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Effect of Corn Oil Methyl Ester and Exhaust Gas Recirculation on Performance and Emission Characteristics of Diesel Engine

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1. Introduction

Energy resources are essential for the scientific development of a nation. The population rate increased year by year which increases the usage of automobiles and energy demand. The fossil fuel demand was drastically increased due to less availability and alternative fuel is essential right now. Biodiesel fuel can partially reduce the demand for fossil fuels. Search expected for suitable substitution fuel in agriculture, transportation and industry area is on an increasing outline with noticeable exhaustion of fossil fuel reserve. The production of corn has been increased year by year in India and the properties of the methyl ester corn oil better than the other vegetable oil. Diesel engines produce major emissions which affect both the environment and human health. The oxides of nitrogen emitted from the diesel engine will affect the environment through acid rain, ozone depletion, smog and human health through coughing, asthma, etc [1]. The popular alternative energy source for fossil fuel is biodiesel due to its renewable, biodegradable, availability and better result to protect the environment from the hazardous exhaust from the engine combustion. [2, 3]. The exhaust emissions of cotton seed methyl oil as fuel in a diesel engine are reduced compared to diesel fuel without engine modifications [4]. The carbon monoxide emission of caster biodiesel was found reduction over to diesel but NOx emission was increased [5]. The performance of Corn oil methyl ester blends achieved slightly lower brake thermal efficiency compared to diesel fuel. Also found that the reduction of Hydrocarbon, carbon monoxide and oxides of nitrogen emission have been decreased [6, 7]. The EGR technique is the most efficient method to lower the oxides of nitrogen from the diesel engine emission, the salient feature of using the EGR technique is to reduce flame temperature and oxygen concentration in the engine combustion [8]. The higher drop of NOx was essentially due to lower combustion chamber flame temperature and less available oxygen content of using Jatropha biodiesel and EGR technique [9]. Exhaust gas recirculation EGR has the best method of reducing NOx emission [10]. The high heat content of exhaust emission carbon dioxide and water compared to air (combined oxygen and nitrogen) during the intake reduces the combustion temperature. The flame temperature of the combustion will be reduced by using EGR due expansion of the flame, the partial amount of exhaust gas passes to the engine during the intake of air [11]. The NOx emission is reduced effective with help of an exhaust gas recirculation system, found that a 15% EGR rate gives better performance in terms of efficiency, fuel consumption and emission compared to without an EGR system [12]. The main drawback of the EGR technique is the temperature of the recirculated exhaust gas cannot be constant and it differs depending on different operating parameters of the engine. These different operating parameters may improve or decrease the engine performance and emissions under the different conditions [13]. The researcher analyzed the diesel engine performance and emission fueled with ethanol biodiesel blends with the effect of EGR and found that EGR has considerably reduced the oxides of nitrogen emission [14]. The premixed stage of engine combustion is increased due to the effect of EGR in a diesel engine. During the peak loads, the heat release rate dropped and increased during low load conditions. It affects to raise the duration of the combustion and ignition delay period. The higher EGR rate of 40% extremely reduces the NOx emission but raises the fuel consumption, emission of particulate matter and engine noise [15]. The EGR of 5%, 10% and15% proportions rate with 20% biodiesel of soybean methyl ester test on the diesel engine, found that lower the brake thermal efficiency, higher the fuel consumption and emissions of HC and NOx are reduced [16]. The performance characteristics of pentanol biodiesel blends on single cylinder diesel combustion engines with the effect of EGR varies from 20% to 30%, there will be a considerable decrease in engine emissions level and also in engine performance [17]. The EGR technique and use of biodiesel blends in diesel engines result in higher fuel consumption and lower efficiency due to lower calorific value when compared to diesel fuel. The emission levels are reduced due to more oxygen content in biodiesel and EGR reduces the flame temperature for the formation of NOx [18]. This research work is to study the effect of 20% EGR and corn oil methyl ester biodiesel blends on the performance and emission characteristics of diesel engine.

