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Performance characteristics of single-cylinder spark-ignition engine and its pollutant emissions by using methanol and ethanol fuel blended with gasoline

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ABSTRACT

Introduction: Increasing air pollution is one of the problems of living in large cities. Motor vehicles are the main source of emissions of these pollutants. Petroleum derivatives, especially gasoline, are the most important fuel for internal combustion engines. The fuel consumption of these engines causes excess emissions of pollutants such as carbon monoxide, carbon dioxide, sulfur oxides and nitrogen oxides. Therefore, the use of an alternative fuel seems necessary. The aim of this study was to investigate performance characteristics of single-cylinder spark-ignition engine and its pollutant emissions by using methanol and ethanol fuel blended with gasoline.

Methods: In this study, Honda single-cylinder four-stroke engine was used. Gasoline was prepared from the locations of the National Oil Distribution Company and separately mixed with methanol and ethanol in different proportions. The tests were performed at 2 engine speeds including 2000 and 4000 rpm. Obtained data were statistically analyzed by SPSS.

Results: The results showed that the combination of methanol fuel with gasoline in variable proportions produced less pollutant at low engine speed compared to that of ethanol fuel. Similarly, this result was also observed at high engine speed. Therefore, methanol fuel is more suitable as an alternative to fossil fuels such as gasoline in terms of emission of pollutants. Regarding the average amount of total emissions resulted from consumption of alternative fuels combined with gasoline, it can be said that the amount of pollutant production decreases with increasing methanol and ethanol content.

Conclusion: The use of methanol and ethanol as an alternative fuel to gasoline in automobiles reduces pollutant emissions Therefore, the problem of pollutants produced by gasoline engines can be significantly reduced through replacing gasoline by ethanol and methanol, and this replacement can result in improvement of health and satisfaction of the people.

Introduction

Increasing air pollution is one of the problems of living in big cities. Motor vehicles are the main source of emissions of these pollutants. Petroleum derivatives, especially gasoline, are the most important fuels for internal combustion engines at the moment. The consumption of petroleum fuels in these engines causes excess emissions of pollutants such as carbon monoxide, carbon dioxide, sulfur oxides and nitrogen oxides. Therefore, the use of an alternative fuel seems necessary(1). If this fuel is produced from renewable sources and consumed without changing the design and construction of the engine, it will have a great advantage. Alcohol can be considered as an appropriate option for this case which has been consumed from the nineteenth century. Among alcohols, ethanol is the most widely used in spark-ignition engines, and the most important reason for this selection is the renewable source of ethanol. The combustion of ethanol in the vehicle produces less carbon monoxide and unburned hydrocarbon, and also has a better anti-impact effect. The lower emission of carbon monoxide in alcohol fuels such as ethanol is due to better flammability and the presence of oxygen in its molecular structure. Therefore, the consumption of alcohol fuels increases the efficiency and output power of the engine (2, 3). On the other hand, higher explosive temperature and lower vapor pressure of ethanol compared to gasoline make it safer to refuel and store. Also, the waste of fuel through evaporation is also less. Because the latent heat of evaporation of ethanol is 3 to 5 times higher than that of gasoline, it causes a lower temperature to be pumped by the engine and consequently increases the engine efficiency. The consumption of alcohol fuels, such as ethanol, does not result in environmental pollution, due to no need to MTBE (the chemical composition of methyl tert-butyl ether or branched materials or isomers and organometallic compounds, as one kind of gasoline supplement). As a result, they are considered as suitable fuels to prevent environmental pollution.

The use of alcohol as fuel has some advantages including the consumption of ethanol with 15% gasoline does not need any correction in the spark-ignition engine, and its burning flame is colorless, unlike fossil fuels (4). Also, unlike gasoline, ethanol is dissolved in any proportion with water. As a result, however, it should be noted that if the fuel is a water content, it will corrode the suction system so that it is necessary to prevent the use of metals such as copper, brass and aluminum in fuel systems. Ethanol, on the other hand, causes corrosion of rubber, and therefore fluorocarbon sucking tubes should be used in fueling systems (5). The energy content of ethanol and gasoline is 23 and 34 KJ/L, respectively. The octane number of alcohol fuels is from 101 to 105 and the gasoline is from 84 to 91. This difference in octane number improves burning and increases efficiency. According to statistics, alcohol cars consume on average 74% of the gasoline cars on driving in highways and cities, which is a clear advantage of the use of alcohol car compared to gasoline car. As in the state of Minnesota, it is no longer used pure gasoline, but instead gasoline with 10 percent alcohol (6).

