The Performance and NO_X Emissions of a IDI diesel Engine at Distinct EGR Rates Fuelled With JB100, JB80, JB60, JB40, JB20 & Diesel.

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ABSTRACT

Engineers have proposed various solutions towards reducing pollutant emissions, especially nitrogen oxides (NO_X), from indirect injection diesel engines. The aim of the present work is to investigate the influence of exhaust gas recirculation (EGR) rates on Jatropha biodiesel (JB), diesel and their blends. A indirect injection (IDI) diesel engine was tested by diesel,100% biodiesel (JB100), blends of 20% diesel and 80% biodiesel (JB80) ,and other blends like JB60, JB40,and JB20. The engine characteristics with Jatropha biodiesel were compared against those obtained using diesel fuel. From the results, it is observed that the biodiesel performance and emission are lower than that of diesel fuel. However, the NOx emission of Jatropha biodiesel is more than that of diesel fuel. The EGR system reduces NO_X emissions by recirculation small amount of exhaust gases into the intake manifold. The main focus of this dissertation is on finding out the best or the most suitable blend of biodiesel which when used gives out least automotive NOx emissions using a EGR sysrem. A single cylinder water cooled IDI diesel engine was used for investigation. Smoke , NOx ,CO, CO_2 emissions were recorded and various engine performance parameters were also evaluated . The results and discussion based on the effect EGR system on engine performance and emission characteristics of JB20, JB40, JB60, JB80, JB100 and diesel fuel without EGR rates and with EGR rates. The performance parameters and NOx emissions are measured and recorded for diesel fuel and JB and their blends. The results showed that, at 15% EGR diesel, JB 20 at 25% EGR, JB 40 at 15% EGR, JB 60 at 20% EGR, JB 80 at40% EGR, and JB 100 at 5% EGR, the NOx emissions are effectively reduced by 10.1%,11.94%,13.4%,15.2%,19.85%, and 24.8% respectively.

Keywords ---Bio-diesel, Jatropha oil, EGR rates, ,NOx emissions.

1. Introduction :

All internal combustion engines generate power by creating explosions using fuel and air. These explosions occur inside the engine cylinder, the next explosion forcing the exhaust gases out of the cylinder. The need to control the emissions from automobiles gave rise to the computerization of the automobile(1). Hydrocarbons, carbon monoxide and oxides of nitrogen are created during the combustion process and are emitted into the atmosphere from the tail pipe. The search for alternative fuels which are eco friendly and can be used as a substitute to conventional HC based fuels is in demand due to concerns about depletion of fossil fuel reserves and also growing awareness against global warming (2). The use of biodiesel is rapidly expanding around the world making it imperative to fully understand the impacts of biodiesel combustion process and pollutant formation. Biodiesel is typically produced through the reaction of vegetable oil or animal fat with methanol in presence of a catalyst to yield glycerin and methyl esters (3, 4,5). The methyl esters produced in this process are called biodiesel . this process at production of biodiesel is called trans esterification (6,7,8, and 9,). In the last years ,many researchers have conducted studies on various compression ignition engines using biodiesels. Biodiesel can lower some pollutant and particulate matter emissions. it can be blended with diesel engine without any major modifications. Non diesel engines combine a fuel mist with air before the mixture is taken into the cylinder, while diesel engines inject fuel into the cylinder after the air is taken in and compressed. In order to create the high temperatures needed to ignite the diesel fuel ,diesel engines have much higher compression ratios than gasoline engines. In the last years, many researchers have conducted studies on various compression ignition engines using biodiesels. Biodiesel can lower some pollutant and particulate matter emissions. it can be blended with diesel engine without any major modifications. The behavior of biodiesel in internal combustion engines is well documented in the literature. Engine performance is slightly lower when using biodiesel because of its lower heating value with respective to that of diesel fuel. The maximum NOx emissions were found for diesel fuel when compared to biodiesel and their blends.

