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EXPERIMENTAL ANALYSIS OF 20% EGR RATE ON VCR DIESEL ENGINE FUELLED WITH JATROPHA BIODIESEL BLENDS

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ABSTRACT

One of themajor problems facing by today's world is **"Global Warming"**. Majority of the Green house gases are emitted into the atmosphere as a result of **"**Fossil Fuel Combustion.**"** Recently UNFCCC organized COP-21 in Paris, whose main agenda is to keep Global average temperature rise well below 2^0 C by the end of this 21st century. With inspiration to COP-21, we focus on reduction in greenhouse gas emissions from the Diesel engines by fueling the engine with Jatropha Biodiesel blends. Research work shows that Jatropha biodiesel fuelled engines emit less CO_2, HC and smoke emissions but higher NOx emissions than conventional diesel fuelled engines.

The objective of this work is to reduce NOx emissions from jatropha biodiesel fueled CI engine with cooled Exhaust Gas Recirculation(EGR) technique without compromising at the performance.Tests were conducted on A VCR, single-cylinder, water cooled, constant speed(N=1500rpm),direct injection diesel engine by operating with pure diesel and Jatropha biodiesel blend JBD20 at a fixed compression ratio of 17.5:1 with and without EGR(E20).The performance, combustion and Emission parameters were evaluated experimentally.The Application of EGR with Jatropha biodiesel results in reduction of NOx, HC, CO_2 and CO emissions without any significant upsurge in smoke emissions.

KEYWORDS:Globalwarming,UNFCCC,COP-21,EGR,JBD-20,BSFC,NOx,ROHR&Mean Gas temperature.

INTRODUCTION

As we all know one of the greatest problems faced by human beings and the earth itself is the growing rate of pollution. The main cause of pollution is the growing number of automobiles and vehicles which rejects a huge amount of exhaust gases on a daily basis. According to statistical reports of India, The transportation sector contributes more to greenhouse gas emissions and leads to the Global Warming. In order to reduce the vehicular emissions, the government of India has formulated emission norms based on EURO norms in the year 1989.These emission norms are implemented in India as BS-I,BS-II,BS-III and BS-IV.

Huge research is carrying out on reduction of emissions from the internal combustion Engines with cost-effective techniques.Internal combustion engine emissions Include CO_2, HC, CO and NOx etc. Among all NOx is more harmful to environment as it leads to formation of smog and acid rain. As we know that fresh air, which is admitted into the engine cylinder consists of 77% of nitrogen and 23% of O_2 by mass. The nitrogen in the combustion chamber will react with oxygen at a temperature greater than 1300^0C forms oxides of nitrogen (NOx). From the previous research work it is clear that Exhaust gas recirculation is the effective and inexpensive in -cylinder treatment method for reducing the oxides of Nitrogen emissions (NOx) from IC engines.

FORMATION OF NOx IN IC ENGINES

NOx is formed inside the combustion chamber in post-flame combustion process in the high temperature region. The NOx formation and decomposition inside the combustion chamber can be described by extended Zeldovich Mechanism. The principal reactions at near stoichiometric fuel–air mixture governing the formation of NO from molecular nitrogen are

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O+N2 → NO+N
N+O2 → NO+O
N+OH → NO+OH

The initial rate controlled NO formation (i.e. when [NO]/[NO2]e_1) can be described by Eq. (1). In the expression,[NO] denotes the molar concentration of the species and[O2]e and [N2]e denotes the equilibrium concentration.

$$\frac{d(\mathrm{NO})}{dx} = \frac{6X10e16}{T^{0.5}} \exp\frac{-69,096}{dxT}[O2]0.5t0e[\mathrm{N2}]e/mol\,s/cm^3$$

The sensitivity of NO formation rate to temperature and oxygen concentration is evident from this equation. Hence in order to reduce the NOx formation inside the combustion chamber, the temperature and oxygen concentration in the combustion chamber need to be reduced. Even though, certain cetane improving additives are capable of reducing NOx, the amount of reduction is reported to be inadequate. Moreover, most of these additives are expensive. Retarded injection is an effective method employed in diesel engines for NOx control. However, this method leads to increased fuel consumption, reduced power, increased HC emissions and smoke. Water injection is another method for NOx control however this method enhances corrosion of vital engine components. In addition, it adds to the weight of the engine system because of requirement of a water storage tank. It is also difficult to retain water at a desired temperature during cold climate.from the above discussion it is clear that EGR is the efeective and in-expensive technique for the reduction of NOx emissions from thediesel engines without any penalty on specific fuel consumption(SFC).

EXPERIMENTAL SETUP AND EXPERIMENTATION

Experimental set-up;-

The experiments were conducted on a single cylinder, direct injection, variable compression ratio, high speed diesel engine. At the rated speed (1500 rpm), the engine develops approximately 5.2kw power output. The engine is coupled to an eddy current dynamometer in order to measure brake power(BP). A mass flow sensor is used to find the mass flow rate of air enter into the cylinder. A non contact PNP sensor is used to measure the engine RPM. A PNP sensor gives a pulse output for each revolution of the crankshaft. The frequency of the pulses is converted into voltage output and connected to the computer. Torque is measured using a load cell transducer. The transducer is a strain gauge base. The output of the load cell is connected to the load cell transmitter. The output of the load cell transmitter is connected to the USB port through interface card. The fuel consumption is measured with the help of optical sensors. These optical sensors are capable of detecting any liquid and give an output in type of signals. The system consists of a burette fitted with two optical sensors one at the high level and the other at the high level. As the liquid passes through the high level optical sensor, the sensor gives a signal to the computer to start the time once the liquid reaches the lower level optical sensor, the sensor gives a signal to the computer to stop the time and refill the burette. The time taken for consumption of a fuel for a fixed volume is calculated. The cylinder pressure is calculated using piezoelectric transducer. The temperature of gases and water at various points are calculated using "K" type thermocouples. An AVL 437C smoke meter is used to measure the smoke opacity of the exhaust gas. AVL 444-5 gas analyzer used to measure NO, CO, HC, CO_2, O_2. Tests were conducted on VCR engine at a compression ratio of 17.5:1 by varying the loads (no load to full load).

