original machine high-pressure tubing on the basis of the same size to reduce its diameter, which can reduce the high-pressure tubing volume, the volume reduction rate of about 21%.

IV. COMPARISON OF FUEL INJECTION CHARACTERISTICS

According to the relevant optimization scheme of the fuel injection system, the fuel injection characteristic test is carried out, and the fuel injection pressure and fuel injection law are compared to determine the optimal scheme. According to the diesel engine test under the calibration conditions of the fuel consumption compared to calculate the amount of a single cycle fuel injection, as the basis for the fuel pump on the adjustment of the gear by a single injection device measured fuel injection data and calculation Value of the same, simulated engine calibration conditions for electrical testing. The test system's principle shown in Figure 2.

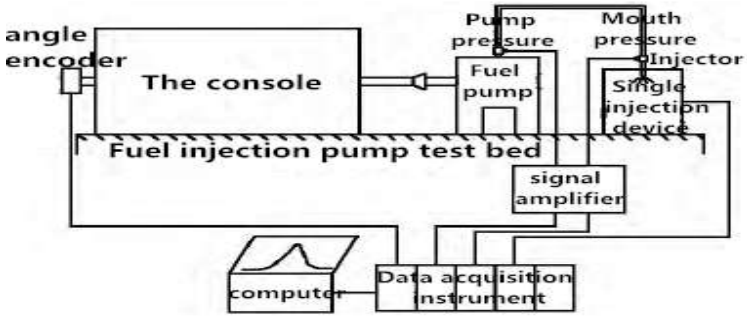

Figure 2. The principle of the test system

A. Optimized fuel injection system injection pressure, fuel injection test

The injection pressure of the mouth of the original fuel injection system is about 44.0 MPa. On the basis of the new fuel injection pump with increasing plunger diameter and lift, the fuel injection pressure and the fuel injection test under the calibration conditions were carried out by selecting two kinds of inner diameter high pressure tubing respectively. , The specific injection pattern shown in Figure 3 to Figure 6.

