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Study on Influence of Injection Advance Angle on Diesel Engine Emission Performance

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Abstract **– Diesel emissions are affected by a variety of factors, such as injection angle, injection pressure, injection whole diameter, injection whole number and spray cone angle and so on. In order to be able to better control the diesel engine at that moment how much emissions and to understand the diesel engine at that moment that the level of emissions. On a L6210ZLC-10 six-cylinder, four-stroke marine diesel engine, by changing the injection advance angle and other conditions unchanged, several groups of comparative tests are done, the average number is taken, and the emission concentration is observed by the control variable method. The effects of fuel injection timing on the emission of CO, Oxo carbon, HC and particulate matter were investigated. The results show that with the increase of injection advance angle, the emission of HC, soot and Co decreases, but the emission of NO_x increases.**

Keywords **– Emission Performance, Injection Pressure, Emissions, Emissions, Injection Timing, Change Effects.**

I. Introduction

In recent years, as the global pollution is more and more serious [12], people's consciousness of environmental protection is also more and more intense [1]. In the pollutant emission, most of the pollutant emission comes from the diesel engine [7]. With the rapid development of science and technology and society, diesel engine is widely used in ship navigation, Hanoi transportation, large-scale machinery and important industry [2]. Therefore, to solve the problem of diesel engine emissions is a thorny problem to be solved in each country, for diesel engine emissions, each country has introduced different emission regulations [11]. These countries are also becoming more stringent about diesel emissions [3]. Diesel engine emissions include Co, HC, PM andNO_x, as shown in figure 1. There are many factors that affect Reciprocating diesel engines emission, such as injection pressure, injection whole diameter, injection whole number, injection time, combustion chamber structure and fuel type, etc. [4] Although many scholars have done a lot of research on diesel engine emissions [5], but how to control diesel engine emissions and the impact of various factors on diesel engine emissions is to be further studied.

There are many ways to reduce the emission concentration [6], constantly changing the fuel injection parameters of the injector is a very effective method, in recent years, and there have been a lot of research on the emission of diesel engines. For example, Wan S C [8] et Al. studied the effect of two injection pressures on carbon deposition in three injectors, observed the amount of carbon oxides, CO and HC emissions, and further obtained the effect on emissions. Zheng Z.Q. [9] et Al. studied the influence of blending ratio on low temperature combustion of diesel / n-butanes, and found that the blended fuel is superior to the traditional fuel. Recently, S. Kang [10] et Al. investigated the effects of nozzle configuration on fuel consumption and exhaust emissions in a 0.4 l single cylinder diesel engine. Although the effect of fuel injection parameters on engine emissions has been fully explained, few studies have been carried out on the effect of fuel injection parameters on engine emissions.

In this paper, based on an L6210zlc-10 six-cylinder four-stroke marine engine, the change of fuel injection advance angle was adjusted by experiment, the concentrations of CO, Oxo carbon, HC and particulate matter were further observed. The results show that the soot, Co and HC emissions decrease and the NO_x emissions increase with the increase of injection advance angle. By changing the injection pressure, the NO_x emission is greatly affected.

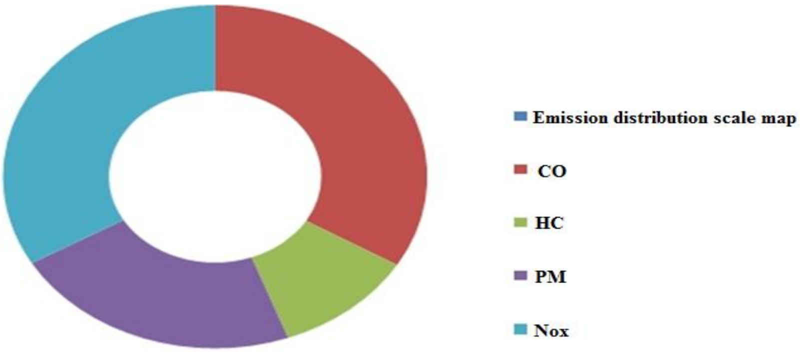

Fig. 1. Proportion of individual emissions.