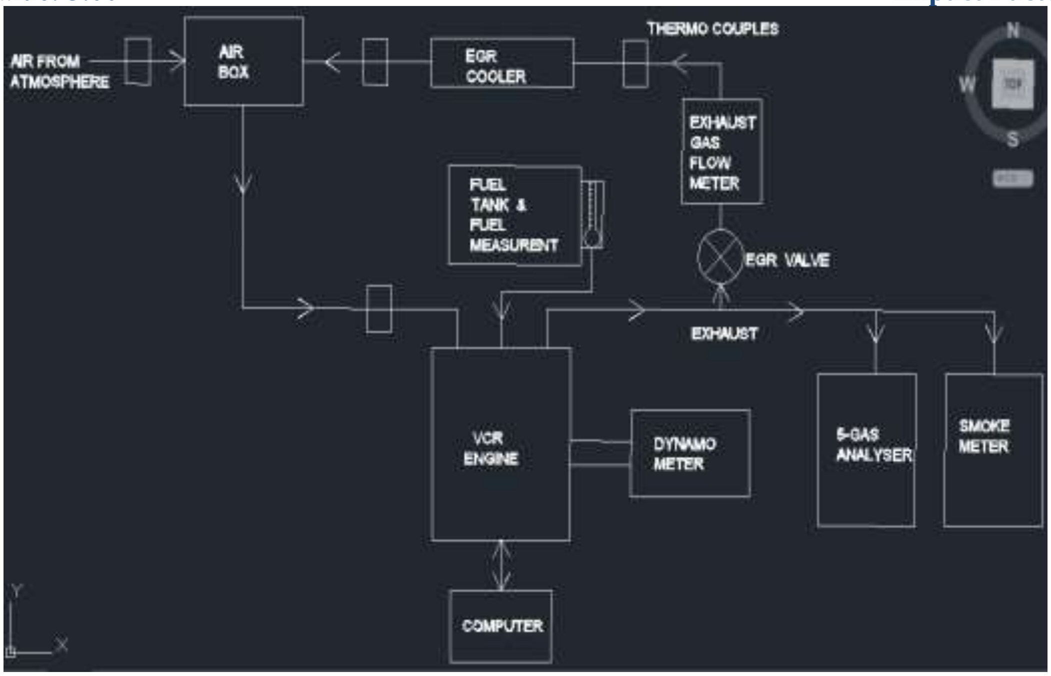

Fig1 : Experimental layout

Make and model	kirloskar, tv1 make
Type of engine	singlecylinder,four stroke, compression ignition, constant speed vertical, water cooled, direct injection, variable compression ratio diesel engine.
Rated output	5.2 kw
Compression ratio	17.5: 1 (standard engine) & 15:1 – 18:1(vcr)
Rated speed	1500 rpm
Bore x stroke	87.5 mm x 110 mm
Swept volume	661 cc

Table 1: specifications of test engine

Properties of the Test Fuel	**Diesel**	**Jatropha bio-diesel(JBD)**
Kinematic Viscosity (At 40°C)	3.9	4.2
Density	835	0.879
Flash point Temperature(in °C)	96	192
Net Calorific value(kj/kg)	42500	38500
Cetane number	49	47

Table 2: properties of test fuels

Experimentation

Tests were conducted on VCR engine at 17.5:1 with pure diesel and jatropha biodiesel blend and acquired performance,combustion and emissions data .further more the engine is tested with the same test fuels by implementing 20% EGR rate and results obtained are compared to that of previous results.

TEST NO	TEST FUEL	EGR %	LOAD (%)	COMPRESSION RATIO	SPEED (RPM)
I	Pure diesel	E-0	0,1/2,3/4, and Full.	17.5:1	1500
II	Pure diesel	E-20	0,1/2,3/4, and Full.	17.5:1	1500
III	JBD-20	E-0	0,1/2,3/4, and Full.	17.5:1	1500
IV	JBD-20	E-20	0,1/2,3/4, and Full.	17.5:1	1500

Table 3:tests conducted on engine and their operating conditions

RESULTS AND DISCUSSION

Parameter	DIESEL-E0%	DIESEL-E20%	JBD20-E0%	JBD20-E20%
Brake power(KW)	2.035	2.030	2.077	2.060
Thermal efficiency(%)	27.277	27.375	27.470	27.402
Volumetric efficiency(%)	78.692	76.90	78.202	77.884
Mechanical efficiency(%)	52.60	48.045	53.790	51.407
SFC (kg/kw-h)	0.345	0.335	0.355	0.347

