

Influence of Fuel Injector Position of Port-fuel Injection Retrofit-kit to the Performances of Small Gasoline Engine

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Abstract. Fuel efficiency and emission characteristics are two main concerns that must be addressed. Fuelling system is one of the crucial variables that must be focused on. Fuel injection system has a long term potential as a medium to supply suppressed fuel because of its high fuel delivery efficiency, low emission characteristics and fuel economy. Fuel injector angle plays an important role in achieving quality combustion. In this study the influences of the injector angle to engine performances and emission characteristics were investigated. Experimental works comprised one throttle opening position with various dynamometer loads for two angles: 48° and 68°. From this study, the result shows that 68° was the optimum angle, which produced high brake power, high brake mean effective pressure, low brake specific fuel consumption and low hydrocarbon emission.

Keywords: Small engine, Port-fuel injection, Fuelling system, Four-stroke engines, Retrofit-kit.

PACS: 45.20.dg Mechanical energy, work, and power

INTRODUCTION

In many countries, motorcycles using carburetor system are still the main option as a medium of transport for many people. The motorcycle is a very popular vehicle for transportation due to its mobility, convenience, economy, and door-to-door functions. One advantage of motorcycles is that their high power to weight ratio gives them good fuel economy.

From 26 million motorcycles registered in year 2001, 70% are from Asian countries while 8% accounts for Europe [1]. Skyrocketing fuel prices in the latter half of 2008 has also forced many people to opt for a motorcycle as a mean of transport for work and leisure rather than driving a car, for the sole purpose of reducing fuel cost. Based on statistic, in Malaysia, there are more than seven millions motorcycles registered in year 2005 and increases by 21% in year 2009 [2] and most of them equipped with carburettor as a fuelling system.

Currently, there are two technologies of fuelling system for small capacity gasoline engines which are carburettor system and electronic fuel-injection (EFI) system. And traditionally, small capacity engines employed the use of carburettors to control the amount of air and fuel that entered to the combustion chambers. The demand for small capacity engines with high power to weight ratio and low emissions is well known. It is well known that EFI system has improved fuel consumption, produced high power, and low emissions characteristics compared to the conventional fuelling system. Komuro et al. [3] has shown that EFI improved fuel economy up to 6%, while hydrocarbon and carbon monoxide can be reduced up to 26% and 70% respectively [4].

Fuel injection systems have a long term potential as a medium to supply suppressed fuel because of their high efficiency, low emission characteristics and increasing fuel economy. Now, urban air quality issues, coupled with fuel petrol that have sky rocketing time by time, many motorcycle manufacturers have decided to implement the fuel injection system to their new motorcycles.

But there are millions of motorcycles still using carburettors and each one of this produces harmful emissions. It is therefore desirable to have a fuel injection retrofit kit system for small engines as a promising technology that offers all of the advantages of fuel injection over traditional carburetted engines.

The motivation for this study is came from Komuro et al. [3] and Latey et al. [4] which have shown that there are much improvements can be made by converting the conventional carburettor system to EFI system alone.

FUEL INJECTION SYSTEM

Due to the increasing number of motorcycle users, fuel efficiency and exhaust emissions are two main concerns that must be addressed. Regulating bodies in major countries have come up with stringent emission regulations, which will be enforced from time to time.

There are three ways to reduce emissions form spark-ignition engines which are; changes in engine design, combustion conditions, and catalytic after-treatment. Some of the variables of the engines and combustions that affect emissions are the air-fuel ratio, ignition timing, and turbulence in combustion chamber. Among these variables, air-fuel ratio is the most importance variable that needs to be focused on. Air-fuel ratios for the internal combustion engine are controlled by fuelling system: either by using carburetor system or fuel injection system.

Fuel injection system is a new generation of fuelling system in automotive industries since it was introduced around 1980s and are more vibrant than the conventional ones – carburetor. Fuel injection system can substantially lower fuel consumption and emissions when compared to conventional carburettor, no matter what fuel they use.

Fuel injection for gasoline engines can be defined by its fuel-injection location such as direct in-cylinder injection (DI) and port-fuel injection (PFI).

Drake and Haworth [5] have said that, DI fuel-injection system is more complicated and requires much more sophisticated control over the fuel-injection, air-fuel mixing and combustion processes compared to PFI system.

