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

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.

Baadhe *et al.*, (2014) [1] 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.

Guldhe *et al.*, (2014) [2] 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.

Stojkovic *et al.*, (2014) [3] 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. Teixeiran *et al.*, (2014) [4] 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 transesteri-fication bio-diesel production efficiency.

Hunan Academy of Forestry, Zhu *et al.*, (2012) [5], 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 *et al.*, (2012) [6] 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, Fang *et al.*, (2011) [7-10], 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 countries, 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 BIO-DIESEL-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

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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 20ºC/ $g \cdot cm^{-3}$	0.856
Cetane number	51
Viscosity at 20ºC/ $mm^2 \cdot s^{-1}$	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 1800 r/min for engine speed; 0.0885, 0.177, 0.266, 0.354, 0.443, and 0.531 MPa indicating the brake mean effective pressure (BMEP) for engine loads.

3. COMBUSTION PERFORMANCES

3.1. Combustion Pressure

Figs. (**1**, **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 1500 r/min, the effect of combustion delay becomes more obviously when the speed increases to 1800 r/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.

Table **2** gives the peak combustion pressure of the fuels at different conditions and their corresponding crank angle. 1) Compared with M0, at 1500 r/min and 0.177 MPa, the peak combustion pressure of M5 and M10 are 5.71 MPa and 5.19 MPa, while the M0 is 6.05 MPa, 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 1500 r/min and 0.443 MPa, the peak combustion pressure of M5 and M10 are 7.28 MPa and 7.29 MPa, the peak combustion pressure are 0.18 and 0.19 MPa 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 in the improved thermal and power condition methanol can play positive effect on combustion. When the speed increases to 1800 r/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.

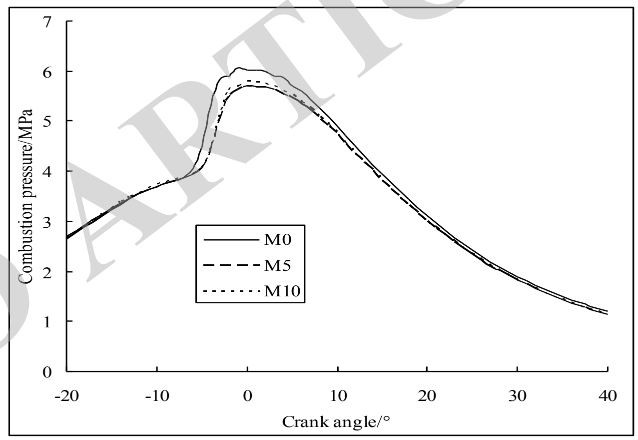

Fig. (1). Combustion pressure at 1500 r/min and 0.177 MPa.

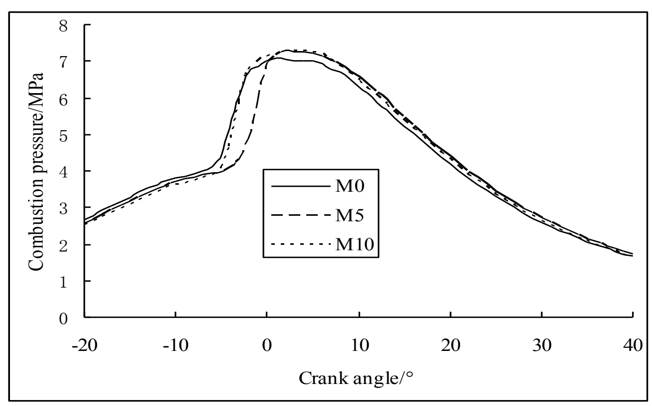

Fig. (2). Combustion pressure at 1500 r/min and 0.443 MPa.

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

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

combustion speed. Finally, heat releases more fast than ever. As a result, peak heat release rate increase which is helpful for concentration of combustion.

4. EMISSION PERFORMANCES

Fig. (**3**) indicates the smoke emissions characteristic of the three fuels at 1800 r/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 NOx emission characteristic at 1800 r/min. 1) Along with the increase of the engine load, NOx emissions of the three fuels increases. The reason is that when the load increases, the combustion temperature and the cylinder pressure increases, resulting in NOx emissions increase. 2) At 1800 r/min, three kinds of fuel NOx emissions has no obvious changes in comparative law. NOx 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 NOx 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 NOx emission. Finally, the high oxygen content of methanol may improve combustion efficiency which makes combustion more sufficiently and increases the NOx emission. As a result, The NOx emissions of M0, M5 and M10 have no obvious changes in comparative law.

Fig. (**5**) indicates the HC emission characteristic at 1800 r/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 1800 r/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.

Table 3. Peak heat release rate.

