Effect of High Cetane Fuel Blended with Methanol on Combustion Characteristics

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Abstract. The influence of high cetane number fuel blended with methanol on the combustion characteristics of diesel engine is studied. Fuels of high cetane number with different cetane number were compounded by FT diesel fuel and methanol. Bench tests were performed on 186F diesel engine. The cylinder pressure and heat release rate of different high cetane number fuels were measured. The change law of ignition delay period and the combustion duration of different methanol blending ratio under and loads were analyzed. The results show that under the rated condition, with the decrease of the mixed fuel cetane number, the maximum combustion pressure and peak value of heat release rate increase, and the corresponding crank angle is delayed. When the cetane number of the fuel reduces from 75 to 64 under constant load, the ignition delay period increases and the combustion duration reduces. The changes of the ignition delay period and combustion duration vary most obviously under 25% load, ranging from 2.8 ℃A to 6.1℃A, respectively. With the same high cetane number fuel, as the load increases, the ignition delay period shortens and the combustion duration increases.

1. Introduction

In our country, due to the energy structure feature of rich coal and poor oil, the development of coal-based synthetic oil fuels to replace some petroleum-based fuels has great advantages [1]. F-T diesel oil is a product of indirect coal liquefaction with high cetane number. Methanol has high oxygen content and high latent heat of vaporization, which can be mass-produced by coal, and is a kind of clean fuel with low price and huge output[2].

The combustion and emissions of diesel are closely related to the physicochemical properties of the fuel. The cetane number of diesel ranges from 45 to 50 normally [3]. Fuel with cetane number higher than 50 is called high cetane number fuel. Cetane number of FT diesel and methanol is 75 and 3, respectively. A small amount of methanol is blended with the FT diesel fuel to obtain the mixed fuel, the cetane number of which still belongs to the high cetane number range. The FT diesel fuel is mixed with methanol to study the effect of high cetane number fuel blended with methanol on the combustion process.

Domestic and foreign scholars have done a lot of research work on the effect of fuel blended with methanol on the combustion process. Han et al.[4] studied the effects of fuel properties such as

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cetane number on low-temperature combustion of diesel engines. Cetane number is the most important factor affecting ignition delay time and inversely proportional to ignition delay time. Donkerbroek[5] et al. founds different cetane number of fuels cause ignition delay time to change, affecting the flame structure and soot generation. Li[6] studied the effect of cetane number on the combustion and emissions of diesel engines. The results show that the cetane number increased from 44 to 64, NOX decreased by 5%, and particulate emissions increased by 15%. Hou Shumei[7] of Tianjin University studied the effects of fuel physicochemical properties on the combustion and emissions of diesel engines. The cetane number is found to determine the time of combustion heat release. After blended with iso-octane, the cetane number of mixed fuels decreases and the delayed ignition period is prolonged, the proportion of premixed combustion increases and soot emissions are reduced. Xie Fangxi[8] et al studied the effect of fuels with different cetane number on the emission characteristics of diesel engines. The results show that: under steady state conditions, with the increase of fuel cetane number, the delayed ignition period is shortened, and HC and NOX decrease.

High cetane number fuels with different cetane number were prepared by F-T diesel fuel blended with methanol. Bench tests were performed on a 186F diesel engine. The cylinder pressure and heat release rate of different high cetane number fuels were measured. The change of ignition delay period and the duration of combustion were analyzed with different methanol mixing ratio at different loads.

2. Fuel, test equipment and scheme

2.1. Preparation and physicochemical properties 3

The F-T diesel used is obtained through the Fischer-Tropsch synthesis, hydrorefining, and cracking reaction of coal. The main component is C9-C23 alkanes with a hydrocarbon content of more than 95%. With low sulfur content, no aromatics and good stability characteristics. The F-T diesel/methanol fuels with different cetane number was prepared with methanol blending ratio of 0, 5%, 10% and 15%.

The parameters such as low heating value, cetane number, and oxygen content of mixed fuels are complex to be tested but can be quickly obtained by using the formula. According to Kay's mixing rule [9], the physicochemical properties of the mixed fuel are calculated by formula (1), and the physical and chemical characteristics of the fuel are shown in Table 1.

$$K = \sum_{i}^{n} \omega_i K_i \tag{1}$$

In the formula, K_i is the characteristic parameter of the mixed fuel; ω_i is the volume fraction of the ith substance; K_i is the physicochemical characteristic parameter of the ith substance; i is the number of components.

