ARTICLE IN PRESS

Materials Today: Proceedings xxx (xxxx) xxx

Contents lists available at ScienceDirect

Materials Today: Proceedings

journal homepage: www.elsevier.com/locate/matpr

Experimental investigation on Jatropha oil Methyl Ester fuelled CI engine using high EGR

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ARTICLE INFO

Article history:
Received 19 March 2020
Received in revised form 25 June 2020
Accepted 1 July 2020
Available online xxxx

Keywords:
Biodiesel
Injection pressure
High ratio of EGR
Conventional diesel combustion mode
Engine

ABSTRACT

The present experiment is carried out to study the effect excess cooled exhaust gas recirculation (EGR) on four-stroke, single-cylinder, air-cooled direct injection (DI) diesel engine. The biodiesel used is 100% JOME (Jatropha Oil Methyl Ester). Here jatropha oil methyl ester fuel is transesterified to reduce the viscosity as per ASTM standard. The experiment is conducted by different BMEP with a constant speed of 1500 rpm. An Extensive level of EGR (up to 75%) was used to achieve lower emissions. Experimental results were showed a reduction in NOx higher rate compares to another emission. Exhaust gas Emissions of hydrocarbons, Nitrous oxide, carbon monoxide was measured using gas analyzer. Thermocouple mounted on tailpipe is used to observed the exhaust gas temperature. The calculated thermal efficiency and exhaust emissions are compared with diesel. Reduction in NOx was 62.5% at 75% EGR at 50% load was observed but hydrocarbon, carbon monoxide emissions are increased with rising of EGR percentage.

1. Introduction

With quick consumption of fossil fuel and sharply rising the demand for petroleum fuel to move towards renewable fuel like biodiesel. Especially in the automobile sector increasing the fuel demand. There are many alternative fuels are used in the engine after the treatment such as transesterification or esterification process to attain the similar physio-chemical properties of diesel. The utilization of biodiesel as an engine fuel is considering in both the academic and industrial field, therefore, researchers and scientists are concentrating on biodiesel as an engine fuel.

Asokan et al. [1] suggested that watermelon and papaya seed biodiesel have prepared and tested the fuel using four stoke single-cylinder engines under various blends among these B20 performance and combustion and emission were very close to diesel fuel. Chunhua Sun et al. [2] have an experiment using different biodiesel-DME blends with EGR. B5 blend showed the shortest ignition delay and higher thermal efficiency. It also suggested an increase of EGR leads to an increase in HC and CO emission. Harish venu et al. [3] noticed that 30% palm oil and 70% diesel and 25 ppm TiO2 is used as the fuel, tested the engine with EGR, and without EGR. Reduction in emissions and specific fuel consumption lower at lower load with EGR.

Tesfa et al. [4] four-stroke, four cylinders, DI, the turbocharged engine was used tested by using waste oil, rapeseed oil, corn oil compared with diesel fuel. Showed an increase in NOx emissions but a decrease in HC, CO and CO2 emissions in all types of biodiesel. Bhaskar et at. [5] conducted a test on a diesel engine fueled with a Fish oil methyl ester. 20% FOME with 20% EGR was used to reduce both NOx and soot emissions. SelmanAydın et al. [6] studied that, Effects of MOB10 (microalgae oils with 10% diesel), AOB10 (animal oil with 10% diesel) and VOB10 (vegetable oil with 10% diesel) was investigated in a power generator diesel engine, among this biodiesel all showed the resulting increase in NOx and CO_2 emissions but the decrease in CO, HC and smoke emissions.

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https://doi.org/10.1016/j.matpr.2020.07.047
2214-7853/

Please cite this article as: S. Sivalingam, P. Palanisamy and A. Baluchamy, Experimental investigation on Jatropha oil Methyl Ester fuelled CI engine using high EGR, Materials Today: Proceedings, https://doi.org/10.1016/j.matpr.2020.07.047

Nomenclature

LTC	Low Temperature Combustion	CN	Cetane Number
kJ	kilo Joules	HC	Hydrocarbon
cSt	centi Stokes	CO	Carbon monoxide
kg/m^3	kilogram per meter cube	NO_x	Oxides of Nitrogen
MJ/kg	mega Joule per Kilo Gram	JOME	Jatropha Oil Methyl Ester
kg/kWh	kilogram Per Kilowatt Hour		

