Impact of injection pressure on NOx and smoke of a CRDI diesel engine fueled with palm oil blended fuels

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

팜 오일 혼합연료를 적용한 CRDI 디젤 엔진에서 분사압력이 NOx 및 매연에 미치는 영향

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

Abstract

This work mainly tested the effects of fuel D, P50D50 (50vol% palm oil + 50vol% diesel) and P50D40E10 (50vol% palm oil + 40vol% diesel + 10vol% bioethanol) at the injection pressure of 300, 350, 400 and 450bar. It was found that the NOx displacement increased with the injection pressure, while the smoke was just the opposite. It is worth noting that in most cases, P50D40E10 had a good emission reduction effect on both NOx and smoke.

1. Introduction

In order to cope with the increasingly severe oil crisis and vehicle emissions pollution problems, researchers are constantly looking for new alternative energy sources, among which biomass oil is considered the most promising category [1]. For diesel engines, bioethanol and biodiesel are common alternative fuels. Bioethanol is often used as a fuel additive, and biodiesel can be used directly as a fuel without modification to the engine. However, some studies have found that although biodiesel can replace part of the use of diesel, it costs more total environmental pollution costs [2].

As the raw material of most biodiesel, the output of vegetable oil has continued to increase in recent years, and palm oil is one of the most important products. Palm biodiesel can usually be produced through transesterification. Palm oil is made by pressing palm fruit, which contains a large amount of gum and high free fatty acids. So its viscosity and density is usually higher, which makes it impossible to directly be used in engines. In order to weaken the high viscosity of vegetable oils, researchers have done a lot of work. Hazar et al. [3] mixed rapeseed oil and diesel at the ratios of 0, 20 and 50%, and heated to 100°C. It was found that fuel performance has been significantly improved, and exhaust gas except NOx has been reduced. Hazar et al. [4] mixed rapeseed oil and diesel at the ratios of 0, 20, and 50%, and heated to 100°C. It was found that fuel performance has been significantly improved, and exhaust gas except NOx has been reduced. Chauhan et al. [5] found that the higher the heating temperature of jatropha oil, the lower the fuel viscosity and the suppression of the formation of CO and HC. Sankumgon et al. mixed jatropha oil, ethanol and diesel, and added surfactants. As a result, it was found that fuel viscosity, CO emissions and flue gas were all reduced.

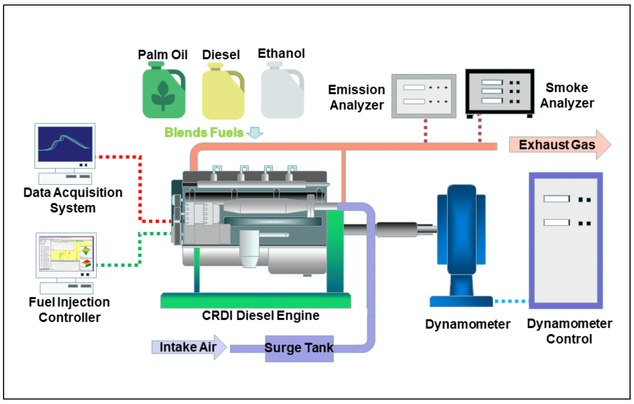
In this study, palm oil, diesel, and bioethanol were separately made into blends, and four increasing injection pressure conditions were set. It mainly explored the influence of injection pressure on NOx and smoke produced by palm oil blended fuels.

2. Experimental setup and method

2.1 Experiment apparatus and fuels

The test system in this study is shown in Figure 1. The engine tested this time is a four-cylinder common rail direct injection (CRDI) diesel engine, and its fuel injection pressure and injection timing are set and controlled by an electronic control unit (ECU). Its specifications are shown in Table 1. The emitted NOx data is measured by the GreenLine MK2 emission analyzer, and the emitted smoke concentration is measured and recorded by the

OP160 non-spectral smoke meter. Diesel, palm oil, and bioethanol were used as test fuels, the properties of which are shown in Table 2.



[Fig. 1] Experimental system.

2.2 Experiment method

The fuels tested in this test were: P50D50 (50vol% palm oil + 50vol% diesel) and P50D40E10 (50vol% palm oil + 40vol% diesel + 10vol% bioethanol). The injection pressures were set at 300, 350, 400 and 450bar respectively, and the pre-injection and main injection were at 21°CA BTDC, 6°CA BTDC respectively. And the engine speed was set at 1600rpm with a load of 40Nm.

