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Experimental Investigations on The Impact of EGR for C.I. Diesel Engine Using Biodiesel

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Abstract: Due to higher overall efficiency and reliability diesel engines have become the prime movers of today's world, there is a continuous increase in demand for fossil fuels in transportation, agriculture and power generation. In these circumstances, it is necessary to search an alternate energy source. Biodiesel is one of the feasible choices of the renewable energies. Properties of biodiesel are similar to that of petroleum diesel. Exhaust gas Recirculation (EGR) is the most preferable solution to decrease the engine emissions as it recirculates the controllable proportion of the engine's exhaust back to intake air. In this study, the experimental investigation was carried out to analyze the performance and emission characteristics of single cylinder diesel engine fuelled with jute biodiesel and exhaust gas recirculation rates of 5%, 10% and 15%. The results show that at lower EGR rates, brake thermal efficiency and mechanical efficiency for jute biodiesel is less than that of diesel at all loads. Whereas, total fuel consumption is seen increasing with increase in EGR rates. Huge reduction in oxides of nitrogen emission is seen with EGR than that of normal engine conditions. Simultaneous reduction of HC and CO was realized at lower EGR rates. The performance and emission characteristics curves reveal that neat jute biodiesel with EGR of 10% is optimal as compared to other test fuels.

***Keywords* —Biodiesel, combustion chamber design, performance, emissions, Jute methyl ester and EGR.**

I. INTRODUCTION

Fossil fuels are the main source of energy production in internal combustion engines. Increase in the energy demand is causing the depletion of fossil fuels and environmental problems [1]. However, the oxides of nitrogen (NOx) and particulate matter (PM) emissions are the major problems for diesel engines. Reducing oxides of nitrogen (NOx) and particulate matter (PM) at the same time is a challenging task in CI Diesel engines [2]. These situations have led to search for an alternative fuel which have better fuel economy and reduces the emissions. Properties of the Biodiesel are very closer to the petroleum diesel so Biodiesels one of the suitable alternate for petroleum diesel [3]. Usage of Biodiesel has led to higher NOX emissions. In this present work NOx emissions are reduced by using EGR [4]. Combustion chamber geometry also play a key role in reducing emissions by achieving proper mixing of the air and fuel in the combustion chamber[4,5]. Usage of Biodiesel affects the performance of diesel engines. Performance of the Biodiesel fuelled IC engine is increased by using turbocharger [6].

Air drawn through the inlet manifold into the cylinder is compressed by piston. Main function of the combustion chamber is to provide proper mixing of the air and fuel in a quick time to reduce the ignition lag period [7]. To achieve this, a regulated air movement called as swirl is used to attain high relative velocity between air and fuel droplets [8]. When the fuel is injected to the combustion chamber, fuel particles get distributed by air motion and turbulence inside [9]. This turbulence is provided by the combustion chamber shape. In this work toroidal cross section combustion chamber is used to provide turbulence in the combustion chamber [10]. Combustion chamber geometry must be considered for better engine operation, performance and emission. Suitable combustion chamber geometry helps in proper swirl and mixing of air and fuel [11].

Biodiesels are unconventional energy resources, they are non-toxic and bio degradable for diesel engines. Biodiesel is the suitable fuel among the available alternate fuels for diesel engine [12]. Biodiesel fuel has better ignition quality (cetane number), absence of sulphur and aromatic contents,

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renewability and biodegradability lower the greenhouse emissions [13]. Moreover no modifications are required to use Biodiesel to a diesel engine.

Exhaust gas recirculation is the method used to reduce NOx emissions in diesel engines [14]. EGR recirculates the controllable proportion of the engine's exhaust back to intake air [15]. Flow of the exhaust gases to the intake air usually controlled by using a valve. This burnt gas reduces the oxygen content in the air available for combustion in the combustion chamber [16]. This causes lower heat release rate and lower peak temperature hence NOx emissions are reduced. The exhaust gas circulates through the EGR cooler which is air or water type cooler, which reduces the gas temperature when EGR is equipped [17]. This have two benefits one is reduction in charge temperature and other is increases the charge density of intake charge [18].

Turbocharger is a device which increases the amount of the air entering the engine to create more power. It is driven by exhaust gas from the engine. Its compressor draws in ambient air and compresses it before it enters into intake manifold at increased pressure [19]. In this experimental setup the turbo charger is fitted to the engine exhaust pipe.

