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Performance and Emissions Characteristics of Diesel Engine Running Using Biodiesel and Its Blends with Kerosene Compared to Regular Diesel

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INCREASE of environmental problems and depletion of fossil fuels are the driving forces to promote biodiesel as an alternative fuel in diesel engines. In the present work, biodiesel was prepared by transesterification of waste cooking oil with methanol, its physical and chemical properties were measured and found to be within acceptable limits of standard specifications of regular diesel fuel. Performance and emissions characteristics of a diesel engine running using biodiesel (B100) and its blends with kerosene were then assessed and compared to those using regular diesel (D100). Two biodiesel blends of biodiesel with kerosene have been used in this study containing 25 and 50% by volume kerosene as (K25) and (K50), respectively. The used engine was a direct injection four stroke, four cylinders diesel engine and was run at two engine speeds being 1250 rpm and 900 rpm. The results showed that the composition of the exhaust gases of the engine running at both speeds was better using biodiesel instead of regular diesel and it has been improved further by blending biodiesel with kerosene. With respect to the brake thermal efficiency, it was found that the use of biodiesel instead of regular diesel reduced the thermal efficiency at 1250 rpm while the reverse was true at a lower running speed of 900 rpm. However at both engine speeds, the thermal efficiency can be improved by blending biodiesel with kerosene.

Keywords: Waste cooking oil, Transesterification, Kerosene, Performance, Emission.

Introduction

Fossil fuel resources are not regarded as sustainable from the economic, ecology and environmental points of view. Burning of fossil fuels is a big contributor for increasing the level of CO_2 in the atmosphere which is directly related to the temperature increase on the earth observed in recent decades. The effect of excessive increase of carbon dioxide emissions on the environment with declining petroleum reserves have been motivated to the need for sustainable and environmentally friendly sources of fuel in recent years. Biodiesel is considered the most suitable alternative fuel that meets these requirements. Biodiesel consists of methyl or ethyl esters of fatty acids and it is usually prepared by transesterification of vegetable oils with alcohols [1-5].

Considerable research has been undertaken recently to understand the performance characteristics of diesel engines if fuelled by biodiesel or its blends with petrol diesel [6-10]. Output power, specific fuel consumption and brake thermal efficiency under different running conditions of the engine such as running speed and load are the most important parameters that determine the performance of the engine. In addition, the composition of the combustion exhaust and NO_x emission are very important parameters that should be considered. Unlike regular diesel fuel, biodiesel has high oxygen content. This results in more complete combustion and lower emissions. However, high oxygen content leads also to lower heating value and hence more fuel consumption and less output power .In addition ,biodiesel is more viscous and less volatile than diesel fuel which may cause some troubles upon running diesel engines using these fuels.

It should be notified that engine performance with diesel and biodiesel as well as its emission characteristics depends not only on the nature of the fuel used but also on the combustion chamber and injector nozzle design, as well as injection pressure, air turbulence, air- fuel mixture quality and actual start of combustion that make test results which varies from one engine to another. In order to improve the flow properties, biodiesel is usually used in blends with petrol diesel. The

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optimum ratio of biodiesel to petrol diesel for better engine performance and less emissions needs to be determined under different operating conditions of speed and load. The costs of feedstock used to produce biodiesel contribute to a large extent of the total production costs. Waste cooking oil is cheap feedstock for biodiesel production. Extensive research work have been made to study the effect of blending biodiesel produced from waste cooking oil with regular diesel fuel on the performance characteristics of a diesel engine as well as the temperature of the combustion exhaust [5-14].

The results of these studies have shown that the specific fuel consumption increases by increasing the percentage of biodiesel in the fuel blend. The reason of this is that the measured heating value of waste cooking oil biodiesel was lower than that of regular diesel fuel. This has been reflected on the brake thermal efficiency which has been slightly reduced when the engine was run using such biodiesel blends with diesel in place of regular diesel. It has been also found that the exhaust temperature increases by increasing the percentage of biodiesel in the blend. In addition to the studies made on the performance characteristics of diesel engines using blends of diesel fuel with biodiesel ,some other studies have been made using blends of diesel with kerosene which may improve cold flow properties in the engine [15-18] .

