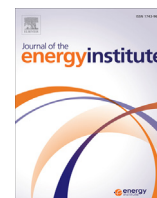




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Impact of DME-biodiesel, diesel-biodiesel and diesel fuels on the combustion and emission reduction characteristics of a CI engine according to pilot and single injection strategies

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ABSTRACT

The purpose of this paper is to investigate the impact of DME-biodiesel, diesel-biodiesel and diesel fuels on the combustion and emission reduction characteristics of a compression ignition engine according to pilot injection and single injection strategies. In this investigation, the effect of pilot injection and single injection modes were studied as they pertain to the combustion and emission characteristics of three alternative fuels. These tests were conducted to display the effect of a DME-biodiesel blend (DME80B20), biodiesel-diesel blend (B80D20), and diesel fuel on a passenger car diesel engine. According to the combustion characteristics, the DME80B20 fuel has a higher pressure than the B80D20 and conventional diesel fuel, while the DME-biodiesel blend exhibits a lower peak in pilot injection. The maximum pressure of the pilot injection mode showed significantly lower pressure than for single injection mode without pilot injection. In a pilot injection cycle, NO_x emissions of DME-blend (DME80B20) are higher than those of diesel and biodiesel-diesel blend (B20D80), regardless of injection timings. The soot emission was nearly zero for both single and pilot injection, though diesel and B20D80 fuel showed a higher distribution of soot emission than that of DME80B20 in the case of pilot injection.

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1. Introduction

The emissions standards for diesel engines are growing increasingly stringent to reduce the concentration of particulate-matter (PM) and nitrogen oxide (NO_x) emissions. It is difficult to reach a state of clean emissions with current combustion technology, thus, various technologies for emissions reduction such as alternative fuels, advanced combustion technologies, and after-treatment technology will be needed to meet the emissions regulations. The use of alternative clean fuels such as dimethyl ether (DME), biodiesels, and bioethanol is one method of reducing the NO_x and PM emissions in diesel engines [1–5].

The chemical formula of DME fuel is CH₃–O–CH₃; it is the simplest ether compound. Among alternative fuels, the application of DME for diesel engines has been discussed by many investigators because it has no carbon–carbon bonds and excellent self-ignition characteristics compared to other fuels [6–8]. The cetane number of DME fuel is significantly higher than that of conventional diesel fuel [9,10], thus, it can be utilized to attain short ignition delay which then suppresses rapid premixed burning [11,12]. Cleaner combustion with low exhaust emissions can be achieved when a CI engine is operated with DME fuel, than with a diesel engine fueled with conventional diesel.

During the combustion of DME fuel in the combustion chamber, the formation of NO_x emission is dependent upon the combustion temperature and oxygen content. Due to its excellent auto-ignition and higher cetane number characteristics, pilot injection can effectively reduce NO_x emission by shortening the ignition delay. The heat of vaporization for DME and diesel fuel at 293 K can be compared at 410 kJ/kg and 233 kJ/kg, respectively [13]; therefore, the latent heat of DME is 1.59 times larger than that of diesel fuel. In general, a decrease in soot emission creates an increase in NO_x emission due to the traditional trade-off relation between PM and NO_x. One of the great challenges for high-speed diesel engines is the simultaneous reduction of soot and NO_x emissions without increased fuel consumption [14,15]. Fuel-

