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Experimental study for the effect of diesel fuel quality product in Iraq on emission and engine performance

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Abstract

A series of experimental was conducted to evaluate the impact of diesel fuel types which are produced in Iraq and compared with others special type of Ethanol Blended Diesel Fuel. The testing was carried on four stroke single cylinder direct injection diesel engine under different speeds and loads in internal combustion engine laboratory, department of machines and equipment, Baghdad Technology Institute. Five types of diesel engine Fuel included Daura, Basra , Beji local Fuel and two biodiesel Fuel 10%Ethanol Blended Diesel Fuel ,and 8%Ethanol Blended Diesel fuel, four levels of engine speeds included 1100, 1600, 2100 and 2600 rpm, and five levels of torques included 2, 4, 6, 8 and 10 Nm were used in this study. Mathematical relationships and computerized program (ECA 100, VDAS) were used to calculate the performance parameters of engine which included brake specific fuel consumption, the exhaust emissions included nitrogen oxide, and carbon monoxide and carbon dioxide were measured by using exhaust gas analyzer type FLUX-2000-4.

The study shows that the Beji fuel was recorded the highest level of bsfc with variable torque and 8% blended is the highest value with variable speed followed by the other types of fuel. Basra has the greatest value of η_{Ith} *at variable speed, 8% blended have higher value of* η_{Ith} *with variable torque .Daura fuel type was recorded the lowest values in emissions than the other types with variable speeds and torque reach to 29.89%,while recorded increasing on indicated thermal efficiency 11.29% .*

Keywords: Diesel engine, Emissions, Ethanol Blended Diesel Fuel.

دراسة عملية لتأثير نوعية وقود الديزل المنتج في العراق على الانبعاثات و أداء المحرك

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الخلاصة:

أجريت تجارب عملية لتقييم تأثير أنواع وقود الديزل المنتج في العراق ومقارنته مع تركيبات خاصةللوقود الحيوي على أداء وانبعاثات العادم لمحرك رباعي الاشواط ذي اسطوانة واحدة يعمل بالحقن المباشر عند سرع مختلفة وكذلك عند أحمال مختلفة في مختبر محركات الاحتراق الداخلي - قسم الآلات والمعدات - معهد تكنولوجيا بغداد. شملت الدراسة خمسة أنواع من الوقود نوع دورة ،البصرة، بيجي (الوقود المحلي) واثنين من وقود الديزل الحيوي (10٪ الايثانول المخلوط وقود الديزل ، و 8 ٪ وقود الايثانول المخلوط وقود الديزل) وتم الاختبارعند أربعة مستويات من سرعات المحرك 1100،1600، 2100 و 2600 rpm، و أستخدم عزم دوران بخمسة مستويات مختلفة 2 ، 4 ، 6 ، 8 و 10 N.m في هذه الدراسة.

تم الحصول على النتائج باستخدام برنامج حاسوب(ECA 100، VDAS) لحساب معاملات أداء المحرك والمتضمنة استهلاك الوقود النوعي ، وانبعاثات العادم. (أكسيد النيتروجين ، أول أكسيد الكربون وثاني أكسيد الكربون) ، تم قياس تراكيزها باستخدام نوع محلل غاز العادم (4 - FLUX-2000).

أثبتت الدراسة أن وقود بيجي سجل اعلى مستويات من bsfc مع العزوم المتغيرة و 8% المخلوط سجل اعلى قيم له في حالة السرع المتغيرة عن غيره من الوقود بينما سجل وقود البصرة احسن نتائج من η_{Ith} في حالة تغيير السرع و 8%المخلوط كان احسن في حال تغيير العزوم .

سجل وقود الدورة أدنى قيم من الانبعاثات اذا ما قورن مع باقي انواع الوقود في حال العزوم و السرع المتغيرة تصل 29.89 % مقارنة مع بقية الوقود بينما سجل زيادة بالكفاءة الحرارية بمقدار 11.29 %

كلمات مفتاحية:محركات الديزل ،الانبعاثات ،وقود الديزل المخلوط ايثانول.

1. Introduction

Reducing of the quantity of pollutant emissions from the diesel engine exhaust is a challenged task in the view of current emission legislation. Combustion modifications, usage of eco-friendly fuels are the key technologies to reduce the amounts of pollutant emissions [1, 2]. Biofuels like ethanol, biodiesel have become an attractive alternative to petro diesel as it conquers the dependency on foreign petroleum and offers lower pollutant emissions in the present context of emission legislation [1- 4]. Most attractive attribute of biofuel is of its low or no slpher content. The Ethanol Blended Diesel is used in diesel engines as direct fuels as well as blends. Many options have been studied like blends of diesel to ethanol as a fuel substitute to reduce certain types of emissions [5]. Studies show that the NO_X from the diesel engine decreases when operated with variable torque and with low speeds, and increase with the high speed more than 1600 rpm. The estimation of NO_X can also be done by correlations which are based on amounts of other emissions like **HC**, **CO** and CO_2 which is adopted in this article [6]. When biodiesel was added in little amounts to ethanol-diesel blends enhance solubility of ethanol in diesel and observed that blends were stable for long time [7- 9]. The diesel are named as Daura, Basra and Beji and blends of ethanol-diesel are named as 10% and 8%. The details of the fuels used along with fuel properties are shown in **Table (1).** The engine is operated with variable load conditions (2, 4, 6,8 and 10)Nm،and with the range of speeds (1100, 1600,2100 and 2600) rpm. The engine performance is evaluated in terms of brake specific fuel consumption (bsfc), and indicated thermal efficiency (η_{Ith}). In this study it was used two devices of gas analyzer one of them is to measure four gases emission (CO, CO2, HC and NO_x). The (FLUX 2000-4) gas–analyzer is an infrared microprocessor based photometer designed to measure CO (carbon monoxide), CO_2 (carbon dioxide), HC (hydrocarbons) and O_2 (Oxygen) coming from cars as shown in **Figure (1**), and using another device to measure the NO_x because the device (FLUX 2000-4) dos not measure the NO_x gas. The testo 350 portable emission analyzer raises the bar in testing serviceability **Figure (2).**The devices weren't designed to measure SO_2 emission.