Table 4 : performance comparison of diesel and JBD-20 test fuels

EMISSION	DIESEL-E0%	DIESEL-E20%	JBD20-E0%	JBD20-E20%
NOx(ppm)	441.2	392.2	475.4	376
HC (%)	35.2	28.8	25.4	25.8
CO_2(ppm)	4.62	4.34	4.26	4.22
CO (ppm)	0.1	0.106	0.092	0.092
SMOKE OPACITY(%)	76.02	78.34	67.6	68.68

Table 5: emissions comparison of diesel and JBD-20 test fuels

COMBUSTION ANALYSIS

Combustion analysis is carried-out with cylinder peak pressure,Ignition Lag period and Mean gas temperature.From the P-Ө diagram (Fig 2&3) it is clear that peak pressure is attained at 5 degrees after TDC.it is almost same for diesel as well as jatropha biodiesel and the peak pressure of the cycle is found to be 60 bar.Comparing both the pressure-crank angle graphs (diesel with and without EGR) we can observe that 20% EGR has no much effect on the cycle peak pressure.From the p-Ө diagrams (fig 2 & 3) The similar effect can be observed when the same engine is running with JBD-20 under similar working conditions.Ignition lag period can be measured easily with the aid ofp-ɵ diagram,it is the time period between the start of fuel ingection(SOFI) and start of combustion (SOC).For both the test fuels (at 0% EGR rate),The ignition lag period is found to be 8 degrees of crank rotation.but when 20%EGR rate was implemented, this Ignition lag period is slightly increased and leads to delay of rate of heat release.Finally delay of ROHR may leads to decrease in peak pressure and peak temperature.From the mean gas temperature graphs it is well known thatmean gas temperature is largely decreased under 20% EGR rate. as the mean temperature curve is lower while using EGR technique hence the peak temperature is lower and that just denotes that much less amount of NOx is emitted from the engine.

1.Cylinder peak pressure:

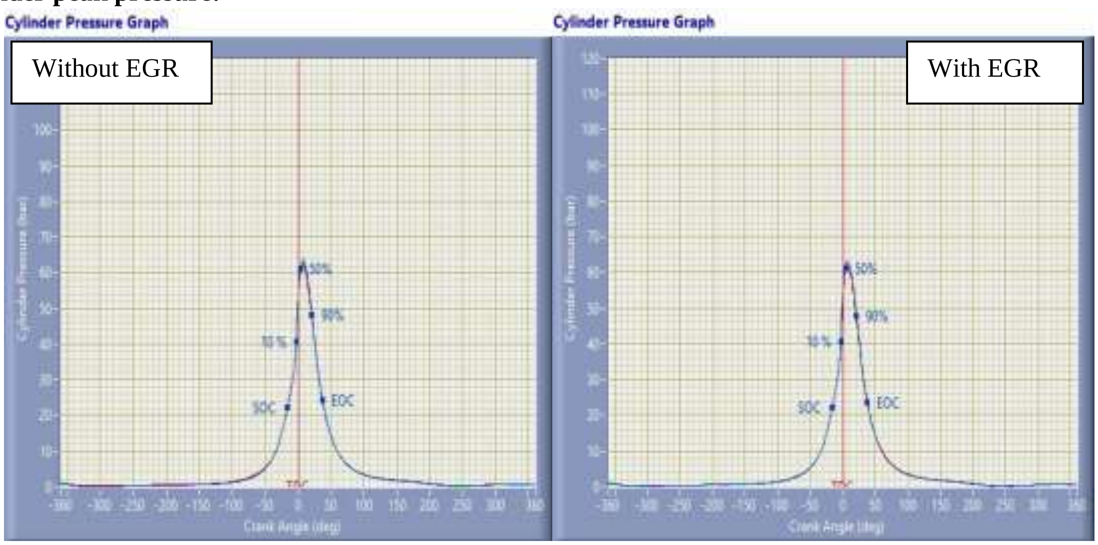

Fig 2: P-Ɵ diagram (Diesel)

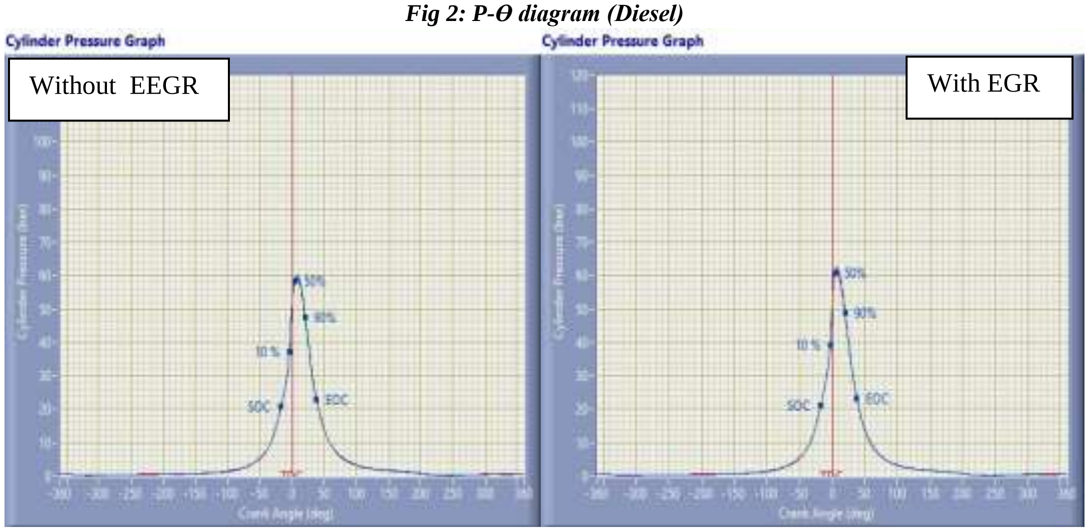

Fig: 3 P-Ɵ diagram (JBD20

2.Mean gas temperature :

