Experimental and theoretical investigation of methanol blends with gasoline on SI engine.

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Abstract

Alcohols have been used as a fuel for engines since 19th century. Among the various alcohols, methanol is known as one of the most suited renewable, bio-based and eco-friendly fuel for spark-ignition (SI) engines. The purpose of this study is to experimentally and theoretical analysis the performance of a four-stroke SI engine operating on methanol-unleaded gasoline blends M0, M5, M10, M15 and M20 containing 0%, 5%, 10%, 15 % and 20% of methanol by volume respectively. The experimental work was conducted on the experimental research engine SI engine, single cylinder, 4 stroke, carburetor fuel system "Variable Compression “Varicomp” duel Diesel / Petrol cycles with Dynamometer test unit" type (GR0306/000/036A) Prodit and made available for me by the Technical College, Baghdad. Under engine speed range was between (1000 to2500 rpm) with compression ratios (CR=8) and commercial gasoline were used in this study.

Whereas the theoretical part dealt with modeling of the same engine using the simulation and analysis engineering software "Lotus Engine Simulation"(LES) version (5.05). Lotus engine simulation (LES) program was used to study the effect of same parameters in experimental testing ,this program gives the best performance of engine at maximum brake power, and the same input data given to the program is taken from the results of experimental results.

The results obtained experimentally were compared with the simulation results in order to compare between the two cases. From the experimental results, The results show that the brake specific fuel consumption and volumetric efficiency were increased with the increase of methanol -gasoline blends content. The exhaust temperature , lost of heat energy with exhaust were decreased and exhaust emissions were reduced with the increase of methanol -gasoline blends content. The simulation results show that the brake specific fuel consumption and volumetric efficiency were increased with the increase of methanol -gasoline blends content.

Keywords: Methanol, Gasoline, Engine performance, Exhaust emissions

1. INTRODUCTION

Fuel additives are very important, since many of these additives can be added to fuel in order to improve its efficiency and its performance. Internal combustion engines have been in use for more than a century and have undergone tremendous changes in design, materials used and operating characteristics. Never ones during their long history of development have they lost their importance as the planet most widely used prime movers. In the past few decades, research efforts have been focused largely on better spark ignition engine, from the perspective of reducing the pollutant emissions without sacrificing performance and fuel economy. Another driving force behind the need to design engines amenable to operate on non-conventional fuels is the rapid depletion rate of currently used fossil fuels . Several studies have been made on the use of pure methanol and methanol-gasoline blends, which affect the engine performance and exhaust emissions, as a fuel in the SI engines.

Eyidogan et al. [1] tested 5%, 10% ethanol-gasoline blends and methanol-gasoline blends in an SI engine. In their experiments, a vehicle which has a four-cylinder, four stroke, multi-point injection system SI engine was used. They observed that the specific fuel consumption increased and exhaust gas temperature decreased depending on the rate of ethanol and methanol in the mixture. Suat Saridemir1,*, Turgay Ergin2 [2]Tested M0, M10, M20, M30 and M40 % methanol -gasoline blends and methanol-gasoline blends in an SI engine. They observed that the specific fuel consumption (SFC) and volumetric efficiency were increased with the increase of methanol -gasoline blends content. The concentration of carbon monoxide (CO) and hydrocarbon (HC) emissions were decreased when methanol blends were introduced. This was due to the high oxygen percentage in the methanol. S. Babazadeh Shayan1 et al ,[3] study the effect of Methanol (M5, M7.5, M10, M12.5, M15) on the performance and combustion characteristics of a spark ignition engine (SI).The experimental results showed that the performance of engine was improved with the use of methanol. Abu-Zaid et al ,[4] researched the performance of an SI engine when using 3%, 6%, 9%, 12%, 15% methanol blended gasoline, and reported that the maximum power output and the minimum brake specific fuel consumption were obtained from M15 fuel blend.

1.2 methanol gasoline blended fuels

Methanol 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.

Experimental apparatus and procedure

2. 1. Engine and Equipment

The internal combustion engine used in the experiments is a single cylinder, variable compression ratio varicomp type (GR 306/000/037A) made by the Prodit company, (Italy). It is 4 strokes, overhead poppet valve and is connected to a hydraulic dynamometer. The engine is adaptable to run either as a (SI) or as a (CI) engine. Spark Ignition engine is used in this work. The compression ratio was varied from (4 to 17.5). The engine is mounted on a stainless steel sturdy main frame which was purposely designed to contain and support all the apparatuses and for carrying out all experimental tests.