According to the devices measure (CO and CO_2) in (% vol) units, (HC and NO_X) in (ppm) units.

Fig .(1) Infrared Exhaust Gas Analyzer

Fig .(2) The NO_X gas analyzer

Table .(1) Properties of selected fuels from Midland Refineries Company

MIDLAND REFINERIES COMPANY / AL - DAURA — شركة مصافي الوسط / الدورة

QUALITY CONTROL & RESEARCHES DEPARTMENT — قسم البحوث والسيطرة النوعية

FORM NO.40

نتائج الفحوصات للنماذج الخارجية

Lab . Insp. Data	دورة	بصرة	بيجي	5%	8%	10%
SP. Gravity @ 15.6 °C	0.8393	0.8304	0.8418	0.8280	0.8289	0.8294
API Gravity @ 15.6 °C	37.1	38.9	36.6	39.4	39.2	39.1
Flash Point °C	72.8					
Desity @ 15°C	0.8388	0.8300	0.8413	0.8276	0.8285	0.8290
Calorific Value Kal /kg	010921	10952	10912	10960	10957	10955

2. Theoretical part:

Engine performance was calculated by the fallowing equations [7- 9].

A) Fuel consumption ($\dot{m}_f$) g/s :

$$\dot{m}_f = \frac{Vf * \rho_f}{t_b} \qquad \text{..............................} (1)$$

Where:

ρ_f = specific mass of the fuel (g/ m³).

t_b = time necessary to empty the burette (s).

V_f = volume of fuel = 8×10^{-6} m^3 .

B) Brake power (b.p) , kW :

$$b.P = \frac{T * 2 * \pi * N}{60 * 1000} \qquad \text{..............................} (2)$$

Where,

T= toque (N.m) .

N=speed (rpm).

C) Brake specific fuel consumption (bsfc) , $\frac{g}{kW.hr}$:

$$bsfc = \frac{\dot{m}_f}{b.p} \qquad \text{..............................} \ (3)$$

D) Indicated thermal efficiency(η_{ith}):

$$\eta_{ith} = \frac{I.p}{HL * \dot{m}_f} \qquad \text{..............................} \ (4)$$

Where,

I.p=Indicated power

H_L= fuel lower calorific value (*kcal/kg).*

Or,

$$H_L = 4.01 \frac{KJ}{Kcal} * \frac{Kcal}{kg} = \frac{KJ}{kg}$$

3. Experimental apparatus:

3.1 Engine Test:

A factorial experiment was conducted to evaluate the impact of fuel type on the performance and emission of four stroke direct injection diesel engine under different speeds and loads. The work was done in department of machines and equipment, Baghdad Technology Institute. A modern single cylinder air cooled diesel engine type TD 212 made in UK was used in this experiment .**Table(2)** show, the engine specification. This engine includes an exhaust thermocouple, a half coupling to link to the test bed dynamometer to measure the power and all essential hoses and fitting as showing in **Figure (3).**

Table .(2) Specifications of test engine [user guide of engine]

Item	Specification
Engine Manufacturer	TQ TD 212, UK
Fuel Type	Diesel
Maximum Power	3.5kW at 3600 rev/min
Maximum Torque	16 Nm at 3600 rev/min
Bore	69 mm
Connecting Rod Length	104 mm
Engine Capacity	232 cm^3
Compression Ratio	22:1
Oil Type	Multi grade SAE 5W-40

