

Effect of Intake Manifold Angle of Port-fuel Injection Retrofit-kit to the Performances of an S.I. Engine

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Abstract. Fuelling system is one of the crucial variables that must be focused on, in order to achieve good fuel efficiency and low engine out emissions. Fuel injection system seems a promising technology as a medium to supply suppressed fuel because of its high fuel delivery efficiency, enhanced fuel economy and reduced engine out emission. Port-fuel injection (PFI) system has been used widely on small four-stroke gasoline engine because of its simplicity compared to direct injection (DI) system. In this study, the effects of intake manifold angle of a PFI retrofit-kit to the engine performances and emission characteristics were investigated. Experimental works comprised wide-open throttle with variable dynamometer loads for two different angles: 90° and 150°. From this study, it was observed that 150° was the optimum angle, which produced high brake power (BP) and brake mean effective pressure (BMEP), brake specific fuel consumption (BSFC) and hydrocarbon (HC) emission.

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 the 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 increasing by time, many motorcycle manufacturers have decided to implement the fuel injection system to their new motorcycles.

However 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 that 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 and in the context of growing environmental concerns, fuelling system appears to be one of the most promising technologies for improving fuel economy and reducing engine-out pollutant emissions. Regulating bodies in major countries have come up with stringent emission regulations, which will be enforced from time to time.

There are three technological solutions to improve fuel economy and reduce emissions from spark-ignition (SI) engines, which are: changes in engine design, combustion quality, and catalytic after-treatment.

Currently, downsizing is considered as the best solution to improve fuel economy and at the same time reduce emissions [5]. Downsizing is a part of changes in engine design, which give high engine power and torque while reducing engine displacement volume. Under bone motorcycle is considered as a small engine with its engine capacity below than 150cc [6]. Even though this solution can give good impact to fuel economy and environmental, but it is not an appropriate solution for the small capacity engine and its require substantial additional costs for major engine modifications. Therefore, combustion conditions are needed in order to improve fuel economy and reduce emissions for motorcycle engine.

Some of the variables of the engines and combustions that affect emissions are the air-fuel ratio (AFR), ignition timing, and turbulence in combustion chamber. Among these variables, AFR is the most important variable that needs to be focused on. AFR for the internal combustion engine (ICE) are controlled by fuelling system: either by using carburettor system or fuel injection system.

EFI system is a new generation of fuelling system in automotive industries since it was introduced around 1980s. Since then, the EFI systems have been used widely on medium to large engines. Fuel-injected engines offer many advantages over carburetted engines such as enhanced fuel economy and lower output of harmful emissions, 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). While DI and PFI have much in common, but apparently they differ in some important ways. Drake & Haworth [7] 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. This is because, rather than premixing the air and fuel, the fuel is injected directly into the combustion chamber and aimed at the spark plug and need higher compression ratio than PFI system. PFI system promotes low capital investment rather than DI because DI system is more expensive than PFI system. In addition, the majority of the motorcycle engine components are conventional in design. In particular, the retrofit PFI kit uses conventional components of an engine excepts replacing carburettor and its intake manifold with retrofit PFI kit. It is therefore desirable to have a PFI system for small engines that offers all of the advantages of fuel injection over conventional carburetted engines, while having a low enough cost to make the system cost effective for small engine usages.

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 intake manifold angle to the performances of the engine as well as emission characteristics.

Experimental Setup and Test Procedure

Experiments were carried out on a 4-stroke 125cc carburetted engine. 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
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. The dynamometer can be used either to provide the required braking power (load) or to motor the test engine by the asynchronous motor. Fuel mass flow-rate was measured by using Ono Sokki mass flow meter – FZ-2000 series.