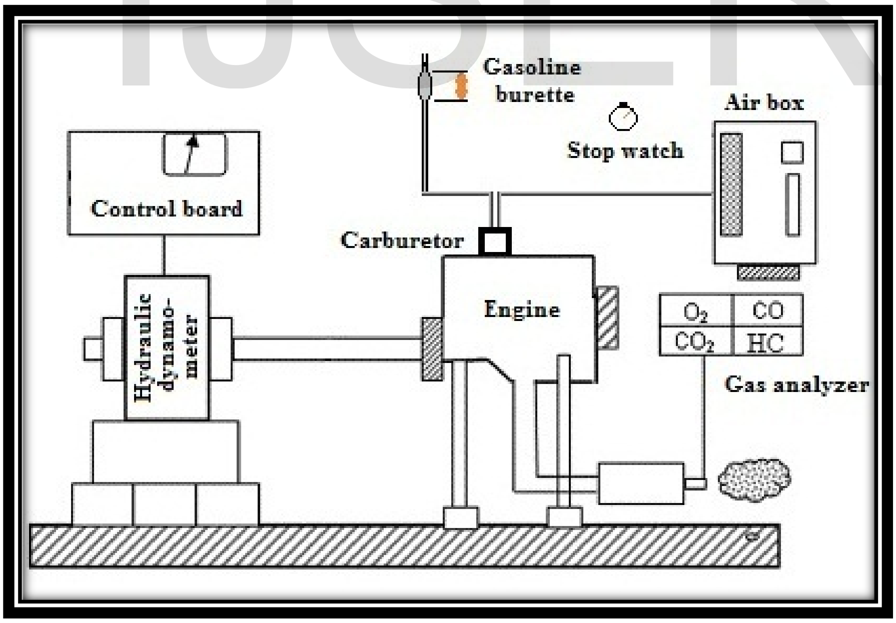


Figure (1): Schematic of experimental apparatus

2.2-Exhaust Gas Analyzer

The exhaust gas analyzer type (mod 2000- 4 Italy) was used to analyze the emissions of exhaust as shown in figure (2).The analyzer detects the CO-CO2-HC-O2 contents. The gases are picked up from the engine exhaust pipe by means of the probe. They are separated from water moisture through the condensate filter and then they are conveyed into the measuring cell. A ray of infrared light, generated by a transmitter, is send through the optical filters on to the measuring elements. The gases in the measuring cell absorb the ray of light at different wavelengths, according to their concentration. The H2 – N2 –O2gases due to their molecular composition, do not absorb the emitted ray. This prevents measuring the concentration through the infrared system. The CO-CO2-HC gases, thanks to their molecular composition, absorb the infrared rays at specific wavelengths (absorption spectrum).However the analyzer is equipped with a chemical kind sensor through which the oxygen percentage (O2) is measured.

Fig (2). The exhaust gas analyzer type (mod 2000- 4)

2. 3. Fuels

Three different fuel samples were experimentally investigated during this study. Base gasoline was obtained from the ALDORA Oil Refinery Company. Methanol with the purity of 99.9% was obtained from Laboratory for chemical. The base gasoline (G) was mixed with methanol (M) to get two test mixtures(M5, M10, M15 and M20).The fuel blends were prepared just before starting the experiment to ensure that the fuel mixture is homogeneous.

2.4 Procedure

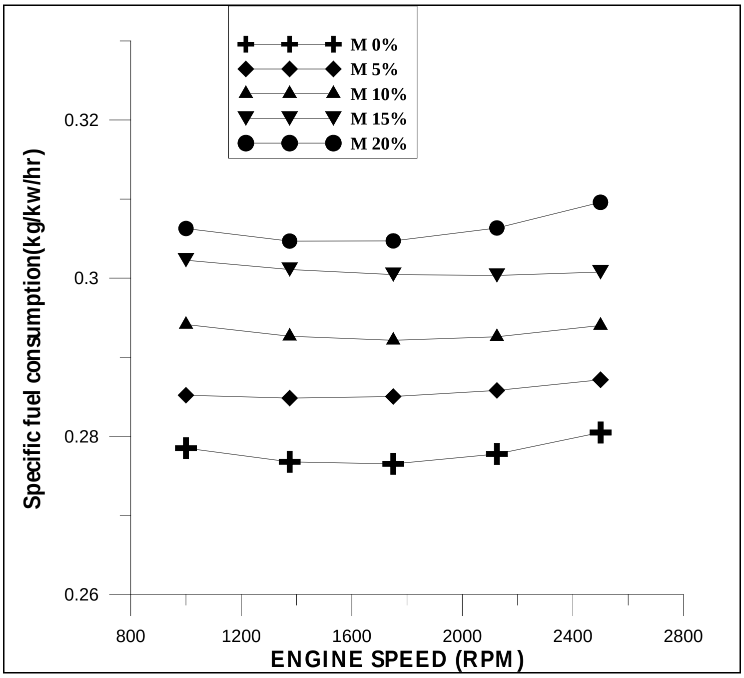
The engine was started and allowed to warm up. Engine tested were performed at 1000,1500, 1750, 2000, and 2500 rpm engine speed at wide open throttle. Before running the engine to a new fuel blend, it was allowed to run for a sufficient time to consume the remaining fuel from the previous experiment.

