Al-Khwarizmi Engineering Journal,Vol. 12, No. 3, P.P. 38- 51 (2016)

Al-Khwarizmi Engineering Journal

Gasoline, Ethanol and Methanol (GEM) Ternary Blends utilization as an Alternative to Conventional Iraqi Gasoline to Suppress Emitted Sulfur and Lead Components to Environment

Miqdam Tariq Chaichan

Energy and Renewable Energy Technology Center/University of Technology

Email: 20185@uotechnology.edu.iq

(Received 19 October 2015; accepted 9 March 2016)

Abstract

Iraqi conventional gasoline characterized by its low octane number not exceed 82 and high lead and sulfur content. In this paper tri-component or ternary, blends of gasoline, ethanol, and methanol presented as an alternative fuel for Iraqi conventional gasoline. The study conducted by using GEM blend that equals E85 blend in octane rating. The used GEM selected from Turner, 2010 collection. G37 E20 M43 (37% gasoline + 20% ethanol+ 43% methanol) was chosen as GEM in present study. This blend used in multi-cylinder Mercedes engine, and the engine performance, and emitted emissions compared with that produced by a gasoline engine.

The results show that this blend can formulate with available Iraqi produced materials. GEM ternary blend offers significant advantages in terms of engine performance compared to gasoline. Also, GEM higher useful compression ratio (HUCR) = 9.25 while gasoline HUCR=7.5. The increment in engine bp was 24.12%, BSFC reduced by 13.9% and brake thermal efficiency increased by 19.59%. The volumetric efficiency increased by 8.06%. Also, CO, HC concentrations were reduced by 30.5%, 25.16% respectively. Smoke opacity reduced by 46.49% and CO_2 concentrations reduced by 5% as well as NOx concentrations that reduced by 1.75%.

Keywords: *Ternary blends, GEM, performance, emissions, higher useful compression ratio.*

1. Introduction

Sulfur and lead content in Iraqi gasoline is considered an environment obstacle in all criterions. Many researchers studied the effect of these pollutants content in Iraqi conventional petrol and defined its hazards. The U.S. Energy Information Administration (EIA) declared that sulfur content in Iraqi petrol produced from Basra wells increased from 1.95 % to recently at around 2.7-2.8 % sulfur content [2]. In the northern Kirkuk field, sulfur content increased from 1.97 % in 1988, to above 2 % after 2003 [1 & 2]. Sulfur has low ignition temperature that its presence can reduce the fuel self ignition temperature. It is found that the response of gasoline fuel to lead compounds is reduced by the presence of sulfur. Thus, the presence of sulfur in the fuel will promote knock in the engine.

Also, vehicles number increased significantly after the year 2003 all over Iraq that resulted in an increase in lead and sulfur emissions into the air. Al-Khalidy [3] measured lead concentrations in 25 stations in Babylon Governorate southern Baghdad. The measured concentrations compared to the standard limits of United States Environmental Protection Agency (EPA). The results showed that the average of measured lead concentrations during the year 2010 was (3.13 $\mu g/m^3$) which was greater than EPA standard limits (2 $\mu g/m^3$).

Ismayyir clarified that Iraqi gasoline production is rather stable but Iraqi produced gasoline specifications needs to be improved. The improvement must continue lower values of Lead and Sulfur [4]. Chaichan studied the emitted particulate matters (PM) and lead (Pb) emissions from single cylinder spark-ignition (SI) engine fueled with Iraqi gasoline. The results showed that lead concentrations depend mainly on fuel quantity entering the engine in spite of any other parameter. Pb concentrations increased with increasing equivalence ratio from lean to rich, increasing engine speed from low to high speeds and increasing torques from low to high [5]. Table 1 represents gasoline specifications according to different standards while Fig. 1 shows changes in Iraqi gasoline blends' specifications. Fig. 2 represents a contour map of the Pb distribution in Baghdad city.

Table 1,
Gasoline specifications according to different standard [6]

Standards	DS-II	Euro III	Euro IV	Iraq*
Year of Implementation	2000-2001	2005	2010	2000
Sulfur, PPM	500	150	50	500
RON, Min	88	91	91	85
MON, Min	-	81	81	-
Benzene, Max., Vol.%	5/3	1	1	-
Aromatics, Max., Vol.%	-	42	35	-
Olefin, Max., Vol.%	-	21	21	-
RVP, kPa	35-60	60 Max.	60 Max.	44-82.5

*- Marketing specifications of Iraqi petroleum products.

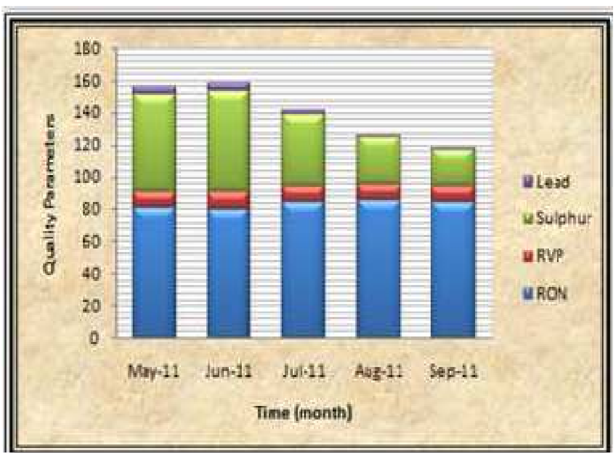

Fig. 1. Changes in Iraqi gasoline blends' specifications [4].

Iraqi gasoline depends on Pb compounds to enhance its octane number, but there are many additives that their addition to gasoline improves its octane rating. Methanol and ethanol considered the best of these additives due to its advantages including energy density, distribution infrastructure compatibility and the possibility of efficiency improvement and pollutant emissions reduction [8]. In spite of all its benefits whether on combustion or emissions, ethanol is known to be aggressive to certain materials used in the vehicle fuel systems construction [9]. In the recent study, the concept of the ternary blend reviewed, and the results of engine performance and emitted emissions reported. The use of ternary blends introduced as an improved advancement to reduce the dependence on Iraqi gasoline with it has high levels of sulfur and lead.

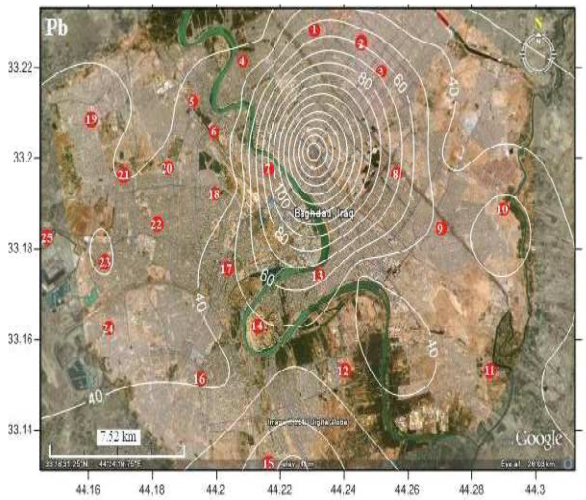

Fig. 2. Contour map shows the Pb distribution in Baghdad [7].