Combustion of fossil fuels, such as gasoline in engines, is the source of 60% of carbon monoxide emissions in cities, which is a major source of contamination and can cause serious damage to human psychological and physiological health. Given that methanol (wood alcohol) is a renewable fuel, it does not increase the level of carbon dioxide and prevents the release of this greenhouse gas. On the other hand, methanol can also be synthesized from the combination of carbon dioxide and hydrogen. The carbon dioxide necessary for this process can be obtained from the chimney of fossil factories and plants, and even after the end of fossil fuels, carbon dioxide can be used to produce artificially methanol (7, 8). Methanol is naturally present in the human body and some fruits. However, it has high toxicity, and consumption of 10 ml and 60-100 ml of methanol results in blindness and death, respectively (if no treatment is performed). Methanol, like other volatile substances, is not only toxic through swallowing but also is dangerous by absorption through skin and lung. Combination of methanol with ethanol reduces its toxicity. Another advantage of this alcoholic fuel is its lower evaporation rate compared to gasoline (9-11). Since the emission of pollutants from engines and motorcycles consuming only gasoline is high, and also has serious risks to human health and the environment, the aim of the present study was to determine performance characteristics of single-cylinder spark-ignition engine and its pollutant emissions by using methanol and ethanol fuel to achieve an alternative fuel to gasoline.

Methods

In this study, Honda single-cylinder four-stroke engine was used to investigate the effects of methanol and ethanol on the engine performance and its emissions of pollutants. All experiments were carried out at the Air Pollution Research Laboratory of Mazandaran University of Medical Sciences. A stopwatch with the resolution of 0.01 of a second and a gas analyzer (model Ipex1) were used to measure time span of fuel consumption and amount of contaminants, respectively. The gasoline used in this study was prepared from the locations of the National Oil Distribution Company and mixed with methanol and ethanol with different volume ratios. To perform design experiment, 50cc gasoline-alcohol fuel with 10 volume ratios (5 mixture of ethanol-gasoline and 5 mixture of methanol - gasoline) including M10%, M30%, M50%, M70%, M100% and E10%, E30%, E50%, E70%, E100% and gasoline fuel alone were separately introduced into in the fuel tank to compare engine performance and emission levels at two engine speeds. After 120 seconds and consumption of fuels, amount of pollutant emissions was measured by the analyzer for the 11 samples of fuels. These experiments were performed at 2 engine speeds of 2000 and 4000 rpm (minimum and maximum). All experiments were performed in 3 replications. In order to be more precise in measuring the engine's performance characteristics and emissions, the engine was run for 15 to 20 min for stabilizing the temperature of its various parts, and then the main experiment was carried out. For each test, the speed, fuel consumption and emission of pollutants were measured (12). Also, in this study, the recorded data of the pollutant emissions were quantified, and statistical analysis (one sample t-test) and chart designing were carried out using SPSS version 16 and Excel 2007 software, respectively. The significant value was defined as $P<0.01$.

Results

The average of three replications indicating the amount of pollutant emissions in each sample with different proportions of methanol-gasoline (Mx) at engine speed of 2000 and 4000 rpm is shown in Table 1.

According to the Table 1, with the increase of methanol content in motor fuels, the amount of contaminants has reduced at both low (2000 rpm) and high (4000 rpm) engine speeds.

The average of three replications for each pollutant resulting from fuel consumption with different ethanol-gasoline (Ex) ratios at both engine speeds of 2000 and 4000 rpm is shown in Table 2. According to this table, by increasing the amount of ethanol in the engine fuel, the amount of pollutants has decreased at both low (2000 rpm) and high (4000 rpm) engine speeds.

According to the Tables 3, the average of 3 replicates indicating the amount of pollutants resulting from gasoline consumption with engine speed of 2000 and 4000 rpm is shown. The results indicate that the consumption of gasoline alone produces high proportion of contaminants.

