Biomechanism and Bioenergy Research 1(2), 21-25

Investigating the Effect of Using of Different Alcohols as Gasoline Additives on an Engine Emitted Pollutants

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INFO

ORIGINAL RESEARCH PAPER

KEYWORDS

Renewable energy; environmental pollution; Engine performance; Bio alcohols.

***Received:* 20 October 2022**

***Revised:* 20 November 2022**

***Accepted:* 30 December 2022**

***Available Online:* 31 December 2022**

ABSTRACT

Fossil fuels are the most commonly used fuels in the world, causing various types of environmental pollution due to the increase in energy consumption; the demand for renewable energy such as biofuels has increased. The aim of this study was to evaluate the performance and pollution of a four-cylinder gasoline engine with biofuels of ethanol, propanol butanol and pentanol at three different speeds of 1000, 1500 and 2000 rpm. The results of the tests showed that adding alcoholic fuels to gasoline increases engine power. Improves engine torque. Brake specific fuel consumption of the engine with proposed fuels increases compared to pure gasoline, but this trend decreases with increasing the speed from 1000 to 2000 rpm. In terms of pollutant emissions, the amount of NO_X pollutant increased with increasing engine speed in fuel combinations, but this pollutant had a lower amount compared to pure gasoline fuel. The emission of HC pollutant decreases by increasing the percentage of pentanol in fuel compounds. In addition, the amount of CO pollutant decreases greatly with the increase of engine speed from 1000 to 1500rpm and the engine speed increases from 1500 to 2000rpm. In addition, with the increase in the volume percentage of pentanol in the fuel compounds, the amount of CO increased.

INTRODUCTION

Changing lifestyles and increasing population have caused an ever-increasing energy demand in the world. Most of the energy used by humans is currently supplied by fossil fuels that are based on oil while their resources are limited and running out (Chandra et al., 2012). The decrease in oil resources, the increase in energy demand, the day by day increase in the price of oil and the adverse environmental effects caused by the consumption of fossil fuels have caused the governments and scientific institutions to worry about the need to replace this source of energy with other sources. Which is economically affordable, renewable and has the least pollution. Bio-renewable resources and their combined fuels can reduce the dependence on petroleum materials, create diesel engines play a significant role in transportation. At the same time, due to continuous and long-term use of gasoline and diesel fuel, lung diseases and cancer invasion have increased dramatically. For this reason, extensive research has been done to find suitable alternative fuels and renewable energies in the world. Biofuels are a group of renewable alternative energies that are produced by renewable resources. Ethanol, butanol, propanol, and pentanol are among the biofuels (Motamedi et al., 2019).

Alcoholic fuels have many advantages to use in diesel and gasoline engines as an oxygenated fuel additive with fossil fuels, such as improving the octane number, reducing air pollutant emissions, and controlling soot emissions. Energy security and global warming concerns are the two main driving forces for the global development of alcohol, which are also trying to animate the agricultural industry (Nigam and A., 2011). Considering that alcohols emit less pollutants when burned in the engine compared to pure gasoline thus, it is possible to use a mixture of gasoline fuel with any type of alcohol (such as ethanol, propanol, butanol, and pentanol), which generally improves engine performance and reduces the emission of pollutants (Zhou et al., 2017). In a study, the performance of the engine and the emissions of gasoline engine pollutants were investigated using the combination of gasoline fuel with ethanol in different volume percentages (0, 5, 10, 15 and 20 %). The results of the study showed that the emission of CO and HC pollutants was greatly reduced compared to pure gasoline (Hsieh et al., 2002). Another research by Awad et al. (Awad et al., 2018) investigated the performance and pollutions of a gasoline engine using a fuel mixture of alcohol and gasoline. The alcohols used, including ethanol, methanol and butanol, were added to gasoline in different volume percentages. Adding alcoholic fuels to gasoline increases braking power, braking torque, effective engine efficiency and specific fuel consumption, because alcoholic fuels have a higher octane number than gasoline and causes had better engine combustion. In addition, in terms of pollutant emissions, alcohol

