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Performance investigation of passenger vehicle fueled by propanol/gasoline blend according to a city driving cycle

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ABSTRACT

The aim of this work is to evaluate the performance of a gasoline engine using different fuel blends of propanol/gasoline. Set of laboratory tests were carried out to investigate the engine performance using four-stroke petrol engine under different operating conditions. The influence of various fuel blends of propanol/gasoline on the engine fuel consumption and its pollutants emission was investigated. The engine maps (fuel consumption & emissions) were used in vehicle simulation code so that the road vehicle performance within the cities according to a standard driving cycle could be determined. The results indicated that the use of propanol/gasoline fuel blend can improve the fuel economy by 2.84% for the blend ratio (propanol/gasoline 15%). Moreover, it decreases the pollutants emission of vehicle engine, especially hydrocarbon, carbon monoxide by 14.18% and 10.87% respectively. Also, the simulation results indicated that the vehicle fuel consumption is improved and the pollutants emissions of for carbon monoxide and hydrocarbon are decreased.

1. Introduction

The ever-growing usage of vehicles and engines inside the cities increases environmental problems [1]. Enormous amounts of pollutants emission are, therefore, generated by the vehicles, especially as CO, HC and NOx within thickly populated cities [2]. These pollutants cause direct and indirect harm to human health and the surrounding environment [3]. Hence, this topic is a great interest for researchers. One of these pollutants is CO_2 gas, which is considered responsible for the greenhouse effect worldwide [4]. The researchers aim to improve fuel economy of vehicle engines by use new types of alternative fuels that can reduce CO_2 emission and other pollutants from the combustion engine [5]. Several investigations have studied the effect of different types of fuel blends with the degradation of engine performance and emission of pollutants [6]. There are many studies that have demonstrated the engine performance and the pollution using fuel blends of ethanol and gasoline [7]. These fuel blends have shown to contribute towards the reduction in pollutants and the fuel consumption according to the research results [8]. There are many different types of fuel blends whose effects have been studied on engine performance, especially fuel consumption and emission of pollutants during different operating conditions inside city [9].

Previous studies have examined the effect of many fuel blends on the performance characteristics of the IC engines. The results of these researches have shown a significant increase in engine output power when using these fuel blends. Experimental results also showed a significant decrease in the pollutants emissions due to the use of specific proportions of these blends [10]. A lot of previous investigations which focused in blending of gasoline with any other alcohol fuel such as (ethanol, methanol, propanol, butanol and pentanol) confirmed that there are an improvement in the engine performance in general and a significant reduction in the pollutants emission [11].

There is a clear paucity in the literature reviews that are interested in studying the effect of propanol-gasoline blends on the engines performance and emission. Some of these studies will be reviewed to know the effect of fuel blends on engine performance. Altun et al. [12] investigated the influence of iso-prpanol gasoline blend on engine performance characteristics and pollutants emission. Experimental work of this study has been carried out on a four-stroke, four cylinder SI engine. It examined two fuel blends 5% and 10% of iso-propanol/gasoline. The results showed that CO emission and HC emission decreased with iso-propanol/gasoline

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blends while CO_2 emission increased. Gong et al. [13] studied the effect of different fuel blends of propanol-gasoline on IC engine performance and emission characteristics. Pollutants emission such as HC, CO and NOx were investigated at different blending ratio, exhaust gas recycle (EGR) rate and spark timing experimentally. Results of study indicated that HC and CO emissions significantly decreased in case of the use of fuel blends than pure gasoline. Yusri et al. [14] investigated the effect of different fuel blends with volume rates 5, 10 and 15% of 2-butanol- gasoline on exhaust emission of 4-cylinder engine. The results showed that with increase in 2-butanol content in the fuel blends, pollutants emission such as CO, HC and NOx decreased whiles CO_2 emission slightly increased. Elfasakhany [15] in this study, three fuel blends of isobutanol/gasoline (3, 7, and 10%) were experimented in order to evaluate SI engine performance and emission at different engine speeds. It concluded that CO and HC emission of engine were lower in case of fuel blends than pure gasoline at low engine speeds. Sivasubramanian et al. [16] examined the use of binary fuel blends propanol/gasoline, as an alternative fuel for direct injection SI engine. It used three fuel blends with rates of 10, 20 and 30% with gasoline to assessment the influence of propanol additives on engine output performance and pollutants emission. The investigation study concluded results that indicated significant reducing of CO and HC emission whiles NOx emissions increased. Furthermore, the fuel blends of propanol/gasoline affected negatively on engine performance characteristics. Dhamodaran [17] studied the effect of different butanol/gasoline blends on engine performance. This study is considered an attempt to evaluate the performance characteristics of four-stroke, four-cylinder fuel injection engine fueled with three different rates of butanol/gasoline blends (10, 20, and 30%). The experimental work was carried out for two engine speeds 1400 and 2800 rpm at constant load. The results showed that the engine emitted lower HC and CO emission in the case of the use of fuel blends of butanol and gasoline. Galloni et al. [18] in this work, practical tests were conducted for two butanol/gasoline fuel blends with rates (20% and 40%) on IC engine four cylinders equipped with fuel injection system. The output results of experimental work indicated a significant enhancement for brake thermal efficiency for all fuel blends. Pollutants emissions HC and CO decreased whereas CO_2 emission and nitrogen oxides increased.

