46 The Effects of Combination for Biodiesel Fuel and EGR in a D.I. diesel Engine

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The emission of diesel engines is recognized as the main cause for the serious air pollution related problems affecting our environment. In this study, we studied the potential of biodiesel fuel, which can reduce smoke emission, as an alternative fuel for diesel engine. Because biodiesel fuel has about 10.5% oxygen content the combustion of the diesel engine improved and exhaust smoke emission density decreased especially at high loads and speeds. And, the EGR(exhaust gas recirculation) system has been widely used to reduce nitrogen oxides(NOx) emission. However, as the EGR rate at a given engine operating condition increases, the combustion instability increases. Therefore, the optimum EGR rate should be carefully determined in order to obtain the better engine performance and emissions. This study shows that the simultaneous reduction of smoke and NOx emissions can be achieved by combination of biodiesel blending fuel(20vol-%) and EGR method(5-15%)

Keywords : Biodiesel Fuel, Diesel Engine, EGR(Exhaust Gas Recirculation), Smoke, Nitrogen Oxides

1. INTRODUCTION

Diesel Diesel-powered vehicles are popular for heavy-load transportation because their fuel efficiency is higher than those of gasoline-powered vehicles. Although diesel engines provide convenience for our daily lives, they produce a foul smell from their emission, which also contains many types of toxic air pollutants, including hydrocarbons, carbon monoxide, nitrogen oxides, sulfur oxides, volatile organic compounds, semivolatile organic compounds and soot. And so, to improve air quality, diesel engines are subject to severe emission regulations. These regulations throughout the world have placed the limitations of design modifications on diesel engines.

Recent studies indicated that the cetane number, aromatic content and type, sulfur content, distillation temperature, and density are important factors for emission control[1-3]. Reduction in the aromatic content and/or removal of heavy fractions, or the use of lighter fuels are considered to be effective measures against the mentioned problems[4-5].

In particular, the smoke emission from the diesel engine is recognized as the main cause strongly influencing the environment. The strict regulations for air quality improvement have placed limitations on the design modification on the engines themselves. And, the use of fossil fuels as an energy source presents its own set of problems, mainly that since they are nonrenewable, their availability is limited. Also, the fossil fuels converts to CO_2 when they are burned, and thus increases the concentration of greenhouse effects in the surroundings[6], too. The increase of CO_2 concentration is considered to be the leading cause of global warming. Furthermore, the world now depends on foreign sources of fossil petroleum fuels to meet its demand.

In this study, one is an experiment that evaluated engine performance with the application of biodiesel fuel in a direct injection diesel engine, and that also investigated the performance of biodiesel fuel as an alternative fuel for diesel engines. Biodiesel fuel contains 10.5% oxygen content which significantly reduces the exhaust smoke emission density at high loads and speeds in direct injection diesel engines. In addition to the experiment, a procedure analyzed the individual unburned hydrocarbon in the exhaust gas.

And, exhaust gas recirculation(below EGR) method was applied for reduction of NOx emission. Because biodiesel Fuel is a kind of oxygenated fuel, combustion speed and temperature of biodiesel fuel is higher than that of diesel fuel on combustion period. In this study, we applied cooled EGR method to control NOx emission.

2. EXPERIMENTAL METHOD AND APPARATUS

A horizontal, water cooled, single cylinder, naturally aspired, direct injection diesel engine was used, and the principal specifications of the engine are shown in Table 1. Properties of the biodiesel fuel and commercial diesel fuel for this experiment are shown in Table 2, and blended fuels-the combination of the commercial diesel fuel and the biodiesel fuels were used in the test. The schematic diagram of the experimental apparatus is shown in Fig. 1. Engine speed and load were controlled by the eddy current dynamometer. Exhaust smoke emission density was measured with a smoke meter(Hesbon; HBN-1500) and the NOx concentration was measured with an exhaust gas analyzer(Motor branch; Mod. 588). After the fuel consumption time was measured with a stop watch, the brake specific energy consumption rate(BSEC) of each fuel was calculated by a volumetric flow meter. The engine was operated with 80±2℃ cooling water under all operating conditions. The engine was operated at speeds of 1000, 1500, 2000 and 2500rpm, with loads between 0% and 100% at 25% intervals. And a specific case of 90% load was investigated, too. The biodiesel fuel was blended in conventional diesel fuel between 0vol-% and 100vol-% at 20vol-% intervals.

