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Experimental Characterization of Diesel Engine Performance Fuelled By Various Sunflower Oil-Diesel Mixtures

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Abstract: Adding bio-fuels to pure diesel may reduce the environmental harming but on other hand, the performance of the combustion would influence. The aim of this study is to present an investigation results on the effects of sunflower oil blend to pure diesel on the performance of single cylinder compression ignition engine. Three mixtures included sunflower oil/diesel ratios of 5:95, 8:92 and 11:89 in addition to pure diesels as a base, were tested. The experimental tests were carried out by using four stroke engine with a single-cylinder and 21:1 compression ratio. The engine performance was measured at various operating conditions. The results indicated that when sunflower-diesel fuel mixture used, the brake power of the engine slightly decreased while, the brake thermal efficiency showed decrease compared with diesel fuel. At the same time, it was found that break specific fuel consumption also increased compared with the pure diesel fuel. The exhaust gas temperature was decreased compared with the case of using pure diesel fuel.

Key words: Biofuel, IC engine, engine performance, diesel engine, fuel mixture

INTRODUCTION

Vegetable oils are produced from numerous oil seed crops. In general, the vegetable oils have high energy content but most of them require processing for safe use in Internal Combustion (IC) engines. Some of these oils already have been evaluated as substitutes for diesel fuels. The term vegetable oils refer to vegetable oils which have not been modified by transesterification or processed to form what is called 'biodiesel'. Previous studies included virgin and used oils of various types namely soy, rapeseed, canola, sunflower, cottonseed and similar oils. In general, raw vegetable oils can be used successfully in short term performance tests of the IC engines in nearly any percentage as a replacement for diesel fuel. But when tested in long term tests, blends above 20% nearly always result in engine damage or maintenance problems. Success is also reporting in using vegetable oils as diesel fuel extenders in blends less than 20% even in long term durability studies. The high viscosity and low volatility of raw vegetable oils are generally considered to be the major drawbacks for their utilization as fuels in diesel engines. Vegetable oil is one obvious fuel particularly because their properties as fuels are close to diesel fuel. Two important properties, the cetane number and the calorific value are similar to diesel. Hence, diesel engines can be operated on vegetable oil without modification (Ghani, 2010).

The use of vegetable oils as a source of energy has been known for a long time since the very first creation of the diesel engine. Most vegetable oils can be converted into biodiesel but the cost of the vegetable oil feedstock is now a key factor in the least cost production of biodiesel for blending with fossil fuel diesel Davies (2007) and Elsbett and Bialkowsky (2003).

Pramanik (2003) studied the properties of *Jatropha curcas* oil and diesel fuel blends in compression ignition engine. From the results of his study he concluded that there are various problems associated with vegetable oils addition to diesel in compression ignition engines. The most effective problems are the high viscosity volatility, ring sticking and gum deposits. The viscosity leads to pumping problems, combustion and atomization in the injection system.

Ghai *et al.* (2008) studied the emissions and performance influence with various sunflower methyl ester blends as diesel engine fuel in 4-stroke, CI engine. The obtained engine performance results were compared with pure diesel. They reported 1.5-4% increase in brake thermal efficiency. Also, they noticed a significant reduction in emissions of hydrocarbons as well as smoke particulates.

Wang *et al.* (2006) carried out experimental evaluation on the performance of a diesel engine and emission of exhaust gases when fuelled with vegetable oils added to diesel at 25, 50 and 75%. The results were compared with

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pure diesel case. The experiments were carried out at fixed engine speed of 1500 rpm but at different loads of 0, 25, 50, 75 and 100% of engine full load. The experimental results show that the power output and fuel consumption are comparable to diesel when fuelled with vegetable oil. Also, they found that the emission of nitrogen oxides from vegetable oil and its blends are lower than that of pure diesel. The carbon monoxide (CO) emission from the vegetable oil blends are lower compared with pure diesel fuel but in the cases of lower engine loads, the CO emissions are all slightly higher.

Rehman *et al*. (2009) presented the performance and emission evaluation of diesel engine fueled with vegetable oil. They used karanja oil, blends of karanja oil and the diesel oil as baseline at various loads. The results showed that diesel engine gives poor performance at lower injection pressure than, esterified karanja oil with diesel. Also, they have reported that vegetable oils have exceptionally high viscosity. The calorific value of esterified karanja oil was found to be 17.95% lower than that of diesel.