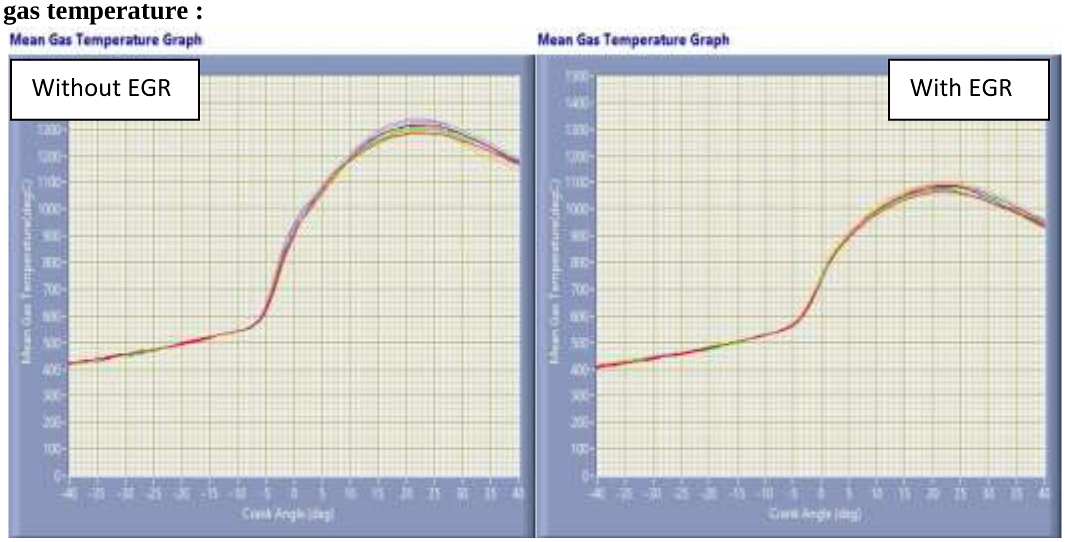

Fig 4:Effect of 20% EGR on Mean gas temperature (Diesel)

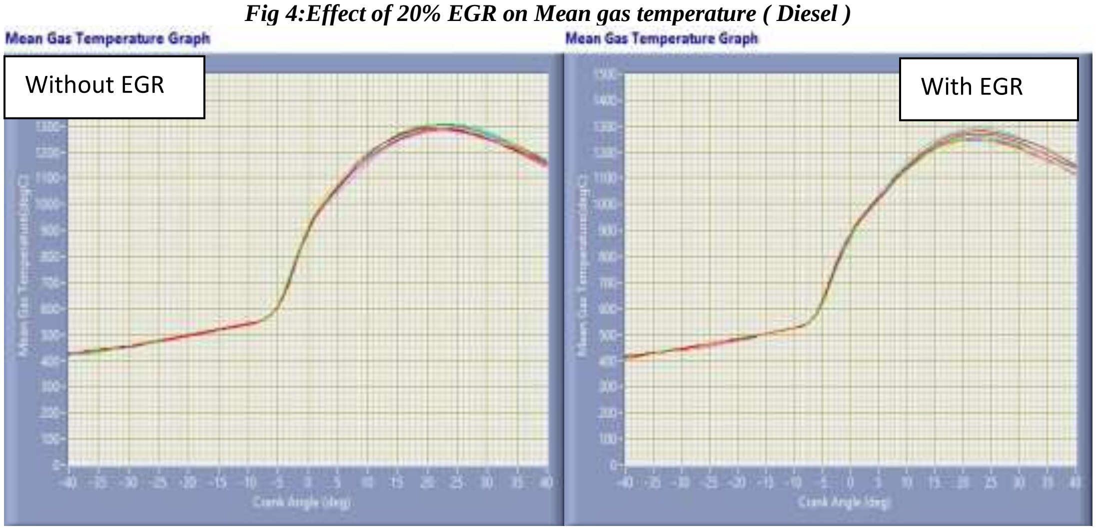

Fig 5: Effect of 20% EGR on Mean gas temperature (JBD20)

PERFORMANCE ANALYSIS

Figure 6 shows the effect of 20% EGR rate on brake thermal efficiency of Diesel and JBD-20 test fuels.the main observation is that JBD-20 blend produced higher thermal efficiency than that of diesel fuel due to excess O2 which is present in the fuel itself further more thermal efficiency is improved slightly when we implement 20%EGR rate.the possible reason for the improvement in thermal efficiency of the engine is reburning of HC particles by utilising the excess O2 in exhaust gas.Figure 7 shows the effect of 20% EGR rate on BSFC of diesel and JBD-20 test fuels.at 0% EGRrate,the BSFC of JBD-20 is slightly higher than that of Diesel fuel.This is due to the higher calorific value of diesel compared to JBD-20 blend.From the figure 8 it is evedent that,volumetric efficiency is 79.69% for the diesel fuel with out EGR but it is only 76.9% when we implement 20%EGR rate. The similar variation is observed in case of JBD-20 blend. Finally we can coclude that vollumetric Efficiency is decreased when we implement 20%EGR rate,the possible reason for decrease in volumetric efficiency of the engine is due to increase in intake temperature of the air.Figure 9 shows effect of 20% EGR rate on Mechanical Efficiency of diesel and JBD-20 Test fuels. As biodiesel possess good lubrication properties, the JBD-20 test fuel exhibit higher mechanical efficiency than conventional Diesel Fuel.From the graph it is clear that mechanical efficiency is dropped slightly when 20%EGR rate was implemented for both the test fuels.

