EFFECT OF ADDING BUTANOL AND ACETONE TO DIESEL FUEL ON EXHAUST GAS EMISSIONS AND SOME ENGINE PERFORMANCE INDICATORS

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ABSTRACT

This study was aimed to evaluate the effect of blending two types of *alcohol* **with pure diesel fuel. A 4-cylinder 4- stroke water cooled direct injection (DI) diesel engine was used. An electric dynamometer was connected to the engine to make load by electric heaters; the load on the engine was fixed at full load. The engine was run with two speed levels : 1300 rpm and 1600 rpm. Three types of fuel were used, including blended n- butanol (B) and Acetone(A) mixed with diesel by two levels named by AB15D85 and AB30D70, respectively, and compared with pure diesel fuel (D), which was the baseline. Gas emission was measured by using gas analyzer type AirRex - HG540. Results obtained from the experiment were statistically analyzed and showed that brake thermal Efficiency registered a slight increase of 5.7% when using(AB30D70) compared with base diesel fuel, while the samples (AB30D70, AB15D85) pointed to a slight increase in BSFC by (5.1%and4.4%) respectively when compared with base diesel fuel. The fuel(AB30D70) detected a sharp reduction in both carbon dioxide (CO_2) unburned hydrocarbon(HC) and Nitrogen oxides (NO_x) by (49.1%,100%, 38%) respectively compared with base diesel fuel**

Key Words; internal combustion engine. brake thermal efficiency. volumetric efficiency, brake specific fuel consumption, exhaust gas temperature.

***part of Misc. dissertation of 1st author .**

مجلة العلوم الزراعية العراقية- 2024 :55(4):1404-1411 شاكر وكاظم

تأثير إضافة البيوتانول والأسيتون إلى وقود الديزل على انبعاثات غازات العادم وبعض مؤشرات أداء المحرك

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المستخلص

تم إجراء تجربة عملية لتقييم تأثير مزج نوعين من الكحول مع وقود الديزل التقليدي. استخدم محرك ديزل مبرد بالماء رباعي الأشواط رباعي الأسطوانات تم ربطه بمولد كهربائي لتسليط الحمل على المحرك مسخنات كهربائية. المحرك يعمل بأقصى حمل وبسرعتين هما 1300 دورة/ الدقيقة و1600 دورة/ الدقيقة. جهز المحرك ليعمل بثلاثة أنواع من الوقود وهي مزيج n- بيوتانول (B) وأسيتون (A) ممزوج بوقود ديزل النقي وبمستويين تم تسميتها بـ (AB15D85 وAB30D70) على التوالي ومقارنتهما بالديزل النقي D. تم قياس انبعاث غاز العادم باستخدام محلل الغاز من النوع HG540. وأظهرت النتائج التي تم الحصول عليها من التجربة أن استخدام العينات (AB15D85 وAB30D70) سجلت زيادة طفيفة في الكفاءة الحرارية المكبحية (BTE) بنسبة 5.7٪ وزيادة طفيفة في استهلاك الوقود النوعي المكبحي (bsfc) مقارنة بوقود الديزل النقي ، في حين لم يظهرالتداخل الثنائي بين مزيجين الوقود المنتخبين مع السرع المختارة أي تأثير معنوي على صفة bsfc مقارنة مع وقود الديزل النقي. بينما سجلت العينة AB30D70 انخفاض حاد في كل من ثاني أوكسيد الكربون (CO_2) الهيدروكربون غير المحترق (HC) واكاسيد النايتروجين (NO_x) بنسب تتراوح (49.1٪، 100٪، 38٪) على التوالي مقارنة مع وقود الديزل النقي.

كلمات مفتاحية: محرك احتراق داخلي ،الكفاءة الحرارية المكبحية، استهلاك الوقود النوعي المكبحي ،درجة حرارة غازات العادم ،الكفاءة الحجمية .