1.1 Formation of Nitrogn Oxides (NO_X) in IC Engines: Diesel engines are to run more efficiently than gasoline engine's cause them to run at a higher temperature. This leads to a pollution problem, the creation of nitrogen oxides **(**NO_X). Fuel in any engine is burned with extra air, which helps eliminate unburned fuel from the exhaust. This air approximately 79% nitrogen and 21% oxygen. When the diesel fuel ignites, the temperature of the air increase to more than 1500^0 F . Some of the oxygen is used to burn the fuel, but the extra is supposed to just pass through the engine unreacted. The nitrogen, since it does not participate in the combustion reaction, also passes unchanged through the engine(10). When the peak temperatures are high enough for long periods of time, the nitrogen and oxygen in the air combines to form new compounds, primarily NO and NO_2. These are normally collectively referred to as 'NO_X'.

1.2 Exhaust Gas Recirculation: Exhaust gas recirculation is an efficient method to reduce NO_X emissions from the engine. The EGR system is designed to reduce the amount of oxides of nitrogen (NO_X) created by the engine during operating periods that usually results in high combustion temperatures, NO_X is formed in high concentrations whenever combustion temperature exceed about 2500^0 F. In this recirculation system a portion of an engine's exhaust gases are recirculated back into the engine cylinders. In diesel engines exhaust gas replaces some of the excess oxygen in the combustion chamber. The EGR system reduces NO_X production by recir culation small amount of exhaust gases into the intake manifold where it mixes with the incoming air. By diluting the air mixture under these conditions, peak combustion temperature and pressure are reduced, resulting in an overall reduction of NO_X output. The aim of the present research study is to investigate the effect of EGR on NO_X emissions and performance parameters of an indirect injection diesel engines (IDI) fuelled with diesel, JBD and their blends. In this research the engine was operated at high load condition (100% maximum load) and fixed speed 1000 rpm with test fuels for analysis.

2. METHODOLOGY

2.1 Physical and chemical properties of test fuels:

Jatropha oil has golden yellow color and is prepared from the seeds of Jatropha curcas. Jatropha biodiesel, diesel and their blends was chosen as a test fuels, because it is non edible oil which doesn't conflict with food industries. The current study is focused to use jatropha biodiesel as blend with conventional diesel to improve its properties and reducing NOx emissions. The blending percentage are denoted by B20, B40, B60, B80, B100. The properties of diesel fuel and JBD blends (B20,B40,B60, B80, B100) were measured Table 1. shows the properties of test fuels.

Table 1.The properties of test fuels

Property	Diesel	JB 20	JB 40	JB 60	JB 80	JB 100
Percentage of JBD by volume(%)	0	20	40	60	80	100
Density(kg/m^3)	817	837.9	857.7	876.0	883.6	905
Calorific value(kJ/kg)	42,000	40,852	40,141	39,937	39,530	39,000

2.2 EGR system operation:

In the current research the exhaust gas coming out of the engine is passed to an EC (Exhaust cooler) . The exhaust from the EC after cooling are passed via a valve and digital manometer. The digital manometer is provided in order to find the total amount of exhaust gas flow (when the EGR control valve is closed) and valve controlling the flow. The digital manometer operates with in the temperature range of $10\text{-}50^0$ C; this is the reason for cooling the exhaust gas after the EGR system. In the main exhaust line a tapping is provided for EGR system. The exhaust gas from the tapping via a valve and is passed to the EGR cooler, where the exhaust gas is cooled before sending it to the engine. A digital manometer is provided at the inlet manifold of the engine in order to know the flow of exhaust gas to the engine. To allow desired percentage of EGR into the engine, the first step find the total flow of exhaust gas with the digital manometer provided after the EC. If the flow is supposing 40mm is the 100% at some particular load. If to pass 10% EGR, the EGR control valve is slowly opened until it reach 4mm reading in the digital manometer provided at the intake manifold of the engine. Simple software was programmed and designed by LABVIEW to calculate the EGR percentage during experiments. Figure .1 shows the schematic diagram of the experimental setup.