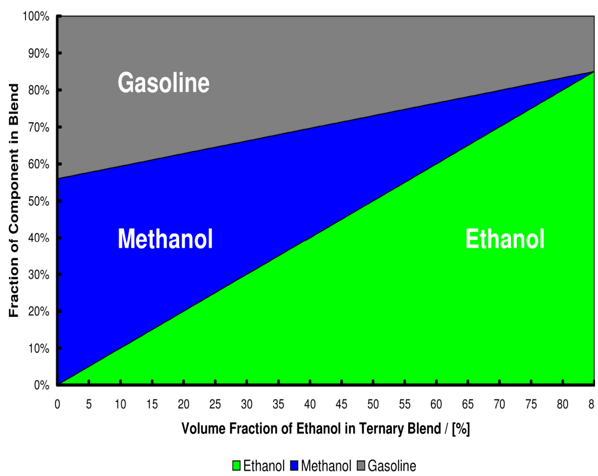

Fig. 3. Family of isostoichiometric GEM blends equivalent to conventional E85 [14].

The fuel blending concept used in the tests to limit the biomass quantity used to produce ethanol by co-blending it with both methanol and gasoline. Turner first introduced this concept in a conference presentation [10]. A detailed published study as SAE paper followed this presentation [11]. This concept can describe as a ternary blend of gasoline; ethanol and methanol can replace a binary gasoline-ethanol mixture (such as E85). This replacement depends on the volume fraction of each component in a way to yield the same stoichiometric air-fuel ratio (AFR). AFR for E85 is 9.7:1 depending on the used gasoline, so a family of equivalent ternary blends can be created [12]. Here, the consideration of two prominent borders like the term G15 E85 M0 that can substitute by G44 E0 M56 and between these two limits a description of a family of blends as GEM blends [13].

Turner et al. put a diagram (Fig. 3) specifies the equivalences that must be used to derive any E85-equivalent blend. When one charts a vertical line, the proportions of the individual blend components read from the y-axis where this line crosses the boundaries between them. All of the isostoichiometric blends have essentially identical volumetric energy content (based on the masses and densities of the individual components) [10 & 11]. Also, any vertical line drawn gives a ternary blend with different percentages of gasoline, ethanol, and methanol. These blends limit and reduce the need for high quantities of ethanol, which means reducing its side effects. Besides, a large part of gasoline replaced with methanol that is a better from an energy security viewpoint [14].

The ternary blend suggested by Turner believed to have the potential to function in Iraq due to the possibility of producing ethanol and methanol from sustainable sources. There is no need for additional infrastructures. Many studies showed that GEM ternary blends formulated with a high proportion of methanol can be cheaper than gasoline on a cost per unit energy basis [15 & 16].

This study aims to provide a practical alternative for Iraqi gasoline that can suppress emitted sulfur and lead components to the environment. The usage of ethanol and methanol is a realistic since both can be produced from sustainable resources that are available in Iraq, or from natural gas and petroleum resources that Iraq is one of the main reservoirs of these materials in the world.

2. Experimental Setup

2.1. Apparatus

Two engines used in the recent study. The first one is a spark ignition engine type (PRODIT GR306/0001) which was used to evaluate the using blends higher useful compression ratio at optimum spark timing. Prodit engine is water cooled, single cylinder, four strokes, and variable compression ratio. Figs (4 a & b) represents the general arrangement of the experimental rig while Table 2 illustrates engine specifications.

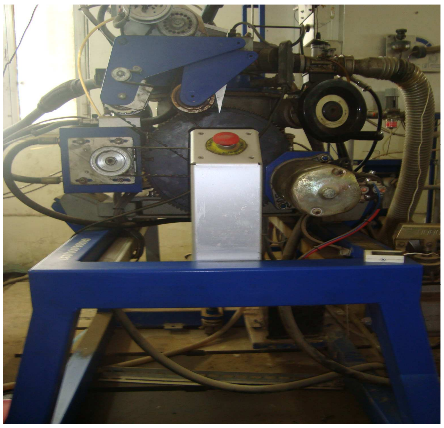

Fig. 4a. Single cylinder Prodit spark ignition engine.

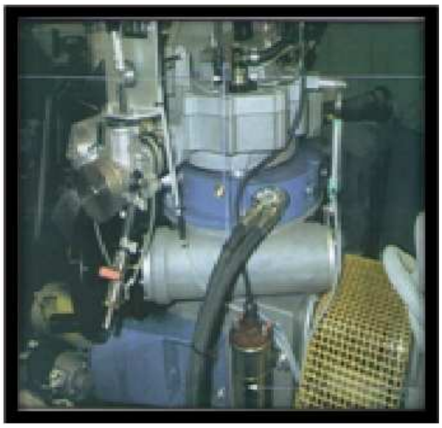

Fig. 4b. Single cylinder Prodit spark ignition engine.

The engine rig coupled to an air tank that damped out the pressure variations in the entering air to the carburetor. The volume of the air drawn measured with the aid of a manometer that translates the pressure drop across an orifice. This set calibrated in the laboratory. The engine supplied fuel comes from the main fuel tank passing through a graduated measuring fuel gauge (burette). The engine output torque measured using a hydraulic dynamometer. This dynamometer calibrated in the laboratory employing calibrated weights. The exhaust gas temperature measured using several thermocouples type K at the beginning of the exhaust tube. The thermocouples calibrated in the laboratory by comparing its readings with that of a set of calibrated thermocouples.

Table 2,
Prodit Engines Specifications.

Manufacturer	PRODIT	No load speed range	500-3600 rpm (Otto cycle)
Cycle	Otto or Diesel, four strokes	Load speed range	1200-3600 rpm (Otto cycle)
Number of cylinder	1 vertical	Intake star	54^o before T.D.C
Diameter	90mm	Intake end	22^o after T.D.C
Stroke	85mm	Exhaust start	22^o before T.D.C
Compression ratio	4-17.5	Exhaust end	54^o after T.D.C
Max .power	4 kW 2800 rpm	Fixed spark advance	10^o (spark ignition)
Max .torque	28 Nm at 1600 rpm	Swept volume	541cm^3

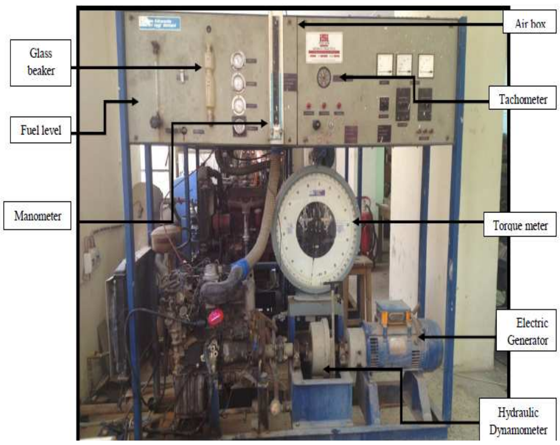

Fig. 5. the experimental rig of SI Mercedes engine.