In a PFI system the low-pressure fuel injector mounted in the intake-port will supply the exact quantity of fuel to mix with air just after the intake valve is opened. Just like the principle of carburetor system, the mixture of air and fuel in PFI system will become homogenous in the intake manifold before the intake valve is open and drawn to the combustion chamber. For this reason, an investigation was made to study the influence of fuel injector positions to the performances of the engine as well as emission characteristics.

EXPERIMENTAL SETUP

Experiments were carried out on a 4-stroke 125cc carburetor engine. The engine is four-stroke, one cylinder, spark ignition (SI) and air-cooled system. Bore and stroke is 51.75mm and 57.94mm respectively. The specifications of the test engine are as shown in Table 1.

Table 1. Specifications of the selected test engine.

Engine Parameters	Value
Engine model and No. of cylinder	4-stroke / 1 cylinder
Stroke x Bore (mm x mm)	57.94 x 51.75
Displacement (cc)	125
Connecting rod length (mm)	130
No. of transmission	4 gear
Ignition system	Spark ignition
Cooling system	Air-cooled system

The test engine was coupled to a CT 110 asynchronous dynamometer test stand for measuring engine speed, load and torque as shown in Figure 1. Maximum torque, power and engine speed that can be measured by the dynamometer are: 50Nm, 7.5kW and 5,000rpm, respectively. Fuel mass flow-rate was measured by using Ono Sokki mass flow meter – FZ-2000 series.

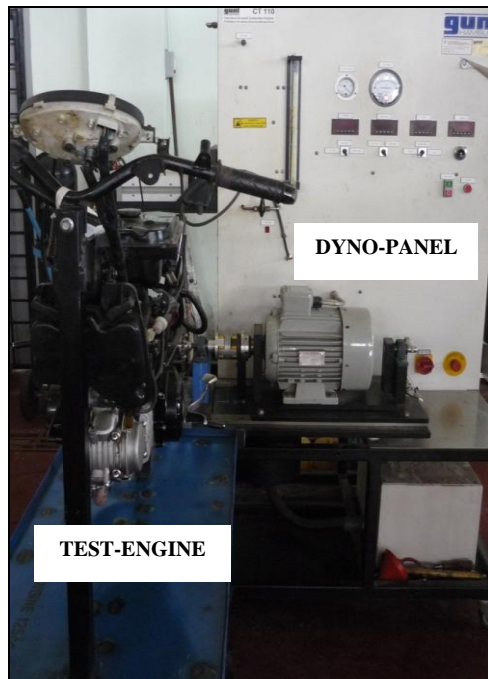


FIGURE 1. Test engine that was connected to an engine dynamometer.

The layout and schematic system of the experiment setup is shown in Figure 2. The test engine was operated in wide throttle opening with variables load-dynamometer. Two fuel injector positions that have been studied are: 48° and 68° (after this noted as PFI 48° and PFI 68° respectively). Fuel research octane number of 95 (RON95) was used as test fuel in this experiment because it is the most widely used unleaded gasoline for small motorcycle users in Malaysia.