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DOI: 10.22103/BBR.2022.20415.1018

fuels produce less CO and NO_X compared to gasoline (Awad et al., 2018). In a comparative performance study, emission, combustion characteristics and particle size distribution - particle number of 10 and 20% methanol (M10 and M20) blends with gasoline in a spark ignition engine were investigated. The results showed that the brake thermal efficiency of methanol-gasoline mixture was higher than that of pure gasoline. Methanol gasoline mixture produces less CO, NO and soot emissions than gasoline. It was found that the combustion characteristics of methanol-gasoline blends are almost similar to gasoline (Agarwal et al., 2014). Methanol gasoline mixture produces less CO, NO and soot emissions than gasoline. It was found that the combustion characteristics of methanol-gasoline blends are almost similar to gasoline (Agarwal et al., 2014). In a study, the pollutant emission of a gasoline engine was investigated using the combination of gasoline fuel with 30% and 50% butanol. When the engine runs on a mixture of gasoline and butanol, the amount of carbon monoxide is reduced by more than 80 percent compared to when the engine runs on pure gasoline. When the engine runs on a mixture of 30% butanol and gasoline, the amount of carbon dioxide is reduced by an average of 4% And if it works with a mixture of 50% butanol and gasoline, the amount of carbon dioxide will decrease by -14% compared to pure gasoline. Engine performance with gasoline when the engine is operated using a mixture of 30% butanol and gasoline, the amount of HC is reduced by an average of 26%. If it works with a mixture of 50% butanol and gasoline, the amount will increase by 4% compared to pure gasoline. To generalize the results of the experiment, it can be stated that the optimal mixture will include 70% gasoline and 30% biobutanol (Pukalskas et al., 2009). Ethanol (C_2H_5OH) is an important renewable fuel that is usually produced from biological materials through fermentation processes (Kim and Dale, 2005; Tulva, 2007). Butanol or butyl alcohol is a four-carbon alcohol (C_4H_9OH) that is miscible with most solvents and slightly soluble in water, and is used as intermediate in chemical synthesis and as a fuel. Propanol (C_3H_7OH) is mainly used as a solvent, but they also act as chemical intermediates in the production of various esters and amines.

In this research, based on the challenges mentioned about the lack of fossil fuels and environmental problems, the performance and emission rate of a gasoline engine using gasoline-alcohol fuel mixtures including: ethanol, propanol, butanol and pentanol with different percentages were investigated and compared with pure gasoline fuel. Due to the fact that so far no study has been done on the tested fuel compounds with the percentages found in this test, which evaluates the performance and pollutants of the gasoline engine at the same time, so it has been addressed in this research.

MATERIALS AND METHODS

Preparation of fuel and how to perform the test

Gasoline used in this experiment was obtained from the fuel station of the university in Hamedan city for 8 liters. The intended test alcohols, which included ethanol, propanol, butanol and pentanol, were prepared with a purity of 99.6%. In addition, the fuel mixture of alcohol and gasoline was prepared in the renewable energy laboratory of the Faculty of Agriculture of Bu-Ali Sina University according to Table 1. Alcohols with different volume percentages were mixed with gasoline in one liter volume and stored in one-liter bottles. G is the symbol of gasoline, E is the symbol of ethanol, Pn is the symbol of pentanol, Pr is the symbol of propanol, and B is the symbol of butanol, so mixture NO.1 includes $Pn_{20}Pr_{20}B_{10}E_{10}G_{40}$, mixture NO.2 $Pn_{15}Pr_{20}B_{10}E_{20}G_{35}$ and mixture NO.3 $Pn_{20}Pr_{20}B_{20}E_{10}G_{30}$. The increasing trend of pentanol was considered with the percentage of other alcohols being constant.