The second spark ignition engine was Mercedes-Benz type, and it was used in the recent study to evaluate the effect of ternary blend fuels on engine performance and emissions. This engine was used in the tests because it represents a wide range of the cars engines in Iraq streets. This engine has 2 liters displacement volume, water cooled, 4-strokes and 4 cylinders. A hydraulic dynamometer coupled to the engine used to measure the brake torque. Fig. 5 shows the experimental rig of the engine, and Table 3 lists the main technical specifications of this engine. This engine selected to the study due to its closeness to the majority of the vehicle's engines used in Iraq.

Table 3,
The main technical specifications of the Mercedes-Benz 200 CE-16 engine.

Item specification	
Engine	4-cylinder-inline engine (four-stroke)
Displacement	2 liters
The production year	1992
Fuel System	Carburetor
Cooling	Water
The piston stroke length	78.70 mm
the cylinder diameter	89.90 mm
The compression ratio	9.60:1
The maximum power delivered by the engine	100 kW at 5500 rpm
Maximum torque	190 Nm at 4000 rpm

2.2. Emission Analyzing

NOx, CO, CO_2 and HC emissions were measured by using gas analyzer type HG-550. The calibrations reading for this measuring device obtained from the factory inspection sheet produced by Hephzbah Co. Ltd at 16/10/2013 since it is a new appliance. Smoke Analyzer type "MOD .SMOKY" used to measure smoke opacity in the recent study. The working principle of this device is the usage of optic absorption of the smoke. A halogen lamp provides the bright of light. The electric signal generated by an optical sensor is electrically conditioned and computed by a microprocessor and then displayed as absorption % vol. The smoke analyzer calibrated in the Central Organization for Measuring and Quality Control labs. The engine noise measured employing a precision sound pressure level meter supplied with microphone type 4615. The device calibrated employing a standard calibrator type pisto phone 4220. Fig. 6 shows the Sniffer L-30 device used to collect the emitted PMs. PMs collected using Whatmann-glass micro-filters. The filters weighed before and after the sampling operation that extend for one hour. Each filter saved in plastic bag temporarily at the end of collecting samples operation until weighing and analyzing the results. Atomic spectrum absorption system was used to evaluate lead concentrations in particles samples manufactured by Shimadzu company type (AA-6200) made in Japan. Fig. 7 represents this system.

Fig. 6. Drawing air equipment to collect PM type Sniffer

Fig. 7. the system used in evaluating of Pb concentrations in particulates (the atomic spectrum absorption system)

The following equations used to calculate the engine performance parameters [17]:

1- Brake power

$$bp = \frac{2\pi * N * T}{60 * 1000} \quad kW \qquad \text{…. (1)}$$

2- Brake mean effective pressure

$$bmep = bp \times \frac{2*60}{V_{sn}*N} \quad kN/m^2 \qquad \text{…. (2)}$$

3- Fuel mass flow rate

$$\dot{m}_f = \frac{v_f \times 10^{-6}}{1000} \times \frac{\rho_f}{time} \quad {kg}/_{sec} \qquad \text{…. (3)}$$

The tested fuels densities (ρ_f) were measured in the Al-Doura Refinery labs.

4- Air mass flow rate

$$\dot{m}_{a,act.} = \frac{12\sqrt{h_o * 0.85}}{3600} \times \rho_{air} \quad \frac{kg}{sec} \qquad \text{…. (4)}$$

$$\dot{m}_{a_{theo.}} = V_{s.n} \times \frac{N}{60*2} \times \rho_{air} \quad \frac{kg}{sec} \qquad \text{…. (5)}$$

5- Brake specific fuel consumption

$$bsfc = \frac{\dot{m}_f}{bp} \times 3600 \quad \frac{kg}{kW.hr} \qquad \text{…. (6)}$$

6- Total fuel heat

$$Q_t = \dot{m}_f \times LCV \quad kW$$

7- Brake thermal efficiency

$$\eta_{bth.} = \frac{bp}{Q_t} \times 100 \quad \% \qquad \text{…. (7)}$$

8- Equivalence ratio [18]:

$$\emptyset = \frac{\dfrac{[G]}{[air] - \frac{[E]}{([E]/[air])_{st}} - \frac{[M]}{[M]/[air]_{st}}}}{\left(\frac{[G]}{[air]}\right)_{st}} \qquad \text{….. (8)}$$

2.3. Materials

Two Iraqi gasoline with ON=82 & 77 produced by Al-Doura refinery used in the recent study. Iraqi gasoline characterized by its low octane number and high lead content. The gasoline properties obtained from in the Al-Doura Refinery Fuel Laboratory. Gasoline with 82 ON used as a reference fuel for comparison because it is the conventional fuel in Iraq while gasoline with 77 ON utilized in the E85 and ternary blends because it is unleaded fuel. Ethanol (99.7% purity) employed in this work. It was distillated from Iraqi drink named (Araq) for several times to purify it from any residuals. E85 (85% Ethanol–15% gasoline) blended fuel prepared by mixing the ethanol (85% by volume) with gasoline (77 ON). Methanol characterized by its phase separation where it can fall out of solution when it is being blended with gasoline in the absence of any dedicated co-solvent. Qi [20] studied methanol-gasoline phase separation but without blending for constant stoichiometry, his result shows that this phenomenon depends on ambient temperature, and it occurs with degrees less than −15°C. Iraqi ambient temperatures do not reduce to this extent even in the north of Iraq where high mountains and lower temperature degrees. Adding ethanol reduces separation trend of methanol. Methanol mixed first with ethanol, and then it blended with gasoline. Table 4 represents the typical properties of the used materials.