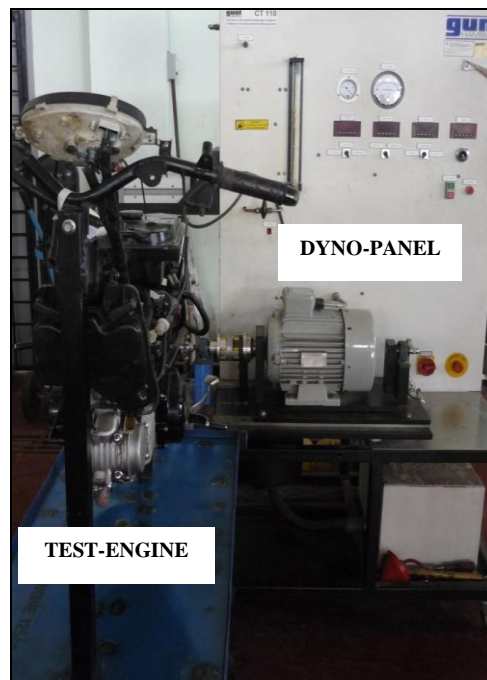


FIGURE 1. The test engine connected to the asynchronous dynamometer.

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 intake manifold angles that have been studied are: 90° and 150° (after this noted as PFI 90° and PFI 150° 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.

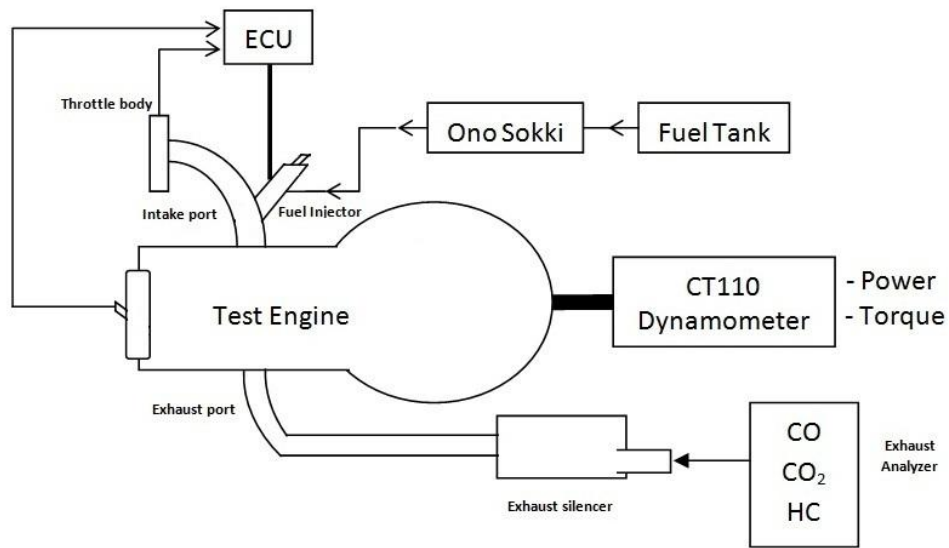


FIGURE 2. Schematic of the experimental work.



PFI 90°

PFI 150°

FIGURE 3. Fabricated intake manifolds with different angle.

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 gas analyzer was used to measure carbon monoxide (CO), carbon dioxide (CO₂), and hydrocarbon (HC) emissions.

Results and Discussion

This section compares the optimum results obtained from different intake manifold angles for performance and emissions characteristics. SI engine performance and emissions characteristics are directly affected by the intake manifold design. These characteristics include: BP, BMEP, BSFC, produced CO₂, CO and HC emissions.

Brake Power. In Figure 4, BP is compared for two different intake manifold angles. From the figure, it shows that the PFI 150° produced higher BP under all dynamometer loads. During the experiments, PFI 90° cannot withstand for two-unit load and the engine was motored by the asynchronous dynamometer motor.

