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Enhancement of M15 Engine Performance by the Addition of Propylene Glycol

NazaruddinSinaga[1]* ,Maizirwan Mel[2], R. BagusSuryasaMajanasastra[1],AjiDigdoyo[1]
[1]Mechanical Engineering Department, Faculty of Engineering, UniversitasDiponegoro, Jalan Prof. Soedharto, SH, Semarang 50275, Central Jawa, Indonesia
[2]Department of Biotechnology Engineering, Faculty of Engineering, International Islamic University Malaysia, Gombak 53100 Kuala Lumpur, Malaysia
* Corresponding author: nsinaga19.undip@gmail.com

ABSTRACT

The researches on fuel alternative for the spark-ignition engine are currently conducted intensively, including the use of methanol-gasoline blend. One of the problems faced against the use of this fuel is the decreasing of engine performance. In this research, the use of the additive in a spark-ignition engine fueled with methanol-gasoline M15was investigated. The purpose of the research was to find an additive that could overcome the decrease of power and torque of an engine fueled with M15 methanol-gasoline blend. So, the study was intended to determine the effect of additive on the engine torque and power, as well as to find the best additive composition which produced relatively the same performance if compared with the pure gasoline engine. The measurements were performed by using a 1200 cc electronic fuel injection car that has maximum power and torque of 51.7 kW and 84.5 Nm, respectively. The engine was tested on a roll chassis dynamometer equipped with an engine scanner and the acquisition data system. The composition of the additive being tested was between 3 to 10 cc/l. It was found that the power and torque relatively unchanged on the additive composition of 9 cc/l. It can be concluded that the engine performance can be kept up by adding the propylene glycol as an additive for methanol-gasoline blend. Therefore, through this study, a method has been found to overcome the decrease in power and torque of an engine fueled with M15 methanol-gasoline blend.

Key words: Engine performance, M15 Engine, Propylene Glycol, Spark Ignition engine.

1. INTRODUCTION

The utilization of fossil fuels has an emphasis on the last decade. This is because these fuels have emissions that are not environmentally friendly and are non-renewable. Therefore, quite a lot of research is conducted to find alternative fuels, either the new fuel or fuel mixture that already exists today, which is renewable. Recently, it has been estimated that greenhouse gases released from fossil fuel combustion are over 34 million tons of CO_2 [1].

Currently, the researches on fuel alternative for the spark-ignition engine are conducted intensively, including the use of methanol-gasoline blend. However, it seems that alcohol use in gasoline engines will be limited to methanol and ethanol. This condition is due to its suitability with the character of gasoline-fueled engines, which have proven not to require engine modification and low exhaust emissions produced.

Methanol (CH_3OH) and ethanol are pure alcohols. Currently, methanol and ethanol are one of the cleanest renewable energy, where they can be blended or directly used to substitute gasoline [2-4]. The world's largest consumer of methanol is China [5].

There were some constraints for using methanol as a motor fuel. Thus, the application is more restrictive and less compatible. Therefore, the installation cost and fueling station will be more expensive [2]. They are still high resistance to the use of these two types of fuel is generally due to problems with corrosion and solubility in water. Because the water content of methanol is quite high, there is a problem in the use of methanol-gasoline blend, which is the separation of methanol and gasoline at low temperatures [6,7]. Also, methanol can be very corrosive to magnesium and aluminum if it contains dissolved or separate water [8,9]. Several techniques can be used to overcome these two problems. One of them is by using additives on the methanol-gasoline mixture, for example, by using propylene glycol and isobutanol. However, there is still very little research has been done on the effects of these additives.

The propylene glycol ($C_3H_8O_2$) has many synonym names [10]. It can be converted from glycerol, a biodiesel by-product, and classified as a diol. This additive has a broad range of solvents such as chloroform, acetone, and water, and has excellent de-icing properties. When applied, it can prevent ice adhesion and de-ice not only at the moment when it was applied [11].

It can also be used as an antifreeze agent, heat transfer fluid enhancement, solvent, and functional fluids [12]. Propylene glycol is preferred over ethylene glycol due to its much lower toxicity. In a well-closed container and at low temperature, the propylene glycol is stable. However, it tends to oxidize in the open air and at high temperatures. The addition of propylene glycol in methanol is chemically stable. It also stable when mixing with ethanol, glycerin or water. Aqueous solutions may be sterilized by autoclaving [13].