In this study, the EGR ratio is defined as:

$EGR(\%) = (V_{EGR}/V_a) \times 100$

Where, V_{EGR} is the recirculated exhaust gas mass flow rate, V_a is the intake air mass flow rate for the case of no EGR.

Table 1 Specifications of test engine

Items	Specifications
Engine Model	ND130
Bore × Stroke(㎜)	95 × 95
Displacement(cc)	673
Compression Ratio	18
Combustion Chamber Type	Toroidal
Coolant Temp.(℃)	80 ± 2

Table 2 Properties of test fuels

Properties	diesel fuel	BDF
Calorific Value MJ/kg]	43.12	39.61
Cetane Number	45	57
Sulfur(Wt%)	0.05	0
Carbon(Wt%)	86.76	77.25
Hydrogen(Wt%)	13.05	11.83
Oxygen content (%)	0	10.5

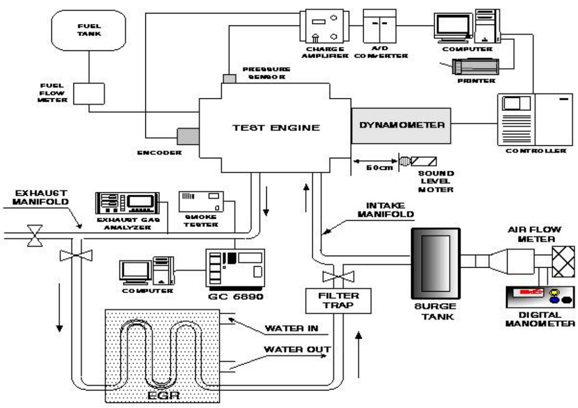

Fig 1. Schematic diagram of experimental apparatus

3. RESULT AND DISCUSSION

3.1 Exhaust Emissions and BSEC characteristics on biodiesel fuel blending ratio

Fig. 2 shows the torque curve of the engine for several blending ratios from 0vol-% to 100vol-% at full load. The torque achieved by the engine at full load for all fuels was similar. Although the heating value of the biodiesel fuel is lower than that of the commercial diesel fuel by approximately 8%, engine torque showed no significant differences because the oxygenated component in the biodiesel fuel improved combustion efficiency.

To investigate the effects of the oxygenated component on engine performance, brake specific energy consumption (BSEC) was measured and calculated at various engine speeds and loads.

Fig. 3 shows BSEC at each blending ratio from 0 to 100vol-% at varying engine speeds and loads. Even though the blending ratio was varied, BSEC did not change significantly. At 2500rpm, which was maximum speed in our experiment, the