Table 1. Percentage of combination of alcohols with gasoline

Type of Fuel mixtures	Ethanol %	Propanol %	Butanol %	Pentanol %	Gasoline %
Fuel mixture 1	10	20	20	10	40
Fuel mixture 2	10	20	20	15	35
Fuel mixture 3	10	20	20	20	30

Tested engine

After preparing the fuel mixtures, the desired tests were performed on a four-cylinder gasoline engine coupled to a dynamometer, manufactured by the Ford factory in Germany (Fig. 1), at 3 different speeds of 1100, 1250 and 1400 rpm. In order to measure the torque and power parameters, PLINT dynamometer manufactured by the Ford factory in Germany was used in the thermodynamics laboratory of Boali Sina University of Engineering, Hamedan. In addition, the AIRREX HG-550 pollutant meter made in Korea was used to check and measure the output pollutants (Fig. 2).

Fig 1. Engine set up and dynamometer coupled to it

Fig 2. Pollutant measuring device to measure pollutants.

Performing the test

After preparing the fuel mixture and transporting it to the laboratory, three liters of pure gasoline was poured into the fuel tank of the already lit engine, so that the engine would run for 15 minutes and the gasoline would circulate in it. Then, the probe of the pollutant measuring device was placed in the exhaust outlet of the engine and the amount of pollutants in the exhaust outlet was measured by it, in such a way that after 5 minutes of placing the prop in the exhaust, the pollutant measuring device starts to measure. The data related to the engine performance, which includes the torque, the temperature of the engine inlet and outlet water, as well as the engine exhaust temperature, were visible on the dynamometer display (Fig. 3) .In the next steps, the engine speed was increased and new data was obtained in each series.

Fig 3. Data output stand related to engine performance.

Then the remaining pure gasoline in the engine tank was drained and mixture 1 (according to Table 1) was added to the tank and the above steps were repeated to measure the pollutants and engine performance.

RESULTS AND DISCUSSION

Power output

After the stability of the engine working conditions for each test, power, torque, fuel consumption and exhaust pollutants such as CO, NO_X and HC were measured and analyzed the experiments were done in three repetitions and their analysis was done with Excel 2013 software.

According to the Fig. 4, the results showed that the engine power increases with the increase in speed when using the fuel mixture of gasoline and alcohol mentioned in the study. The addition of alcohols in different volume percentages has increased the engine power compared to pure gasoline. The lowest amount of power related to pure gasoline at a speed of 1000 rpm by the amount of 1.39 kW; and the highest power is related to fuel NO. 3 at a speed of 2000 rpm at the rate of 4.06 kW with the highest percentage of pentanol. Which is due to the high calorific value and the presence of excess oxygen in the structure of alcohols compared to gasoline, which increases the combustion efficiency in the combustion chamber (Gravalos *et al.*, 2013).

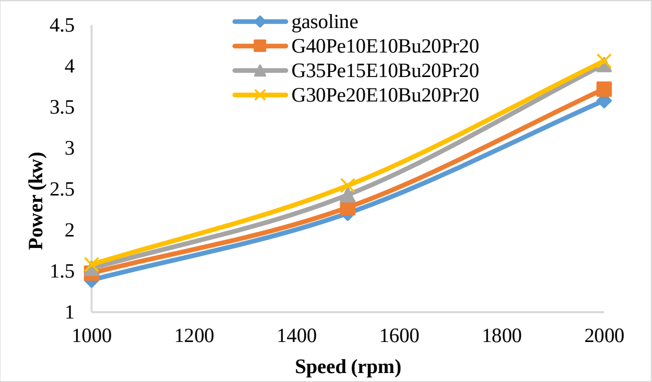

Fig4. Engine power

Torque output

According to the Fig., the torque of the tested engine increases with the increase of the engine speed. In all fuels, this process is similar and close to each other, and in the base fuel, the process is similar to other fuels, that is, with the increase in speed, the torque increases from 1000 to 2000 rpm. In all fuels, the amount of torque increases with the increase in the volume percentage of pentanol. The highest torque for fuel NO. 3 at 2000 rpm is 19.6 N.M. In previous studies, it has been shown that increasing the amount of alcohol due to the presence of hydrogen increases the engine torque by 3.6% (Pukalskas S *et al.*, 2009).