Table 4,
The specifications of gasoline, ethanol, methanol and the tested blends [14]

Fuel component	Gasoline	Ethanol	Methanol
Formula	Various	C_2H_5OH	CH_3OH
Stoichiometric AFR	14.18	8.96	6.44
Density (kg/l)	0.731	0.789	0.791
Gravimetric LHV (MJ/kg)	43.12	26.80	19.90
Volumetric LHV (MJ/l)	31.52	21.15	15.75
Carbon intensity (gCO_2/l)	2297.3	1509.7	1088.0
Carbon Intensity (gCO_2/MJ)	72.88	71.38	69.10
RON (to ASTM D2699)	95.3	108.6	108.7
MON (to ASTM D2700)	85.0	89.7	88.6
Sensitivity	10.3	18.9	20.1

The fuel sensitivity (RON-MON) clarifies the fuel antiknock trend where higher fuel sensitivity means higher knock resistance. Paraffin fuel tends to have low sensitivity while olefins, aromatics, diolefins, napthenes, and alcohols tend to be high sensitive fuels. Table 4 declares that Methanol has the maximum sensitivity between the tested fuels and Ethanol follows it. The differences between the sensitivities of these two alcohol fuels and gasoline are large indicating higher knock resistance.

From Fig. 3 it can be seen that E85 contains no methanol; the binary equivalent for it consist of gasoline and methanol mixture occurs at M56. In Turner works [10, 11 & 14] the first described Blend (G15 E85 M0), the second Blend (G44 E0 M56) and the equivalent to E85 or the third Blend (G29.5 E42.5 M28). In the recent study, ethanol limited as possible as a result of using no flex-engines that resist its aggressive effects. However, if for any reason, the supplied bio-ethanol prevented. As for a reduction in feedstock supply, or legislations that avoid the use of ethanol due to its interrupt with the food chain. One can exchange the limited amount of ethanol introducing methanol in a ternary blend instead of it. The blend used in this study was (G37 E20 M43) where gasoline with 77 ON used. All isostoichiometric ternary blends mentioned above embrace correspondent volumetric energy content (based on the masses and densities of the individual components). As the right- and left-hand edges demonstrate a stoichiometric AFR of 9.7:1 (i.e. E85 and M56, respectively) [11].

Table5 illustrates the compositions of E85 and the ternary blend used in the recent study and their properties. All these properties measured in AL-Doura Refinery Laboratories.

Table 5,
The compositions of the tested ternary blends fuels and their properties.

Fuel component	Gasoline	E85	G37 E20 M43
Stoichiometric AFR	14.98	9.69	9.71
Density (kg/l)	0.731	0.781	0.769
Gravimetric LHV (MJ/kg)	43.12	29.09	29.56
Volumetric LHV (MJ/l)	31.52	22.71	22.71
Carbon intensity (gCO_2/l)	2297.3	1627.9	1623.9
Carbon Intensity (gCO_2/MJ)	72.88	71.69	71.49
RON (to ASTM D2699)	82	97.4	96.4
MON (to ASTM D2700)	75.0	85.7	85.3
Sensitivity	07.3	11.7	11.1

The sensitivity of the tested GEM is close in magnitude to E85 ones indicating similar knock resistance.

2.4. Error Analysis

To ensure the reality of the results within an experimental uncertainty of (95% confidence level), and to confirm repeatability, the experiments conducted three times at least for each set of tests. The averaged value used in the analysis. This procedure employed in all measurements because some degree of uncertainty that may come from a variety of sources. The evaluating process of this uncertainty correlated with measurements. An estimate of the level of confidence associated with the value gives the complete statement of a measured value. Table 6a & b represent the experimental accuracies of the measuring devices used in the study. The uncertainty measuring procedure illustrated in Reference [19] used, and the uncertainty for present tests was:

$$e_R = [(0.2)^2 + (1.17)^2 + (0.46)^2 + (1.1)^2 + (0.69)^2 + (0.22)^2 + (1.4)^2 + (0.26)^2 + (0.92)^2 + (0.7)^2 + (0.93)^2 + (0.022)^2 + (0.3)^2]^{0.5} = \pm 2.77\%$$

Table 6a,
Experimental Accuracies for Prodit engine rig.

Measurements	Accuracies in this study
Thermocouples	± 0.2 %
Engine speed tachometer	± 1.17%
fuel flow meter	± 0.46 %
Air flow meter	± 1.1 %
dynamometer	± 0.69%

Table 6b,
Experimental Accuracies for Mercedes Benz engine rig

Measurements	Accuracies in this study
Thermocouples	± 0.22 %
Engine speed tachometer	± 1.4%
fuel flow meter	± 0.26 %
Air flow meter	± 0.92 %
Sound pressure level measurement	± 0.7
dynamometer	± 0.93%
Emitted exhaust gasses concentrations measurement	± 0.022
Smoke opacity meter	± 0.3

2.5.Test Procedure

The first set of test was conducted using single cylinder Prodit engine to evaluate the exact higher useful compression ratio (HUCR) for E85 and GEM blends. The second round of tests conducted using multi-cylinders Mercedes engine. All tests carried out under steady state operating conditions at various engine speeds. Engine torque was fixed when the engine was run at variable speeds to evaluate its effect on performance and emissions. A spark ignition engine running on GEM (ethanol and methanol blended with gasoline) performance and emission characteristics assessed and compared with a conventional Iraqi gasoline of ON=82.

The daily procedure employed was:

1. Drain tank and fuel system completely at the end of each test.
2. Prepare the test blend and fill the engine with 25 liters of the new test fuel blend. This procedure was used to ensure the homogeneity of the blend and prevent the reaction of ethanol with water vapor.
3. The engine allowed warming up for 20–30 min. This time was sufficient for the engine to consume the remaining fuel from the previous experiment also.
4. The dynamometer control was used to obtain the required engine load. The engine speed, fuel consumption, and load were measured while the brake power, brake torque and brake specific fuel consumption (BSFC) were computed.
5. For each test case, three runs performed and an average value obtained from the experimental data.
6. After the engine achieved the steady state, CO, CO_2, HC, and NOx concentrations measured by exhaust gas analyzer, while the smoke opacity recorded from the smoke meter.

3. Results and Discussions

The first set of tests conducted with the Prodit engine to evaluate the higher useful compression ratio (HUCR) for the tested fuels. Fig. 8 shows the effect of variable compression ratios on resulted brake power (bp) for a broad range of engine speeds for gasoline fuel of octane number (ON) = 82. Brake power increased with increasing CR till CR=7.5, at CR=8 the behavior changed, and knocking took place. Engine knock causes engine vibration, loud noise, and brake power drop. Engine load was forced to be reduced to prevent knock; that is why the curve dropped at engine speeds higher than 1750 rpm. The results of the figure indicate that the HUCR for Iraqi conventional gasoline is 7.5.

Fig. 9 illustrates the effect of CR when E85 used. The results manifest achieving higher brake power and higher compression ratios without knock occurrence. These findings indicate that E85 has higher octane rating compared to gasoline. The HUCR for E85= 9.25 where at CR= 9.5 knock happened. This CR (9.25) is less than that evaluated by (Turner, 2010) due to the used gasoline. Turner used gasoline of ON=95 while the gasoline used in this study was of ON= 70.

