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Research Note

Evaluation of Methanol Gasoline Fuel Blends on Exhaust Emission of Single Cylinder Spark Ignition Engine

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ABSTRACT

There are great concerns, that the IC Engines are responsible for extreme atmospheric pollution. Therefore, the studies on use of alcohols in 4-Stroke spark ignition (SI) Engines are important. In this study, the properties of the blended fuels were calculated. The effect of methanol-gasoline blends on emissions was investigated experimentally. The emissions were measured with the use of methanol-gasoline blends (M5 and M10) have been compared with the pure gasoline. The test was conducted at the constant speed of 90 km/h and at different wheel powers. From the analysis, it was concluded that when the engine was fuelled on methanol gasoline blends, CO_2, CO, HC and NO_x vehicular emissions were found to decreased at all wheel powers at 90 km/h. In addition, air-fuel ratio also increased with the increase percentage of methanol in the gasoline.

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ABBREVIATIONS

A/F	Air fuel Ratio	**m**	Mole fraction of methanol in the methanol gasoline mixture
PM	Particulate Matter	**x**	Number of carbon atoms in the fuel
CO	Carbon Monoxide	**y**	Hydrogen to carbon ration of the fuel
CO_2	Carbon Dioxide	**z**	Oxygen to carbon ration of the fuel
HC	Hydrocarbons	**Ψ**	Nitrogen to oxygen ratio of the air
NO_x	Nitrogen Oxides	**Φ**	Equivalence ratio
RPM	Revolution per minute	**MW_f**	Molecular weight of the fuel
M5	5% methanol + 95% gasoline (vol %)	**n**	Number of moles
M10	10% methanol + 90% gasoline (vol %)	**LHV**	Lower heating value

INTRODUCTION

The use of alternative fuels is highly dependent on the politics of both exporting and importing countries. Any countries use of alternative fuel depends on the severity of its need to reduce imports to balance payments, make jobs to reduce unemployment and the availability of indigenous natural resources [1]. There will be a need for alternative fuels for S.I Engines. Most of the alternative fuels for engines that look promising, with the exception of vegetable oils, are inherently more suited to the spark-ignition engine rather than to the diesel engine because they have poor Cetane numbers and good octane numbers. Therefore, increase in use of alternative fuels will tend to increase rather than decrease the proportion of the market occupied by the spark ignition engine [2].

The alcohols of primary interest as alternative fuel for the spark ignition engine are methanol and ethanol; because, research has been carried out with the other

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alcohols such as is-propanol and tertiary butanol, only methanol and ethanol can be produced in large quantities. Various biomass resources can be used to produce both ethanol and methanol. It should be noted that methanol can be only produced from the natural gas due to the various economic reasons [3-5].

Various properties of alcohols make them attractive for their use in SI engine. From which octane numbers look promising. There, it appears to be some difficulty in the measurement of the octane numbers of ethanol and methanol, since the number in the literature varies widely. This may be due to either high combustion pressure pulses being mistaken for knocking, the use of different operating conditions, or non-uniform mixing of fuel and air. It is probable therefore that the true values do not lie at the lower ends of the ranges given, and therefore it can be seen that the alcohols offers the better research octane number and improved motor octane number as shown in Table 1 [6]. This should lead to a possible increase in compression ratio by the order of 2 or 4, but this is not easily achieved since it can be seen that the pre ignition tendency of the alcohols is much worse than the gasoline. Pre ignition is defined as "the uncontrolled ignition of the mixture in the engine cylinder by a hot surface, independently of the spark". The hot surface is usually either part of the spark plug or part on the deposits of combustion chamber walls. The phenomenon is quite distinct from the knock, which is generally expected to be the spontaneous commencement of the combustion at number of points within the unburned potion of the charge ("end-gas") [7, 8].