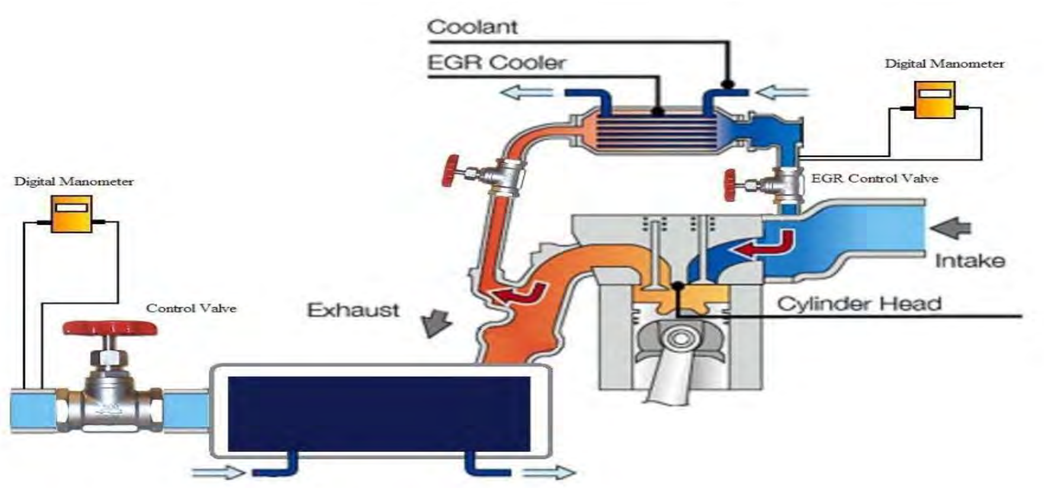
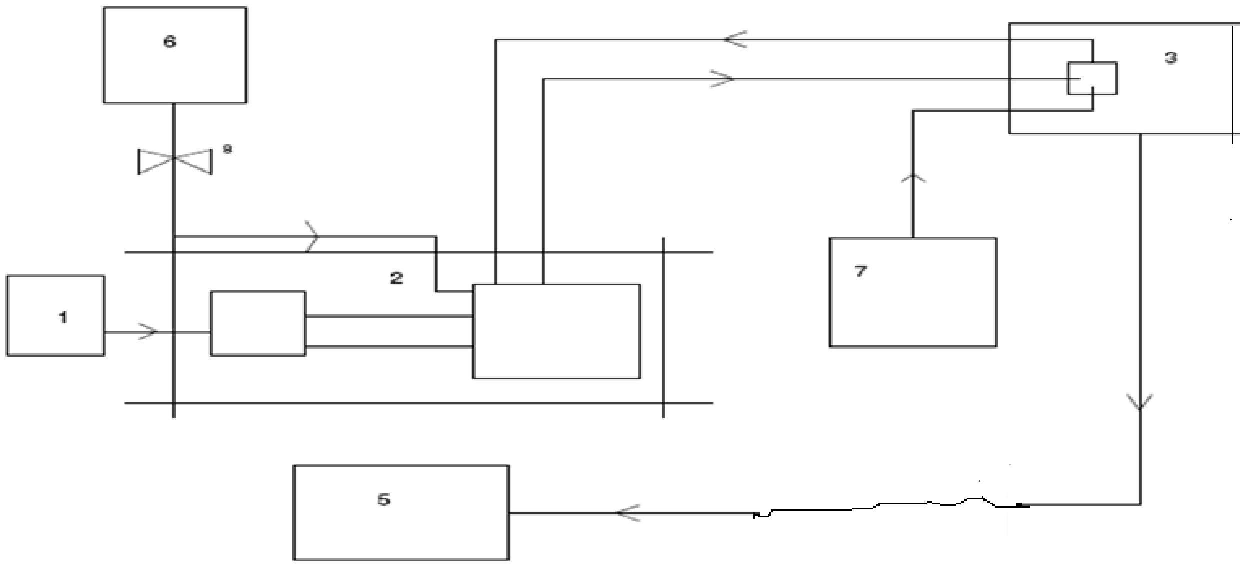


