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Study on the Effect of Injection Pressure on Reciprocating Diesel Engines Emission Performance

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***Abstract* – There are many factors that affect engine emission performance, such as fuel supply advance angle, fuel type, gasification temperature and fuel injection parameters, etc. In order to be able to know exactly how much the engine that period of emissions and the engine that period of fuel injection pressure can reduce the concentration of certain emissions. In this paper, a six-cylinder, four-stroke marine diesel engine L6230ZLC-10 is tested by control variable method by changing injection pressure and other conditions unchanged. The effects of engine injection pressure on emissions of carbon monoxide, Oxo carbon, hydrocarbon and particulate matter were investigated. The results show that with the increase of fuel injection pressure, the emissions of soot and carbon monoxide decrease, and the emissions of nitrogen oxide increase slightly, and the emissions of hydrocarbon decrease first and then increase, but the overall decrease is dominant. By changing the injection pressure, the soot emission is greatly affected.**

***Keywords* – Emissions Performance, Fuel Injection Pressure, Effects, Changing, Factors, Emissions.**

I. INTRODUCTION

Climate change is one of the most important global issues facing the international community [6]. In recent years, with the aggravation of global warming, people are more and more aware of protecting the environment. Engine emissions as one of the main sources of air pollution [4], how to reduce diesel engine emissions has attracted more and more attention of researchers. The main emissions from diesel engines are carbon monoxide, nitrogen oxide, hydrocarbons, particulate matter, and so on [5], as shown in figure 1. There are many factors that affect engine emissions [7], such as fuel injection parameters, fuel types and combustion chamber structure. The quality of emissions from these engines [8] affects not only the atmosphere, water sources and oceans, but also the quality of our lives. However, how to control the emission of the engine and the factor [9] which affects the emission of the engine are the problems which need to be further studied by the researchers in many countries.

It is an effective way to reduce the emission by changing the fuel injection parameters [3], there has been extensive research on the emission problem of the engine. For example, Zhao G F [1] et Al. observed the amount of carbon oxide, carbon monoxide and hydrocarbon emissions by changing the pre-injection amount and timing of the pre-injection of the engine. Recently, Wang Can [2] et Al. optimized the soot emission of the engine by adjusting the main jet timing. However, although the effect of fuel injection parameters on engine emissions is well explained, few people have studied the effect of fuel injection parameters on engine emissions.

In this paper, based on a six-cylinder four-stroke marine engine L6230ZLC-10, the change of fuel injection pressure was adjusted by experiment, changes in concentrations of emissions such as carbon monoxide, Oxo carbon, hydrocarbon and particulate matter were observed further. The results show that with the increase of injection pressure, the emissions of soot and carbon monoxide decrease, and the emissions of nitrogen oxide increase slightly, and the emissions of hydrocarbon decrease first and then increase, but the overall decrease is the main. By changing the injection pressure, the soot emission is greatly affected.

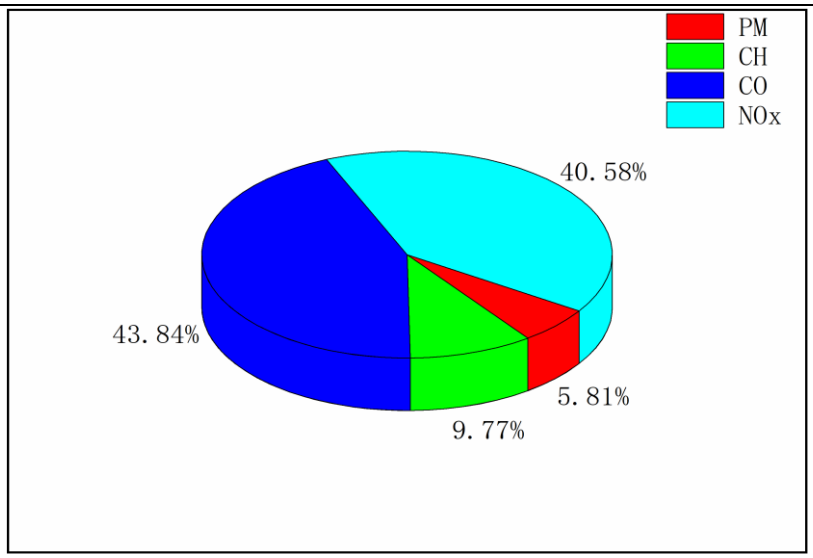

Fig. 1. Proportion of individual emissions.