Kerosene is a fuel with lower cetane number than diesel fuel, gives a longer ignition delay and may produce lower emissions. It has been found that blending diesel fuel with kerosene results in a reduction in specific fuel consumption, an increase in the brake thermal efficiency and an increase in the exhaust temperature as well as the emissions of CO_2 and NO_x gases. Blending of kerosene and biodiesel was studied in the view of the effect of such blending on the properties of the blend such as density, viscosity, flash point, pour point, cloud point and cetane index. Blending of biodiesel with kerosene enhanced the requirement of this fuel as a substitute of diesel fuel .Kerosene can reduce the flash point, viscosity and can reduce the characteristics of cold flow properties of biodiesel [19, 20]. The present work concerns with studying the effect of such blending on the performance of a diesel engine as well as the composition of the combustion exhaust.

Experimental

Production of biodiesel using used cooking oil as a feedstock

Waste cooking oil has been transesterified using methanol at its boiling point using 1% sodium hydroxide as a catalyst while stirring using magnetic stirrer. Since the reaction is reversible, excess of methanol has been used equivalent to twice the stoichiometric amount being around six moles alcohol to each oil mole. The reaction progress has been followed up during the reaction by the analysis of samples withdrawn from the reaction mixture over definite time intervals. Thin layer chromatography was used as an analysis tool until no residual glycerides were detected in the samples indicating completion of the reaction. Glycerol obtained as a byproduct of the reaction was separated and the residual catalyst in the methanol/ester product was neutralized using mineral acid and the whole mixture of biodiesel in methanol was then washed out using distilled water. The methanol in excess of the stoichiometric amount has been then recovered under vacuum.

The produced biodiesel has been then tested for its main fuel properties using standard ASTM methods of analysis.

Engine testing

Diesel fuel (D100) and the prepared biodiesel (B100) fuel as well as blends of biodiesel with kerosene were evaluated according to the performance characteristics and composition of the combustion exhaust of a diesel engine running using these fuels. Two biodiesel blends of biodiesel with kerosene have been used containing 25 and 50 % by volume kerosene; (K25) and(K50) respectively. The experimental runs were carried out at two speeds being 1250 rpm and 900 rpm and at each speed, the engine was run at different loads. The used engine was a direct injection four stroke, four cylinders diesel engine (capacity 1931cm^3). A schematic layout of the experimental set-up used is described in Fig.1. The instruments and measuring devices used in this set-up include:

1- Hydraulic dynamometer which is essentially a torque measuring device.
2- Tachometer and stroboscope which are used to measure the engine speed. Temperature thermocouples to measure the temperature of the cooling water, inlet and exit as well as the temperature of the exhaust.
3- Air tank and orifice meter which is used to

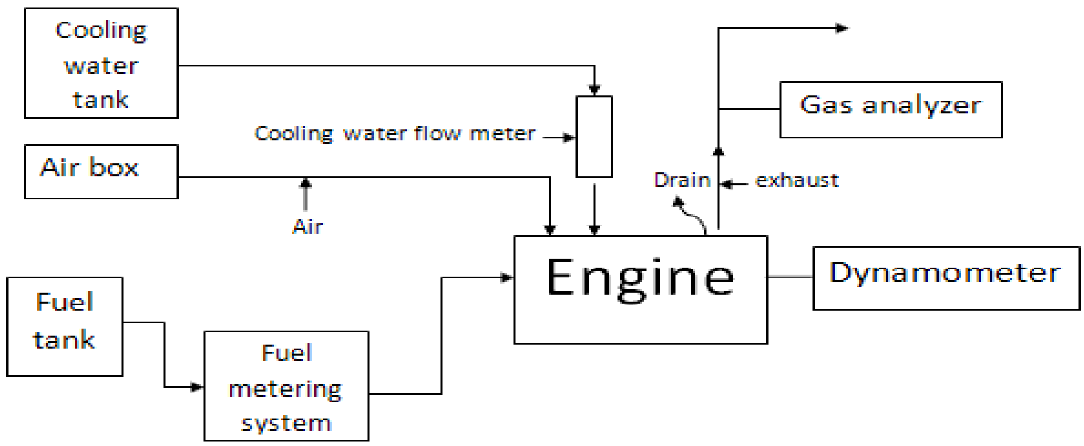

Fig. 1. Schematic diagram of experimental setup.

calculate the air flow rate.

