Effect of Wet Ethanol on Performance and Smoke Emission of Direct Injection Diesel Engine with Cold EGR System Fueled by Diesel Fuel and Jatropha Oil

by Nazaruddin Sinaga

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I. INTRODUCTION

Diesel engines are widely used as a mode of transportation because of better performance and higher efficiency than gasoline engines. Increased use of diesel engines has resulted in increased fuel consumption and air pollution. Increased fuel consumption contributes to the depletion of petroleum reserves. In addition, diesel engines produce soot emissions that are harmful to health. To overcome this problem, jatropha oil can be used as a substitute for diesel fuel because jatropha oil has physical properties that are almost similar to diesel fuel [1]. However, jatropha oil results in reduced performance of diesel engines and produces higher soot emissions than diesel fuel ones. This is because jatropha oil has high viscosity and low heating value compared to diesel fuel [2].

To reduce soot emissions due to the use of jatropha oil, methanol additives are mixed into diesel fuel and jatropha oil [3]. Ethanol is another type of alcohol that is also widely used as an additive in diesel fuel. This is because ethanol has a high oxygen content which results in increased combustion efficiency and the addition of ethanol can also reduce soot emissions [4]. Besides, the water content in ethanol can also reduce soot emissions [5]. Syam Pandey et al. (2019) also revealed that ethanol has higher latent heat than that of diesel fuel, causing the combustion temperature decreases incisively during the combustion process in the cylinder [6]. Previous research was also conducted by Sham Shamun, et al. (2018) that ethanol addition into diesel fuel can reduce soot emissions from diesel engine [7]. Meanwhile, ethanol has a lower heating value which results in an increase of fuel consumption [8]. EGR (Exhaust Gas Recirculation) is one of the methods to reduce NOx emission produced by diesel engines by reducing the temperature in the combustion chamber [9]. The decrease in the air in the combustion chamber results in a reduction of combustion temperature reducing NOx emissions [10]. The EGR system is divided into two based on temperature, namely hot EGR and cold EGR [11].

Based on the previous literature studies, the investigation of the addition of wet ethanol into diesel engine fuel with the EGR system has never been performed. Therefore, this study focuses on investigating the effect of wet ethanol on soot emissions and performance produced on direct injection diesel engine with the EGR system on variations of diesel fuel and jatropha oil blends. Performance and soot emissions are produced for a variety of fuel blends compared to those produced from pure diesel fuel.

II. EKSPERIMENTAL SET-UP

In this study, the performance and smoke emission from diesel engines were investigated with diesel fuel and jatropha oil blends, as well as wet ethanol additives. Diesel fuel was produced by PT. Pertamina, while wet ethanol and jatropha oil were obtained from the market. The physical properties of fuel and additives are shown in Table 1. Variations in jatropha oil in fuel blends were in the range of 10% to 30% and wet ethanol additives were varied from 5% to 15% of the total volume of the mixture. Experiment results of various fuel blends were compared with the results of the experiment using a diesel engine with pure diesel fuel. To facilitate analysis, several terms are used to express the type of fuel. The D100 is pure diesel fuel, J10WE5 represents fuel with 10% jatropha oil and 5% wet ethanol, and the rest is diesel fuel. To overcome the separation problem between diesel fuel and jatropha oil with wet ethanol additives, a mixer was used to produce a homogeneous mixture.

Table 1. Fuel Properties

No	Properties	Diesel	Jatropha	Wet ethanol
1	Cetan Number	48	41,8	5-8
2	Water Content (% v)	0,05	3,16	1,8
3	Viscosity (at temperature 400c (mPa.s))	2,0-5,0	3,23	2,51
4	Calorific Value (MJ / kg)	45,21	37,97	26,8
5	Flash Point (0C)	60	198	38
6	Oxygen content (%)	-	10,9	34,8

This experiment uses a four-cylinder direct injection diesel engine where the specifications are shown in Table 2. Diesel engine shaft was connected in-line with a dynamometer (sea type water brake dynamometer and accuracy of ± 0.3Nm) to measure engine torque. The engine speed was monitored using a tachometer (TZN4S-14R Temperature Switch Autonics type are ± 0.3% accuracy). A burret was used to measure fuel consumption by tracking the time to consume 30 ml of fuel. Exhaust gas temperature was measured using a K type thermocouple installed in the exhaust gas line. Fresh air and EGR rates were measured using orifice plates with U manometer. This experiment was carried out at a constant engine speed of 2,500 rpm. This experiment also investigated the use of hot/cold EGR and without EGR with a variety of fuel blends. Cold EGR means that part of the circulated exhaust gas is cooled first by a heat exchanger before it enters the combustion chamber. Engine load was determined by varying the water valve openings in the dynamometer in the range of 25% to 100% at 25% intervals for variations in fuel blends with additive. The experimental set up is illustrated in Figure 1.