Discussion

Increasing air pollution is one of the problems of living in big cities. Motor vehicles are the main source of emissions of these pollutants. Petroleum derivatives, especially gasoline, are the most important fuels for internal combustion engines. The fuel consumption of these engines causes excess emissions of pollutants such as carbon monoxide, carbon dioxide, sulfur oxides and nitrogen oxides. Therefore, the use of an alternative fuel seems necessary (1, 13). Sekmen *et al.* studied on the use of gasoline-ethanol mixture instead of gasoline alone in a four-stroke engine. The amount of pollutant emissions for mixture of ethanol and gasoline with various proportions including pure gasoline, mixture of 10% ethanol and 90% gasoline, 20% ethanol and 80% gasoline, 30% ethanol and 70% gasoline was measured. The results showed that by increasing the amount of ethanol to gasoline, the amount of pollutant emissions including NOx, HC, CO2, CO decreased. Also, the combustion temperature and, finally, the exhaust temperature decreased, due to higher latent heat of evaporation of alcohol (14). The significant level of the one-sample T-test in Table 4 is less than 0.01, and thus it can be possible to confirm the hypothesis of equal means (2.09) for the

Table 1. The amount of pollutant resulting from fuel consumption with different methanol /gasoline ratios at engine speed of 2000 an 4000 rpm (in ppm).

Pollutant	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	8	60
CO	6.2	0.5
HC	24	60
CO2	1.4	5
Pollutant	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	1	12
CO	0.45	1.8
HC	12	50
CO2	1	3.5
Pollutant	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	8	40
CO	0.5	0.35
HC	30	18
CO2	2.4	5
Pollutant	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	1	18
CO	0.5	2
HC	18	62
CO2	1	4.2
Pollutant	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	0	30
CO	0.32	1.82
HC	30	450
CO2	1.45	4.4

decrease of pollutant production after consumption of methanol at an error level of 0.01. (P <0.01). As a result, according to the average amount of total pollutant production, it can be said that, with 99% confidence, the amount of pollutants produced from methanol consumption alone or along with gasoline decreases with increasing methanol content. In previous study, the properties of gasoline containing 0, 5, 10, 15 and 20% ethanol were studied. The results of this study have shown that ethanol can have a great effect on reduction of pollutant levels. Adding ethanol to gasoline leads to an increase in the amount of oxygen in the fuel (15). Considering that the

Table 2. The amount of pollutant resulting from fuel consumption with different ethanol /gasoline ratios at engine speed of 2000 and 4000 rpm (in ppm).

Pollutant ethanol 10% , gasoline 90% (E10)	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	0	22
CO	8.5	9.4
HC	132	600
CO2	0.92	1.17
CH4	6.8	8.2
Pollutant ethanol 30% , gasoline 70% (E30)	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	20	60
CO	4.6	7.2
HC	3.5	265
CO2	1.45	1.94
CH4	3.44	6.68
Pollutant ethanol 50% & gasoline 50% (E50)	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	21	30
CO	1.22	6.3
HC	40	580
CO2	1.73	4.08
CH4	0.9	5.6
pollutant ethanol 70% و gasoline 30% (E70)	2000 rpm (low engine speed)	4000 rpm (high engine speed)
NO	26	5
CO	3	7
HC	43	620
CO2	1.45	1.94
CH4	1.46	4.19
Pollutant ethanol 100% & gasoline 0% (E100)	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	13	56
CO	3.2	6.6
HC	212	460
CO2	0.226	5.28
CH4	3.44	6.68

Table 3. The amount of pollutant resulting from consumption of gasoline at engine speed of 2000 and 4000 rpm (in ppm).

Pollutant gasoline 100%	**2000 rpm (low engine speed)**	**4000 rpm (high engine speed)**
NO	20	63
CO	9.7	12.3
HC	180	490
CO2	11.1	16.12

Table 4. One sample T- test for equal means of contaminant values resulted from consumption of alcohol alone or along with gasoline.