The Effects of alcohol on Engines

Table 1 shows that methanol and ethanol have much lower calorific values than gasoline, which means that their Stoichiometric air-fuel ratios are much lower. Therefore, for a given volume of air, much more fuel is needed. They also have much higher latent heats, and these two facts together mean that the cooling effect of the fuel on the intake charge is much greater than with gasoline. Consequently, charge temperatures at full load are reduced, resulting in increased volumetric efficiencies and more torque and power from the engine [9, 10]. Methanol has long been used in racing engines, where its ability to produce more torque and charge cooling are useful , but only by operating very rich, which would not be practical in other applications due to the resulting poor fuel economy.

As per the literature survey, the effects are less desirable at part load, however, and drivability tends to be adversely affected. This is usually overcome by the use of greatly increased heating of the intake manifold, either by exhaust heating, coolant heating, or both. The reason for the problem is that combustion tends to be erratic unless a certain proportion of the fuel is vaporized, which allows an ignitable mixture to be present in the spark gap at the time of the spark. An advantage of alcohols at part load, however is that they can burn much leaner, enabling better thermal efficiency to be obtained. The reason for this is that the flame speed is increased above that of gasoline. One study showed part load brake thermal efficiency on ethanol was as good as or better than on gasoline, methanol, or propane, and NO_x and HC emissions were lower than with any of these fuels. Methanol gave an improvement over gasoline in part load brake thermal efficiency which ranged from 22 to 24%. Ignition timing could be retarded and exhaust temperatures were reduced with respect to operation on gasoline, indicating a faster burn rate [6, 8, 11].

Methanol can be ignited in an engine from a hot spot in the combustion chamber, and "glow plug" model engines operate using a platinum filament which is electrically heated for start-up, then disconnected when the engine is running. However, this method gives very little control over-ignition timing and would be unsatisfactory in automotive applications [12].

It has already been mentioned that methanol and ethanol have a greater cooling effect on the intake charge than gasoline, and this effect persists throughout the engine cycle. Since the formation of oxides of nitrogen (NO_X) is a function of the time-temperature histories of each portion of the charge, this reduction in temperature causes a reduction in exhaust emissions of NO_x. Furthermore, since methanol engines can be made to run leaner, and would indeed be made so because of the fuel economy advantage, a further reduction in charge temperatures and NO_x emissions could be achieved. These reductions in NO_x are somewhat offset by any increase in compression ratio, but nevertheless, NO_X emissions are about half the values obtained with gasoline. Exhaust emissions of unburned hydrocarbons are also reduced, partly because of the leaner operation possible with methanol and partly because any completely unburned fuel emerges as methanol instead of hydrocarbons. (flame ionization detectors have a response factor to methanol of only about 0.25). One study showed a reduction in unburned HC of about 50%, while another showed an increase, possibly because the car was set up very lean on methanol to show up the best fuel economy. This would tend to penalize hydrocarbon emissions because for any fuel hydrocarbon emissions tend to rise when the mixture is made lean due to the reduced temperatures in the combustion chamber, exhaust port and tail pipe [13].

Many researchers showed that when gasoline-alcohol blends are used, durability of the engine is not affected, but with pure methanol, problems occur from deposit formation, rust and wear [10].

TABLE 1. Various properties of different fuels

Property	Gasoline	Diesel Fuel	Methanol	Ethanol	Compressed natural gas (CNG)	Hydrogen
Chemical formula	C_4 to C_{12}	C_3toC_{25}	CH_3OH	C_2H_5OH	CH_4	H_2
Molecular weight	100-105	200	32.04	46.07	16.04	2.02
Composition, weight %						
Carbon	85-88	84-87	37.5	52.2	75	0.0
Hydrogen	12-15	33-16	12.6	13.1	25	100
Oxygen	0	0	49.9	34.7	0	0.0
Specific gravity	0.72-0.78	0.81-0.89	0.796	0.796	0.424	0.07
Density, kg/l	0.72	0.8	0.79	0.79	0.13	0.0013
Boiling point, °C	27	188	65	78	-162	-2368
Vapour pressure, kPa	55	1.4	32	15.9	16547	-
Octane no.						
Research octane no.	90-100	-	107	108	120+	130+
Motor octane no.	81-90	-	92	92	-	-
Cetane no.	5-20	40-55	-	-	-	-
Solubility in water, vol. %	negligible	negligible	100	100	-	-
Freezing point, °C	-40	-40	-97	-114	-182	-275
Viscosity, mPa-s	0.37-0.44	2.6-4.1	059	1.19	0.01	0.009
Flash point °C	-43	74	11	13	-104	-
Auto ignition temperature °C	257	316	464	423	540	585
Flammability limits, volume %						
Lower	1.4	1	7.3	4.3	5.3	4.1
Higher	7.6	6	36	19	15	74
Latent heat of vaporization, kJ/kg	349	232	1177	923	510	448
Heating value, MJ/kg						
Lower	42	42	20	27	50	120
Higher	44	45	23	30	55	141
Specific heat, kJ/kg-K	2	1.8	2.5	2.4	2.34	14.2
Stoichiometric air fuel ratio	14.7	14.7	6.45	9	17.2	34.3