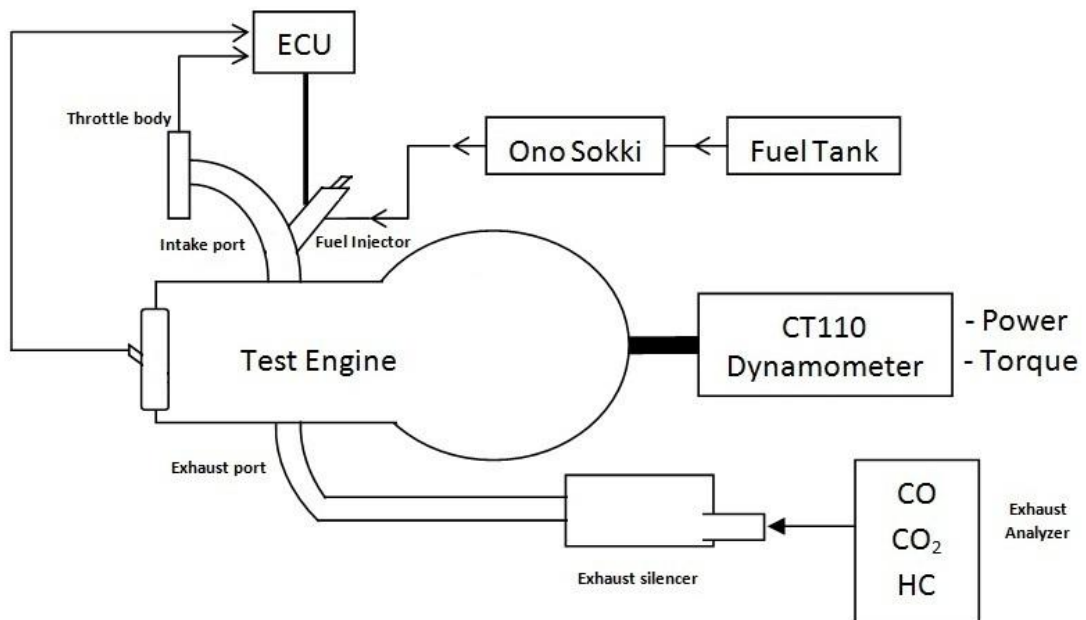


FIGURE 2. Schematic system for engine testing.



FIGURE 3. Fabricated intake manifold with different fuel injector angles.

Measurements were taken for torque, actual speed, air-flow, air-inlet pressure and fuel consumption. Calculations were made for brake power (BP), brake mean effective pressure (BMEP), and brake specific fuel consumption (BSFC). Exhaust emissions such as green house gases like carbon dioxide (CO₂) and other toxic gases like carbon monoxide (CO), and hydrocarbon (HC) were measured by using exhaust gas analyzer.

RESULTS AND DISCUSSION

This section compares the optimum results obtained from different fuel injector positions for performance and emissions characteristics. SI engine performance and emissions characteristics are directly affected by the fuel injector positions. These characteristics include: brake power, brake mean effective pressure, brake specific fuel consumption, produced CO₂, CO and HC emissions.

Brake Power

In Figure 3, BP is compared for two different fuel injector positions. From the figure, it shows that the PFI 68° produced higher BP under all dynamometer loads. The highest BP produced by PFI 68° compared to PFI 48° is at two-unit load which is 65% higher.

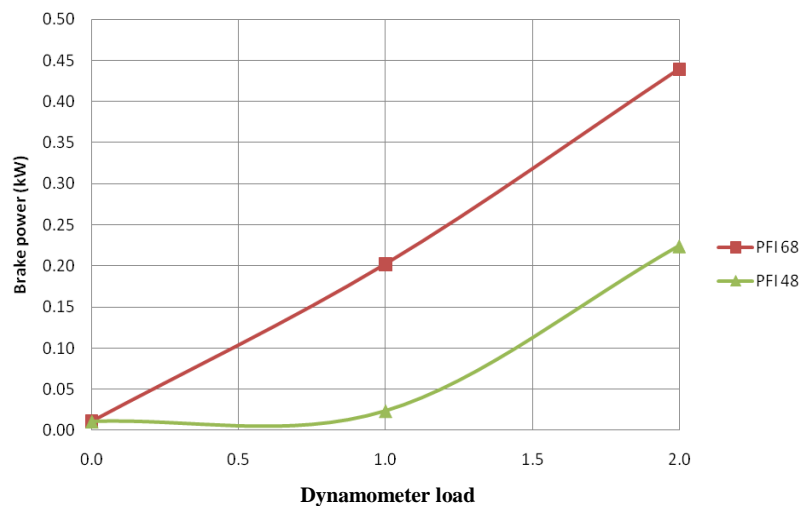


FIGURE 3. Variation of brake power versus dynamometer load for different injector positions.

Brake Mean Effective Pressure

Figure 4 show that the variations of BMEP for all type of fuel injector positions. From the figure, it can be seen that the pattern and trend of BMEP curve follows BP curve. Same as BP, PFI 68° produced high BMEP during all loads. It is desirable to have high BMEP to produce high power per in-cylinder pressure.