Table1. Main physical and chemical properties of the test fuel.

Fuel	Composition (volume fraction)%		Cetane number	Low heat value / (kJ kg^{-1})	Density / (g/cm^{-3})	Sulfurcontent / (mm^2/s)
	F-T diesel	Methanol				
F-T diesel (FM0)	100	0	75	47.35	0.76	2.25
Methanol	0	100	3	20.26	0.79	0.58
FM5	95	5	71	46.00	0.76	2.10
FM10	90	10	68	44.64	0.76	2.03
FM15	85	15	64	43.29	0.76	1.96

2.2. Test equipment

Four-stroke, naturally-aspirated, air-cooled ,direct-injection and non-road diesel engine 186FA was used in the test. The main test equipment is: CWF25D eddy current dynamometer; EWE-5000DAQ in-cylinder combustion pressure collection system produced; KSM071860 pressure sensor. Figure 1 shows the bench test.

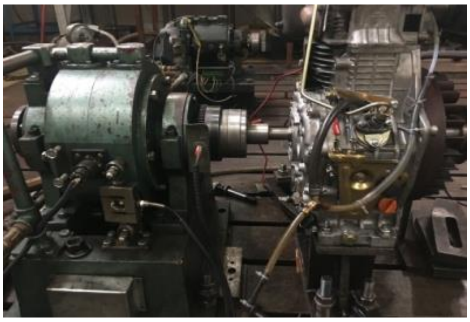

Figure 1. Experimental setup.

2.3. Test scheme

The indicator diagram of different cetane number fuels under conditions of 3600r/min, 25%, 50%, 75%, 100% load were tested. The cylinder pressure, instantaneous heat release rate, the ignition delay period and combustion duration were analyzed.

3. Analysis of combustion characteristics

3.1. Cylinder pressure

Figure 2 is the cylinder pressure curve of different high cetane number fuels under the rated conditions (3600r/min, 100% load). As can be seen from the figure, with the cetane number decreasing from 75 to 64, the maximum combustion pressure increased by 2.2%, 4.5%, and 6.7%, and the corresponding crank angles lag behind by approximately 1° CA and 1° CA, 2 ° CA respectively. The cetane number of F-T diesel is high, so it has high activity and ignition delay period is short. With the increase of methanol blending ratio of mixed fuel, the cetane number decreases and the ignition delay period increases, which leads to more mixture gas forming in the premixed combustion stage and the increasing of the pressure peak.

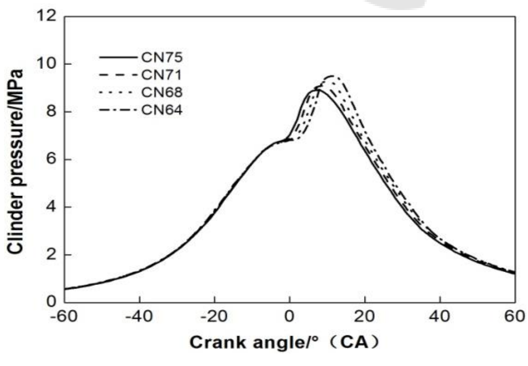

Figure 2. Cylinder pressure curves of different cetane number fuels.

3.2. Instantaneous heat release rate

Figure 3 is the instantaneous heat release rate curve of different high cetane number fuels under the rated conditions. As can be seen from the figure, when the fuel cetane number decreases from 75 to

64, the instantaneous peak heat release rate increases by 8.0 J (℃A)$^{-}$1, 14.5 J • (°CA)$^{-1}$, 23.5 J respectively. • (°CA)$^{-1}$, the corresponding crankshaft angles are shifted back by approximately 2 ℃A, 1 ℃A, and 2 ℃A, respectively. With the decrease of cetane number, the starting point of combustion is postponed and the delayed ignition period is prolonged. The fuel injected during the ignition delay period increases, and a large amount of flammable mixture is formed in the cylinder, which burns rapidly in the period of fast burning. The viscosity of methanol is low, which leads to good effect of atomization. The combustion rate is accelerated and the peak value of heat release rate increases.