The tested fuels include pure biodiesel and regular diesel fuel as well as blends of biodiesel with kerosene. In each run, the following readings were recorded for performance evaluation:

1- Dynamometer reading (load) and engine speed in rpm.
2- Fuel flow rate as well as air flow rate.
3- Cooling water flow rate and its temperature rise.
4- Exhaust gas temperature.

On the basis of these readings, the performance parameters of the engine have been estimated which include:

1- Brake specific fuel consumption.
2- Brake thermal efficiency.
3- Exhaust gas temperature.
4- Air- fuel ratio.
5- CO, CO_2 and NO_x emissions.

Results and Discussions

Properties of prepared biodiesel

Physical and chemical properties of the prepared biodiesel are listed in Table 1 together with the Egyptian standard specifications of regular diesel and kerosene fuels. It is clear that the properties of biodiesel of waste cooking oil are within the range of its values according to the Egyptian standard specifications of diesel fuel. The high viscosity of biodiesel contributes to higher carbon deposits in the engines which may cause some problems upon long term running of the engine. The flash point of waste cooking oil biodiesel is higher than that of diesel oil which makes it safer to store, use and handle than diesel fuel. The calorific value of biodiesel is lower than that of diesel oil which can be attributed to the presence of chemically bonded oxygen in vegetable oils which lowers the heating value by about 10%.

Results of engine testing

The effects of blending biodiesel with kerosene on the performance parameters and composition of the combustion exhaust of a diesel engine running at 1250 rpm at different brake power are illustrated in Figures 2-7. Table 2 lists the values of these parameters as well as the composition of the exhaust when the brake power was 7 kW.

It is clear from this Table that the specific fuel consumption using biodiesel (B100) is 370.8gm/kW.hr which is higher than that using regular diesel fuel (D100) which is 315.1gm/kW.hr. However, it can be reduced by adding kerosene to biodiesel where it was lowered to 352.4 and 361.6 gm/kW.hr by blending biodiesel with 25% and 50% kerosene, respectively. Such increase in fuel consumption has been reflected on the calculated brake thermal efficiency whereby it was lower using biodiesel (B100) as compared to that in case of running the engine using regular diesel (D100). The brake thermal efficiency, however, can be improved by blending biodiesel with kerosene. In view of the composition of the exhaust, it is quite clear that the use of biodiesel instead of regular diesel has greatly reduced the emission of CO, CO_2 as well as NO_x. Such reduction in the emissions has been further reduced by blending biodiesel with kerosene.

According to the results listed in Table 3, it is clear that the performance characteristics and composition of the combustion exhaust of a diesel engine running at a lower speed; 900 rpm (brake power = 5 kW), were both better using biodiesel instead of regular diesel. Moreover they can be further improved by blending biodiesel with kerosene .Blending biodiesel with 25% kerosene by volume (K25) has raised the brake thermal efficiency from 24 % to 25.3%.

TABLE 1. Physical and chemical properties of diesel, kerosene and waste cooking oil biodiesel.

Properties	Method	Biodiesel	Diesel oil	Kerosene
Specific gravity	ASTM D-4052	0.8836	0.835	0.8
Kinematic viscosity, cSt, @ 40^o C	ASTM D-445	5.1	≤7	2.7
Pour point, °C	ASTM D-97	6	4.5-15	−47
Flash point, °C	ASTM D-93	91	≥55	37-65
Cetane number	-------	59.82	≥55	42-45
Calorific value, kJ / kg	ASTM D-224	40000	42000	43000

TABLE 2. Performance characteristics and composition of the combustion exhaust of a diesel engine running at 1250 rpm (brake power = 7 kW).

Parameters	D100	K25	K50	B100
Specific fuel consumption, gm/kW.hr	316.3	352.4	361.6	370.8
Thermal efficiency, %	27.1	25.9	25.2	24.6
Air-fuel ratio	24.2	24.2	22.8	23.9
CO emission, ppm	682	518	598	607
CO_2 emission, %	7.69	4.42	5.25	4.74
NO_x emission, ppm	392	169	175	219

TABLE 3. Performance characteristics and composition of the combustion exhaust of a diesel engine running at 900 rpm (brake power =5 kW).