3- RESULTS and DISCUSSIONS

A-Experimental results

1-BSFC (Brake Specific Fuel Consumption)

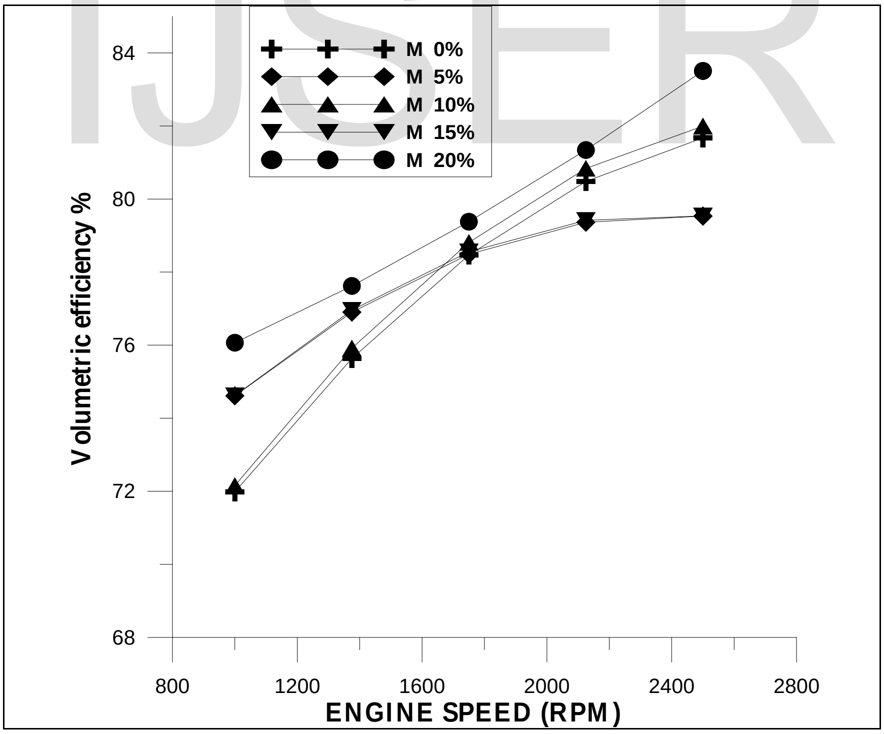
Fig.1 shows the variations in brake specific fuel consumption with respect to engine speed at constant load. It is shown in the figure that 20% methanol addition in base fuel causes increment in BSFC in comparison to iso-octane at 1600, 1750 and 2000 rpm. It is well known fact that heating value of fuel affects the BSFC. The lower energy content of methanol iso-octane fuels causes some increment in BSFC of the engine when it is used without any modification. The increment mainly depends upon the percentage of methanol addition in iso-octane. The heating value of methanol are approximately 39.27% & 54.85% less than the values of iso-octane. Therefore, more blends of fuel are required to produce the same power at the same operating conditions due to its lower heating value in comparison to base fuel.



Fig(1). The effect of methanol addition on the BSFC

2-Volumetric Efficiency

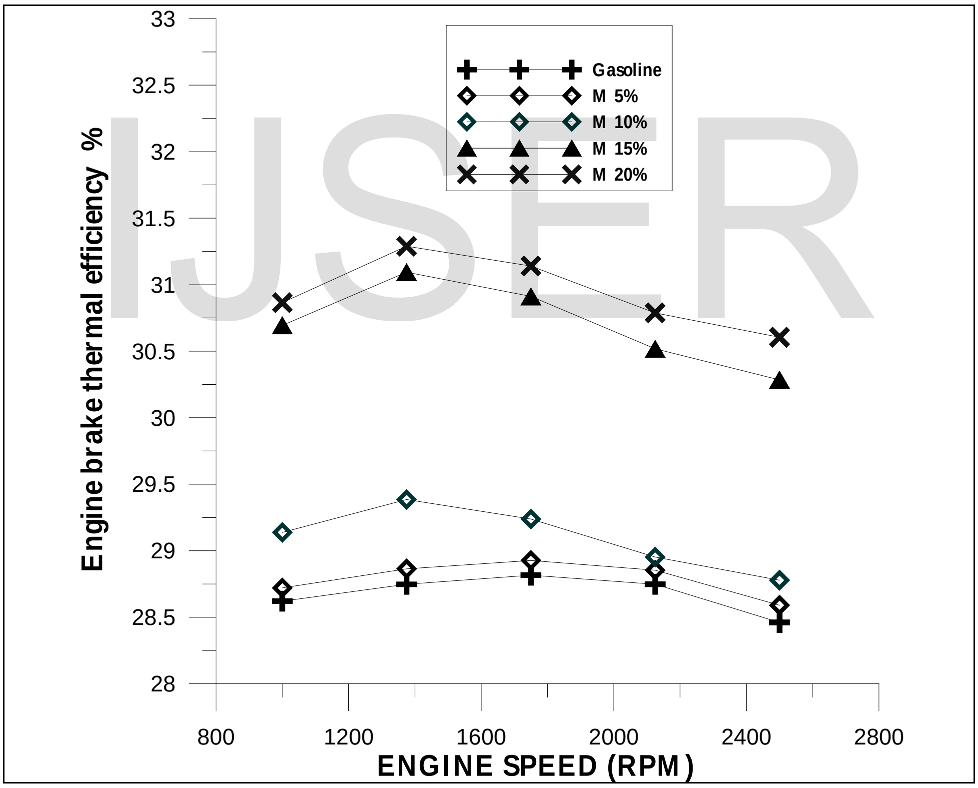
Fig. 2 represents the change in volumetric efficiency with the change in engine speed at the constant load for all tested fuels. It is shown in the figure that volumetric efficiency of M20 is maximum among all the fuels and it is because of the reasons that as liquid fuels have high latent heat of vaporization, they produce a cooling effect on the intake charge during vaporization. Therefore, there will be an increase in intake charge density and consequently in volumetric efficiency. A/F ratio is another important parameter that affects volumetric efficiency. When stoichiometric A/F ratio is high that means there is more quantity of air injected in inlet air and results in increased volumetric efficiency. The methanol has highest latent heat of vaporization and A/F ratio is low therefore volumetric efficiency of M20 is maximum. The volumetric efficiency of iso-octane is lower than the M20, M15, M10, and M5 and it is because of the reason that latent heat of vaporization of iso-octane is lowest among all the fuels.



