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Research Paper

Torque and Power Characteristics of Single Piston LPG-Fueled Engines on Variations of Ignition Timing

Karakteristik Torsi dan Daya Mesin Piston Tunggal Berbahan Bakar LPG pada Variasi Waktu Pengapian

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Abstract
Liquefied Petroleum Gas (LPG) is an alternative fuel that has all key properties for the Spark Ignition (SI) engine. However, because of its properties, ignition timing on an LPG SI engine needs to be advanced from the reference angle to get the optimum performance. Therefore, this article presents the torque and power characteristics of a single piston LPG engine on variations of ignition timing. Evaluation of engine performance is carried out at the ignition timing of 15^o, 17^o, and 19^o BTDC. The results showed the highest torque for LPG fuel was 10.64 Nm which was achieved at 3500 rpm with ignition timing of 19^o BTDC, while the highest power for LPG fuel was 6.9 hp which was achieved at 5936 rpm with ignition timing of 19^o BTDC.

Key words: Single piston engine; LPG; Ignition timing; Torque; Power

Abstrak
Liquefied Petroleum Gas (LPG) adalah bahan bakar alternatif yang memiliki semua properti utama untuk mesin Spark Ignition (SI). Namun, karena sifat-sifatnya, timing pengapian pada mesin SI berbahan bakar LPG perlu dimajukan dari sudut referensi untuk mendapatkan kinerja optimal. Oleh karena itu, artikel ini menyajikan karakteristik torsi dan daya dari mesin LPG piston tunggal pada variasi waktu pengapian. Evaluasi kinerja mesin dilakukan pada waktu pengapian 15^o, 17^o, dan 19^o sebelum TMA. Hasil penelitian menunjukkan torsi tertinggi untuk bahan bakar LPG adalah 10,64 Nm yang dicapai pada 3500 rpm dengan waktu pengapian 19^o sebelum TMA, sedangkan daya tertinggi dengan bahan bakar LPG adalah 6,9 hp yang dicapai pada 5936 rpm dengan waktu pengapian 19^o sebelum TMA.

Kata Kunci: Mesin piston tunggal; LPG; Waktu pengapian; Torsi; Daya

1. Introduction

Liquefied Petroleum Gas (LPG) is a derivative product of natural gas production and crude oil refineries. The content of LPG is mainly propane (C_3H_8) or butane (C_4H_{10}) or a mixture of both and there are small concentrations of propylene and butylene. To give a smelly effect, ethyl mercaptan is added so that it can be detected if there is a leak [1].

The use of fuel oil increases air pollution so that it will damage the environment and reduce the level of human health, so that LPG fuels become an alternative, in addition to ethanol and natural gas [2]. LPG as a fuel is widely used in developed countries such as Korea, Turkey, Russia, and Poland. During 2000-2018, world LPG consumption increased significantly with global consumption of 26.8 million tons in 2017 [3].

The use of LPG as vehicle fuel generally has a positive effect on exhaust emissions and economically. The levels of CO, CO_2, HC, and NOx emissions produced by LPG engines are much lower than the gasoline operation mode, both on the use of the urban cycle and the extra-urban cycle [4]. LPG has several advantages compared to gasoline such as high octane numbers (around 112) and energy content of 46.4 MJ / kg, while the energy content of gasoline is 44.4 MJ / kg or 34.8 MJ / l. LPG has a relatively high energy content per unit mass, but the energy content per unit volume is low [5]–[7]. However, the use of LPG generally produces lower power than a gasoline engine [8].

With more advanced systems and technologies, power losses can be reduced to 5% - 10% [9]. In addition, the use of LPG can reduce specific fuel consumption (sfc) to 28.38%, and have lower energy prices than gasoline with a difference of up to 47.40% [1]. The factor that causes a decrease in power is different combustion speeds, where LPG has a lower combustion speed than gasoline, so ignition time must be advanced [1], [5], [10]. One method to improve engine power is by modifications on ignition timing so that the fuel gets enough time for the combustion process. Therefore, this study aims to see the characteristics of torque and power due to the advancement of ignition timing.

