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EFFECT OF HOT EGR ON PERFORMANCE AND EXHAUST GAS EMISSIONS OF EFI GASOLINE ENGINE FUELED BY GASOLINE AND WET METHANOL FUEL BLENDS

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ABSTRACT

The aim of this study is to investigate the effect of EGR and wet methanol as the fuel blends on the performance and emission of EFI gasoline engine. The content of wet methanol blended with the gasoline fuel was 5 to 15% by volume. EGR rate was 7.25% by volume of mass inducted into the combustion chamber. Engine speeds were varied in the range of 2500 to 4000 rpm with 500 intervals for constant load of 25% from the maximum achievable load. By comparing the engine equipped by the EGR and without EGR system at the constant engine speed of 4000 rpm, a brake torque increases up to 12.9% for the case of engine fueled by pure gasoline fuel, while it increases up to 10.2% for the engine fueled by 15% wet methanol blend. At the same condition, BSFC decreases approximately 16.6% for the engine fueled by pure gasoline fuel, whilst it decreases up to 15.2% for the engine fueled by 15% wet methanol blend. The increase of brake torque and reduction of BSFC for engine equipped with the EGR system impacts on an engine brake thermal efficiency. The result shows that the brake thermal efficiency increases approximately 19.9% for the engine using EGR system compared with the engine without EGR system at the engine speed of 4000 rpm fueled by neat gasoline fuel, whereas it increases up to 18% fueled by 15% wet methanol blend. The use of EGR system, however, impacts adversely to the exhaust gas emissions produced by the engine. By comparing the engine equipped with the EGR and without using EGR system at the constant engine speed of 4000 rpm, CO emission increases approximately 94.7% for the engine fueled by neat gasoline fuel and up to 50% for the engine fueled by 15% wet methanol blend. At the same condition, the work indicates HC emission increases up to 50.7% and 78.6% for the engine fueled by pure gasoline fuel and 15% wet methanol blend, respectively. The brake torque increases small up to 2.9% and 0.4% for the engine fueled by 15% wet methanol compared with that of engine fueled by the neat gasoline fuel without and with EGR systems, respectively, at the constant engine speed of 4000 rpm. At the same condition, CO emission decreases approximately 73.7% and 79.7%, whilst HC decreases approximately 44% and 33.6%, respectively.

Keywords: hot EGR, performance, exhaust gas emissions, EFI gasoline engine, wet methanol.

INTRODUCTION

Methanol is one of the alternative fuels possessing a higher octane number as compared to gasoline. Vancoillie *et al.* expressed that methanol and ethanol are potential to improve engine performances and reduce exhaust gas emissions [1]. Another study also revealed the advantages of alcohol as a fuel including high heat evaporation, improvement knock endurance and high flame velocity [2]. Balki and Sayin found that methanol and ethanol increase brake mean effective pressure (BMEP), brake thermal efficiency (BTE) and volumetric efficiency at various compression ratio [3]. Bahattin *et al.* represented that the use of pure methanol at the same compression ratio causes the reduction of power and CO, CO2, NOx emissions, while BTE and HC emission increase [4]. Eyidogan *et al.* observed that methanol has higher oxygen content than ethanol resulting the increase of combustion efficiency and the reduction of BSFC [5].

Exhaust gas recirculation (EGR) is one of the potential techniques for controlling NOx emissions. Jinyoung *et al.* found that the use of EGR decreases NOx emissions and improves the fuel economical aspect [6]. Zhang *et al.* represented that EGR decreases BSFC and NOx emissions [7]. Wei *et al.* exhibited that the use of hot EGR in SI engine improves the combustion quality and thermal efficiency [8]. Syaiful *et al.* studied wet and pure methanol effects on the performance and smoke emission of diesel engine in the cooled EGR system [9].

Based on the references above, methanol blended with gasoline increases engine performance, decreases fuel consumption and decreases exhaust gas emissions. EGR usage is able to reduce NOx emissions, fuel consumptions and increases thermal efficiency. Pure methanol price, however, is more expensive than gasoline, approximately 31 times more. Therefore, this study explores wet methanol as fuel blend for gasoline engine since it has a lower price than pure methanol (wet methanol and gasoline prices are similar).

EXPERIMENTAL SET UP

In order to investigate the influence of fuel blends on the performance and exhaust gas emissions of gasoline engine, the physical properties of fuels are very important to be understood. Several physical properties for fuel blends are expressed in Table-1. From Table-1, it is shown that the water content in the wet-methanol is approximately 25%, which is very high as compared to pure methanol. The octane number of wet-methanol is

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higher than gasoline. The caloric value of wet-methanol, however, is approximately half of gasoline. These properties of fuels were examined by BPPT (A government institution for assessment and application of technology).