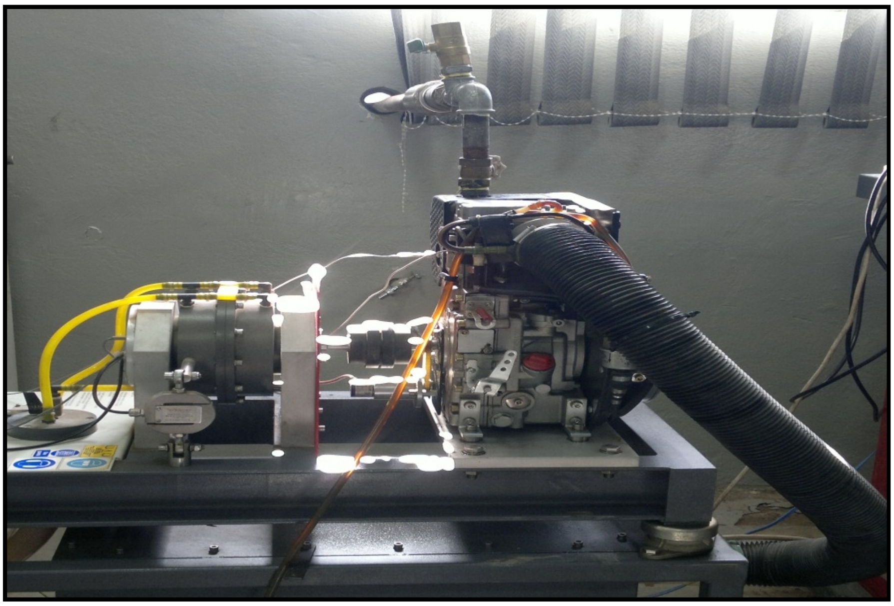

Fig .(3):The engine test

3.2 The rig instruments:

The instrumentation unit is designed to housing the instruments necessary for measuring the engine performance, which include fuel consumption, torque, speed, brake power display, exhaust temperature display. The instrumentation unit links to USB, which may connect to the computer then the data, is obtained through a program to record all engine data parameter as show in **Figure (4).**

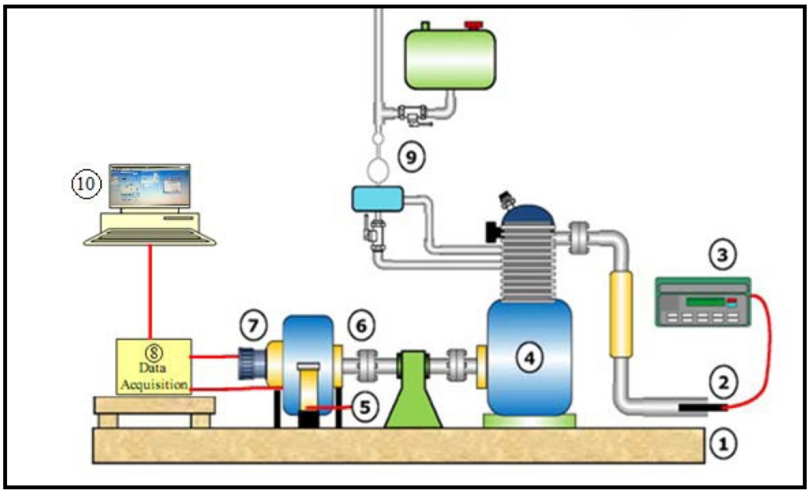

Fig .(4): Schematic diagram of the test diesel engine and exhaust analyzer

1-engine chassis 2- exhaust gas analyzing probe 3- exhaust gas analyzer 4- single cylinder diesel engine 5- load cell 6- dynamometer 7- tachometer 8- Data Acquisition 9- fuel burette 10- computer.

3.3 Blended tank:

A fuel tank was manufactured by hand in the industrial work area with dimensions (length 20cm ,width 10cm and height 15cm) with maximum capacity 3 liters, and have a mixing electrical device to ensure the perfect mixing of the diesel fuel with the ethanol fuel. This tank is used as a special work when we want to running the engine on blended fuel. The **Figure (5)** below shows the blended ethanol tank and diesel fuel tank.

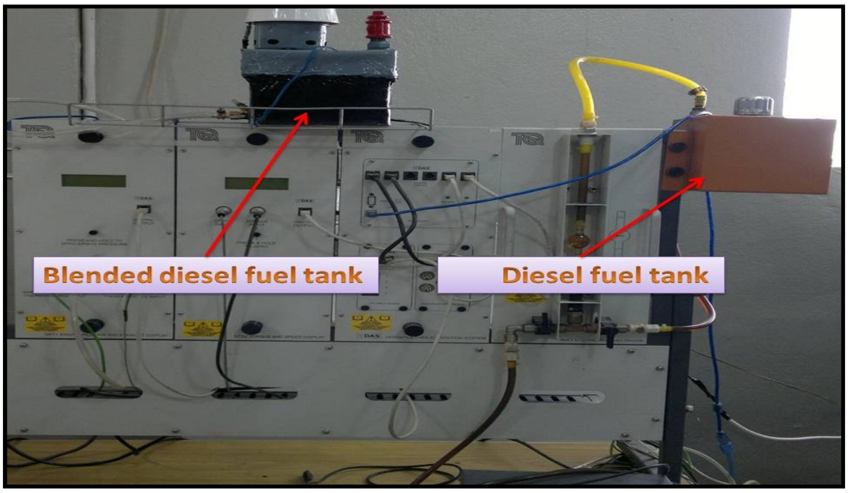

Fig .(5): the blended tank and fuel tank.

4. Results and Discussion:

Figure(6) represented the relationship between $\mathbf{NO_X}$ and Torque at engine speed 2100 rpm, it was observed that the value of $\mathbf{NO_X}$ increased with Toque increasing .The lowest value of NO_X is found in Daura, followed by Ethanol Blended Diesel Fuel ***(8%)***, Beji, Basra and 10% blended fuel .