Parameter	D100	K25	K50	B100
Specific fuel Consumption, gm/kW.hr	369.4	360.9	370.2	379.6
Thermal efficiency, %	23.2	25.3	24.6	24
Air-fuel ratio	29.4	28.4	26.7	28.1
CO emission, ppm	1053	676	648	792
CO_2 emission, %	5.41	5.37	6.15	5.76
NO_x emission, ppm	302	217	216	281

The effects of engine load on air- fuel ratios for the studied fuels are shown in Fig.4. Air- fuel ratios decreased with the increase in engine loads due to the increase in fuel consumption. Fuel consumptions were lower for kerosene-biodiesel blends K25 and K50 compared to biodiesel fuel .

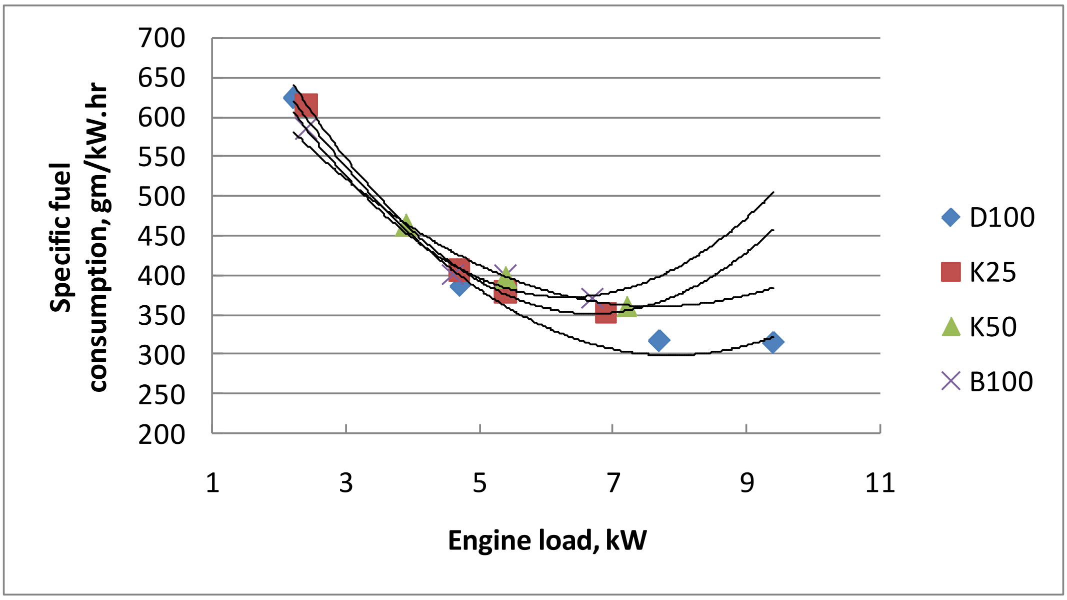

Fig.2.Variations of specific fuel consumption with brake power during running the engine at a speed of 1250 rpm using the used fuels.

