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Combustion and Emission Performances of Diesel Engine Fueled With Biodiesel-Methanol Blend Fuels

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Abstract: To study the application of biodiesel-methanol blends on diesel engines, combustion and emission experiments are done on a single cylinder diesel engine. Results show that with the blend of methanol, the combustion delays; the peak combustion pressure decreases at small load and increases at middle and large loads; peak heat release rate is similar; HC, CO and smoke decrease; variation of NO_x emission is not clear. The study proves that with the methanol blending, major emission pollutants can be reduced and the combustion process can be improved at middle and large loads.

Keywords: oil crisis, Bio-diesel, diesel engine, Biodiesel-Methanol blend fuels

1. INTRODUCTION

As a renewable clean resource-"Bio-diesel", which have a huge impact on the development of social economic, improving the ecological environment, and energy, security, sustainable development. Therefore, the application of the Bio-diesel on Diesel Engine is a far-reaching influence for the Diesel Engine Industry.

1.1. The status of Bio-diesel production technology and trends of Bio-diesel

At this stage, addition to traditional production methods acid-base catalysis in industry, super-critical methods, Bio-catalysis, and solid catalyst are still during the test.

Rama Raju Baadhe, Ravichandra Potumarthi, Vijai K. Gupta(2014) stated that Lipase catalyzed bio-diesel production is still not a mature process, it needs for a detailed understanding of the various processes. They introduced the various factors involved in the production of Bio-diesel Catalyzed detailedly.

Abhishek Guldhe, Bhaskar Singh, Ismail Rawat, Krishan Ramluckan, Faizal Bux(2014) studied the micro-algal biomass and found that they can extract the lipids from it, which means the micro-algal biomass can be promising potential of the oil produced for conversion into

bio-diesel.

Ivan J.Stojkovic, Olivera S.Stamenkovic, Dragan S.Povrenovic, Vlada B.Veljkovic(2014) compared the different bio-diesel escrow methods. All they have advantages and disadvantages, industrial production should be based on the need to adopt a different purification method. Camilo Barroso Teixeiran, Jose Valdo Madeira Junior, Gabriela Alves Macedo(2014) proposed an environmental friendly method of producing Bio-diesel, and had used physical techniques such as microwave, ultrasound and membrane reactors to improve the enzyme transesterification bio-diesel production efficiency.

Hunan Academy of Forestry Li Chang Zhu, Li Pei wang, Xiao Zhi hong, Chen Zhen, Zhang Liang bo (2012), who studied the use of woody biomass materials biodiesel approach. They studied the fatty acid composition of Cornus fruit oil, jatropha oil, tallow oil, and other woody plants Pistacia seed oil for bio-diesel production and physical and chemical indicators in-depth, and proposed that they can be used as woody biomass diesel feedstock.

Chemical Engineering, Xiangtan University, Wang, Liu Zhongyi, Chen Yu Long, Lesley, Wu Ji Jun (2012) pointed out that the development of bio-diesel technology has been promoted toward the solid catalyst, whole-cell

lipase-catalyzed biodiesel, direct hydrogenation, which is the future direction of Bio-diesel production technology route.

School of Chemical Engineering, Sichuan University, Lu Hong Fang, Shi Guoqiang, Liu Yingying, Liang Bin (2011), who explained European and American are relatively abundant in raw materials. In contrast, materials can not meet our production needs in China. China is still a vegetable oil-importing country, and the lack of arable land. So in order to avoid the phenomenon of "competing with rations", looking for other raw materials to accelerate the development of bio-diesel is the way China should strive for in the future.

1.2. The application of Bio-diesel on diesel engine

Energy shortage is increasingly aggravating the contradiction of Auto industry of the world, in order to achieve sustainable development, The international community has increasingly emphasised on the development of new energy and alternative fuel cars. thus giving a chance for the using of Bio-diesel on Diesel Engine.

Many countries are speeding up to study Bio-diesel Engine.

2. Instruments and conditions of Biodiesel-Methanol blend fuels trials on diesel engine

2.1. Device and test

ZS195M, a single cylinder diesel engine, is used for test. Its main parameters: the cylinder diameter is 95 mm, the piston stroke is 115 mm, the compression ratio is 17.5, the rated power is 9.7 kW, advanced angle of fuel supply is 22 degrees before TDC. The emission test system includes an exhaust gas analyzer AVL Digas4000 and a smoke Opacimeter AVL Dismoke4000. Extinction coefficient $K (m^{-1})$ is chosen as smoke value. A dynamic system for combustion test includes a CB566 combustion analyzer, a pressure sensor, a charge amplifier, a photoelectric sensor and a crankshaft position generator. cylinder pressures are recorded and averaged.