Properties of blended fuels

Gasoline is the refined petroleum product which consist the many hydrocarbons with the molecular weight of 114 and the values of x, y and z can be calculated. The properties will vary when we use the blended fuel. Therefore, it is the prime requirement to find the basic properties of the blended fuel.

Assuming an ideal, non-reacting mixing process, the formation of one mole of total fuel blend is expressed as:

$$[(CH_yO_z)_x]_{Blend} = [(1-m)\,(CH_yO_z)_x]_{Gasoline} + [m\,(CH_yO_z)_x]_{Methanol}$$

The indexes of the blended fuels can be obtained as follows:

$$x = (1-m).x_{gasoline} + m.x_{methanol}$$

$$y = \frac{(1-m).y_{gasoline}.x_{gasoline} + m.y_{methanol}.x_{methanol}}{(1-m).x_{gasoline} + m.x_{methanol}}$$

$$z = \frac{(1-m).z_{gasoline}.x_{gasoline} + m.z_{methanol}.x_{methanol}}{(1-m).x_{gasoline} + m.x_{methanol}}$$

Table 2 shows the composition of the methanol-gasoline blend in the $(CH_yO_z)_x$ form. Data for methanol and gasoline are taken from Heywood [14, 15]. Values of x, y and z for methanol gasoline blends are calculated with the help of composite fuel concept using the given base fuel composition.

TABLE 2. Composition of methanol-gasoline blends in the $(CH_yO_z)_x$ form

	Gasoline	M5	M10	Methanol
X	8	7.65	7.3	1
Y	2.25	2.26	2.27	4
Z	0	0.0065	0.013	1

Table 3 shows the number of moles of reactants and products for stoichiometric combustion of the blended fuel. Number of moles of reactants and products for Stoichiometric combustion can be obtained as:

$$\text{moles of reactants} = 1 + x\left(1 + \frac{y}{4} - \frac{z}{2}\right)(1 + \Psi)$$

$$\text{moles of products} = x + x\frac{y}{2} + x\Psi\left(1 + \frac{y}{4} - \frac{z}{2}\right)$$

TABLE 3. Ratio of number of moles of products to reactants for gasoline-methanol blends at stoichiometric condition

	Gasoline	M5	M10	Methanol
Moles of products	64.16	61.34	58.57	8.65
Moles of reactants	60.66	57.99	55.38	8.15
Moles products/ Moles reactants	1.057	1.057	1.057	1.061

Figure 1 shows similar trends for the number of moles of reactants of gasoline, M5 and M10 methanol-gasoline blends as function of equivalence ratio which is based one mole of fuel. There are no significant differences between different fuels used for the equivalence ratio of greater than 1.

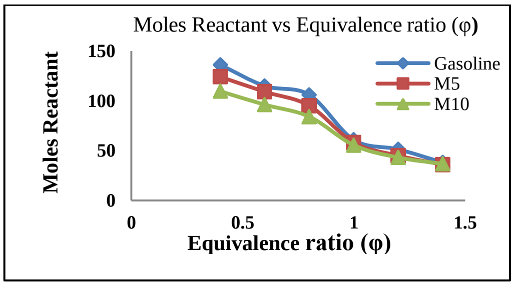

Figure 1. Number of moles of reactants of methanol-gasoline blends as function of equivalence ratio based one mole of fuel

Analysis of composition of moles of products from different fuels such as gasoline, M5 and M10 of methanol-gasoline blends showed that for the equivalence ratio greater than 1 no significant differences exist (Figure 2).

