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Performance and Emission Characteristics of Spark Ignition Engine Fuelled with Ethanol and Methanol Gasoline Blended Fuels

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1. Introduction

Depletion of fossil fuels and environmental pollution has led researchers to anticipate the need to develop bio-fuels. Alcohols are an important category of bio-fuels. Methanol can be produced from coal, biomass or even natural gas with acceptable energy cost. Also, gasification of biomass can lead to methanol, mixed alcohols, and Fischer–Tropsch liquids (Chum and Overend, 2001). Ethanol is produced from sugars (particularly sugar cane) and starch by fermentation. The biomass industry can produce additional ethanol by fermenting some agricultural by-products (Prasad et al., 2007). Lignocellulosic biomass is a potential source for ethanol that is not directly linked to food production (Freudenberger, 2009). Shapouri et al. (1995) showed that the net energy value of corn ethanol has become positive in recent years due to technological advances in ethanol conversion and increased efficiency in farm production. Corn ethanol is energy efficient, as indicated by an energy ratio of 1.24, that is, for every Btu dedicated to producing ethanol, there is a 24-percent energy gain. Goldemberg et al. (2004) demonstrated, through the Brazilian experience with ethanol, that economy of scale and technological advances lead to increased competitiveness of this renewable alternative, reducing the gap with conventional fossil fuels. Consequently alcohols are particularly attractive as alternative fuels because they are a renewable bio-based resource and oxygenated, thereby providing the potential to reduce particulate emissions in spark ignition engines. Kim and Dale (2004) estimated that the potential for ethanol production is equivalent to about 32% of the total gasoline consumption worldwide, when used in E85 (85% ethanol in gasoline) for a midsize passenger vehicle. Such a substitution immediately addresses the issue of reducing our use of non-renewable resources (fossil fuels) and the attendant impacts on climate change, especially carbon dioxide and the resulting greenhouse effect (von Blottnitz and Curran, 2007). The conversion of biomass to bio-fuel has some ecological drawbacks. It is well known that conversion of biomass requires additional energy inputs, most often provided in some form of fossil fuel. Also, agricultural production of biomass is relatively land intensive, and there is a risk of pollutants entering water sources from fertilisers and pesticides that are applied to the land to enhance plant growth (Pimentel, 2003; Niven, 2005).

The use of alcohol blended with gasoline was a subject of research in the 1980s and it was shown that ethanol and methanol gasoline blends were technically acceptable for existing spark ignition engines. There is a considerable amount of literature relative to various blends of ethanol, methanol and gasoline. Winnington and Siddiqui (1983) studied the effect of using ethanol gasoline blends as a fuel on the performance of spark ignition engines. The Ricardo engine, over the test range of 8:1 to 10:1 compression ratio, showed an average drop in power compared to premium gasoline of 2.5% on blend A and 7.5% on blend B. The specific fuel consumption of the ethanol gasoline blend showed an increase compared to premium gasoline of around 0.5% and 4% on blends A and B, respectively. The Peugeot engine tests showed that the power was down, overall, by around 1% and 2.5% on blends A and B, respectively, and the specific fuel consumption was increased by about 0.5% for blend A and 1% for blend B. El-Kassaby (1993) investigated the effect of ethanol gasoline blends on spark ignition engine performance. The performance tests showed that the engine showed power improvement with ethanol addition, the maximum improvement occurring at the 10% ethanol and 90% gasoline fuel blend. Abdel-Rahman and Osman (1997) carried out performance tests using different percentages of ethanol in gasoline fuel, up to 40%, under variable compression ratio conditions. The results show that the engine showed power improvement with the percentage addition of the ethanol in the fuel blend. The maximum improvement occured at 10% ethanol/90% gasoline fuel blend. Yacoub et al. (1998) quantified the performance and exhaust gas emissions for an engine optimized to operate on C1–C5 alcohol/gasoline blends with matched oxygen content. The performance and exhaust gas emissions characteristics of the blends were quantified by using a single-cylinder spark ignition engine. Lower alcohols (C1, C2 and C3)/gasoline blends showed a wider range of operation relative to neat gasoline. Ethanol/gasoline blends showed the highest knock resistance improvement among all tested blends. On the other hand, higher alcohol (C4 and C5)/gasoline blends showed degraded knock resistance when compared with neat gasoline. Al-Hasan (2002) showed that blending unleaded gasoline with ethanol increased the brake power, torque, volumetric and brake thermal efficiencies and fuel consumption, while it decreased the brake specific fuel consumption and equivalence air–fuel ratio. Wu et al. (2004) tested ethanol/gasoline blended fuel in a conventional engine under various air–fuel equivalence ratios (λ) for its performance and emissions. When air–fuel ratio is slightly smaller than one, maximum torque output and minimum brake specific heat consumption (bshc) are available. Using ethanol/gasoline blended fuels improves torque output. However, bshc does not change noticeably. Yücesu et al. (2006) examined the effect of compression ratio on engine performance and exhaust emissions at stoichiometric air/fuel ratio, full load and minimum advanced timing for the best torque in a single cylinder, four stroke, with variable compression ratio spark ignition engine. The engine torque increased with increasing compression ratio up to 11:1, the increasing ratio was about 8% when compared with 8:1 compression ratio. The highest increasing ratio of engine torque was obtained at 13:1 compression ratio with E40 and E60 fuels, the increment was about 14% when compared with 8:1 compression ratio. Minimum brake specific fuel consumption (BSFC) was obtained at 11:1 compression ratio with E0 fuel. A comparison with 8:1 compression ratio, showed that the BSFC decreased 10% and after 11:1 compression ratio the BSFC increased again. The maximum decrease in BSFC was found to be 15% when E40 was used. Liu et al. (2007) showed that the engine power and torque will decrease when increasing the fraction of methanol in the fuel blends under wide open throttle (WOT) conditions. However, if spark ignition timing is advanced, the engine power and torque can be improved under WOT operating conditions. Engine thermal efficiency is thus improved in almost all operating conditions. Engine combustion analyses show that the fast burning phase becomes shorter, however, the flame development phase is slightly delayed. Koç et al. (2009) investigated the effects of unleaded gasoline (E0) and unleaded gasoline/ethanol blends (E50 and E85) on engine performance in a single cylinder four-stroke spark-ignition engine at two compression ratios (10:1 and 11:1). The engine speed was changed from 1500 to 5000 rpm at WOT. The results of the engine test showed that ethanol addition to unleaded gasoline increased the engine torque, power and fuel consumption. It was also found that ethanol/gasoline blends allow increasing compression ratio (CR) without knock occurrence. Yücesu et al. (2007) proposed a new approach based on artificial neural network (ANN) to determine the engine torque and brake specific fuel consumption. Ethanol/unleaded gasoline blends (E10, E20, E40 and E60) were tested in a single cylinder, four stroke spark ignition and fuel injection engine. The tests were performed by varying the ignition timing, relative air–fuel ratio (RAFR) and compression ratio at a constant speed of 2000 rpm and at WOT. Maximum brake torque (MBT) timing of the engine showed no significant variation with unleaded gasoline and unleaded gasoline/ethanol blends. When the ignition timing retarded, ethanol blends yielded higher brake torque of the engine than unleaded gasoline. The maximum torque was obtained at 0.9 RAFR for all test fuels for both compression ratios 8:1 and 10:1. The engine torque of ethanol blended fuels was higher than that of E0 obtained at richer working region than stoichiometric air–fuel ratio especially at 10:1 compression ratio. The BSFC varied depending on both engine torque and especially the heating value of the used fuel. The BSFC increased in proportion to the ethanol percentage. From the results of mathematical modelling, the calculated engine torque and specific fuel consumption were obviously within acceptable uncertainty margins. Najafi et al. (2009) proposed the use of ANN to determine the engine power, torque, brake specific fuel consumption, brake thermal efficiency, volumetric efficiency and emission components based on different gasoline/ethanol blends and speeds. Experimental data demonstrated that the use of ethanol/gasoline blended fuels will marginally increase the brake power and decrease the brake specific fuel consumption. It was also found that the brake thermal efficiency and volumetric efficiency tend to increase when ethanol/gasoline blends are used. Analysis of the experimental data by the ANN revealed that there is a good correlation between the ANN-predicted results and the experimental data.