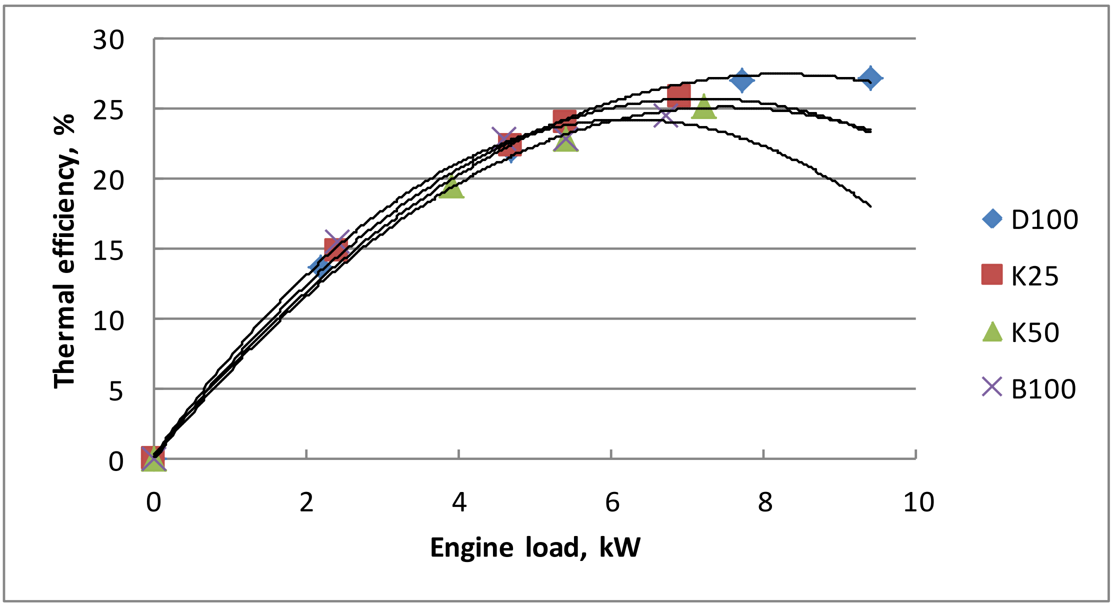

Fig.3. Variations of thermal efficiency with brake power during running the engine at a speed of 1250 rpm using the used fuels.

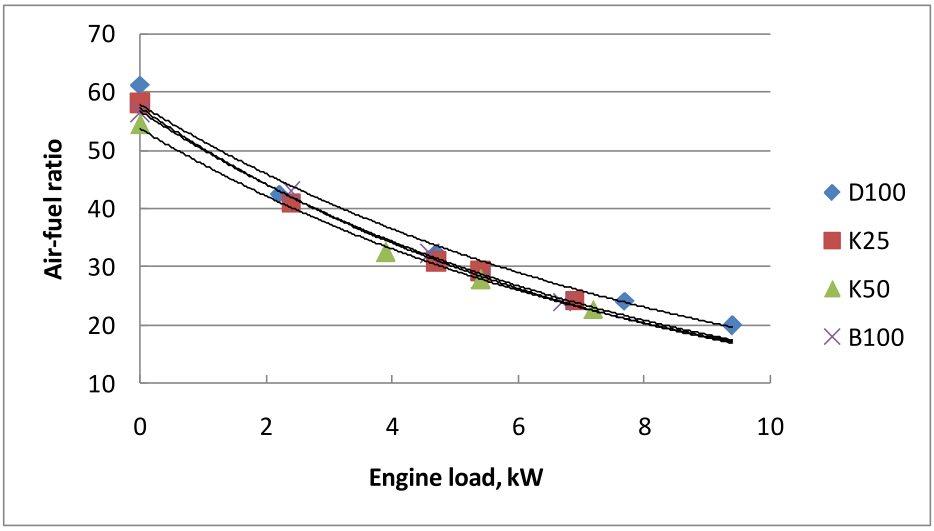

Fig. 4.Variations of air- fuel ratio with brake power during running the engine at a speed of 1250 rpm using the used fuels.

Figures 5-7 illustrate the variations of the concentration of carbon monoxide (CO),carbon dioxide (CO_2) and nitrogen oxides (NO_x) gases in the exhaust upon increasing the engine load. It is obvious that the concentration of carbon monoxide decreases by increasing the load while the reverse is true in case of the two other gases.