Table-1. Physical properties of fuel blends.

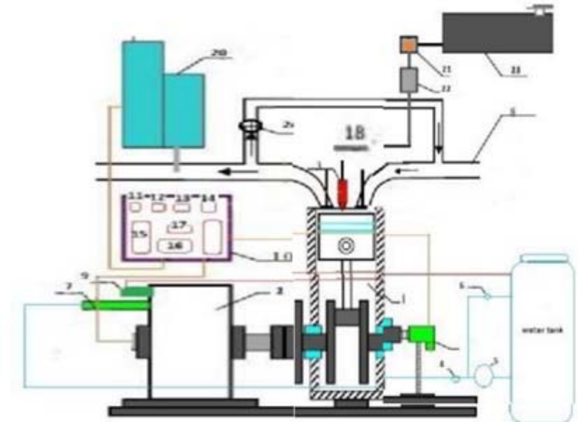
No	Parameters	Wet-methanol	Gasoline
1.	Octane number	110.37	88
2.	Water content (%vol)	24.88	-
3.	Kinematic viscosity (at 40°C) (mPa.s)	0.46	0.494
4.	Density (at 15°C) (kg/cm^2)	796	752
5.	Caloric value (MJ/kg)	21.61	45.95
6.	Flash point (°C)	13.8	-10 s/d -15

This experiment uses an engine of TOYOTA YARIS with specification denoted in Table-2. This engine was fabricated in 1999 with EFI (electronic fuel injection) system. By using 4 cylinders, this engine is able to produce a maximum power up to 50 kW at the engine speed of 6100 rpm. While the maximum torque is achieved up to 90 Nm at the engine speed of 4100 rpm.

Table-2. Gasoline engine specification.

Year	1999
Number of cylinder	4
Cylinder volume	997 cc
Bore x stroke	69 x 66.7 mm
Max. power output	50 kW at 6000 rpm
Max. Torque	90 Nm at 4100 rpm
Compression ratio	10 : 1
Fuel system	EFI
BMEP	164.5 psi

The experimental set up for this study is expressed in Figure-1. The fuels were placed in the fuel tank (23) with a stirring device, which was not used in this investigation due to wet-methanol dissolve ability in the gasoline. A fuel valve (21) was applied for adjusting the fuels consumption before entering a burret (22). A constant fuel flow rate was injected through a fuel injector (18) entering into an intake manifold (8). A partial exhaust gases was recirculated entering into the engine (1) through an EGR valve (24). An engine torque was measured by using a hydraulic dynamometer (2). The brake torque was obtained by braking a rotor part in the dynamometer using water supplied by a water pump (5). Water flow rate was adjusted by a water valve (4) and bypass water valve (6). Water flowed into the dynamometer through a water inlet (7) and flowed out from the dynamometer through a water outlet (9). All measurement data were informed by a display panel (10).



1. Engine
2. Dynamometer
3. Spark plug
4. Water valve
5. Water pump
6. Bypass water valve
7. Water inlet
8. Intake manifold
9. Water outet
10. Display panel
11. Exhaust gas temperature display
12. EGR inlet temperature display
13. EGR outlet temperature display
14. Inlet gas temperature in intake manifold display
15. U-manometer
16. Engine load display
17. Engine speed display
18. Fuel injector
19. EGR
20. Gas analyzer
21. Fuel valve
22. Burret
23. Fuel tank
24. EGR valve

Figure-1. Schematic diagram of experimental set up.

The brake power was calculated by measuring engine torque using absorber dynamometer (water brake) with an error of 4.7%. The fuel consumption was determined by using a burret with data error of 0.4%. Exhaust gas temperature was measured using thermocouple type K (that has been calibrated) with uncertainty of 0.6%. The exhaust gas emissions were monitored using a Stargas 898. The mass rates of EGR and fresh air were measured by using the orifice with the errors of 0.46 and 0.78%, respectively.

RESULTS AND DISCUSSION

Brake power

Figure-2 shows the effects of EGR and fuel blends on the brake power for the various engine speeds. The solid lines express for the case of system without EGR, whilst the dotted lines represent the case of system with EGR. The wet-methanol percentages are in the range of 5 to 15%, which are represented by M0, M5, M10 and M15. M0 expresses for the neat gasoline, M5, M10 and M15 states for 5, 10 and 15% by volume of wet-methanol in the fuel blends, respectively. As can be seen in Figure-2, the brake power increases as the increase of engine speed. The brake power reaches up to 27.1 kW at the engine speed of 4000 rpm for the engine fueled by 15% wet-methanol with EGR system. By using EGR, the brake power increases 10.2% compared without EGR for the constant engine speed of 4000 rpm and 15% wet-methanol in the fuel blends. The use of EGR improves the combustion temperature [6]. When the combustion temperature increases, the reaction rate increases, which causes the increase of exothermic energy.

