Effects of diesel-ethanol blends on NOx and PM reduction in a CRDI diesel engine

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CRDI 디젤기관에서 디젤과 에탄올 혼합이 NOx 및 PM 저감에 미치는 영향

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요 약

In this study, pure diesel fuel (E0), 95% E0 blend with 5% ethanol by volume (E5), 90% E0 blend with 10% ethanol by volume (E10) and 85% E0 blend with 15% ethanol by volume (E15) were tested in a CRDI diesel engine. The engine speed and load was controlled at 1500 rpm and 70 Nm. Different fuel injection timings including pilot and main was also investigated. The experimental results show that biodiesel-ethanol blends give lower NOx and PM emissions compared with the diesel fuel due to the high evaporation latent heat and high oxygen content of ethanol.

1. Introduction

Compared with gasoline engine, diesel engine has the advantages of high compression ratio, high thermal efficiency, large output power and stability, which has been widely used in road and non road transportation. However, high nitrogen oxides (NOx) and particulate matter (PM) emissions are significant drawbacks of diesel engines, especially for PM particles [1,2]. PM particles emitted from diesel engines, also known as diesel exhaust particulates (DEP), are particulate components of diesel exhaust, including diesel soot and aerosols such as ash particles, metallic abrasion particles, sulfates, and silicates. Carbonaceous PM is mainly composed of black carbon (BC), primary organic aerosols (POA) and secondary organic aerosols (SOA). SOA are known to contain harmful reactive oxygen species (ROS) and can damage lung tissue. When released into the air, PM can seriously affect air quality and threaten human health, especially for the human respiratory system due to its respirable size (generally under 100 nm). PM and soot emitted from conventional vehicles also are main causes of the decline in urban air quality. People have paid close attention to these urban environmental issues in recent years, including coarse particulates (PM10: 2.5 μm < diameter < 10 μm), fine particulates (PM2.5: diameter < 2.5 μm) and ultra-fine particulates (PM0.1: diameter < 0.1 μm). In particular, numerous studies have shown that long-term exposure to PM2.5 air pollution will directly increase the morbidity and mortality of respiratory and cardiovascular diseases. The smaller the diameter of PM particles, the more easily they enter the human body and even penetrate human tissues, which poses a great threat to human health [3,4].

Therefore, it is necessary to find some new methods to reduce the NOx and PM emissions emitted from diesel engines. At present, one of the more mature technical means, such as exhaust gas after treatment system, including diesel particulate filter (DPF) and selective catalytic reduction (SCR), which can reduce NOx and PM to the specified range, but it needs to pay higher equipment maintenance costs [5,6]. Biodiesel is a more mature alternative fuel that can be used directly or mixed with diesel on diesel engines without any modification. Because there are some oxygen atoms in biodiesel itself that can improve the problem of local

oxygen deficiency during combustion, greatly improve the combustion efficiency and reduce the emission of CO and PM, but NOx slightly increased [7,8].

On the other hand, ethanol is also an oxygenated fuel with high latent heat of evaporation. Therefore, in this study, the effect of diesel–ethanol blends on NOx and PM reduction was investigated in a 4–cylinder common rail direct injection (CRDI) diesel engine.

2. Experimental setup and methods

In this study, pure diesel fuel (E0), 95% E0 blend with 5% ethanol by volume (E5), 90% E0 blend with 10% ethanol by volume (E10) and 85% E0 blend with 15% ethanol by volume (E15) were tested in a CRDI direct injection diesel engine. The engine speed and load was fixed at 1500 rpm and 70 Nm, respectively. Different fuel injection timings including pilot and main was also investigated. Table 1 and 2 shows the engine specifications and the tested fuels' properties, respectively.

[Table 1] The specifications of tested engine

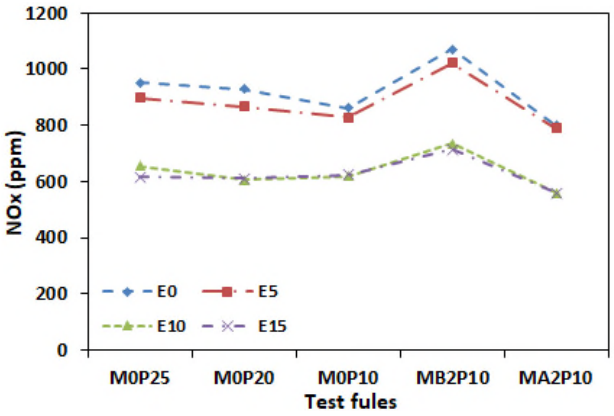
Engine type	CRDI diesel engine
Fuel injection system	Bosch common-rail
Air system	Turbocharger with WGT
Bore × Stroke (mm)	83 ×92
Displacment (cc)	1991
Compression ratio	17.7:1
Maximum power (ps/rpm)	115/4000
Maximum torque (kgm/rpm)	26.5/2000

[Table 2] The properties of tested fuels

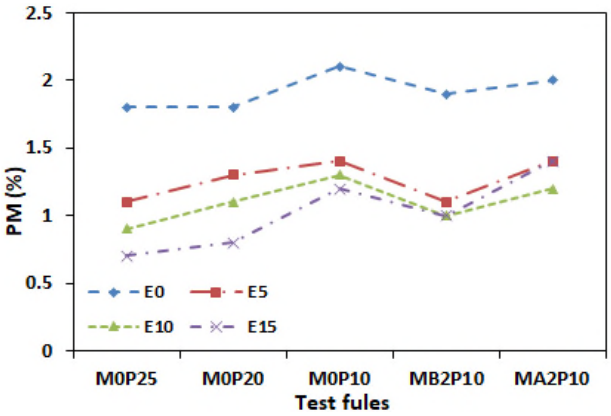
Properties	Diesel	Ethanol
Density (kg/m3at15℃)	836.8	799.4
Viscosity (mm2/sat40℃)	2.719	1.10
Calorific value (MJ/kg)	43.96	28.18
Cetane index	55.8	8
Flash point (℃)	55	12
C/H/O/wt%	86.1/13.9/0	52.2/13.1/34.7

3. Results and discussion

Figure 1 shows the NOx emissions from the diesel engine fueled with 0%, 5%, 10% and 15% ethanol according to different fuel injection timings. As shown in Fig.1, the NOx emissions decreased obviously with the increase of ethanol content in diesel fuel under all experimental conditions. The NOx emissions had the maximum value at MB2P10, 1070 ppm for E0, 1021 ppm for E5, 735 ppm for E10 and 714 ppm for E15. This is because ethanol has good volatility and high latent heat of evaporation, it absorbed a lot of heat around it during atomization, thus reducing the combustion temperature in the cylinder, resulting in low NOx emission [9]. Figure 2 shows the PM emissions from the diesel engine fueled with 0%, 5%, 10% and 15% ethanol according to different fuel injection timings. As shown in Fig.2, the PM emissions decreased obviously with the increase of ethanol content in diesel fuel under all experimental conditions. This is mainly related to the high oxygen content of ethanol. The oxygen contained in ethanol itself improves the local oxygen shortage in the cylinder and forms a more uniform mixture [10].



[Fig. 1] NOx emissions



[Fig. 2] PM emissions

4. Conclusion

Compared with the diesel fuel, biodiesel-ethanol blends show lower NOx and PM emissions due to the high evaporation latent heat and high oxygen content of ethanol.

Acknowledgement

This research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF) funded by the Ministry of Education (Project No. 2019R1I1A1A01057727), and the Korea government (MSIT) (No. 2019R1F1A1063154).

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