2. Methodology

2.1. Production of biodiesel from Corn oil

Corn oil is specific as feedstock for the production of biodiesel. Corn oil was transformed into corn oil methyl esters with the help of catalyzed transesterification. Transesterification is a chemical process of raw corn oil with alcohol in the presence of KOH base converted to corn oil methyl ester and glycerin. The Production of biodiesel from Corn oil is shown in Fig. 1. The properties of diesel and corn oil methyl ester (biodiesel) are tabulated in Table 1. In the synthesis procedure, a biodiesel yield of 65.2 ± 0.08 g was recorded using a mixture of 80.0 ± 0.08 g algal oil, 0.8 ± 0.006 g KOH and 34.1 ± 0.05 g methanol [19].

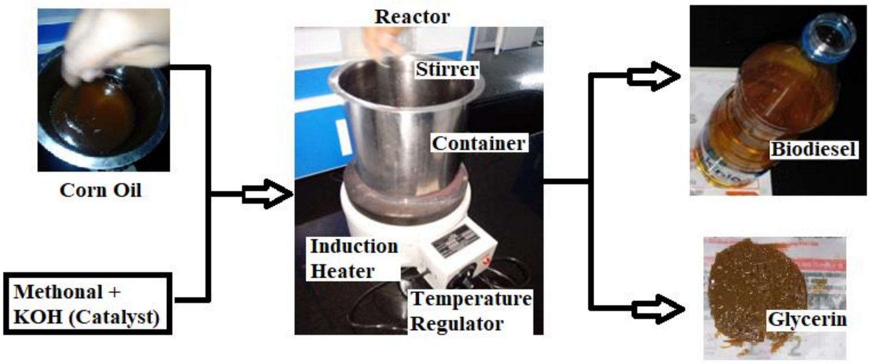

Fig. 1 Production of biodiesel from Corn oil

Table 1

Properties of diesel and corn oil methyl ester

Fuel property	Unit	Diesel	20B	40B
Density	kg/m^3	832	834	848
Viscosity	Pa-s	0.00416	0.00467	0.00543
LHV	MJ/kg	42	40.9	39.9
HHV	MJ/kg	45	44.1	43.0
Cetane number	-	52.4	52.6	52.9
Flash Point	°C	62	76	95
Fire Point	°C	71	83	103

2.2. EGR technique and engine setup

Exhaust gas recirculation is the most efficient technique for superior power to control the formation of NOx emission in the engine. EGR is recirculating the portion of exhaust gas to the inlet air of the engine with the help of regulating the EGR valve. The EGR valve controls the flow rate of exhaust gas to mixing with the inlet air.