Rickwinder Singh [7] performed a test on eucalyptus oil blend with n-butanol and diesel as a fuel used in diesel engines, the test revealed that (20% biodiesel-65% diesel-15% butanol) blend shows the reduction in NOx and CO_2 emissions due to cooling effect of butanol. Ladommatos et al. [8] showed that an increase in thermal throttling leads to a reduction in O2 concentration and reduces the ignition delay. Santhosh et al. [9] revealed that using higher alcohol fuel 1- pentanol blend with diesel fuel reduced NOx emissions by increasing ignition delay and latent heat of vaporization. Rajasekarana et.al. [10] Low-density polyethylene (LDPE) oil blended with 1 decanol and diesel with 20% of EGR, 600 bar injection pressure is used to reduce the NOx emission and increase the BTE. [11–20] showed EGR an effective method to reduce NOx emission. Above all the article's maximum usage of EGR is 30%.in the present paper to conduct the experiment using excessive EGR in a single-cylinder air-cooled diesel engine and study the performance and combustion characteristics of biodiesel.

Fig. 1. Sample of Jatropha Seeds.

2. Materials and methods

2.1. Transesterification

The viscosity of pure oil is high, it is not directly used an engine fuel because of higher viscosity. In order to lower the viscosity level using transesterification process. Here 1 L of oil is preheated to remove the moisture content in the fuel then 4:1 methanol/oil ratio and add 1% KOH weight of oil. Initially mix the KOH and methanol then it is poured to oil bowl. Now start to rotate the stirrer at the speed of 300 rpm up to 2 hrs., then it is poured into separating funnel, it allowed to settle down for 12 hrs. After settle down time over, the bottom portion of glycerol is removed from the separating funnel. The impure biodiesel remaining in the funnel, it is washed by using distilled water to remove residual glycerol, soap, methanol and KOH. At last, the biodiesel is warmed till the temperature reaches 115 °C. Because the water content in the fuel was removed.

The properties of JOME and diesel are shown in Table 1. After Transesterification process the properties are listed here. If raw oil is used in the engine fuel then the injector clogging, improper atomization may occur. It leads to lower the brake thermal efficiency and increases engine out emissions. The heating value of JOME lower than Diesel. But cetane number, flash point and fire point of JOME is higher than diesel. Biodiesel having higher cetane number than diesel, it indicates better ignition properties of JOME and it may increase the combustion efficiency. The Jatropha seeds are shown in Fig. 1.

Table 1
Properties of Jatropha Oil Methyl Ester.

S. No	List of Properties	Diesel	JOME
1	Lower heating value, MJ/kg	42	37
2	Kinematic viscosity, Cst @ 40 °C	3.7	4.8
3	Density kg/m^3	820	855
4	Cetane number	49	51
5	Flash point, °C	68	134
6	Fire point, °C	84	144
7	Oxygen, wt %	0	11

3. Experimental setup and description

The engine used in the present study is single cylinder, air-cooled, diesel engine with applying excess amount of Exhaust gas recirculation mode shown in Fig. 2

1. Surge tank
2. EGR setup
3. Pressure sensor
4. Gas Analyzer
5. Dynometer
6. Fuel pump
7. Pressure regulator
8. Fuel injector
9. Engine base
10. Single cylinder Engine

The surge tank is used to continuous flow of air, if incoming air is pulsating the volumetric efficiency will drop down. In order to avoid this drawback provided surge tank. Exhaust gas temperature was reduced by using a water-cooled heat exchanger. Increasing EGR, will increase the ignition delay during that time sufficient mixing of air and fuel, it enhances the combustion efficiency.

The power output of the engine was measured by electrical dynamometer. AVL Di-gas analyzer 444 instrument is used to measure the exhaust emission. It is used to measured HC, CO, NOx, O_2, and CO_2. The gas analyzer probe is inserted into the exhaust pipe to measured the emissions. To measure the exhaust gas temperature by using k type thermocouple and a temperature indicator. Here