Fig(2). The effect of methanol addition on the volumetric efficiency

3-Thermal Efficiency

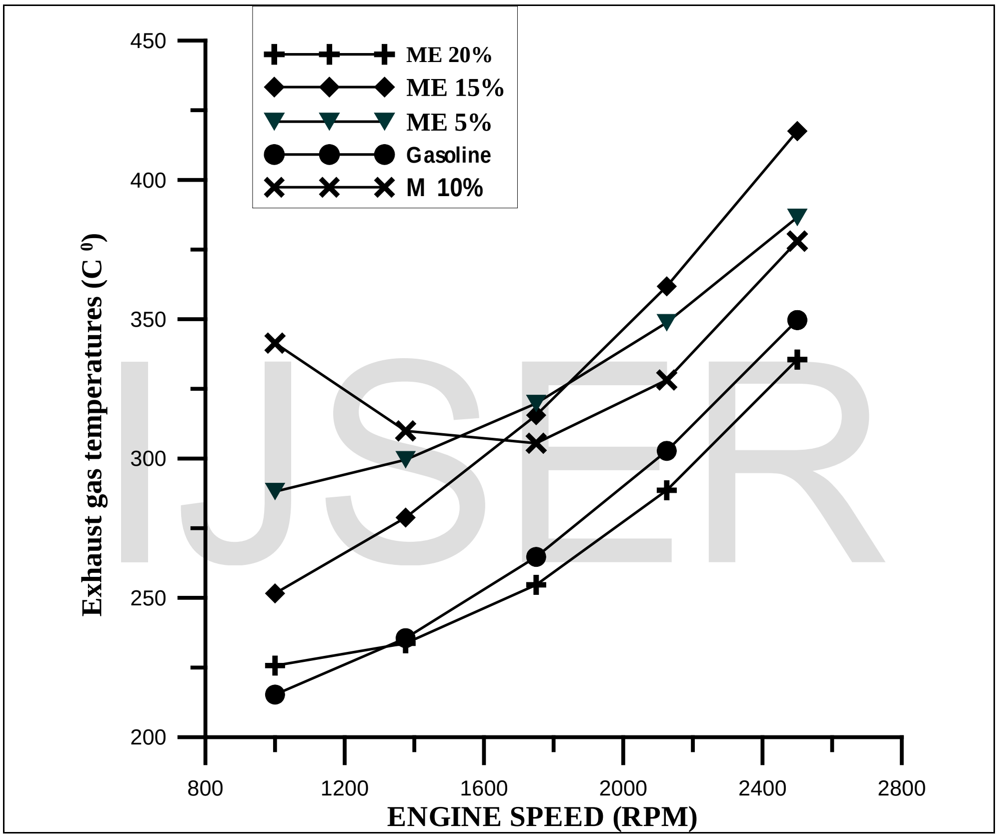
Fig. 3 represents the effect of engine speed on the thermal efficiency of various fuels at a constant load. It is shown in the figure that thermal efficiency increases with the increase in engine speed and it is because of the reason that at higher speed, less quantity of heat is being lost through the cylinder wall. Maximum thermal efficiency was obtained for M20 at a engine speed of 1200 & 1750 rpm. It is interesting to note that thermal efficiency of M20 fuel is higher than the base fuel. So there is a complete combustion of the fuel at 1400 rpm which results in high thermal efficiency.



Fig**(**3). The effect of methanol addition on the thermal efficiency

4-Exhaust Temperature

Fig.4 shows the variations in exhaust gas temperature with respect to engine speed for various fuels tested at a constant load. It is shown in the figure that exhaust temperature increases with the increase in engine speed for all the tested fuels. This is explained with several reasons. With the increase in engine speed, combustion gases gets less time to remain in contact with cylinder wall and therefore more quantity of energy is released with exhaust gases which increases the temperature of exhaust gases. At 2000 rpm, the value of exhaust temperature is maximum for M20 fuel and minimum for E5 fuel. At 1750 rpm, the value of exhaust temperature is maximum for M15 fuel and minimum for M20 fuel. These variations in exhaust temperature can be attributed to increase in thermal efficiency or A/F ratio which affects the combustion temperature.