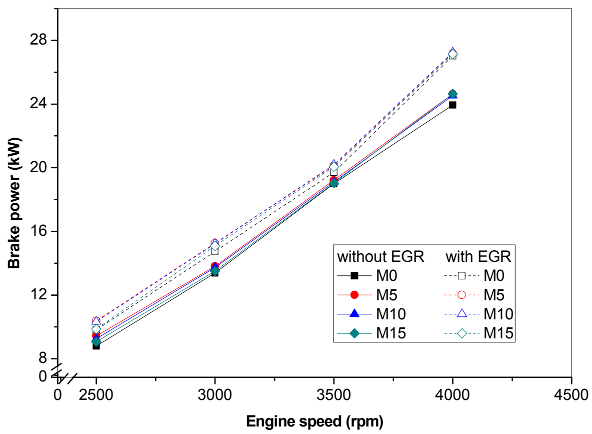


Figure-2. Comparison of brake power between with and without EGRs for different fuel blends at various engine speeds.

Brake specific fuel consumption (BSFC)

Figure-3 demonstrates the comparison of BSFC between the case without EGR and with EGR for engine fueled by gasoline/wet-methanol blends. The solid lines represent for engine without EGR system and the dotted lines assert for engine with EGR. The BSFC decreases as increasing the engine speed. The use of EGR causes the reduction of BSFC for the same engine speed and fuel blends. This is because the use of EGR is able to reduce throttling loss that can reduce fuel consumption [8]. The BSFC decreases up to 16.6% when the engine is fueled by the neat gasoline with EGR. The BSFC increases approximately 7.2% for the engine fueled by 15% wet-methanol as compared with the engine fueled by the neat gasoline without EGR at the engine speed of 3000 rpm. While the BSFC increases 8.4% for the engine using EGR at the engine speed of 3000 rpm.

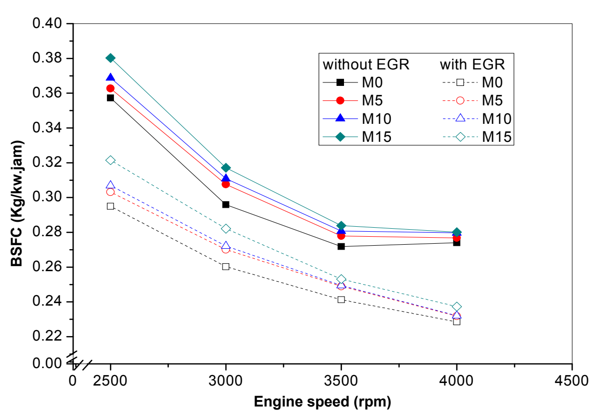


Figure-3. Comparison of BSFC between with and without EGRs for different fuel blends at various engine speeds.

Brake thermal efficiency (BTE)

Figure-4 denotes the effects of EGR and fuel blends on brake thermal efficiency (BTE). As mentioned previously, the solid lines represent engine without EGR for the different fuel blends. The values of BTE at the engine speed of 2500 rpm are having small differences. At the engine speed of 4000 rpm without EGR for the various fuel blends, the BTE increases approximately 6.4%. BSFC increases up to 18% for the engine using EGR compared with the case without EGR for the constant engine speed of 4000 rpm. This is caused by the high temperature exhaust heating the intake, promote combustion and improve of thermal efficiency.

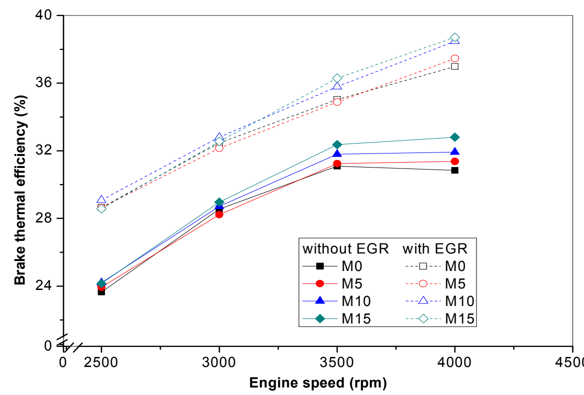


Figure-4. Comparison of BTE between with and without EGRs for different fuel blends at various engine speeds.