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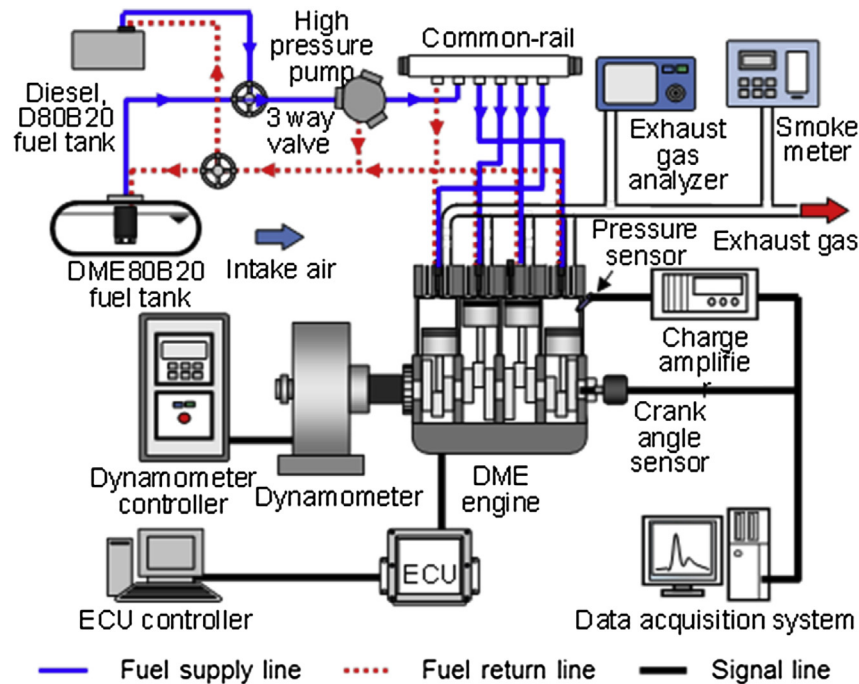


Fig. 1. Schematic diagram of the experimental apparatus.

injection systems in CI engines play an important role in engine performance and emission reduction. In diesel combustion, the pilot injection resulted in a decrease in combustion temperatures and a downward trend in main combustion, which contributes to a reduction in the premix combustion period. Many studies have shown that problems related to DME-fueled engine systems include low lubricity, lower DME heating value, and higher NO_x emission from the engine. Methods for overcoming low lubricity include the use of additives on DME viscosity-enhancing materials such as biodiesel, conventional diesel fuel, and other fuels [1,16,17]. Lowering the initial heat-release rate during the combustion process can reduce NO_x emissions. The generation of NO_x emission is dependent on the maximum temperature of combustion and fuel-injection timing. Suh et al. [4] demonstrate that the use of multiple injections is an effective method for reducing NO_x emissions, though more information is needed regarding DME combustion and the simultaneous reduction of nitrogen oxides and soot emissions in the DME-fueled engine. The use of pilot-injected conventional diesel fuel to reduce NO_x emission in diesel engines has been widely reported; however, further study with regard to the multiple injection strategy of DME fuel in diesel engines is needed.

In general, pilot injection strategy is known for reducing NO_x emissions and noise because it can suppress rapid combustion phase, however, pilot injection strategy leads to increase PM emissions owing to its trade-off relationship. With this point of view, DME fuel has oxygen contents and no carbon–carbon bonds [6,7]; therefore, it can be expected to reduce NO_x and PM emissions simultaneously when applying pilot injection strategy.

The purpose of this study was to investigate the effects of pilot injection strategy on the combustion and emission reduction characteristics of a compression ignition engine fueled with DME-biodiesel, diesel-biodiesel and diesel fuels. In this investigation, the emission characteristics of the test fuels were studied according to the pilot injections in order to obtain the reduction effect of combustion pressure for NO_x , soot, HC, and CO concentration. The thermodynamic heat release characteristics were also investigated. The effects of pilot injection on combustion and emission characteristics are compared with the results from biodiesel and conventional diesel fuel.

2. Experimental and numerical methodologies

The experimental setup was composed of a common-rail diesel engine from a passenger car, an engine dynamometer system, an electronic control system, and a data acquisition system, as shown in Fig. 1. The experimental engine used in this work was a four-cylinder

Table 1
Specifications of the test engine.

Item	Specifications
Engine type	4-stroke VGT DI Diesel
Number of cylinders	4
Bore $\times$ Stroke (mm)	77.2 $\times$ 84.5
Displacement volume (L)	1.582
Valve type	DOHC 4 valves per cylinder
Compression ratio	17.3
Engine Management System	Bosch EDC 16
Max. power (kW/rpm)	86/4000
Max. torque (N·m/rpm)	260/2000
Max. speed (rpm)	4750

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