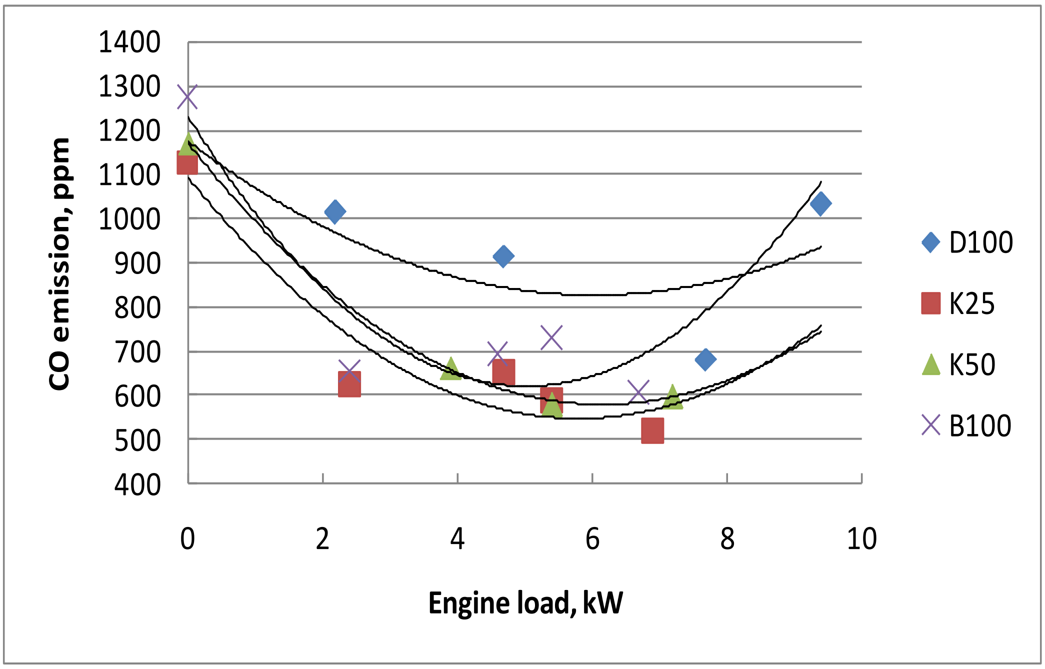

Fig.5.Variations of carbon monoxide with brake power during running the engine at a speed of 1250 rpm using the used fuels.

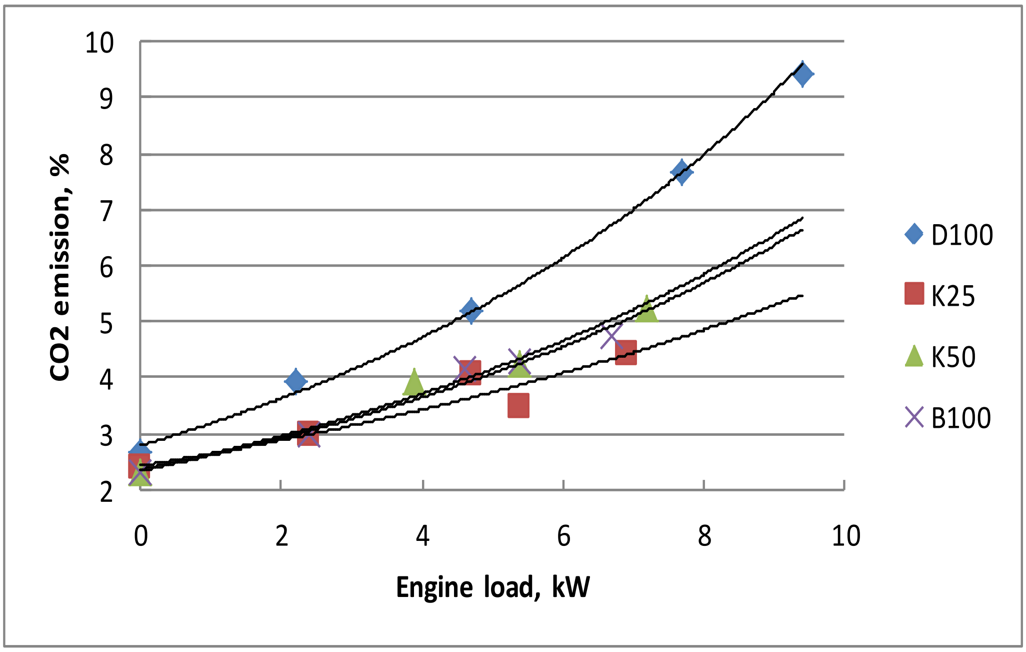

Fig.6. Variations of carbon dioxide with brake power during running the engine at a speed of 1250 rpm using the used fuels.