2.2. Fuel proportion

Bio-diesel for blend is the product using waste cooking oil as feedstocks. Three fuels for test are M0 (bio-diesel), M5 (5 vol.% of methanol, 95% of bio-diesel) and M10 (10 vol.% of methanol, 90% of bio-diesel). Table 1 lists the major characteristics of bio-diesel.

Table 1. Properties of fuels

Properties of fuels	Biodiesel
Density at 20°C/ $g \cdot cm^{-3}$	0.856
Cetane number	51
Viscosity at 20°C/ $mm^2 \cdot s^{-1}$	5.5
Low heat value/ $MJ \cdot kg^{-1}$	37.3
Oxygen content/ %	10
Latent heat of vaporization/ $KJ \cdot kg^{-1}$	254

2.3. Condition

Engine operation condition is chosen as follows: 1500 and 1800r/min for engine speed; 0.0885, 0.177, 0.266, 0.354, 0.443, and 0.531MPa indicating the brake mean effective pressure (BMEP) for engine loads.

3. Combustion performances

3.1. Combustion pressure

Fig.(1) and Fig.(2) show the combustion pressure comparison of the three fuels at different conditions. Research shows that: 1) Compared with the M0, the combustion pressure curve in cylinder of M5 and M10 lag overall and the addition of methanol makes combustion initial point of M5 and M10 lag. 2) Compared with the M10, in a small load, the ignition delay period of M5 and M10 is no difference on the whole. While in the medium load, the ignition delay period of M5 is longer. 3) Compared with 1500r/min, the effect of combustion delay becomes more obviously when the speed increases to 1800r/min. Because increase of the engine speed makes the cylinder air movement strengthen, and the corresponding crank angle increases within the same time, so that the combustion lag more obviously.

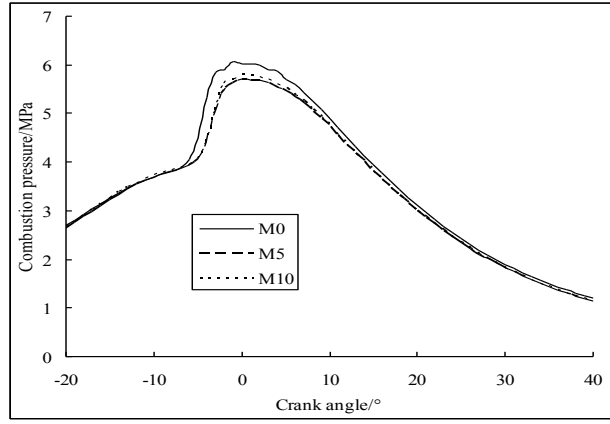


Fig.(1). Combustion pressure at 1500r/min and 0.177MPa

Table 2 gives the peak combustion pressure of the fuels at different conditions and their corresponding crank angle. 1) Compared with M0, at 1500r/min and 0.177MPa, the peak combustion pressure of M5 and M10 are 5.71MPa and 5.19MPa, while the M0 is 6.05MPa, mainly due to the poor ignitability of methanol and low heat value of methanol. With the increase of methanol content, the ignitability of M5 and M10 bring down and the low heat value of M5 and M10 are much lower; at 1500r/min and 0.443MPa, the peak combustion pressure of M5 and M10 are 7.28MPa and 7.29MPa, the peak combustion pressure are 0.18 and 0.19MPa higher than M0. Because on the one hand the prolonged ignition delay period increases the quantity of combustible mixed gas and on the other hand

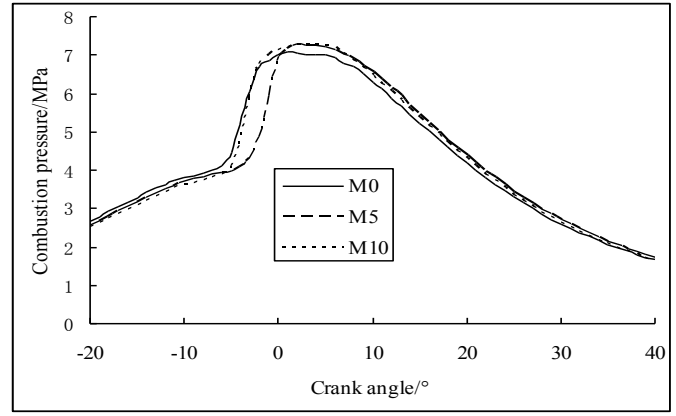


Fig.(2). Combustion pressure at 1500r/min and 0.443MPa

in the improved thermal and power condition methanol can play positive effect on combustion. When the speed increases to 1800r/min, the discipline is similar. 2) Compared with M5, the peak combustion pressure of M10 is higher than M5. Because the high oxygen content of M10 accelerates the combustion speed of the fuel and improves combustion efficiency. 3) Compared with M0, in a small load, the corresponding angles of peak combustion pressure of M5 and M10 are close to TDC; With the increase of the load, compared with M0, the corresponding angles of peak combustion pressure of M5 and M10 leave away from TDC.