Figure 1. A schematic diagram of EGR system

3. Experimental Setup:

The properties of blended jatropha biodiesel and diesel fuels are detailed in table 1.the experimental installations used in the present work consists of a single cylinder , water cooled IDI diesel engine. Specifications of this engine are given in table 2. This engine was connected to electrical loading system.



1. **Electrical loading 2. Single cylinder 4-stroke diesel engine & Alternator 3. Exhaust gas recirculation system 5. Gas Analyzer& Smoke meter 6. Fuel Tank 7. Air drum 8. Control valve**

Figure 2 . Line diagram of experimental setup.

Table 2. The specifications of test engine

Sl. No.	Particulars	Specifications
1	Make	Field marshal Diesel engines
2	Model	FM-4
3	Rated Brake Power (BHP/kW)	10/7.35110
4	Rated speed (rpm)	1000
5	Number of cylinder	One
6	Bore x Stroke (mm)	120x139.7
7	Compression ratio	17:18
8	Coling System	Water Cooled
9	Lubrication System	Forced Feed
10	Cubic Capacity	1580 cc
11	Injection Pressure	145 kg/cm^2
12	Specific Fuel Consumption	265 gm /kWhr OR 195 gm / bhp /hr
13	Sump Capacity	4.5 Ltr
14	Lubricating oil Consumption	15 g /hr
15	Gross Weight	490 kg

Figure 3. Photograph of experimental setup

The fuel supply system was connected with the fuel tank and the temperature of intake air, exhaust gas and engine coolant were measured. k type thermometers (The wires from thermocouple data logger which connected to USB cable connected with PC). Circle edge orifice plate was used for measuring air intake mass flow rate. A U-tube manometer was used for measuring pressure drop across the orifice plate. NOx , CO,CO_2, HC were measured using a AVL fire gas analyser. Figure 3. Shows the schematic diagram of the equipment setup.

4. Results And Discussion :

The result showed that with EGR at 15% EGR diesel, JB 20 at 25% EGR, JB 40 at 15% EGR, JB 60 at 20% EGR, JB 80 at40% EGR, and JB 100 at 5% EGR, the NOx emissions are effectively reduced by 10.1%, 11.94%,13.4%,15.2%,19.85%, and 24.8% respectively at 100% load. Similarly soot emissions, CO_2, CO were recorded and various engine performance parameters were also recorded. Table 3. Shows the effect of EGR on engine performance and NO_X emission with JB 100, JB 80, JB60, JB40, JB20 and diesel test fuels relative to the existing engine without EGR system.

4.1 NO_X Emissions: Brake specific NO_X emissions of diesel engine fueled with different test fuels and their bends at 100% load conditions are illustrated in the tables 3,4,5,6,7 and 8. Kinetics of NO_X formation is governed by Zeldovich mechanism. The principle source of NO_X formation is the oxidation of atmospheric nitrogen at sufficiently high temperature. NO_X formed in cylinder areas where high temperature peaks appear mainly during the uncontrolled combustion. The NO_X emissions of all the biodiesel-diesel blends have been found higher than diesel at higher loads. It is quite obvious, that with biodiesel addition in diesel more amount of oxygen is present in combustion chamber, leading to formation of higher quantity of NO_X in biodiesel-diesel blends fueled engines. From the following tables at 100% load the NO_X emissions from all the biodiesel and their blends are higher than that of diesel. For JB 100, JB 80, JB 60, JB 40 and JB 20 the maximum amount of NO_X produced at full load are 882 (ppm), 848 (ppm), 806 (ppm), 775 (ppm), 737 (ppm) respectively. For diesel the maximum amount of NO_X produced at full load is 643 (ppm) only. The reason is possibly due to the lower calorific value and higher density of biodiesel. This is the most important emission chart eristic of biodiesel the NO_X emission is the most harmful gaseous emission from engines and emission can be reduced by several methods. One of the method is using of EGR rates reducing the NO_X emissions. The result showed that with EGR at 15% EGR diesel, JB 20 at 25% EGR, JB 40 at 15% EGR, JB 60 at 20% EGR, JB 80 at40% EGR, and JB 100 at 5% EGR, the NOx emissions are effectively reduced by 10.1%, 11.94%,13.4%,15.2%,19.85%, and 24.8% respectively.