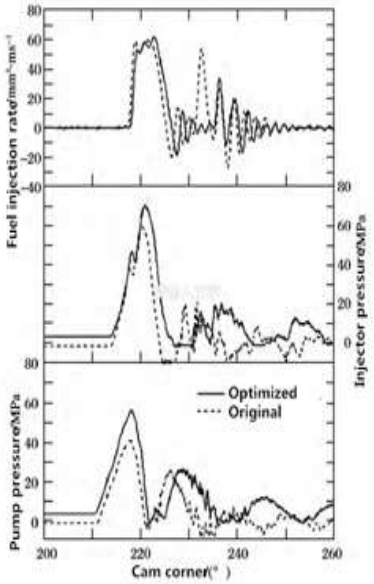

Figure3. Nozzle Option A and Two Kinds of High Pressure Tubing Spray Wave forms

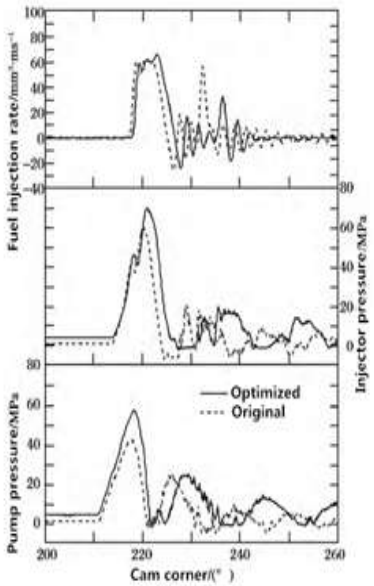

Figure4. Nozzle Option B and Two Kinds of High Pressure Tubing Spray Wave forms

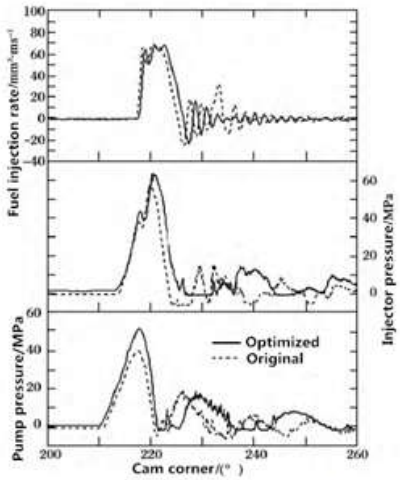

Figure5. Nozzle Option C and Two Kinds of High Pressure Tubing Spray Wave forms

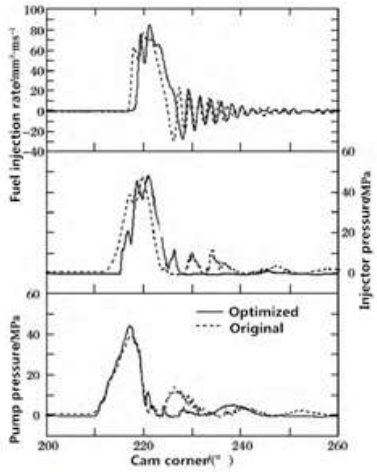

Figure6. Nozzle Option D and Two Kinds of High Pressure Tubing Spray Wave forms

Figure 6 shows that the original fuel injection system to replace the new fuel injection pump program, the maximum fuel injection pressure from 44.0 MPa increased to 48.0 MPa, 9% increase, and no secondary injection. With the ptimized small diameter high pressure tubing, the injection pressure is increased to 49°C. 1 MPa. Figure 3 to 6 shows that the use of injector A program, the small diameter high-pressure tubing compared to the original machine high-pressure tubing maximum injection pressure from 64.3 MPa increased to 70.6 MPa, increased by 9.8%, and the secondary jet phenomenon than the original high-pressure tubing has been weakened.For the nozzle B program, small diameter high pressure tubing compared to the original machine high pressure tubing maximum injection pressure from 60.4 MPa to 70.2 MPa, increased by 9.0%, the secondary jet phenomenon is also weakened.For the injector C program, the maximum injection pressure for the high-pressure tubing is 53.7 MPa, but the secondary injection phenomenon is obvious; match the small diameter high pressure tubing, the maximum jet pressure increased to 63.6 MPa, increased by 18.4%, the secondary jet phenomenon disappears.

With the reduction of the oil pressure of the injector, the maximum injection pressure is obviously improved, but the fueling duration will be lengthened, and even the secondary injection phenomenon may occur. The use of small diameter high pressure tubing can also increase the maximum injection pressure, Effectively weaken the secondary jet phenomenon, and even can eliminate the secondary jet phenomenon. According to the fuel injection characteristics of the comparative test to determine the optimized fuel injection system using fuel injector program C and small diameter of the high-pressure tubing. Compared to the original fuel injection system, the optimized fuel injection system has a maximum injection pressure of 44.0 MPa increased to 63.6 MPa, the increase rate of 44.5%.

V. OPTIMIZATION OF THE WHOLE PROGRAM EMISSION TSET

A. Test results and analysis

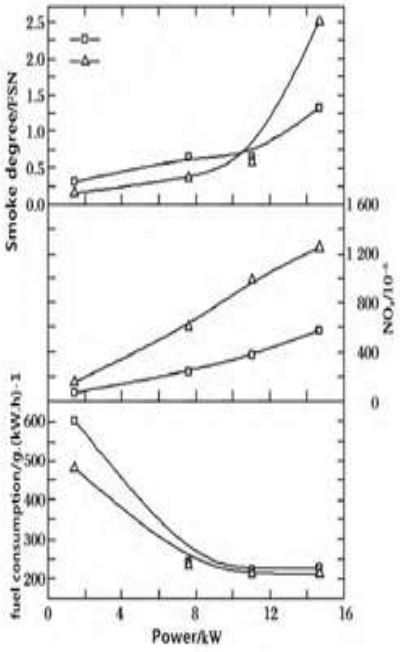

Figure7. Comparison of calibration speed emission data

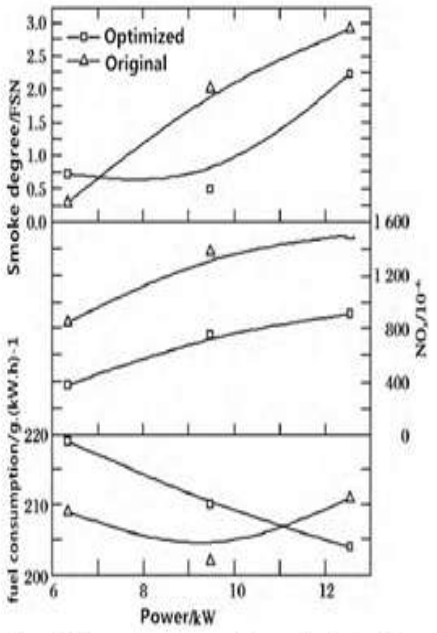

Figure8. Comparison of intermediate speed emission data

The fueling characteristics determine the atomization capacity of the fuel, and the vortex ratio and the shape of the combustion chamber determine the quality of the oil and gas mixture, which further affects the combustion characteristics and emission characteristics[7]. Therefore, based on the optimization of the fuel injection system, the intake and combustion system of the engine are optimized and improved. At the same time, the comparison between the height of the nozzle and the advance angle of the fuel injection is carried out. Figure 7-8, eight cases of the cycle test the weighted emission ratio as shown in Table 2. Experiments show that the diesel engine eight operating conditions of the cycle of discharge test results to fully meet the non-road country three emission targets, and a greater margin.

Table 2. The main technical parameters of the prototype

emission	CO	HC	NOx	HC + NOx	PM
test results	1.130	0.803	5.649	6.452	0.197
China-III limit	5.5	-	-	7.5	0.6

VI. CONCULSION

a. Reduce the nozzle flow can effectively improve the fuel injection pressure, is conducive to fuel atomization, but will make fueling duration longer, and may even produce secondary jet phenomenon;

b. Reducing the diameter of the high pressure tubing can also increase the maximum injection pressure effectively, and can effectively reduce the secondary injection phenomenon, and even eliminate the secondary injection phenomenon;

c. Through the injection pressure and fuel injection of the law can effectively measure the fuel injection system program, compared to the diesel engine test more efficient;

d. The optimized fuel injection system fully meets the requirements of the non-road country three emission requirements, in order to meet the non-road country three emission standard single-cylinder diesel fuel injection system optimization pointed out the direction.

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