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A review on retrofit fuel injection technology for small carburetted motorcycle engines towards lower fuel consumption and cleaner exhaust emission

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ABSTRACT

Most motorcycles in developing countries use carburettors as the fuel delivery system especially for models with cubic capacity of less than 350 cc. However, small gasoline carburetted engines suffer from low operating efficiency, high fuel consumption and produce high level of hazardous emissions. A retrofit fuel injection system (FIS) is a system that is developed to totally replace the conventional carburettor system to improve its fuel economy and exhaust emissions, providing a low-cost alternative in an effort to reduce fuel costs and air pollution. This paper provides a comprehensive review on the retrofit fuel injection technology developed for small gasoline spark ignition (SI) motorcycle engines from 50 cc to 350 cc. Three main retrofit FIS schemes – the throttle body injection (TBI), port fuel injection (PFI) and direct injection (DI) – are compared, in terms of configurations, complexity, costs and performances.

Contents

1. Introduction

Motorcycles equipped with carburettor systems have become the main option of transportation in many countries around the world since the early 1910s. Interests in motorcycles have been the highest in Asia with an estimated 313 million motorcycles on road since 2012. Fig. 1 shows the distribution of worldwide motorcycles in 2012, with Asia accounted for 78% of the total number, followed by Europe (14%) and Latin America (5%). In Asia, China has the highest number of motorcycles (100 million units), followed by India (40 million units) and Indonesia (30 million units) [1]. The continuous growth in the usage of small, carburetted-engine motorcycles especially in developing countries such as India, China, and Vietnam is as a result of up-and-coming economies, enlarged urbanization, improvement of infrastructure and personal wealth [2]. The continuous increase in fuel prices has also

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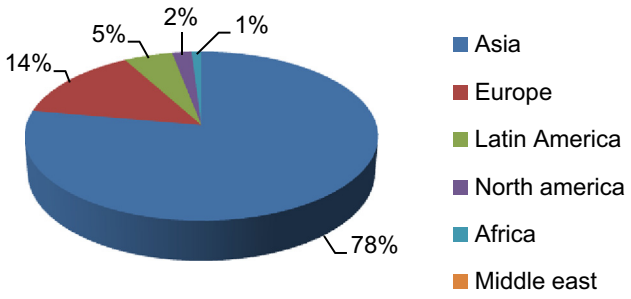

Fig. 1. Worldwide motorcycle fleet.

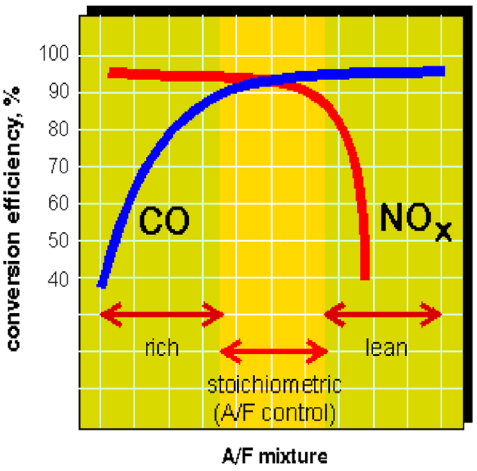

Fig. 2. Efficiency of catalytic converter as a function of A/F.

forced more people to choose motorcycles as a mode of transport due to its smaller engine capacity, hence, lower fuel consumption [3]. However, most of these motorcycles are using carburettor as the fuel delivery system, which is well known for its low operating efficiency, high fuel consumption and high level of hazardous emissions.