Methanol has a simple chemical structure, able to atomize [14], a higher octane number, and is more environmentally friendly [15]. Brinkman et al. [16] showed that methanol-gasoline blend has a higher octane number (RON). Research conducted by Zhao et al. [17] showed that the methanol-gasoline blend could reduce hydrocarbon and CO2 emissions, but the brake specific fuel consumption increases.

Eyidogan et al. [18]. Abu Zaid et al. [19] and Yamin et al. [20] reported that the engine torque and power increased with the addition of methanol, and found that the optimum methanol content, which gives the best engine performance is 15%. However, Gravalos et al. [21] and Rifal&Nazar [22] found that the brake power and brake torque of methanol gasoline blends are lower than those of gasoline for all engine speeds. They also found that the BSFC of methanol blend fuels is higher than that of gasoline. Yanju [23] also showed that the engine torque decreases for M10 and M20 compared with that for gasoline.

Therefore, it is essential to study the effect of the propylene glycol addition on the engine power and torque of the methanol-gasoline engine. The present research will focus on the study to improve the quality of alternative fuels of methanol-gasoline mixtures by adding propylene glycol additive to increase the solubility of methanol in gasoline fuel. The purpose of the research was to find an additive that could overcome the decrease of power and torque of an engine fueled with M15 methanol-gasoline blend. So, the study was intended to determine the effect of additive on the engine torque and power and to find the best additive composition which produced relatively the same performance when compared with the pure gasoline engine.

2. METHODS AND MATERIALS

The measurements were performed by using a 1200 cc electronic fuel injection car that has maximum power and torque of 51.7 kW and 84.5 Nm, respectively, which was tested on a chassis dynamometer equipped with an engine scanner. The engine specification is shown in Table 1. The composition of the additive being tested was varied between 3 to 10 cc/l. The fuels used in the study are pure gasoline (RON 88), and methanol-gasoline blend M15 which is mixed with several compositions of additive in the concentration of 3 cc/l (M15-3), 4 cc/l (M15-4), 5 cc/l (M15-5), 6 cc/l (M15-6), 7 cc/l (M15-7), 8 cc/l (M15-8), 9 cc/l (M15-9), and 10 cc/l (M15-10). In these tests, the purity of methanol is 85%, which has a certificate from the Technology Centre Laboratory of Industrial Pollution Prevention, Semarang, Indonesia. The material properties are shown in Tables 2, 3, and 4.

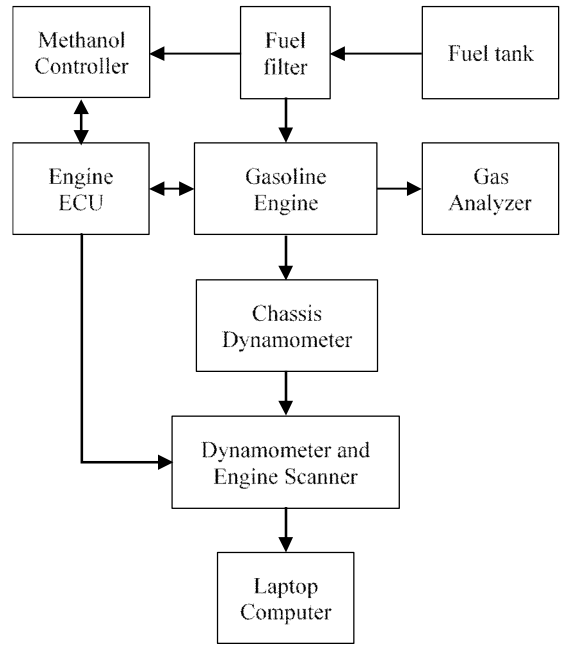

Figure 1: Data acquisition system for engine performance measurements

Table 1: Main specification the engine

Description	Specification
Engine type	1.2L- 12valve- 3 cylinder-DOHCMIVEC (3A92)
Fuel supply	ECI-MULTI
Cylinder capacity	1,193 CC
Compression ratio	10.5: 1
Maximum power	57 kW (6000 rpm)
Maximum torque	100 Nm (4000 rpm)
Emission standard	Euro-6
Fuel system	Multipoint electric port fuel system

Table 2: Physical properties of gasoline (Pertamina, 2017)

Properties	Specification
Chemical formula	Various
Oxygen content by mass (%)	0
Density at NTP (kg/l)	0.74
Lower heating value (MJ/kg)	42.9
Volumetric energy content (MJ/l)	31.7
Stoichiometric air to fuel ratio (kg/kg)	14.7
Research octane number (RON)	88

Figure 1 depicts the control and data acquisition system for the measurements. The methanol injection controller works by bypassing the commands from the engine control unit to fuel injector so that the injection time value can be synchronized with the one selected on the switch controller. For this study, the injection time of M15was kept the same as for pure gasoline, since the current study aims to observe the effect of fuel additive in an unmodified vehicle engine.