The effects of using ethanol and methanol unleaded gasoline blends on emissions characteristics in spark ignited engine have been investigated by other researchers. Research studies of exhaust emission levels from spark ignited engine are important from different perspectives. The combustion of fuel in an engine generates by-products that we all know as emissions. The four main engine emissions are carbon monoxide (CO), carbon dioxide (CO_2), hydrocarbons (HC), and oxides of nitrogen (NOx) (though others, such as particulates and formaldehyde, are also produced). Gasoline, as a compound hydrocarbon, is not a particularly clean-burning fuel. Alcohols, in comparison, burn nearly pollution-free. Alcohols already contain oxygen integral with the fuel, which can lead to a more homogenous combustion. Alcohols burn with a faster flame speed than gasoline, and they do not contain additional elements such as sulphur and phosphorus. Rajan and Saniee (1983) investigated the characteristics of hydrated ethanol with gasoline as a means of reducing the cost of ethanol/gasoline blends for use as a spark ignition engine fuel. Engine experiments indicate that, at normal ambient temperatures, a water/ethanol/gasoline blend containing up to 6 vol% of water in the ethanol constitutes a desirable motor fuel with power characteristics similar to those of the base gasoline. As a means of reducing the smog causing components of the exhaust gases, such as the oxides of nitrogen and the unburnt hydrocarbons, the water/ethanol/gasoline blend is superior to the base gasoline. Palmer (1986) showed that 10% of ethanol addition to gasoline could reduce the concentration of CO emission up to 30%. Bata et al. (1989) had tested different blend rates of ethanol gasoline fuels in engines, and found that the ethanol could reduce the CO and UHC emissions. Taylor et al. (1996) used four alcohol fuels to blend with gasoline and concluded that adding ethanol can reduce CO, HC and NO emissions. Chao et al. (2000) indicated that using ethanol gasoline blended fuels increases the emission of formaldehyde, acetaldehyde and acetone several times than those from gasoline. Gautam et al. (2000) investigated the emissions characteristics between higher alcohol/gasoline blends and neat gasoline. It was found that the cycle emissions of CO, CO_2 and organic matter hydrocarbon equivalent from the higher alcohol/gasoline blends were very similar to those from neat gasoline. Cycle emissions of NOx from the blends were higher than those from neat gasoline. However, for all the emissions species considered, the brake specific emissions (g/kW h) were significantly lower for the higher alcohol/gasoline blends than for neat gasoline. This was because the blends had greater resistance to knock and allowed higher compression ratios, which increased engine power output. The contribution of alcohols and aldehydes to the overall organic matter hydrocarbon equivalent emissions was found to be minimal. Al-Hasan (2002) investigated the effect of using unleaded gasoline/ethanol blends on a four stroke, four cylinder spark ignition (SI) engine performances and exhaust emission. The results showed that the CO and HC emissions concentrations in the engine exhaust decrease, while the CO_2 concentration increases. Hsieh et al. (2002) investigated the engine performance and pollutant emission of a commercial SI engine using ethanol–gasoline blended fuels with various blended rates (0%, 5%, 10%, 20%, 30%). It was found that with increasing the ethanol content, the RVP of the blended fuels initially increases to a maximum at 10% ethanol addition, and then decreases. Results of the engine test indicated that using ethanol/gasoline blended fuels, CO and HC emissions decrease dramatically as a result of the leaning effect caused by the ethanol addition, and CO_2 emission increases because of the improved combustion. Finally, it was noted that NOx emission depends on the engine operating condition rather than the ethanol content. He et al. (2003) investigated the effect of ethanol blended gasoline fuels on emissions and catalyst conversion efficiencies in a spark ignition engine with an electronic fuel injection system. Ethanol can decrease engine-out regulated emissions. The fuel containing 30% ethanol by volume can drastically reduce engine-out total hydrocarbon emissions (THC) at operating conditions and engine-out THC, CO and NOx emissions at idle speed, but unburned ethanol and acetaldehyde emissions increase. According to Yüksel and Yüksel (2004) one of the major problems for the successful application of gasoline–alcohol mixtures as a motor fuel is the realization of a stable homogeneous liquid phase. To overcome this problem, authors designed a new carburetor. Sixty percent ethanol and forty percent gasoline blend was exploited to test the performance, the fuel consumption, and the exhaust emissions. Experimental results indicated that using ethanol–gasoline blended fuel, the CO and HC emissions decreased dramatically as a result of the leaning effect caused by the ethanol addition, and the CO_2 emission increased because of the improved combustion. Bayraktar (2005) investigated experimentally and theoretically the effects of ethanol addition to gasoline on an SI engine performance and exhaust emissions. Experimental applications have been carried out with the blends containing 1.5, 3, 4.5, 6, 7.5, 9, 10.5 and 12 vol% ethanol. Numerical applications have been performed up to 21 vol% ethanol. Engine was operated with each blend at 1500 rpm for compression ratios of 7.75 and 8.25 and at full throttle setting. Experimental results have shown that among the various blends, the blend of 7.5% ethanol was the most suitable one from the engine performance and CO emissions points of view. However, theoretical comparisons have shown that the blend containing 16.5% ethanol was the most suited blend for SI engines. Jia et al. (2005) investigated emission characteristics from a four-stroke motorcycle engine using 10 vol% ethanol/gasoline blended fuel (E10) at different driving modes on the chassis dynamometers. The results indicate that CO and HC emissions in the engine exhaust were lower with the operation of E10 as compared to the use of unleaded gasoline, whereas the effect of ethanol on NOx emission is not remarkable. Hydrocarbon species except ethanol, acetaldehyde and ethylene emissions were decreased somewhat from ethanol/gasoline blends-fuelled motorcycle engine relative to gasoline-fuelled engine. Additionally, this analysis showed that aromatic compounds and fatty group ones are major compounds in motorcycle engine exhaust. Ceviz and Yüksel (2005) investigated the effects of using ethanol/unleaded gasoline blends on cyclic variability and emissions in a spark-ignited engine. Results of this study showed that using ethanol/unleaded gasoline blends as a fuel decreased the coefficient of variation in indicated mean effective pressure, and CO and HC emission concentrations, while increased CO_2 concentration up to 10 vol.% ethanol in fuel blend.

