Emission and Noise Characteristics of a Diesel Engine Fuelled with Diesel-Chicken Oil Biodiesel Blends

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Abstract—**Biodiesel is a renewable, safe, environmentally friendly, and significant source of energy which produces a lesser amount of greenhouse effect gasses. The biodiesel source is local chicken frying oil, synthesized by the trans-esterification process. In this research, the Particulate Matter (PM) exhaust gas emissions and sound emissions are examined. Emissions such as PM (PM1.0, PM2.5, PM7.0, and PM10), nitric oxides (i.e. NO and NO_2), CO, CO_2, and noise were investigated at variable loads with constant engine speed. Fuel samples, i.e. pure diesel (D100) and 20% Biodiesel (B20) and 30%Biodiesel (B30) blends were tested. Conventional diesel was found to emit more particulate and sound emissions, while B30 had lower emissions than B20 and conventional diesel. The lowest average values regarding exhaust gas emissions was 0.00690ppm for PM1.0, 7.44ppm for NO_2, and 190.727ppm for CO, presented in B30. However, emissions from the engine decreased with increase in the blending ratio of biodiesel. Furthermore, the lowest average value of CO_2 was found in B30 and was about 1.457%.**

Keywords-chicken frying oil; B20; B30; emissions; noise; engine

I. INTRODUCTION

Vehicles are almost entirely fuelled by internal combustion engines which burn fossil fuels such as Liquefied Petroleum Gas (LPG) and oil. But global fossil fuel reserves are limited and in the not so distant future will become depleted. The most prominent alternative to the classic internal combustion engine is undoubtedly Electric Vehicles (EVs). In recent years, interest in electric cars has been growing, and over the past decade, EV production has increased dramatically by 1500% [1]. Nowadays, millions of people suffer from severe illnesses and even die from causes such as cancer, respiratory diseases, cardiovascular diseases, vision loss, etc. which are affiliated with hazardous exhaust gases produced by fossil fuel engines. Besides, many countries, which have signed the Kyoto Protocol, fail to comply with their obligation to lower their level of greenhouse gases. The addition of nanoparticles to diesel is one of the most effective ways of converting diesel to a cleaner source of energy [2]. Biodiesel is considered as an improved, renewable, and non-hazardous fuel substitute. It is obtained from animal fats or vegetable oils, and it is commonly manufactured by the trans-esterification process. Biodiesel has more oxygen content than oil diesel [3-7]. Cooking waste is an alternative option for the production of economically and environmentally friendly biodiesel. While waste cooking oil has high free fatty acids and cannot be used directly into the engine, but it can convert into biodiesel by trans-esterification. The blends of biodiesel with various sources of oil affect more the performance and the emissions of the engine. Authors in [8-10] investigated bio-diesel from waste edible oil, coconut oil, and castor oil obtained by trans-esterification in blends with conventional diesel fuel.

Methanol, methyl esters, ethanol, and deposit oils formed from biomass are known as biofuels [11]. Trans-esterification is the process in which alcohol and esters (triglyceride) react together and form methyl esters (biodiesel) and glycerol. It is the most common method to make biodiesel from edible oils, waste food oil, animal fats, and waste eating greases (yellow grease). Those oils are considered possible candidates to complete the vacuum created by the reduction of conventional diesel fuels [12]. Waste edible oils produce excellent results, are environmentally friendly, have reduced cost, and decreased

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Corresponding author: Abid Ali Khaskheli exhaust gas emissions. Biodiesel with blends has successful performance and reduces PM, CO_2, and CO emissions as compared to diesel fuel [13-15].

In this study, wasted frying chicken oil was collected from the local city of Nawabshah, Pakistan. That oil was converted into biodiesel by trans-esterification [23]. The current research investigated the emissions of a diesel engine using different oil blends and conventional diesel. PM, NO_x, CO_2, CO and sound emissions were measured for the performance comparison of biodiesel and conventional diesel fuel.