Table 3: Physical properties of methanol

Properties	Specification
Chemical formula	CH3OH
Density (kg/l)	0.794
Relative molecular mass	32
Boiling point (^{o} C)	65
Stoichiometric air-fuel ratio	6.5
Auto-ignition temperature (^{o} C)	500
Lower heating value (MJ/kg)	20.26
Research octane number (RON)	110
Laminar flame speed (m/s)	0.523

The engine is connected to an engine scanner to read and record the engine speed, engine coolant temperature, mass air flow, ignition time, injection time, air-fuel ratio, and engine speed. The device can be used to measure engine power and torque too. This device is simple and easy to use because it only requires a connection to the OBD II socket of the vehicle. Besides, there are also two ports that can be connected to the measurement system of the eddy current dynamometer. All the experiments were carried out on the dynamometer roll chassis, where the eddy current dynamometer is used with a power capacity of 250 kW.

Initial testing is conducted using pure gasoline (PGF), by running it until it reaches a steady-state. The measurement is carried out on a fully open throttle condition. By adjusting the load on the dynamometer, the torque and power data can be obtained from the highest to lowest engine speed. The data used in this measurement is the average value of the three-time tests. The test was carried out using M15 fuel without additives, which was placed on a particular fuel tank. After completing the first test, then proceed with testing using M15-3, M15-4, until M15-10. For each change of additive composition, the fuel is emptied from the tank and cleaned using a compressor.

3. RESULTS AND DISCUSSION

In this section, the engine power and torque will be evaluated, which uses M15 fuel without additives and with propylene glycol additives. The data presentation is divided into two groups, each with five types of mixtures, both for power and torque data.

3.1 .Engine Brake Power

Figures 2 and 3 show the engine power curves as a function of engine speed for various types of fuel mixtures tested. As expected, it is generally seen that, for all types of mixtures, the engine power will increase with increasing engine speed, then decrease after a certain speed. By observing the power curves in Figures 2 and 3, it is clear that the addition of propylene glycol additives 3 cc/l to 5 cc/l will further reduce the engine power. Furthermore, the addition of additives of 6 cc/l to 9 cc/l increased the power again. In the composition of propylene glycol 9 cc/l, the power produced by the engine is almost the same as the power produced by the engine when using pure gasoline. This condition shows that there is an optimum value of additive composition of the gasoline-methanol mixture, which is in the composition of 9 cc/l.

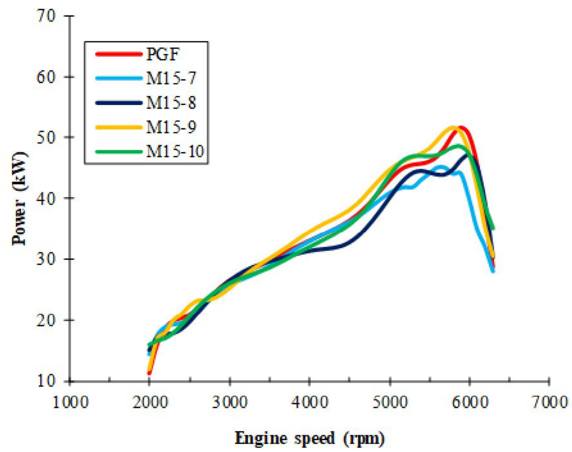

Figure 2: Effect of additive composition on engine power for PGF, ME15-3, ME15-4, ME15-5, andME15-6