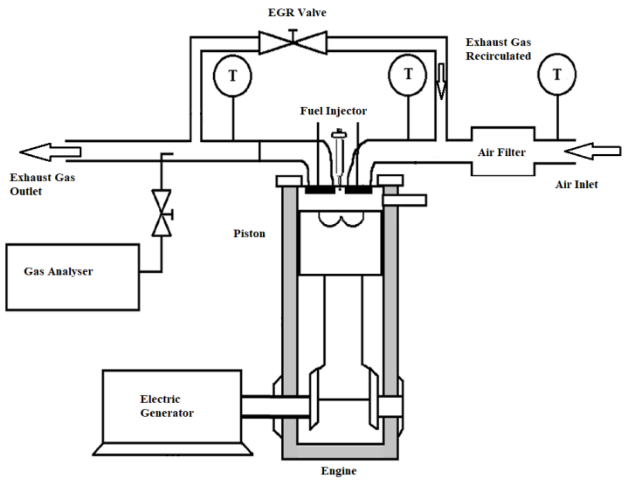

Fig. 2 Engine setup with EGR

Thermocouples are used to measure the temperature of fresh air, inlet air and exhaust gas. Based on the researcher's work the effective rate of EGR was 20%, hence the experiment was conducted with 20% EGR. The line diagram of the engine setup with EGR is shown in Fig. 2. The engine test stand is before taking the measurement, the engine was run for 15 minutes to obtain the rated speed. The variation in fuel consumption time, manometer reading, and emissions are noted for each load condition and each blend. The experiments were conducted with the diesel, blends 20 Band 40 B for two conditions of 0% EGR and 20% EGR over the engine operation. Results were compared with two EGR conditions along with mentioned fuel proposition. The fuel 20B is comprises (20% Corn oil methyl ester + 80% diesel v/v) and 40 B comprises (40% Corn oil methyl ester + 60% diesel v/v). The test engine is single cylinder Compression ignition, four stroke, direct injection, water cooled and constant speed engine. The specification of an engine and Exhaust gas analyzer and uncertainty is given in Tables 2 and 3.

Table 2

Engine specification

S. No	Parameter	Unit	Description
1.	Make	-	Kirloskar
2.	Type	-	Four strokes, single cylinder compression ignition engine
3.	No of Cylinder	No	1
4.	Stroke	mm	203
5.	Bore	mm	127
6.	Rated Power	kW	8
7.	Compression ratio	-	16.5:1
8.	Rated Speed	rpm	1500

Table 3

Exhaust gas analyzer and uncertainty

Parameter	Resolution	Accuracy	Range
Hydrocarbon	1ppm	+/-5% of reading +/-12 ppm Volume	0-5000 ppm Over-range:10,000 ppm
Carbon Dioxide	0.1%	+/-5% of reading +/-0.5% Volume	0-16% Over-range 25%
Nitric Oxide	1ppm	+/-4% or 25ppm	0-5000ppm
Sensor response	15 seconds		
Warm up	Less than 3 minutes		

3. Result and discussion

Tests were conducted with different brake power at the two different EGR condition of 0% and 20% with 100% diesel, 20B (20% biodiesel + 80% diesel) and 40B

(40% biodiesel + 60% diesel). The engine was allowed to run for 10min to reach a steady state before measuring the readings.

3. 1 Brake Thermal Efficiency (BTE)

Fig. 3 represents the variation of brake thermal efficiency for diesel, 20 B and 40 B biodiesel blends at different brake power with 0% EGR conditions. The brake thermal efficiency of diesel, 20 B and 40 B at brake power of 5.54 kW are 32%, 28.2% and 24% respectively. The BTE of biodiesel blends is decreased compared to diesel due to the lower heating value of biodiesel. The BTE will be decreased with the increase in the composition of biodiesel blends because the lower heating value, high viscosity and high fire point lead to slow down the combustion process.