From the literature review, it is obvious that alcohol gasoline blended fuels can effectively increase the brake power and decrease the emissions without major modifications to the engine design. This chapter was prepared for the purpose of presenting the results of experience to date with a selected list of possible alternative fuels to be used in SI engines.

2. Ethanol and methanol gasoline blended fuels

Methanol and ethanol based liquid fuels can be used as substitutes for gasoline fuels in conventional engines, such as spark ignition engines, without modification to the engines. Several test fuels were used in this study. The first was unleaded gasoline as a base fuel. The others were ethanol and methanol blended gasoline fuels.

2.1 Blend properties

Each fuel has its own set of combustion-related properties. These properties change the engine performance and emission characteristics. Laboratory tests were then carried out using ASTM tests standards to determine the combustion-related properties. A list of fuel properties that compares ethanol and methanol gasoline blended fuels is given in Table 1. It shows heat of combustion, Reid vapour pressure (RVP), research octane number (RON), density at 15.5 ^oC and distillation temperature including initial boiling temperature (IBT), 10%, 50%, 90% distillation temperatures and final distillation temperature.

Ethanol (ethyl alcohol) C_2H_5OH is a clear, colorless liquid with a characteristic, agreeable odor. Ethanol is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group, –OH, bonded to a carbon atom. Ethanol melts at –114.1 °C, boils at 78.5 °C, and has a density of 0.789 g/mL at 20°C (De Caro et al., 2001). The heating value of ethanol is lower than that of gasoline. Table 1 further indicates that the heating value of the blended fuel will decrease with the increase of the ethanol content. RON increases with the increase of ethanol concentration. Compared to unleaded gasoline, RON of the blended fuels is increased by 3.5, 8.6 and 14.1, respectively. Therefore, ethanol is an excellent additive for preventing engine knock and improving engine performance where high octane requirements exist. Despite the improved octane performance of ethanol/gasoline blends, engine driveability is generally degraded. Cold starting is more difficult because of the added heat of vaporization in blends. Hot starting is complicated because of increased volatility, which leads to potential vapor locking conditions (Sinor and Bailey, 1993). Adding 10vol.%, 20vol.% and 30vol.% ethanol to gasoline increase the RVP of the base gasoline of about 24.53 kPa, 19.61 kPa and 18.31 kPa, respectively. The increase in vapor pressure for low level blends of ethanol is caused by dilution of hydrogen bonding between ethanol molecules in the final blend. When ethanol is diluted in gasoline, the hydrogen bonding effect is reduced and the ethanol molecules behave more like their low molecular weight would indicate, resulting in increased volatility (Bailey, 1997). Adding ethanol also modifies the distillation curve of the gasoline. It can also be observed that the addition of ethanol to gasoline increases IBT, but the rates of 10%, 50%, 90% and final distillation temperatures decrease. Ethanol forms a minimum boiling azeotrope with gasoline, causing the distillation curve to be depressed between 10vol.% and 90vol.% distilled points.

Methanol CH_3OH, which is also called methyl alcohol, is colorless, odorless, water-soluble liquid. It freezes at -97.8 ºC, and boils at 64.6 ºC. It is miscible with water in all proportions, and spillages are rapidly dispersed. Blends with between 6.7 % and 36 % of air are flammable. The auto-ignition temperature of methanol is 467 ºC, which is high compared with 222 ºC for gasoline. This may account for the high octane number, 106, of methanol; a typical gasoline has an octane number of 90 to 100. Although methanol is not the cheapest fuel, its properties make it competitive with the other fuels. Methanol used as an additive or substitute for gasoline could immediately help to solve both energy and air pollution problems (Reed and Lerner, 1973). The heating value of methanol is less than that of gasoline and ethanol so that its blends contain less MJ/kg. Methanol gasoline blends cause slight but significant decrease in efficiency of the engine. Methanol has also a high RON, which increases with the increase of methanol concentration. Compared to unleaded gasoline, RON of the methanol blended fuels is increased by 3.4, 9.6 and 13.6, respectively. This number reflects the fact that the blending of methanol with gasoline is a very effective method of increasing the octane number of the fuel. Moreover, the result of this effect demonstrates the elimination of knocking. It's possibility of replacing anti-knock additives in gasoline with a low percentage of methanols in a blend, helping to minimize air pollution (Yamamoto, 1972). Adding 10vol.%, 20vol.% and 30vol.% methanol to gasoline increases the RVP of the base gasoline at about 22.43 kPa, 31.58 kPa and 33.74 kPa, respectively. Because of the disruption of hydrogen bonding in methanol when it is blended with a hydrocarbon, the vapor pressure of a blend of methanol and gasoline deviates greatly from ideal behavior, exhibiting a much higher vapor pressure than would be expected. This excess vapor pressure can lead to vapor problems (driveability problems), difficulties with hot starts, stalling, hesitation, and poor acceleration (Ceci1, 1974). Several solutions to these problems have been proposed (Fitch and Kilgroe, 1970; Adelman, 1972). It is possible to add high vapor pressure liquids or gases such as butane either generally or preferably during cold start situations. Either gasoline or LPG could be injected at cold starts to accomplish the same effect. Aside from the cold start problem, the performance of the methanol fuelled engine has been shown to be equivalent to a gasoline fuelled engine. Adding methanol also modifies the distillation curve of the gasoline. It can also be observed that the addition of methanol to gasoline increases IBT, 90% and final distillation temperature rates, but 10% and 50%, decrease.

Property item	**Test fuel**							**Test method**
	Gasoline	**E10**	**E20**	**E30**	**M10**	**M20**	**M30**	
Heat of combustion (MJ/kg)	44.133	42.447	40.672	38.673	41.615	38.233	36.247	ASTM D340
Reid vapour pressure (kPa)	35.00	59.53	54.61	53.31	57.43	66.58	68.74	ASTM D323
Research octane number	84.8	88.3	93.4	98.9	88.2	94.4	98.4	ASTM D2699
Density at 15.5°C (kg/l)	0.7678	0.7760	0.7782	0.7794	0.7692	0.7707	0.7734	ASTM D1298
Distillation temperature (°C)								
IBT	38.5	39.5	40.3	40.7	43.2	43.7	44.5	ASTM D86
10 vol.%	57.2	52.3	55.4	55.7	48.2	50.4	51.3	
50 vol.%	93.5	71.8	71.6	72.5	81.0	79.7	81.6	
90 vol.%	156.0	143.7	143.1	142.7	165.1	164.8	164.7	
End point	181.7	176.1	176.6	176.5	206.2	206.3	206.7	

Table 1. Properties of different ethanol and methanol gasoline blended fuels.