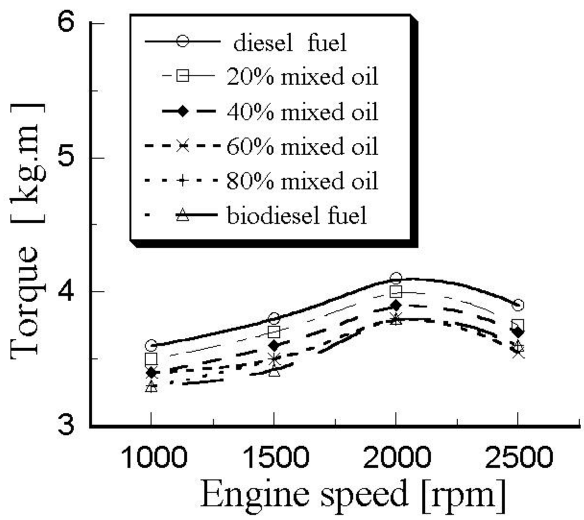

Fig. 2 Torque at full load

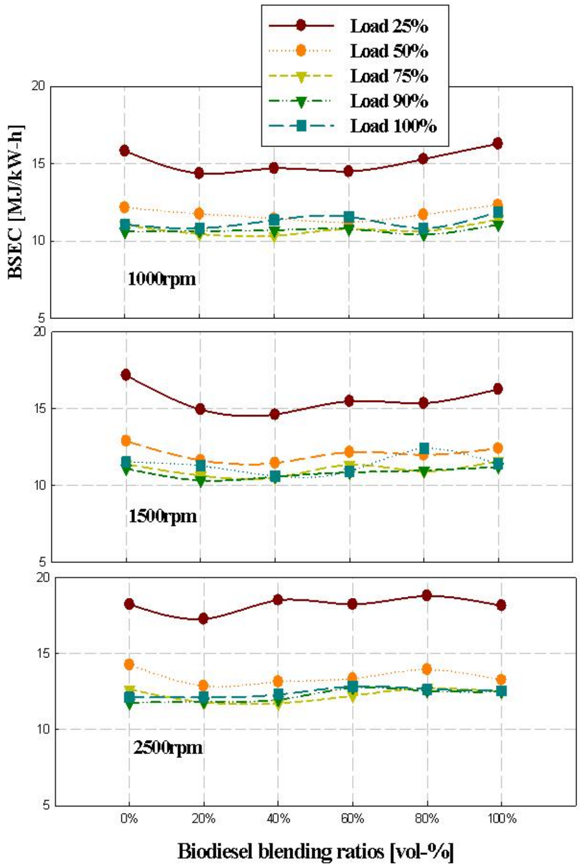

Fig. 3 Comparison of BSEC at various engine loads and speeds on biodiesel blending level

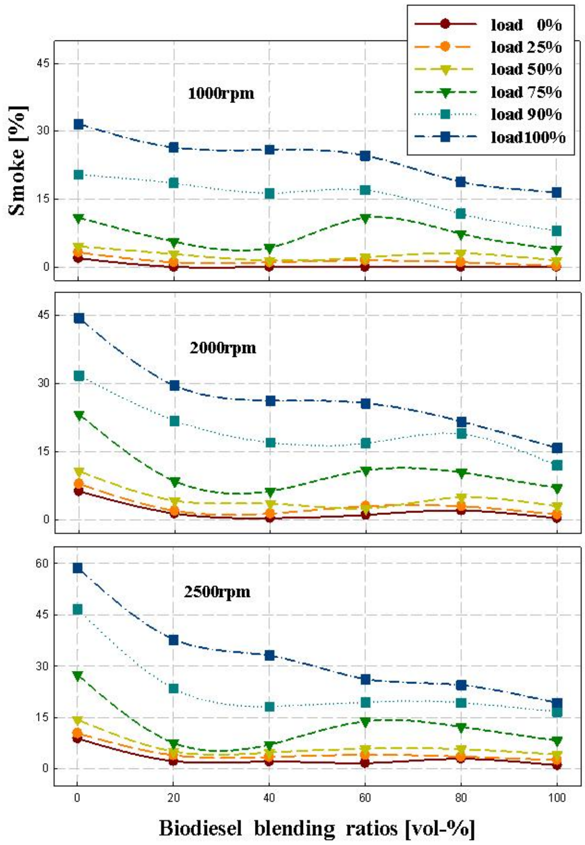

Fig. 4 Comparison of smoke at various engine loads and speeds on biodiesel blending level

cases in which the engine used biodiesel fuel showed better performance than the cases in which the engine used diesel fuel. This result means that the effects of oxygen components in biodiesel fuel can be used throughout the operating region; that is, the effects of the oxygen component in fuel were much more significant in the combustion chamber at higher loads and speeds than at lower loads and speeds. Additionally, combustion efficiency was improved due to the oxygenated component into biodiesel fuel at high loads and speeds.