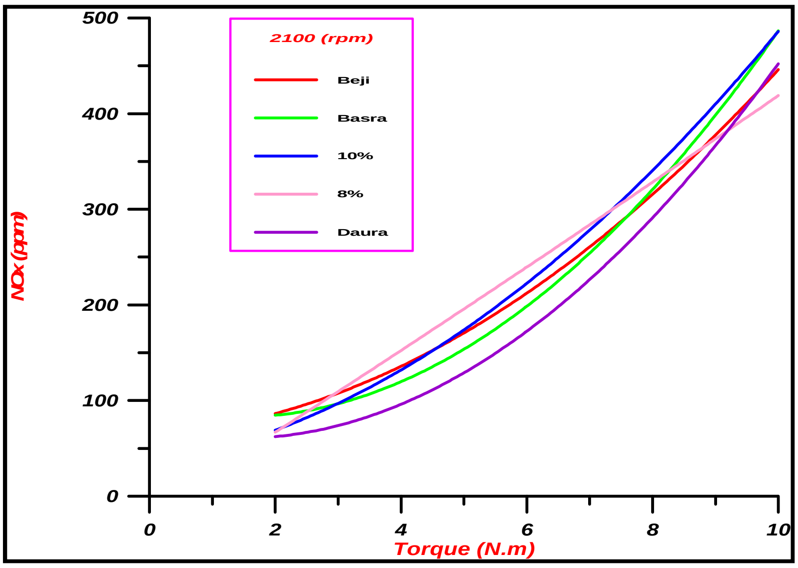

Fig .(6) Effect of Fuel Types, Torques on Nitrogen oxide (ppm) at engine speed = 2100rpm.

Figure(7) shows the relationship between $\mathbf{NO_X}$ and speed at minimum torque 2 Nm, it was found that the $\mathbf{NO_X}$ is decreased with the low speeds and slightly increase with the high speeds**,** and the lowest emission was founded in **Beji** fuel at 2100 rpm , while 8% blended fuel was recorded a highest rate of $\mathbf{NO_X}$ with the highest speed.

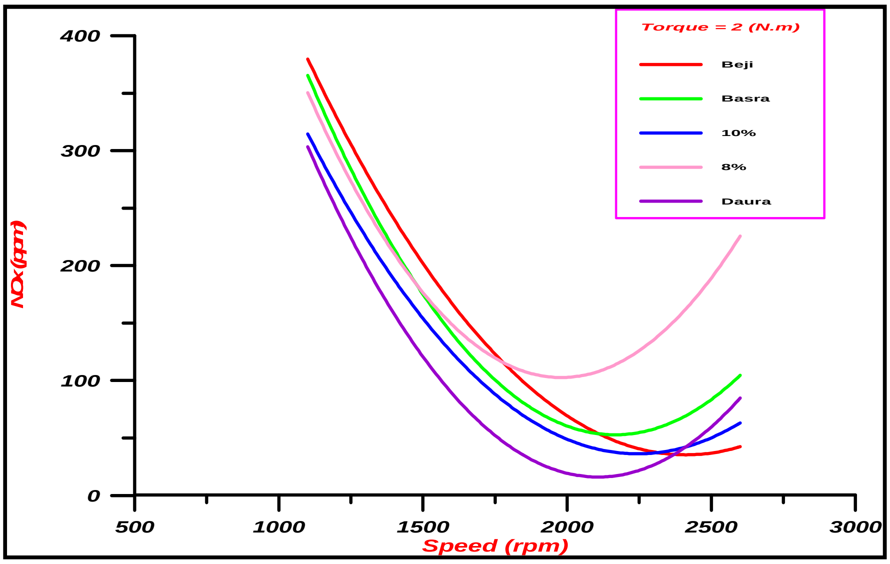

Fig .(7) Effect of Fuel Types, Speed on Nitrogen oxide (ppm) at torque=2Nm

Figure (8) shows that the fuel type has a clear impact on CO emitted, Basra type recorded the highest rate of CO followed by 8% and the other types. The reason may be Basra has low viscosity index that means the viscosity of Basra affected by high temperature and decrease engine temperature, consequently increased the CO formed.

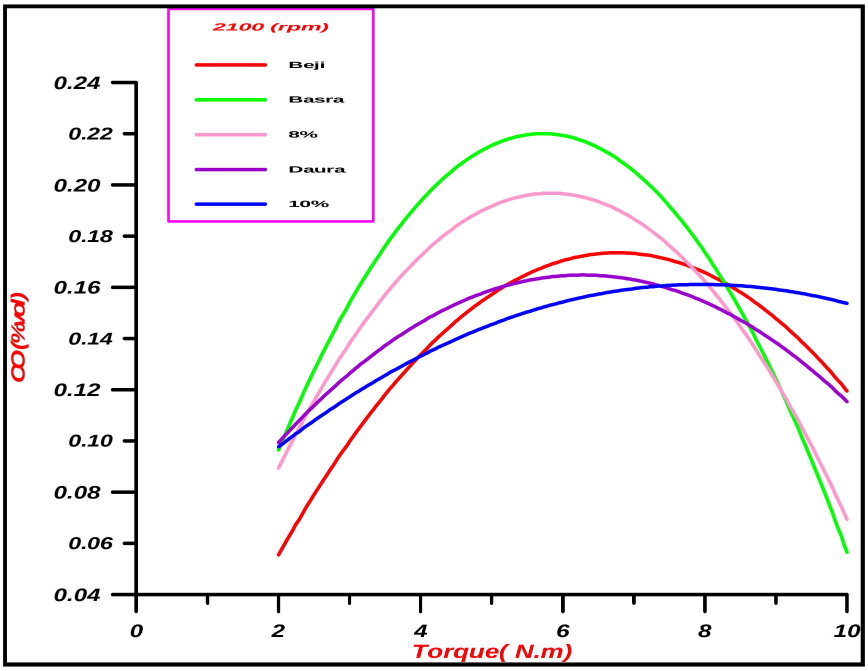

Fig .(8) Effect of Fuel Types, Torques on Carbon monoxide (%vol) at engine speed = 2100 rpm

Figure (9) shows that the rate of **CO** was affected by engine speed. At engine speed 1100 rpm recorded the highest rate of **CO** with Beji fuel followed by 10 % blended and others. The lowest rate of **CO** was recorded at engine speed 2100 rpm with 8% and 10% blended. The reason may be when increasing engine speed there was no excess air to burn the mixture and as a result incomplete combustion which led to emitted more CO emission.