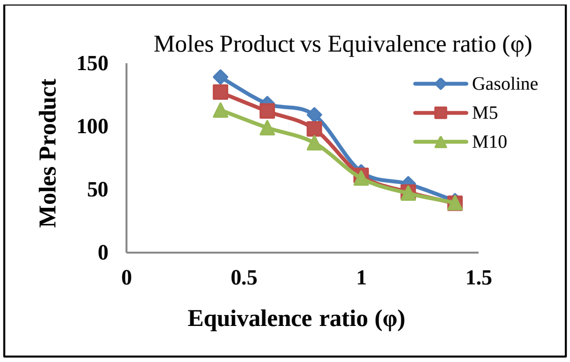

Figure 2. Number of moles of products of methanol-gasoline blends as function of equivalence ratio based one mole of fuel

Figure 3 depicts no significant changes in the ratio of moles of products to reactants of gasoline, M5 and M10 methanol-gasoline blends as function of equivalence ratio.

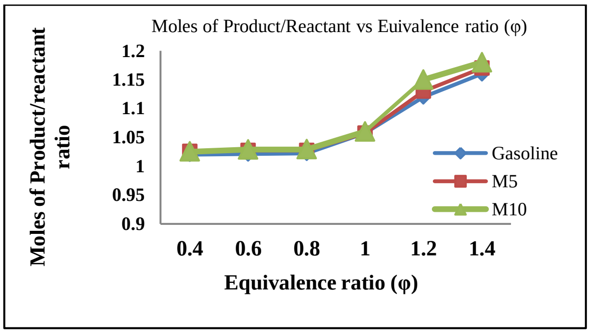

Figure 3. Ratio of moles of products to reactants of methanol-gasoline blends as function of equivalence ratio based one mole of fuel

In addition of these properties, molecular weight and the lower heating value are also important properties of the blended fuel. The molecular weight of the blended fuel can be obtained by using the fuel composition by using the following relation:

$$\mathrm{MW_f = x(12 + 1.y + 16.z)}$$

The lower heating value of the blended fuel mixture on a molar basis is given as (see Table 4):

$$\mathrm{LHV_f = (1 - m).LHV_g + m.LHV_m}$$

TABLE 4. Molecular weight and lower heating value of the blended fuel

	Gasoline	M5	M10	Methanol
$\mathrm{MW_f}$	114	109.88	105.68	32
LHV	42	40.9	39.8	20

Experimental set-up

Schematic diagram of experimental set is shown in Figure 4. A blend of methanol with gasoline has been used in the experiment. Two types of blends have been used to perform the test, which is on the volume basis, M5 and M10. Properties of the test fuel were shown in Table 1 which is obtained by the literature. The test was performed on a chassis dynamometer. The test was carried out for four different wheel powers with an increment of 5 KW at the vehicle speed of 90 Km/h. Exhaust emissions were measured with the help of exhaust gas analyser. The test was repeated three times and the result of these repetitions were averaged. The specifications of exhaust gas analyser are shown in Table 5.

