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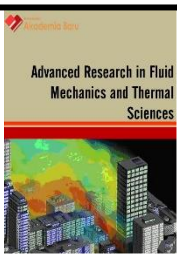

An Experimental Study for Emission of Four Stroke Carbureted and Fuel Injection Motorcycle Engine

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ABSTRACT

Anti-pollution laws in many countries impose a limit on the volume of poisonous gases which may be emitted from a vehicle's exhaust. The aim of this study is to compare the emission characteristic of a carbureted and fuel injection system of a four-stroke motorcycle engine. For this objective, a carbureted engine of Honda Wave 125 cc was converted into a fuel injection system. Emissions of CO, CO2 and hydrocarbon (HC) were measured in the lab. The test was conducted at three different speeds: 2000, 4000 and 6000 RPM; and at two loads: 5Nm and 10Nm. Upon conversion of the motorcycle engine, the results show improvement in term of reduction of emissions of all three gasses. Emission at a 5 Nm load improved by 62.6%, 29.75% and 11.33% for CO, HC and CO_2 respectively. The results also showed a similar trend at a 10 Nm load, where the emissions improved to 75.86%, 30.1% and 47.71% for CO, CO_2 and HC respectively. The results show that fuel injection is evidently a better system as it delivers lower emissions.

Keywords:
Carbureted engine; Fuel injection system; CO_2; Hydrocarbon (HC)

1. Introduction

Green technology is the rage these days and many scholars want to contribute towards the advancement of this technology. One area of concern is air pollution which is something people want to avoid, with scholars working towards the improvement of air quality. Normally, emission comes from propulsion systems such as a vehicle engine.

People are now concerned about pollution produced by engines, and as a consequence new regulation have been put in place. Car and engine manufacturers are obliged to follow these regulations to avoid being fined by the authorities. A small gasoline engine is defined as an internal combustion engine (ICE) which has a small combustion chamber whose capacity is measured in cubic centimeters (cc) ranging from 50 cc to 150 cc. Automobiles in this category include motorcycles,

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which are popular worldwide as a means of transportation, particularly ones run by a carburetor system, due to their mobility, convenience, economy and their versatility on different roads. The laws limiting the volume of poisonous gas emissions make the use of small fuel injection systems a plausible solution.

The emission legislation of Euro 6C [1], that became effective in Europe in the year 2017 motivated industry players to improve their products, with EFI being one of the technologies that satisfy the Euro 6C legislation. Earlier, on 2014, the Global Technical Regulation under the United Nations' World Forum for Harmonization of Vehicle Regulations was established for eradicating air pollution [2].

There is no doubt that motorcycles are a major means of transport in Malaysia, as well as in Southeast Asia. It is estimated that 60% to 75% of all road vehicles in Asia including India, Indonesia, Taiwan, Thailand and China are motorcycles [3]. Most motorcycles in South East Asia still have carburetors as the main engine system. Carburetor is unable to hold the mixture of fuel and air close to the stoichiometric thereby causing the production of more emissions even when a catalytic converter is installed in the exhaust system. Therefore, it has lower efficiency and high emission values thereby making it impossible to comply with the prevailing emission legislations [4]. Another technology such as fuel injection is more advanced compared to this technology.

1.1 Carbureted and Fuel Injection System

The carburetor and fuel injection system has a basic common working theory where performance is measured in terms of the amount of fuel and fresh air entering the engine cylinders. Both systems feed fuel and air into the engine. Basic components in the cylinders of both systems are pistons and combustion chamber wherein the reaction between fuel and air occurs during combustion, thereby releasing energy. However, there are many differences between the carburetor and fuel injection with the main difference being the method which fuel is injected. For an engine with a fuel injection system, the fuel is introduced into the internal combustion engine by using an injector [5]. A fuel injector comprises of a valve-nozzle combination which introduces a spray fuel into the air flow. The amount of fuel that is injected is calibrated either by solenoid actuation (electronically controlled) or cam actuation (mechanically controlled) [6]. On the other hand, for carburetor system, suction is created by an air intake air which accelerates through a venturi tube and draws fresh air into the combustion chamber.