Fig(4). The effect of methanol addition on the exhaust gas temperature

5-Effects of Alcohol Blending on Exhaust Emissions

The CO emissions in the exhaust gases represent the lost chemical energy that is not fully used in the engine. Generally, CO emission is affected by air–fuel ratio, fuel type, combustion chamber design and atomization rate, start of injection timing, injection pressure, engine load, and speed. The most important among these parameters is the air–fuel ratio. The variation in the CO emissions of the engine is shown in Fig5. when methanol–gasoline fuel blends are compared to pure gasoline fuel. The results show that the concentration of carbon monoxide decreases with increases methanol blending ratios. This is due to the reduction in carbon atoms concentration in the blended fuel and the high molecular diffusivity and high flammability limits which improve mixing process and hence combustion efficiency. It is observed that CO increases with increasing load for all the percentage of methanol. If percentage of additive increases CO reduces. This is due to the batter combustion of gasoline when methanol used as an additive. The concentration of CO decreases with the increase in percentage of methanol in the fuel. This may be attributed to the presence of O2 in methanol, which provides sufficient oxygen for the conversion of carbon monoxide (CO) to carbon dioxide (CO2).

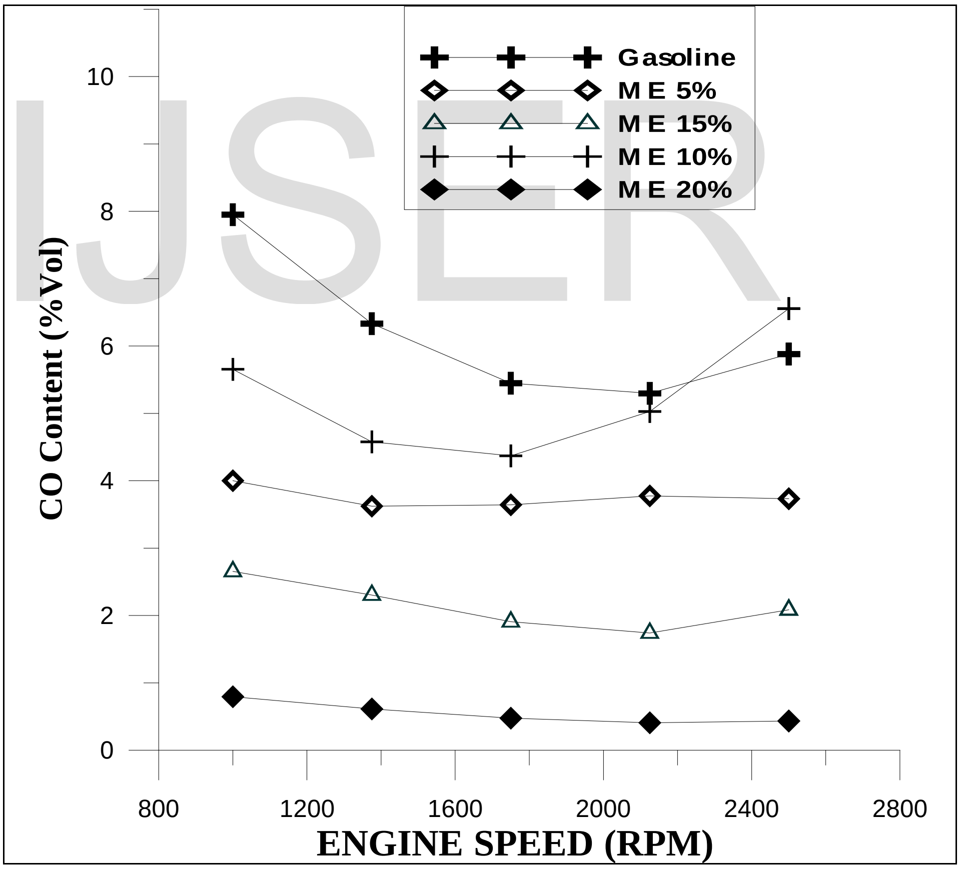


Fig. 5. The effect of methanol addition on the CO emission

Unburned hydrocarbon emissions (UBHC) consist of fuel that is a combination of completely unburned and partially burned. UBHC emission is mostly due to the retention of unburned fuel in crevices in the cylinder. Figs. 6 show the changes in the UBHC emission of the engine using methanol–gasoline fuel blends. As seen in the figures, the UBHC emission was gradually reduced when the methanol ratio increased in the fuel blend, due to the effect of different methanol contents on UBHC emission. The petrol fuel operation showed the slightly higher concentrations of UBHC in the exhaust at all loads. Since methanol is an oxygenated fuel, it improves the combustion efficiency and hence reduces the concentration UBHC in the engine exhaust.