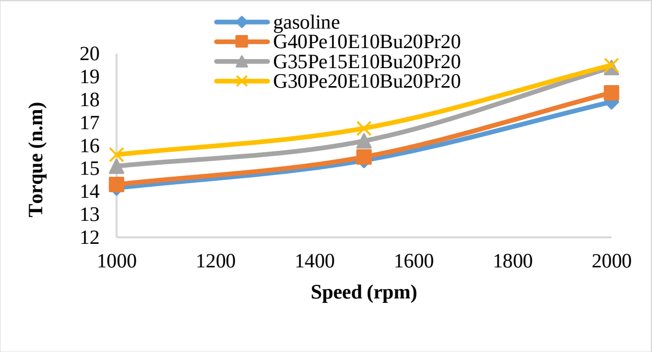

Fig 5. Engine torque

BSFC (Brake specific fuel consumption)

According to the form of adding the alcohols used in the test to gasoline, the specific fuel consumption of the engine decreases with the increase in speed from 1000 to 2000 rpm, but as the proportion of pentanol in the fuel mixture increases, the specific fuel consumption increases compared to pure gasoline. The highest consumption of special fuel is related to fuel NO. 3 at a speed of 1000 rpm; and the lowest amount of specific fuel consumption is related to the base fuel at engine speed of 2000 rpm. In the case of fuel mixtures that contain a lower volume percentage of pentanol, the improvement of specific fuel consumption can be due to the increase in combustion due to the presence of additional oxygen molecules, lower viscosity and lower density of the fuel mixture (Yilmaz and Atmanli, 2017).

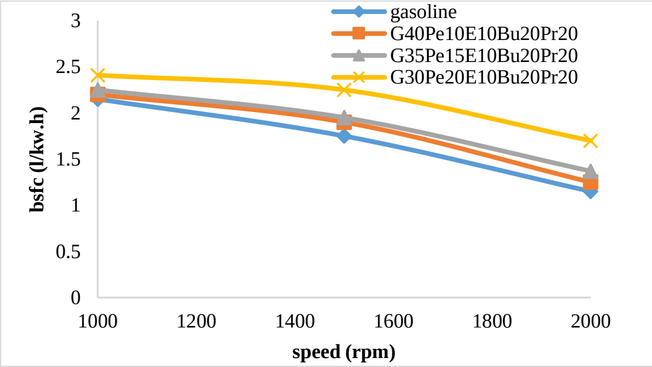

Fig 6. Engine brake specific fuel consumption

NO_X (Nitrogen oxide)

The Fig. shows the variation in NOx emissions with respect to engine load for pure gasoline and blended fuels. The oxygen content of fuel blends is higher than that of pure gasoline, which gives carbon and oxygen a chance to complete the chemical interaction, thus increasing the combustion temperature in the engine (Yücesu *et al.*, 2006). In all the tested fuels, it shows that NOx emission increases gradually with increasing engine speed because more fuel entering increases the temperature in the combustion chamber. As the volume percentage of pentanol increases, the amount of NO_X pollutant emission decreases and reaches its lowest value in fuel number 3 at 33ppm at 1500 rpm.

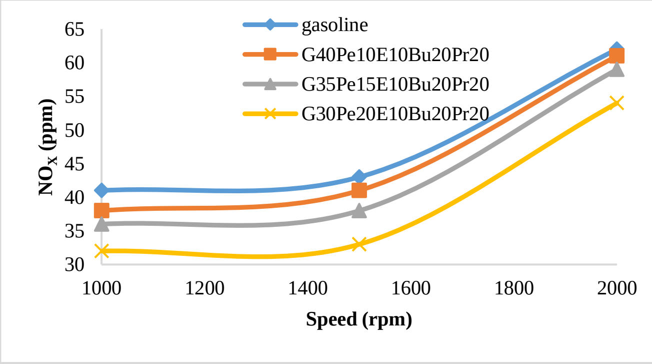

Fig 7. NO_X emission

Unburned Hydrocarbon (UHC)

As can be seen in the Fig., the amount of UHC in the base fuel goes through a decreasing process and reaches its lowest level at 1500 rpm. Also, with the increasing trend of pentanol, the amount of UHC emission decreases, it is increasing at the speed of 1000 to 1500 rpm and the trend decreases sharply from the speed of 1500 to 2000 rpm and it reaches its lowest level in the base fuel. Emission of hydrocarbons in the engine is a sign of combustion quality. Fuel properties, fuel-air ratio, fuel injection characteristics, and operating conditions are factors that determine the formation of unburned hydrocarbons. Therefore, the reduction of hydrocarbon emissions with the increase of pentanol is due to the presence of excess oxygen in alcohols (Ashok *et al.*, 2019).