II. Test Subjects and Protocols

A. *Purpose of the Experiment*

The emission levels of Exhaust Pollutants Co, HC, NO_x and particulate matter of L6210ZLC-10 engine as a function of fuel injection advance angle were measured by bench test, the influence of injection advance angle on them is obtained.

B. *Test Main Unit*

The laboratory is equipped with DYDAMOMETER dynamometer, fuel consumption meter, Z6210ZLCZ-1 six cylinder marine diesel engine, marine diesel engine cooling system and cooling system.

Fig. 2. Experimental engine.

C. *Test Engine and Main Technical Specifications*

Table 2- 1. Shows some parameters of the engine.

Serial Number	Name	Specifications
1	Model number	L6210ZLC-10

Serial Number	Name	Specifications
2	Type	Inline
3	Number of cylinders	6
4	Stroke	4
5	Compression ratio	14
6	Cylinder diameter	205

Table 2- 1 some parameters of the engine.

D. *Test Plan*

By changing the injection advance angle of marine diesel engine, the emission performance of marine diesel engine is studied.

During the test, the ambient air pressure of marine diesel engine is always 102.0 PA under the same ambient conditions. Other conditions are to follow the control variable method to measure, control other variables, and change the fuel injection advance angle of this variable on the impact of marine diesel engine emissions. In the test process, using a unified diesel and oil, fuel system, high-pressure oil pump, injector, high-pressure oil pipe and other parts are not changed. Two groups of test data were recorded in each working condition. In order to have a good comparability of the experiment, the experiment will be done in about two hours as far as possible. The specific test plans are listed in Table 2-2.

Table 2-2. l6210zlc-10 test engine main test program.

Working Condition	**Injection Pressure /MPa**	**Orifice Diameter /㎜**	**Number of Spray Holes/one**	**Injection Advance Angle /° CABTDC**
Speed 860 R / min, 75% load	97	0.35	8	6
				9
				11
				13
				15
				17

III. Test Results and Analysis

A. *Study on the Effect of Injection Advance angle on Diesel Engine Emission Performance*

When the injector of a diesel engine begins to inject fuel, the crankshaft angle from the Piston to TDC is called the injection advance angle. The injection advance angle of diesel engine is very important in the whole injection system. The fuel injection advance angle of diesel engine has a great influence on the running condition of the diesel engine. When the fuel injection advance angle is too large, it will lead to a long burning period, which will lead to the rough work of the engine. When the injection advance angle is too small, the combustion process of diesel engine will be delayed too much, and the peak pressure will also decrease, thus the thermal efficiency of diesel engine will decrease significantly. When the injection advance angle of diesel engine is properly increased, the particle emission can be reduced, but the NO_x emission will gradually increase, it can be seen that it is very difficult to meet both emission regulations simply by adjusting the injection advance angle. When the injection advance angle of diesel engine exceeds a certain value, not only the value of NO_x emission increases, but also the value of CO and HC emission increases. Generally speaking, fuel injection is advanced, fuel is injected into the cylinder at lower temperature and pressure, ignition delay period is prolonged, premixed combustion ratio is increased, resulting in increased emissions, increased cycle temperature, combustion process is ended ahead of schedule, the oxidation time of the soot in the exhaust gas is prolonged, which is beneficial to reducing the soot and particle emissions. Delayed fuel injection reduces the initial heat release rate and the maximum combustion temperature, thereby reducing emissions. However, the delayed injection results in the delay of combustion process, the decrease of maximum explosion pressure, the deterioration of fuel economy, the afterburning phenomenon, the increase of exhaust temperature and the decrease of power. Delayed injection at low speed and low load results in incomplete combustion due to low combustion temperature, resulting in increased unburned HC and particulate emissions. Therefore, if you want to ensure that the diesel engine has good emission performance, you must select the best injection advance angle. In recent years, countries around the world increasingly stringent emission standards, to find an effective and reasonable way to reduce emissions is crucial. In this chapter, the relation between the size of the injection advance angle and the amount of the emission is deduced.