Table 2. Engine Specifications

Properties	Diesel
Isuzu	Isuzu
Type 4BJ1	Tipe 4BJ1
Number of cylinders	4, vertical in-line, Direct Injection
Cylinder diameter	93 mm
Step length	102 mm
Total cylinder volume	2771 cc
Compression ratio	18,2 : 1
Maximum torque	178,96 Nm (pada 2000 rpm)
Maximum power	52,2 kW (pada 3000 rpm)

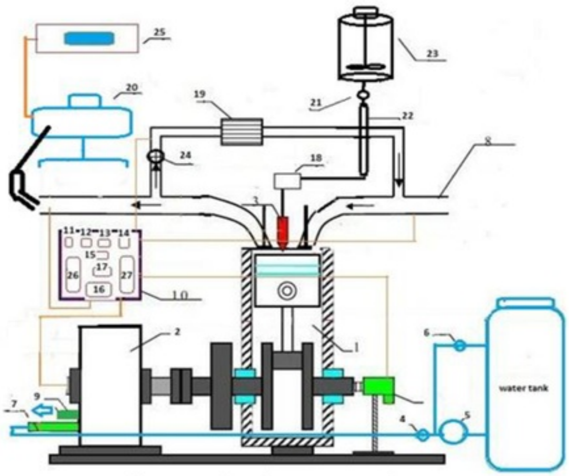

Figure 1. Testing system scheme

1. Diesel engine
2. Dynamometer
3. Injector
4. Water flow valve
5. Pump Dynamometer
6. Valve By pass
7. EGR water inlet
8. Intake manifold
9. Outlet water EGR
10. Display temperature
11. Exhaust temperature
12. Intake temperature EGR
13. Discharge temperature EGR
14. Mixed temperature
15. U Manometer
16. Display Load Engine
17. Tachometer
18. Injection pump
19. EGR Cooler
20. Smoke meter
21. Fuel VALVE
22. Burret
23. Fuel Mixer
24. EGR Valve
25. Gas analyzer

III. RESULTS AND DISCUSSION

3.1 Engine Performance

3.1.1 Brake Torque

Figure 2 shows the brake torque values for various fuels at different engine loads without or with hot/cold EGR. From Figure 2, it can be observed that the brake torque increases with increasing engine loads. The addition of 10% wet ethanol (J10WE10 fuel) as an additive to diesel fuel and jatropha oil increases the brake torque by 2.3% compared to that from jatropha oil and diesel fuel blend (J10). This is due to high latent evaporation heat on wet ethanol so that the fuel evaporates better, and the presence of wet ethanol increases the combustion process in the combustion chamber [12]. The use of EGR increases the duration of combustion, causing an increase in cylinder pressure resulting in an increase in torque, eventually. [13]. The highest brake torque increase is 13.6% with J10WE10 fuel on the hot EGR system.

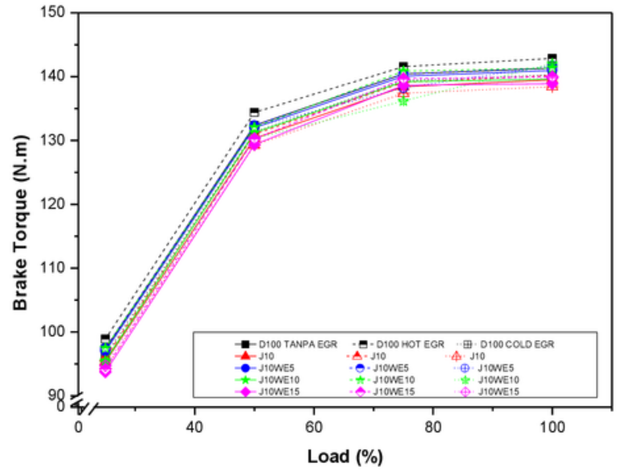

Figure 2. Brake torque for various fuels with variations in engine load

3.1.2 Brake Power

Figure 3 shows the brake power value for various fuels in different engine loads with or without hot/cold EGR. From Figure 3, it can be observed that brake power increases with increasing engine loads. The addition of 10% wet ethanol (J10WE10 fuel) as an additive to diesel and jatropha oil fuels increases brake power 2.3% compared to those from J10 fuel. The high percentage of oxygen in wet ethanol causes an increase in the combustion process in the combustion chamber resulting in an increase in engine power [14]. The use of EGR slightly increases engine power because unburned fuel in the circulating exhaust gas enters into the combustion chamber. The exhaust gas contributes to the subsequent combustion cycle so that the use of EGR increases engine power. The highest increase in brake power is 13.6% with J10WE10 fuel on the hot EGR system.