Fig. 4 shows the effect of the biodiesel fuel blending ratio on exhaust smoke emission density at various engine speeds and loads. As seen in this figure, there was a remarkable difference in the exhaust smoke emission density among diesel fuel, blended fuel, and 100vol-% biodiesel fuel. In particular, the densities were more remarkable at high loads and speeds. The main cause for this difference may be due to the presence or absence of oxygen components among diesel fuel, blending fuel, and 100% biodiesel fuel. This suggests that the oxygen components in the biodiesel fuel itself increasingly facilitated the oxidization of fuel particles at high loads and speeds during the diffusion combustion period. In general, the oxygen concentration in the diffusion combustion period was leaner than that in the premixed combustion period. The exhaust smoke emission density from the diesel fuel exhibited significant differences in proportion to the load that changed from low to high. However the emissions from the biodiesel fuel did not show significant differences in proportion to the varying load. When biodiesel fuel was used in the diesel engine, the differences between created quantity and oxidized quantity of carbonaceous particulate matter were reduced, and it was thought that the oxygen component in biodiesel fuel increased the oxidization rate of fuel particles.

Fig. 5 presents the results of the investigation of effect on NOx emission, which was conducted under the same conditions as those outlines in Fig. 4. The NOx concentration increased slightly as the biodiesel fuel ratio increased. The NOx emission was formed as the cylinder temperature increased, possibly due to the oxygen component in the biodiesel fuel[7-9].

Fig. 6 shows the effect of oxygen content in fuel between non-load and full load at various engine speeds. In the non-load region, the exhaust smoke emission density does not change significantly with increased oxygen content in fuel. Note that smoke emissions barely exhausted at an oxygen content above 2wt-% at load 0%. At full loads, exhaust smoke emission density was reduced significantly with increased oxygen content in fuel.

In particular, when the oxygen content in fuel was above 8%, the exhaust smoke emission density was below 25% at all operating ranges.

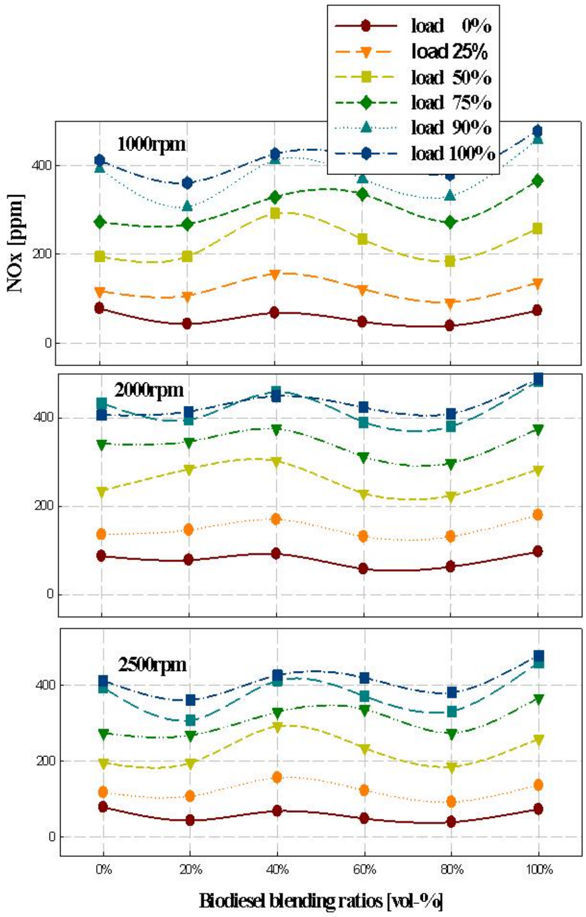

Fig. 5 Comparison of NOx at various engine loads and speeds on biodiesel blending level

