The Effects of DTBP on the Pollutant of Diesel Engine

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Abstract. Methanol and biodiesel, which are two of the oxygenated alternative fuels of diesel, have the potential to reduce diesel engine emission. However, if methanol is blended into biodiesel with a large proportion, the cetane number of the blend will be decreased a lot. A cetane number improver - Di-Tert-Butyl Peroxide (DTBP) with the mass proportion of 0.25%, 0.50%, 0.75% was added into methanol/biodiesel blend with 15% methanol (BM15). The engine bench test of the blend was finished in a 186FA type single-cylinder diesel engine without any change, to investigate the effect of DTBP on the engine pollutant. It is revealed that at the rated mode, DTBP can effective reduce NOx, CO and HC emissions, however the exhaust smoke is increased a little.

1. Introduction

Energy shortage and environmental pollution are important issues facing the world, and even worse in China. In 2016, China's oil dependency on international oil market has already broken through 58%. It is estimated that this number will be near to 69% by the year 2020. More than a half of total amount of fossil oil has been consumed by engines in China.

Methanol and biodiesel, both oxygenated fuels, are two of the promising alternative fuels. As an alcohol fuel, potential resources of methanol are huge in China. Methanol is mainly produced from coal, especially by the low-grade high-sulfur coal and recycling coke oven gas. China is abundant in coal resources, but relatively less in fossil oil. Coal to methanol, which is with simple production process and low cost, is a mature technology in chemical industry of China. Wang et al [1] studied the reliability of diesel engine fueled with B5 biodiesel for 1000h, the result shows that B5 biodiesel can be used in diesel engine, and the engine performance changes little. Özener's [2] study also shows that biodiesel could be used in diesel engine without any modification, and emission pollutant can be reduced. As a kind of clean green energy, biodiesel has been got widespread attention and become an important alternative fuel of diesel [3-5].

However, the cetane number of methanol is 5. When methanol is blended with a large proportion, the cetane number of the blend will be decreased rapidly. The cetane number improvers can shorten the ignition delay period and accelerate the combustion speed of the engine. 2,4-Di-tert-butylphenol （DTBP） is a kind of cetane number improver which is most commonly used organic peroxide. Liang etc.[6] added DTBP to diesel and studied the emissions of diesel engine. The study shows that the diesel engine has the best comprehensive emission data when the mixed volume fraction of DTBP to diesel is 0.3%.

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In this paper, DTBP was chosen to added into methanol/biodiesel blend, and the physical and chemical properties of the blend were tested. A bench test was carried out on a direct injection diesel engine and the pollutant of diesel engine were analyzed.

2. Material and methods

2.1. Fuel preparation

Referring to the existing research and through the test for methanol blending ratio, in this study, the blending ration of methanol is 15%, and it is named as BM15. According to the researches [7, 8], DTBP($C_8H1_8O_2$) can increase the cetane number of diesel fuel 6.5-8 by adding 1% (wt). In the test, DTBP is added into BM15 with the ratio of 0.25%, 0.50% and 0.75%, named as BM15+DTBP0.25, BM15+DTBP0.50 and BM15+DTBP0.75. The cetane number and LHV (lower heat value) of the blends are calculated according to Kay's mixing role. And the main properties of the fuels are listed in table 1.

Table 1. Physical-chemical properties of the fuels.

Parameters	DTBP	BM15	BM15+DTBP0.25	BM15+DTBP0.50	BM15+DTBP0.75
Cetane number	-	43.25	44.38-44.75	46.00-44.75	47.63-44.75
Oxygen content (wt %)	21.92	16.87	16.88	16.89	16.90
LHV ($MJ \cdot kg^{-1}$)	32.67	34.74	34.74	34.73	34.73
Density ($g \cdot cm^{-3}$ at 20°C)	0.80	0.86	0.86	0.86	0.86
Kinetic viscosity ($mm^2 \cdot s^{-1}$ at 40°C)	3.32	3.22	3.22	3.22	3.22

2.2. Test apparatus and method

The engine bench test was carried out on 186FA diesel engine. The 186FA is a four strokes, air cooled, direct injection, single-cylinder diesel engine, and the engine specifications are listed in table 2. The engine was operated at 3000 r/min with 10%, 25%, 50%, 75% and 100% load particularly. The injection timing and fuel injection quantity of the engine were unchanged. During the experiment, the pollutant concentration were recorded.

A type FGA4100 exhaust gas analyzer of was utilized to measure NOx, CO and THC concentration online. The precision of exhaust gas analyzer for NOx, CO, and THC concentrations was <4%, <5%, and <4%, respectively. The exhaust smoke was detected by a FBY-201 bosch smoke meter.

Table 2. Engine specifications of 186FA.