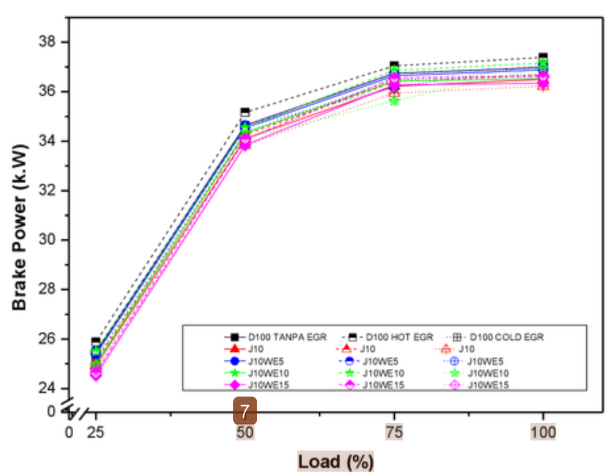

Figure 3. Brake power for various fuels with variations in engine load

3.1.3 Brake Spesifik Fuel Consumption (BSFC)

Figure 4 illustrates the BSFC value for various fuels at different engine loads with or without hot/cold EGR. From Figure 4, it can be observed that BSFC increases with increasing engine loads. 15% wet ethanol (J10WE15 fuel) as an additive to diesel fuel and jatropha oil fuels increases BSFC of 2.2% compared to those from J10 fuel. The increase in BSFC due to the lower wet ethanol heating value than diesel fuel causes increased fuel consumption compared to pure diesel fuel [15]. The use of hot EGR can reduce fuel consumption better than cold EGR. The duration of combustion is increased due to high intake temperature in the hot EGR system [13]. It can be concluded that the use of hot EGR reduces fuel consumption lower than that from cold EGR. The use of hot EGR reduces 15.2% BSFC on J10WE15 fuel with full engine load.

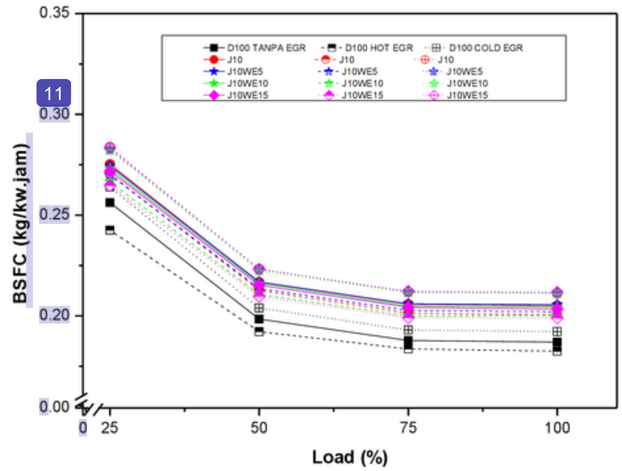

Figure 4. BSFC for various fuels with variations in engine load

3.1.4 Brake thermal efficiency (BTE)

Figure 5 illustrates the value of BTE for various fuels in different engine loads with or without hot/cold EGR. In this experiment, it can be observed that BTE increases with increasing engine loads. Addition of 15% wet ethanol to J10 fuel increases BTE of 2.62%. The increase in BTE due to the high percentage of oxygen in wet ethanol causes better combustion in the combustion chamber [14]. The use of EGR causes a decrease in the BTE value caused by some of the fresh air entering the cylinder replaced by exhaust gas so that the oxygen percentage in the combustion chamber decreases [15]. BTE enhancement using the hot EGR system is 9.21% with J10WE15 fuel at full engine load.