Speed (r/min), BMEP (MPa)	M0	M5	M10
	Peak Heat Release Rate/KJ·$(^\circ)^{-1}$	Peak Heat Release Rate/KJ·$(^\circ)^{-1}$	Peak Heat Release Rate/ KJ·$(^\circ)^{-1}$
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

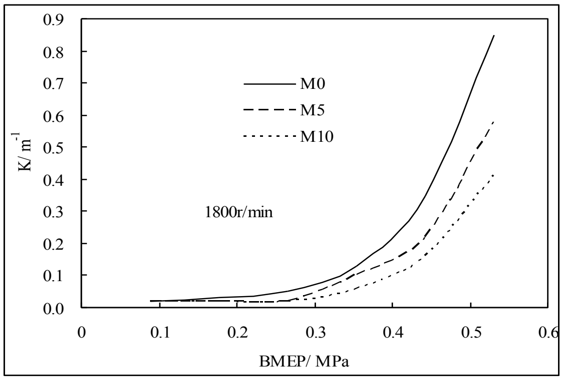

Fig. (3). Smoke emission at 1800 r/min.

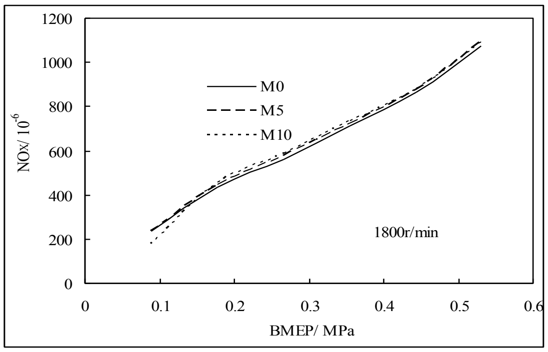

Fig. (4). NOx emission at 1800 r/min.

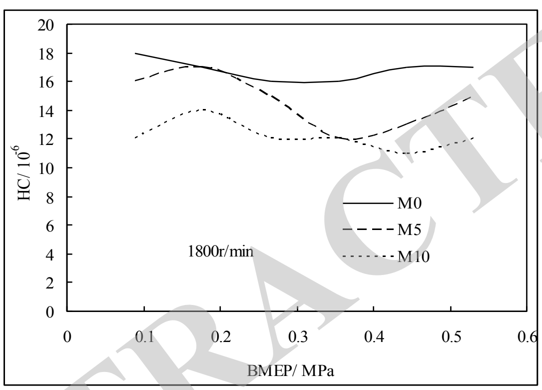

Fig. (5). HC emission at 1800 r/min.

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.

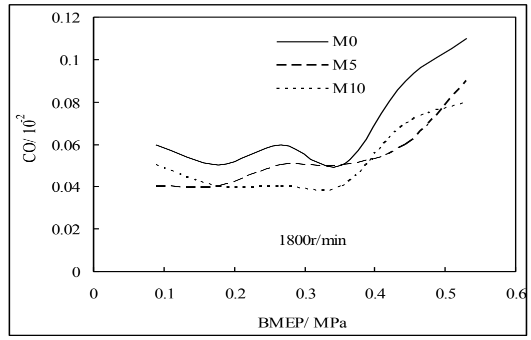

Fig. (6). HC emission at 1800 r/min.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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REFERENCES

[1] Baadhe, R.R.; Potumarthi, R.; Gupta, V.K. Chapter 8-Lipase-Catalyzed Biodiesel Production: Technical Challenges. *Bioenergy Research: Advances and Applications.* Elsevier: USA, **2014**, pp. 119-129.

[2] Guldhe, A.; Singh, B.; Rawat, I.; Ramluckan, K.; Bux. F. Efficacy of drying and cell disruption techniques on lipid recovery from microalgae for biodiesel production. *Fuel*, **2014**, *128*(15), 46-52.

[3] Stojkovic, I.J.; Stamenkovic, O.S.; Povrenovic, D.S.; Veljkovic, V.B. Echnologies for crude biodiesel obtained by alkali-catalyzed transesterification. *Renew. Sust. Energ. Rev.*, **2014**, *32*, 1-15.

[4] Teixeiran, C.B.; Madeira Junior, J.V.; Macedo, G.A. Biocatalysis combined with physical technologies for development of a green biodiesel process. *Renew. Sust. Energ. Rev.*, **2014**, *33*, 333-343.

[5] Li, C.; Li, P.; Xiao, Z.; Chen, Z.; Zhang, L. Development status of woody biodiesel feedstock and industrial prospects of China. *J. China Agric. Univ.*, **2012**, *17*(6), 165-170.

[6] Wang, C.; Liu, Z.; Chen, Y.; Xu, Y.; Wu, J. The study of progress in biodiesel technology. *Guang Dong Agric. Sci.*, **2012**, *1*, 107-112.

[7] Lu, H.; Shi, G.; Liu, Y.; Liang, B. Production and properties of biodiesel progress. *Chem. Indust. Eng. Prog.*, **2011**, *30*(1), 128-136.

[8] Wang, D.R. Progress in the development and application of biodiesel. *Fine Chem. Indust. Raw Mater. Intermediates*, **2012**, *10*, 15-17.

[9] Li, P.; Wang, X.; Li, Y. Status of biodiesel and its progress. *Energ. Energ. Conserv.*, **2012**, *10*, 32-64.

[10] Yang, Y.; Tian, C. Biodiesel industry situation and development countermeasure in China. *J. Chin. Cereals Oils Assoc.*, **2010**, *25*(2), 151-154.

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