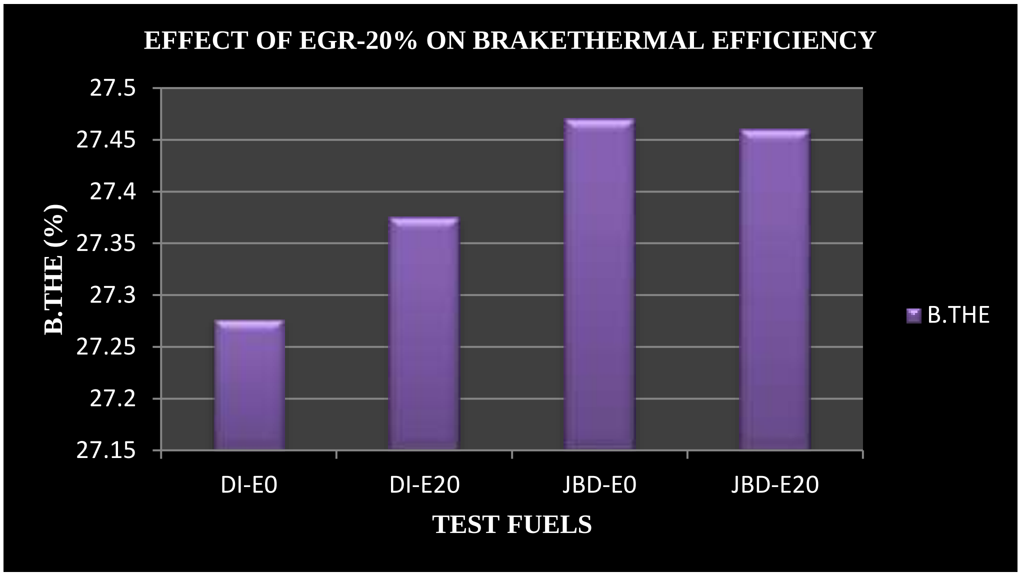

Fig 6: Effect of 20% EGR on brrake thermal efficiency of engine

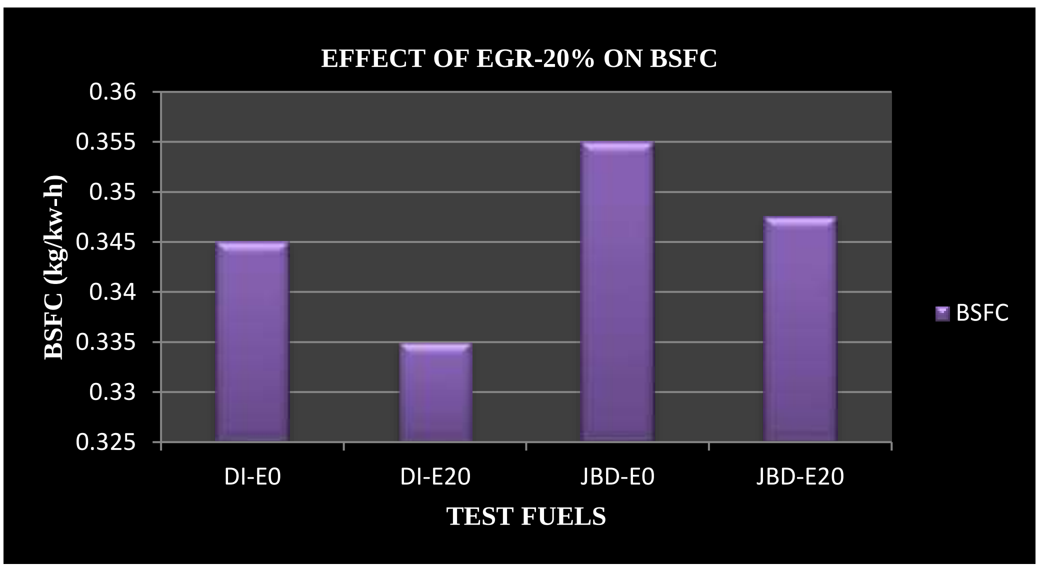

Fig 7: Effect of 20% EGR on BSFC

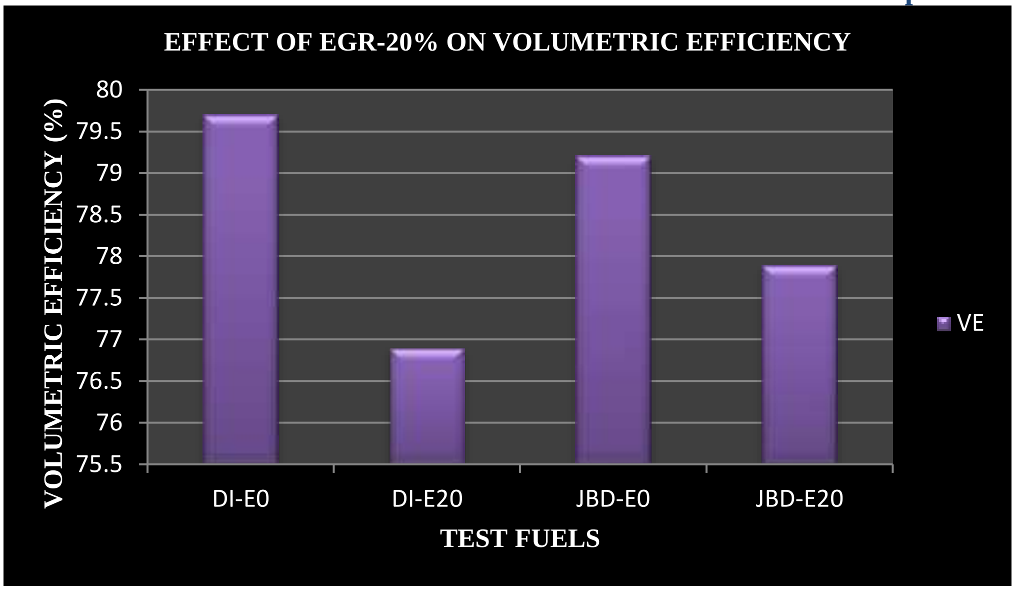

Fig 8: effect of 20%EGR on volumetric efficiency of the engine

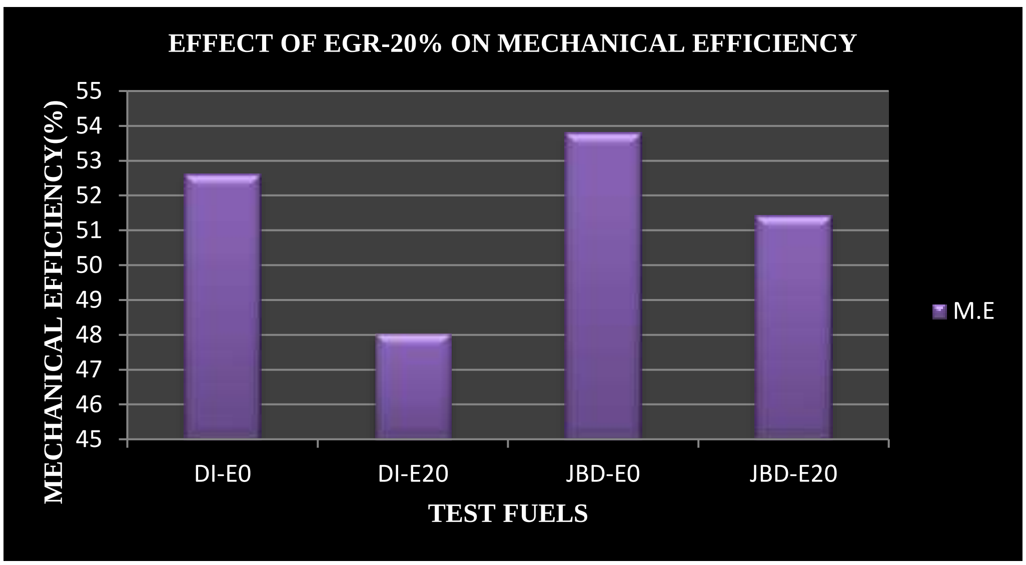

Fig.9:Effect of 20% EGR on mechanical efficiency of engine

EMISSION ANALYSIS

From the fig.10, it is clear that JBD-20 test fuel emit more NOx emissions than diesel fuel,this is because the presence of O_2 in jatropha biodiesel.As an example at 0% EGR diesel fuel emit 441.2ppm and JBD-20 emit 475.26 ppm NOx under similar working conditions.with the implementation of 20%EGR rate the above NOx levels were decreased to 392.2ppm and 376 ppm respectively.HC emissions(fig 11) also decreased with the implementation of EGR especially at part loads and exhibit slight increase in HC eissions at high loads.CO_2 emissions (fig. 12) were decreased with JBD-20 test fuel when compared to that of diesel fuel. Further more 20%EGR rate does not alter concentration of CO2 emissions in ingine Exhaust.

Fromthe figure 13, it is evidend that CO emissions were less in case of JBD-20 When compared to diesel fuel.as an example at 0% EGR diesel emit 0.1% CO emissions where as JBD-20 emit only 0.092% CO emissions.At last the concentration CO not affected by EGR in case of JBD-20 test fuel when compared to that of Diesel fuel.The comparative analysis of smoke opacity is indiated in % as shown infigure 14.The smoke opacity of the JBD-20 test fuel was lower than that of Diesel fuel at all operating conditions.This may be due to the oxygen amount in the JBD blend which contribute to complete and stable combustion process.The smoke opacity of the test fuels increased under 20% EGR rates.