II. EXPERIMENTAL METHOD

The working principle of the compression-ignition (CI) diesel engine consists of four strokes with a single, horizontal type, water-cooled cylinder used for changing performance parameters. The model name/serial number of the testbed diesel engine was DWE-6/10-JS-DV. The testbed, fully equipped with instruments such as thermometer, dynamometer, tachometer, flow meter, and flue gas analyser, is shown in Figure 1.

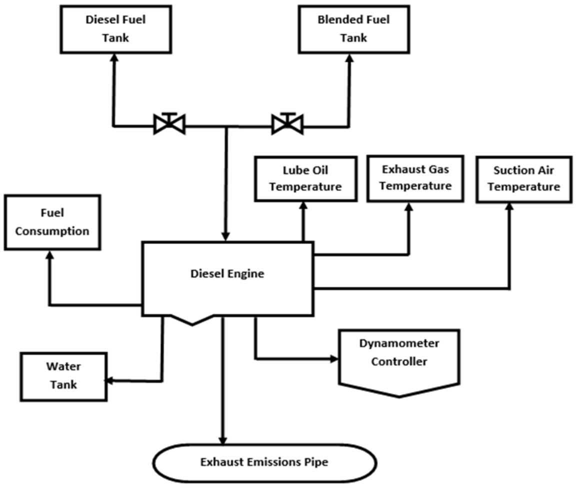

Fig. 1. Diesel engine test bed diagram

Two fuel tanks were added to the diesel motor with ground and normal pipelines. The fuel tanks were linked with normal lines, and the fuel supply could be controlled with two different valves. One fuel tank was filled with diesel fuel and the other with biodiesel. In this work, three fuel types were tested: D100 (diesel 100%), B20 (biodiesel 20% + diesel 80%) and B30 (biodiesel 30% + diesel 70%). All samples were investigated for PM and exhaust gas emissions on varying load under constant motor speed. The specifications of the diesel engine are shown in Table I [23].

A. *Fuel Parameters*

Fuel parameters can affect engine emissions. Biodiesel produced specific almost identical parameters when it was blended in diesel fuel in different ratios. In this research, blends were arranged by volume percentage. The settings of all samples on ASTM standards are shown in Table II [23].

TABLE I. ENGINE SPECIFICATIONS

Number of cylinders	1
Cooling system	Water-cooled
Type	Horizontal
Piston size (bore)	80mm
Displacement of the piston (strokes)	95mm (477cc)
Compression ratio	23:1
Starting method	Manual
Output/rotational speed	8.5PS/2200rpm(max)

TABLE II. FUEL PARAMETERS OF ALLA SAMPLES

Physical property	Unit	D100	B20	B30	ASTM standard	Testing limits
Total acid number	mgKOH/g	0.24	0.27	0.28	D-664	0.80 max
Specific gravity at 15.6 ^{0}C	-	0.83	0.85	0.84	D-891	0.8-0.9
Kinematic viscosity at 40°C	mm^2/s	1.98	2.78	2.43	D-445	1.9-6.0
Density at 40°C	g/cm^3	0.85	0.86	0.86	D-1298	0.86– 0.90
Cetane-index (calculated)	-	56.9	54.4	53.5	D-976	47 min
Flash point	^{0}C	103	123	115	D-93	130 min
Pour point	^{0}C	0	+1.5	+1.8	D-97	-15 - +5^{0}C
Calorific value	MJ/kg	44.8	43.2	43.8	D-240	37.5 - 45
Oxygen content	wt. %	0	2.53	3.71	-	-

B. *PM and Exhaust Gas Measurements*

The PM emissions depend on load, speed, and fuel characteristics of the engine. In this study, PM emissions of four distinct particle sizes, PM1.0, PM2.5, PM7.0, and PM10 along with exhaust gas emissions (CO_2, CO, NO, and NO_2) were measured from the diesel engine. A PM hand held device was used for particulate emissions and a Flue Gas Analyser model no. Test 350-XL was used for exhaust gas emissions (Figure 2). The measurements of the Gas Analyser are shown in Table III.