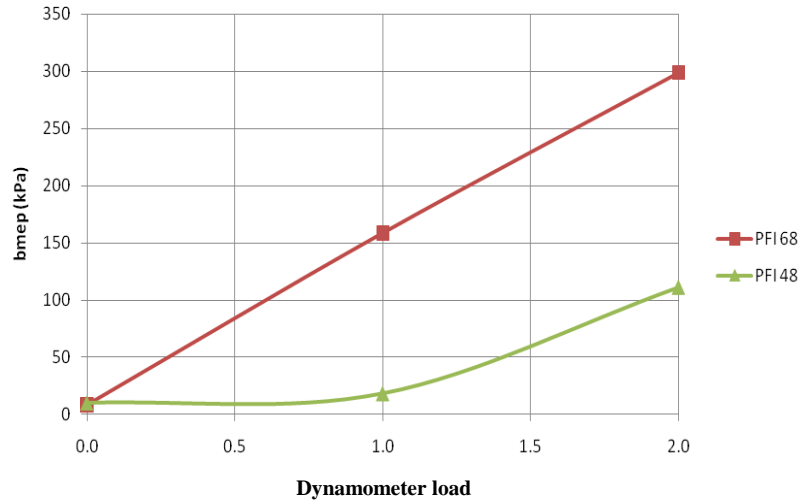


FIGURE 4. Variation of brake mean effective pressure versus dynamometer load for different injector positions.

Brake Specific Fuel Consumption

Figure 5 presents a comparison of BSFC between different fuel injector positions. BSFC for PFI 48° is the highest with average of over than 191% at all loads compared to PFI 68°. This means that, PFI 68° is the optimum angle that used fuel efficiently to produce work compared to PFI 48°.

For SI engine, it is desirable to have low values of BSFC. From Figure 5, obviously BSFC for all fuel injector positions is too high at zero load and decreases as the load increases. BSFC is due to engine speed. When load was applied to the engine, the engine speed decreased and BSFC decreased as well. This is due to the less working cycles in a specific time [6].

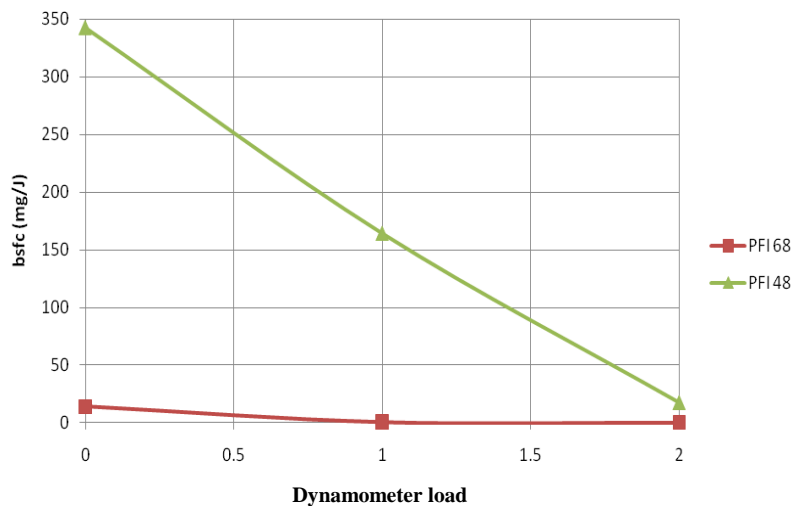


FIGURE 5. Variation of brake specific fuel consumption versus dynamometer load for different injector positions.

CO₂, CO and HC Concentration

CO₂, CO, and HC concentration are shown in Figure 6, Figure 7 and Figure 8 respectively for different fuel injector positions. All of these exhaust gases depend on air/fuel ratio.

From Figure 6, it shows that CO₂ concentration emitted from PFI 68° is doubled from PFI 48° at all loads. A rich mixture produces more CO in exhaust gases [6] and this condition must be avoided. However, this condition occurred during PFI 68° to provide maximum power [7]. Figure 7 presents that PFI 68° produced high CO concentration compared to PFI 48°.

HC concentrations measured during experiments are as Figure 8. PFI 48° emits high HC gases as much as 32% at zero and one-unit load, and 44% at two-unit load. For PFI 48°, due to its low angle position, an incomplete mixture was assumed between the injected fuels and entrained air. This situation produced a thin fuel film at the wall of intake manifold and non-homogenous air-fuel mixture was drawn to the combustion chamber. This might affected combustion process and resulted to incomplete combustion, hence increased emissions of unburned HC. From the same figure, it can be seen that, PFI 68° emitted low HC emission. This could be due to better air-fuel mixture was drawn into the combustion chamber.

