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Effect of Biodiesel - Diesel Blends on Exhaust Emission and Performance of Compression Ignition Engine

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Abstract: *The present work investigates the engine performance parameters and emissions characteristics for in-line four cylinders four stroke direct injection diesel engine using biodiesel blends without any engine modifications. A two fuel blends samples and efficient diesel are used, neat diesel (100% diesel fuel), B20 (20% biodiesel and 80% diesel fuel), and B50 (50% biodiesel and 50% diesel fuel) respectively. Engine performance test carried out at full load, with variable speeds ranging from 1000 to 2600 rpm at an interval of 200 rpm. The engine emission was measured in all tests. The study results indicated that there has been a decrease in the brake thermal efficiency by (3.5768%) for the B20 and (7.671%) for the B50. The increase in specific fuel consumption was (6.243%) for the B20 and (13.1257%) for the B50 over the entire studied speed range compared to neat diesel fuel. The engine exhaust gas emissions measures declared that a higher CO by (4.069%) for the B20 and (7.303%) for the B50. HC increased by (5.295%) for the B20 and (12.594%) for the B50. Lower CO2 was obtained by (3.56%) for the B20 and (7.778%) for the B50 emissions, and lower exhaust gas temperature by (3.163%) for the B20 and (6.369%) for the B50 compared to diesel fuel. Therefore, it can be concluded that B20 and B50 can be used in diesel engines without any engine modifications as an alternative petroleum diesel fuel.*
Keywords: biodiesel-diesel blends, compression ignition engine, CO, HC, emissions.

I. Introduction

Alternative fuels received much attention due to the depletion of world petroleum reserves and increased environmental concerns. Biodiesel offers an attractive alternative processed form of vegetable oil to be used as fuels in compression ignition engines. Sometime in the 21st century, crude oil and petroleum products will become very scarce and costly to find and produce. At the same time, there will likely be an increase in the number of automobiles and other IC engine [1]. Although fuel economy of the engine is greatly improved from the past and will properly continue growing, the number alone dictates that there will be a high demand for fuel in the coming decade [2]. Biodiesel is a part of the biofuel concept; the biofuel is a necessary abbreviation of Bio-organic fuel. This is a scientific name for any plant or animal substance that can burn. Biofuels are renewable liquid fuels made from plant matter rather than fossil fuels [3]. Today's primary biofuels are ethanol and biodiesel. Biofuels can help reduce air toxics emissions, greenhouse gas buildup, and dependence on imported oil [4].

Khan et. al. [5] compared the petroleum diesel with the biodiesel fuel, the biodiesel has a lower emission of pollutants, and it is biodegradable and enhances the engine lubricity and contributes to sustainability.

Karthikeyan [6] studied the effect of cerium oxide (CeO_2) nano-fuel additive on the performance, combustion and emission characteristic of Grape seed Oil Methyl Ester (GSOME). With fuel properties of B20 (80% Diesel 20% GSOME), B20 CeO_{250} (80% Diesel 20% GSOME 50ppm CeO_2), B20 CeO_{2100} (80% Diesel 20% GSOME 100ppm CeO_2) and neat biodiesel were studied and compared. The study carried out at a constant speed of 1500 rpm. Experimental results show a significant improvement in the performance and reduction in harmful emission for the CeO2 nano additive biodiesel emulsion fuels compared to those of B20 .

Chaichan M T. [7] studied the effect of using sunflowers oil to make biodiesel by transesterification reaction process. A four-stroke diesel engine used to investigate the emission and engine performance of the neat biodiesel, two biodiesel-diesel blends compared to pure diesel. The experimental results show that when using biodiesel alone or as a blend with diesel fuel in C.I engine, we get lower brake thermal efficiency, lower exhaust gas temperature, and a higher brake specific fuel consumption, but in return using biodiesel will decreases the exhaust emission of CO, CO_2, and HC and this is a result of a more complete combustion of the fuel, and using biodiesel will reduce the dependence on the diesel fuel.

A.M. Liaquat and H.H. Masjuki [8] investigated the engine performance parameters and emissions characteristics for direct injection diesel engine using coconut biodiesel blends without any engine modifications. A total of three fuel samples, such as DF (100% diesel fuel), CB5 (5% coconut biodiesel and95% DF), and CB15 (15% CB and 85% DF) respectively were used. As results of investigations, there has been a decrease in torque and brake power, while the increase in specific fuel consumption has been observed for biodiesel blended fuels over the entire speed range compared to neat diesel fuel. In case of engine exhaust gas emissions, lower HC, CO and, higher CO_2 and NOx emissions have been found for biodiesel blended fuels compared to diesel fuel.