II. TEST SUBJECTS AND PROTOCOLS

A. *Test Main Device*

Dynamometer model No: Y3300-AX, Sampling probe, L6230ZLC-10 six cylinder marine diesel engine, Mexa-1500ds gas analyzer, AVL472 particulate matter testing equipment, Filter paper for sampling particulate matter, Weighing Chamber and Analytical Balance, Horiba MEXA-ONE Analyzer, marine diesel engine intercooling system, intake system, exhaust system and cooling system are equipped in the laboratory.

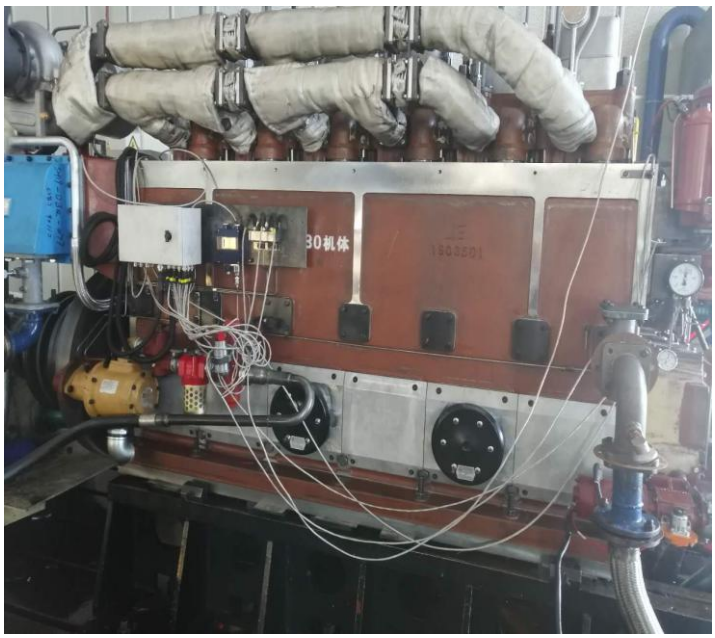

Fig. 2. Experimental engine.

B. *Test Plan and Purpose*

The emission levels of exhaust pollutants CO, HC, NO and particulate matters of L6230ZLC-10 engine with the change of injection pressure were measured by bench test, and the influence of injection pressure on them was obtained.

In the test, the exhaust back pressure of marine diesel engine is always 2.5kPa. Some of the engine parameters are shown in Table 1 below. The change of emission concentration is observed by controlling the difference of injection pressure. Other conditions are to follow the control variable method to measure, control other variables, to test the impact of a variable on the emission performance of marine diesel engine. During the test, the fuel system, high-pressure oil pump, injector, high-pressure oil pipe and other parts are not changed by using unified diesel oil and engine oil. Two sets of test data are recorded for each working condition. In order to have a good comparability, the test will be completed in about two hours as much as possible.

Table 1. Some parameters of the engine.

Serial Number	Name	Specifications
1	Model number	L6230ZLC-10
2	Type	Inline
3	Number of cylinders	6
4	Stroke	4
5	Compression ratio	14
6	Cylinder diameter	225

III. TEST RESULTS AND ANALYSIS

A. *Study on the Effect of Different Injection Pressure on Engine Emission Performance*

Carbon monoxide, soot and nitrogen oxide cannot be produced when the fuel is fully burned, at its best. Carbon Dioxide and water vapor are the products of complete combustion [10]. However, in the actual operation of the engine, emissions far more than these, there are other emissions. These emissions are the result of incomplete combustion of engine fuel, which is very fast, very short time for the fuel to fully mix with the air, and, of course, very short time for the fuel to burn. When the fuel does not have enough time to oxidize, it produces a series of emissions that do not burn completely, such as soot particles, nitrogen oxide, hydrocarbon and carbon monoxide. Many ways to increase the performance of an engine are associated with these emissions. If you want to increase the engine load Torque, you have to use the excess air coefficient less than 1 is too dense mixture, but at this time the carbon monoxide emissions will increase greatly. In many cases, the engine needs cold start, precisely because of cold start, there will be a lot of negative effects. At lower temperatures, soot production increases and fuel evaporates less effectively, resulting in many fuels being expelled without adequate combustion or even combustion. Sometimes, many people want to raise the temperature in the cylinder to achieve better performance, but the engine has a combustion temperature of more than 2,000 °C, which happens to be the most favorable condition for nitrogen oxide, most of the nitrogen in the mixture is oxidized to nitrogen oxide, such as Nitric Oxide, nitrogen dioxide, and so on. When the mixture in the cylinder is uneven, oxygen-deficient, there will be soot particles generated. Nitrogen Oxide and soot are arguably the most common and most prolific of the emissions. In recent years, countries have become more stringent in their emission requirements, and it is important to find an effective and reasonable way to reduce emissions. This chapter explains how emissions are generated at different injection pressures, thus reducing the relationship between injection pressure and emissions.