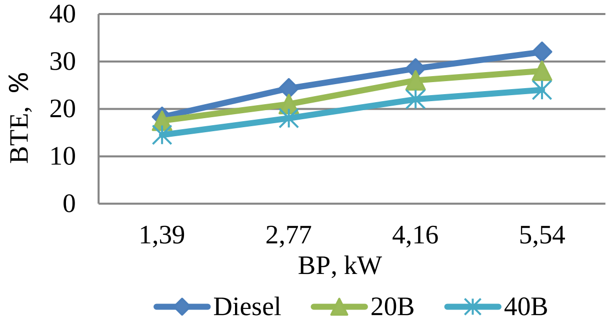

Fig. 3 Variation of BTE with BP for 0% EGR

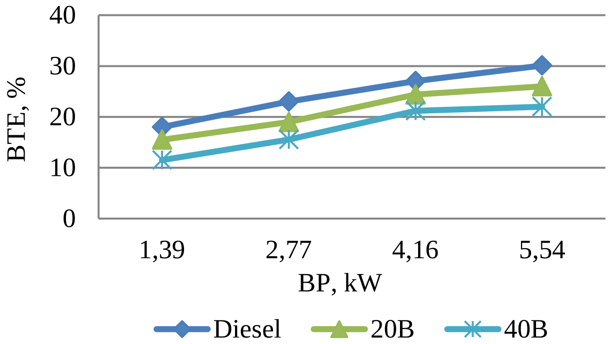

Fig. 4 Variation of BTE with BP for 20% EGR

Fig. 4 shows the comparison between brake thermal efficiency and brake power with 20% EGR condition for diesel, 20 B and 40 B biodiesel blends. The brake thermal efficiency is about 30.1% for 100% diesel, 26.4% for 20 B and 22.3% for 40 B blend at a brake power of 5.54 kW. The BTE decreased with an increased percentage of EGR because of improper combustion due to dilution of exhaust gas and fresh air in the combustion. The BTE was reduced from 24% to 22% for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%.

3.2. Brake Specific Fuel Consumption (BSFC)

The variation of brake specific fuel consumption at different brake power for diesel, 20 B and 40 B biodiesel blends with 0% EGR conditions is shown in Fig. 5. The brake specific fuel consumption of diesel, 20 B and 40 B at brake power of 5.54 kW are 0.16 kg/kW-hr, 0.19 kg/kW-hr and 0.24 kg/kW-hr respectively. The BSFC of biodiesel blends is increased compared to diesel due to lower energy content and high viscosity of biodiesel [22].

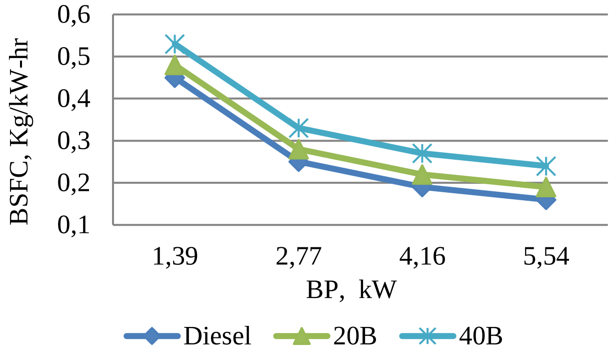

Fig. 5 Variation of BSFC with BP for 0% EGR

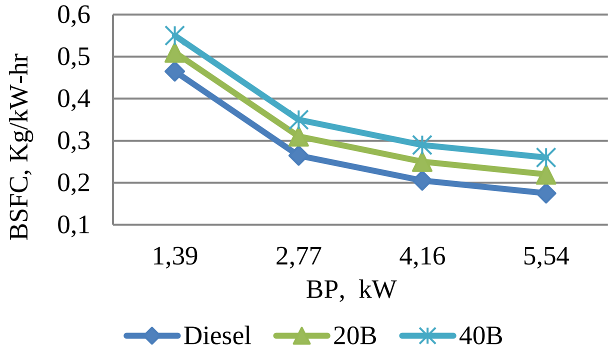

Fig. 6 Variation of BSFC with BP for 20% EGR

The variation of brake specific fuel consumption at different brake power for diesel, 20 B and 40 B biodiesel blend with 20% EGR conditions is shown in Fig. 6. The brake specific fuel consumption is about 0.175 kg/kW-hr for 100% diesel, 0.22 kg/kW-hr for 20 B and 0.26 kg/kW-hr for 40 B blend at brake power of 5.54 kW. The BSFC increased with increased the percentage of EGR because of lower oxygen availability in the combustion air. The BSFC was raised from 0.24 kg/kW-hr to 0.26 kg/kW-hr for 40 B at brake power of 5.54 kW when the EGR condition from 0% to 20%.

3.3. Exhaust Gas Temperature (EGT)

Fig. 7 represents the variation of exhaust gas temperature for diesel, 20 B and 40 B biodiesel blends at different brake power with 0% EGR conditions. The exhaust gas temperature of diesel, 20B and 40B at brake power of 5.54 kW are 168°C, 163°C and 160°C respectively. The EGT of biodiesel blends is reduced compared to diesel due to the lower calorific value of biodiesel. A significant rate of reduction was observed due to incomplete combustion taking place inside the cylinder [22].