II. EXPERIMENTAL SETUP

The experiments are carried out on a single cylinder four stroke water cooled diesel engine coupled to eddy current dynamometer. The whole experiment setup is mounted and balanced on the mild steel channels. The experimental set up consists of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel measurements, process indicator and engine indicator. For the measurement of the flow of cooling water level and calorimeter water level a device called rotameters are installed to the equipment. A single cylinder four stroke, naturally aspirated, direct injection and water cooled diesel engine which has displacement volume of 661 cc, compression ratio (CR) of 17.5 and rated power output of 5.2 kW at 1500 rpm is used for conducting experiments. The rated speed of the engine is 1500 rev/min. an eddy current dynamometer is coupled to the engine for purpose of loading.

The test engine setup along with EGR is shown in fig 2. And toroidal combustion chamber design is shown in fig 3.

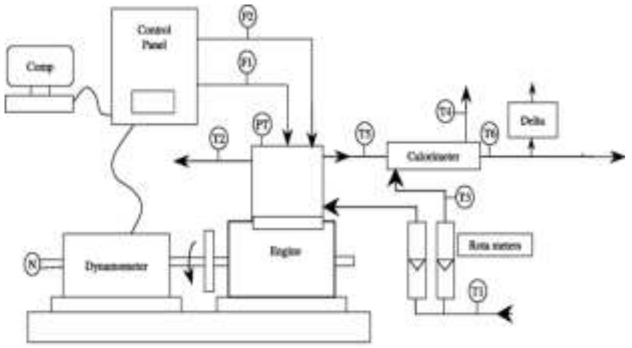

Fig: 1 Test Engine Layout

Fig: 2 Test Engine Setup with EGR

Fig:3 Toridal combustion chambers

S.No.	Parameter	Specification
1	Make	:Apex innovations Ltd.
2	No. of cylinders	:1
3	No of strokes	:4
4	Cylinder bore	:87.5mm
5	Stroke length	:110mm
6	Connecting rod length	:234mm
7	Orifice diameter	:20mm
8	Compression ratio	:12:1 – 17.5:1
9	Power	:5.2kw
10	Speed	:1500 rpm
11	Fuel	:Diesel
12	Injection pressure	:180bar
13	Injection point variation	:0 to300 BTDC
14	Dynamo meter type	:Eddy current
15	Dynamo meter arm length	:185mm

Table:1 Engine Specification

III. RESULTS AND DISCUSSION

3.1 Effect of Different Engine Performance parameters on Diesel Engine

Fig .4. shows the BTE variations with BP at various EGR compositions. It can be seen for the Fig that, BTE increases with increase in the load. BTE values at 5%, 10% and 15% EGR were recorded as, 19.05, 19.18 and 18.33 respectively. As compared with diesel, BTE for 5% EGR has increased by 1.57%, with 10% EGR BTE has increased by 2.24% and with 15% EGR has decreased by 2.24%. The decrease in BTE with increase in EGR may be due to reduced soot oxidation rate which has decreased the combustion quality. As such, BTE is found better for lower EGR rates. However, 10% EGR shows better BTE as compared with other test conditions. This may be attributed to the desired amount of oxygen available in biodiesel and sufficient time

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available for proper mixing of fuel-air and less fuel-rich zones for appropriate combustion [20].

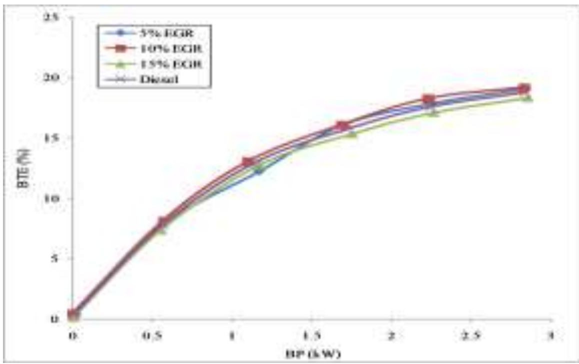

Fig: 4 Brake Power Vs Brake Thermal Efficiency

Fig. 5 shows the mechanical efficiency variations as a function of BP at various EGR compositions. It is seen from the Fig that, mechanical efficiency increases with increase in the load and this trend is similar at all EGR compositions. Under full load conditions, mechanical efficiency values for 5%, 10% and 15% EGR were recorded as 79.26%, 81.26% and 77.23% respectively. As compared with diesel, mechanical efficiency with 5% EGR has decreased by 1.24%, with 10% EGR mechanical efficiency increased by 1.28% and with 15% EGR mechanical efficiency has decreased by 3.74%. The decrease in mechanical efficiency at 5% and 15% EGR compositions may be attributed to the incomplete combustion due to unavailability of required amount of oxygen in the combustion chamber. The variations of BTE confront the same in this regard.