Pankajkumar *et al*. (2011) conducted an experimental investigation to evaluate and compare the performance and exhaust emission levels of sunflower and cottonseed oil methyl esters (bio-diesels) of Greek origin as supplements to the diesel fuel at blend ratios of 10/90 and 20/80, in a fully instrumented, six-cylinder, turbocharged and after-cooled, Direct Injection (DI). They concluded that all the tested bio-diesel blends can be used safely and advantageously in the present bus diesel engine, at the tested small blending ratios.

Rakopoulos *et al*. (2011) studied and evaluate experimentally the use of sunflower, cottonseed, corn and olive straight vegetable of Greek origin. They have used the same engine used by Pankajkumar *et al*. (2011) in volume proportions of 10 and 20%. The tests were conducted at two different engine speeds and three different loads. Fuel consumption and exhaust smoke are measured. The vegetable oil blends show reduction of emitted smoke combined with slight increase in NO_x with no influence on the thermal efficiency.

The objective of the present experimental investigation is to show the influence of compression engine performance when Bio-fuel is added to the pure diesel. The bio-fuel in the present study is the Iraqi local made sunflower oil. Three ratios of sunflower to diesel of 5:95, 8:92 and 11:89 were tested under various engine speeds. The results are presented in graphical form to realize the impact of the added bio-fuel on the engine performance parameters.

MATERIALS AND METHODS

Preparation and characterization of fuel mixture: Three different mixtures of sunflower oil blends and pure diesel have been chosen for use in this investigation. They included of sunflower oil to diesel as 5-95, 8-92 and 11-89 and pure diesel. The vegetable oils were obtained from commercial suppliers. Properties of the four different samples were experimentally evaluated by laboratory tests in North refinery Company in Baiji/Iraq. Properties of the fuel were obtained by groups of tests are included the specific weight based on the American Petroleum Institute (API) standard procedure. The device specifications and the test procedure are according to the American Society for Materials Testing (ASTM) and API. After measuring the specific weight at the thermal reference, the API is calculated by:

$$API = \frac{141.5}{SG} - 131.5 \quad (1)$$

where, SG is the measured specific gravity. Doctor Test used to indicate the presence or absence of each (H_2S, RSH). RSH refer to the group of chemical components of alkalis type that contain hydrogen and carbon.

Distillation test is achieved by apparatus consisting of distillation process of heating reservoir made of glass, heater, manometer and bottle collection. The method of the test by take amount of 100 mL of the sample and put it in the reservoir heating and reservoir set on the heater power at temperature of 90°C. The sample was heated to the boil. The vapor sample was passed into tube and then to the corridors in cold water for distillation and record.

The pour test achieved by a device consists of internally integrated refrigeration cycle. The operation of this device is to pre-chilled the sample in the freezer and monitor the temperature of each thermometer three degrees down the bottle. Then draw the bottle and set it inclined by 45° observe if there was liquidity in the fluid. This degree is called freezing temperature of sample. Above this temperature three degree is the temperature of pour.

Color test is achieved by Lovibond Tint meter method. In this test, the degree of color visual model is achieved by using the standard (ASTM) color. Also the testes include viscosity test. And finally measurement of the flash point and is defined as the point gets less than the glow of vapors emitted from the sample. The results are shown in Table 1.

Characterization results shown in Table 1 indicate that the SG is increased slightly to 0.842 compared to the

Table 1: Properties of the four samples of fuel mixtures

Test	Sunflower to diesel ratio 11:89	8:92	5:95	Pure diesel
Specific gravity at 15.6°C	0.842	0.842	0.842	0.834
API	36.6	36.6	36.6	38.2
Color	1.0	1.0	1.0	1.0
Flash point (°C)	67	66	61	61
Pour point	-3	-3	-3	-3
Viscosity (CST) at 40°C	3.7	3.7	3.6	3.4
Cetane	53.97	52.47	51.85	55.27
Distillation				
IBP	170	170	168	167
5%	197	196	193	195
10%	214	212	213	209
20%	237	236	233	230
30%	255	252	251	249
40%	272	271	271	265
50%	283	283	283	280
60%	300	300	300	294
70%	318	317	313	305
80%	344	343	340	320
85%	356	355	355	330
90%	360	360	360	342
95%	-	-	-	360
EBP	360	360	360	360

API: Specific weight of American Petroleum Institute, CST: Cent stock, IBP: Initial boiling point and EBP: End boiling point

pure diesel which is 0.834. The flash point of the mixture is increased from 61 for the pure diesel sample to 66 and 67 for the 8:92 and 11:89 mixtures, respectively. Meaning that, the added sunflower oil is affecting considerably the flash point of the fuel.