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INTRODUCTION

Emissions resulting from the fuel combustion of fuel in diesel engines, primarily when operating at high loads, are considered gases that contribute to environmental pollution and have a significant role in global warming. Advanced technology offers an innovative solutions to reduce these negative effects (6,19). It has become necessary to search for alternative fuels, such as using alcohol or extracting biofuels to reduce emissions by mixing it with diesel fuel in certain proportions. Nowadays, the scientific community shows an emerging interest in studying n-butanol as a blending component. The safer character of butanol with respect to ethanol for transportation, fuel handling and storage, together with its higher cetane number, higher heating value, lower volatility, higher flash point, better lubricity and better miscibility with diesel fuels (especially at a low temperature) of n-butanol have contributed to such interest. The main advantage of alcohol is that it contains a certain percentage of oxygen, which helps to complete the combustion and reduce exhaust emissions, as alcohol achieves a higher latent temperature compared to pure diesel fuel, and for this reason it has become necessary to use alcohols mixed in certain proportions with diesel engine fuel (17). A practical experiments showed that adding ethanol to diesel fuel led to some problems. Therefore, researchers paid great attention to study the addition of n-butanol as a blending element with diesel fuel, as it is the safest compared to ethanol in terms of using in IC engines (12), n-butanol is an alcoholic fuel more suitable for diesel engines than ethanol due to its higher heating value, good solubility, less corrosiveness in existing pipes and very close to diesel properties. Butanol mixes easily with diesel without using any surfactant, so Butanol appears as a good effective alternative fuel(13), while acetone is added to butanol as the former is more volatile than butanol and has a higher quality. The anti-knock effect is higher than the quality of butanol, so it is used as an additive with butanol.(8) indicated that when adding to a diesel fuel a mixture of acetone butanol ethanol (ABE) with percentages of (10,20,30) respectively and fuled this mixture on adiesel engine with two levels of speed (1500,1800)rpm with two loads (1.6,3.2) kW, the specific fuel consumption was increased , and mentioned that the BSFC for the mixing ratio 10% was less than neat diesel fuel 100%, knowing and they reported that the bsfc was decreased with an increasing the loads. These results can be attributed to the high latent heat of vaporization of acetone, butanol, and ethanol that dampens the ignition and significantly delayed the combustion process by releasing heat in the expansion stroke (9, 14,21). Carbon dioxide (CO_2) is one of the sources of greenhouse gases and is responsible for the greenhouse effect, in addition, the resulting carbon dioxide emission is an indicator on the completion of the combustion process (1), when adding a mixture of acetone-butanol to diesel fuel at a percentage of (20.10)% to a single-cylinder engine with three speeds (1400,2000,2600) r.p.m. The CO_2 emissions of iso-BA- diesel mixtures and n-BA-diesel mixtures were reduced at low speed (1000-1600rpm) mixtures of 20% n-BA-diesel had lower emissions compared to diesel and iso-BA-diesel (5). Unburned hydrocarbons (HC) are a source of pollution in nature via exhaust emissions, which are produced in high quantities during the engine starting process and especially when the engine temperature is below ambient temperatures(15), when an acetone-butanol mixture is added. To diesel fuel with a percentage of (20,10)% using a single-cylinder engine at three rpm (1600,2000,2400) HC emissions have been increased for iso-BA-diesel blends, while n-BA-diesel blends have lower emissions compared to diesel fuels and iso-BA-diesel(5).The target of this research is to evaluate adding a mixture of n-butanol and Acetone to diesel fuel by two levels and their effect on some performance of diesel engine and exhaust gases emission run at fixed full load with two levels of engine speed.

MATERIALS AND METHODS

Fuel

Three fuel types were used in this study, including a mixture of Acetone and n-butanol(AB) with diesel fuel named AB15D85 and AB30D70 compared with diesel fuel as a baseline. Details of mixing levels are shown in table 1.

Table 1. Types of fuel used in the experiment and mixing ratios

No.	types of fuel	Diesel fuel ratio(D)	Mix ratio(AB)	(Acetone) ratio	n-butanol ratio
1	Diesel	100%	------------	---------------	---------------
2	AB15D85	85%	1:3 (15%)	3.75%	11.25%
3	AB30D70	45.6	1:3 (30%)	7.5%	22.5%

The analysis of these fuel were carried out at Iraqi Ministry of Oil/ Petroleum Research and Development Center ,results analysis represented in Table2

Table 2. Laboratory test results

Type of fuel	Cetane index (Calc)	Kinematic viscosity at 40 ^oC	Density at 15.6 ^oC, g/cm^3	Calorific Value, kJ/kg
Diesel	57.1	2.6468	0.8811	45301
AB15D85	47.1	2.2066	0.81815	49278
AB30D70	45.6	1.83844	0.81612	41547

Engine Test:

Four –stroke four –cylinder direct injection water –cooled diesel engine was used in the experiment. the technical specification of the compression ignition engine is given in table 3.