2.2 Testing procedure

The performance and emission characteristics of the spark ignition engine running on ethanol and methanol blended with gasoline were evaluated and compared with neat gasoline fuel. Apparatuses used in the present study were an engine, a dynamometer and an exhaust analyzer. The schematic diagram of the experimental set-up is shown in Figure 1. A single cylinder, carburetted, four-stroke, spark ignition non-road engine (type Bernard moteures 19A), was chosen. Non-road gasoline engines differ from automotive engines in several technical specifications. Because of these design differences, the effects of alcohol/gasoline blended fuel changes on performance and emission characteristics from non-road gasoline engines are quite different from the effects of alcohol/gasoline blended fuel changes on performance and emissions from automotive gasoline engines. This engine had a 56 mm bore and a 58 mm stroke (total displacement 143 cm^3). Its rated power was 2.2 kW. The ignition system was composed of the conventional coil and spark plug arrangement with the primary coil circuit operating on a pulse generator unit. The engine was coupled to a hydraulic dynamometer. Exhaust gases were sampled from the outlet and then were measured on line by an exhaust analyzer Bosch.

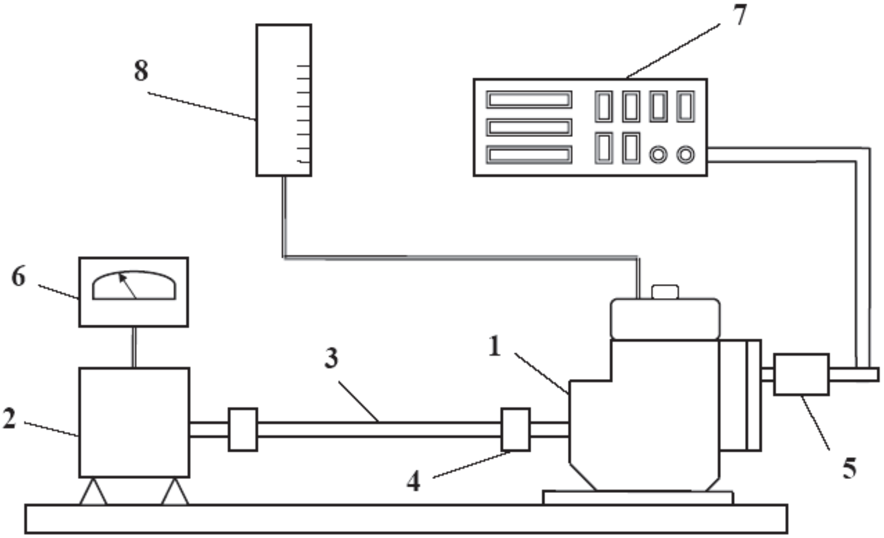

Fig. 1. The schematic diagram of the experimental set-up. (1) Engine, (2) Dynamometer, (3) Shaft, (4) Flywheel, (5) Exhaust pipe, (6) Dynamometer control unit, (7) Gas analyzer, and (8) Fuel measurement system.

A series of experiments were carried out using gasoline, and various ethanol/methanol blends. The test blends were prepared just before starting the experiment to ensure that the fuel mixture was homogeneous and prevent the reaction of ethanol with water vapor. The engine was started and allowed to warm up for a period of 20–30 min. Before running the engine with a new fuel blend, it was allowed to run for sufficient time to consume the remaining fuel from the previous experiment. All the blends were tested under varying engine speed conditions. Engine tests were performed at maximum to idling rpm engine speed. The required engine load was obtained through the dynamometer control. The engine speed, fuel consumption, and load were measured, while the brake power, brake torque and brake specific fuel consumption (BSFC) were computed. For each experiment, three runs were performed to obtain an average value of the experimental data.

After the engine reached a stable working condition (steady state), emission parameters such as CO, CO_2, HC, and NO_x from an online exhaust gas analyser were recorded. CO, CO_2, HC, and NO_x emissions reached average values of the acquired data within 20s for each stable operating condition. The concentration of each gas was measured continuously by digital data acquisition. The exhaust gas temperature was monitored during the experiments to ensure that the engine was in a steady state condition.

2.3 Engine performance characteristics

The results of the brake power, torque, and specific fuel consumption for ethanol and methanol gasoline blended fuels at different engine speeds are presented here.

Fig. 2a shows the influence of ethanol gasoline blended fuels on engine brake power. When the ethanol content in the blended fuel was increased, the engine brake power slightly increased for all engine speeds. However, the brake power of gasoline was slightly lower than that of E10–E30, especially for low engine speeds (e.g., 1000 rpm). With an increase in ethanol percentage, the density of the blend and the engine volumetric efficiency increased and this caused an increase in power. A similar behaviour has been reported by almost all investigators on various types of engines and conditions (Al-Hasan, 2002; Bayraktar, 2005). Fig. 2b shows the effect of different ethanol gasoline blended fuels on engine torque. The increase of ethanol content increased slightly the torque of the engine. The brake torque of gasoline was lower than those of E10–E30, especially for low engine speeds. Due to the addition of ethanol the octane number raised. Therefore, antiknock behaviour improved and allowed a more advanced timing that result in higher combustion pressure and thus higher torque (Agarwal, 2007). From the experimental results, the brake specific fuel consumption (BSFC) was calculated in order to understand the variations of fuel consumption in the test engine using different ethanol gasoline blended fuels. The BSFC (g/kWh) is defined as the ratio of the rate of fuel consumption (g/h) and the brake power (kW). Fig. 2c indicates the variations of the BSFC for different ethanol gasoline blended fuels under various engine speeds. As shown in this figure, the BSFC decreased as the ethanol percentage increased. Also, a slight difference exists between the BSFC using pure gasoline and using ethanol gasoline blended fuels. As engine speed increases reaching 1600 rpm, the BSFC decreases reaching its minimum value. This is due to the increase in brake thermal efficiency (Najafi et al., 2009).

Fig. 3a shows the effect of methanol gasoline blended fuels on engine brake power. With an increasing fraction of methanol engine power slightly decreased for all engine speeds. The brake power of gasoline was higher than those of M10–M30, especially for high engine speeds (e.g., 2500 rpm). Fig. 3b shows the influence of methanol gasoline blended fuels on engine torque. The increase of methanol content decreased slightly the torque of the engine. The brake torque of gasoline was higher than those of M10–M30. Fig. 3c indicates the variations of the BSFC for methanol gasoline blended fuels under various engine speeds. As shown in this figure, the BSFC increased as the methanol percentage increased. Also, a slight difference exists between the BSFC while using gasoline and while using methanol gasoline blended fuels. As engine speed increased reaching 1600 rpm, the BSFC decreased reaching its minimum value. However, if the spark ignition time is advanced by 2^o without any further optimizations, under WOT full load operation conditions, the engine power shows almost no reduction and BSFC can be decreased as well (El-Emam and Desoky, 1984; Liu et al., 2007).