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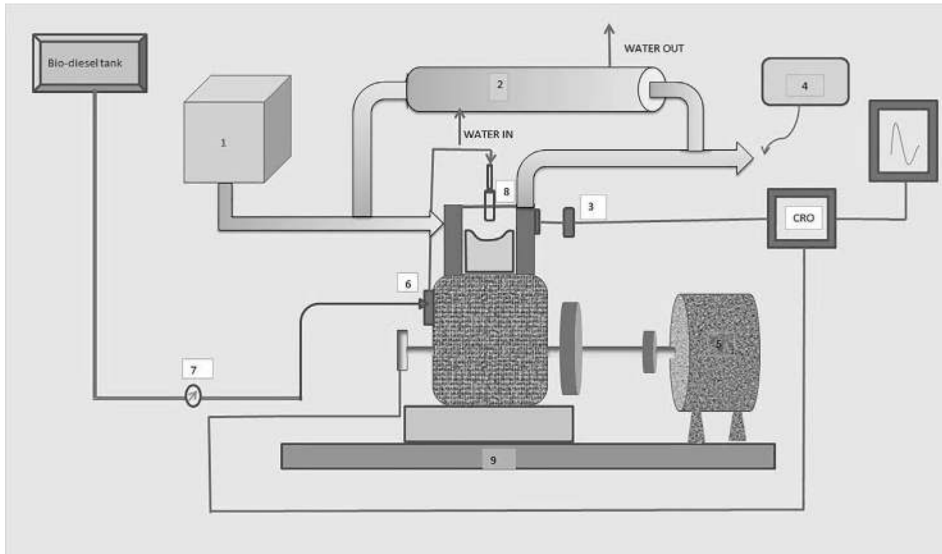

Fig. 2. Experimental setup single cylinder diesel engine.

Table 2
Engine specification.

Cooling type	Air
Stroke	110 mm
Bore	87.5 mm
Compression ratio	17.5:1
Injection pressure	210 bar
Injection timing	23 bTDC
Rated output	4.4 kW @ 1500 rpm

single cylinder air-cooled, 4.4 kW engine is used. The engine specification is shown in Table 2.

4. Experimental procedure

Here sole JOME biodiesel is used to run the engine, no blends are used. The experiment was conducted on no-load to 100% load at speed of 1500 rpm. At each load 12.5 to 75% of EGR is supplied to the engine and observed the combustion, performance, and emission of the engine. The gas analyzer probe is used to measuring the CO_2 emissions at the inlet of engine and CO_2 at the exhaust tail-pipe. Using CO_2 value calculated the percentage EGR allowed into the engine.

EGR (%) = CO_2 inlet /CO_2 exhaust *100

5. Results and discussion

In this section to discuss the diesel and biodiesel with different proportion of EGR and its effects on engine performance and exhaust emissions were explored.

5.1. Engine performance, emissions and combustion characteristics

5.1.1. Effect of EGR on Brake thermal efficiency

The graph 3 plotted between of brake thermal efficiency and Brake mean effective pressure, the diesel curve has higher break thermal efficiency compare to 100% biodiesel. The reason is diesel having higher calorific valve than the biodiesel. If the EGR percentage is increased the break thermal efficiency get decreased because the replacement of oxygen. Further increasing the EGR percentage the oxidation of air and fuel get reduced. The readings are taken only up 75% EGR at 50% load operation because the engine goes

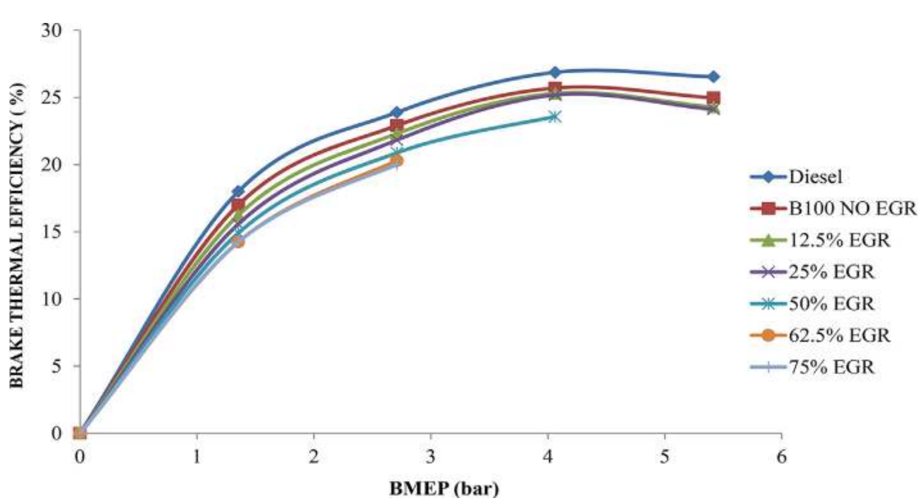

Fig. 3. Effect of Brake Thermal Efficiency on BMEP.