There are many types of fuel injection such as throttle body injection (TBI), port fuel injection (PFI), sequential port fuel injection (SPFI) and direct injection (DI). Nowadays, most automotive engines use port fuel injection, with the increased use of direct fuel injection [7, 8]. Even though a DI system is more advanced compared to PFI, this study considers the PFI system due to its benefits over the DI system. The most outstanding benefit of the PFI system is its low capital investment which differs greatly from the high cost of the GDI, which is also highly complex and strenuous to implement on a commercial engine. Meanwhile, GDI system has been found to emit higher numbers of particulates than PFI system [9]. In comparison to a carbureted engine, the injection system requires a high fuel pressure system. Carburetor operates at a fuel pressure of 0.04 MPa – 0.05 MPa, which is much smaller compared to PFI which runs between 0.25 MPa to 0.45 MPa while GDI runs between 4 MPa to 13 MPa [4, 10, 11]. Higher pressure means better atomization and penetration of the fuel which facilitates better mixing before spark occurrence thereby reducing the amount of emission produced [12].

1.2 Exhaust Gas Emission

In the experiment carried out in this study, exhaust pollutants (emissions) of the engine, including carbon monoxide (CO), carbon dioxide (CO_2), and unburned hydrocarbon (HC) were investigated at different engine speeds and loads. Carbon dioxide is directly related to the combustion of fuel and larger amounts of CO_2 in exhaust result in better fuel combustion [13]. However, the maximum acceptable amount of CO_2 in gasoline is 12.62% (value from stoichiometric calculation) [14] . The HC is mostly caused by an unburned fuel–air mixture. Carbon monoxide (CO) is a by-product of the combustion of rich fuel–air mixture, which is as a result of inadequate oxygen to fully burn all the carbon in the fuel converting it into CO_2. Lower HC and CO in gas emission from the exhaust indicate that the engine is in good condition.

A number of studies by previous researches show that a carburetor system produces high emission compared to a fuel injection system. In studying the amount of pollutants emitted by a carbureted engine, an experiment was conducted on 60 carbureted motorcycles [15]. Different engine sizes were tested on a chassis dynamometer for various mileages. The result showed that on average, the carbureted engine produces seven times the allowable limit of CO emission set by the Euro-3 certification. Stahman and Rose [16], in their emission study of the differences between carbureted and fuel injected engines found that the use of fuel injection engines could help reduce CO emissions by 50 to 60 percent, while HC emissions could be reduced by 25 to 50 percent. The revelations made by these studies on the high CO pollutants released in the air were the reason behind the replacement of the carburetor with the fuel injection systems in the 1970s.

2. Methodology

Honda Wave 125 cc motorcycle has been used for this study. As shown in Table 1, the engine is a four-stroke, single-cylinder and naturally aspirated engine. In this experiment, the carburetor has been replaced with a fuel injection system. During installation, some of the parts, such as the bracket, have been re-designed and fabricated so as to be able to support the new system. The engine setup along with the test cell which constitutes of an appropriate data acquisition system, are shown in Figure 1.

Table 1
Engine Specification

Parameter	Value
Engine Type	4-Stroke, OHC, Air Cooling, Carburettor
Maximum Torque	10,00 Nm @ 5000 RPM
Cylinder Bore	52.5 mm
Stroke	57.9 mm
Air Cleaner	Paper Core Filter Type
Ignition System	CDI
No of Cylinder	1
Starter	Kick-starter and electric
Transmission	4 Speed
Displacement	124.9 cc
Compression Ratio	9.3 : 1
Maximum Power	9,10 HP (6,6 kW) @ 7500 RPM

For the engine conversion, this study utilizes a standard EFI kit which is illustrated in Figure 2. The system has ECU and a complete throttle unit made up of a throttle sensor and an injector as its main components for controlling the fuel. Other than that, an external fuel system has been installed on the system comprising of components such as a fuel tank, fuel pump, fuel regulator and fuel filter, all of which are assembled together as shown in Figure 3. For better combustion of fuel, the system requires a fuel pump that can produce enough pressure during combustion. For this reason, a pump that has a pressure of 300kPa and flow rate of 25L/hr has been selected. Additional specifications are presented in Table 2.