It is observed in the literature review that alcohol/gasoline fuel blends result in decreased CO and HC emissions and increased NOx and CO_2 emissions [19]. There are many studies that have been conducted practically on methanol, ethanol and butanol but only a few on propanol fuels. Therefore, this research is concerned with the performance of the gasoline internal combustion 4-cylinders engine when using different blends of propanol/gasoline. To conduct this research, a laboratory setup equipped with all equipments and instrumentation systems to measure the engine performance variables according to different operating factors was established. Various fuel blends of propanol/gasoline (the ratio of blend denoted by symbol “P” followed by number of the ratio of propanol fuel in gasoline as volume percentage) fuel were prepared in different percentages P0, P5, P10, P15 and P20 so as to operate the engine and determine the best blend ratio that would give less fuel consumption, improve engine performance and reduce pollutants emission [20]. Laboratory experiments were carried out at different engine speed and loads. The torque and power of the engine during operation, as well as the fuel consumption and the emission of pollutants during the experiments were measured with precise instruments.

These experimental results were used to determine the engine maps for specific fuel consumption and emitted pollutants such as CO, HC and NO_x. The experimental results were used as an input data for the vehicle simulation code. By running the vehicle simulation model according to a driving cycle within cities, the fuel consumption of the vehicle has been determined on the road and the percentage of exhaust emission is determined during different operating conditions. As the vehicle is exposed within the city to acceleration resistance frequently, causing an increase in fuel consumption and thus increase in the emission of pollutants [21]. Therefore, this research contributes to find alternative types of fuel, especially the blend of propanol/gasoline to operate the vehicle inside the city. The results showed that during the operation of the vehicle inside the city under different operating conditions, fuel consumption and pollutants emission of CO and HC decrease in the case of fuel blend P 15 than pure gasoline fuel.

2. Materials and methods

This section describes the instrumentation system for the investigational experiments, with an accurate description given for all engine test equipments. The method of fuel blending is described in detail, and the physical and chemical properties are listed in tables. It also includes a detailed description of the vehicle test procedures according to city driving cycle.

2.1. Experimental setup

For carrying out the experiments, 4-cylinder IC engine is used with technical specifications as shown in Table 1. The engine is installed on the test bench with hydraulic brake to determine engine torque at different engine speeds. SI engine performance characteristics were measured, including engine torque, engine speed, volume/mass flow rate of intake air, fuel consumption, engine temperatures such as exhaust, oil, and coolant temperature. In order to measure air flow rate into combustion chamber of the engine, it is necessary to ensure the continuity of the air intake without any oscillations; thus an air tank was designed due to this purpose as shown in Fig. 1 [22]. An air flow meter was installed in front air tank to measure volume flow rate of air during the experiments.

Also, to measure the fuel consumption of the engine, the engine fuel pump was immerged inside a container on a weighing scale. In this method, fuel consumption can be determined during certain time with high accuracy. To determine the percentage of different pollutants CO, HC and NO_x emission, an exhaust gas analyzer was used. Thermocouples were also installed to determine the temperature of engine oil - cooling water - exhaust gas and engine body. A digital thermometer was used to record all engine temperatures during experimental tests. Fig. 1 shows a schematic diagram of IC engine with the measuring equipments used in the laboratory.

2.2. Errors and uncertainties

Practical experiments of IC engines require high attention in

Table 1
Technical specification of SI engine.

Engine parameter	value
Engine model	G4eh
Engine type	SI-Gasoline
Displacement, cm^3	1341
Number of cylinder	4 in line
Compression ratio	9.5
Bore/Stroke, cm	7.15/8.35
Max.power kW@rpm	61.78@5500
Max.torque Nm@rpm	116.7@3000