4.2 Brake Thermal Efficiency: From the tables [3, 4, 5, 6,7 and 8] it can be found that the brake thermal efficiency of jatropha biodiesel and its blends is lower than the diesel may be due to the lower calorific value of biodiesel and slightly higher viscosity. Diesel and JB 20 shows maximum brake thermal efficiency among the blends. i.e. JB 40, JB60, JB 80, and JB 100 show the probably the same brake thermal efficiency. For all the fuels EGR rate increase from 5 to 40% with increment of 5%. From table 3. It shows that 5% EGR JB 100 test fuel have maximum NO_X reduction percentage at that point brake thermal efficiency decreases 1.25% only. Like the following test fuels are decreases in brake thermal efficiency JB 80, JB 40, JB 20, and diesel, it shows clearly in the tables 4, 6, 7 and 8 at their EGR rates i.e. 40, 15, 25,and 15% respectively. This decrease behavior is possible due to the dilution of fresh charge with exhaust gases, which results in the lower flame velocity and lead to incomplete combustion of fuel. For JB 60 test fuel at 20% EGR rate NO_X emission is effectively reduced 19.81% at that point brake thermal efficiency increases slightly 0.77%. The increases in brake thermal efficiency may be due to re burning of unburned hydro carbons which enters the combustion chamber with the re circulated exhaust gases. Furthermore, the re-circulated exhaust gases mix well with the fresh charge helps to complete the fuel combustion. The result related to NO_X emissions and brake thermal efficiency are very much similar to earlier studies reported by Scholl et al.(8) and Nabi et al (9).

Table 3. Reduction process of No_x JB 100 as a fuel at 100% load.

Fuel: Jatropha (JB-100) Calorific Value: 39000 kJ/kg Density: 905 kg/m^3

Parameters	Existing Engine	Engine + 5% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	882	663	24.8	
BTE (%)	34.13	32.88		1.25(Decreases)

Table 4. Reduction process of No_x JB 80 as a fuel at 100% load.

Fuel: Jatropha (B-80) Calorific Value: 39530 kJ/kg Density: 883.6 kg/m^3

Parameters	Existing Engine	Engine + 40% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	848	680	19.81	
BTE (%)	35.74	33.64		2.1 (Decreases)

Table 5. Reduction process of No_x JB 60 as a fuel at 100% load.

Fuel: Jatropha(B-60) Calorific Value: 39937 kJ/kg Density: 876 kg/m^3

Parameters	Existing Engine	Engine + 20% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X (ppm)	806	683	15.2	
BTE (%)	34.08	34.85		0.77(increases)

Table 6. Reduction process of No_x JB 40 as a fuel at 100% load.

Fuel: Jatropha(B-40) Calorific Value: 40141 kJ/kg Density: 857.7 kg/m^3

Parameters	Existing Engine	Engine + 15% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X(PPM)	775	671	13.4%	
BTE(%)	35.69	34.26		1.43 (Decreases)

Table 7. Reduction process of No_x JB 20 as a fuel at 100% load.