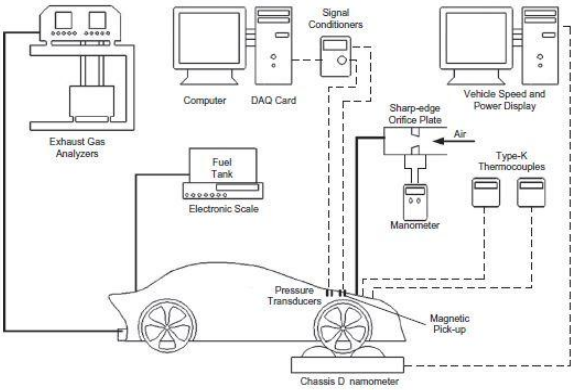

Figure 4. A systematic layout of test set up

TABLE 5. Specification of the experimental setup

Item	Specification
Engine Type	Single cylinder 4 stroke engine
Fuel	Gasoline and methanol blends
Cooling system	Water cooled
Stroke (mm)	110
Bore (mm)	80
Compression ratio	9.2:1
Loading	Chassis Dynamometer
Fuel measurement	Optical sensors
Ignition source	Spark Plug
Spark variation range	0-70 btdc
Emission measurement	Horiba, 5 Gas analyser
Smoke measurement	AVL 437C Smoke meter
Type of injection	Direct injection
Injection pressure (bar)	200
Load indicator	Digital, range 0-50 kg, supply 230V, AC

RESULTS AND DISCUSSION

Methanol is an oxygenated fuel which contains the oxygen atom in their basic form. When it added to the fuel it provides the more oxygen for the combustion process. This effect is known as the leaning effect. Due to this effect CO emission decreases significantly[16, 17]. Unburned hydrocarbons caused due to the improper mixing and combustion [18]. Generally, the main sources of engine-out unburned HC emissions are misfires, exhaust valve leakage, liquid fuel effects, oil films and deposits [19, 20]. The oxide of nitrogen is a mixture of nitric oxide and nitrogen dioxide which is formed by the oxidation of nitrogen. The formation of NO_x is related to the combustion temperature [18, 21].

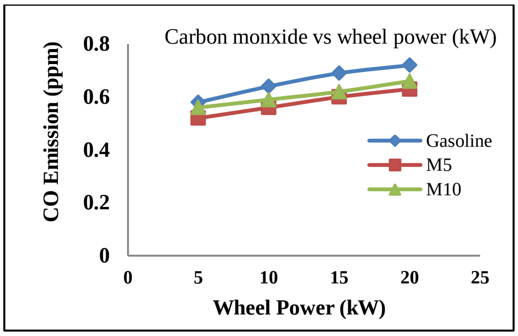

Figure 5. CO emissions for testing fuels at various wheel powers.

Carbon monoxide emission

Comparison of CO emissions for test fuels at various wheel powers shows the blended fuel with methanol had less emission. Figure 5 shows carbon monoxide emission for methanol blended fuels had less emission than gasoline.In comparative analysis of M5, M10 and pure gasoline; it is observed that value of CO is maximum in pure gasoline. The decrease in CO emissions observed for M5 and M10 were 12 and 8% on average, compared to pure gasoline. While the maximum reduction in CO emissions found for the wheel power of 15 and 20 KW.

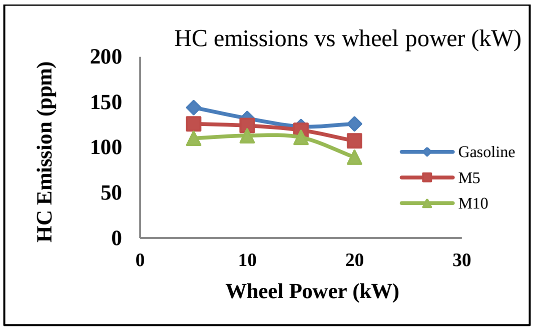

Figure 6. HC emissions for testing fuels at various wheel powers

Hydrocarbons emission

In fact, emissions of HC, NO_x and CO_2 for blended were also less than gasoline. The illustrative obtained data for mission of HC, NO_x and $CO_2$with respect to wheel power are shown in Figures 6, 7 and 8, respectively. Generally, emission may slightly increase with wheel power; that is due to more fuel consumption which is not related to types of fuel. In comparative analysis of M5, M10 and pure gasoline, it is observed that value of HC emission is minimal for M10. In compare to gasoline, the average decrement in HC emission for M5 and M10 are 9 and 19%, respectively. The result shows the highest decrement in unburned hydrocarbons emissions for M5 and M10 are at the wheel power of 20.