Table 3. Engine test specification

parameters	Specification
Engine Manufacturer	Kia Bongo (Korea)
Type of engine	J2 2701
Engine cylinder number	4
Cooling system	Water type
Piston Displacement	$2694cm^3$
stroke	95mm
Bore	95mm
Engine oil type	SAE10W-30
Nominal Output	59.656kW at 4000 rev /min
Maximum Torque	164.75Nmat2400 rev/min

The engine was connected to an electric dynamometer to produce and measure the load using three electric heaters. Figure 1 showed the engine test rig including instrumentation unit to illustrate and control the speed, load, fuel consumption measured by a Burette tube, exhaust and water cooled temperature measured by thermometer type K , air consumption was measured by using air box and manometer . A schematic diagram for the test rig was showed in figure 1

Test procedure

The temperature, humidity and atmospheric pressure in the laboratory were recorded, and the fuel tank was filled with pure fuel and the engine was running for (15-20) minutes until the reaching stability of engine temperature. The engine speed was fixed at (1300 rpm) and all data were taken the load was fixed at 100 %load (full load) which includes The temperature of the air entering the engine T_2 and the ambient air temperature T_1, as well as the amount of atmospheric pressure, the relative humidity of the ambient air H_1 and the humanity of air entering the air box H_2. The time of consumed fuel (50ml) was calculated by using a graduated cylinder (burette) and stopwatch (2, 7), then the exhaust emission device were recorded which represented the proportions of containment of exhaust gases coming out of the exhaust pipe which include The unburned hydrocarbons (HC), , carbon dioxide (CO_2), Nitrogen oxides (NO_x). All the above operations were repeated for three times and all data were taken after the engine works at full load. Note that the required load was obtained by means of a three-phase electric generator, and by (9) electric heaters. All the above steps were repeated by running engine at 1600 rpm. All previous steps were repeated with two other types of fuel, AB15D85, and AB30D70. After the fuel tank was cleaned from previous type of fuel and changing fuel filter ,the specific fuel consumption and thermal efficiency were measured by the equation (2, 11).

RESULTS AND DISCUSSION

1-Effect of fuel type and speed on BTE :

Figure (2) shows the effect of fuel types and speed on Brake Thermal Efficiency when tested engine loaded at full load with two levels of engine speeds .it can be seen from the figure that fuel type (AB30D70) detected the highest value of BTE 31.24 % ,however the base diesel fuel registered 29.45% , the reason may be due to the increasing of oxygen level in the fuel(AB30D70) which led to make the combustion more efficient, while the fuel sample(AB15D85) pointed the lower value of BTE 26.17% by a reduction 11% than pure diesel fuel . the reason may due to the levels of Cetane index of this fuel that close to the cetane index of diesel fuel and also may be due to the value of calorific value of AB15D85 is higher than pure diesel fuel which led to minimize the duration of combustion and consequently reduce the BTE. This results agree with results obtained by (4, 20).