Eiman A. Eh. [9] studied the effects of three types of fuel, biodiesel from new oil, biodiesel from waste cooking oil, and diesel fuel on engine performance and emissions. The three fuels were examined experimentally by using a diesel engine and gas analyzer to perform a comparison between them. This research aim was to evaluate the effect of each fuel on the performance of the engine on a different set of speed at a fixed throttle setting (full throttle and medium throttle). The amounts of gas emissions from the exhaust were recorded, and compared the results obtained in these cases. Also, the fuel characteristics helped in the calculations for a better understanding of fuels through various experimentations. The results showed that waste cooking oil performance is a mediate one between new oil biodiesel and diesel fuel. The emission of waste cooking oil biodiesel was small with consideration to its efficient combustion. Biodiesel, in general, has a higher brake power and torque because it is clean burning and has a smoother running.

Sam Ki Yoon, et.al [10] investigated the effects of canola oil biodiesel (BD) to improve combustion and exhaust emissions in a common rail direct injection (DI) diesel engine using BD fuel blended with diesel. Experiments were conducted with BD blend amounts of 10%, 20%, and 30% on a volume basis at various engine speeds. As the BD blend ratio increased, the combustion pressure and indicated mean effective pressure (IMEP) decrease slightly at the low engine speed of 1500 rpm, while they increased at the medium engine speed of 2500 rpm. The brake specific fuel consumption (BSFC) increased at all engine speeds while the carbon monoxide (CO) and particulate matter (PM) emissions were considerably reduced.

The aim of this research was to evaluate the possibility of using biodiesel as an alternative to diesel fuels. The procedure used was to add biodiesel to diesel fuel with constant volumes fraction to supply blends of diesel and biodiesel can fuel the conventional diesel engine without the need for any modifications.

II. Experimental Setup

2.1. Experimental apparatuses

An internal combustion engine, compression ignition, four cylinder in-line, four strokes and natural aspirated FIAT Diesel engine. Table 1 represents the major engine specifications. The power was measured by using the hydraulic dynamometers shown in Fig. 1.

Table 1 Engine specification

Engine type	Four cylinder, four stroke
Combustion type	Compression ignition (self-ignition)
Fuel system	Direct injection system
Cooling system	water cooled
Engine displacement	3.666 Liters
Valve per cylinder	Two
Bore	100 mm
Stroke	110 mm
Compression ratio	17

Fig. 1, the engine and dynamometer

2-1 Measurement of engine speed

The engine is a test device so the measurement of the engine speed is done by a mean of tachometer fitted with the engine and a digital tachometer fixated on the crankshaft Figs. 2 and 3.

Figure (2) the engine tachometer

Figure (3) digital tachometer

2-2 Fuel consumption

The measuring of the volumetric fuel consumption is done by using glass bulbs of known volume and having a mark on the top and bottom of the bulbs, a mean of stopwatch takes time, the volume is divided by time will give the volumetric flow rate.

2-3 Measurement of brake torque

In this study, the measuring of the brake torque is done by using the hydraulic dynamometer. The dynamometer works on the principle of dissipating the power in fluid friction.

2-4 Air consumption

To measure the mass flow rate of the consumed air, we used the air box. The orifice of the intake air measures the difference pressure between the atmosphere and the intake pressure by a mean of manometer. The measured value is used to calculate the mass flow rate by the equation.

2-5 Exhaust temperature

The measurement of the temperature was achieved by using a thermocouple and a digital reader, the measurement instrument was connected to the exit pipe of the exhaust manifold by a mean of prop.

2-6 Exhaust emission

The device used to measure the emission of exhaust gases is the flux 2000-4, which can detect the CO-CO_2-HC-O_2 the gases is pick up by a probe from the chimney, then separated from moisture by a mean of condensate filter and go to the measuring cell.

2-7 Biodiesel preparation

Transesterification reaction is a process by which an ester is converting to a different kind of ester known as biodiesel. The process begin with the mixing of methanol and the catalyst (KOH) to form meth-oxides, and the amount of Methanol used ranges (20% - 50%) of the volume of the oil. After that, the oil is heated to a range of temperature of 48^{o}C to 60^{o}C to speed the reaction when adding the alcohol to the oil in a vessel with a mixer. After 1-2 hours the reaction is finished, and a two main component is produced, glycerin and biodiesel. As the glycerin is much denser than the biodiesel, so, they can be separated by gravity. To remove any impurities and the remaining of the catalyst the biodiesel can be washed with distilled water. The resulted biodiesel fuel is mixed with the diesel fuel at two ratios B20 (20% biodiesel 80% diesel) and B50 (50% biodiesel 50% diesel), the emissions and performance of the engine fueled and operated with these blends are compared to the diesel fuel operation characteristics. Table (2) the properties of the biodiesel blends.