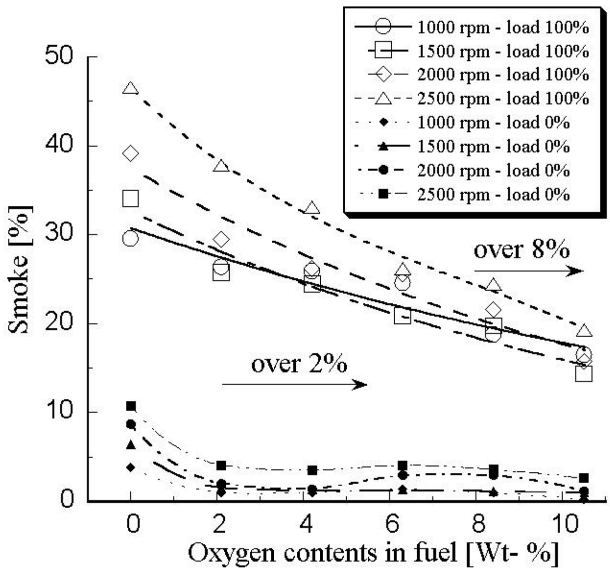

Fig. 6 Comparison of smoke density of load 0% vs. full load with various oxygen contents

3.2 The Effects of EGR on biodiesel fuel

EGR is currently considered an effective technique for reducing NOx emissions in diesel engine, but it can result in a substantial increase in smoke emission. from the point of view of smoke emission, the application of EGR represents a source of contamination with a large amount of smoke. As it stated above, smoke emission was reduced remarkably with biodiesel fuel, NOx emission was increased slightly with biodiesel fuel.

Fig. 7 shows the effects of EGR with biodiesel fuel 20%(+diesel fuel 80%) on smoke for the various engine speeds and loads. This figure showed that the increasing of EGR rates caused increasing of smoke emission.

In particular, exhausted smoke emission of biodiesel blended fuel was more increased than that of diesel fuel above 20% EGR rate. As seen in this figure, EGR rate of 20% or more did not match biodiesel blended fuel(20%) in a diesel engine.

Fig. 8 shows the effects of EGR with biodiesel fuel 20%(+diesel fuel 80%) on NOx emission for the various engine speeds and loads. This figure showed that the increasing of EGR rates caused decreasing of NOx emission.

From Fig. 8, it is evident that EGR was very effective in reducing NOx emission at all operating conditions.