Type	Direct-injected, 4 stokes, air-cooled, natural aspiration
Number of cylinders	1
Cylinder bore(mm)×stroke(mm)	86×72
Displacement(L)	0.418
Compression ratio	19
Rated power(kW) / speed(r/min)	5.9/3000
Nozzle number × orifice diameter(mm)	5×0.20
Injection advanced angle (°CA BTDC)	12
Combustion chamber	ω type

3. Results and discussion

3.1. NOx concentration

Figure 1 presents the NOx concentration of the diesel engine fueled with the fuels at 3000 r/min. Figure 1 presents the effect of DTBP on NOx concentration. As can be seen, with the increase of DTBP amount, the NOx concentration of the engine is reduced. When the engine is working at 3000r/min and Pe=0.57kW, and the addition of DTBP is 0.25%, 0.50% and 0.75% in BM15, the volume concentration of NOx in exhaust gas is reduced by 2.59%, 7.58% and 10.2% compared with that of BM15. This is because DTBP reduces the ignition delay period. Less mixture in the premixed duration and the maximum pressure and temperature in the cylinder are reduced, resulting in the reduction of NOx.

3.2. Smoke

Figure 2 is the smoke of the engine at 3000 r/min. It can be seen that with the increasing amount of DTBP, the smoke of the engine is increased. When the engine is working at 3000r/min and Pe=0.57kW, and the addition of DTBP is 0.25%, 0.50% and 0.75% in BM15, the exhaust smoke is increased by 12.5%, 25% and 50% respectively compared with that of BM15. Study [9] has shown that, OH has 3 times stronger ability than O to oxidize C2H2, and 20 times stronger than H. As C2H2 is the precursor of aromatic hydrocarbon, the oxidation reaction brakes the formation of aromatic hydrocarbon, then reduces the amount of soot generated. In addition, OH also has strong oxidation of the generated soot. All of the analysis above demonstrates that methanol has significant effect on the inhibition of soot formation. When DTBP is added into BM15, the ignition delay period shortens. Less mixture is in the premixed combustion period and more mixture is in the diffusion period, making a little increase of soot.

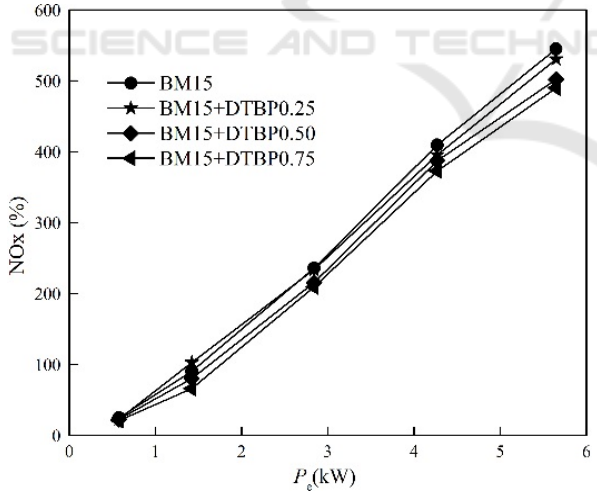

Figure 1. NOx concentration.

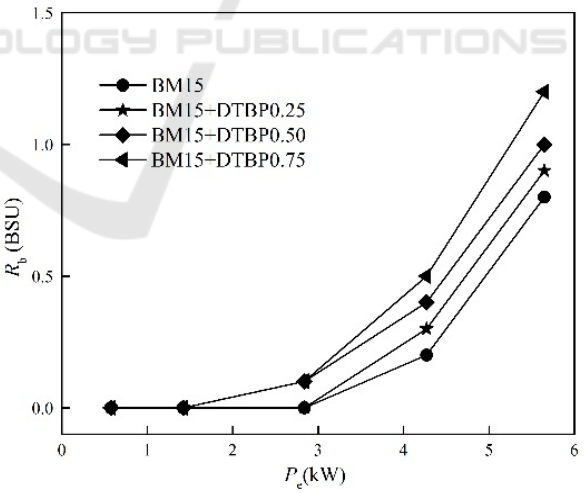

Figure 2. smoke number.

3.3. CO concentration

CO is an intermediate product of the fuel combustion and an product of incomplete combustion. Figure 3 illustrates with the increasing amount of DTBP, the CO concentration is decreased gradually. When the engine is working at 3000r/min and Pe=0.57kW, and the addition of DTBP is 0.25%, 0.50% and 0.75% in BM15, the volume concentration of CO in the exhaust is 0, 12.5%, and 25% lower than that of BM15. DTBP improves the ignitability of the blend and shortens the ignition

delay period. The low temperature and lean zone of the fuel spray is narrowed, accelerating the combustion of CO. With the increase of engine load, the CO concentration is reduced first and then increased a little at high load. When the engine fueled with BM15 at 25% load, the CO concentration is increased a little compared with at 10% load.

3.4. HC concentration

HC is mainly produced by the mixture in the poor-oil area around the fuel spray, generated by the incomplete combustion. As methanol has a low boiling point and high heat of vaporization, methanol is easy to evaporate from the fuel droplet, and the evaporated methanol forms a low temperature, lacking of oil area in the mixture [10, 11]. It is hard to combust completely for mixtures in such area, and thus more HC can be formed. Figure 4 shows the HC concentration of the diesel engine. When DTBP is added to BM15, the HC concentration of the engine is reduced. When the engine is working at 3000r/min and Pe=0.57kW, and the addition of DTBP is 0.25%, 0.50% and 0.75% in BM15, the volume concentration of HC in the exhaust is 5.0%,10.0%,20.0% lower than that of BM15.