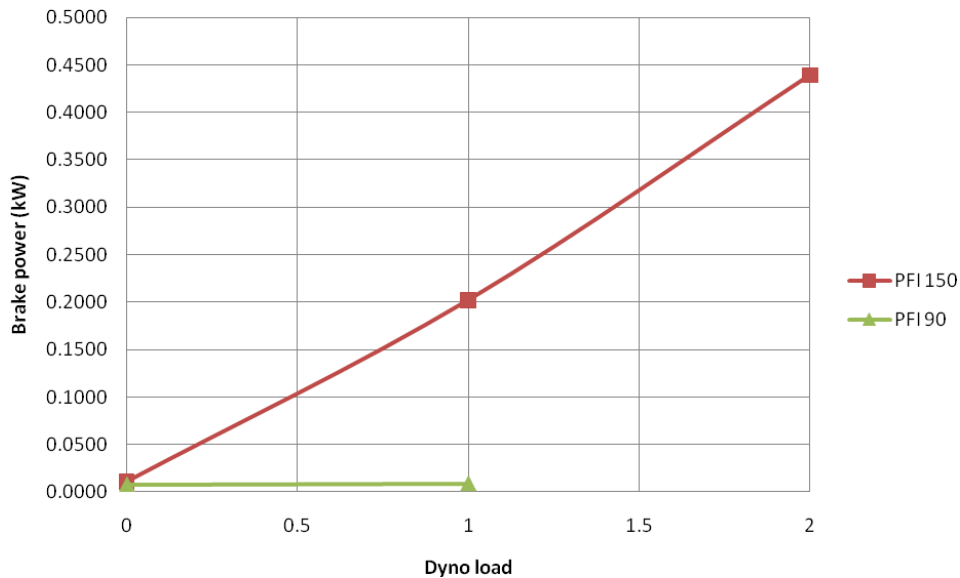


FIGURE 4. Variation of brake power versus dynamometer load for different intake manifold angles.

Brake Mean Effective Pressure. Figure 5 show that the variations of BMEP for all type of intake manifold angles. From the figure, it can be seen that the trend of BMEP curve follows BP curve. Same as BP, PFI 150° produced high BMEP during all loads. For an ICE, it is desirable to have high BMEP to produce high power per in-cylinder pressure.

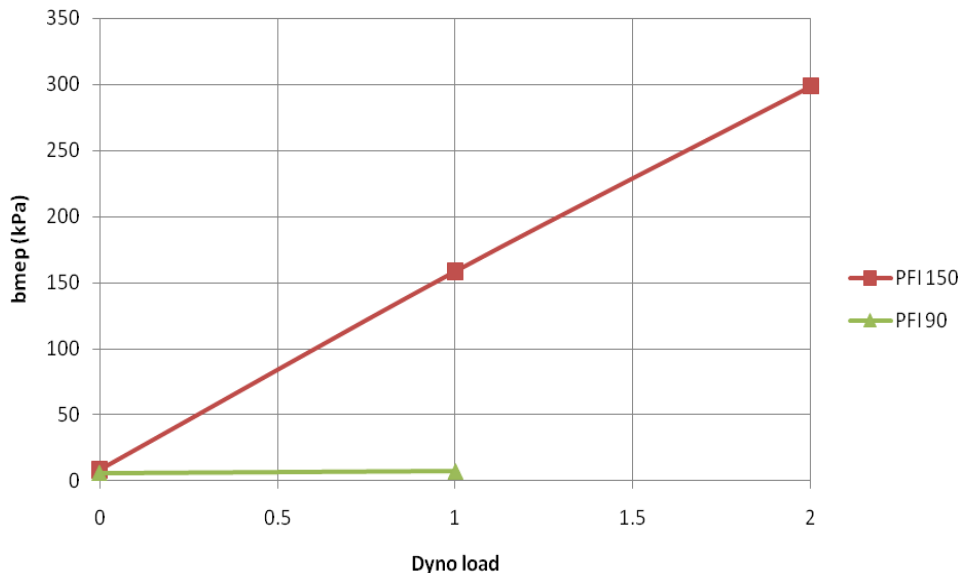


FIGURE 5. Variation of brake mean effective pressure versus dynamometer load for different intake manifold angles.

Brake Specific Fuel Consumption. Figure 6 presents a comparison of BSFC between different intake manifold angles. BSFC for PFI 90° is the highest at all loads compared to PFI 150°. This means that, PFI 150° is the optimum angle that provided high volumetric efficiency and used fuel efficiently to produce work compared to PFI 90°.

For SI engine, it is desirable to have low values of BSFC. From Figure 6, obviously BSFC for all intake manifold angles is higher 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 [8].