B. *Effect of Different Injection Advance angle on CO Emission*

CO is a colorless odorless gas, it and oxygen carrier in the blood of Hemoglobin affinity is 200-250 times oxygen. CO binds to hemoglobin to form carbonyl hemoglobin, which reduces the amount of ox hemoglobin and the ability of blood to supply oxygen to human tissues. When the volume fraction of CO in the air exceeds 0.1%, there will be headache, palpitation and other toxic symptoms; when the volume fraction exceeds 0.3%, death can be caused within 30 minutes. CO is the main intermediate product of combustion of HC fuel. If the oxygen concentration and temperature of the reaction gas are high enough and the chemical reaction takes long enough, CO will oxidize CO_2. When the oxygen concentration in the mixture is relatively high, CO emissions are very small; when the oxygen concentration in the mixture is relatively low, the fuel cannot be fully burned, a large amount of CO will be generated. In addition, when the combustion temperature is too high, part of the carbon dioxide will be decomposed into CO. Figure 3 below is a comparison of CO emissions with injection timing.

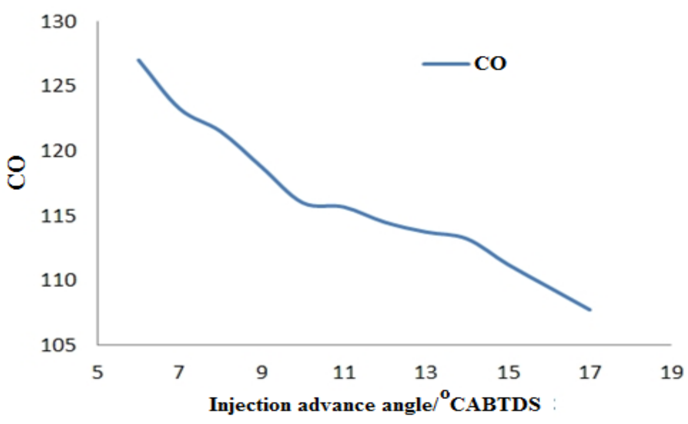

Fig. 3. Curve of CO emission versus injection advance angle.

As can be seen from the Fig. 3, the CO emission decreases with the increase of the injection advance angle, and the CO emission decreases by 35.25% with the increase of the 6° CABTDC to 17° CABTDC. The main reason is that the fuel injection angle is advanced, the mixture in the cylinder is more evenly mixed, the combustion time is longer, the combustion will be more fully, the temperature in the cylinder will rise, the combustion of CO will be reduced, and some of it is oxidized to carbon dioxide. So CO emissions are reduced.

C. *Effect of Different Injection Advance angle on Soot Emission*

In the combustion process of the engine, when the oil-gas combination is not uniform and the mixing is not sufficient, the heterogeneous combustion will occur in the combustion process. The gaseous or liquid fuel and HC compound can be cracked directly at high temperature under the condition of partial hypoxia and high temperature. After a series of complicated chemical reactions and physical evolution, the initial carbon microsphere soot is formed, because of its large surface area and porous structure, it is easy to adsorb a large amount of gaseous and liquid substances during combustion, and finally form the common soot particles. As shown in Fig. 4 is the diesel fuel injection ahead of the different angle of comparison of soot emissions.