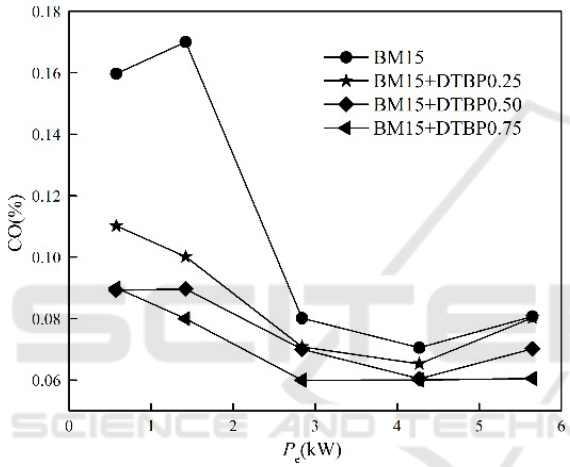

Figure 3. CO concentration.

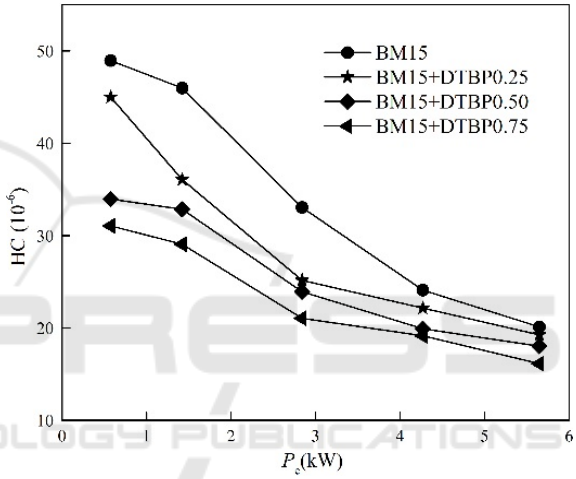

Figure 4. HC concentration.

4. Conclusions

The cetane number improver (DTBP) was chosen to added into methanol/biodiesel blend, and the physical and chemical properties of the blend were tested. The 186FA diesel engine bench test is conducted at rated rotation to analyze the pollutant of the diesel engine using diesel, biodiesel and methanol/biodiesel with or without DTBP. The results can be summarized as following:

(1) With the increase of DTBP amount, the NOx concentration of diesel engine is reduced, but soot is increased a little.

(2) With the increasing amount of DTBP, the CO concentration is decreased gradually, and the HC concentration of the engine is also reduced.

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References

[1] Wang Z, Xu G J, Huang H L, Wang L, Zha H and Ma J R 2009 *Reliability test of diesel engine fueled with biodiesel* (Transactions of the CSAE, vol 25) p 169-172

[2] Özener L O, Yüksek, Ergenç A T and Özkan M 2014 *Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics* (Fuel, vol 115) p 875-883
[3] Wang X, GeY S, Yu L X and Feng X Y 2013 *Comparison of combustion characteristics and brake thermal efficiency of a heavy-duty diesel engine fueled with diesel and biodiesel at high altitude* (Fuel vol 107) p 852-858
[4] Lapuerta O A M and Rodríguez-Fernández J 2008 *Effect of biodiesel fuels on diesel engine emissions*, (Fuel vol 34), p 198-223
[5] Li R N, Wang Z, Li M D, Xu G J, Mao G P and Wang X Z 2012 *Study on effect of peroxide properties of biodiesel and emission* (ACTA ARMAMENTARI II, vol 33) p 1545-1548
[6] Liang C, Ji C W and Dai X X 2009 *Experimental study on the effect of DTBP on combustion and emission of diesel engine* (Vehicle Engine, vol 4) p 83-87
[7] Lü X C, Zhang W G, Yang J G and Huang Z 2005 *Effect of Cetane Number Improver on Heat Release Rate and Emissions of High Speed Diesel Engine Fueled with Ethanol Diesel Blend Fuel* (Journal of Combustion Science and Technology, vol 11) p 56-61
[8] Wang Z, Qu L, Li M D and Chen L 2012 *Effect of DTBP on biodiesel combustion and emission characteristics of engine fuelled with bio-diesel* (Transactions of the Chinese Society of Agricultural Engineering, vol 28) p 60-66
[9] Schmidt K and Gerpen J V 1996 *The Effect of Biodiesel Fuel Composition on Diesel Combustion and Emissions* (SA E paper)
[10] Zhang J Q, Lu H B, Wang X B and Jiang D M 2004 *Combustion and Emission Characteristics of a DI Diesel Engine Fueled by Diesel Methanol Blends* (Journal of Combustion Science and Technology, vol 10) p 171-175
[11] Cheung C S, Zhua L and Huang Z 2009 *Regulated and unregulated emissions from a diesel engine fueled with biodiesel and biodiesel blended with methanol* (Atmospheric Environment, vol 43) p 4865-4872