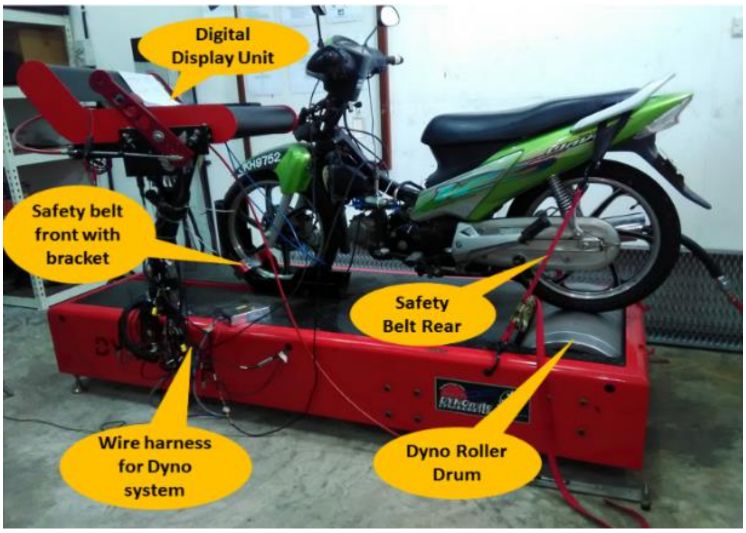

Fig. 1. DYNOmite Dynamomete

Table 2
Fuel Pump Specification

Pump Types	Value
Supply Voltage	12V DC
Working Current	< 2A
Pressure	300kPa
Flow rate	25L/hr
Working temperature	-40°C - 80°C

ECU needs a power supply for its operation, however, it cannot be directly connected to a motorcycle battery because this can drain battery power faster. For this reason, the ECU is connected to the ignition switch for power supply. By doing this, power is supplied to ECU only if the engine is ON. This can potentially save battery power. Originally, the fuel pump was powered by a 12V battery through two terminal connectors,: positive and negative. However, due to the possibility of a high load during engine high speed and instability of power supply, the design was changed. Instead of connecting the fuel pump to the motorcycle battery, it was directly connected to the external power supply through two terminals. The ECU is connected to the engine plug cable so as to facilitate the measurement of the engine’s speed.

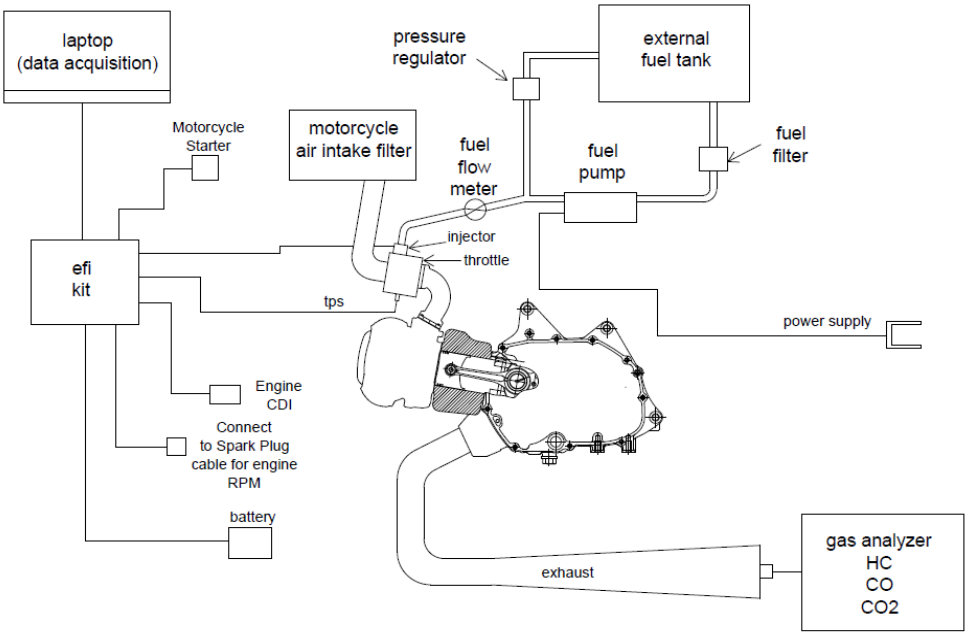

Fig. 2. Engine conversion

Exhaust gas was measured using gas analyzer which is part of DYNOmite Dynamometer system. DYNOmite Dynamometer can measure 5 different types of gases: O_2, NO_x, CO, HC and CO_2 as well as measure AFR (airflow ratio). However, for purposes this study, only three gasses were measured: CO_2, CO and HC.