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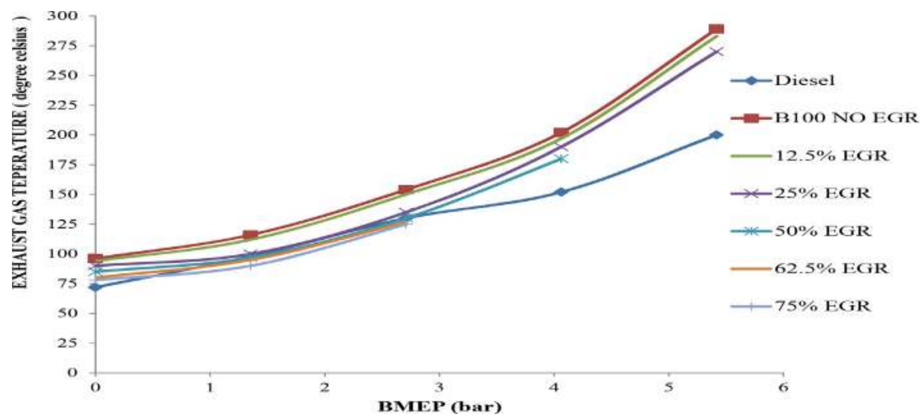

Fig. 4. Effect of exhaust gas temperature on BMEP.

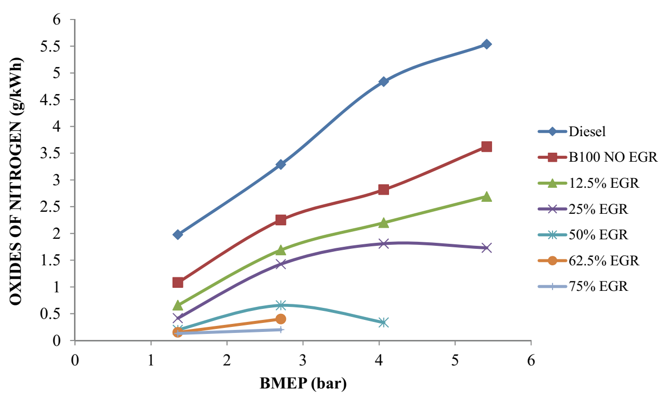

Fig. 5. Effects of Oxides of Nitrogen on BMEP.

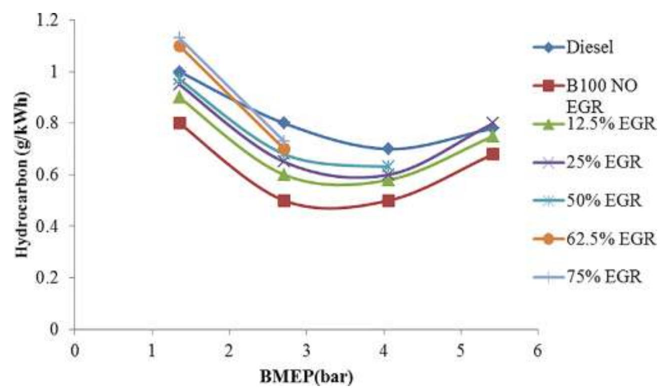

Fig. 6. Effect of Hydrocarbon on BMEP.

off mode due to insufficient oxygen in the cylinder. At 75% and 100% load operation used only 50% and 25% EGR Fig. 3.

5.1.2. Effect of EGR on exhaust gas temperature

In this part the Fig. 4 clearly shows the pure biodiesel having higher exhaust gas temperature than diesel because of elevated viscosity at biodiesel it keeps on burning during the flow of exhaust gas in the tailpipe. Increasing EGR percentage reducing trend was obtained due to insufficient time for burning the air fuel mixture. At 62.5% and 75% EGR lowest exhaust gas temperature owing to lesser exhaust gas temperature.

5.1.3. Effect of EGR on Oxides of Nitrogen

NOx emission is formed mainly due to higher in-cylinder temperature and pre mixed combustion. Here diesel having higher pre mixed combustion leads due higher NOx emission. In case of JOME having more viscosity the burning time is more in diffusion combustion stage. Furthermore, increasing the EGR rate leads to elevating the ignition delay, it again increases the diffusion combustion duration. Which is clearly indicating in this graph 5 lower the NOx emission with increasing the EGR percentage. This is the reason for lesser NOx about 31.5% less than diesel at 0% EGR. Fig. 5 shows increase EGR decrease the NOx 24.9%,36.25%,70.8%,97.6%,97.7% at 12.5%,25%,50%0.62.5%,75% EGR.