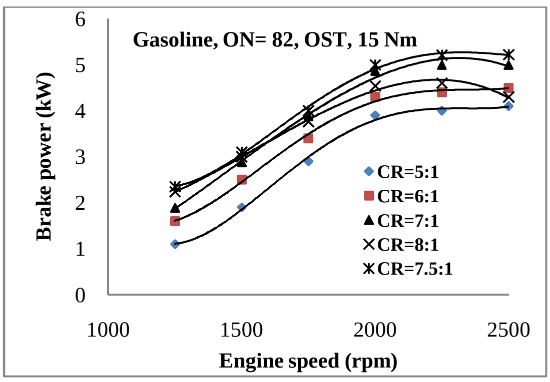

Fig. 8. Compression ratio effect on resulted engine brake power for wide range of speeds fueled with conventional Iraqi gasoline.

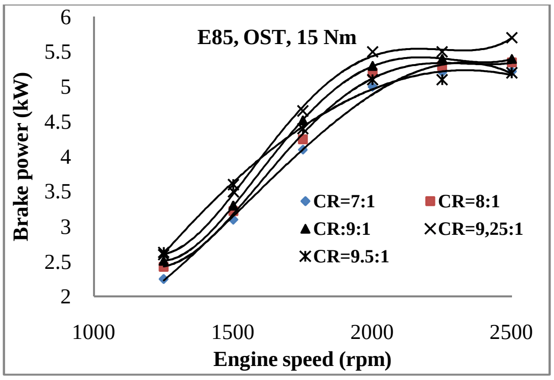

Fig. 9. Compression ratio effect on resulted engine brake power for wide range of speeds fueled with E85.

Using GEM with the selected volumetric ratios gave the same results as similar to E85, which indicates a correct choice as Fig 10 manifests. The HUCR for GEM is 9.25 equaling that for E85. Methanol has superior knock resistance because of its additional cooling effect due to its high latent heat of vaporization. It is possible to achieve higher compression ratios using better octane rating gasoline. The gasoline of ON=70 used because it is unleaded fuel. These results confirm that GEM blends have a bigger advantage over gasoline because it prevents knock more than gasoline.

Fig. 11 represents a comparison between the higher useful compression ratios for the tested fuels. As the E85 and GEM curves approach one another gasoline curve diverge away from them. This result indicates that using proposed GEM fuel gives a fuel with a better octane rating that is suitable for the high compression ratio engines. GEM blend has the similar knocking behavior of E85. The ternary blends equivalent to E85 blend is close to pure ethanol that explains this high knock resistance.

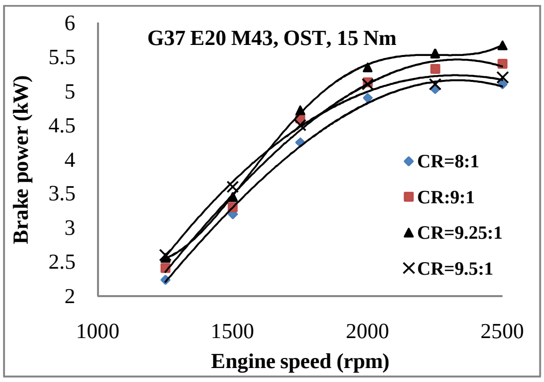

Fig. 10. Compression ratio effect on resulted engine brake power for wide range of speeds fueled with GEM Ternary fuel

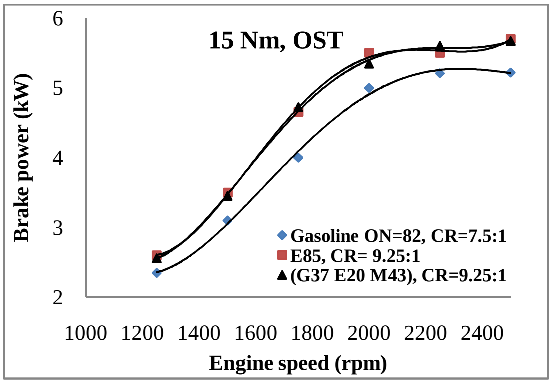

Fig. 11. Comparison between brake powers resulted from using the HUCR for the three tested fuels.

The GEM fuel used in the second set of tests to operate a four cylinders Mercedes engine to evaluate the engine performance and emissions. Fig. 12 represents a comparison between tested GEM and Iraqi conventional fuel when both fueled the Mercedes engine. The octane rating and knock resistance for GEM fuel is higher than that for gasoline which made the engine run at higher brake powers. The increment in bp for the tested range was 24.12% when GEM was used compared with gasoline.

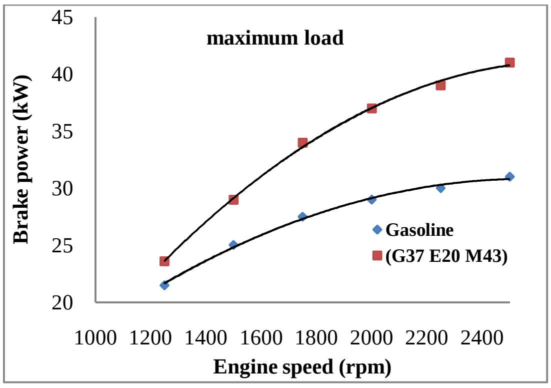

Fig. 12. Wide range of engine speeds effect on resulted engine brake power when fueled with conventional Iraqi gasoline and GEM Ternary fuel

BSFC considered as the main disadvantage of fuels containing alcohols due to their lower LHV compared to gasoline. However, increasing bp reflects in reducing bsfc as equation 6 indicates and as Fig. 13 shows. Gasoline engine needs more fuel consumption to achieve the maximum bp while GEM blend displays less bsfc to reach to its maximum loads at each speed. The reduction in bsfc was 13.9% when GEM was used compared with gasoline.

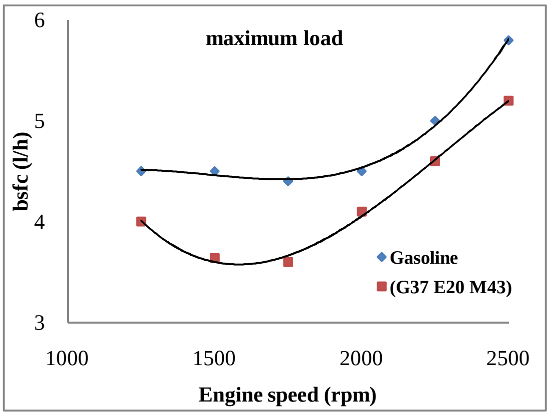

Fig. 13. Wide range of engine speeds effect on resulted engine brake specific fuel consumption when fueled with conventional Iraqi gasoline and GEM Ternary fuel

Increasing bp and reducing bsfc caused the brake thermal efficiency for GEM blend at a range of tested engine speeds to increase compared to gasoline as Fig. 14 illustrates. It is clear that the GEM blend displays significant efficiency increments. The ethanol and methanol have higher burning velocities and smaller in-cylinder cooling losses. In addition to the increase of the delivered torque due to the higher octane rating of GEM blend. The increment was 19.59% when GEM was used compared with gasoline.