Fig. 8 shows the comparison between exhaust gas temperature and brake power with 20% EGR condition for diesel, 20 B and 40 B biodiesel blends. The exhaust gas temperature is about 166 °C for 100% diesel, 161 °C for 20 B and 158 °C for 40 B blend at brake power of 5.54 kW. The main feature in the reduction of EGT is the poor quality of air/fuel mixture in the combustion chamber which leads to improper combustion in the engine and consequently lesser exhaust gas temperatures with an increased percentage of EGR rates. The EGT was reduced from 160 °C to 158 °C for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%.

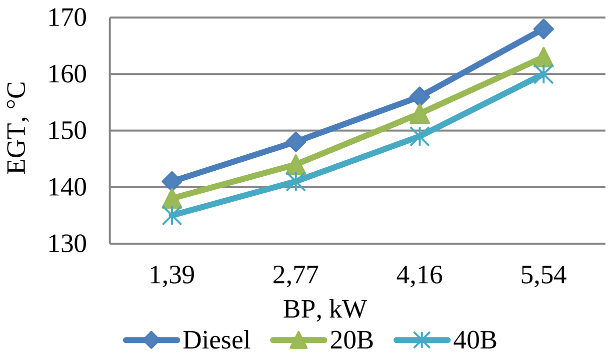

Fig. 7 Variation of EGT with BP for 0% EGR

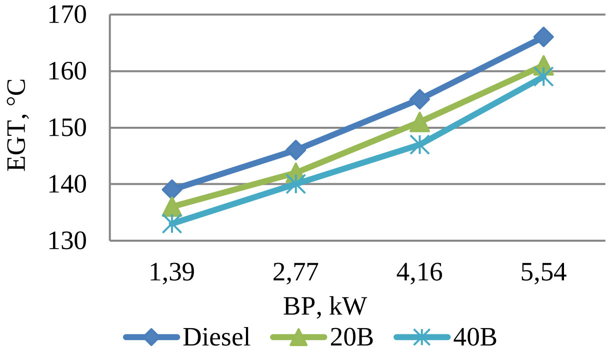

Fig. 8 Variation of EGT with BP for 20% EGR

3.4. Carbon dioxide emission (CO_2)

The variation of carbon dioxide at different brake power for diesel, 20 B and 40 B biodiesel blends with 0% EGR conditions is shown in Fig. 9.

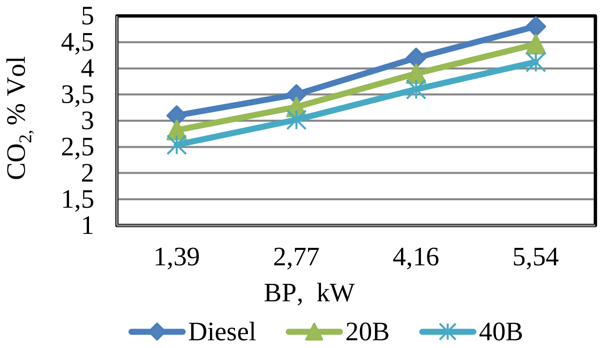

Fig. 9 Variation of CO_2 emission with BP for 0% EGR

The availability of excess oxygen in biodiesel enhances the combustion process in engine cylinders compared to diesel fuel. Biodiesel has more hydrogen to carbon ratio which leads to reduce the formation of carbon dioxide significantly. The carbon dioxide of diesel, 20B and 40B at brake power of 5.54 kW are 4.8% Vol, 4.5% Vol and 4.1% Vol respectively. The carbon dioxide emissions of the blends were not much different from those of conventional diesel. The addition of oxygenates into diesel fuel resulted in only a slight reduction in CO_2 emissions [21].