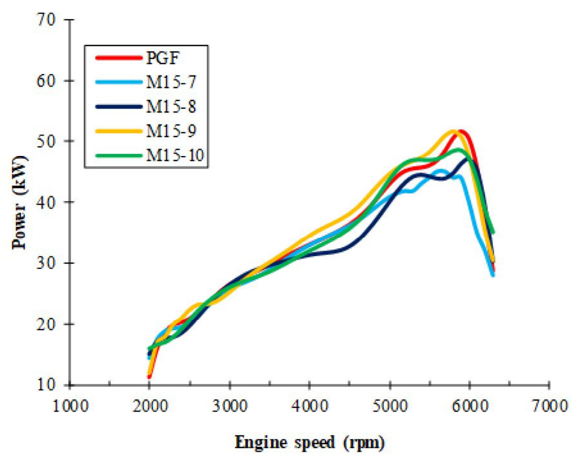

Figure 3: Effect of additive composition on engine power for PGF, ME15-7, ME15-8, ME15-9, andME15-10

Table 5 presents the difference in the engine brake power of all test fuels with respects to the engine speed at a different composition of the additive. As shown in Table 4, the maximum power of pure gasoline fuel is 51.66 kW at 5900 rpm. The power of the engine when using M15 plus additive tends to decrease in comparison to the pure gasoline fuel. Furthermore, the minimum engine power was observed for M15-5 at 4600 rpm engine speed, where the power is only 39.5 kW, or decreasing 24 % in comparison to pure gasoline. The maximum power of the fuel blend with the additive is on

M15-9 where the brake power is 51.7 kW at 5900 rpm. The presence of methanol increases the mass injected into the engine[24-26]. In this case propylene glycol increases the brake power of the gasoline-methanol blend if added with the right composition. The brake power rising is due to the nature of propylene glycol, which can increase the solubility of methanol in gasoline so that the homogeneity of the mixture is more evenly distributed, better flow capability, as well as other chemical effects that improve the combustion properties of gasoline-methanol fuel.

Table 5: Effect of additive on maximum engine power

Fuel Blend	Engine speed (rpm)	Max. Power (kW)	Max. Power Difference
PGF	5900	51.66	-
M15-3	5900	48.60	-6%
M15-4	5400	42.20	-18%
M15-5	4600	39.50	-24%
M15-6	5100	40.20	-22%
M15-7	5300	45.00	-13%
M15-8	5800	47.00	-9%
M15-9	5900	51.70	0%
M15-10	5900	48.50	-6%

3.2. Engine Brake Torque

As shown in Figures 4 and 5, the engine torque curve is shown as a function of engine speed for various types of fuel mixtures tested. For all types of gasoline-methanol fuels, the engine torque curve is quite lower than that of pure gasoline, except for M15-9. By observing the torque curves in these figures, it is clear reduction of the engine torque mainly occurs in high-speed regions, which is above 3500 rpm. For M15-3 and M15-9, the torque produced above this speed is higher than the pure gasoline fuel. It also appears that the addition of additives to the M15 does not change the maximum torque position for the M15-3, M15-4 and M15-5 fuels, which is fixed at a speed of 2800-3000 rpm. Then, for M15-6, M15-7, and M15-8 fuels, there is a shift in the maximum torque position to a speed of 2200-2500 rpm. For the M15-9 and M15-10 fuel mixture, the position shifts to a speed of 5200 rpm.

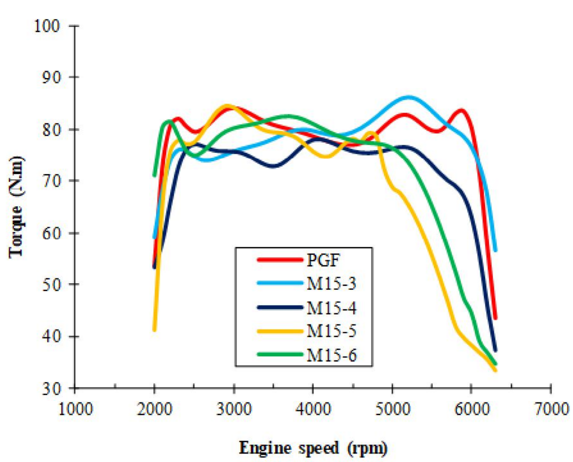

Figure 4. Effect of additive on engine torque for pure gasoline and additive composition of 3 to 6 cc/l

Table 6 shows the effect of additive composition on the engine torques. The engine fueled with pure gasoline has a maximum torque of 84.46 Nm at 3000 rpm. The maximum engine torque value due to the addition of propylene glycol is relatively unchanged, which is in the range of 78.1 to 86.6 Nm.