It has long been proven that for maximum efficiency and minimum harmful emission production, the correct amount of fuel and air mixture is needed to create a complete combustion in the engine, where the mass of air should be 14.7 times the mass of fuel [4]. This ideal mixture of fuel and air is known as the 'stoichiometric' mixture. However, in practice, this mixture has never been formed perfectly by any machine. Fig. 2 shows the efficiency of the catalytic converter in reducing pollutants as a function of air to fuel ratio (A/F). The use of carburettor cannot closely follow this required ratio because the rate of air and fuel going into the engine cannot be controlled effectively. The carburettor follows the basic principle of atmospheric pressure and as a result, a poor mixture is produced. This leads to an incomplete combustion and hence, higher emission levels that results in various health problems related to air pollution, where it is reported that 13% of the burden of diseases in developing countries and 2% to 6% in developed countries are related to air pollution [5]. To handle this issue, regulating bodies for automotive emissions have come up with emission regulations, which are becoming more and more stringent from time to time [6]. Therefore, fuel injection system (FIS) is expected to be one of the most promising technologies towards improved fuel economy and driving performance as well as reduced engine-out pollutant emissions [7,8].

Fuel injection technology has been around for nearly as long as the automotive industry itself, although crudeness, unreliability and cost made it economically impractical for mainstream automobiles until the 1980s [9,10]. FIS is a system that mixes air with fuel in an internal combustion (IC) engine. It has been used widely in gasoline and diesel engines. Early injection systems used mechanical methods to meter the fuel, known as mechanical fuel injection. In a modern design, FIS consists of mainly electronic components including electronic solenoids, which act as injectors to inject the fuel [11,12]. Basic FIS consists of a fuel pump, a pump regulator, an injector, an electronic control unit (ECU) and various sensors to measure various parameters related to the crank/cam position, flow of air, and exhaust gas oxygen. The operation of the FIS is electronically controlled by the ECU to ensure optimum performance by maintaining the correct amount of A/F produced by the engine so as to avoid problems such as knocking and detonation of the engine.

A retrofit fuel injection technology has been introduced by past researchers to provide the benefits of fuel injection systems to the existing small, carburetted engine motorcycles. The benefits of the retrofit system include its lower implementation cost and simplicity compared to the commercially available fuel injection system. Several studies on the retrofit fuel injection system for small, carburetted motorcycles have been conducted and one of the main challenges in implementing the retrofit system is to adapt it into the existing system [13–15]. Despite this, most retrofit fuel injection systems are able to deliver better performance than the carburettor system.

Since the retrofit FIS can provide a low-cost but effective solution towards better fuel economy and cleaner exhaust emissions for existing small, carburetted motorcycles, it should be given more attention. Therefore, this paper aims to provide a detailed review on the retrofit fuel injection technology developed for small gasoline spark ignition (SI) motorcycle engine from 50 cc to 350 cc as a low-cost alternative to reduce fuel costs and to improve exhaust emissions.

2. Retrofit fuel injection system (FIS) technology on spark ignition (SI) engine

There are several retrofit FIS concepts for use on small capacity carburetted engines developed by past researchers. These have given some enlightenment on how the system should be operated, along with the experimental setup. Usually, the engine's mechanical and electrical systems were modified to include a small automotive style port fuel injector with dedicated throttle body/manifold design, fuel pump, pressure regulator and engine control unit (ECU), together with additional mounted sensors such as temperature sensor, pressure sensor and oxygen sensor at certain parts of the system [16]. In other words, the carburetted motorcycle is retrofitted with the fuel-injection component by replacing the carburettor and manifold parts, while retaining all the conventional components in the motorcycle, i.e. the engine and electrical systems. Most retrofit systems utilize the use of the original spark ignition setting that comes with the engine or factory setting, which is known as the 'stock setting'. This approach has been used to produce simple and low cost working systems so as to avoid major modifications in the original system to meet the requirements of the targeted retrofit technology.

In a modern commercial fuel injection system, the ECU controls the engine status in real-time by controlling the amount of fuel supplied, as well as the angle of the ignition advance [17,18]. The status of the engine is defined by the current rotational speed (in rotations per minute, RPM) and charge, measured as the degree of the throttle opening or the pressure in the suction manifold [19]. The ECU also depends on the indications of the oxygen sensor to measure the oxygen level in the combustion gases. This measurement informs the ECU whether the supply of fuel in the cylinders is too lean (too little fuel) or too rich (too much fuel). Corrections,