Experimental apparatus: The research engine used in this investigation is type TD111 manufactured by DIDACTA ITALIA having specifications as listed in Table 2. The combustion chamber is cylindrical in shape with a compression ratio of 21:1. The characteristics of the experimental engine use in the present work are shown in Table 2.

The engine is coupled to a hydraulic dynamometer to measure the engine torque and load control. TD114 data acquisition unit is connected to the measuring sensors in the engine and also being able to measure the input fluid parameters. The air consumption box and viscous flow meter in the unit are used to measure the air flow to the engine.

The fuel consumption is determined by measuring the time taken for the engine consume given volume for fuel say 8 mL. Thermocouples, type K (Ni-Cr)/(Ni-Al), were connected to TD114, were installed to measure the exhaust gas temperatures at the outlet pipes. The engine speed was measured by movistrob tachometer having a range of 150-4000 rpm. The fuel mass flow rate was measured using stopwatch and calibrated glass tube divided into three volumes, of 8, 16 and 32 mL. The schematic diagram of the experimental set up is shown in Fig. 1.

Table 2: The specification of the used engine Wang *et al.* (2006)

Parameter	Value
Type of engine	TD111 single cylinder
The No. of stroke	4- stroke
Bore	70 mm
Stroke	60 mm
Displacement volume	230 CC
Compression ratio	21:1
Mechanical efficiency	81%
Max. speed	3600 RPM
Max. power	3.5

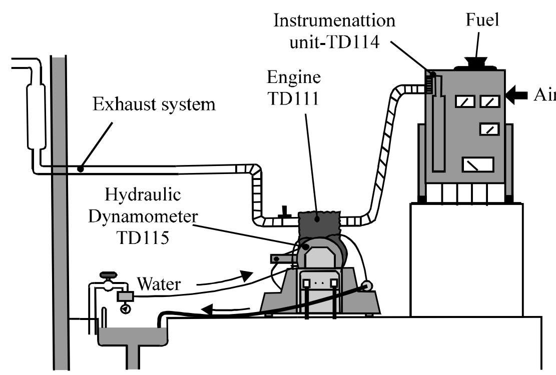

Fig. 1: Schematic diagram of the experimental set up

Test procedures and performance prediction: Initially, the engine was run for a warming-up. The procedure began with normal operation at idling speed. Measurements of the engine performance, carried out with fuel blends, were accomplished under condition similar to those occurring if the fuel was substituted for diesel fuel without any modification to the engine. These tests were performed at engine speed ranges from 500-3000 rpm with increment of 500 rpm. The required engine load was obtained thought the hydraulic dynamometer. Before running the engine to a new fuel blend, it was allowed to run for sufficient time to consume the left fuel from the previous experiment. Baseline tests were conducted with 100% diesel fuel. Then, same performance measurement procedures were conducted using the other three sunflower oil/diesel mixtures. The experimental data measurements could then be performed for different fuel blends. In each test, the operating conditions were stabilized and the variables that were continuously measured were recorded. This included dynamometer speed, torque, time required to consume 8 mL of fuels, pressure drop and the exhaust gas temperature.

Performance: The engine performance parameters such as Brake Power (BP), Brake Specific Fuel Consumption (BSFC) and thermal brake efficiency, η_{bth} were estimated using the following equation:

$$BP = 2\pi N\tau \quad (2)$$

$$BSFC = \frac{\dot{m}_f}{BP} \quad (3)$$

$$\eta_{bth} = \frac{BP}{\dot{m}_f \times Q_{HV} \times \eta_C} \quad (4)$$

Where:

N = The revolution per min

τ = The measured torque, m_f is the mass flow rate of fuel and Q_{HC} is the high calorific value. Assuming the combustion efficiency

η_c = 97%, the performance parameters were predicted and hence presented in graphical format at various engine speeds

RESULTS AND DISCUSSION

The results of the experimental measurements by using sunflower additives to the diesel are demonstrating reduction in the exhaust temperature and decreasing in the brake power decreasing of the single cylinder compression ignition engine compared to the base line pure diesel fuel. The engine characteristics behaviors are varying according to the added percentage of sunflower blend. On other hand, the brake specific fuel consumption is increasing. This is similar to the experimental findings of Kannan (2010) and Nagarhalli *et al.* (2010). The engine performance parameters obtained from the analysis of the experimental data are demonstrated in Fig. 2-5 and expressed in terms of the volume percentage of sunflower oil-diesel fuel blends in order to quantify the effect of sunflower oil blends addition in diesel fuel on engine performance.