Variation	**Mean**	**Standard deviation**	**Test statistic**	**P Value**
Total level of methanol consumption alone or along with gasoline	2.09	0.21	-11.18	0.333
Total level of ethanol consumption alone or along with gasoline	2.1	0.52	-2.721	0.235

significant level of the one-sample T-test in Table 4 is less than 0.01, it can be possible to confirm the hypothesis of equal means (2.09) for the decrease in pollutant production after consumption of ethanol at an error level of 0.01. (P <0.01). As a result, according to the average amount of total pollutant production, it can be said that with 99% confidenc,e the amount of pollutants produced from ethanol consumption alone or along with gasoline decreases with increasing methanol content. According to Figure 1, combination of methanol with gasoline in different ratios produced much less pollutant at both high and low speeds compared to that of ethanol, and pollutants emitted from gasoline alone were high. Regarding emission of pollutants, it can be seen that fuel methanol is more suitable as an alternative to fossil fuels such as gasoline.

In the present study, according to Figure 1, the emissions of carbon dioxide (CO2) emissions were the least in both methanol and ethanol, and the amount of hydrocarbon emissions (HCs) was the most in both methanol and ethanol, compared to gasoline.

Conclusion

The results showed that the use of methanol and ethanol as an alternative to fuel gasoline in automobiles led to the decrease in pollutant emissions. Also, the results indicated that combination of methanol fuel in variable proportions

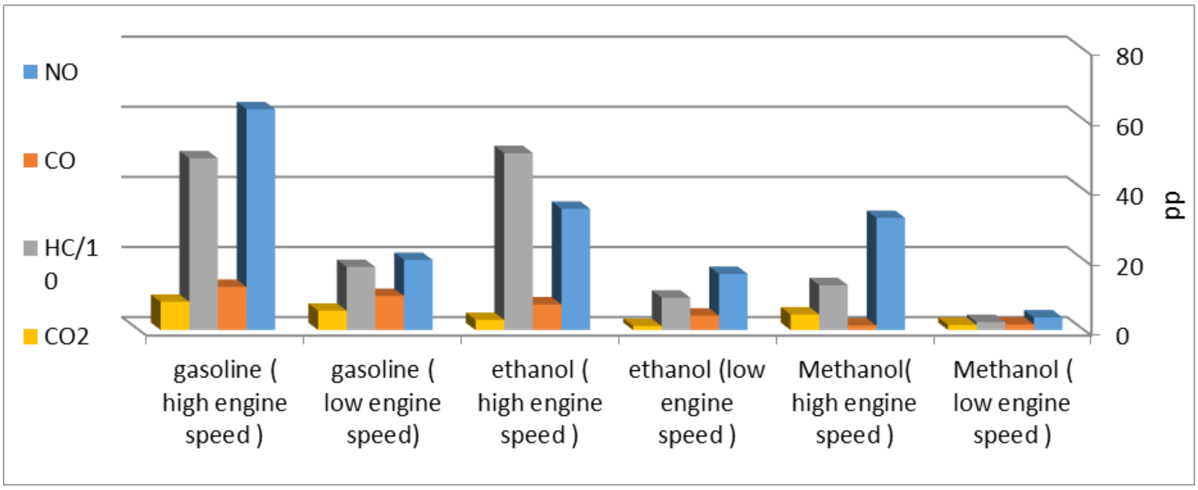

Figure 1. The average amount of pollutants resulted from the consumption of methanol / ethanol with variable ratios of gasoline at both low (2000 rpm) and high (4000 rpm) speeds (in ppm).

with gasoline produced less pollutant at both high and low engine speeds than that of ethanol fuel. It is possible to find out that methanol fuel is more suitable as an alternative to fossil fuels, such as gasoline, in terms of emission of pollutants. Carbon dioxide (CO2) emission was the least and hydrocarbon (HCs) emission was the most in both methanol and ethanol mixtures with gasoline. Therefore, the problem of pollutants produced by the use of gasoline in internal combustion engines can be significantly reduced by the use of ethanol and methanol as alternative fuels to gasoline, and this replacement can result in improvement of health and satisfaction of the people.

Ethical disclosure

None declared.

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Authors' Contribution

Authors are responsible for the content of the article and approve it

Conflict of interest

The authors declare that they have no conflict of interest.

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