Exhaust gas temperature (EGT)

The effect of EGR for the various fuel blends and engine speeds is expressed in Figure-5. The use of EGR for the same fuel blend caused reduction of EGT siince the use of EGR reduces oxygen from fresh air causing the reduction of combustion temperature.

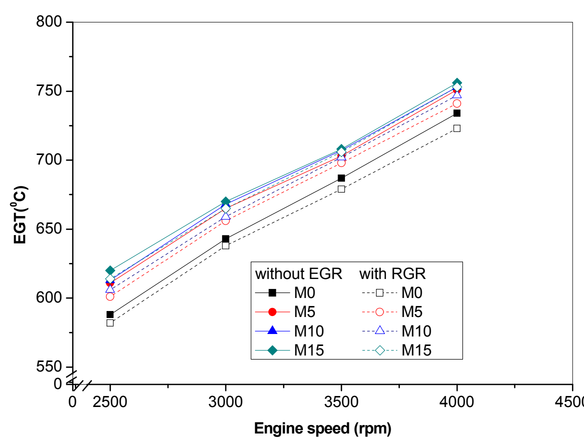


Figure-5. Comparison of EGT between with and without EGRs for different fuel blends at various engine speeds.

The decrease of combustion temperature also represents the decrease of EGT. EGT decreases up to 1.5% when the engine is equipped by the EGR compared

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without EGR for the engine fueled by the neat gasoline at the engine speed of 4000 rpm. For the case of engine fueled by 15% wet-methanol blends at the engine speed of 4000 rpm, the EGT decreases approximately 0.4%.

CO emission

Figure-6 demonstrates the influence of EGR and fuel blends on the CO emission. As can be seen in Figure-6, the CO emission decreases as the engine speed increases. In the case of the engine fueled by the neat gasoline, the use of EGR causes the increase of CO. This is due to the incomplete combustion caused by reduction of oxygen from fresh air. This condition, however, is not seen for the engine fueled by fuel blends.

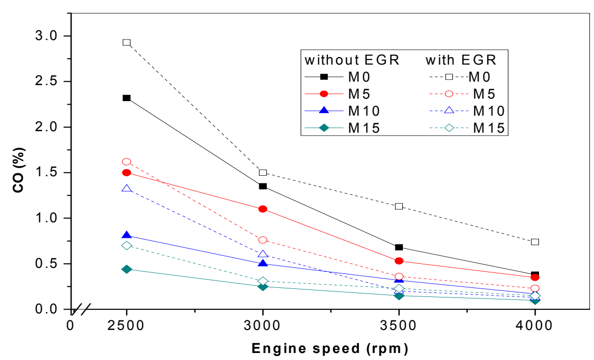

Figure-6. Comparison of CO emission between with and without EGRs for different fuel blends at various engine speeds.

HC emission

Figure-7 shows the impact of EGR usage on the HC emission for different of fuel blends. HC emission decreases as the increase of engine speeds. HC emission increases when the engine equipped by EGR due to the lack of oxygen from the fresh air. HC emission increases up to 50.7% for the case of engine equipped by EGR at the engine speed of 4000 rpm with the neat gasoline. When the engine fueled by 15% wet-methanol, HC emission decreases up to 78.6% at the engine speed of 4000 rpm.

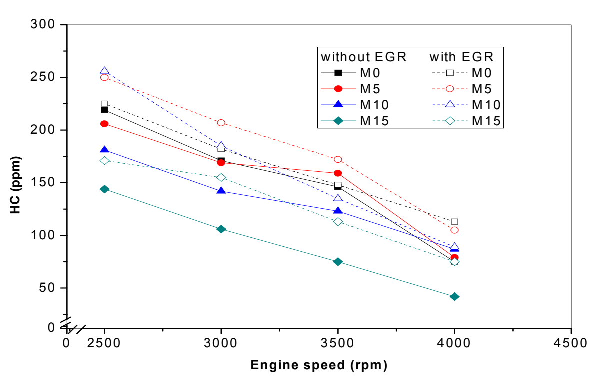

Figure-7. Comparison of HC emission between with and without EGRs for different fuel blends at various engine speeds.

CONCLUSIONS

The experimental study for the effect of EGR and fuel blends has been carried out. The use of EGR increased the brake power up to 10.2% at the constant engine speed of 4000 rpm. EGR usage causes the decreases of BSFC and increases when wet –methanol was used as fuel blend. EGT reduces approximately 0.4% when EGR was used and the engine fueled by 15% wet-methanol. The use of EGR increased the CO emission for the engine fueled by the neat gasoline. This was not observed for the case of engine fueled by fuel blends. The increase of HC is also seen when the EGR is used.

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