Table 2. Peak pressure and its position

Speed (r/min)	BMEP (MPa)	M0		M5		M10	
		Peak pressure /MPa	Angle/°	Peak pressure /MPa	Angle /°	Peak pressure /MPa	Angle /°
1500	0.177	6.05	-1	5.71	0	5.79	0
1500	0.354	6.72	0	6.71	1	6.84	2
1500	0.443	7.10	1	7.28	2	7.29	3
1500	0.533	7.64	2	7.77	2	7.82	2

3.2. Heat release rules

Curves of heat release rate have the similar regularities with combustion pressure curves. Accordingly, here only specific parameters are given and analyzed, shown in table 3. With the load increase, peak heat release rate at small load reduces because the poor

combustion environment. When the load increases, temperature and pressure in cylinder improve. More important, oxygen content of methanol is high enough to accelerate the combustion speed. Finally, heat releases more fast than ever. As a result, peak heat release rate increase which is helpful for concentration of combustion.

Table 3. Peak heat release rate

Speed (r/min), BMEP (MPa)	M0	M5	M10
	Peak heat release	Peak heat release	Peak heat release
	rate/ $\text{KJ} \cdot (^{\circ})^{-1}$	rate/ $\text{KJ} \cdot (^{\circ})^{-1}$	rate/ $\text{KJ} \cdot (^{\circ})^{-1}$
1500, 0.086	0.092	0.088	0.076
1500, 0.177	0.158	0.163	0.172
1500, 0.354	0.188	0.193	0.209
1500, 0.533	0.161	0.178	0.193

4. Emission performances

Fig.(3) indicates the smoke emissions characteristic of the three fuels at 1800r/min. 1) In the entire range of the mean effective pressure, it can be seen that as the load increases, the smoke emissions of the three fuels also increases. Because when the engine speed is constant, the intake air of diesel engine in every cycle is basically the same, and the regulation of load is by changing the amount of fuel injection to achieve the cycle. Loop fuel injection quantity increases with increasing load, which led to the increase of the smoke. 2) Compared with M0, M5 and M10 can effectively reduce the emission of the smoke, and with the increase of methanol content, the reduction is more obvious. The smoke emissions of M5 and M10 decreased by 7.83% and 12.3% averagely. At small load, the smoke emissions of the three fuels are especially low and no difference on the whole. Because fuel combusts more sufficiently in oxygen-rich state. While at medium and high load, the smoke emissions of M5 and M10 are significantly lower than M0. On the one hand, the addition of methanol adds oxygen content of blended fuels and makes combustion more completely. On the other hand, when blended with methanol, it can reduce the combustion temperature of cylinder and restraint a portion smoke emissions generated by the pyrolysis. Thus, after adding methanol, the smoke emissions of blended fuels significantly reduce at high loads.

Fig.(4) shows the NO_x emission characteristic at 1800r/min. 1) Along with the increase of the engine load, NO_x emissions of the three fuels increases. The reason is that when the load increases, the combustion temperature and the cylinder pressure increases, resulting in NO_x emissions increase. 2) At 1800r/min, three kinds of fuel NO_x emissions has no obvious changes in comparative

law. NO_x emission is mainly determined by the oxygen content and the combustion temperature. Firstly, 50% oxygen content of methanol increases the oxygen content of blend fuels, which promotes the NO_x emission. Secondly, with the increase of methanol content, the latent heat of vaporization value of M5 and M10 increases, which are higher than that of M0. Therefore, when the fuels are injected into the combustion chamber, blended fuels with high latent heat of vaporization value absorb a lot of heat, reducing the temperature of the combustion cylinder, which may decrease the NO_x emission. Finally, the high oxygen content of methanol may improve combustion efficiency which makes combustion more sufficiently and increases the NO_x emission. As a result, The NO_x emissions of M0, M5 and M10 have no obvious changes in comparative law.

Fig.(5) indicates the HC emission characteristic at 1800r/min. Compared with M0, HC emissions of M5 and M10 are averagely 21.7% and 46.7% lower than that of M0. As the load increases, HC emissions of three kinds of fuel present fluctuated trends within certain range. On the one hand, the high oxygen content of methanol is in favor of completing combustion; on the other hand, high latent heat of vaporization value of methanol absorbs a lot of heat and reduces temperature of the combustion cylinder, making combustion initial point of M5 and M10 lag. These two factors synthesize make HC emission have no regularity.