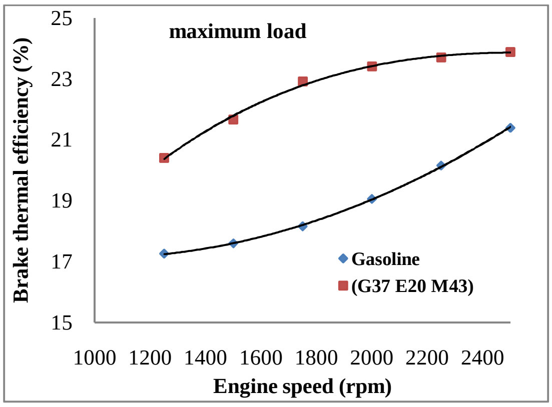

Fig. 14. Wide range of engine speeds effect on resulted brake thermal efficiency when fueled with conventional Iraqi gasoline and GEM Ternary fuel.

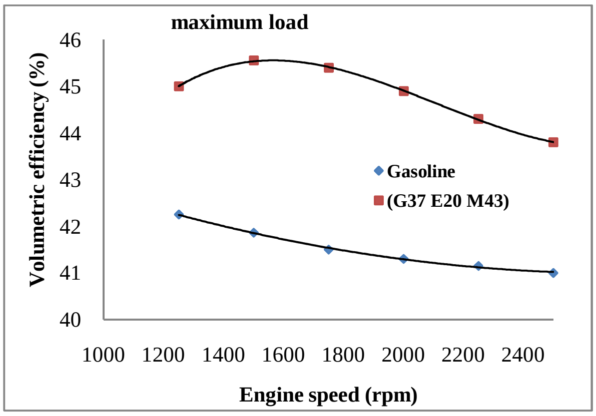

Fig. 15. Wide range of engine speeds effect on resulted volumetric efficiency when fueled with conventional Iraqi gasoline and GEM Ternary fuel.

Ethanol and methanol as oxygenated alcohols have oxygen in their structure. This oxygen increased the volumetric efficiency for GEM when compared with gasoline as Fig. 15 clarifies. Also, the rise in the volumetric efficiency with engine speed at maximum torques can be explained by the ascending in brake thermal efficiency with engine speed. More fuel is needed to achieve torque output. The increment was 8.06% when GEM was used compared with gasoline.

GEM blend characterized by its lower heating value compared to gasoline. This character caused lower exhaust gas temperature for the most of tested engine speed range as Fig. 16 reveals. For the engine speed range from 2200 to 2500 GEM exhaust gas temperatures preceded gasoline one due to the high engine speed and its operation at maximum loads. This increment reduced the overall reduction to 1.85% when GEM was used compared with gasoline.

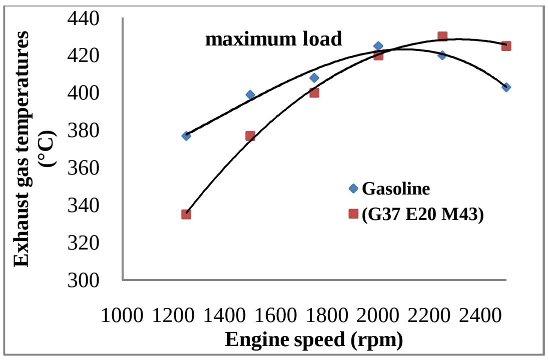

Fig. 16. Wide range of engine speeds effect on resulted engine exhaust gas temperatures when fueled with conventional Iraqi gasoline and GEM Ternary fuel.

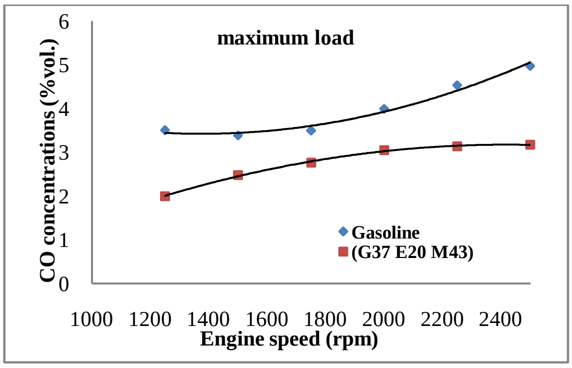

Fig. 17. Wide range of engine speeds effect on resulted CO concentrations when fueled with conventional Iraqi gasoline and GEM Ternary fuel

The higher volumetric efficiency added to higher oxygen content in the GEM structure caused a considerable reduction in CO concentrations, as Fig. 17 elucidates. The decrease in these concentrations was 30.5% when GEM was used compared with gasoline.

The same effect observed on HC concentrations for the same reasons as Fig. 18 expounds. Using GEM as fuel reduced HC concentration about 25.16% compared with using conventional Iraqi gasoline.

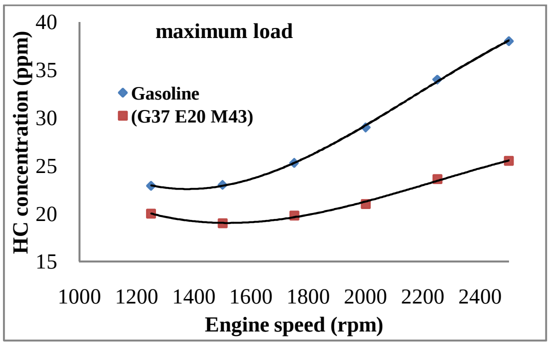

Fig. 18. Wide range of engine speeds effect on resulted unburnt hydrocarbons concentrations when fueled with conventional Iraqi gasoline and GEM Ternary fuel

CO and HC reductions mean better combustion that resulted in higher CO_2 concentrations, as Fig. 19 indicates. CO_2 concentrations for GEM increased but still lower than that emitted by gasoline. The reduction in CO_2 concentrations was 5% when GEM was used compared to gasoline. Thus, if the methanol produced from natural feedstock process, a much more attractive fuel exists.