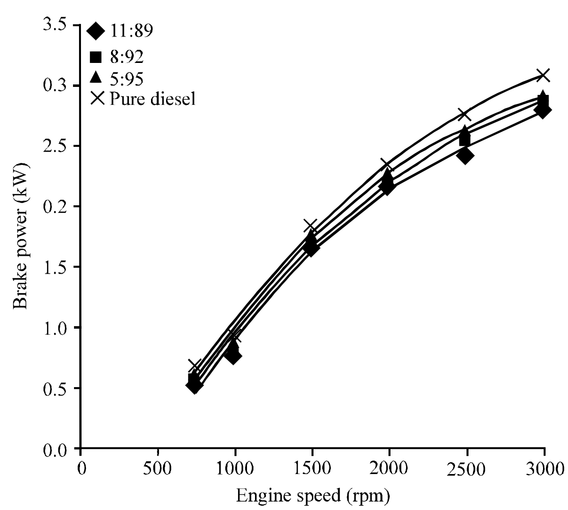

Fig. 2: Effect of fuel blends types on the BP at different speeds

Figure 2 shows the variation of the brake power as function of speed for four samples fuels. This figure clearly indicates that brake power increases as the engine speed increases for all fuels. At 2000 rpm, the brake power decreases by 2.5, 5.5 and 6.8% when using the samples 5:95, 8:92 and 11/89, respectively, compared with pure diesel fuel. Due to the decrease in air-fuel mixture temperature at the beginning of the combustion stroke resulted from the decreases in the lower heating value of the vegetable oil-diesel blends. As a consequent, combustion temperature decreases. The lower cetane

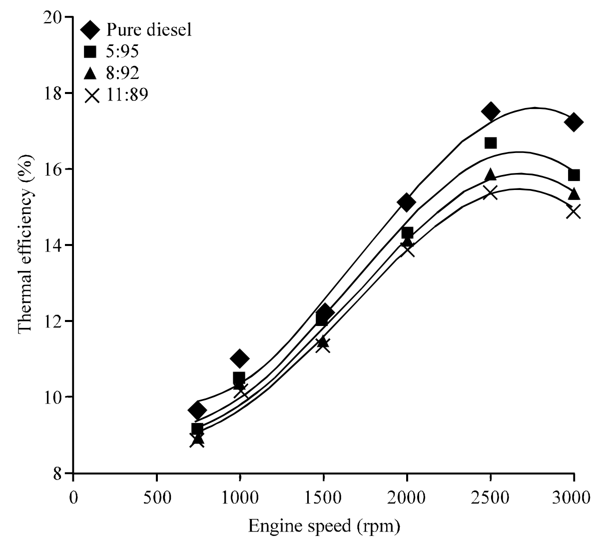

Fig. 3: Effect of fuel blends types on the brake thermal efficiency at different speeds

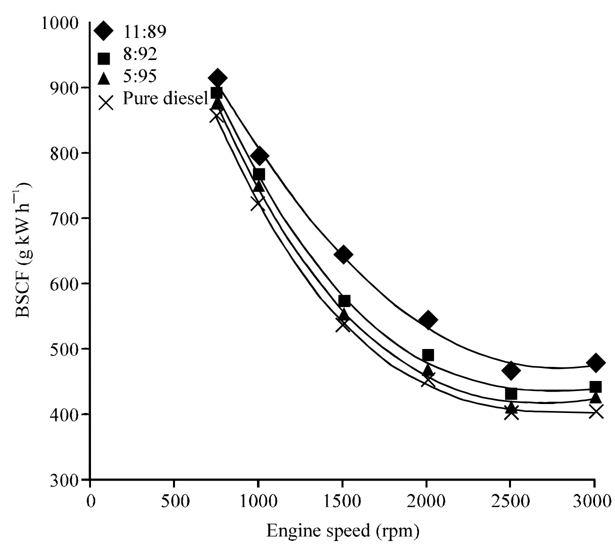

Fig. 4: Effect of fuel blends types on the BSFC at different speeds

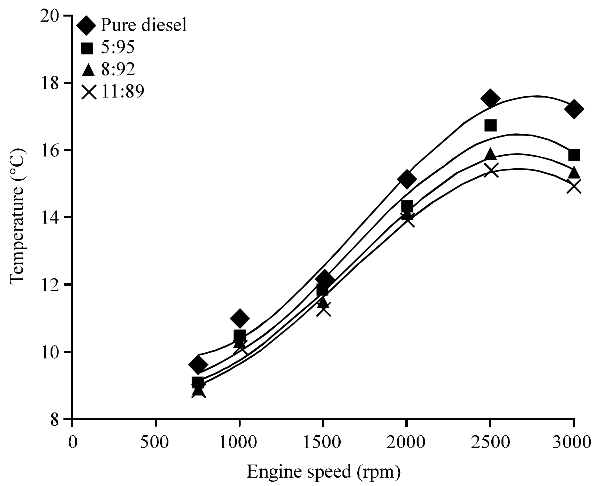

Fig. 5: Effect of fuel blends types on the exhaust temperature at different speeds