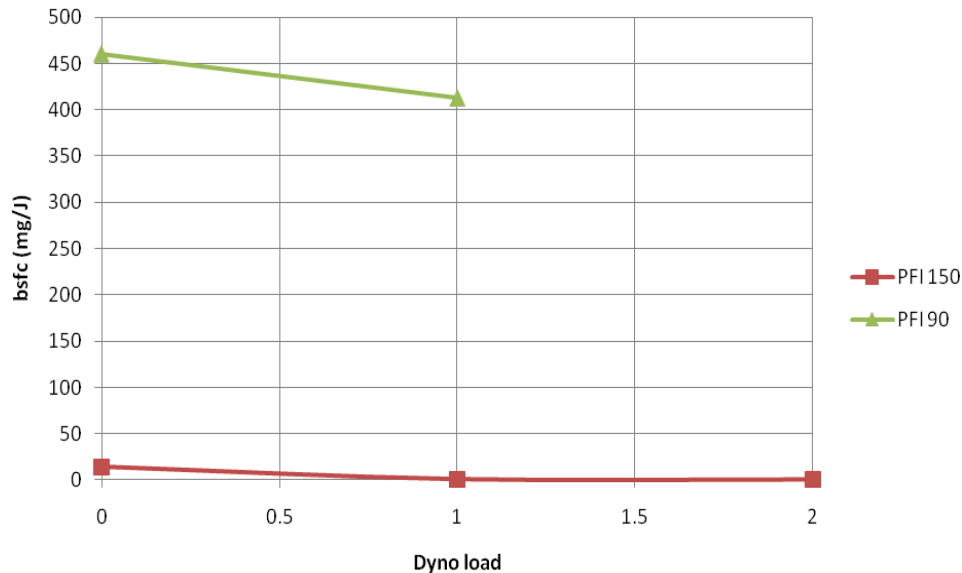


FIGURE 6. Variation of brake specific fuel consumption versus dynamometer load for different intake manifold angles.

CO, CO₂, and HC Concentrations. CO, CO₂, and HC concentration are shown in Figure 7, Figure 8 and Figure 9 respectively for different intake manifold angles. These exhaust gases depend on AFR values.

From Figure 7, it shows that CO concentration emitted from PFI 150° is much higher than PFI 90° at all loads. A rich mixture produces more CO in exhaust gases [8] and this condition must be avoided. However, this condition occurred during PFI 150° to provide maximum power [9]. Figure 8 presents that PFI 150° produced high CO₂ concentration compared to PFI 90°.

HC concentrations measured during experiments are as Figure 9. PFI 90° emits high HC gases as much as 32% at zero load and 3% at one-unit load. For PFI 90°, 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 150° emitted low HC emission. This could be due to better air-fuel mixture was drawn into the combustion chamber.

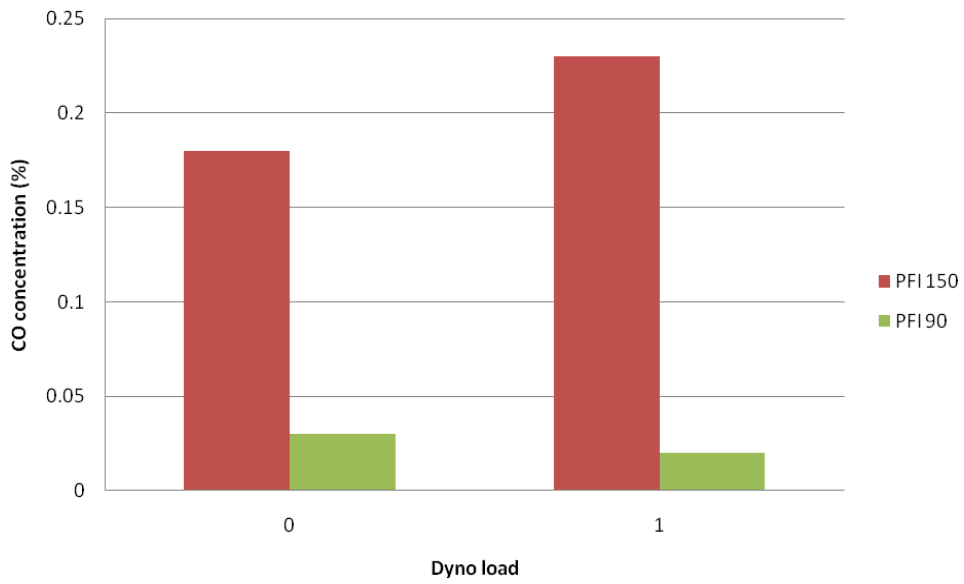


FIGURE 7. Variation of CO concentration versus dynamometer load for different intake manifold angles.