Fig. 2. Hand held PM measuring device and gas analyzer

TABLE III. GAS ANALYZER MEASUREMENTS

Gas	Measuring range	Unit	Accuracy
NO	0 to +300	ppm	±2ppm (0 to +39.9 ppm)
NO_2	0 to +500	ppm	±5ppm (0 to +99.9 ppm)
CO_2	0 to +50	Vol.%	±0.3Vol.% + 1% of mv (0 to 25Vol.%)
CO	0 to 500	ppm	±5% of mv (+40 to +500ppm) ±2ppm (0 to +39.9ppm)

C. *Engine Noise Level Measurements*

The noise level was determined by a sound pressure level meter (Figure 3). The three different fuels were measured for noise level on varying load conditions at a constant speed. All fuel samples were measured for varying load on the engine from 0 to 20N.m. Three different directions, front, left, and back, were selected for measuring. The microphone was set up at 1m away from the engine cylinder at the above mentioned three locations. The specifications of the microphone are given in Table IV.

Fig. 3. Held hand noise level meter

TABLE IV. HAND HELD NOISE METER SPECIFICATIONS

Type	Electric condenser microphone
Range of dB level	35dB to 150dB
Determination	0.1dB
Accuracy	±1.5dB
Microphone diameter	½ ″
Dynamic range	55dB

III. RESULTS AND DISCUSSION

A. Engine Emissions

The engine emissions depend on operating conditions, engine type, fuel, lubricating oil, and the control of the emission systems. In general, the exhaust contains PM, nitric oxides, CO, and CO_2. PM, and CO emissions decreased when the ratio of biodiesel blended in the diesel increased [16-18]. The average emissions values are shown in Table V.

TABLE V. AVERAGE ENGINE EMISSIONS OF ALL SAMPLES

Fuel	PM1.0 (ppm)	NO (ppm)	NO_2 (ppm)	CO_2 (%)	CO (ppm)
D100	0.0269	65.909	11.845	1.832	361.272
B20	0.0123	73.090	15.318	1.542	287.727
B30	0.00690	53	7.44	1.457	190.727

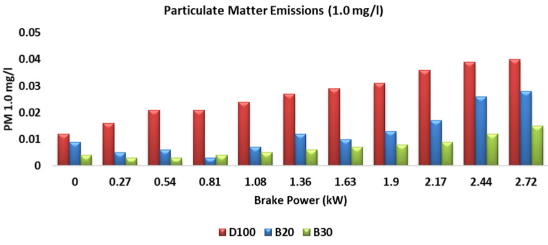

Fig. 4. Comparison results for PM1.0 emissions

B. Particulate Matter (PM) Emissions

PM is an air-suspended mix of active and liquid particles of varying size, shape, surface region, number and compound arrangement, solvency, and source [19]. Diesel fuel is a major PM source. Both B20 and B30 samples had less PM emissions than pure diesel, with B30 having the least emissions. The PM emission results are shown in Figures 4-6.