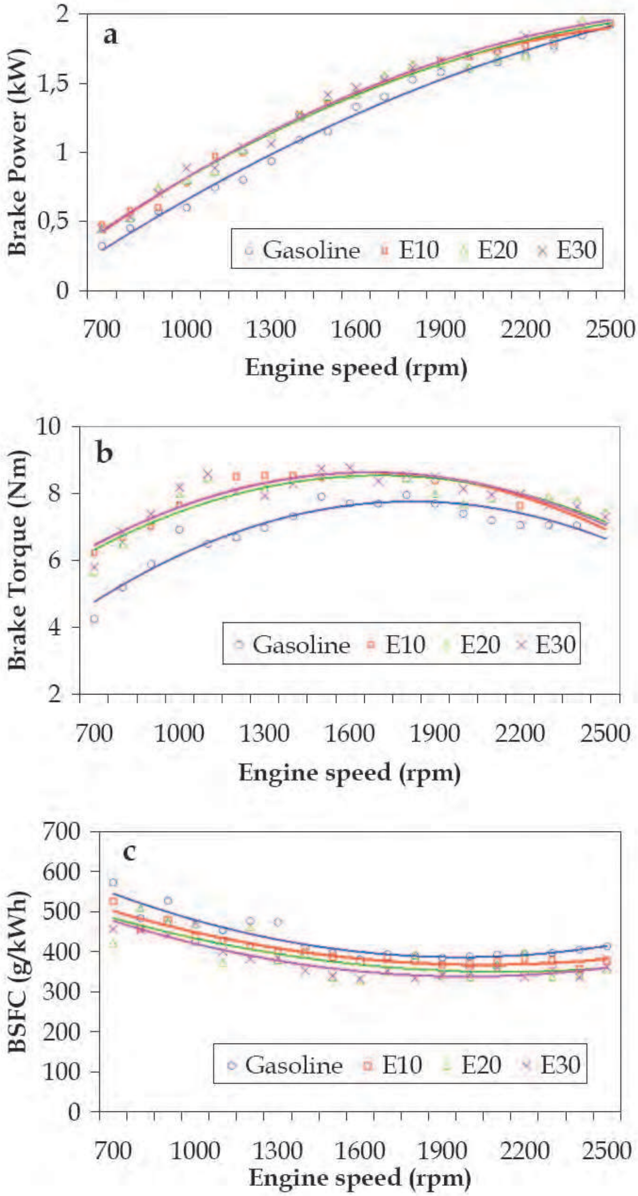

Fig. 2. Experimental results of engine performance characteristics using different ethanol gasoline blended fuels under various engine speeds. (a) Brake power, (b) Brake torque, and (c) Brake specific fuel consumption.

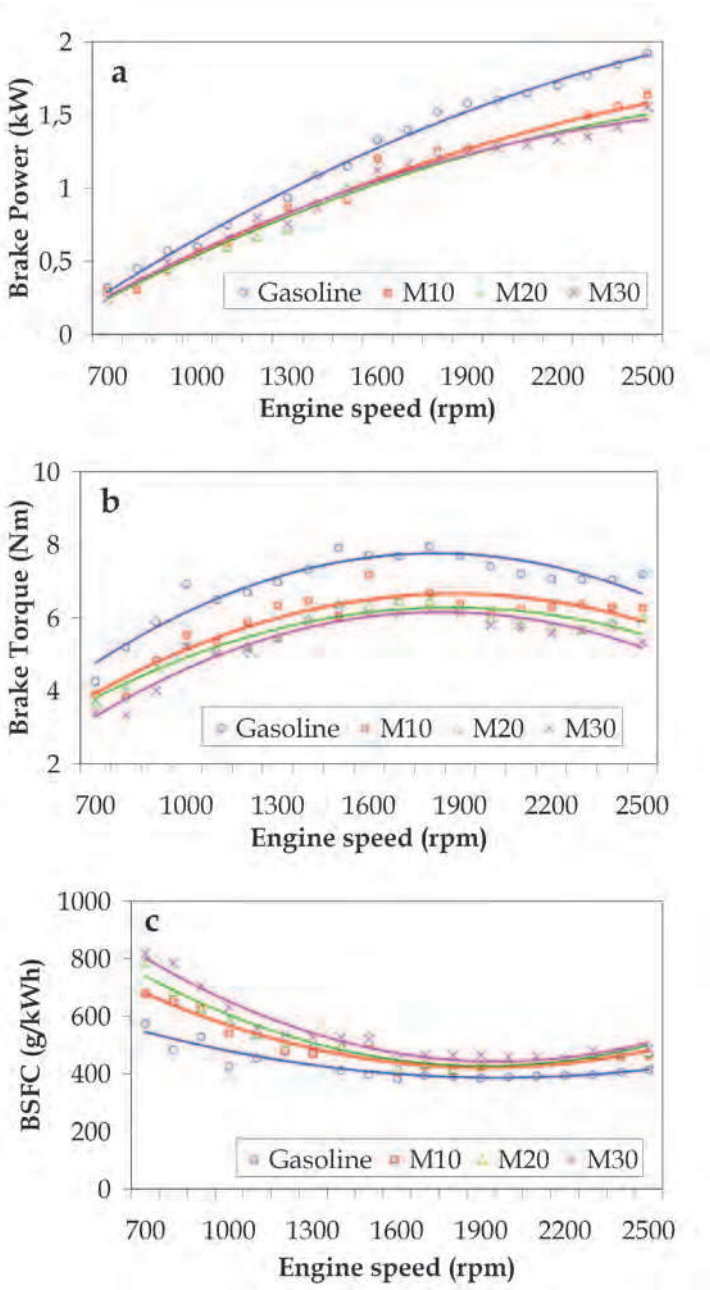

Fig. 3. Experimental results of engine performance characteristics using different methanol gasoline blended fuels under various engine speeds. (a) Brake power, (b) Brake torque, and (c) Brake specific fuel consumption.

The influences of ethanol and methanol addition to unleaded gasoline on SI engine performance characteristics at variable engine speeds are illustrated in Figs. 4 & 5. As shown in Figs. 4a and 4b the brake power and torque slightly decreased as the percentage of ethanol increased for all engine speeds. In fig. 4c, the BSFC decrease continued until the percentage of ethanol reached 40%. Above this point, BSFC started to increase.