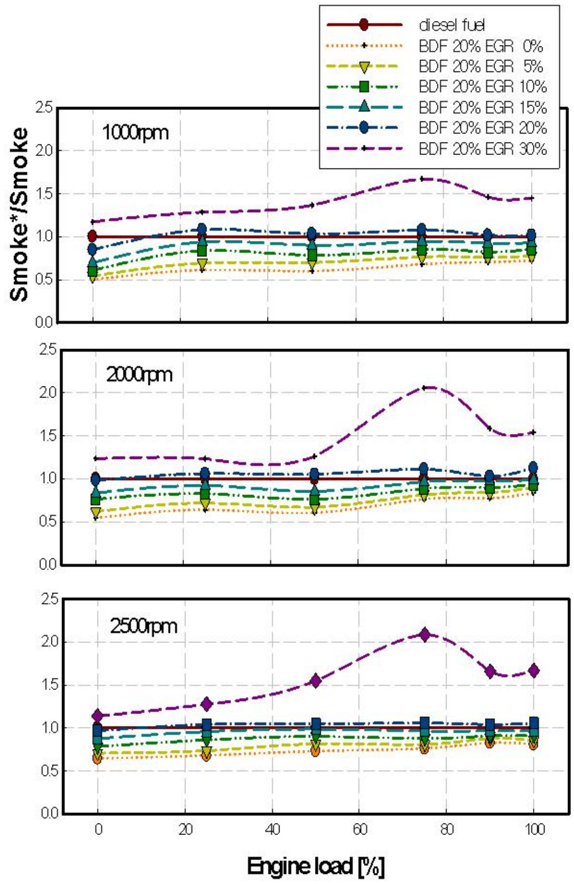

Fig. 7 Variation of smoke vs. EGR rate at various engine speeds and loads

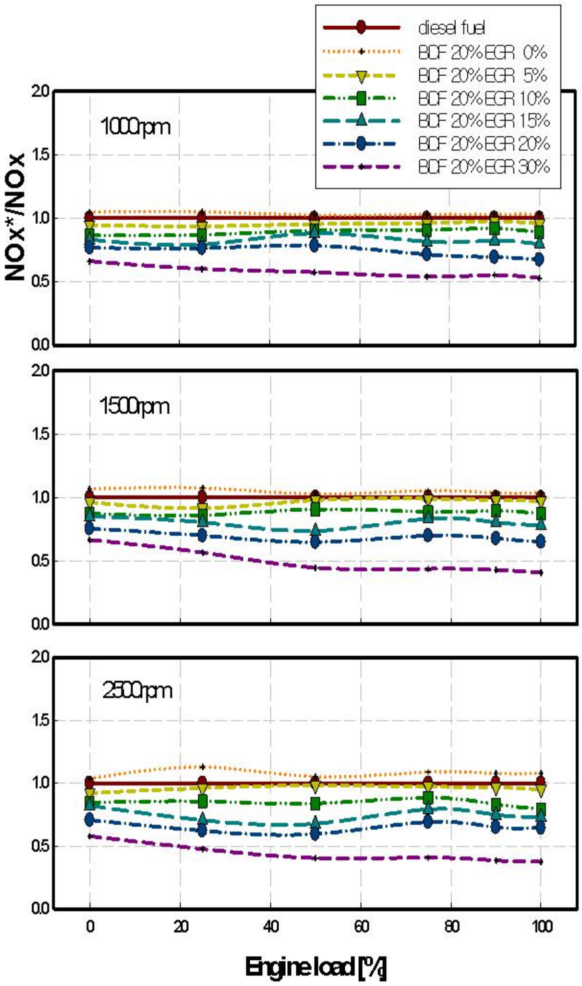

Fig. 8 Variation of NOx emission vs. EGR rate at various engine speeds and loads

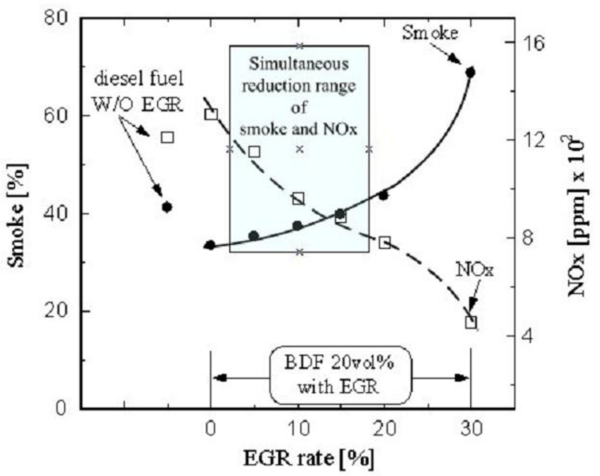

Fig. 9 Simultaneous reduction of smoke and NOx with EGR from 5 to 15%

Fig. 9 shows the effect of EGR with biodiesel 20vol-% on smoke and NOx emission. Typical results of EGR where NOx reduction is attained but with a corresponding increase in smoke can be clearly recognized.

4. Conclusions

A four stroke, single cylinder, water cooled, direct injection diesel engine operating with blended biodiesel fuel at various engine speeds and loads was experimentally investigated. The ratio of the blended biodiesel fuel was set as a parameter in the experiment to clarify the effect of the oxygen component on smoke emission and NOx emission, and to determine the relationship between exhausted smoke emission density and NOx emission with EGR method.

The conclusions extracted from this investigation are summarized as follows:

(1) When biodiesel fuel or blended biodiesel fuel was used in place of a commercial diesel fuel, there was no significant difference in engine torque and brake specific energy consumption.

(2) As oxygen content in the fuel increased, the exhausted smoke emission density was reduced significantly. In particular, when the oxygen content in the fuel was above 8wt-% at a higher load, the smoke reduction rate was significant at all engine speeds.

(3) The combination of biodiesel blended fule(20%+diesel fuel 80%) and EGR mathod(5-15%) achieved the simultaneous reduction of smoke and NOx

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