The variation of carbon dioxide at different brake power for diesel, 20 B and 40 B biodiesel blends with 20% EGR conditions is shown in Fig. 10. In general, the CO_2 emission increase with an increase in the EGR rate due to the exhaust gas recirculation carrying a considerable quantity of CO_2 emission into the engine. The oxide of carbon emission depends on the air-fuel ratio, the effect of EGR decreases the air-fuel ratio which leads to an increase in the CO_2emission. The CO_2 emission is about 5.1% Vol for 100% diesel, 4.7% Vol for 20 Band 4.4% Vol for 40 B blend at brake power of 5.54 kW. The CO_2 was raised from 4.1% Vol to 4.4% Vol for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%.

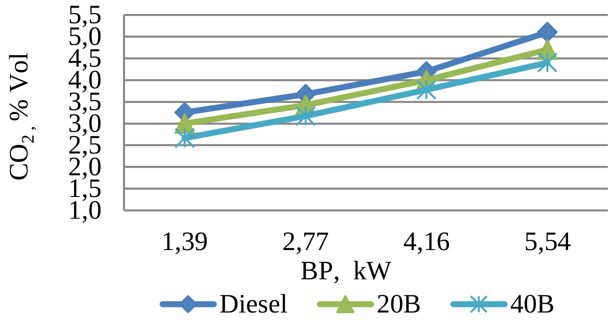

Fig. 10 Variation of CO_2 emission with BP for 20% EGR

3.5. Oxides of Nitrogen Emission (NOx)

Fig. 11 represents the variation of oxides of nitrogen emission for diesel, 20 B and 40 B biodiesel blends at different brake power with 0% EGR conditions. It was noticed that NOx emission increased with an increase in brake power. The NOx emission of diesel, 20 B and 40 B at brake power of 5.54 kW are 188 ppm, 167 ppm and 149 ppm respectively.

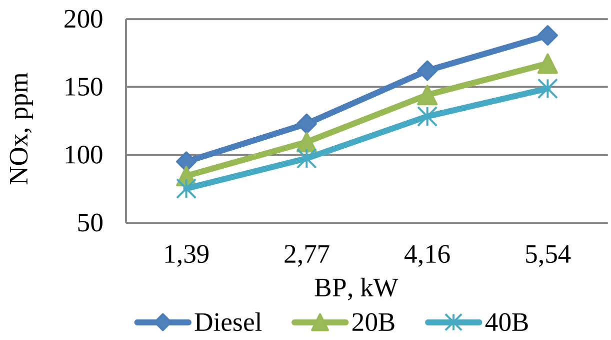

Fig. 11 Variation of NO_x emission with BP for 0% EGR

The combustion temperature of the biodiesel blend was slightly lower than diesel fuel due to lower heat value, which leads to reduced NOx emission. Methyl ester has oxygen participating in the combustion process, the atoms of which are of a much lesser mass compared with hydrocarbon compounds which condition a better combustion reaction and a lesser amount of combustion products is emitted. It can be observed that all biodiesel fuel blends reduced NOx emissions [21].

Fig. 12 shows the comparison between oxides of nitrogen emission and brake power with 20% EGR condition for diesel, 20 B and 40 B biodiesel blends. The NOx emission is about 177 ppm for 100% diesel, 158 ppm for 20 B and 140 ppm for 40 B blend at brake power of 5.54 kW. The NOx was reduced from 149 ppm to 140 ppm for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%. The use of EGR has drastically decreased the NOx emissions at all loads of brake power. The most important cause of the drop in NOx emission is lesser combustion temperature.