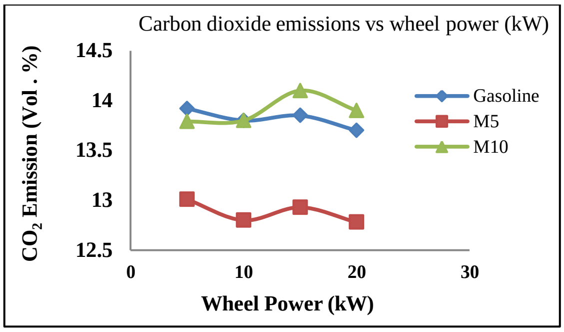

Figure 7. NO_x emissions for testing fuels at various wheel powers

Oxides of nitrogen emission

In comparative analysis of M5, M10 and pure gasoline, it is observed that value of NO_x is higher in M5 and M10 for 10 kW and 15 kW, as M5 and M10 has more oxygen than the pure gasoline. Lower NO_x emissions for M5 and M10 are found at 20kW wheel power. M5 shows the maximum reduction in NO_x emissions at 20 kW wheel power which is by 17%, as compared with pure gasoline.

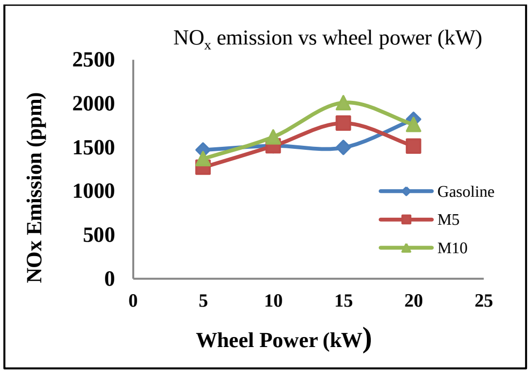

Figure 8. CO_2 emissions for test fuels at various wheel powers

Carbon dioxide emission

Comparative analysis of M5, M10 and pure gasoline showed that value of CO_2 is higher in M10 for 15 kW and 20 kW by 3% on average, which is desirable. It is again due to the presence of the higher oxygen in methanol. There is a decrease in CO_2 emissions for M5 by 8% on average and M10 for 5 kW and 10 kW by negligible values, when compared with gasoline.

CONCLUSIONS

The composite fuel concept that has been discussed in this paper is simple and robust for calculating the various properties of the blended fuel. The number of moles of reactants and products is a function of fuel composition and equivalence ratio. The molecular weight of the unburned mixture is not much affected by the ethanol concentration. The exhaust emissions of an SI engine have been investigated with the methanol-gasoline blends at the vehicle speed of 90 km/h. The test result shows the decrease in the emissions of CO and HC with the increased percentage of methanol. This is due to the improved combustion process by the presence of higher molecules of oxygen in methanol. By using the methanol, CO_2 and NO_x emissions increased as compared with gasoline due to the different engine running conditions. While the emissions of CO, HC and NO_x are found to decrease at the wheel power of 20 kW for M5 and M10. By the above test results, it is concluded that the use of M5 and M10 leads to the maximum reduction in emissions for the 20 kW wheel power at the vehicle speed of 90 km/h depending on the engine conditions.