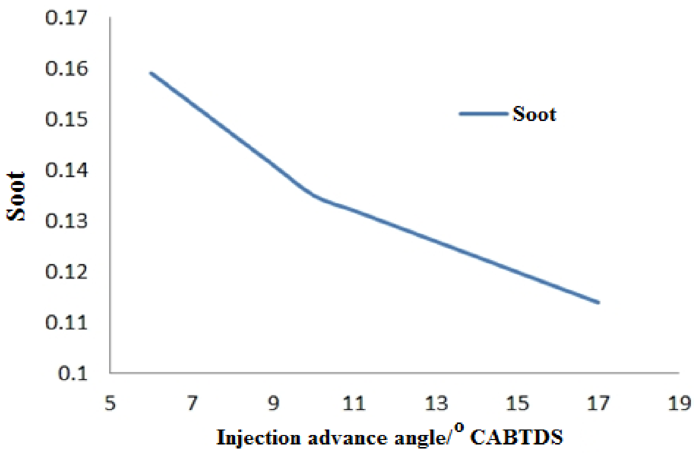

Fig. 4. Soot emissions versus injection advance angle.

As can be seen from the Fig. 4, the soot emission decreases as the injection advance angle increases. When the injection advance angle was increased from 6° CABTDC to 17° CABTDC, the soot emission was reduced by 39.63%. The main reason is that the formation of soot requires high temperature and lack of oxygen. With the increase of fuel injection advance angle, the ignition delay in cylinder will be prolonged, thus the premixed combustion time will be increased, in this way, most of the mixture in the cylinder will be in oxygen sufficient conditions of combustion, so that the combustion is very full. Furthermore, the sufficient condition of soot formation is not satisfied. Therefore, soot emission decreases with the increase of injection advance angle.

D. *Effect of Different Injection Advance angle on HC Emission*

HC emissions from diesel engines are completely generated by the combustion process, basically no crankcase emissions and evaporation emissions. Total HC emissions from internal combustion engines include a wide variety of compounds with different activities in photochemical reactions in the troposphere and different degrees of harm to human health. UNBURNED HC emissions are generated by exhaust, crankcase and evaporation channels. Figure 5 below shows the HC emissions under different injection advance angles of diesel engines.

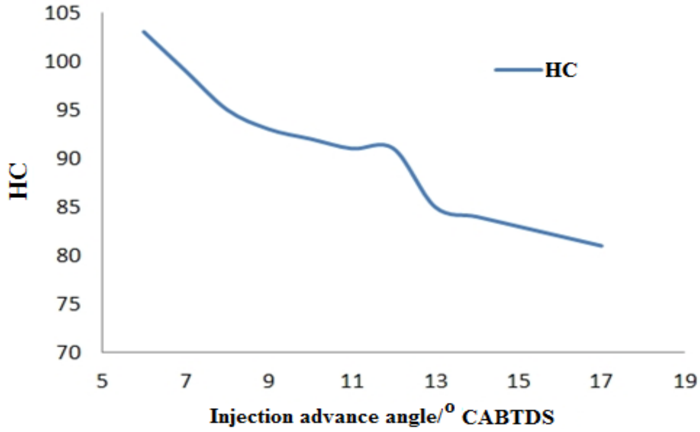

Fig. 5. Curve of HC emission versus injection advance angle.

As can be seen from Fig. 5, HC emissions decrease as the injection advance angle increases. When the injection advance angle increased from 6° CABTDC to 17° CABTDC, HC emissions decreased by 81.43%. The main reason is that with the increase of the injection advance angle, the mixture in the cylinder will be more evenly mixed, and the later combustion time will be longer, which makes the fuel burn more fully, thus, the temperature in the cylinder will be increased to a certain extent, which will increase the probability of HC being oxidized to H2o and CO2 during the combustion process, the HC emission will decrease with the increase of injection advance angle.

E. *Effect of Different Injection Advance angle on* NO_x *Emission*

NO is a colorless gas, NO_x emission from diesel engine exhaust mainly refers to Nitric Oxide, nitrogen dioxide and so on, which is called NO_x, of which NO accounts for about 95%. The combustion process of diesel engine greatly influences the maximum value and variation of NO_x formation, and the amount of NO_x formation depends on the reaction temperature, oxygen concentration and reaction time. Figure 6 shows a comparison of NO_x emissions from diesel engines with different injection advance angles.