2. Method

This research was carried out on gasoline-fueled motorcycles modified into LPG (motorcycle specifications are presented in Table 1) by installing an LPG vaporizer to reduce pressure and convert the liquid phase into a gas phase. LPG used is a 3 kg tube packaging with a regulated pressure regulator. At the mouth of the carburetor, a perforated cap is installed to reduce the venturi cross-sectional area, thereby increasing the airspeed and reducing the inlet pressure. In addition, it is also to adjust the need for air that is less than the use of gasoline because the carbon content of LPG is lower than gasoline. [11]. The carburetor modification scheme is presented in Figure 1. Tests are carried out with variations in ignition timing of 15^{o} (standard), 17^{o} and 19^{o} BTDC. Modification of ignition timing variations by shifting the reluxtor to the rotor as shown in Figure 2.

Table 1. Engine specification

Items	Specification
1. Engine	: 4 strokes, SOHC
2. Cooling system	: Air
3. Number of cylinders	: Single, horizontal
4. Cylinder volume	: 124.9 cc
5. Fuel system	: Carburetor
6. Bore x stroke	: 52.4 x 57.9 mm
7. Compression ratio	: 9.0: 1
8. Maximum power	: 9.3 PS at 7500 rpm
9. Maximum torque	: 10.1 Nm at 4000 rpm
10. Clutch	: Multiple clutch, automatic centrifugal, wet type
11. Transmission	: Manual, 4 speeds
12. Tank capacity	: 3.7 liters

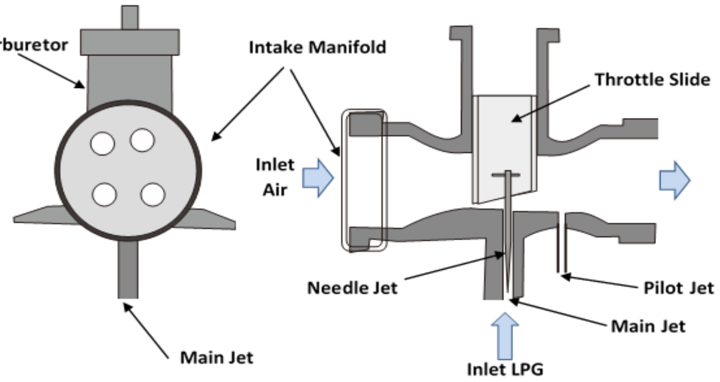

Figure 1. Carburetor modifications

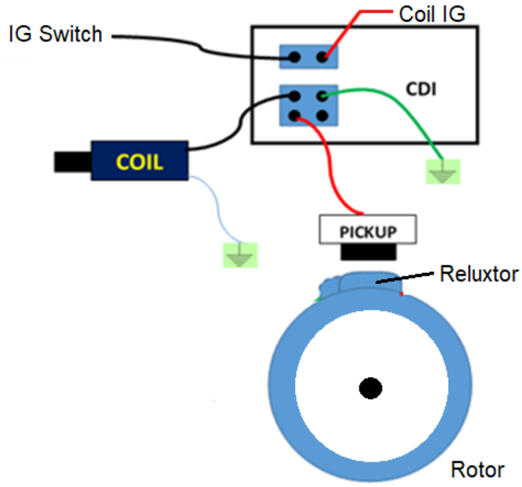

Figure 2. Reluxtor modifications

Furthermore, Figure 3 presents the engine testing using a dynamometer type Rextor Pro Dyno, where torque and power are measured on the rear wheels. The specifications of single piston engines used in this study are presented in Table 1.