number also has an effect of increasing the ignition and causing delay, thus, the brake power decreases for all tested samples. Similar observations have been reported by the experimental works of many previous researchers, such as Sugozu *et al.* (2010) who studied the performance and emissions characteristics of a diesel engine fueled with biodiesel and diesel fuel mixtures and Ejilah *et al.* (2010) studied the effect of diesel fuel-*Jatropha curcas* oil methyl ester blend on the performance of a variable speed compression ignition engine.

The effect of sunflower additions to the pure diesel on engine brake thermal efficiency, η_{bth} at different engine speed is shown in Fig. 3. It is clear that η_{bth} increases as the engine speed increases for all tested samples of fuel mixtures. Also, contrary to the behavior of η_{bth} showed a decrease as 4.6, 9.2 and 12.1% with using the samples of 5:95, 8:92 and 11/89, respectively, compared with pure diesel fuel for the engine speed of 2500 rpm. This behavior is due to the lower brake power of the sunflower oil-diesel blends. Ghai *et al.* (2008) studied the emissions and performance influence with sunflower methyl ester as diesel engine fuel and obtained same behavior.

The lower cetane number also has the effect of increasing the ignition delay, thus brake power decreases for all the sunflower oil-diesel blends. This can be attributed to slight increase in BSFC and slight decrease in the exhaust temperature and A/F ratio at this speed compared to the pure diesel fuel.

Figure 4 shows the BSFC as function of speed for the four tested samples of fuels. The results are indicating that the BSFC decreases as the engine speed increases and reach minimum speed value at 2500 rpm and then increasing with increase the speed for all fuel blends. At the same time, it can be found that BSFC also increases as the added percentage of sunflower oil is increased, compared to the case of pure diesel.

This is due to the decrease in the lower heating value of fuel blend. The engine would consume more fuel in cases of addition than that with pure diesel fuel to generate the same power output, due to the decrease in the lower heating value of fuel blends, hence the increase BSFC. At these corresponding conditions the difference in viscosity between the sunflower oil-diesel blends and diesel was about tenfold the viscosity of sunflower oil-diesel blends is higher than that of pure diesel fuel. It can be seen that diesel had BSFC lower than the row sunflower oil-diesel blends. Similar observations have been reported by Rakopoulos *et al.* (2011) who studied and evaluate experimentally the use of sunflower, cottonseed, corn and olive straight vegetable of Greek origin. Also, same conclusions were drawn from the experimental results of Wang *et al.* (2006) on the performance and gaseous exhaust emissions of a diesel engine using blends of a vegetable oil.

The measurement results of the exhaust gas temperature at various engine speeds, for four tested fuel mixtures, are presented in Fig. 5. The exhaust gas temperature increases as the engine speed increases for all fuel samples. At engine speed of 2500 rpm, it is found that exhaust gas temperature decrease about 2, 6 and 10°C for the oils diesel blends samples 5:95, 8:92 and 11/89, respectively compared to pure diesel fuel. The exhaust gas temperature is an indication of combustion temperature which is a function of ignition time. Diesel fuel has smallest ignition time related to the fuel heat of vaporization and the heating value. Therefore with sunflower oil-diesel blends, combustion temperature and exhaust gas are decreasing according as the percentage of sunflower oil increased. This is due to the increase in the heat of vaporization of the mixture fuel blends.

CONCLUSIONS

The performance influence by adding sunflower oil to the diesel fuel of single cylinder compression ignition engine was investigated experimentally and compared to the base line pure diesel fuel. Three ratios of oil to diesel mixtures (5:95, 8:92 and 11:89) have been tested.

Exhaust temperature and brake power are decreasing by adding the sunflower oils to the diesel. The decrement is higher as the addition percentage of the oil is higher.

Brake specific fuel consumption increased by adding sunflower oil to the diesel fuel. The consumption is increasing as the added percentage is increased. This behavior was reasonable in view of the fact that the engine would consume more fuel with mixed fuel case than the pure diesel fuel case to generate the same power output.

Brake thermal efficiency is decreasing when sunflower oil is added to the diesel. This is due to the increase in brake specific fuel consumption and decrease in combustion temperature. The explanation for this behavior lies in the lower brake power of the sunflower oil-diesel blends.

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