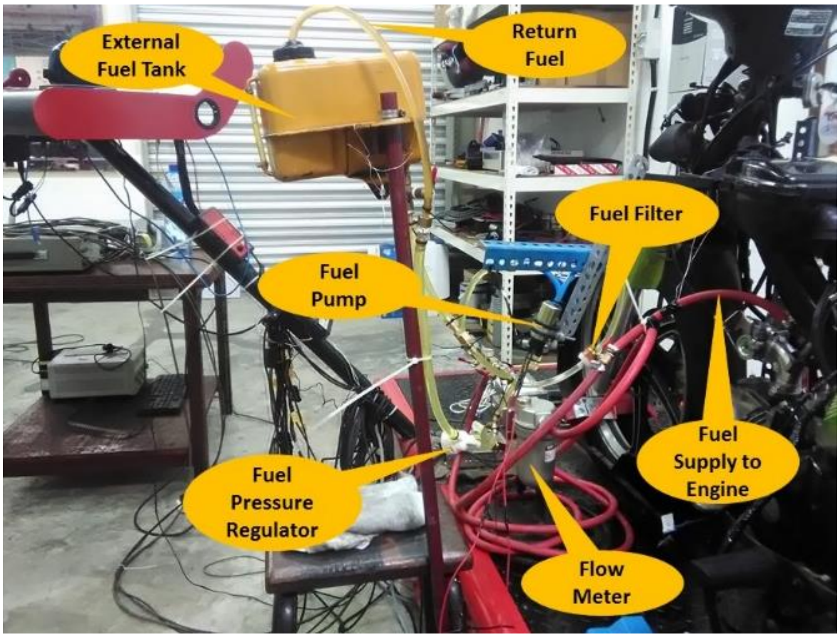

Fig. 3. Fuel system assembly

In this study, for better data consistency, measurements were read 5 seconds after placing a gas probe in the exhaust (Figure. 2). Engine temperatures were allowed to stabilize at each test condition before data was collected. During the experiment, engine temperature was checked and controlled using an infrared thermometer.

Different RPMs and loads were set for each of the required readings. During the test, the gear was set at 4, which is the higher gear ratio for this motorcycle. The test was made in the steady state which means speed is constantly set at 2000, 4000 and 6000 for a specified brake loading at 5 Nm and 10 Nm. Emission reading for both carbureted and fuel injection system was measured while the motorcycle was placed on the dynamometer.

The aim of the experiment was to compare the measurements of a carbureted system versus a fuel injection system. Both systems were subjected to the same test method and procedures. Before the measurements were read, the fuel injection system was tuned to its maximum performance which point the air-fuel ratio of the system is set to a value close to the stoichiometric ratio. The ratio was subsequently read using a gas analyzer.

3. Results

3.1 Emission Measurement at a Load of 5 Nm

Figures 4 and 5 illustrate the variation of CO, CO_2 and HC emissions in accordance with speed changes at a load of 5Nm for both carbureted and fuel injection engines. For both systems, it is evident that the amount of CO_2 emission increases with a rise in engine speed. Conversely, the amount of HC emissions, decreases when engine speed is raised. The figure clearly shows increasing quantities of CO_2 and declining quantities of HC for carbureted and fuel injection systems at varied engine speeds. Stoichiometrically, hydrocarbon fuel combustion should generate only CO_2 and water (H_2O).

A study by Monasari *et al.,* [17] on the analysis of gas emissions and fuel consumption on the SI engine, it was found that as the engine rotation increases, the CO_2 emissions increase. The study stated that the amount of CO_2 in the exhaust indicates the occurrence of a complete combustion process. In a previous study on the 1.4i SI engine by Ozsezen, it was brought to light that unburned HC emissions reduced at higher engine speeds [18]. At high speeds, the air–fuel mixture homogenizes to increase in-cylinder temperature. This condition in turn enhances combustion efficiency. Thus, HC emission decreases more at high engine speeds than at low speeds [19].