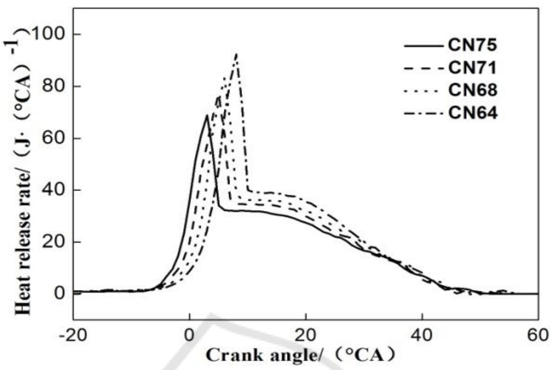

Figure 3. Instantaneous heat release rate of different cetane number fuels.

3.3. The ignition delay period

Figure 4 shows the change in the ignition delay time of different high cetane number fuels with various loads at 3600 r/min. It can be seen from the figure that the ignition delay period is prolonged with the decrease of cetane number. When the cetane number increases from 75 to 64, the increase of the ignition delay period under 25% load is most obvious, increasing by 2.8 ℃A. F-T diesel is mainly composed of straight chain n-alkanes with low aromatic hydrocarbons, so the carbon chain is easy to break, and the cetane number is high. The cetane number of methanol is relatively low. As the blending ratio increases, the cetane number of the mixed fuel decreases, the ignition property deteriorates, and the ignition delay period prolongs. For the same high cetane fuel, when the loads increases, the ignition delay period decreases. With the increasing load, the temperature and pressure in the cylinder increase and the mixture gas ignites more easily. The ignition delay period is shortened, and the combustion start point is advanced.

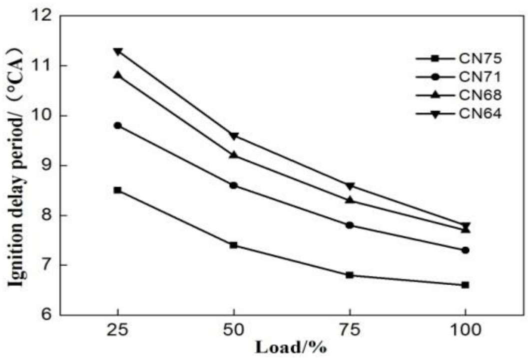

Figure 4. The ignition delay period of different cetane number fuels.

3.4. Combustion duration

Figure 5 shows the change in the combustion duration of different high cetane fuels under various loads at 3600 r/min. It can be seen from the figure that the combustion duration decreases with decreasing cetane number. When the cetane number decreases from 75 to 64, The combustion duration is shortened most obviously under 25% load , decreasing by 6.1℃A. With the decrease of cetane number, the ignition delay period is prolonged and the mixture of oil and gas becomes more uniform. The premixed combustion period is prolonged but the diffusion combustion period is shortened, so the combustion duration is shortened. For the same high cetane fuel, the combustion duration increased with increasing load. As the diesel engine load increases, the amount of diesel injected into the cylinder per cycle increases, the duration of combustion increases.

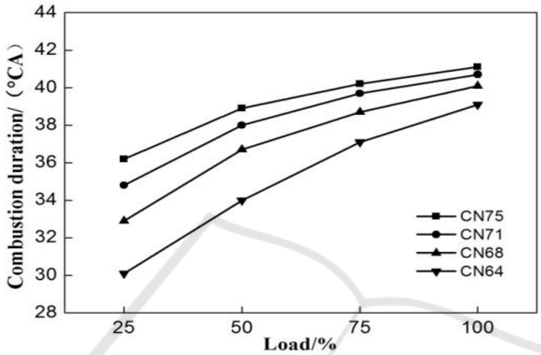

Figure 5. Combustion duration of different cetane fuels.

4. Conclusions

1) Under the rated condition, as the cetane number of mixed fuel increases from 75 to 64, the maximum combustion pressure of the diesel engine increases by 6.7%, and the peak value of heat release rate Increases by 23.5 • $(°CA)^{-1}$. The corresponding crank angle of the both two are delayed backwards.

2) The ignition delay period of high cetane fuels increases with cetane number decreases. When the cetane number decreases from 75 to 64. The ignition delay period increases most obviously under 25% load, increasing by 2.8℃A. For the same high cetane fuel, the ignition delay decreases with the load increasing,.

3) The combustion duration decreases as the cetane number decreases. When the cetane number decreases from 75 to 64. The combustion duration decreases most obviously under 25%, decreasing by 6.1℃A. With the same high cetane fuel, the combustion duration increases as the diesel engine load increases.

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