Fig.(6) shows the CO emission characteristic at 1800r/min. 1) In a small load, less fuel-injection quantity makes the temperature of the combustion cylinder reduce and oxidation weak, resulting in CO emissions increase. With the increase of the load, the gas temperature rises and the oxidation enhances, making CO emissions reduce.

When the load increases beyond a certain value, low oxygen concentration and high fuel-injection quantity make CO emissions increase. 2) Compared with M0, the CO emissions of M5 and M10 decreased by 1.5% and 1.67% averagely. Because the high oxygen content of

methanol improves combustion efficiency, which makes combustion more sufficiently, methanol-containing blended fuel can overcome the disadvantages of part hypoxia in the combustion process, improving combustion, thereby reducing CO emissions.

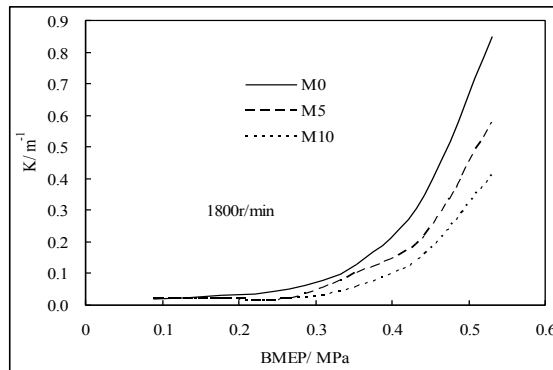


Fig.(3). Smoke emission at 1800r/min

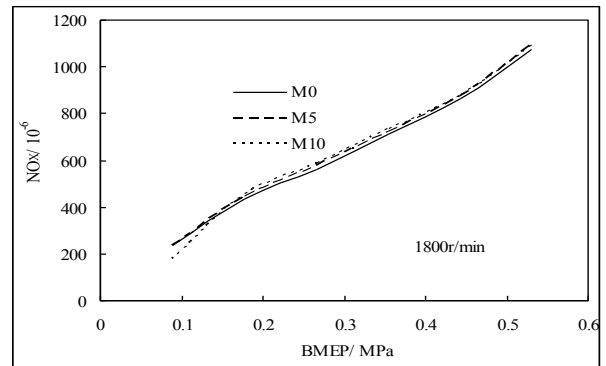


Fig.(4). NOx emission at 1800r/min

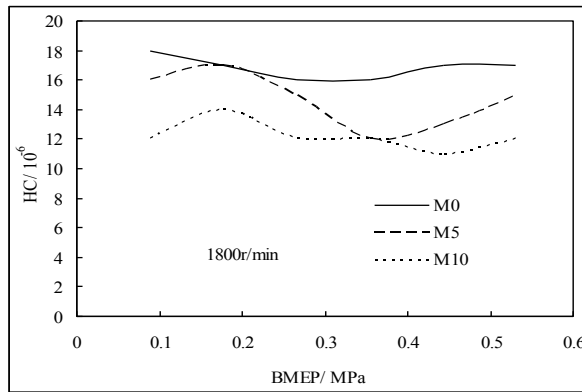


Fig.(5). HC emission at 1800r/min

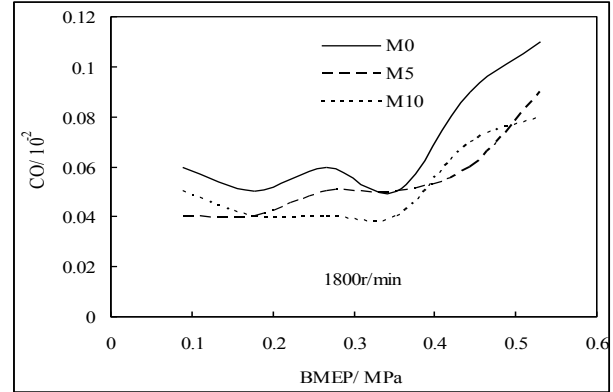


Fig.(6). CO emission at 1800r/min

5. Conclusion

In consideration of plenty of merits of Bio-diesel. Many countries are stepping up research on bio-diesel. The arrival of the energy crisis will certainly promote the further development of bio-diesel. In this paper, we introduce the state of the Bio-diesel and mainly show the experiment of diesel engine fueled with Biodiesel-Methanol blend fuels, and analyses the performance of its Combustion and Emission. With advances in technology, the application of Bio-diesel on Diesel Engine will be further optimized.

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