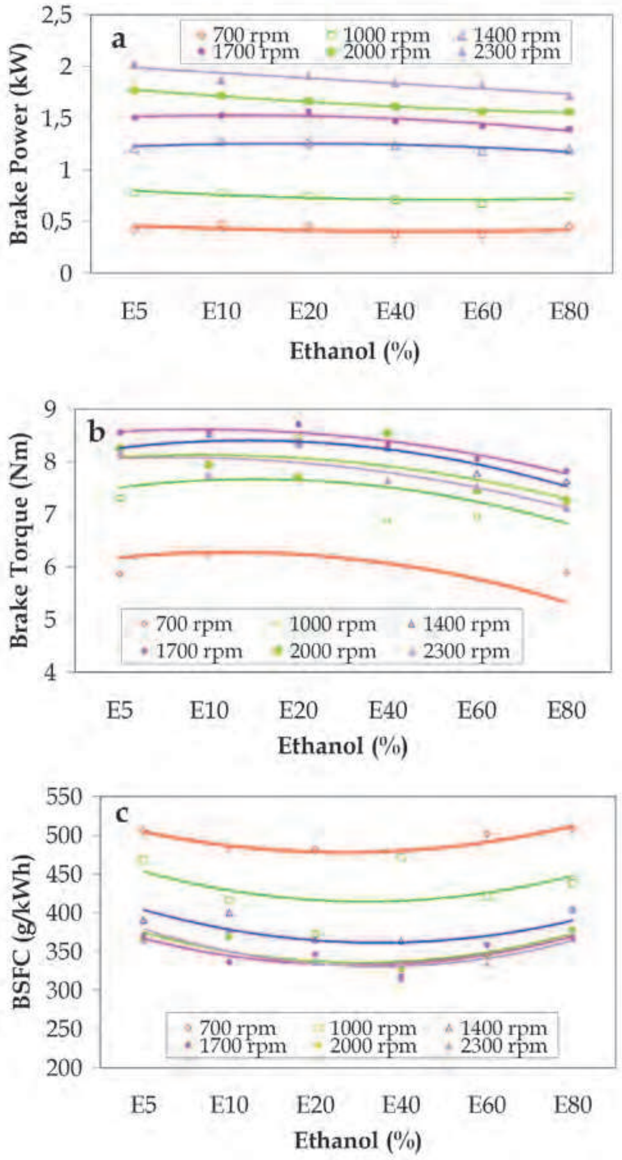

Fig. 4. The influence of ethanol addition on the engine performance characteristics. (a) Brake power, (b) Brake torque, and (c) Brake specific fuel consumption.

As shown in Figs. 5a, 5b and 5c brake power, brake torque and BSFC characteristics have opposite line tendency between lower and higher engine speeds. These characteristics increased as the percentage of methanol increased for lower engine speeds (700-1400 rpm), while the characteristics slightly decreased for higher engine speeds (1700-2300 rpm).

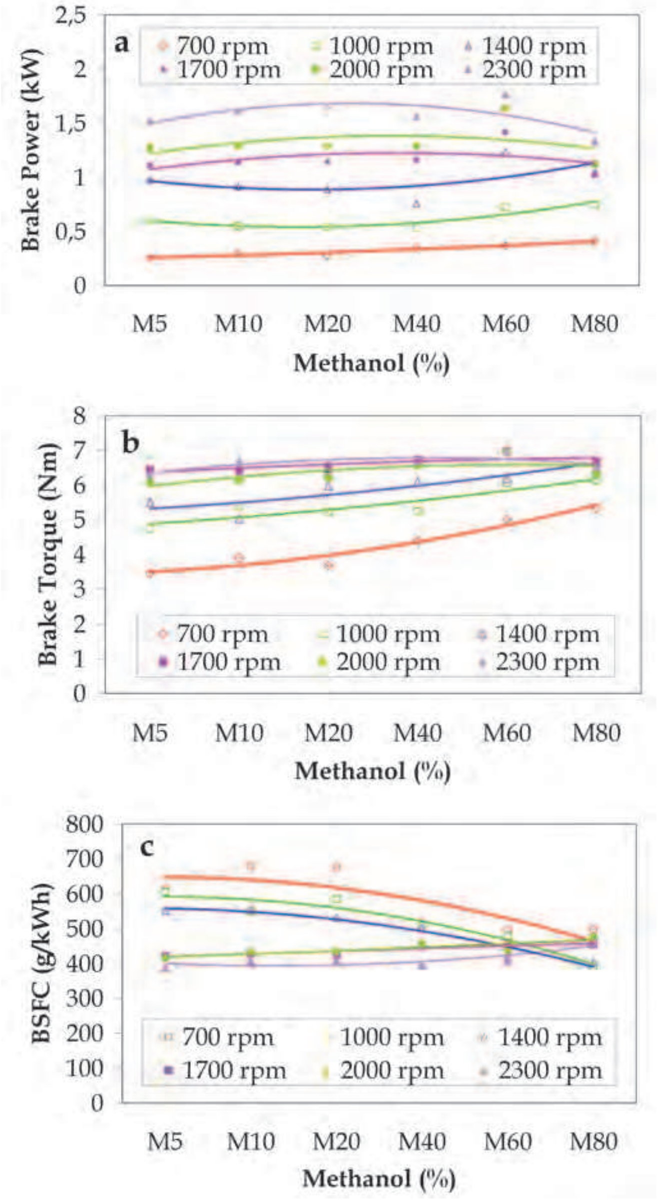

Fig. 5. The influence of methanol addition on the engine performance characteristics. (a) Brake power, (b) Brake torque, and (c) Brake specific fuel consumption.

Fig. 6 shows the comparison between brake power characteristics under different ethanol and methanol blended fuels and engine speeds. One can see that ethanol/gasoline blends have significant higher brake power values than methanol/gasoline blends until the percentage of these blends reaches 40% for lower engine speeds (700-1400 rpm).Beyond this point, both brake power characteristics start to converge. For higher engine speeds (1700-2300 rpm), brake power characteristics are converging until the percentage of the blends reaches 60 %, while beyond this percentage start to diverge. This is due to the influence of the combustion-related properties of the blended fuels. Fig. 7 shows the comparison between BSFC characteristics under different ethanol and methanol blended fuels and engine speeds. One can see that ethanol/gasoline blends have significant lower BSFC values than methanol/ gasoline blends. For lower engine speeds, BSFC characteristics values are converging, while BSFC characteristics values are diverging for higher engine speeds.