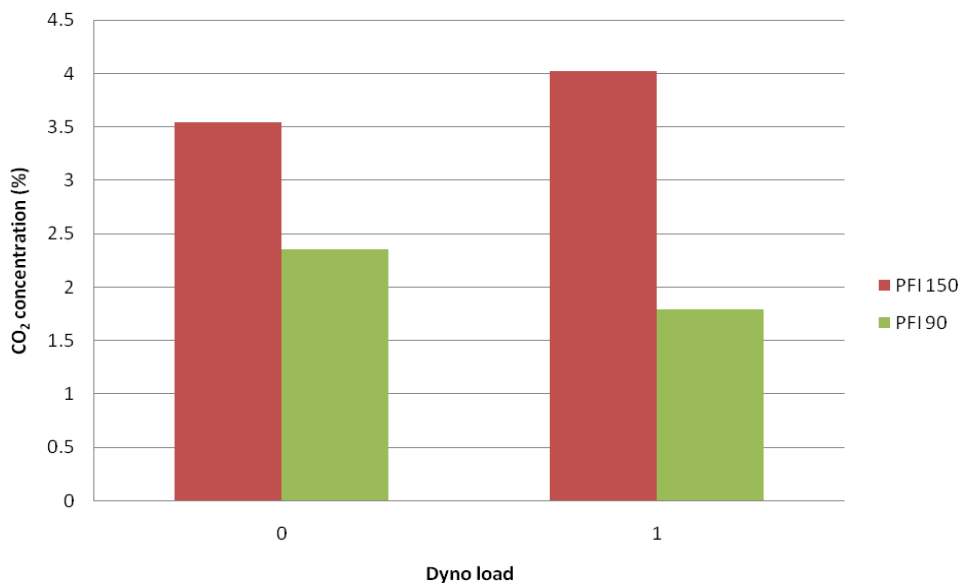


FIGURE 8. Variation of CO₂ concentration versus dynamometer load for different intake manifold angles.

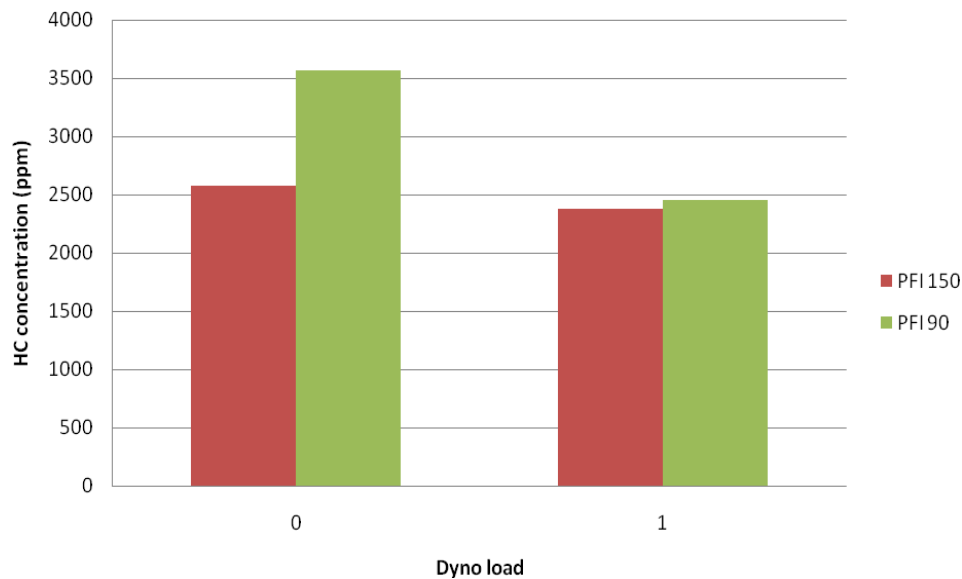


FIGURE 9. Variation of HC concentration versus dynamometer load for different intake manifold angles.

Summary

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 150° produced extremely high BP and BMEP with extremely low BSFC.
- PFI 150° emitted low HC concentration but high CO and CO₂ concentrations.

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