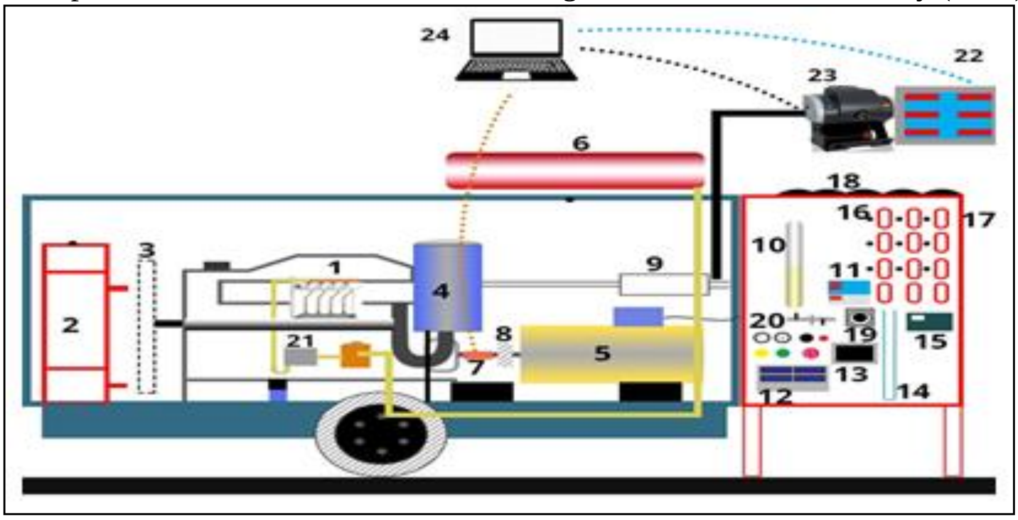

Fig. 1. Engine test rig .1-Engine 2-Radiator 3-Fan 4-Air box 5-Electric Dynamometer 6-Fuel Tank 7- Torque Device 8- coupling 9-Silencer 10- Burette Tube 11-volt-Ameter Device 12-Measuring Display device 13- weather Station 14 Manometer 15--Vibration Device 16-load regulator 17-Instrumentation Unit 18-Electric Heaters 19-Tacometer 20-Oil Pressure device 21-Injection Pump 22- emission analyzer 23 Opacity meter 24- PC

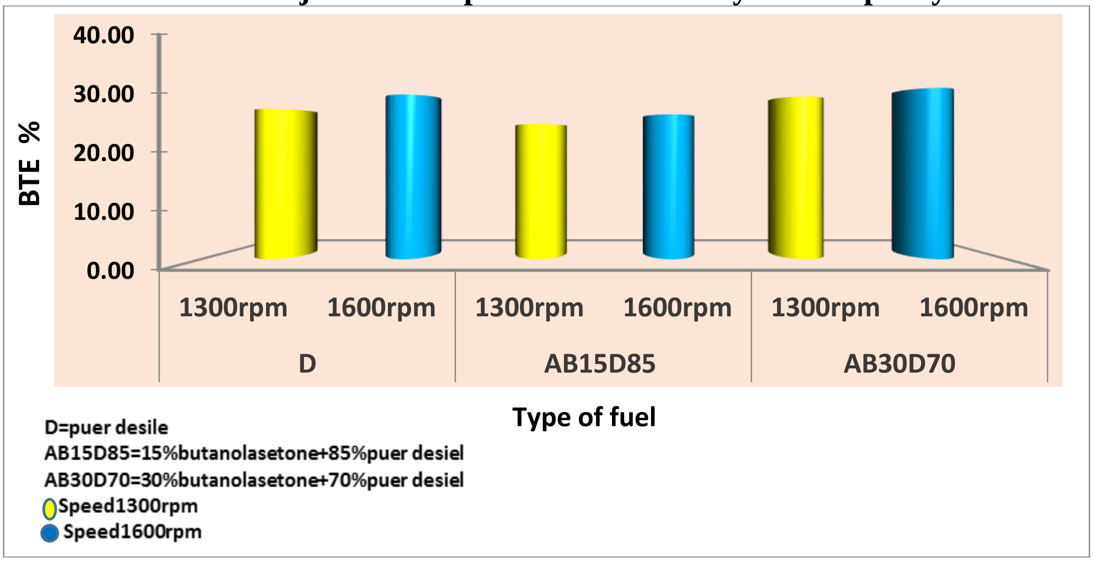

Fig 2. Effect of adding butanol and acetone to diesel fuel on BTE

2- Effect of fuel type and speed on BSFC :

Fig (3) illustrates the effect of fuel types on (BSFC) of tested engine that runs at two speeds, 1300rpm and 1600rpm, with the engine loaded at full load. It can noted from the figure that pure diesel fuel registered the lowest value of BSFC than two types of AB diesel mixture , the reason may be due to the highest content of oxygen in the mixture which led to consume more fuel for producing the same torque and power.as a result the fuel (AB30D70) and fuel(AB15D85) detected a slightly increase in BSFC by 5.1% and 4.4% when comparing with base diesel fuel . This results agree with results gained by (3, 10,18,21) and from the same figure it can be seen that the levels of (bsfc) has been effected by engine speed ,as engine speed increase the levels of(bsfc) decrease.

3- Effect of fuel type and speed on CO_2 Emissions:

The values of Carbone dioxide that emitted from the tested engine that run at full load with two levels of engine speed and fueled by the selected types of fuel were displayed in figure (4) .when comparing fuel (AB15D85,AB30D70) with base diesel fuel, it can be seen that the lowest reduction of CO_2

pointed by using (AB30D70) followed By (AB15D85) by 49% and 35.5% respectively comparing with diesel fuel at engine speed 1300rpm, the reason may due to the high efficient of fuel combustion. It can be seen that this results are similar to that results obtained by (16). and from the same figure it can be seen that the levels of emitted CO_2 has been effected by engine speed ,as engine speed increase the levels of CO_2 are rising.