REFERENCES

1. Agarwal, A.K., 2007. Biofuels (alcohols and biodiesel) applications as fuels for internal combustion engines. Progress In Energy and Combustion Science, 33(3): 233-271.
2. Koenig, A., W. Lee and W. Bernhardt, 1976. Technical and Economic Aspects of Methanol as an Automotive Fuel, Society of Automotive Engineers, 1976(6):1-12
3. Cardona, C.A. and Ó.J. Sánchez, 2007. Fuel ethanol production: process design trends and integration opportunities. Bioresource Technology, 98(12): 2415-2457.
4. Cheng, W.H., Methanol production and use,1994: New York: Maercel Dekker.
5. Evrendilek, F. and C. Ertekin, 2003. Assessing the potential of renewable energy sources in Turkey. Renewable Energy, 28(15): 2303-2315.
6. Menrad, H. and B. Nierhauve, 1983. Engine and vehicle concepts for methanol-gasoline blends, Society of Automotive Engineers,1983(10):67-71
7. Dietsche, K. and M. Klingebiel, Bosch Automotive Handbook, 1 ed1976: John Wiley & Sons Inc., Postfach.
8. Thring, R., 1983. Alternative fuels for spark-ignition engines, Society of Automotive Engineers 1983(10):55-59.
9. Adelman, H., D. Andrews and R. Devoto, 1972. Exhaust emissions from a methanol-fueled automobile, Society of Automotive Engineers, 1972(2):2096-2101.
10. Koenig, A., H. Menrad and W. Bernhardt, 1978. Alcohol fuels in automobiles. Publication of: Australian Government Publishing Service.
11. Johnson, R. and R. Riley, 1976. Single Cylinder Spark Ignition Engine Study of the Octane, Emissions, and Fuel Economy Characteristics of Methanol-Gasoline Blends, Society of Automotive Engineers, 1976(2):1-6
12. Ganguly, A., P. Chatterjee and A. Dey, 2012. Studies on ethanol production from water hyacinth—A review. Renewable and Sustainable Energy Reviews, 16(1): 966-972.
13. Al-Hasan, M., 2003. Effect of ethanol–unleaded gasoline blends on engine performance and exhaust emission. Energy Conversion and Management, 44(9): 1547-1561.
14. Heywood, J.B., Internal combustion engine fundamentals. Vol. 930. 1988: McGraw-Hill New York.
15. Hsieh, W.-D., R.-H. Chen, T.-L. Wu and T.-H. Lin, 2002. Engine performance and pollutant emission of an SI engine using ethanol–gasoline blended fuels. Atmospheric Environment, 36(3): 403-410.
16. Qi, D., S.Q. Liu, C.H. Zhang and Y.Z. Bian, 2005. Properties, performance, and emissions of methanol-gasoline blends in a spark ignition engine. Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering, 219(3): 405-412.
17. Richard, L. and P. Bechtold, 1997. Alternative fuels guidebook. Society of Automotive Engineers, Inc. Warrendale, PA, USA.
18. Ozsezen, A.N. and M. Canakci, 2011. Performance and combustion characteristics of alcohol–gasoline blends at wide-open throttle. Energy, 36(5): 2747-2752.
19. Kaiser, E.W., W.O. Siegl and R.W. Anderson, 1994. Fuel structure and the nature of engine-out emissions, Society of Automotive Engineers , 1994(10):1-6
20. Stanglmaier, R.H., J. Li and R.D. Matthews, 1999. The effect of in-cylinder wall wetting location on the HC emissions from SI engines, Society of Automotive Engineers, 1999(3):1-5.
21. Karabektas, M. and M. Hosoz, 2009. Performance and emission characteristics of a diesel engine using isobutanol–diesel fuel blends. Renewable Energy, 34(6): 1554-1559.

Persian Abstract

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چکیده

نگرانی های زیادی در زمینه آلوده شدن جو به وسیله موتورهای احتراق داخلی وجود دارد. بنابراین مطاله در زمینه استفاده از الکل در موتورهای چهار زمانه احتراق جرقه ای دارای اهمیت است. خواص سوخت های ترکیبی در گذشته مورد مطالعه قرار گرفته است. اثر آلایندگی سوخت ترکیبی متانول-بنزین به صورت تجربی مورد مطالعه قرار گرفته است. آلایندگی سوخت ترکیبی متانول-بنزین در مقایسه با بنزین خالص بررسی شده است. آزمایش در سرعت ثابت ۹۰ کیلومتر در ساعت در با استفاده از دنده های مختلف انجام شده است. مشخص شد که زمانی که موتور با استفاده از سوخت متانول ترکیبی با بنزین به حرکت در آمده $CO_{۲}$، HC، و NO_x کمتری در تمامی دنده ها در سرعت ۹۰ کیلومتر در ساعت آزاد کرده است. به علاوه نسبت سوخت به هوا با افزایش متانول افزایش یافته است.