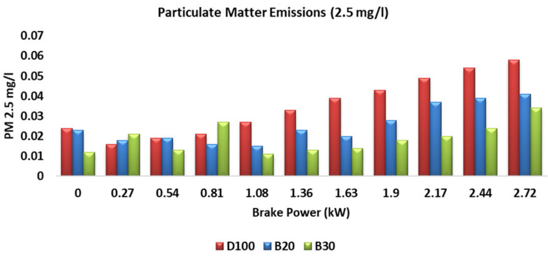

Fig. 5. Comparison results for PM2.5 emissions

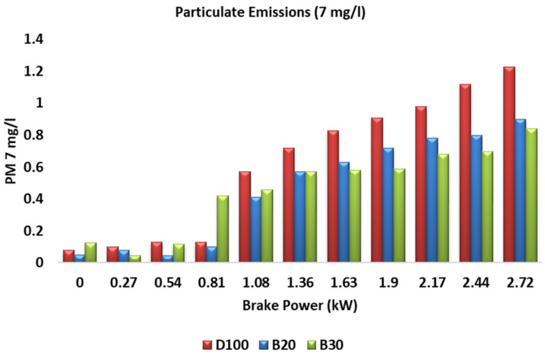

Fig. 6. Comparison results for PM7.0 emissions

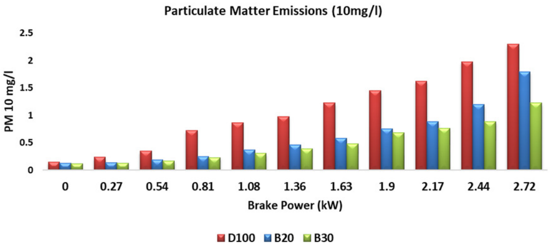

Fig. 7. Comparison results for PM10 emissions

C. Nitric Oxides (NO_x) Emissions

Biodiesel has a shorter deferred start, NO_x outflow reduction, and a high cetane profile. In any case, high burning temperatures came to the ignition because of more upper ignition timing and more extended staying period and NO_x discharges were increased. Biodiesel diminishes the NO_x discharges by enhancing fuel properties [20].

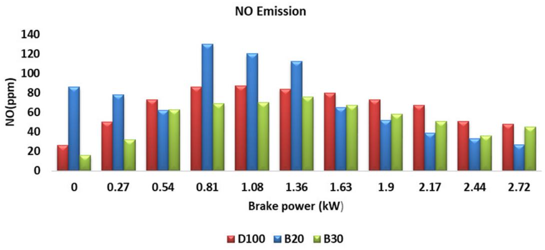

Fig. 8. Comparison results for NO emissions

Consequently, NO emissions reduced by increasing loads. In this comparative study, NO_x emissions increased in B20 as compared to D100 at different loading conditions of the engine. The B30 had lower NO_x emissions due to the decreasing exhaust gas temperature with quick combustion from the engine [23]. The NO_x emissions of B30 increased at middle engine load, while they reduced with increasing load. The results of NO_x emissions are shown in Figures 8-9.

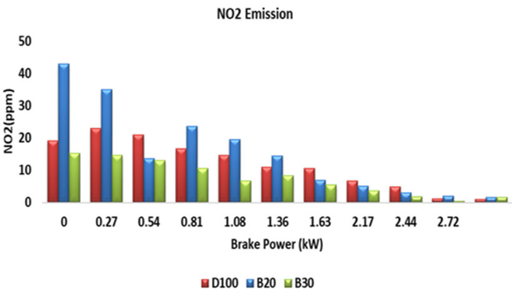

Fig. 9. Comparison results for NO_2 emissions

D. Carbon Dioxide (CO_2) Emissions

CO_2 is a colorless and non-combustion gas released when fuels with carbon content burn entirely. Consequently, CO_2 is a significant parameter in engine exhaust emissions. The CO_2 emissions increase when engine's speed and loading increase. The exhaust emissions of CO_2 were determined for varying loads at a constant engine speed [21]. In this study, the percentage of CO_2 emissions decreased when the ratio of blends in biodiesel increased. Therefore, the average value of CO_2 emissions from B30 was 0.373%. The CO_2 emissions for all samples are shown in Figure 10.

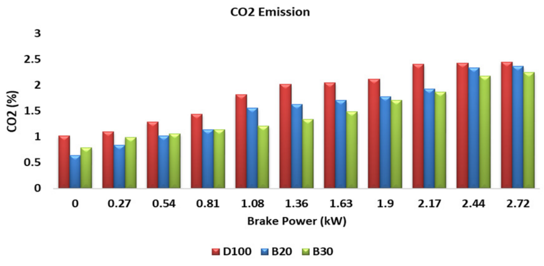

Fig. 10. Comparison results for CO_2 emissions

E. Carbon Monoxide (CO) Emissions

CO emissions depend on the speed of the engine. They occur when the combustion is insufficient, and therefore, fuel cannot oxidize [25]. Oxygen content in ethanol is high, which allows lower CO emissions and increased burning quality [26]. CO production results from oxidation of fuel, including carbon and hydrogen, with oxygen. In this work, three different fuels were studied for CO emissions on variable load and at a constant speed. CO emissions reduced when the blending ratio of biodiesel in diesel increased. The comparison results of carbon monoxide emissions are shown in Figure 11.