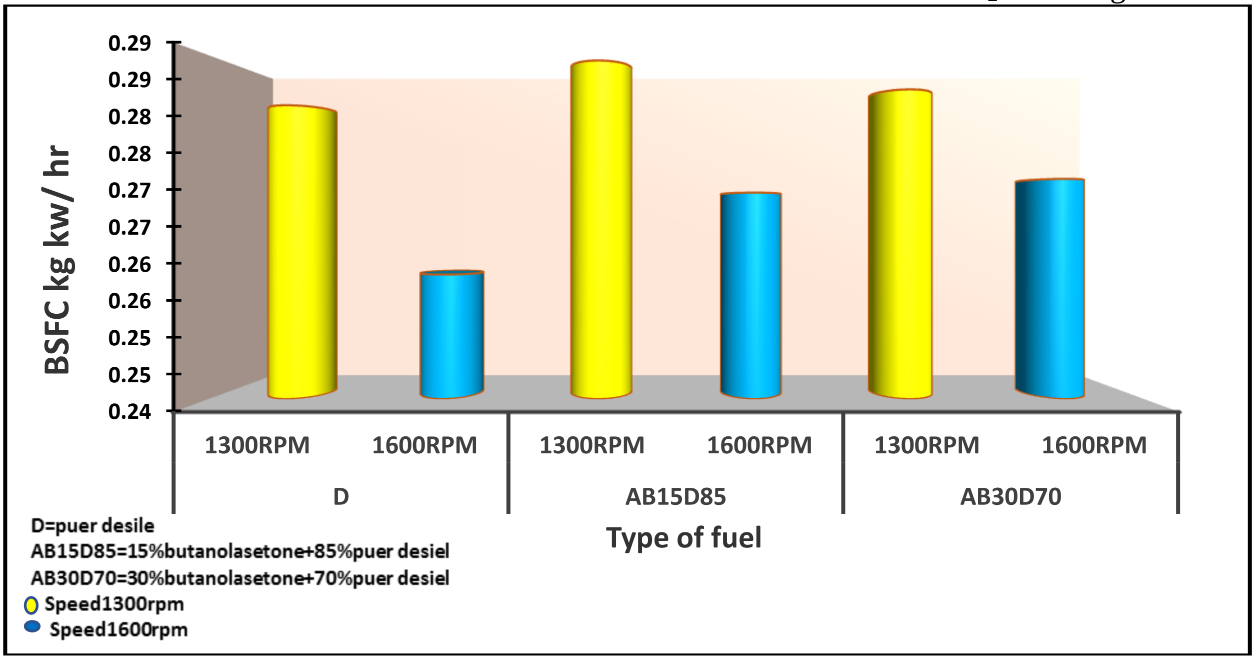

Fig 3. Effect of adding butanol and acetone to diesel fuel on BSFC

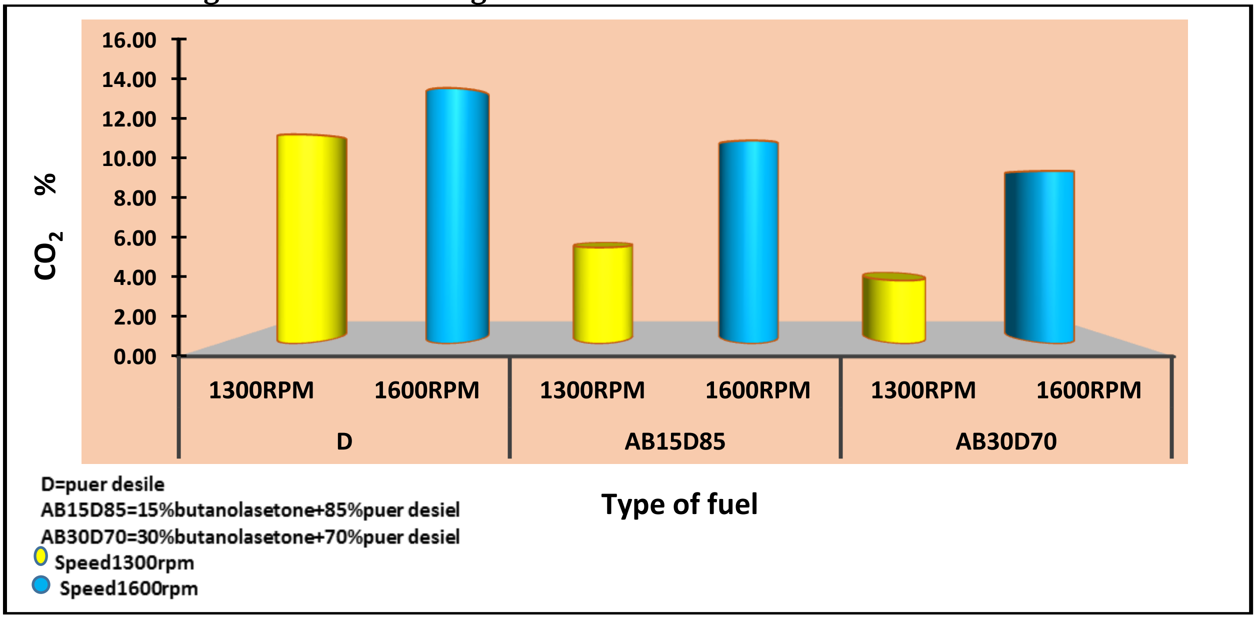

Fig 4. Effect of adding butanol and acetone to diesel fuel on(CO_2)

4- Effect of fuel types on HC Emissions:

The effect of fuel types and speed on exhaust emitted HC can be illustrated in figure (5) .It can be seen that fuel(AB30D70) and Fuel(AB15D85) registered a sharp reduction in HC by 100% and 77.5% that emitted by the engine when compared with the pure diesel fuel; the reason may be due to the lower hydro carbon emission of(n- butanol + acetone) that have lower viscosity which affects the spray penetration of the fuel and so that the BA-diesel mixture offers longer or deeper penetration of the spray compared to base diesel fuel; as a result , complete and efficient combustion has been obtained; this result is similar to the results gained by (4), and from the same figure, it can be seen that the levels of emitted HC has been effected by engine speed, as engine speed increases the levels of HC are rising.

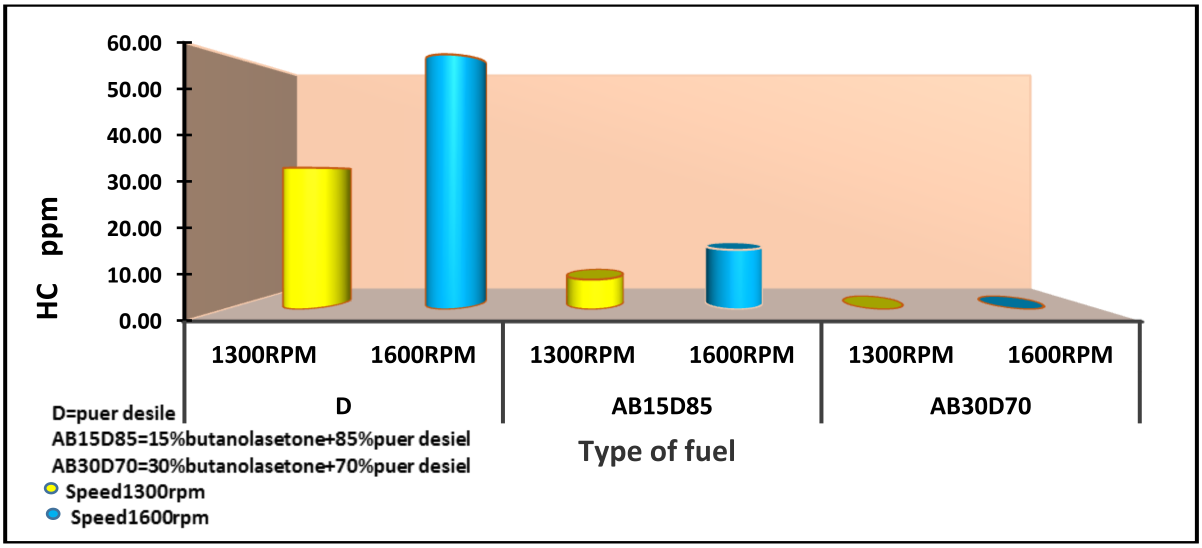

Fig 5. Effect of adding butanol and acetone to diesel fuel on(HC)