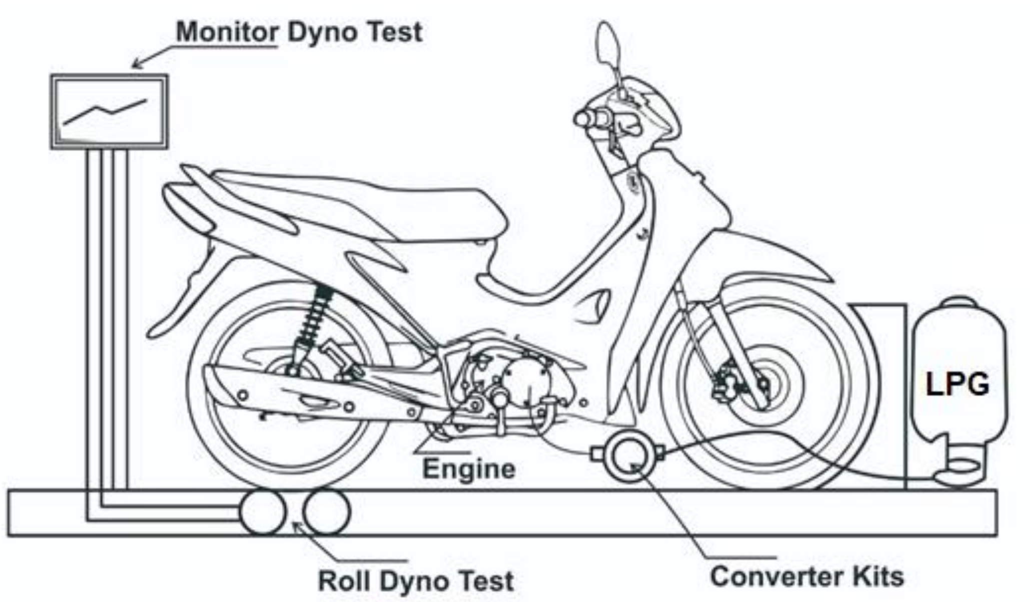

Figure 3. The motor testing scheme on the dynamometer

3. Result and Discussion

Figure 4 shows the results of torque testing fueled by gasoline and LPG with ignition timing 15° BTDC for gasoline and 15°, 17°, and 19° BTDC. The maximum torque with gasoline achieved at 5000 rpm by 11.76 Nm, while by LPG is 9.17 Nm at 3845 rpm and 15° BTDC, 9.76 Nm at 3380 rpm and 17° BTDC, and 10.64 Nm at 3500 rpm and 19° BTDC, respectively.

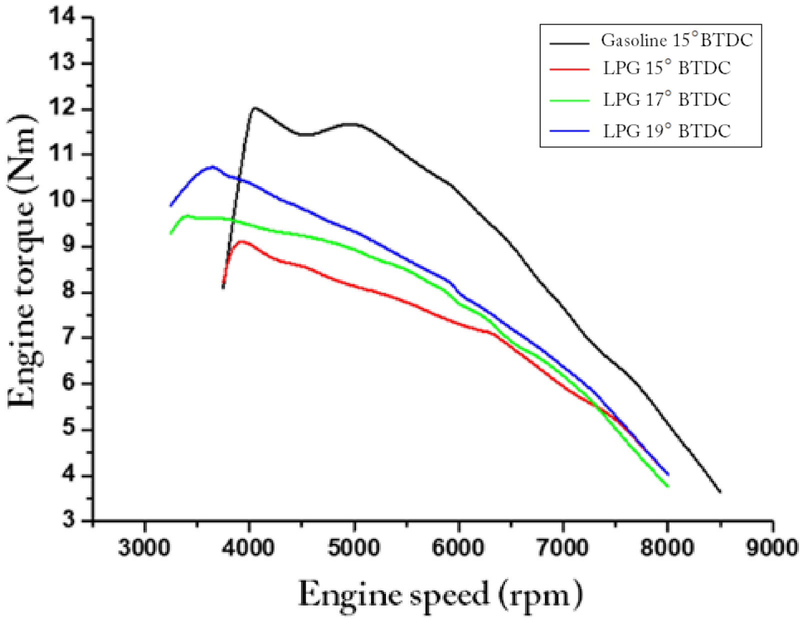

Figure 4. Torque vs engine speed

Engine torque increases along with the advancement of ignition timing, it is greatly influenced by the combustion process in the combustion chamber, where LPG fuel requires a longer time because the speed of flame propagation in the combustion process is slower than gasoline. Ideally, the higher the engine rotation, the greater the degree of ignition must be advanced and that does not occur linearly [12]–[14]. Under 4000 rpm, the use of LPG provides an opportunity to produce more torque than gasoline. While at higher engine speeds, torque with LPG tends to be lower than gasoline.