Table (2) fuel properties

No.	Blending ratio	Lower calorific value (KJ/Kg)	Specific gravity(Kg/m^3)	Flash point (^{o}C)	Pour point (^{o}C)	Viscosity(mm^2/s at 40^{o}C)
1	B0 (neat diesel)	44844	0.8266	92	-6	14.3
2	(B20)	43360.63	0.83728	116.8	-7.419	24.748
3	(B50)	41135.575	0.8533	159.93	-9.882	42.867

2-8 Experimental engine procedures

After preparing the fuel specimen for the work which the consist of the three ratios of blended fuel of biodiesel-diesel (B0, B20, B50) and the fuel of certain number (58), we prepare the engine to do the experiment. For the three ratios of the blended fuel and after reaching the steady state for the engine, we take all the measurement as were explained previously for the fuel and air consumption and the exhaust temperature and emission. The entire test is done for a variable engine speed ranging from 1000 rpm to 2600 rpm with an increment increases of 200 rpm and at a maximum load on the engine from the dynamometer.

The following equation is used in calculation the engine performance parameters [11]:

Brake power $bp = \frac{2\pi * n * t}{60 * 1000}$ KW …….. 1

Fuel mass rate $mf = \frac{Vf * 10^{-4} * \rho f}{1000 * time}$ Kg/sec ……… 2

Air mass flow rate $\dot{m}_{a,act.} = \frac{12\sqrt{ho}}{3600} * \rho a$ Kg/sec ………3

$\dot{m}_{ath} = \frac{\pi * b^{\wedge}2}{4} * l * k * \frac{N}{2*60} * \rho air$ Kg/sec ………4

Brake specific fuel consumption $bsfc = \frac{mf}{bp} * 3600 \frac{Kg}{KW.hr}$ ……..5

Brake thermal efficiency $\eta_{bth} = \frac{bp}{\dot{m}f * LHV} * 100\%$ ……….6

III. Result and Discussions

The main purpose of this work was to evaluate the impact of using biodiesel fuel blends on the combustion characteristics of the fuel in C.I.E. The performance and the exhaust emission of the engine was measured and compared to neat diesel operation.

Fig. 4 shows the effect of engine speed on the brake thermal efficiency. The engine brake thermal efficiency was increased by (2.9614%) for the B20, and (8.117%) for the B50 compared to the neat diesel.

Fig. 5 shows the exhaust gas temperature for the tested blends. Exhaust gas temperatures decreased by (3.163%) and (6.369%) for B20 and B50 respectively compared to the neat diesel. This result indicates the tested blends low combustion flame temperatures.

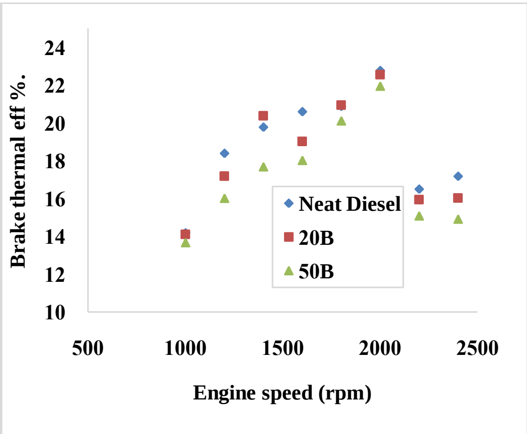

Fig 4, engine speed impact on the brake thermal efficiency

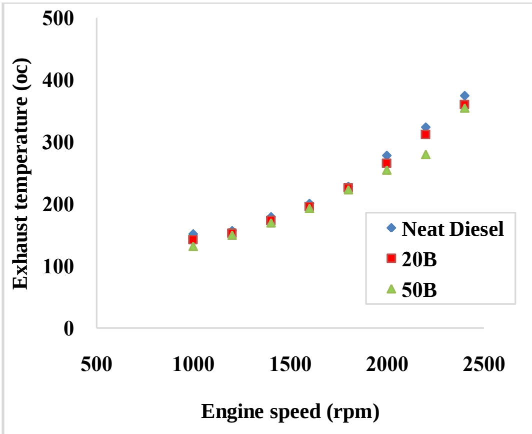

Fig 5, engine speed impact on exhaust gas temperature

Fig. 6 declares the brake specific fuel consumption of the engine for the tested fuels. The brake specific fuel consumption increased by (4.376%) for the B20 and (9.296%) for the B50 compared to the diesel fuel. This fuel consumption increment is due to the high density of the biodiesel and its lower combustion flame temperature.

Fig. 7 presents the variation of the Carbon monoxide for the tested fuels. CO decreased by (6.243%) for the B20 and (13.1257%) for the B50 compared to neat diesel.