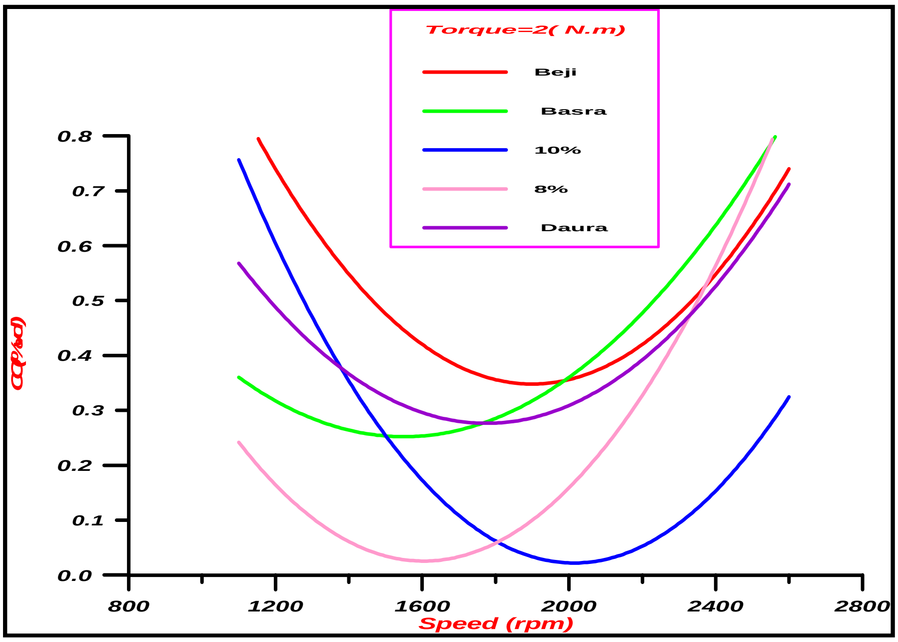

Fig .(9) Effect of Fuel Types, Speed on Carbon monoxide (%vol) at torque=2Nm

Figure (10) represented the relationship between $\mathbf{CO_2}$ and Torque at engine speed 2100 rpm, it was observed that the value of $\mathbf{CO_2}$ increased with torque increasing and sharply increase with the high torque and the lowest emission was founded in **Beji** fuel fallowed Basra, Daura, 8% and10% blended.

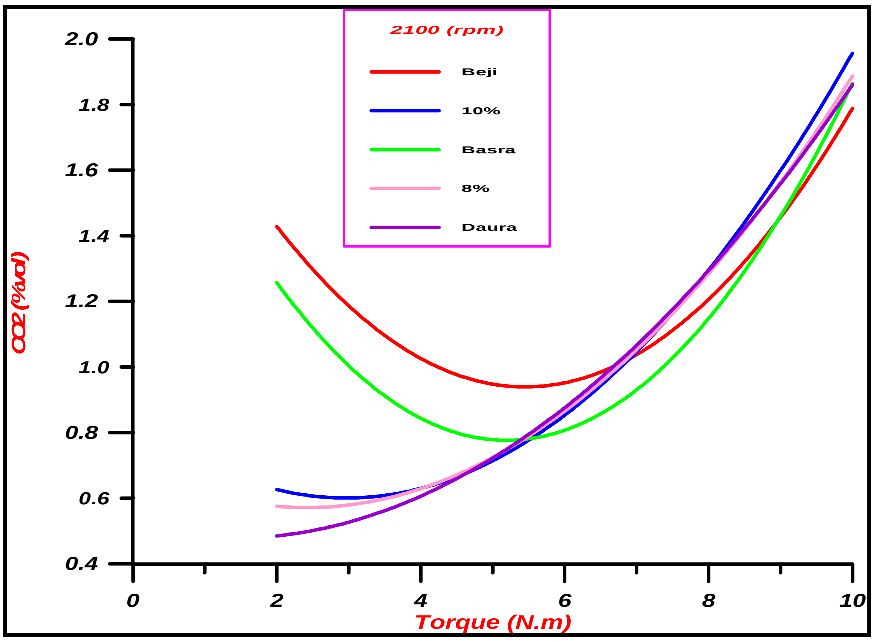

Fig .(10) Effect of Fuel Types, Torques on Carbon Dioxide (%vol) at speed =2100rpm