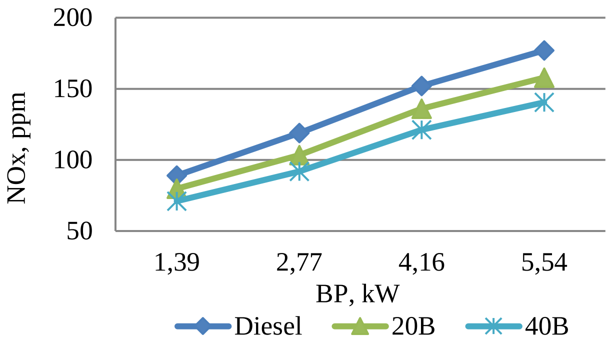

Fig. 12 Variation of NO_x emission with BP for 20% EGR

3.6. Hydrocarbon Emission (HC)

The variation of hydrocarbon emission at different brake power for diesel, 20 B and 40 B biodiesel blends with 0% EGR conditions is shown in Fig. 13. The blending of corn oil methyl ester with diesel reduced the formation of HC emissions. The hydrocarbon emission of diesel, 20 B and 40 B at brake power of 5.54 kW are 51 ppm, 42 ppm and 35 ppm respectively. The reduction of HC emission is due to excess oxygen in methyl ester fuel enhancing the combustion process to complete combustion. It was also observed that the blends containing a higher percentage of biodiesel would have lower HC emissions. These findings are attributed to the oxygen content of fatty acid methyl esters which leads to more complete combustion [22].

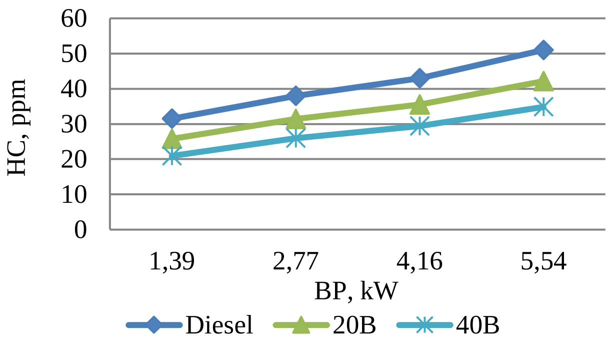

Fig. 13 Variation of HC emission with BP for 0% EGR

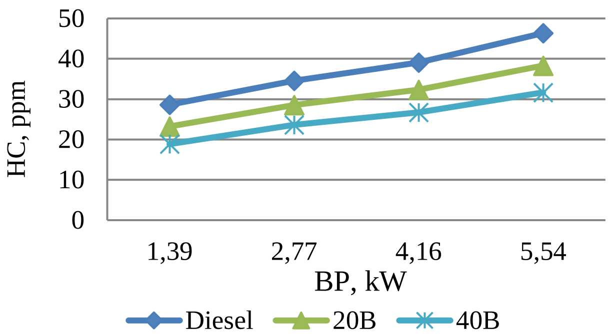

Fig. 14 Variation of HC emission with BP for 20% EGR

The variation of hydrocarbon emission at different brake power for diesel, 20 B and 40 B biodiesel blends with 20% EGR conditions is shown in Fig. 14. In general, the HC emission decreased with the increase in the EGR and increase with the increase in the brake power. The HC emission is about 46 ppm for 100% diesel, 38 ppm for 20B and 32 ppm for 40B blend at brake power of 5.54 kW. The HC emission was reduced from 35 ppm to 32 ppm for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%.

3.7. Particulate Matter (PM)

The variation of particulate matter at different brake power for diesel, 20 B and 40 B biodiesel blends with 0% EGR conditions is shown in Fig. 15. The blending of corn oil methyl ester with diesel reduced the particulate matter. The particulate matter of diesel, 20 B and 40 B at brake power of 5.54 kW are 0.41 gms, 0.35 gms and 0.28 gms respectively. The reduction of PM is due to excess oxygen in methyl ester fuel enhances the combustion process to complete combustion. The oxygenates blended with diesel fuel effectively deliver oxygen to the zone of the burning diesel spray resulting in reduced PM generation [22].