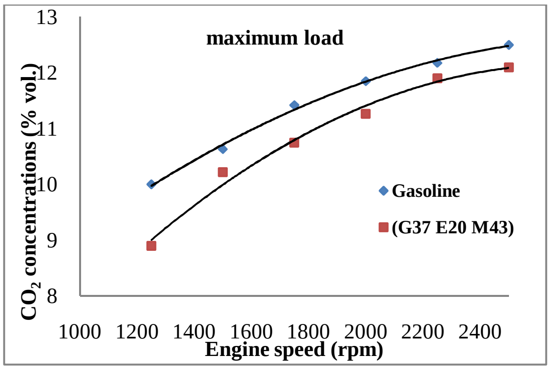

Fig. 19. Wide range of engine speeds effect on resulted CO_2 concentrations when fueled with conventional Iraqi gasoline and GEM Ternary fuel

Gasoline has significant trends to form NOx due to its slight peak temperature rise. GEM engines produced relatively lower NOx concentrations, as Fig. 20 represents. Alcohol fuels with its lower combustion temperatures handle the resulted lower NOx emissions. So, although GEM engine operated at higher loads due to its high resistance to knock, the combustion heat generated inside combustion n chamber still less than that of gasoline due to lower blend heating value compared to gasoline. The reduction in NOx concentrations was limited to 1.75% when GEM was used compared with gasoline.

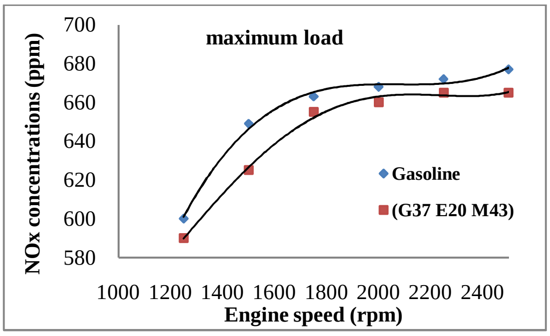

Fig. 20. Wide range of engine speeds effect on resulted NOx concentrations when fueled with conventional Iraqi gasoline and GEM Ternary fuel

Smoke opacity depends mainly on oxygen abundance; that is why GEM engine emitted lower smoke compared to gasoline, as Fig. 21 indicates. The oxygen content in GEM fuel reduced all combustion emissions. The reduction was 46.49% when GEM was used compared with gasoline.

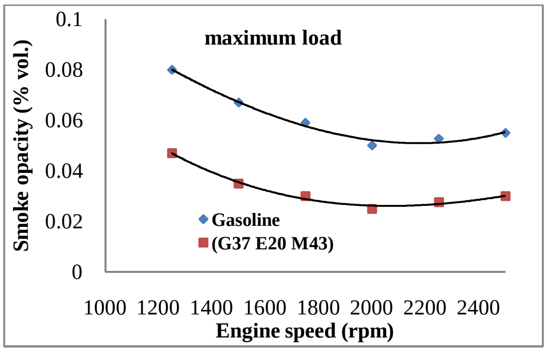

Fig. 21. Wide range of engine speeds effect on resulted smoke opacity when fueled with conventional Iraqi gasoline and GEM Ternary fuel

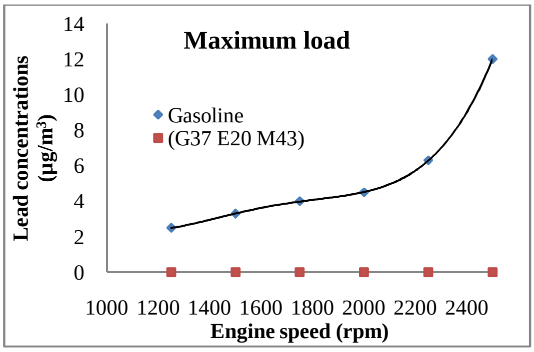

Fig. 23. Wide range of engine speeds effect on lead concentrations when fueled with conventional Iraqi gasoline and GEM Ternary fuel

A higher heat release inside the combustion chamber means higher elevated combustion pressures that result in higher combustion noise. GEM engine with lower combustion pressure due to the lower heating value produced lower engine noise with about 3.58% compared with the gasoline engine as Fig. 22 reveals.

Increasing engine speed needs to increase the delivered fuel, as a result, increase emitted lead concentrations from gasoline engine as Fig. 23 represents. On the other hand, GEM blend emitted no lead where its components are lead-free. This result attached an important issue for the Iraqi environment, and it is the aim of this study. The objective is to save Iraq environment from high lead concentration due to the utilization of conventional gasoline.

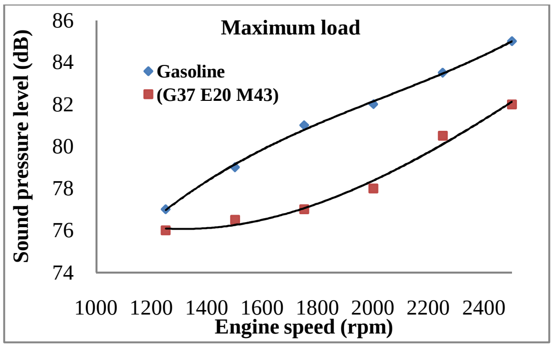

Fig. 22. Wide range of engine speeds effect on resulted noise when fueled with conventional Iraqi gasoline and GEM Ternary fuel.

4. Conclusions

The experimental tests have successfully underlined the potential of ternary blends to provide an alternative fuel for Iraqi conventional gasoline fuel. The tests results indicate that blends can formulate with available Iraqi produced materials. GEM ternary blends offer significant advantages in terms of engine performance compared to gasoline. In the first tests set with the single cylinder engine, the results declared that the HUCR for gasoline (82) = 7.5, HUCR for E85=9.25, and HUCR for the tested GEM=9.25.

The second set of tests using the multi cylinders engine, the results clarified that using GEM caused:

- BP increased by 24.12% due to higher octane rating.
- BSFC reduced by 13.9% and brake thermal efficiency increased by 19.59%.
- Volumetric efficiency increased by 8.06% due to ethanol and methanol oxygen content.

This content caused GEM ternary blends offer significant advantages in terms of emitted engine emissions compared to gasoline, where CO concentrations reduced by 30.5%, HC concentrations reduced by 25.16% and smoke opacity reduced by 46.49%. CO_2 concentrations reduced by 5% as well as NOx concentrations that reduced by 1.75%.

Notation

IT	injection timing
CN	cetane number
DI	direct injection
N	engine speed (rpm)
T	engine torque
V_{sn}	swept volume
°BTDC	degree before top dead centre
bmep	brake mean effective pressure
BTE	brake thermal efficiency
CA	crank angle
CR	compression ratio
UBHC	unburnt hydrocarbon
CO	carbon monoxide
CO_2	carbon dioxide
NOx	nitrogen oxides
dB	decibel
LCV	Lower calorific value

5. References

[1] Rameshni M, Parsons P E W , Regulation Effects on Sulfur Removal Facilities, Sulfur Recovery Symposium, AICHE'S 5th International Conference, March 10-14, 2002

[2] EIA, Iraq country analysis brief, 2005. Available at: http://www.eia.doe.gov/cabs/iraq.html (1 of 20)

[3] Al Khalidy Kh S H, Chabuk A J A, Kadhim M M A, Measurement of Lead Pollution in the Air of Babylon Governorate/Iraq during Year 2010, World Academy of Science, Engineering and Technology, vol. 6, 2012

[4] Ismayyir D K and Dawood L M, Assessment of gasoline major quality parameters, The Sixth Jordan International Chemical Engineering Conference, JIChEC06, Amman, Jordan, 2012.