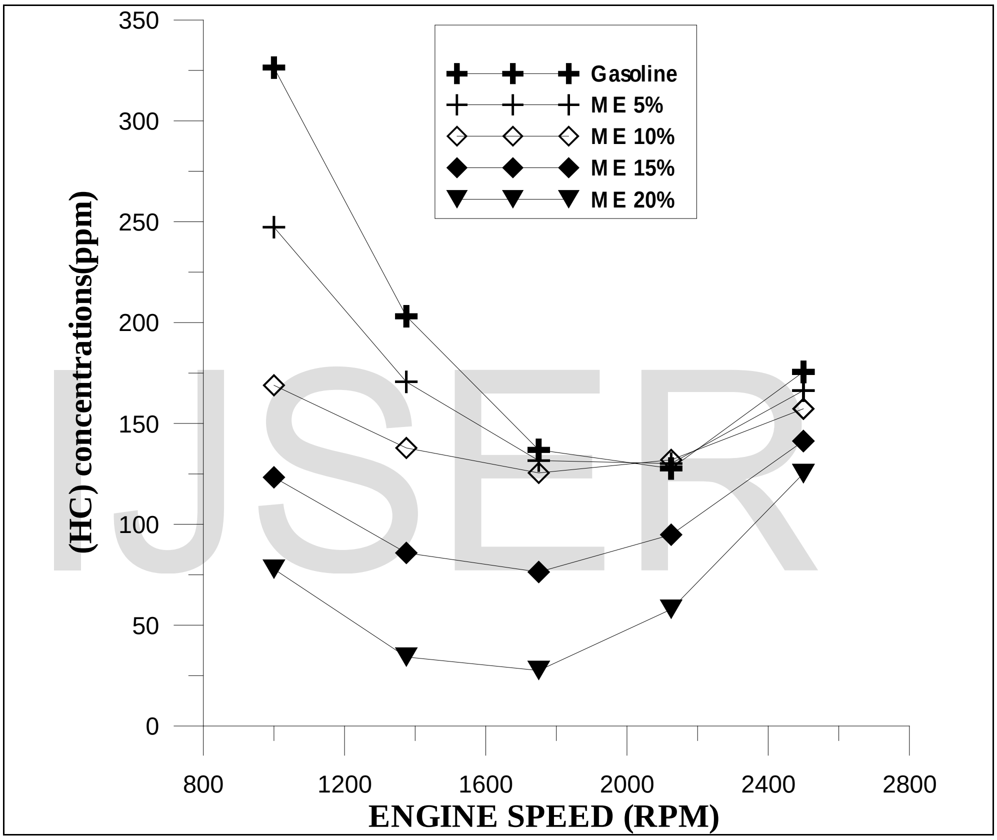


Fig. 6 . The effect of methanol addition on the HC emission

B-Engine simulation results

Engine performance including brake specific fuel consumption , volumetric efficiency and brake thermal efficiency by used effect of same parameters in experimental testing. Figure (7) show the network of (S-I-engine) used in this study.

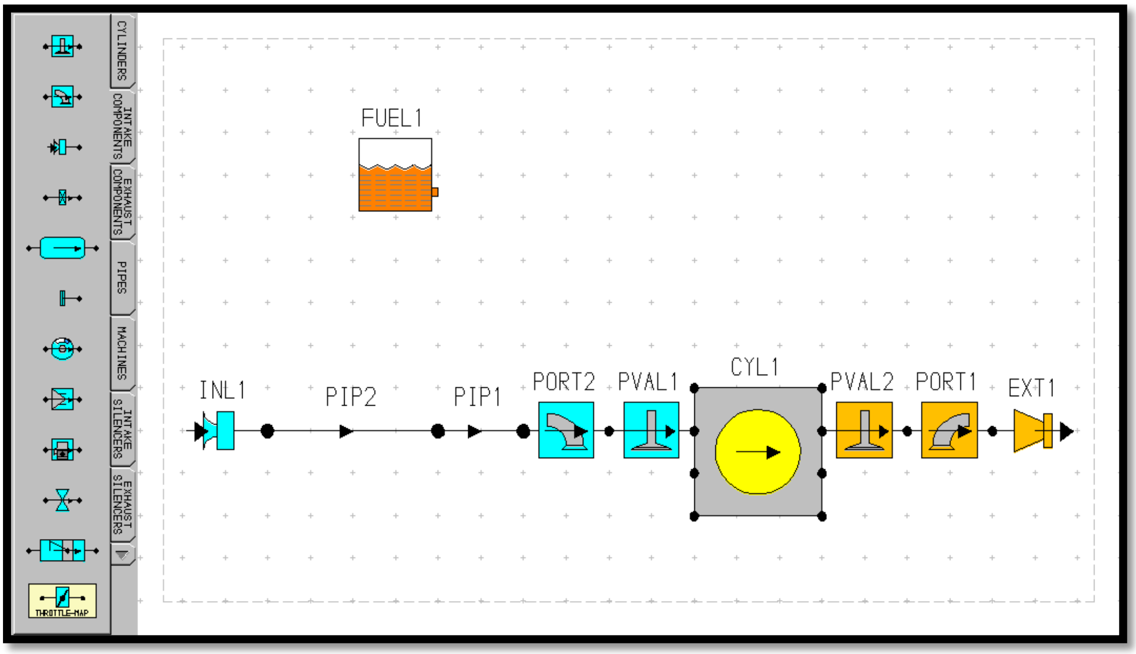
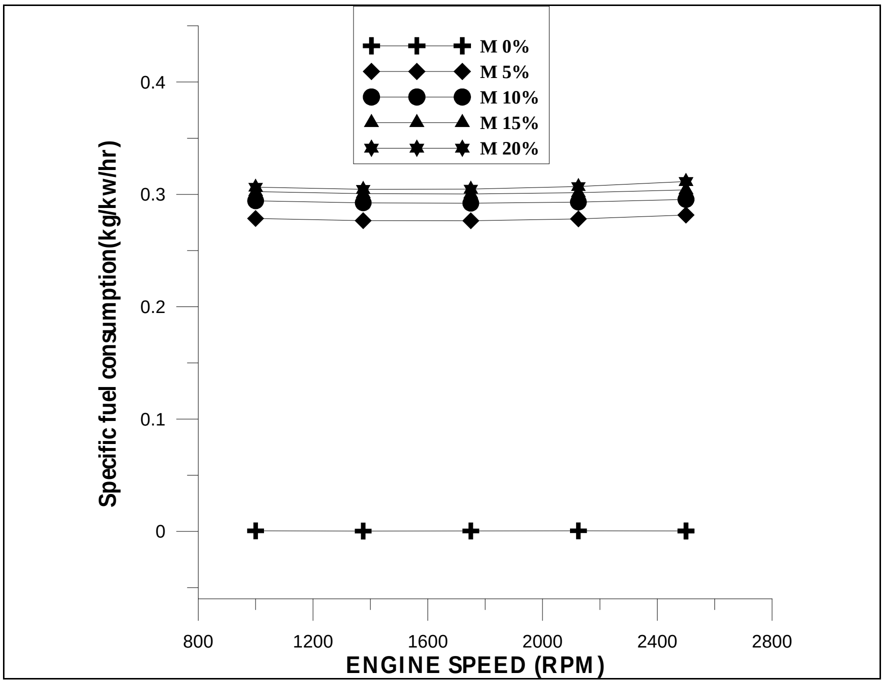