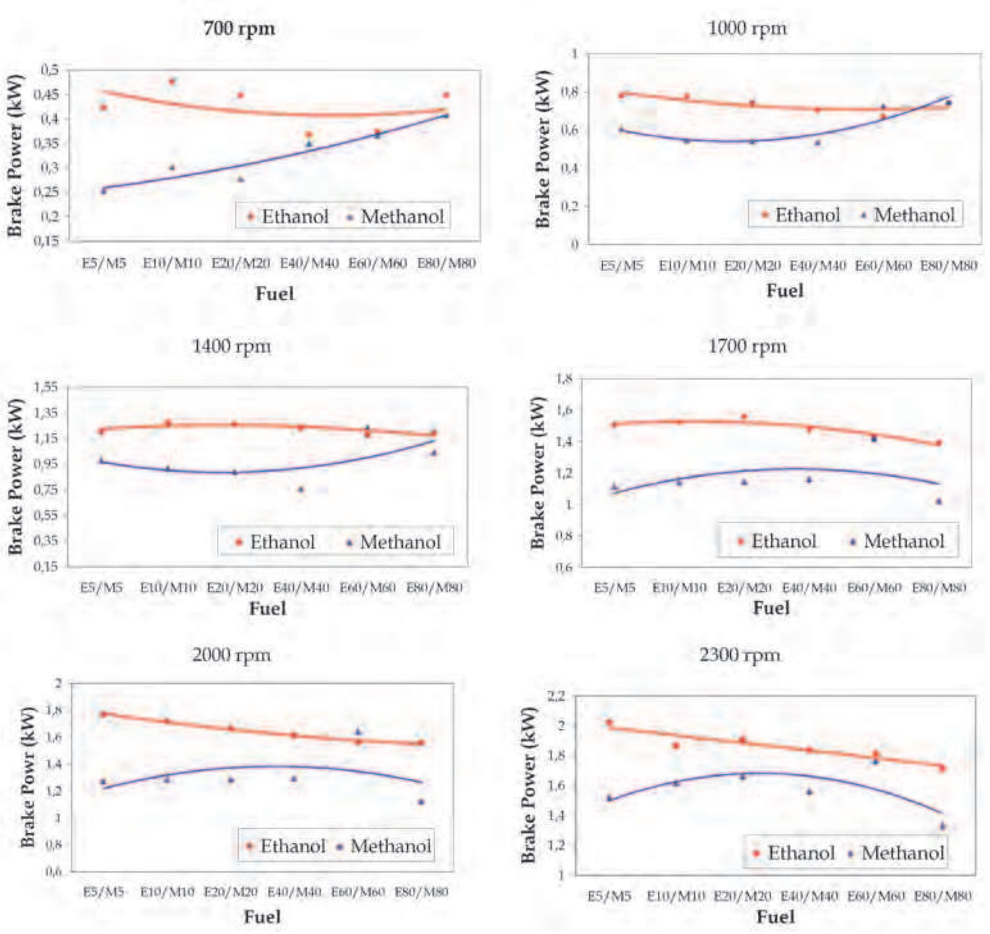

Fig. 6. Comparison of brake power characteristics using different ethanol and methanol gasoline blended fuels.

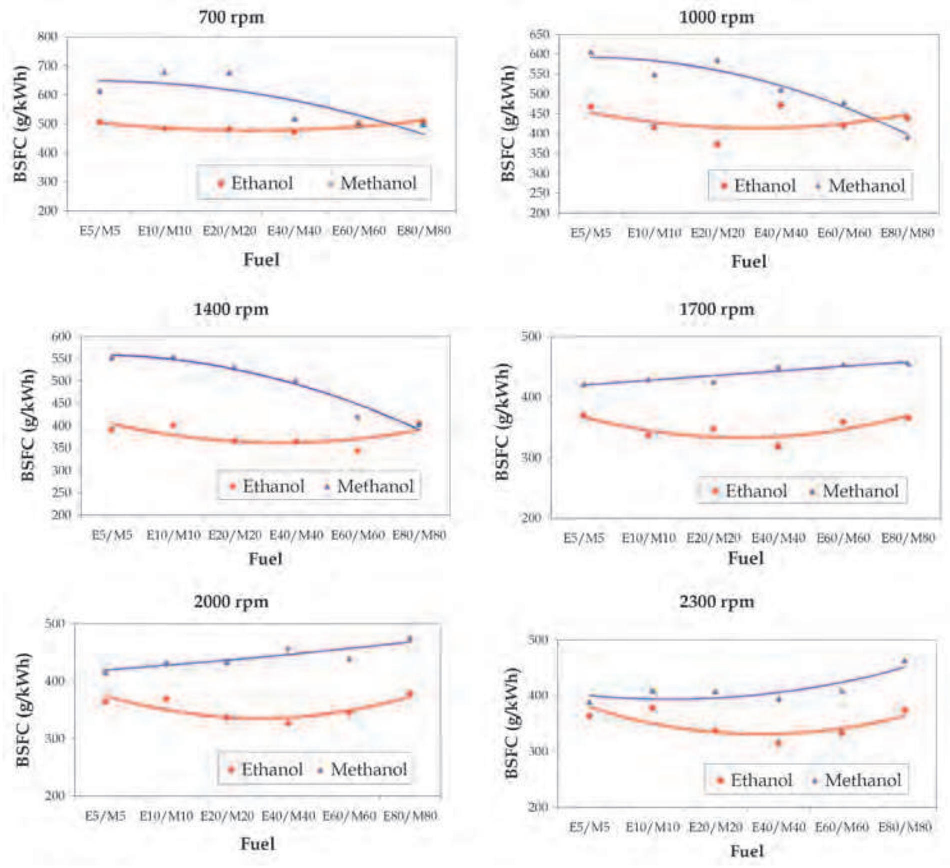

Fig. 7. Comparison of brake specific fuel consumption using different ethanol and methanol gasoline blended fuels.

Adding ethanol to gasoline will lead to improved performance characteristics in a spark ignition non-road engine with low efficiency. It was experimentally demonstrated that adding 30% ethanol to the blend led to an increase in the engine brake power, torque and decreased the BSFC. These findings broadly concur with those of previous studies. The brake power and brake torque of methanol gasoline blends are lower than those of gasoline for all engine speeds. Also, the BSFC of methanol blend fuels is higher than that of gasoline. Therefore, it was shown that the addition of moderate amounts of methanol to gasoline should not appreciably affect the performance characteristics of an unmodified spark ignition engine. This effect is attributed to the following factors: a) the lower heating value per unit mass of methanol and b) the lower stoichiometric air-fuel ratio of methanol gasoline blends.

2.3 Engine emission characteristics

To investigate the effect of different ethanol/methanol gasoline blended fuels on exhaust emissions, results of the engine test at 2000 rpm with full throttle valve opening were selected for comparison, as shown in Fig. 8.

CO is a toxic gas that is the result of incomplete combustion. When ethanol and methanol containing oxygen is blended with gasoline, the combustion of the engine becomes better and therefore CO emission is reduced (Stump et al., 1996; Yasar, 2010). As seen in Fig. 8, the values of CO emission are about 3.654% (3.637%), 3.161% (3.145), 2.842% (2.825), 2.337% (2.306%), 1.851% (1.824%) and 1.275% (1.248%) for E5 (M5), E10 (M10), E20 (M20), E40 (M40), E60 (M60) and E80 (M80) fuels, respectively.