As both HC and CO_2 show clear direction of its value, however, CO shows a slight increase in value from 3.63 to 4.29 for the carbureted engine and 0.5 to 3.11 for the fuel injection engine.

In the event that there is inadequate oxygen to convert all the carbon emitted to CO_2, then some of the fuel remains unburned and is thereby released as CO. Larger quantities of CO are generated when an engine is accelerating at high speed [20]. Even in situations where the intake of the air-fuel mixture is isometric or minimal. some CO will be generated in the engine.

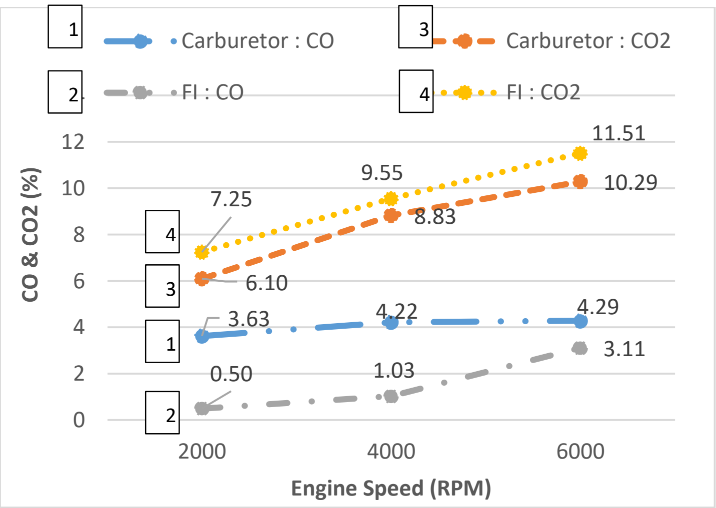

Fig. 4. CO and CO_2 measurement at load 5 Nm

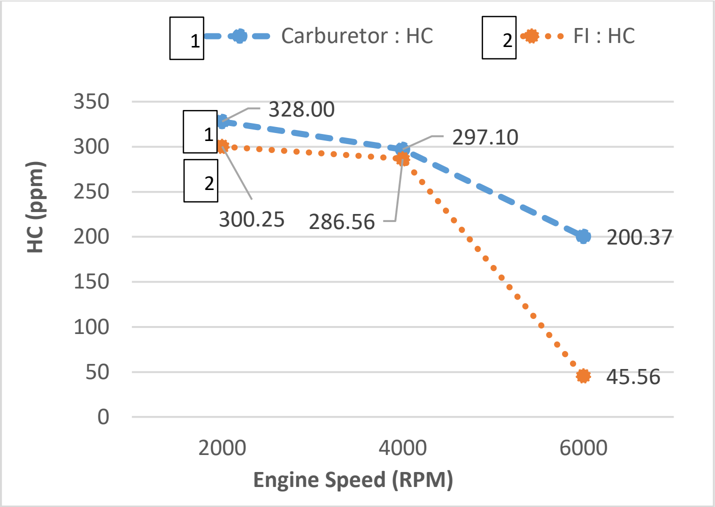

Fig. 5. HC measurement at load 5 Nm

The experimental results in this study show that both systems produce different quantities of gas emissions and that a fuel injection systems much better than a carbureted system [16]. A comparison of the performance at speeds of 2000, 4000 and 6000 shows that, the quantity of CO emissions reduced by 86.2%, 75.6% and 26.1% respectively. Therefore, this translates to an average improvement of 62.6% at all three set speeds. The results also show a similar trend in HC emissions, which show an average reduction of emission by 29.75% while CO_2 emissions improved by 11.33%.

A better combustion process which utilizes a fuel injection system results in reduced emissions of HC, CO and CO_2. The fuel injection nozzles used in the new system facilitate breaking down of the fuel into very fine particles, which easily vaporize during the induction process [16]. This process improves homogeneity of fuel injection.