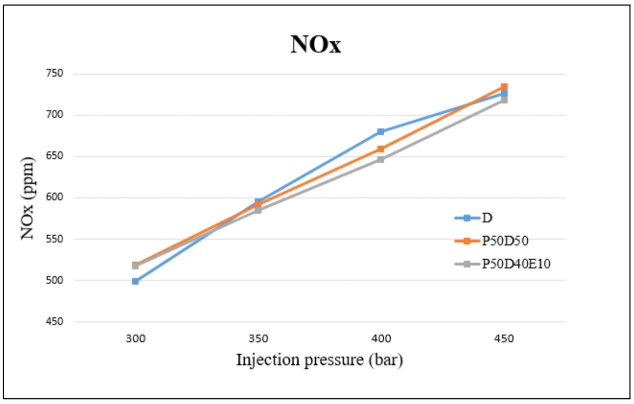
[Table 1] Engine specification

Item	Parameters
Engine type	In-line four-cylinder
Fuel injection system	Bosch common-rail direct injection
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] Fuels properties

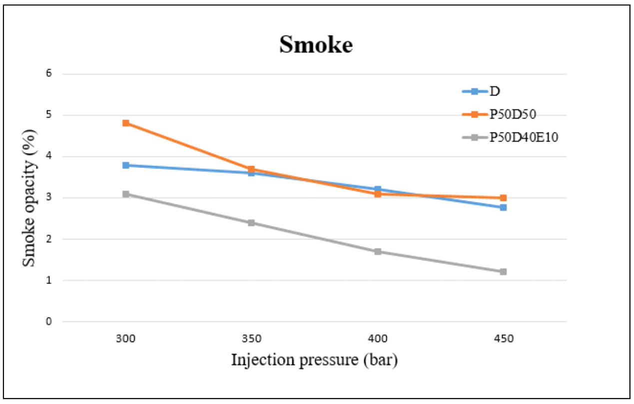
Properties (units)	Palm oil	Diesel	Bioethanol
Density (kg/m3 at 15 °C)	903.8	836.8	799.4
Calorific value (MJ/kg)	39.34	43.96	28.18
Viscosity (mm2/s at 40 °C)	42.21	2.719	1.1
Cetane index	42	55.8	8
Flash point (°C)	260	55	12
Oxygen content (%)		0	34.7

3. Results and Discussion



[Fig. 2] NOx emissions.

The formation of NOx involves the effects of in-cylinder combustion temperature, equivalence ratio, oxygen concentration and reaction time etc. The NOx emissions of the three fuels had similar trends, all of which increase with the injection pressure. This may be due to the fact that the high injection pressure provided tiny spray droplets, which facilitated rapid fuel evaporation and heat release, and increased the temperature in the cylinder. Simultaneously, it can be observed that P50D40E10 generated less NOx than P50D50 under all conditions, which may be due to the use of the bioethanol contained in it. The lower heating value and higher latent heat of vaporization of bioethanol greatly reduced the temperature in the cylinder, which was detrimental to the formation of NOx. It was also found that P50D50 and P50D40E10 had better emissions performance than Fuel D at moderate injection pressures.



[Fig. 3] Smoke emissions.

The particulate matter mainly comes from the high temperature and oil-rich area with low oxygen concentration in the cylinder. Contrary to the variation in NOx, the smoke output was negatively related to the injection pressure. High spray pressure provided good atomization conditions and droplets with smaller particle size, which can reduce the formation of particle precursors. Fuel D was relatively stable with changes in injection pressure, while P50D50 showed a larger fluctuation. P50D40E10 always had the lowest smoke emission, which may be because bioethanol greatly improved the viscosity and oxygen content of the fuel. It reduced the temperature in the cylinder and also facilitated the continued oxidation of particulate matter.

4. Conclusion

The experimental results showed that with the gradual increase in injection pressure, the NOx emitted by the three fuels increased, but the formation of smoke had been positively improved. In addition, the performance of fuel D was similar to that of P50D50, and P50D40E10 emited the least NOx and smoke under most conditions.

References

[1] ATMANLI, Alpaslan, et al. Extensive analyses of diesel–vegetable oil–n-butanol ternary blends in a diesel engine. Applied Energy, 2015, 145: 155-162.

[2] YILDIZ, Ibrahim, et al. Environmental pollution cost analyses of biodiesel and diesel fuels for a diesel engine. Journal of environmental management, 2019, 243: 218-226.

[3] HAZAR, Hanbey; AYDIN, Hüseyin. Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)–diesel blends. Applied Energy, 2010, 87.3: 786-790.

[4] CHAUHAN, Bhupendra Singh, et al. Performance and emission study of preheated Jatropha oil on medium capacity diesel engine. Energy, 2010, 35.6: 2484-2492.

[5] SANKUMGON, Akechai, et al. Properties and performance of microemulsion fuel: blending of jatropha oil, diesel, and ethanol-surfactant. Renewable Energy Focus, 2018, 24: 28-32.