CO_2 is non-toxic but contributes to the greenhouse effect. The CO_2 concentrations at 2000 engine speed with full throttle valve opening using ethanol and methanol gasoline blends were decreased in comparison to gasoline. Because the ethanol and methanol contain less C atoms than gasoline, it gives off lower CO_2 (Knapp, 1998; Celik, 2008). The value of CO_2 emission is about 13.88% for gasoline fuel, while the values of CO_2 are about 13.12% (12.96%), 12.95% (12.78%), 12.25% (12.12%), 11.73% (11.68%), 10.42% (10.39%) and 9.78% (9.57%) with E5 (M5), E10 (M10), E20 (M20), E40 (M40), E60 (M60) and E80 (M80) fuels, respectively.

The HC concentration in the exhaust gas emission at 2000 rpm with full throttle valve opening, for gasoline fuel was 345 ppm, while the HC concentration of E5 (M5), E10 (M10), E20 (M20), E40 (M40), E60 (M60) and E80 (M80) fuels was 341 (304), 301 (297), 282 (223), 265 (234), 273 (261) and 380 (372) ppm, respectively. The HC concentration at 2000 rpm using E5 (M5), E10 (M10), E20 (M20), E40 (M40) and E60 (M60) was decreased by 8.98% (11.88%), 12.75% (13.91%), 18.26% (35.36%), 23.19% (32.17%) and 20.86% (24.35%), respectively, while the HC concentration of E80 (M80) fuels was increased by 10.14% (7.83%), respectively in comparison to gasoline. These results indicate that ethanol and methanol can be treated as a partially oxidized hydrocarbon when they are added to the blended fuel. Therefore, HC emissions decrease to some extent as ethanol/methanol added to gasoline increase. The low ethanol/methanol and high ethanol/methanol content blends reduce the cylinder temperature as the heat of vaporization of ethanol/methanol is higher when compared to gasoline. The lower temperature causes misfire and/or partial burn in the regions near the combustion chamber wall. Therefore, HC emissions increase, and engine power can slightly decrease. This behaviour has been reported by other investigators on various types of engines and conditions (Celik, 2008; Najafi et al., 2009).

It shows that as the percentage of ethanol/methanol in the blends increased, NOx emission was decreased. The NOx concentration in the exhaust gas emission at 2000 rpm with full throttle valve opening, for gasoline fuel was 2247 ppm, while the NOx concentration of E5 (M5), E10 (M10), E20 (M20), E40 (M40), E60 (M60) and E80 (M80) fuels was 1957 (1945), 1841 (1828), 1724 (1574), 1498 (1379), 1366 (1338) and 1223 (1207) ppm, respectively. The NOx concentrations at 2000 rpm using E5 (M5), E10 (M10), E20 (M20), E40 (M40), E60 (M60) and E80 (M80) fuels were decreased by 12.91% (13.44%), 18.07% (18.65%), 23.27% (29.95%), 33.33% (38.63%), 39.21% (40.45%) and 45.57% (53.72%), respectively in comparison to gasoline. Since ethanol/methanol have a higher heat of vaporization relative to that of neat gasoline, the blends temperature at the end of intake stroke decreases and finally causes combustion temperature to decrease. As a result, engine-out NOx emissions decrease (He et al., 2003; Celik, 2008).

The fuel blends containing high ratios of ethanol and methanol had important effects on the reduction exhaust emissions. Experimental results demonstrate that the most suitable fuels were E40 and M20 in terms of HC emission. CO, CO_2 and NOx concentrations of E80 and M80 were the lowest when compared to the other blend fuels.

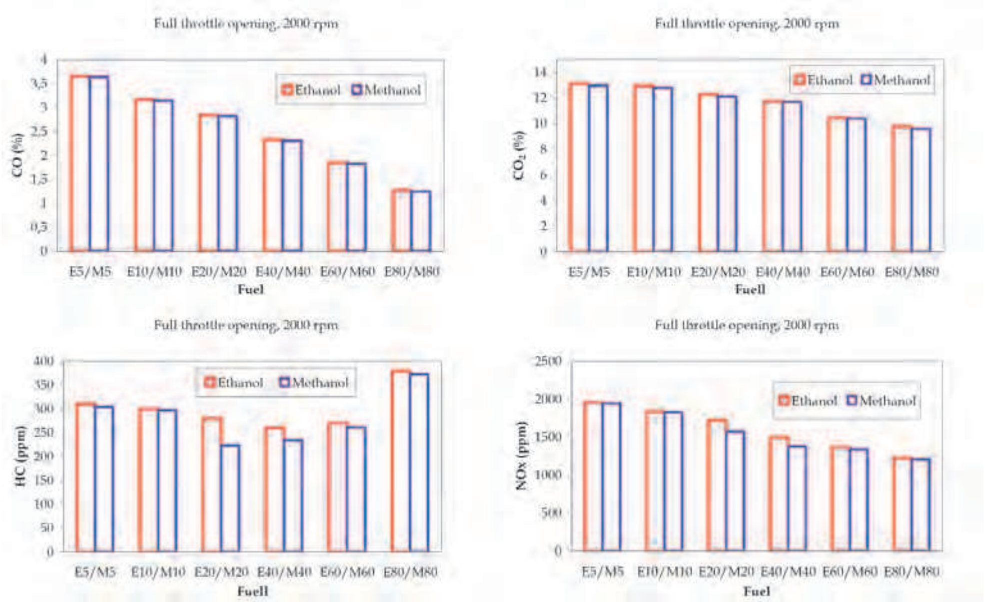

Fig. 8. The effect of various ethanol/methanol gasoline blend fuels on CO, CO_2, HC and NOx emissions.

3. Conclusion

The present chapter demonstrates the influences of ethanol and methanol addition to unleaded gasoline on non-road SI engine performance and emission characteristics. The use of ethanol gasoline blended fuels increase the brake power and brake torque, and decreases the BSFC. Methanol gasoline blended fuels show lower brake power and brake torque and higher BSFC than gasoline. The performance characteristics of methanol gasoline blended fuels are worse than for ethanol due to the influence of the combustion-related properties. The use of fuel blends containing high ratios of ethanol and methanol, at 2000 engine speed with full throttle valve opening, have significant effects on the reduction exhaust emissions.

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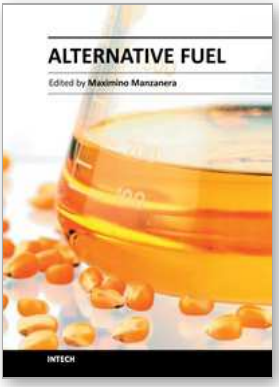

Alternative Fuel

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Renewable energy sources such as biodiesel, bioethanol, biomethane, biomass from wastes or hydrogen are subject of great interest in the current energy scene. These fuels contribute to the reduction of prices and dependence on fossil fuels. In addition, energy sources such as these could partially replace the use of what is considered as the major factor responsible for global warming and the main source of local environmental pollution. For these reasons they are known as alternative fuels. There is an urgent need to find and optimise the use of alternative fuels to provide a net energy gain, to be economically competitive and to be producible in large quantities without compromising food resources.

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