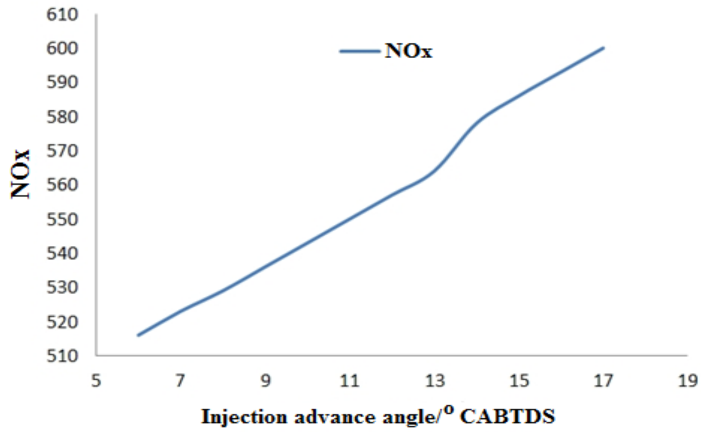

Fig. 6. Curve of NO_x emission with injection advance angle.

As can be seen in figure 6, with the increase of injection advance angle, the NO_x emission increases gradually. When the injection advance angle was increased from 6° CABTDC to 17° CABTDC, the NO_x emission increased by 90.36%. The main reason is that the formation of NO_x is inseparable from high temperature and rich oxygen. When the injection advance angle increases continuously, the temperature in the cylinder will gradually increase, which provides good conditions for the formation of NO_x and satisfies the conditions for the formation of NO_x, increasedNO_x production resulting in increased NO_x emissions. There is another reason, as the injection advance angle increases, the ignition delay will continue to extend, there will be more fuel for oxygen-rich combustion, meet the second condition of NO_x formation, therefore, the NO_x emission will increase with the increase of injection advance angle.

In a word, with the increase of injection advance angle, the emission of soot, HC and Co decreases, but the emission of NO_x increases. By changing the injection advance angle, the HC and NO_x emissions are greatly affected. The increase of injection advance angle has both advantages and disadvantages.

IV. Conclusion

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

1. With the increase of the injection advance angle, the emission of CO decreases gradually, the injection angle is advanced, the mixture in the cylinder is more even, the combustion time is longer, the combustion is more full, the temperature in the cylinder is higher, the CO produced by combustion is reduced, and some of it is oxidized to carbon dioxide.
2. The formation of soot requires high temperature and Hypoxia. With the increase of fuel injection advance angle, the sufficient condition of soot formation is not satisfied. Therefore, soot emission decreases with the increase of injection advance angle.
3. With the increase of the injection advance angle, the mixture in the cylinder will be more evenly mixed and the combustion time will be longer, which makes the fuel burn more fully and the temperature in the cylinder will be increased to a certain extent, this increases the probability of HC oxidation to H2o and CO2 during the work-making stage, and the HC emission decreases with the increase of the injection advance angle.
4. With the increase of injection advance angle, the NO_x emission increases gradually. The formation of NO_x is closely related to high temperature and rich oxygen.
5. When the injection advance angle increases, the temperature in the cylinder will increase gradually, promoting the formation of NO_x.
6. With the increase of fuel injection advance angle, the ignition delay period will be prolonged; more fuel will be used for oxygen-enriched combustion to meet the second condition of NO_x formation, so the NO_x emission will increase with the increase of fuel injection advance angle.
7. By changing the injection advance angle, the HC and NO_x emissions are greatly affected. The increase of injection advance angle has both advantages and disadvantages. The emission of soot, HC and CO decreases, but the emission of NO_x increases.

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