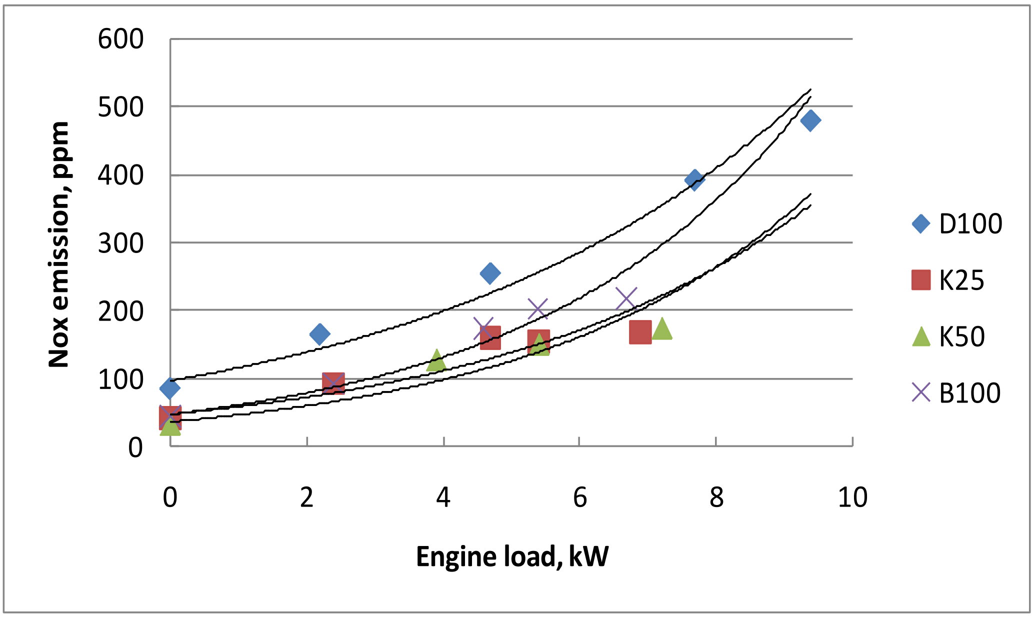

Fig.7.Variations of nitrogen oxides with brake power during running the engine at a speed of 1250 rpm using the used fuels.

Conclusions

The results of this work have shown that the composition of the combustion exhaust of a diesel engine can be improved by running the engine using biodiesel instead of regular diesel and it can be improved further by blending biodiesel with kerosene. With respect to the brake thermal efficiency, it was found that the use of biodiesel instead of regular diesel reduces the brake thermal efficiency at high running speeds while the reverse would be true at low running speeds. However, the thermal efficiency can be improved by blending biodiesel with kerosene whatever the running speed is high or low.

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خصائص الاداء والانبعاثات لمحرك ديزل يعمل بخليط من الديزل الحيوى والكيروسين مقارنه بالديزل البترولى

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إن زيادة المشاكل البيئيه واستنزاف الوقود الحفرى هي القوى الدافعه لتعزيز وقود الديزل الحيوى كوقود بديل في محركات الديزل. تم تحضير وقود الديزل الحيوى من خلال الاستره لزيت الطهي مع الميثانول. تم قياس الخصائص الفيزيائيه والكيميائيه للديزل الحيوى ووجد أنها ضمن الحدود المقبوله للمواصفات القياسيه للديزل البترولى. تم قياس خصائص الأداء والانبعاثات لمحرك الديزل باستخدام الديزل الحيوى ومزجه مع الكيروسين ومقارنته بالديزل البترولى. تم استخدام خليط من الديزل الحيوى و الكيروسين بنسبه حجميه 25 و 50 ٪ من الكيروسين. المحرك المستخدم فى التجارب محرك حقن مباشر، أربعه اشواط، أربعه اسطوانات، ويعمل المحرك بسرعتين 1250، 900 لفه فى الدقيقه. أظهرت النتائج أن مكونات غازات العادم للمحرك الذى يعمل عند السرعتين كان أفضل باستخدام الديزل الحيوى عن الديزل البترولى و تم تحسينه عن طريق مزج الديزل الحيوى مع الكيروسين. استخدام الديزل الحيوى بدلا من الديزل البترولى خفض الكفاءه الحراريه عند 1250 لفه فى الدقيقه بينما كان العكس صحيحا عند سرعة تشغيل المحرك 900 لفه فى الدقيقه. عند تشغيل المحرك بالسرعتين، يمكن تحسين الكفاءه الحراريه عن طريق مزج الديزل الحيوى مع الكيروسين.