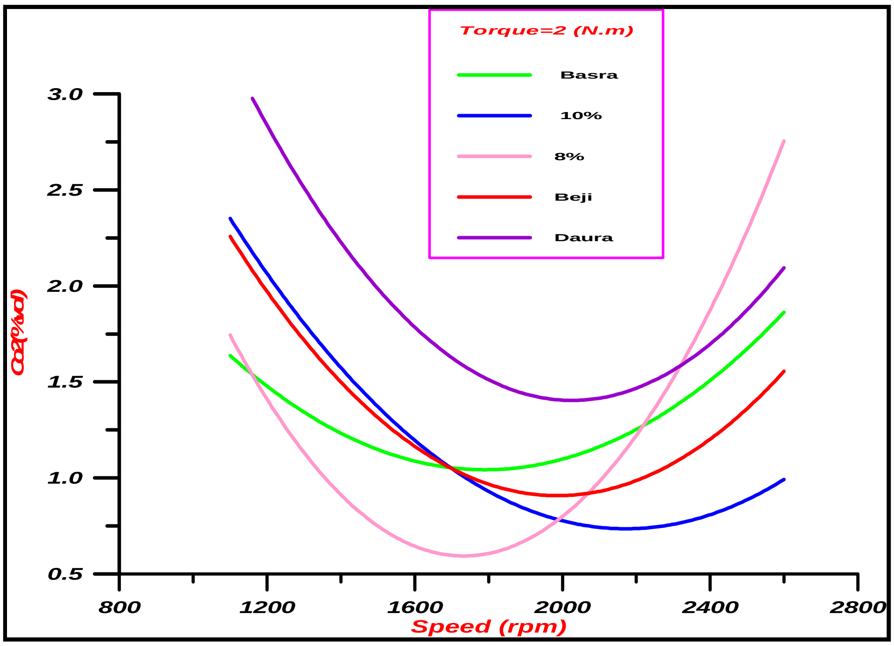

Fig .(11) Effect of Fuel Types, Speed on Carbon Dioxide (%vol) at torque=2Nm

Figure(11) shows the relationship between $\mathbf{CO_2}$ and speed at minimum torque 2 Nm, it was found that the $\mathbf{CO_2}$ is decreased with the low speeds and slightly increase with the high speeds and the lowest emission was founded in **Beji** fuel at 2100 rpm.

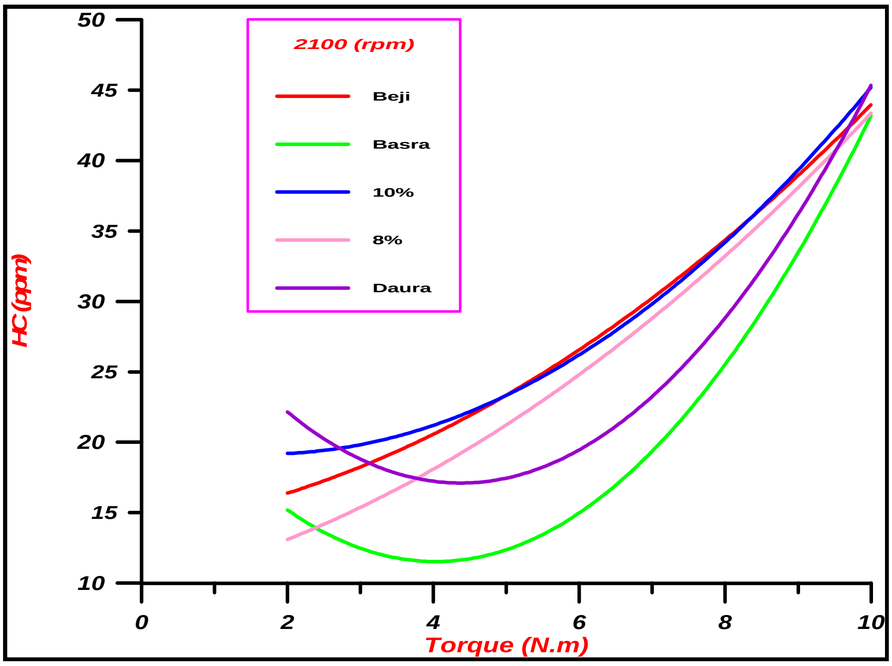

Fig (12) Effect of Fuel Type, Torque on HC (ppm) at speed=2100rpm

Figure (12) represented the relationship between **HC** with Torque at 2100 rpm, it is observed that the value of **HC** increased with torque increasing and increase with the high Torque and the lowest emission was founded in Basra fuel followed by Daura, 8% blended and the other types.

Figure (13) shows the relationship between HC with engine speed at minimum torque 2 Nm, with in the range of engine speed from1100 to 1600rpm , it was found that the **HC** is decreased under 2100rpm and sharply increase when engine speed increase to 2100rpm, also the lowest emission was founded in 10% blended fuel within the range of engine speed 1600 to 2600 rpm.