Fuel: Jatropha(B-20) Calorific Value: 40852 kJ/kg Density: 837.9 kg/m^3

Parameters	Existing Engine	Engine + 25% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X(PPM)	737	649	11.94%	
BTE(%)	39.91	35. 19		4.72 (Decreases)

Table 8. Reduction process of No_x Diesel as a fuel at 100% load

Fuel: Diesel Calorific Value: 42000 kJ/kg; Density: 817 kg/m^3

Parameters	Existing Engine	Engine + 15% EGR rate	NO_X reduction(%)	change in BTE(%)
NO_X(PPM)	643	578	10.1	
BTE(%)	41.09	38.093		2.1(Decreases)

5. Conclusions

The objective of this research work is to characterize the effect of EGR on the development of combustion instability and NO_X emission formation of IDI diesel engine when diesel, JSVO and their blends is fuelled in it at 100% load. It was found the addition of exhaust gases to the intake air increases the amount of combustion – accompanying gases which in turn increases the heat capacity and lowers the combustion temperature. And during EGR rate the other effect is the reduction of oxygen concentration in the intake air, which restrains the generation of NO_X.. It was found during exhaustive trial that the fuels like diesel, JB 100, JB 80, JB 60, JB 40 and JB 20 are operated with different EGR rates and without EGR system at 100% load. The EGR have proved to be the most effectively reducing the NO_X emissions .However, various conclusions achieved can be summarized below.

- The brake thermal efficiency of JSVO and its blends was found to be lower than diesel, which may be due to lower calorific value and slightly higher viscosity of biodiesel.
- At 15% EGR rate, 10.1% of NO_X emissions reduced and brake thermal efficiency decrease to 2.1% of diesel fuel . It may be due to the reduction of oxygen concentration in the intake air.
- At 25% EGR rate, 11.94% of NO_X emissions reduced and brake thermal efficiency decrease to 4.72% of JB 20 fuel . It may be due to the increase the heat capacity and lowers the combustion temperature..
- At 15% EGR rate, 13.4% of NO_X emissions reduced and brake thermal efficiency decrease to 1.43% of JB 40 fuel . It may be due to the combustion reaction occurs at lower temperatures, since the NO_X emissions forming reaction is lower at lower temperatures, less NO_X emission is formed..
- At 20% EGR rate, 15.2% of NO_X emissions reduced and brake thermal efficiency increase to 0.77% of JB 60 fuel . It may be due to the re-circulated exhaust gas mix well with fresh charge helps to complete the fuel combustion.
- At 40% EGR rate, 19.81% of NO_X emissions reduced and brake thermal efficiency decrease to 2.1% of JB 80 fuel . It may be due to the dilution of fresh charge with exhaust gases, which results in lower flame velocity and lead to incomplete combustion of fuel.
- At 5% EGR rate, 24.8% of NO_X emissions reduced and brake thermal efficiency decrease to 1.25% of JB 100 fuel . It may be due to the decrease in flame temperature due to the reduction of oxygen concentration in the combustion chamber.
- For all testing fuels at high loads there is a significant change of brake thermal efficiency.
- The exhaust gas temperature of the test fuels (biodiesel), and their blends was found to be lower than that of normal diesel.
- The NO_X emissions of both the biodiesel-diesel blends have been found higher than diesel at higher loads.

ACKNOWLEDGEMENTS

The author would like to thanks. Prasanthi kumari. Nunna faculty of ECE Dept. UPES-DDN and Rohan sathwik. Patteti. student of St. Judes School for their assistance during the experiments.

Nomenclature

JB	Jatropha bio-diesel
JB 20	20% Jatropha/ 80% diesel
JB 40	40% Jatropha/ 60% diesel
JB 60	60% Jatropha/ 40% diesel
JB 80	80% Jatropha/ 20% diesel
JB100	100%Jatropha
EGR	Exhaust gas recirculation
NO	Oxides of Nitrogen

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