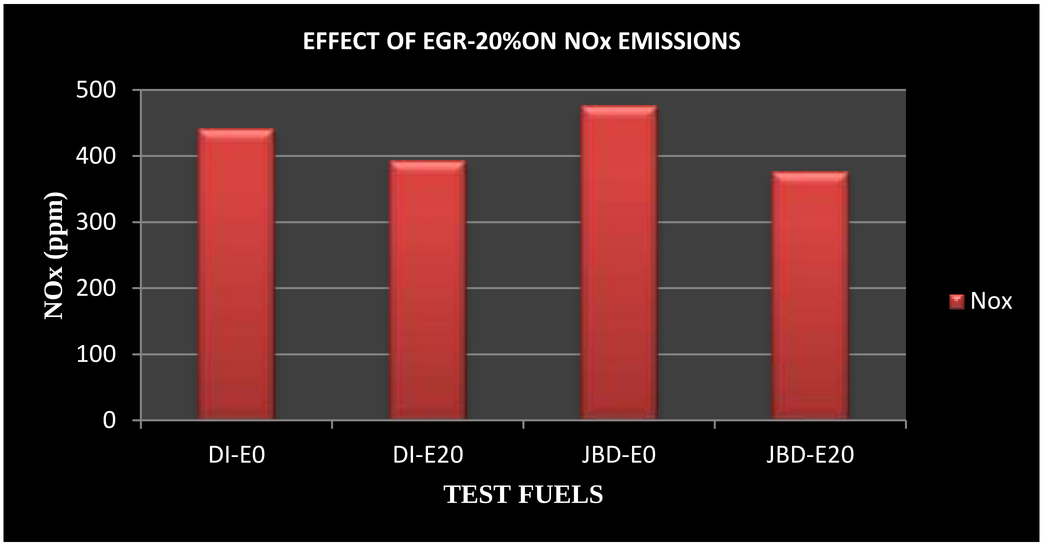

Fig.10:Effect of 20%EGR on NOx emissions of engine

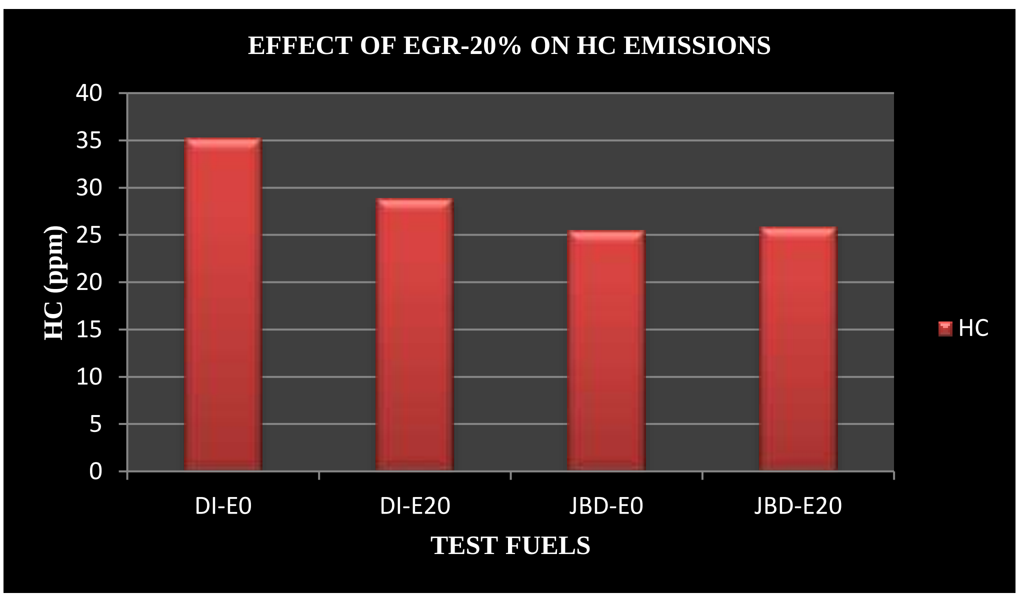

Fig.11:Effect of 20%EGR on HC emissions of engine

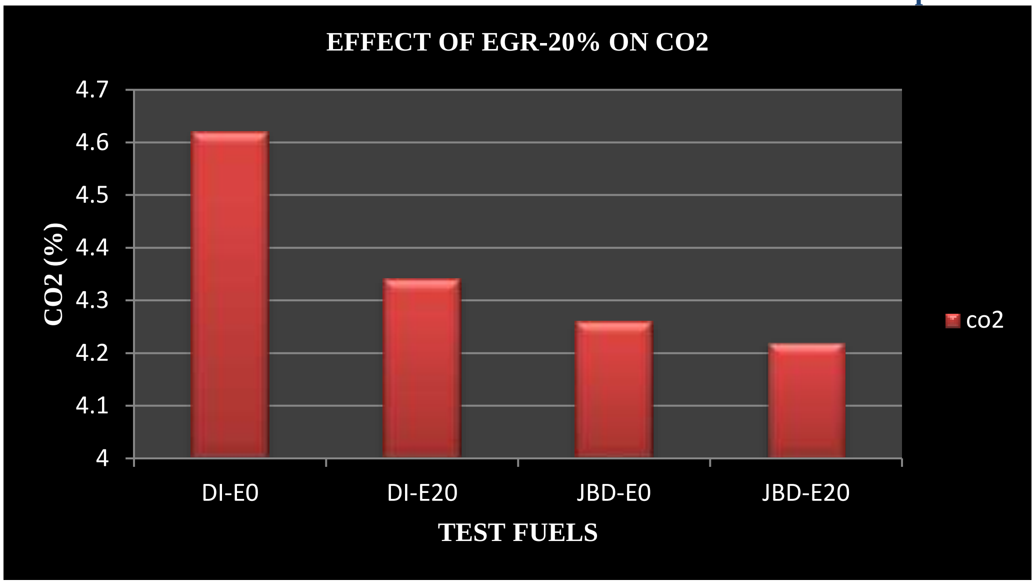

Fig.12:Eeffect of 20%EGR on CO_2 emissions of engine

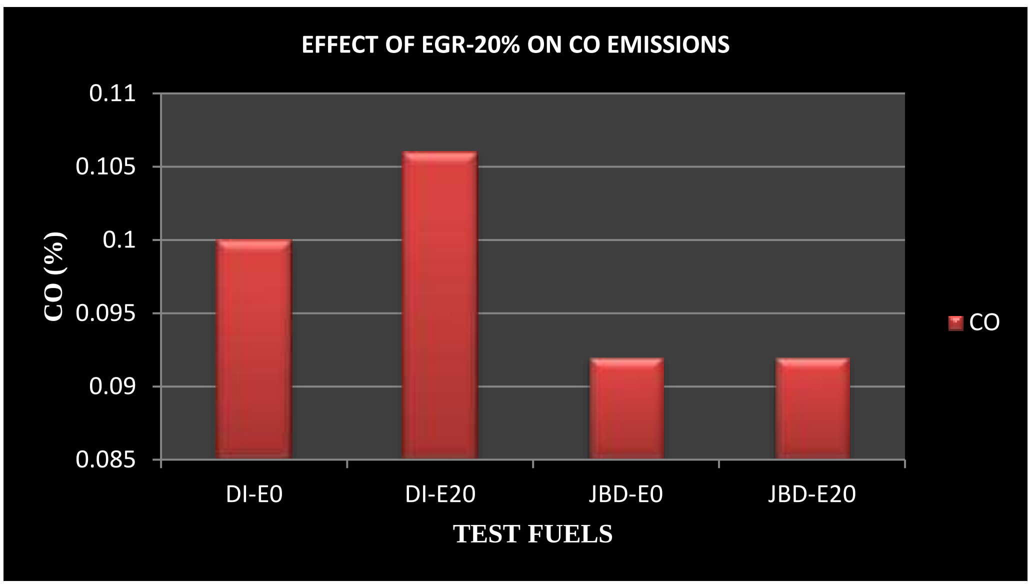

Fig. 13:Effect of 20% EGR on CO emissions of engine

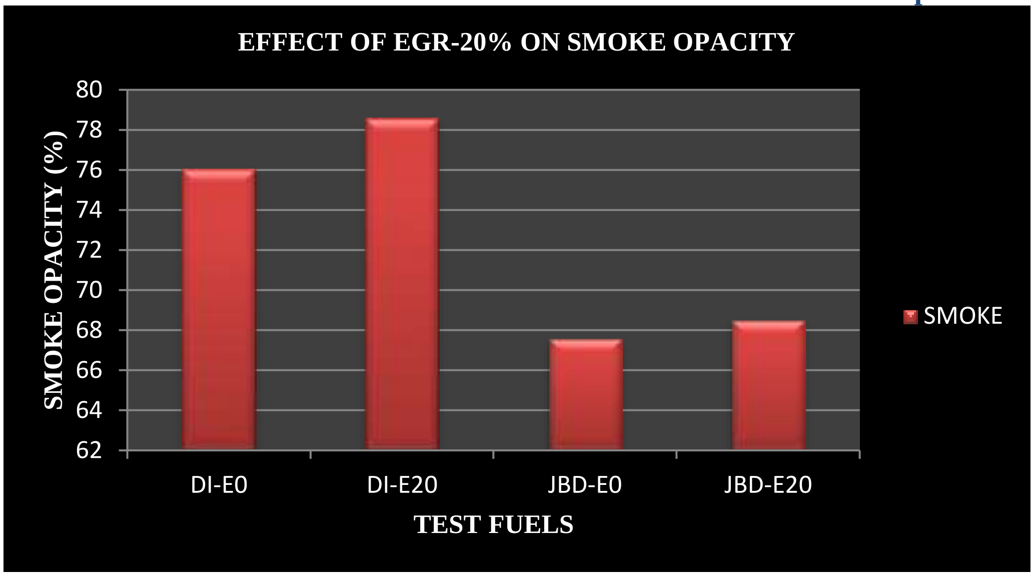

Fig.14: Effect of 20% EGR on Smoke emissions of engine

Fig.15:Experimental set-up

CONCLUSION

After the detailed investigation of the Test engine through the performance, combustion and emission data, we came to the conclusion that:

- The implementation of cold exhaust gas recirculation to the test engine could reduce the concentration of O_2 in the fresh air thereby reducing the combustion temperature.
- The presence of CO_2 along with the fresh charge in the combustion chamber reduces the flame temperature due to increase in specific heat capacity of the cylinder gases.
- As EGR lowers the peak temperatures, there is a drastic decrease in the NOx emissions from the engine. The magnitude of drop in NOx emissions at high loads is relatively more when compared to that of low loads. NOx emissions were hugely decreased in the case of JBD20 test fuel with EGR when compared to diesel with EGR.Maximum reduction in NOx is observed with JBD-20 test fuel at full load (120ppm).
- Un burnt hydrocarbons were reduced due to exhaust gas recirculation by 26.7% .
- The CO_2 levels were decreased considerably by 1.90%.

  Hence by implementing cold EGR technique to Jatropha Biodiesel fuelled engines we can reduce NOx, Un burnt HC, $CO_2$and smoke emissions by without sacrificing the performance.

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