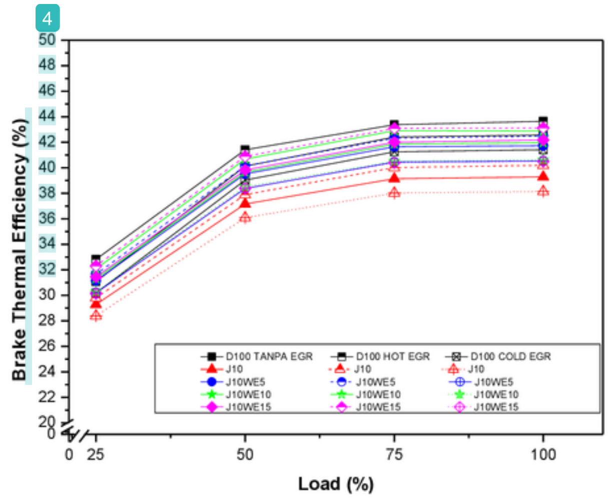

Figure 5. BTE for various fuels with variations in engine load

3.2 Exhaust gas temperature (EGT)

Figure 6 shows the EGT value for various fuels at different engine loads with or without hot/cold EGR. From Figure 6, it can be observed that the addition of 15% wet ethanol in J10 fuel decreases the EGT value by 2.03% with an engine load of 75%. The use of EGR decreases EGT because the amount of oxygen circulated into the combustion chamber is less [16]. Reduced oxygen concentration results in incomplete combustion, causing decreased combustion temperature [17] The decrease in EGT with the cold EGR system is 7.03% for J10WE15 fuel.

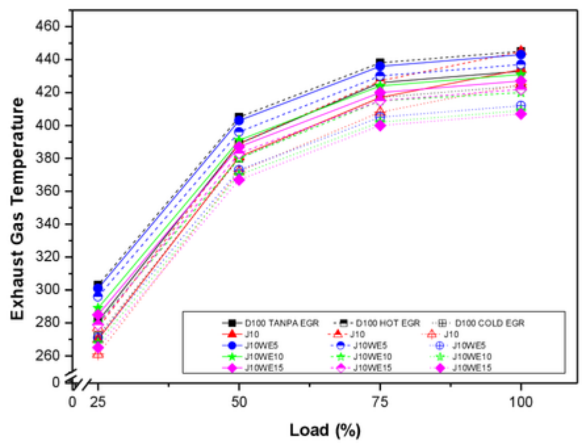

Figure 6. EGT for various fuels with variations in engine load

3.3 Exhaust Gas Emission

3.3.1 Smoke Emission

The opacity value represents smoke emission. Figure 7 illustrates the value of opacity for various fuels at different engine loads with or without hot/cold EGR. In this experiment, it is observed that opacity increases with increasing engine loads. Opacity increased by only 1.03% on the addition of the J10WE15 fuel with full engine load. Increased smoke opacity is caused by the high fuel injected into the combustion chamber so that carbon increases due to incomplete combustion. The use of EGR reduces the oxygen concentration in the combustion chamber resulting in an increase in opacity caused by a decrease in carbon oxidation [18]. The use of cold EGR increases the opacity to 31.03% with J10WE15 fuel at 75% engine load.

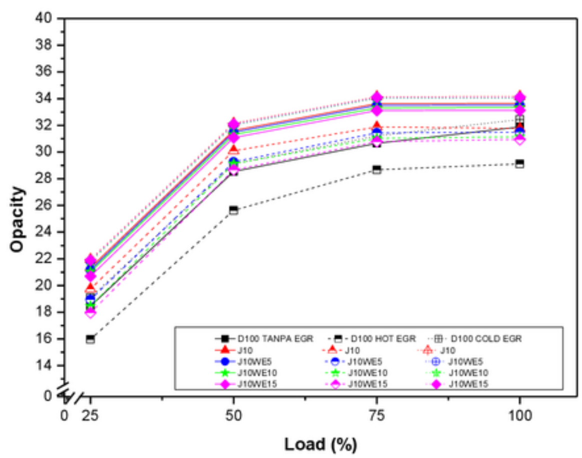

Figure 5. Opacity for various fuels with variations in engine load

IV. CONCLUSION

Wet ethanol is an alternative renewable fuel that can improve engine performance and reduce exhaust emissions. From the results of this study, it was found that the use of wet ethanol as an additive in diesel fuel has an impact on engine performance and exhaust emissions with the EGR system. From this experiment, it was found that torque and brake power was increased by 13.6% with 10% wet ethanol in the hot EGR system. BSFC was decreased by 15.2% on the hot EGR system with J10WE15 fuel, while the BTE was increased by 9.21% with fuel J10WE15. In this work, the EGT was reduced by 7.03% with J10WE15 fuel, while the opacity was increased by 31.03% with J10WE15 fuel in the cold EGR system.

V. ACKNWOLEDGEMENT

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