In order to obtain equivalent torque to gasoline, it would need to advanced ignition timing around 15° from reference for gasoline, as presented in Figure 5 [15]. In addition, a decrease in torque is also caused by a decrease in volumetric efficiency due to the closure of carburetor air horn, and LPG pressure from the tank to the vaporizer that is too small (less than 2 bars). Supposedly, this study uses LPG coupling so that the pressure in the LPG pipe to the vaporizer is the same as the LPG pressure in the tube.

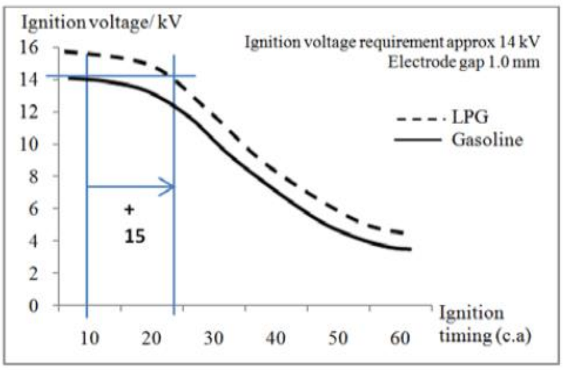

Figure 5. Ignition timing for LPG engine

Furthermore, Figure 6 shows the results of power testing by gasoline with ignition timing of 15° BTDC and by LPG with ignition timing of 15°, 17°, and 19° BTDC. Maximum power by gasoline is achieved to 8.7 hp at 5936 rpm. Meanwhile, for LPG with an ignition timing of 15° BTDC is 6.4 hp at 6325 rpm, the ignition timing of 17° BTDC is 6.7 hp at 5870 rpm, and ignition timing of 19° BTDC is 6.9 hp at 5936 rpm.

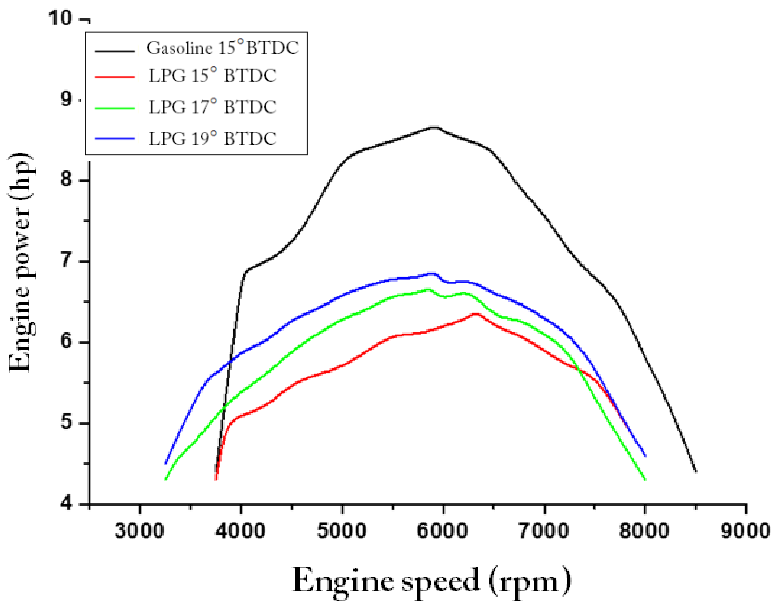

Figure 6. Power vs engine speed

From Figure 6, the maximum power of the engine with LPG is lower than gasoline, with the same reason for torque. However, at low engine speed, the use of LPG is quite promising. It can be seen that the power curve starts to increase at 3200 rpm, while with gasoline, an increase in the new power curve starts at engine speed above 3700 rpm.

4. Conclusion

Testing the 4 strokes single piston engine with LPG shows that ignition timing affects the torque and power. The highest torque for LPG is 10.64 Nm which is achieved at the engine speed of 3500 rpm with the ignition timing of 19^{o} BTDC, while the highest power with LPG is 6.9 HP at engine speed of 5936 rpm and the ignition timing of 19^{o} BTDC. However, the engine torque and power of LPG engine according to this study are still under gasoline due to the limitation of ignition angle, which should be 15^{o} from the reference. Another factor is volumetric efficiency due to the closure of carburetor air horn and LPG pressure in the fuel line is too small (less than 2 bars).

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