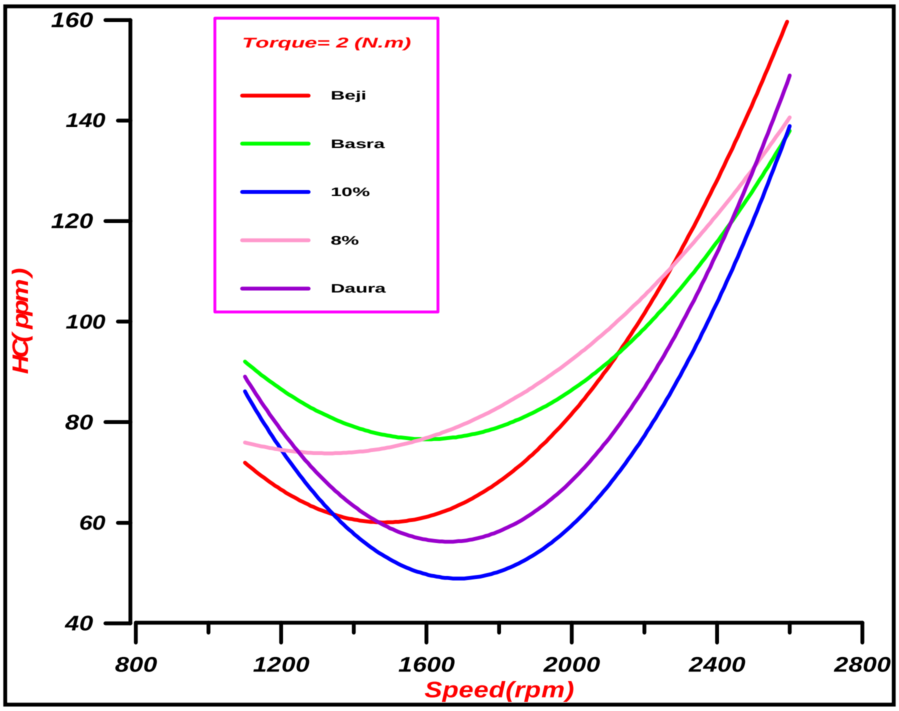

Fig .(13) Effect of Fuel Types, speed on HC(ppm) at torque=2N.m

Figure (14) shows that the Indicated thermal efficiency η_{Ith} was affected by engine speed. At engine speed 2100 rpm recorded the highest Indicated thermal efficiency is optioned with 10% blended fuel at torque 2Nm and sharply decreased with load increasing followed by Daura fuel and others. The smallest rate of efficiency is that when increasing torque that with Basra fuel at torque 10Nm.

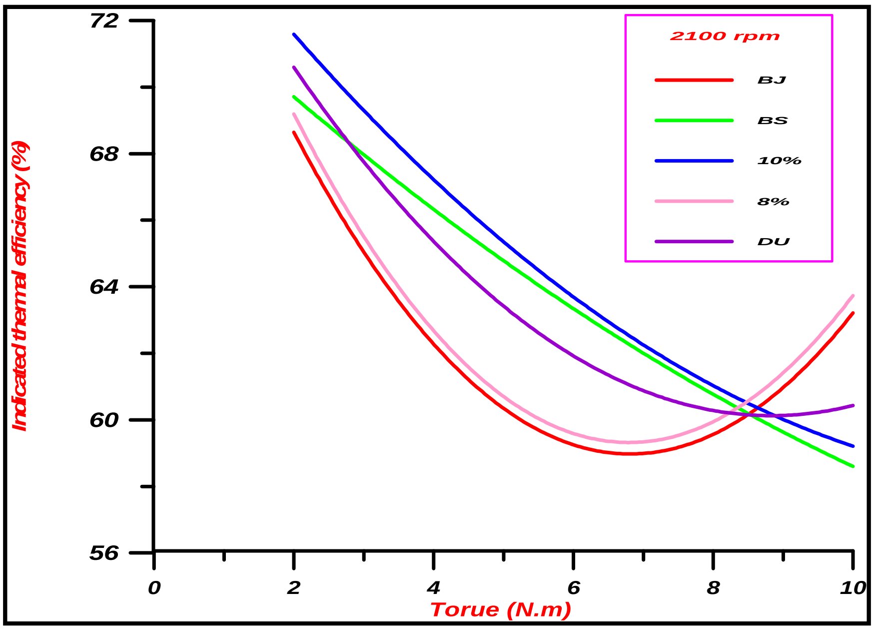

Fig .(14) Effect of Fuel Types, Torque on Indicated thermal efficiency(%) at speed = 2100rpm

Figure (15) shows that the Indicated thermal efficiency η_{Ith} was affected by engine speed, 2100 rpm recorded the highest Indicated thermal efficiency with Basra fuel followed by 10%blended. The smallest rate of efficiency when increasing the speed at Daura fuel.

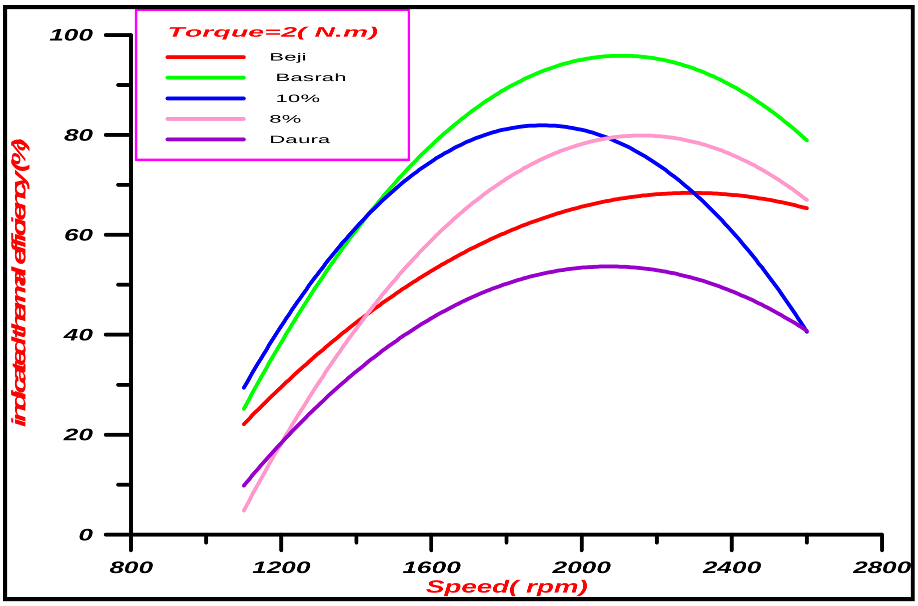

Fig .(15) Effect of Fuel Types, speed on Indicated thermal efficiency(%) at torque=2N.m

Figure(16) states the variation of the brake specific fuel consumption(bsfc) with variable torque , it was found the bsfc decreases sharply for all types of fuel within the range of engine torque T= 2 Nm to T=8Nm and decreases slightly when engine torque over T=8 Nm. The highest value was recorded with Basra and the lowest value was recorded with 10% blended.