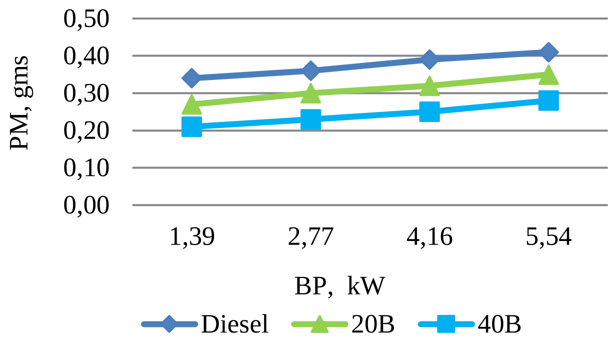

Fig. 15 Variation of PM with BP for 0% EGR

The variation of particulate matter at different brake power for diesel, 20 B and 40 B biodiesel blends with 20% EGR conditions is shown in Fig. 16. In general, the PM decreased with the increase in the EGR and increase with the increase in the brake power. The PM was reduced from 0.28 gms to 0.24 gms for 40 B at brake power of 5.54 kW when the EGR condition was from 0% to 20%.

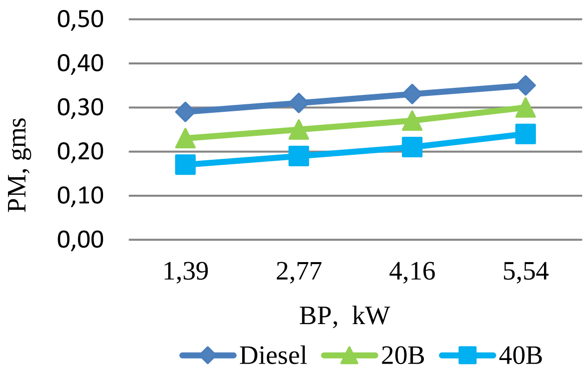

Fig. 16 Variation of PM with BP for 20% EGR

4. Conclusions

The effect of EGR on the performance and emissions of a CI engine has been experimentally investigated using different corn oil methyl ester blends with diesel. The performance of using Corn oil methyl ester blends and EGR reduced the significant level of engine emissions. The summarized result of 40 B fuel with 0% EGR and 20% EGR at brake power of 5.54 kW are,

- The brake thermal efficiency was reduced from 24% to 22% and the exhaust gas temperature was dropped by 2 °C due to a lower heating value.
- The brake specific fuel consumption was raised from 0.24 kg/kW-hr to 0.26 kg/kW-hr. The increase in the concentration of corn oil methyl ester would have consumed more fuel due to the lower calorific value.
- The Carbon dioxide emission was raised from 4.1% Vol to 4.4% Vol. The oxide of carbon emission depends on the air-fuel ratio, the effect of EGR decreases the air-fuel ratio which leads to an increase in the CO_2 emission.
- The oxide of nitrogen was reduced from 149 ppm to 140 ppm. The most important cause of the drop in NOx emission is lesser combustion temperature.
- The hydrocarbon emission was reduced from 35 ppm to 32 ppm. The reduction of HC emission is due to excess oxygen in methyl ester fuel enhancing the combustion process to complete combustion.
- The PM was reduced from 0.28 gms to 0.24 gms. The oxygenates blended with diesel fuel effectively deliver oxygen to the zone of the burning diesel spray resulting in reduced PM generation.

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EFFECT OF CORN OIL METHYL ESTER AND EXHAUST GAS RECIRCULATION ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE

S u m m a r y

The current research work on the effect of exhaust gas recirculation on the diesel engine for the analysis of performance and emission characteristics with corn oil methyl ester blends. The engine was tested with three fuels are 100 diesel, 20 B (20% COME + 80% Diesel) and 40 B (40% COME + 60% Diesel) with EGR condition of 0% and 20% rate. The engine was evaluated with performance characteristics such as thermal efficiency, brake specific fuel consumption, exhaust gas temperature and emissions such as carbon dioxide, hydrocarbon, oxides of nitrogen and particulate matter. The analyzed results of the brake thermal efficiency were reduced with increased brake specific consumption and the exhaust emissions are decreased with the increase of biodiesel blend and increased EGR rate.

Keywords: corn oil methyl ester, exhaust gas recirculation, oxides of nitrogen, performance, emissions.

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