Influences of palm oil biodiesel blends on combustion and emission characteristics under idling conditions in a CRDI diesel engine

Gui-Rong Wu*, Jun-Cong Ge*, Min-Soo Kim*, Nag-Jung Choi*,†
*Dept. of Mechanical Design Engineering, Jeonbuk National University
† e-mail: njchoi@jbnu.ac.kr

CRDI 디젤기관에서 공회전시 팜유바이오디젤 혼합연료가 연소 및 배기특성에 미치는 영향

무귀영*, 갈준총*, 김민수*, 최낙정*†
*전북대학교 기계설계공학과
† e-mail:njchoi@jbnu.ac.kr

Abstract

In this study, three different concentrations of ethanol additives of 5, 10, and 15% vol were added to pure palm biodiesel to explore its impact on emissions under idling speed conditions. The results showed that ethanol additives have a significant effect on reducing CO and PM, but it promotes the production of NOx. When the concentration is higher, the emission of HC increases significantly.

1. Introduction

Biodiesel and ethanol are two green alternative fuels with high oxygen content. Biodiesel is a non-toxic, sulfur-free and biodegradable fuel with high cetane number, which is usually derived from oily crops, animal fats and algae as raw materials through transesterification. It can significantly improve engine exhaust emissions and shorten the life cycle of carbon dioxide emissions [1]. However, the disadvantages of high viscosity and high density of biodiesel are also obvious. This will affect the accuracy of fuel injection timing and atomization effect, thereby affecting the combustion effect of biodiesel [2]. On the contrary, as a commonly used fuel additive, ethanol has certain properties opposite to biodiesel, such as smaller density and viscosity, which can neutralize some of the disadvantages of biodiesel. Research [3] pointed out that the addition of ethanol additives reduced the density and cetane number of the tested biodiesel. Study [4] also found that the increase of the concentration of ethanol additives will extend ignition delay and combustion duration.

The effect of ethanol additives on engines under different operating conditions is also slightly different. Kim et al. [5] found that at idle speed, the emissions of carbon monoxide (CO) and carbon hydroxide (HC) increased with the concentration of ethanol in the diesel-biodiesel blends, while the soot and nitrogen oxides (NOx) decreased significantly. When the engine is idling, the combustion is poor and the mixture is thick, which is one of the worst working conditions. Various indicators at engine idle speed are also important metrics.

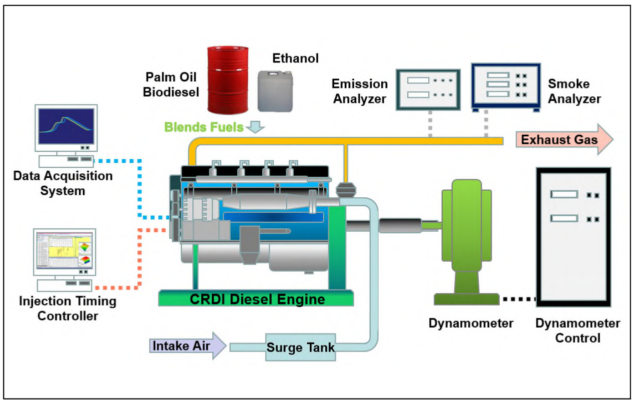
This experiment explored the effects of different proportions of ethanol additives on the combustion characteristics, engine performance and emission characteristics of engines fueled by pure biodiesel under idling speed with low load conditions.

2. Experimental setup and method

2.1 Experiment apparatus and fuels

The experimental system is shown in Figure 1. As shown in Table 1, this test was conducted on a common rail direct injection (CRDI) diesel engine. The injection timing and injection pressure are set by the engine electronic control unit (ECU) by connecting to WinOLS software. Exhaust gas data was measured and recorded by the GreenLine MK2 and Emission Analyzer

(HPC501), while emission PM was measured by an opaque smokometer (OPA-102). Pure palm biodiesel and bioethanol were used as test fuels, and their characteristics are shown in Table 2.



[Fig. 1.] Experimental system.

[Table 1.] Engine specification

Engine type	In-line four-cylinder
Fuel injection system	Bosch common-rail direct injection
Air intake system	Turbocharger with WGT
Bore × stroke (mm)	83 × 92
Displacement (cc)	1991
Compression ratio	17.7/1
Maximum power (ps/rpm)	115/4000
Maximum torque (kgm/rpm)	26.5/2000