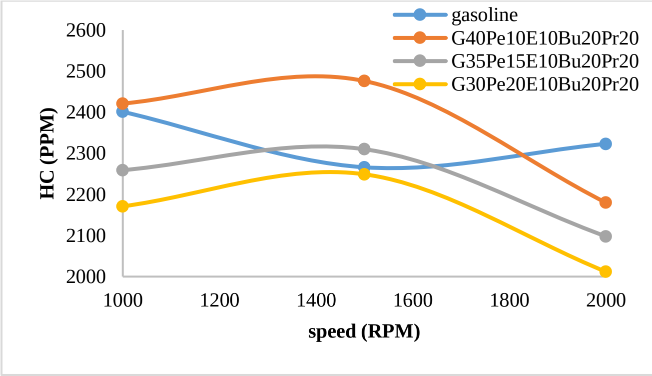

Fig 8. HC emission

CO (Carbon monoxide)

The amount of CO produced from pure gasoline goes through a relatively increasing trend from 1000 to 1500 speed, and the amount of CO decreases from 1500 to 2000 rpm speed. The amount of CO pollutant decreases from the speed of 1000 to 1500 rpm as the percentage of pentanol increases, and from the speed of 1500 to 2000 rpm, the amount of CO production goes through an increasing trend. In similar experiments, researchers found that by adding alcohols to gasoline, the amount of CO increases due to the increase in oxygen. Another reason for the increase in CO can be the decrease in the combustion time of gasoline and alcohol mixtures (Can *et al.*, 2004).

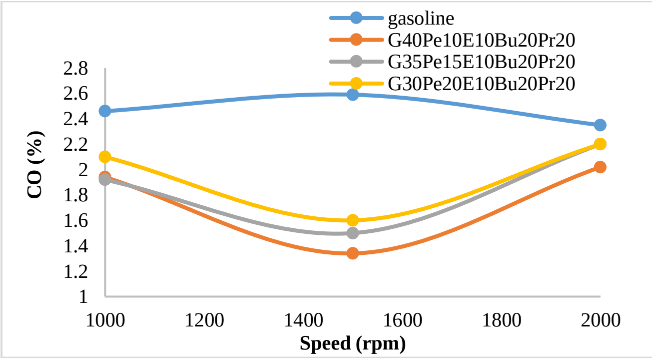

Fig 9. CO emission

CONCLUSIONS

In this study, engine performance and pollutant emission of a gasoline engine were analyzed. By analyzing the effect of pure gasoline, (Pn20Pr20B10E10G40), (Pn15Pr20B10E20G35) and (Pn20Pr20B20E10G30) on the performance and pollutants of the engine, the following results were obtained:

- The volumetric percentage of pentanol in fuel compounds has increased compared to pure gasoline because the excess oxygen in the structure of alcohols increases the combustion efficiency due to the increase in engine power.
- The torque of the tested engine increases due to the increase of oxygen in the structure of alcohols; because oxygen reacts with unburned carbons and causes improvement of combustion.

- The specific fuel consumption of the engine decreases with the increase in the percentage of pentanol in the fuel mixture.
- The emission of NO_X pollutant is affected by the oxygen content in alcohols and causes chemical interaction between carbon and oxygen and reduces the amount of NO_X.
- In terms of HC emission, with the increase in volume percentage of alcohols, the emission of this pollutant has decreased, which can be due to the properties of the fuel and the operational conditions of combustion.
- The amount of CO emissions decreases from 1000 to 1500 rpm and increases from 1500 to 2000 rpm. The increase and decrease of CO can be due to the longer duration of alcohol and gasoline.

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