5- Effect of fuel type and speed on NO_x Emissions: From Figure (6) it can seen that as the percentage of AB increased in the mixture the levels of emitted NOx emissions decreased. Fuel types (AB30 D70 and AB15 D85) pointed a reduction in NO_X by 38% and 26.5% respectively when comparing with pure diesel fuel , the reason may due to low calorific value of oxygenated fuel that mixture with diesel cause a reduction in combustion temperature and consequently declined the levels of NO_x emission. This results agree with combustion product by the published data gained by (16).

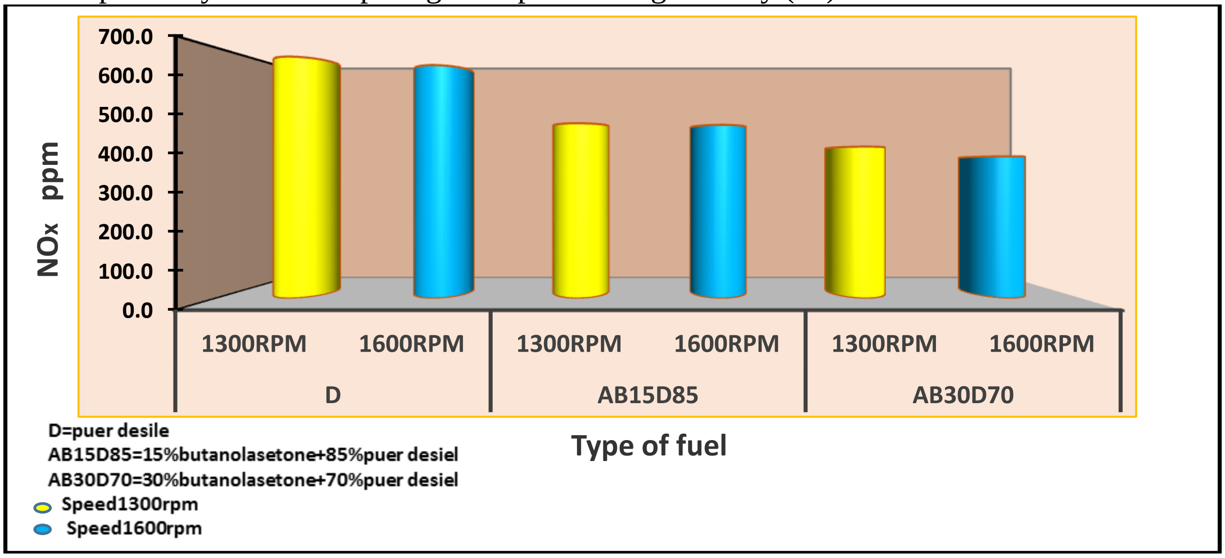

Fig 6. Effect of adding butanol and acetone to diesel fuel on(NO_X)

Conclusions

1- increasing mixture ratio of (acetone + n-butanol) added to pure diesel fuel, the emissions of exhaust gases (unburned hydrocarbons, nitrogen oxides, and carbon dioxide) decreased compared to diesel fuel without additives.

2- The using of the sample (AB30D70) with mixing ratios (7.5% acetone + 22.5% n-butanol + 70% diesel) gave the best performance indicators for the engine and the lowest emissions of exhaust gases.

3- With an increase the mixture ratio (acetone + n- butanol) added to pure diesel fuel, the rate of brake specific fuel consumption and brake thermal efficiency increased.

4- Increasing the speed from 1300.pm to 1600 rpm increased the brake thermal efficiency and the emissions of (carbon dioxide and unburned hydrocarbons), while the specific brake fuel consumption and nitrogen oxides decreased

Recomodation: Based on the results obtained, the recommendations can be summarized as follows:

1- Using the sample (AB30D70) with mixing ratios (7.5% acetone +22.5% n-butanol +70% diesel) as it gave the best performance indicators for the engine and the lowest emissions of exhaust gases.

2- Using mixtures of (Acetone + n-Butanol + Diesel) in different proportions and testing them on heavy duty diesel engines by taking into account that the ratio of (acetone) is less than that of (n-butanol) and avoiding equal proportions between the two substances when mixing.

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