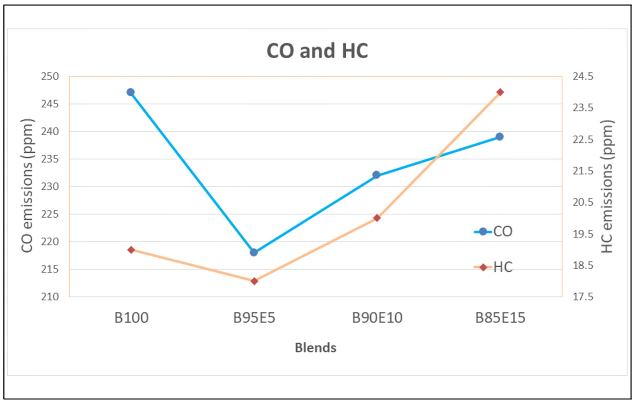
[Table 2.] Fuel properties

Properties	Palm oil biodiesel	Bio ethanol
Density(kg/m3 15℃)	877	799.4
Viscosity(mm2/s 40℃)	4.56	1.1
Calorific value(MJ/kg)	39.72	28.18
Cetane index	57.3	8
Oxygen content(℃)	11.26	34.7

2.2 Experiment method

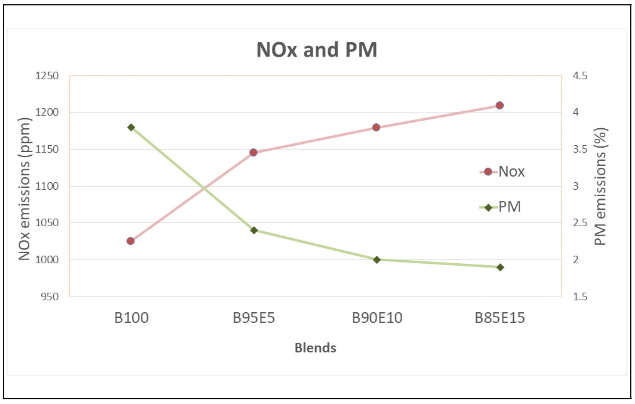
In the test, bioethanol was mixed with pure palm biodiesel at a ratio of 5, 10, 15% vol. The engine speed is stable at 750 rpm, and the load is set at 30 Nm to simulate the operation of different accessories. The injection pressure is set to 350 bar, and the pilot and main injection timings are set at 18° and 5°CA BTDC, respectively.

3. Results and Discussion



[Fig. 2.] CO and HC emissions at 30Nm.

CO and HC are almost always the product of incomplete combustion of fuel. It can be seen that when biodiesel is mixed with 5% vol ethanol additives, the emissions of CO and HC are well suppressed. This may be because the lower viscosity of ethanol improves the viscosity and atomization effect of the fuel, so that the fuel can better contact the air. However, as the concentration of ethanol increases, CO and HC emissions are observed to increase accordingly. The addition of ethanol reduces the cetane number of the blend, increases the latent heat of vaporization of the fuel, prolongs the ignition delay, and reduces the cylinder temperature, which will be detrimental to the complete combustion of the fuel. In addition, the higher H/C ratio of ethanol will introduce more H into the fuel, thus promoting a surge in HC emissions.



[Fig. 3.] NOx and PM emissions at 30Nm.

The formation mechanism of NOx is more complicated and often depends on cylinder temperature, oxygen concentration, reaction time and equivalence ratio. The lower cetane number of ethanol prolongs the ignition delay of the blend, the oil and gas can be fully mixed, and the action time is prolonged. The higher oxygen content of ethanol is also conducive to the formation of NOx. Therefore, NOx emissions increase with ethanol concentration. PM is more formed in areas rich in oil and less oxygen. The higher oxygen content of ethanol dilutes the enrichment of the fuel, and the higher latent heat of vaporization leads to a lower temperature, which makes ethanol have a significant effect on the inhibition of PM formation.

4. Conclusions

The results of this study show that under the conditions of engine idling and low load, ethanol additives have different effects on the main emissions. The lower concentration of ethanol additives significantly improved the emissions of CO and HC, but as the concentration increased, the emissions of both also gradually increased. Additives have the most obvious inhibitory effect on PM, but at the same time promote the formation of NOx.

Acknowledgments

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

References

[1] TUTAK, Wojciech, et al. A comparative study of co-combustion process of diesel-ethanol and biodiesel-ethanol blends in the direct injection diesel engine. Applied Thermal Engineering, 2017, 117: 155-163.

[2] SUH, Hyun Kyu; LEE, Chang Sik. A review on atomization and exhaust emissions of a biodiesel-fueled compression ignition engine. Renewable and Sustainable Energy Reviews, 2016, 58: 1601-1620.

[3] MADIWALE, S.; KARTHIKEYAN, A.; BHOJWANI, V. Properties investigation and performance analysis of a diesel engine fuelled with Jatropha, Soybean, Palm and Cottonseed biodiesel using Ethanol as an additive. Materials Today: Proceedings, 2018, 5.1: 657-664.

[4] KUSZEWSKI, Hubert. Experimental investigation of the autoignition properties of ethanol–biodiesel fuel blends. Fuel, 2019, 235: 1301-1308.

[5] KIM, Ho Young; GE, Jun Cong; CHOI, Nag Jung. Effects of Ethanol–Diesel on the Combustion and Emissions from a Diesel Engine at a Low Idle Speed. Applied Sciences, 2020, 10.12: 4153.