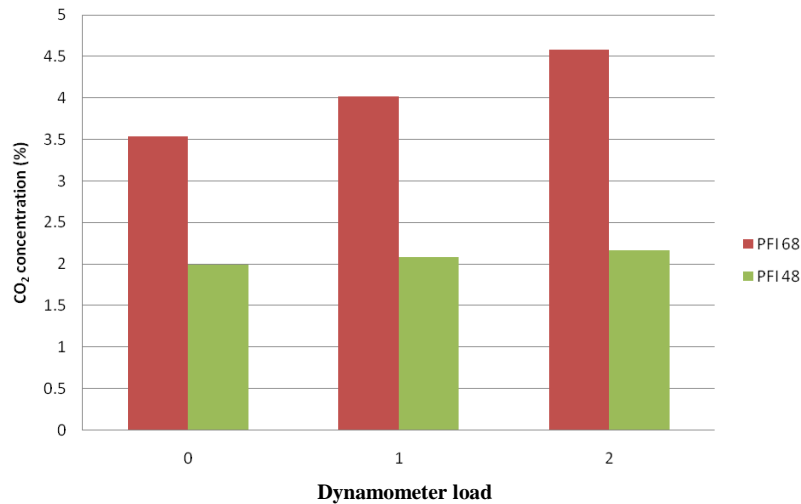


FIGURE 6. Variation of CO₂ concentration versus dynamometer load for different injector positions.

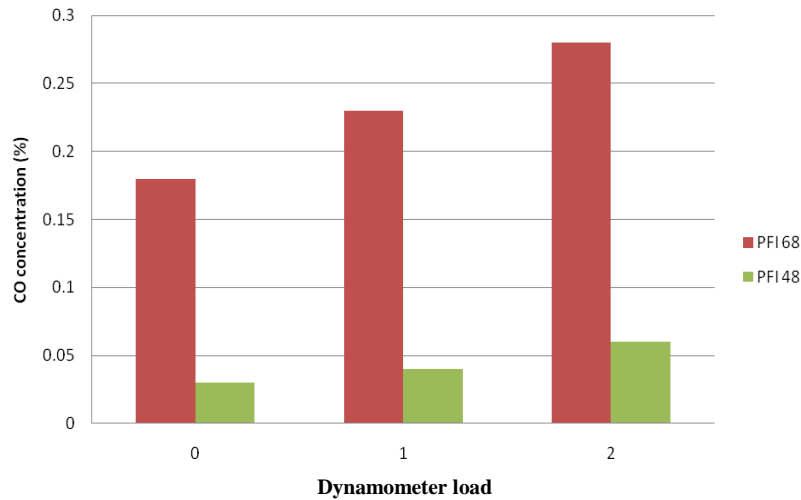


FIGURE 7. Variation of CO concentration versus dynamometer load for different injector positions.

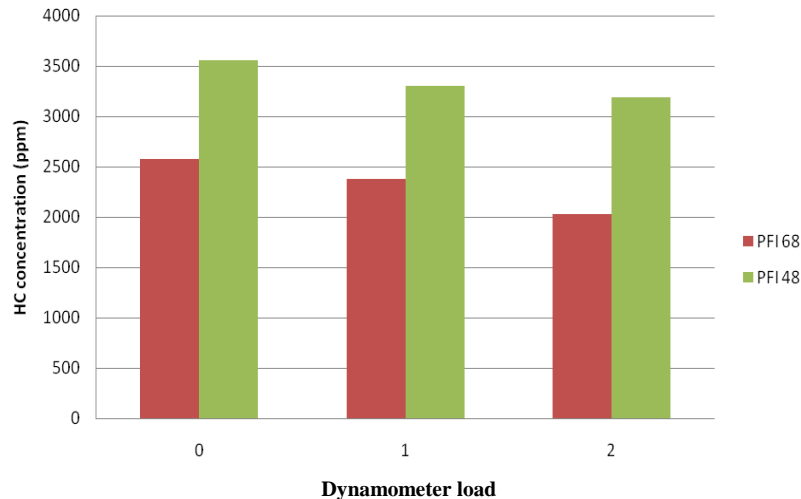


FIGURE 8. Variation of HC concentration versus dynamometer load for different injector positions.

CONCLUSIONS

Performance and emission characteristics for small PFI gasoline engine were experimentally investigated. From the previous results and discussion, many interesting observations were obtained. This study has shown that:

- PFI 68° produced high BP and BMEP with extremely low BSFC.
- PFI 68° emitted low HC concentration but high CO and CO₂ concentrations.

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