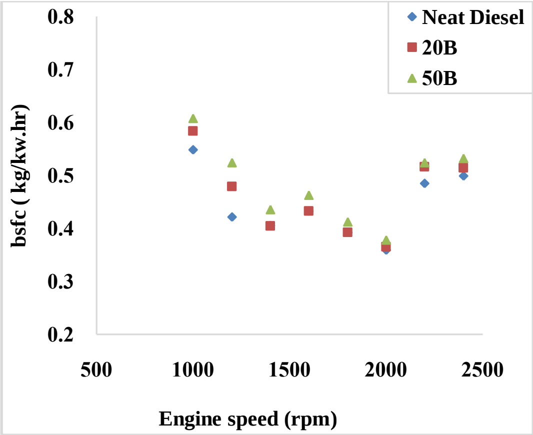

Fig 6, engine speed impact on the engine bsfc

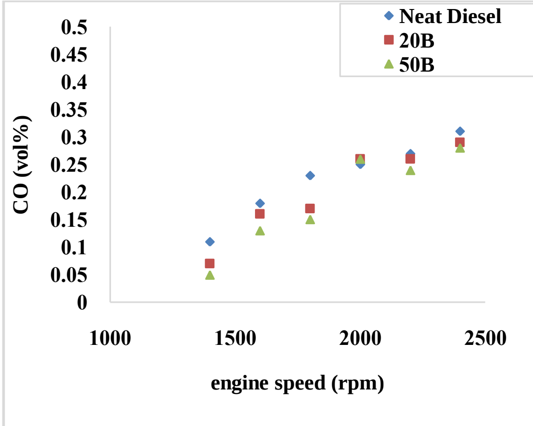

Fig 7, engine speed impact on exhaust CO emissions

The unburnt Hydrocarbon compounds were increased by (13.65%) for the B20 and (24.64%) for the B50 compared to the ordinary diesel as illustrated in Fig. 8. On the contrary, we see a reduction of carbon dioxide by (9.95%) for the B20 and (14.975%) for the B50 as Fig. 9 illustrates.

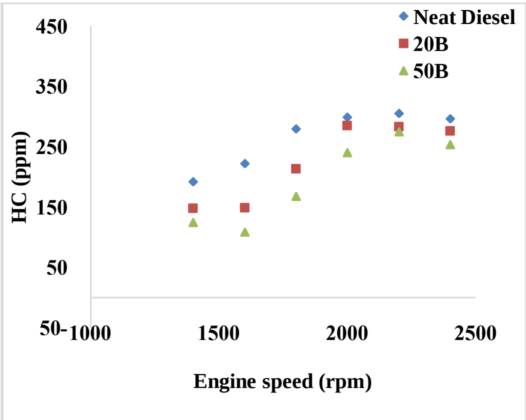

Fig 6, engine speed impact on the exhaust HC emissions

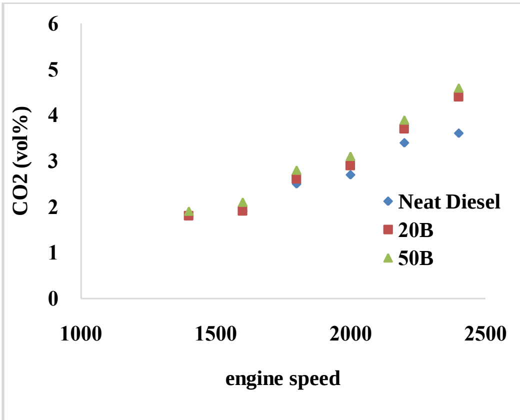

Fig 7, engine speed impact on exhaust gas temperature

IV. Conclusion

Using biodiesel as an additive to diesel fuel was investigated in this article. The aim was to evaluate the possibility of using the tested blend in conventional diesel engines without modifications. The obtained results declared that:

1- Biodiesel is a safe alternative to reduce the consumption of petroleum diesel by reducing the amount of diesel fuel used.
2- Using biodiesel blends as an alternative fuel can be done without any engine modifications.
3- A notable reduction in exhaust gas CO2 emission produced when the engine was fuels with biodiesel blends compared to diesel fuels.
4- An insignificant reduction in brake thermal efficiency obtained when biodiesel blends were used.

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NOMENCLATURE

ºBTDC	Degree before top dead centre
Bp	Brake power
Bsfc	Brake specific fuel consumption
CA	Crank angle
CIE	Compression ignition engine
E0	diesel
E20	20% ethanol + 80% diesel
E50	50% ethanol + 50% diesel
w_1	The filter weight before sampling operation in (g).
w_2	The filter weight after sampling operation in (g).
Vt	The drawn air total volume (m3)
Qt	Elementary and final air flow rate through the device (m3/sec).
t	The sampling time in (min).
η_{bth}	Brake thermal efficiency