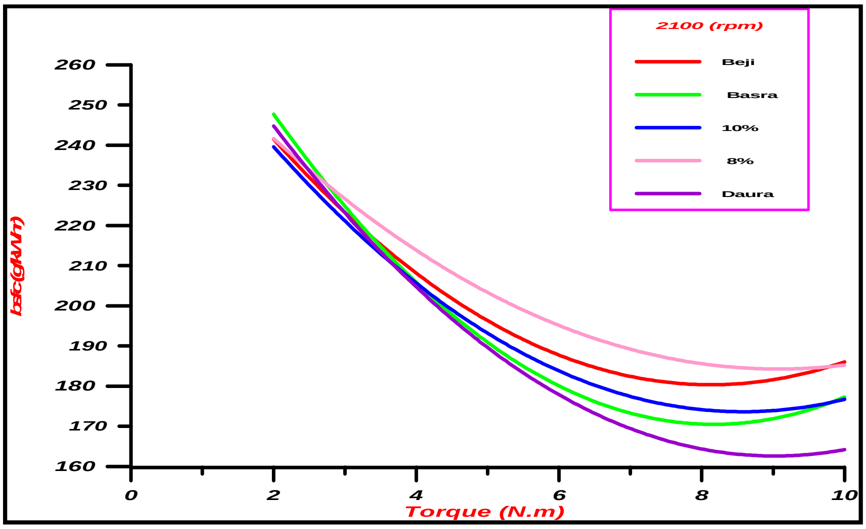

Fig .(16) Effect of Fuel Types, Torque on bsfc (g/kW.hr) at engine speed =2100rpm

Figure (17) shows the difference among of fuel types in brake specific fuel consumption(bsfc) with variable speeds at torque 2Nm. Basra and 8% blended recorded the lower value of (bsfc) compared with the other types of fuel (Daura, Beji and 10% blended) at lower speeds and finally increasing .

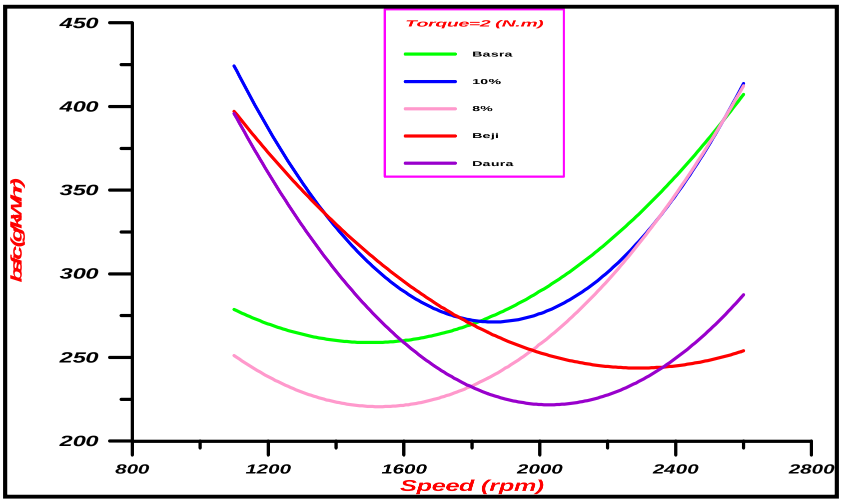

Fig .(17) Effect of Fuel Types, speed on bsfc (g/kW.hr) at torque=2N.m

5. Conclusions:

The result which obtained from the experiment can be summarized as follows:

- The lowest value of **CO** and **HC** concentration on emissions was at ethanol blended diesel fuel (10%and 8%). Its consider the best types, while recorded high level on NO_X and CO_2 emission.
- The beji fuel recorded lowest level with NO_X emissions with variable speed followed by the other types of fuel.
- The beji fuel has recorded the lowest value of CO_2 concentration on emission with variable torque followed by Daura, Basra and the worst type of fuel were 10% and 8% ethanol blended respectively.
- The summary of increasing percentage of CO_2 on 10% ethanol blended up to 0.57% while the same fuel has 54% decreased in **HC,** a 46% decrease in **CO** and 14.7% decrease in NO_X.
- Increasing the engine torque led to decreasing brake specific fuel consumption (bsfc), while the increasing the bsfc as a results of increasing of speeds so for the first case (variable torque) Beji fuel recorded the highest rate of bsfc and in the second(variable speed) 10% blended ethanol recorded the highest value followed by 8% and other types.
- At variable torque 8% ethanol blended has recorded the highest rate of indicated thermal efficiency reach to 64.5% followed by Basra which was reached to 62.85% followed by the others, while with the variable speed Basra fuel type recorded the highest rate of indicated thermal efficiency reach to 72.35% followed by 8%, Beji, Daura and 10% .

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