B. *Effect of Different Injection Pressure on Soot Emission*

In particulate matter, the most abundant component is soot, which produces more soot in the absence of oxygen and at high temperatures, both of which are necessary for soot formation. Of course, the conditions that affect the formation of soot are not only hypoxia and high temperature, but also excess Air Coefficient A. When $\varphi_a < 0.5$, soot would be formed in the cylinder; when $0.5 < \varphi_a < 0.6$, soot would gradually increase; when $\varphi_a > 0.9$, soot would gradually decrease with the increase of oxygen, but now the nitrogen oxide is growing. So to get the best emissions results, it's best to put the excess air factor between 0.6 and 0.9. Figure 3 below is a comparison of soot emissions as a function of injection pressure.

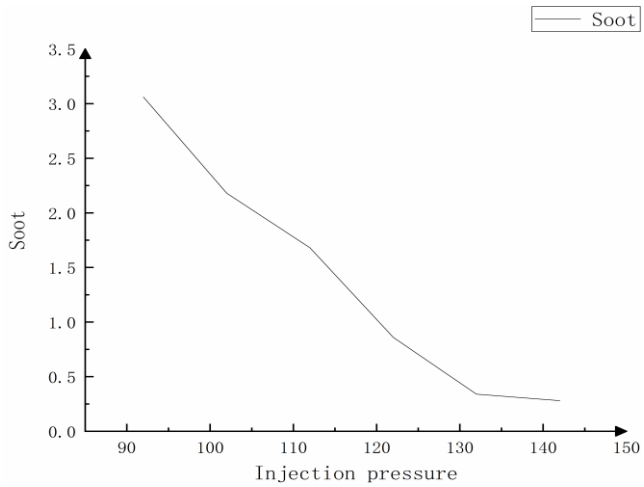

Fig. 3. Curve of soot versus injection pressure.

As can be seen from Fig. 3, with the gradual increase of fuel injection pressure, the emission of soot tends to be lower and lower. With the increase of the injection pressure, the fuel atomization in the engine cylinder will become better, and the smaller the droplet particles, the more uniform. As a result, the more homogeneous the mixture, the more concentrated or dilute the mixing area is reduced. This increases the burning rate, which in turn Burns more fully and reduces soot emissions. Another reason is that the increase in combustion temperature and exhaust temperature provides a good oxidation environment for soot, a large amount of soot can be successfully oxidized into carbon and oxygen products such as carbon dioxide, so the emission of carbon and oxygen will be reduced.

C. *Effect of Different Injection Pressure on Carbon Monoxide Emission*

Generally speaking, carbon monoxide is a kind of colorless, tasteless, toxic neutral gas, when its concentration is too high, it will do great harm to the human body, serious will lead to life-threatening. When the oxygen in the mixture is sufficient, carbon monoxide emissions are small; when the oxygen in the mixture is insufficient, the fuel cannot be fully burned, resulting in a large amount of carbon monoxide. Of course, the conditions that affect the formation of carbon monoxide are not only oxygen, but also air-fuel ratio or excess air coefficient. When oxygen is sufficient, the fuel can be fully burned, at this time the product is carbon dioxide; when oxygen is insufficient, because oxygen is insufficient, the fuel cannot be fully burned, and there will be a large amount of carbon monoxide. In addition, when the combustion temperature is too high, part of the carbon dioxide will be broken down into carbon monoxide. Fig. 4 below is a comparison of carbon monoxide emissions as a function of injection pressure.