Fig (7). The network model of (S-I- engine).

1-BSFC (Brake Specific Fuel Consumption)

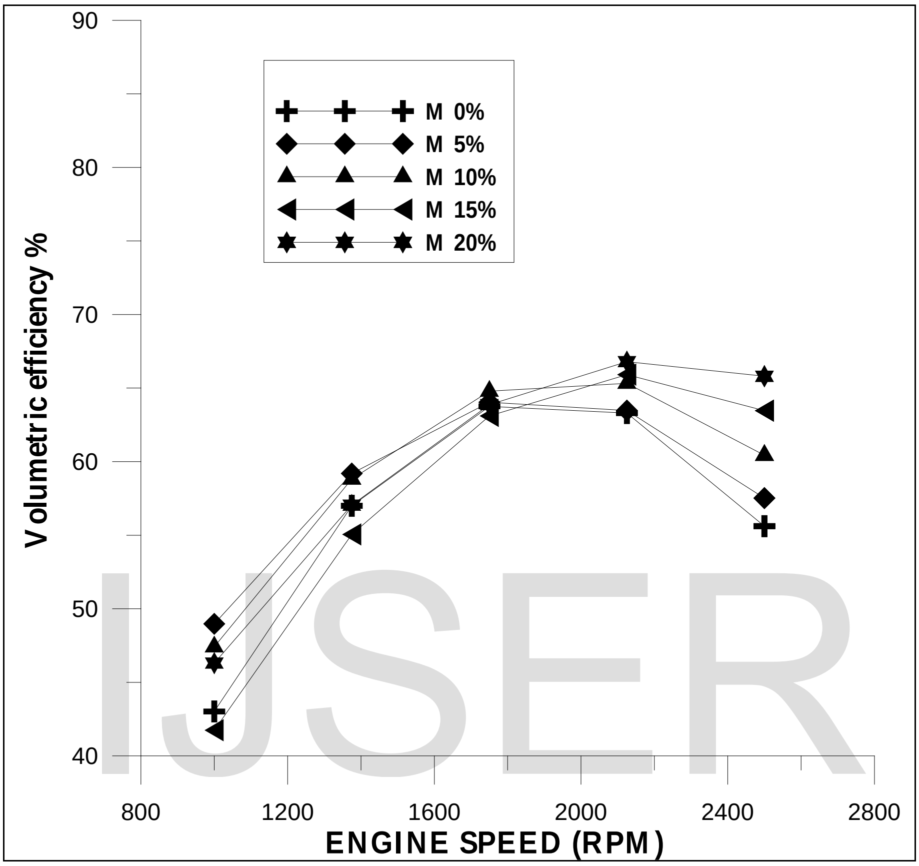
Fig.8 shows the variations in brake specific fuel consumption with respect to engine speed at constant load. It is shown in the figure that 20% methanol addition in base fuel causes increment in BSFC in comparison to iso-octane.