[5] Chaichan M T, Experimental evaluation of the effect of some engine variables on emitted PM and Pb for single cylinder SIE, Association of Arab Universities Journal of Engineering Science, vol. 2, No. 20, pp: 1-13, 2013.

[6] Anurag A. Gupta A A, Automotive fuel specification in India –the journey & path forward, Indo-Japanese Conference on Fuel Quality & Vehicular Emissions-2009. Organized by BIS &Petrofed India Habitat Centre, New Delhi.17-18 March, 2009.

[7] Habib R H, Awadh S M and Muslim M Z, Toxic heavy metals in soil and some plants in Baghdad, Iraq, Journal of Al-Nahrain University, vol. 15, No. 2, pp:1-16, 2012,

[8] Casier B, Experimental research on the behavior of alcohols and mixtures with alcohols as fuel for spark ignition engines, MSc, Ghent University, Ghent, Belgium, 2013.

[9] Chaichan M T, Evaluation of the effect of cooled EGR on knock of SI engine fueled with alternative gaseous fuels, Sulaimani Journal for Engineering Science, vol. 1, No. 1, pp: 7-15, 2014.

[10] Turner J W G and Pearson R J, Using methanol to break the biomass limit of ethanol, Biofuels East 2010 Conference, Cambridge, UK, 17th March, 2010.

[11] Turner J, Pearson R, Purvis R, Dekker E, GEM Ternary Blends: removing the biomass limit by using iso- stoichiometric mixtures of gasoline, ethanol and methanol, SAE Technical Paper 2011-24-0113, 2011, doi: 10.4271/2011-24-0113.

[12] Anderson J E, Kramer U, Mueller S A and Wallington T J, Octane numbers of ethanol- and methanol gasoline blends estimated from molar concentrations, Energy Fuels, vol. 24, pp: 6576-6585, 2010, DOI: 10.1021/ef101125c.

[13] Brusstar M and Gray C, High efficiency with future alcohol fuels in a stoichiometric medium duty spark ignition engine, SAE Technical Paper 2007-01-3993, 2007, doi:10.4271/2007-01-3993.

[14] Turner J W G, Pearson R J, McGregor M A, Ramsay J M, Ben-Iosefa E D, Dolan G A, Johansson K and Bergström K, GEM Ternary Blends: testing iso-stoichiometric mixtures of gasoline, ethanol and methanol in a production flex-fuel vehicle fitted with a physical alcohol sensor, SAE paper No. 2012-01-1279, 2012.

[15] Turner J W G, Pearson R J, Bell A, de Goede S and Woolard C, Iso-stoichiometric Ternary Blends of gasoline, ethanol and methanol: investigations into exhaust emissions, blend properties and octane Numbers, SAE paper No. 2012-01-1586, 2012.

[16] Anderson J, Leone T, Shelby M, Wallington T et al, Octane numbers of ethanol-gasoline blends: measurements and novel estimation method from molar composition, SAE Technical Paper 2012-01-1274, 2012, doi:10.4271/2012-01-1274.

[17] Keating E L, 2007, Applied combustion, 2nd eddition, Taylor & Francis Group, LLC.

[18] Abdul Haleem S M, Theoretical and experimental investigation of engine performance and emissions of a four strokes spark ignition engine operated with hydrogen blended gasoline, Ph D thesis, College of Engineering, Al-Mustansiriya University, Baghdad, Iraq, 2007.

[19] ASHREA GIUDE LINE. Guide engineering analysis of experimental data, Guideline 2-1986.

[20] Qi D H, Liu Sh Q, Liu J C and Bian Y Zh, Properties, performance, and emissions of methanol gasoline blends in a spark ignition engine, Proc. Instn Mech. Engrs Journal of Automotive Engineering, vol. 219, Part D, pp: 405-412, 2005.

استخدام خلائط تيرنرية من الجازولين والأيثانول والميثانول (GEM) كبديل لوقود الجازولين العراقي لتقليل مكونات الكبريت والرصاص المنبعثة الى البيئة

مقدام طارق جيجان
مركز تكنولوجيا الطاقة والطاقات المتجددة/ الجامعة التكنولوجية
البريد الألكتروني:20185@uotechnology.edu.iq

الخلاصة

يتميز وقود الجازولين العراقي بانخفاض رقمه الأوكتاني الذي لا يتجاوز ٨٢ وارتفاع محتواه من الكبريت والرصاص. في هذة الدراسة تم استخدام خليط مكون من ثلاثة مركبات أو خليط تيرنري مكون من الجازولين والأيثانول والميثانول كبديل للجازولين العراقي التقليدي. تمت الدراسة باستخدام خليط GEM مساوي في تصنيفة الوكتاني لخليط E85. تم اختيار خليط GEM من مجموعة Turner, 2010. فلقد اختير خليط G37 E20 M43 (٣٧% جازولين + ٢٠% ايثانول + ٤٣% ميثانول) في الدراسة الحالية. تم استخدام هذا الخليط في محرك متعدد الأسطوانات نوع مرسيدس وتمت مقارنة اداء المحرك والملوثات المنبعثة عنه بتلك الناتجة عن محرك جازولين.

بينت النتائج أنه يمكن تشكيل هذا الخليط من مواد عراقية متوفرة، ويوفر هذا الخليط فوائد كبيرة لحالة أداء المحرك مقارنة بالجازولين. إن نسبة الأنضغاط النافعة العليا له هي ٩.٢٥، بينما للجازولين كانت هذة النسبة ٧.٥. كما ازدادت القدرة المكبحية بحدود ٢٤.١٢%، وقلّ الأستهلاك النوعي المكبحي بحدود ١٣.٩% وازدادت الكفاءة الحرارية المكبحية بحدود ١٩.٥٩%. ازدادت الكفاءة الحجمية بحدود ٨.٠٦%. كذلك قلت تراكيز ملوثات CO و HC بحدود ٣٠.٥ و ٢٥.١٦% على التوالي. وقلت عتامة الدخان بحدود ٤٦.٤٩% ومثلها تراكيز CO_2 قلت بحدود ٥% بينما تراكيز NOx فقد قلت ١.٧٥%.