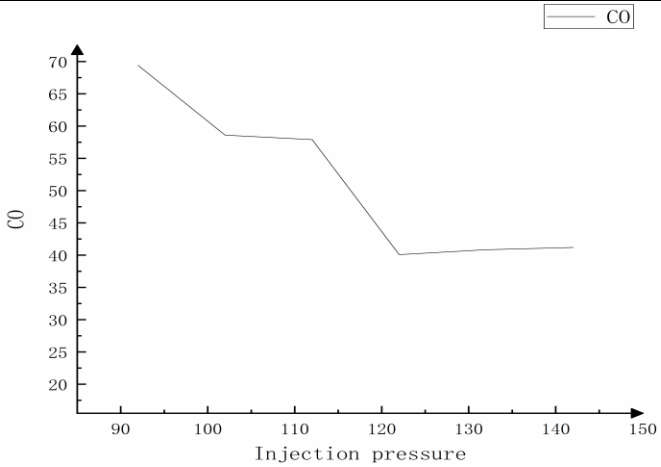

Fig. 4. Carbon monoxide versus injection pressure.

As can be seen from Fig. 4, with the increase of fuel injection pressure, the carbon monoxide emission shows a decreasing trend. As the fuel injection pressure increases, the fuel atomization and combustion quality in the engine cylinder will be improved, and the mixture will be more evenly mixed, with much less concentrated or dilute mixing area. In this way, carbon monoxide emissions will be reduced. Another reason is that the increase in exhaust temperature also promotes the reaction of carbon monoxide to carbon dioxide, and carbon monoxide will be reduced, so the emission of carbon monoxide will be reduced.

D. *Effect of Different Injection Pressure on Hydrocarbon Emission*

Organic compounds consisting only of carbon and hydrogen are called hydrocarbons, which are also called hydrocarbons. There are many types of hydrocarbon, hydrocarbon fuel, oxidation products, lubricants, fuel combustion inadequate products, and so on. The Olefins, aromatics, and polycyclic aromatic hydrocarbon in hydrocarbons are harmful. Methane, the simplest hydrocarbon, accounts for most of the carbon and hydrogen. Methane chemical properties are less reactive than other gases and can be used as a fuel, with negligible environmental harm. Figure 5 below shows a comparison of hydrocarbon emissions with the injection pressure.

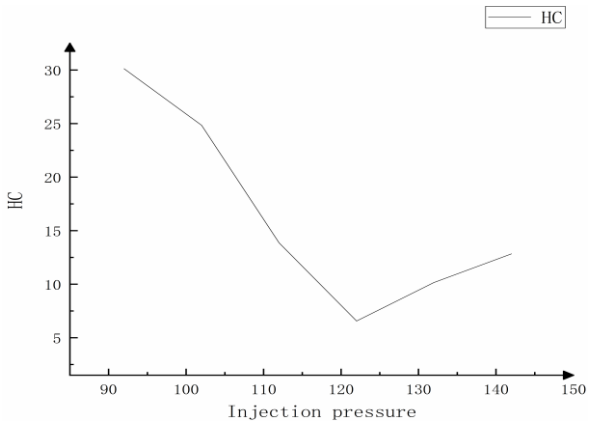

Fig. 5. Curve of hydrocarbon versus injection pressure.

As can be seen from Fig. 5, with the increase of fuel injection pressure, the hydrocarbon emission is reduced greatly first and then increased. When the injection pressure increased from 92 MPA to 122 MPA, the hydrocarbon emission was greatly reduced. The reason is that with the increase of fuel injection pressure, the fuel atomization effect and combustion quality in the engine cylinder are good, the mixture is fully burned, the

temperature in the cylinder and the temperature of the cylinder wall are increased, and the quenching effect of the wall surface is weakened, so the hydrocarbon emissions are reduced. When the injection pressure increased from 122 MPA to 142 MPA, the hydrocarbon emission increased. The reason is that when the injection pressure is higher and higher, the phenomenon of the wet wall in the combustion chamber will gradually increase, the mixed gas will increase unevenly, the evaporation of the wet wall will also begin to increase, and the incomplete combustion of the fuel will increase, so the hydrocarbon emissions are increasing.