3.2 Emission Measurement at a Load of 10 Nm

Figure 6 and Figure 7 illustrate the variation of CO, CO_2 and HC emissions in accordance with speed variations at a load of 10 Nm for both carbureted and fuel injection engines. Both results at a load of 5 Nm and 10 Nm show similar trends in their results; the quantity of CO emissions increases with a rise in engine speed. Meanwhile, when engine speed is raised in a carbureted engine, the quantity of CO_2 emission increases but the amount of HC emissions decreases.

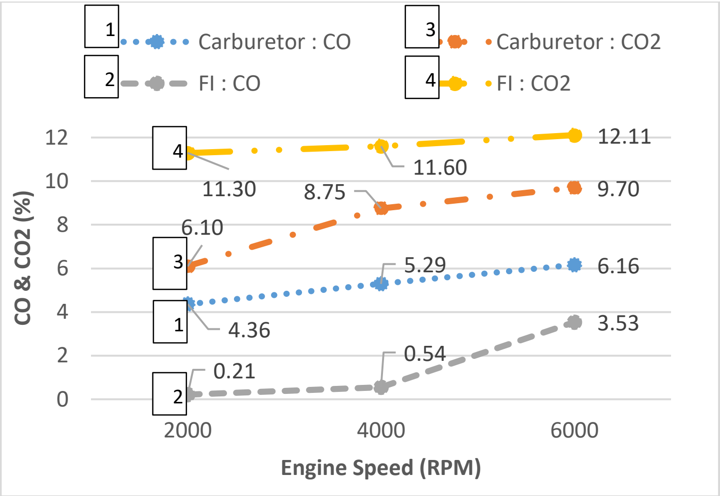

Fig. 6. CO and CO_2 measurement at load 10 Nm

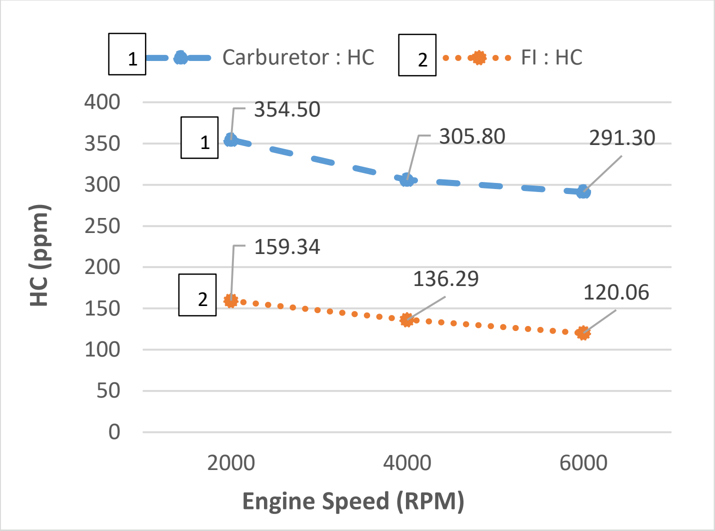

Fig. 7. HC measurement at load 10 Nm

A comparison between carburetor and fuel injection systems, at speeds of 2000,4000 and 6000 show that, CO emissions reduced by 95.1%, 89.79% and 42.69% respectively. Therefore, this translates to an average improvement of 75.86% at all three set speed. CO_2 and HC emissions improved by 30.1% and 56.42% respectively.

Comparing Figure 5 to 7, it is clear that, at same speed the HC, CO and CO_2 increase as the load increases. This is due to more fuel is introduced to achieve the desire engine torque and hence it leads to increase in emission [21] .

Compared to the carburetor, the fuel injected engine combustion process is significantly much more efficient. Precise fuel delivery by an injector along with the mixing of the air and fuel ensures maximum possible fuel efficiency. As a consequence, fuel economy is maximized while the emission level is minimized.

4. Conclusions

The conversion of a motorcycle engine from a carbureted system to a fuel injection system was done in this study, followed by an experimental exercise as specified speeds and load conditions for each of the systems. The results of the study lead to the conclusion that a fuel injection system is better than a carbureted engine. This is because the injection system, which is more advanced, has more effective fuel control than carbureted system. Despite the existence of the carburetor for the past century, this study proves the superiority of the fuel injection system in producing lower emissions.

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