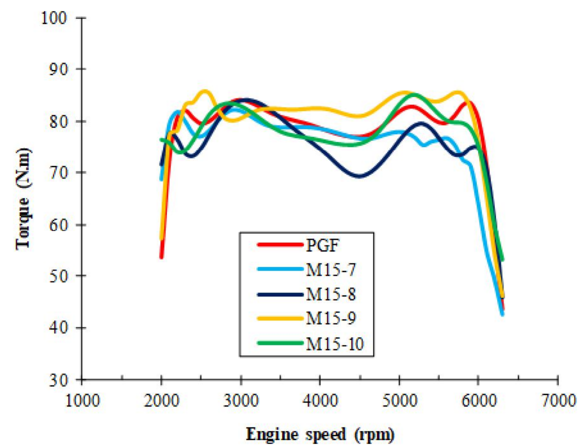

Figure 5: Effect of additive on engine torque for pure gasoline and additive composition of 7 to 10 cc/l

Table 6: Effect of additive on maximum engine torque

Fuel Blend	Engine speed (rpm)	Max. Torque (Nm)	Max. Torque Difference
PGF	3000	84.46	-
M15-3	2800	86.30	2%
M15-4	2800	78.10	-8%
M15-5	3000	84.70	0%
M15-6	2200	82.90	-2%
M15-7	2200	83.10	-2%
M15-8	2500	84.30	0%
M15-9	5200	86.60	3%
M15-10	5200	85.10	1%

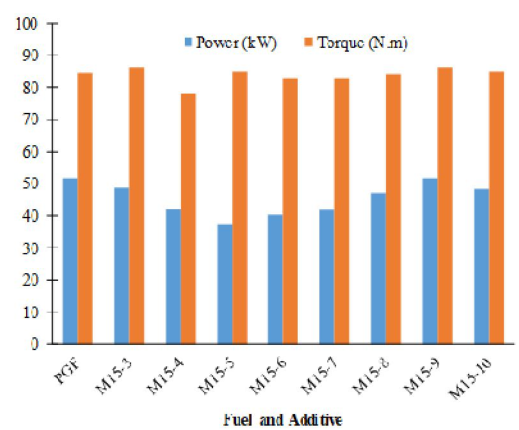

Figure 6: Effect of additive on maximum engine power and maximum torque

The highest maximum torque is achieved when using M15-9, where the value is 86.6 Nm at 5200 rpm, which is slightly higher than the torque produced by the pure gasoline. Generally, it can be said that the addition of propylene glycol does not have a significant effect on the maximum torque produced by the engine, as clearly shown in Figure 6.

From the observation of the power and torque above, it also can be said that the effect of adding propylene glycol additive to the M15 methanol-gasoline fuel mixture will change the shape of the power curve and the torque produced, likewise with the maximum power value produced. However, the maximum torque produced does not change significantly. The power differences can be explained as follows.

Methanol has a higher octane number, so when mixed with gasoline, the fuel blend also has a higher octane number. The magnitude of the octane number depends on the percentage of methanol added and the initial octane number of gasoline. If the fuel has an octane number higher than the engine requirements, the engine performance will reduce, and exhaust emissions will increase [27].

The lower heating value of the methanol is another reason why the torque and power are slightly lower than pure gasoline, as can be seen in Tables 2 and 3, which has a value of 20.09 MJ/kg while gasoline has a value of 42.9 MJ/kg. This is consistent with the results of Rifal&Nazar [21] and Gravalos et al. [20].

4. CONCLUSION

In this research, it has been experimentally studied the effect of the addition of methanol and propylene glycol additives to the pure gasoline fuel with RON 88. The general conclusion is that the addition of these two types of substances affects the power and torque produced by the engine. By mixing methanol into pure gasoline (M15) without additives will reduce the power and torque, where the right choice of the additive composition will increase the maximum torque and power. In this study, the composition of propylene glycol, which provides the highest power and torque, is 9 cc/l, where the maximum power produced by the engine is 51.7 kW at a speed of 5900 rpm, and the maximum torque produced is 86.6 Nm at 5200 rpm. Therefore through this research, a method has been found to overcome the decrease in power and torque of an engine fueled with an M15 methanol-gasoline blend.

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