F. Noise Characteristics

Usually noise level decrement is accompanied with biodiesel practice. Noise is fundamentally influenced by motor speed because of upward and descending cylinder development in the motor chamber [22]. Diesel fuel has a lesser amount of aromatic compounds than biodiesel. The aromatic compounds increase the ignition delay by decreasing the noise level. In this research, the noise levels were measured for different loading conditions of the engine. Therefore, three locations (i.e. front, left, and back) were designated for noise level study. All corresponding positions were 1m away from the piston head cylinder. The noise level depends on the load and the blending ratios of biodiesel [24]. The noise level decreased slightly after increasing the middle brake load of the engine. The results showed that diesel produced higher noise level than B20 and B30. The B30 sample exhibited the least noise level due to its improved oxygen content. The results are shown in Figures 12-14.

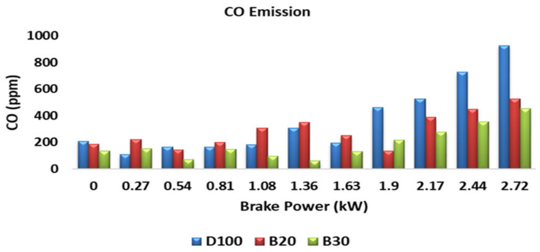

Fig. 11. Comparison results for CO emissions

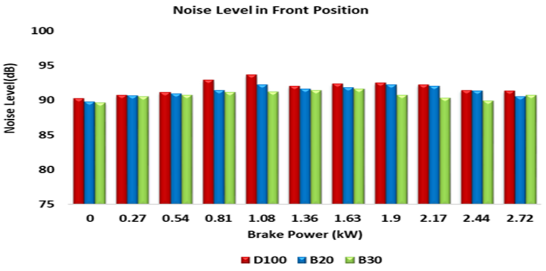

Fig. 12. Comparison results of engine's noise level (front position)

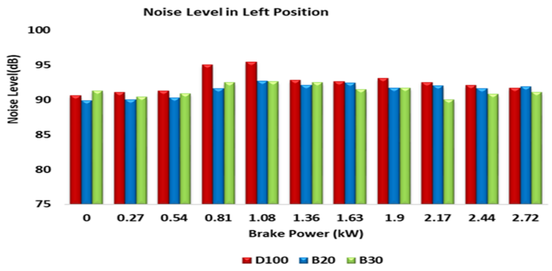

Fig. 13. Comparison results of engine's noise level (left position)

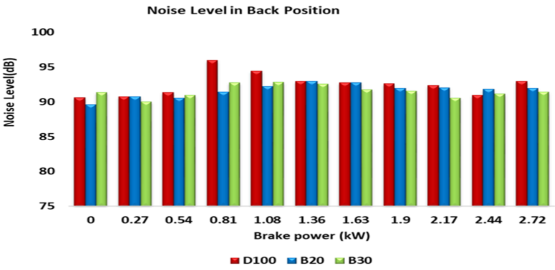

Fig. 14. Comparison results of engine's noise level (back position)

IV. CONCLUSIONS

PM1.0 was the higher emitted PM component. B20 produced less PM emissions than D100, while B30 produced even less on variable loadings. Nitric oxide emissions increased for B20 as compared to D100 at different loading conditions, while for B30 they were less than diesel and B20 due to the lower exhaust gas temperature and quick combustion. CO_2 emissions increased when the speed and loading conditions of the engine increased. Lower average value of CO_2 emissions in the engine was observed when using B30. CO emissions moreover deceased with increasing blending ratio of biodiesel due to the high oxygen content of the blends. The noise level was reduced when the B30 was used due to the improved combustion process because the addition of biodiesel provided more oxygen atoms in the combustion chamber.

ACKNOWLEDGMENT

This research work was conducted in the Thermodynamics Engineering Laboratory at the Department of Mechanical Engineering, Quaid-e-Awam University of Engineering, Science & Technology Nawabshah, Pakistan.

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