Fig(8). The effect of methanol addition on the BSFC

2-Volumetric Efficiency

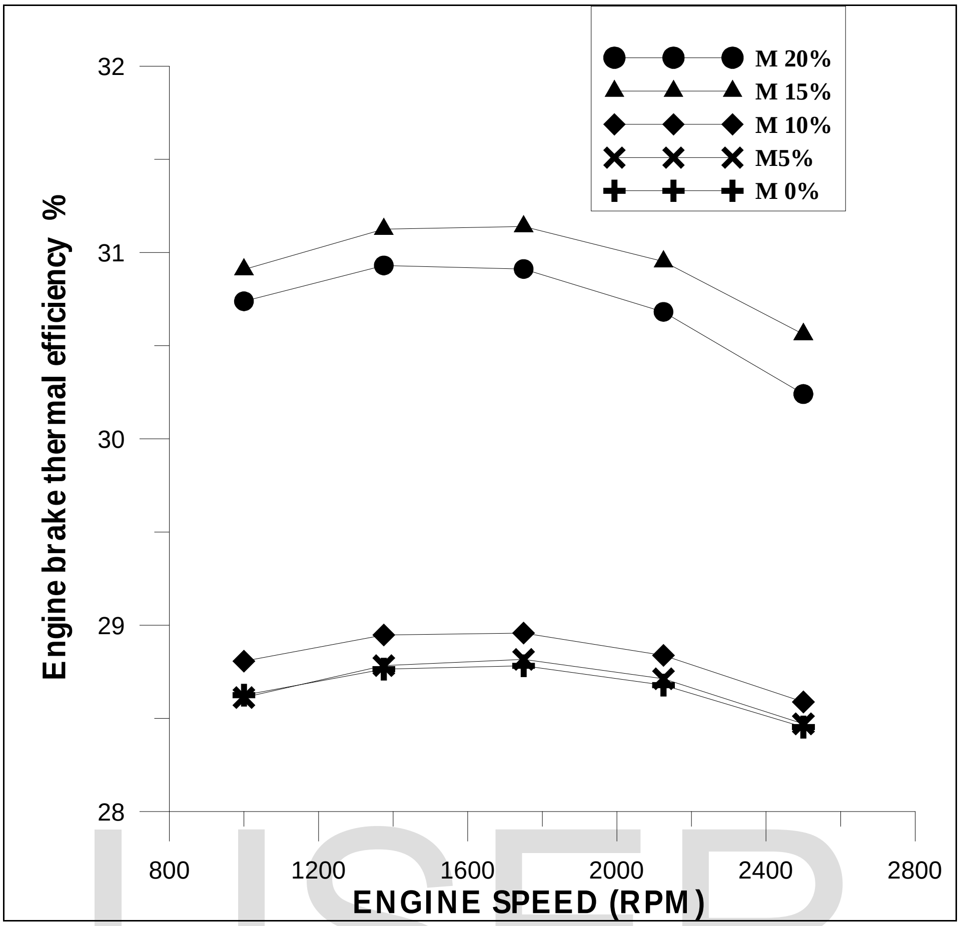
Fig. 9 shows the relationship between the volumetric efficiency and the percentage of methanol in the fuel blends. It is obvious from Fig. 9 that as the methanol percentage increases, volumetric efficiency increases, since the amount of air introduced into the engine cylinder increases.



Fig(9). The effect of methanol addition on the volumetric efficiency

3-Thermal Efficiency

Fig. 10 shows the relationship between the thermal efficiency and the percentage of methanol in the fuel blends. It is obvious from Fig. 10 that as the methanol percentage increases, thermal efficiency increases.



Fig(9). The effect of methanol addition on the thermal efficiency

4-CONCLUSION

In this study, it was seen that when engine was fueled with methanol–gasoline blend, engine performance parameters such brake thermal efficiency and volumetric efficiency increases with increasing methanol amount in the blended fuel while bsfc decreased. The results show that the concentration of exhaust emissions decreases with increases methanol blending ratios.

Nomenclature

Symbol	Meaning	Unit
A/F	Air to fuel ratios	
Bp	Brake power	KW
bsfc	Brake Specific fuel consumption	kg/(kW.hr)
CO	Carbon monoxide	
CO_2	Carbon dioxide	
S.I.engine	spark ignition engine	
HC	Unburned hydrocarbons	Ppm
Ho	Differential manometer	Cm
$\dot{m}a$	Air mass flow rate	kg⁄sec
$\dot{m}f$	Fuel mass flow rate	kg⁄sec
L.C.V	Lower calorific value	(kJ/kg)
T	Torque of engine	(N.m)
N	rotational speed	(rpm)

The following equations were used in calculating engine performance parameters:[5]

1- The brake specific fuel consumption.

$$\text{bsfc} = \frac{\dot{m}f}{bp} \times 3600 \quad kg/(kW.hr) \text{.....(1)}$$

2- Brake thermal efficiency is defined as in Eq.

$$\eta\text{bth} = \frac{bp}{\dot{m}f\ L.C.V} \text{ .... (2)}$$

3- Air mass flow rate

$$\dot{m}a, act = \frac{12\sqrt{(h\_o\ )}}{3600} \times \rho\ air \quad kg/sec \text{...................(3)}$$

4- Fuel mass flow rate

$$\dot{m}f = \frac{vf \times 10^{-6}}{time} \times \rho_f \quad \text{kg⁄sec..................(4)}$$

5- Air-fuel ratio

$$\text{A/F} = \frac{\dot{m}a}{\dot{m}f} \text{.................. (5)}$$

6- Brake power

$$bp=\frac{2\pi\times N\times T}{60\times 1000}\ \text{kW}\ldots\ldots\ldots\ldots\ldots(6)$$

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