E. *Effect of Different Injection Pressure on Nitrogen Oxide Emission*

No is a colorless gas, itself is not toxic, but slowly oxidized to NO in the atmosphere. No is a brown gas, with a strong pungent smell, was inhaled after the body and water combined into nitric acid, causing cough, asthma, and even emphysema and myocardial damage. No is a major factor in the formation of photochemical smog containing toxic ozone near the ground. The majority of NO emission from engine is NO, so we only study and analyze NO emission. The main reactions leading to the generation and disappearance of NO are:

$$O_2 \leftrightarrow 2O \quad (1)$$

$$N_2 + O \leftrightarrow NO + N \quad (2)$$

$$O_2 + N \leftrightarrow NO + O \quad (3)$$

It's reacting in a very dense mixture

$$N + OH \leftrightarrow NO + H \quad (4)$$

The formation of NO increases exponentially with increasing temperature. At temperatures below 1800K, NO production rates are extremely low; at 2000K, high rates can be achieved. The increase of oxygen content will also increase the production of NO. Because NO is produced more slowly than fuel combustion, only a small fraction of NO is produced in a very thin reaction band, and most of NO is produced in the burned gas after the flame has left it. If the residence time of reactants in high temperature environment is not enough, NO cannot reach the equilibrium content and NO emission will be reduced. Oxygen concentration and in-cylinder temperature are closely related to NO production. Low oxygen concentration and in-cylinder temperature must be provided to control NO production. Figure 6 below shows a comparison of Nitric Oxide emissions with fuel injection pressure.

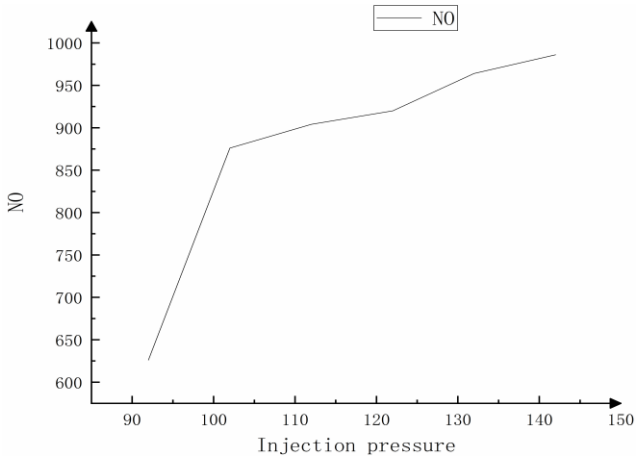

Fig. 6 Nitric Oxide versus injection pressure.

As can be seen in figure 6, emissions from Nitric Oxide will increase slightly as the injection pressure increases. The reason is that with the increase of fuel injection pressure, the ignition delay period of the engine is shortened, the diffusion burning speed is improved, the combustion condition in the cylinder is improved, the maximum combustion temperature in the cylinder is increased, and the NO emission increases with the increase of the temperature in the cylinder. At the same time, the excessive Air Coefficient in the combustion chamber of the engine is large, and the oxygen molecules are sufficient to meet the high temperature and oxygen-rich environment, so the NO emission increases.

In conclusion, with the increase of injection pressure, the emissions of soot and carbon monoxide are reduced, the emissions of nitrogen oxide are slightly increased, and the emissions of hydrocarbon first decrease and then increase, but the overall reduction is dominant. By changing the injection pressure, the soot emission is greatly affected. The advantages of increased injection pressure outweigh the disadvantages.

IV. CONCLUSION

In this paper, the effects of injection pressure on emissions of carbon monoxide, Oxo carbon, hydrocarbon and particulate matter were studied by adjusting injection pressure experimentally, and the conclusions are as follows:

1. With the increase of fuel injection pressure, the combustion rate is increased, the combustion will be full, the mixture is more uniform, the mixing area is much less, and the emission of carbon smoke and carbon monoxide is reduced.

2. With the increase of injection pressure, the ignition delay period of the engine is shortened, the diffusion burning rate is increased, the combustion condition in the cylinder is improved, the maximum combustion temperature in the cylinder is increased, and the emission of nitrogen oxide is increased slightly.

3. With the increase of fuel injection pressure, the fuel atomization effect and combustion quality in the engine cylinder are good, the mixture is fully burned, the temperature in the cylinder and the temperature of the cylinder wall are increased, the quenching effect on the wall is weakened, the emission of hydrocarbon first decreases and then increases, but the overall pattern is one of reduction.

4. With the increase of injection pressure, the emissions of soot and carbon monoxide are reduced, the emissions of nitrogen oxide are slightly increased, and the emissions of hydrocarbon first decrease and then increase, but the overall reduction is dominant. By changing the injection pressure, the soot emission is greatly affected. The advantages of increased injection pressure outweigh the disadvantages.

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