5.1.4. Effect of EGR on hydrocarbon and carbon monoxide

The diesel shows in Fig. 6 the higher Hydro carbon than the JOME because of biodiesel is oxygen content fuel, the biodiesel capable to start burning in the place of insufficient oxygen. But increasing the percentage of EGR, the in-cylinder temperature is reduced. Even though biodiesel is oxygen content fuel it is unable burn completely during this stage. It clearly shows when rising the percentage of EGR higher the hydro carbon emission. The similar trend was shown Fig. 7. Increasing EGR reducing the Oxygen content ultimately the CO unable oxidize into CO_2.

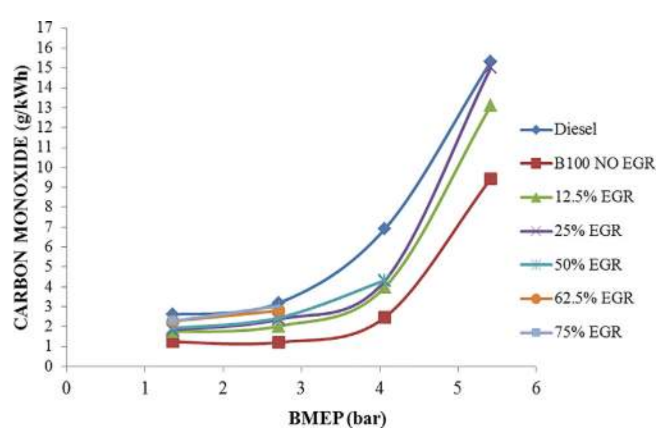

Fig. 7. Effect of carbon monoxide on BMEP.

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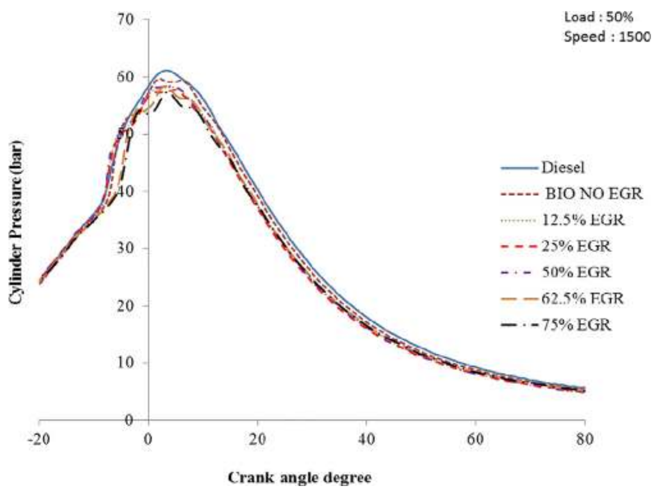

Fig. 8. Effect of Cylinder Pressure on Crank Angle.

5.1.5. Combustion characteristics

Fig. 8 shows the variation of Cylinder Pressure with Brake mean effective pressure, Diesel has higher pressure 61 bar then biodiesel has 59.2 bar because of higher calorific value. increasing EGR slightly reduce the pressure 58.6, 58.4, 58.2, 57.7, 57.2 bar for 0%, 12.5%, 25%, 50%, 62.5%, 75% EGR at 50% load. Because of replacing the oxygen, there is a reduction in the combustion reaction.

6. Conclusion

1. The combustion performance and emission performance were studied using cooled EGR. Conclude that lower levels of NOx were achieved between 55 and 75% EGR. This is because of higher specific heat and water vapor present in the EGR, it was absorbed the cylinder temperature.

2. Even though there is reduction in NOx emission there is increases in HC and CO emissions and deterioration in the thermal efficiency. At 62.5% EGR HC emission starts decreasing trend because reducing the locally rich mixture.

3. There are possibilities to increase the thermal efficiency, reduce the NOx and smoke emission simultaneously for adapting the strategies like increasing injection pressure, advancing or restarting the injection angle and increasing EGR percentage.

CRediT authorship contribution statement

Sivakuamar Sivalingam: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Writing - original draft. **Ponnusamy Palanisamy:** Supervision, Validation. **Anbarasan Baluchamy:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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