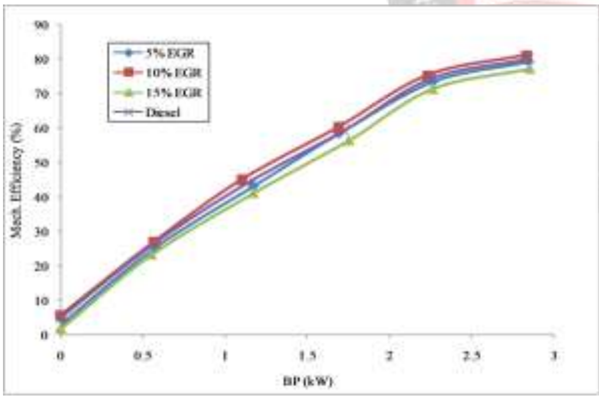

Fig: 5 Brake Power Vs Mechanical Efficiency

TFC variations with BP at various EGR compositions are presented in Fig 6. It can be seen from the Fig that TFC decreases with increase in the load. The TFC values for 5%, 10% and 15% EGR were recorded as 8.57, 7.97 and 8.66 cc/min respectively. As compared with diesel TFC for 5% EGR has increased by 3.62%, for 10% EGR TFC decreased by 3.76% and 15% EGR has increased by 4.71%. With increase in EGR composition, TFC is seen increasing. It may be due to the partial replacement of intake air with products of combustion, which inhibits the normal combustion and in turn decrease in power output. So as to compensate the power output of the engine, additional fuel is consumed which is seen as increase in TFC [21].

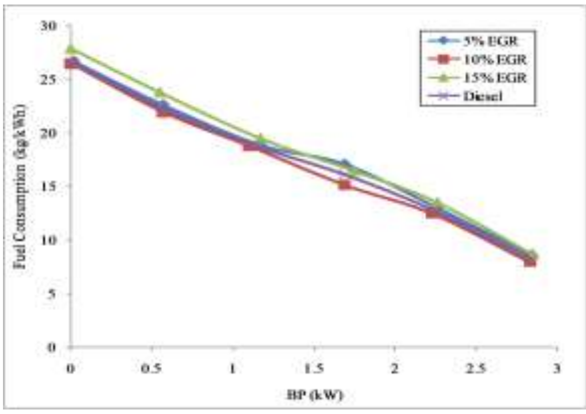

Fig: 6 Brake Power Vs Specific Fuel Consumption

Fig. 7 shows the variations of CO emission as a function of load at various EGR compositions. It can be seen from the Fig that, CO emission decrease first and the increase with increase in the load. CO emission with 5% EGR is higher by 2.2% as compared with diesel. Whereas, CO emission with 10% and 15% EGR are found to be lower by 10.76% and 2.15% respectively as compared with diesel. This may be due to the reduced air/fuel ratio and also the oxygen present of biodiesel enhances the combustion resulting in reduced CO emission.

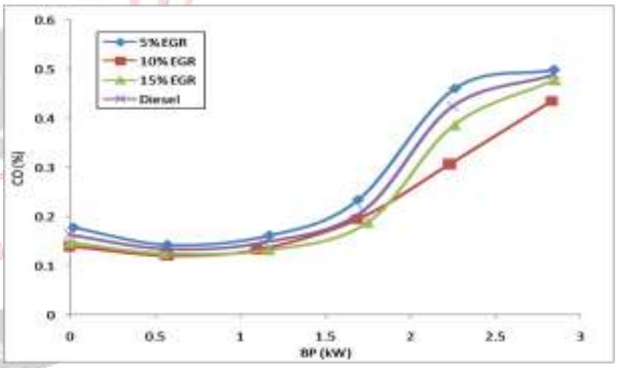

Fig:7 Brake Power Vs CO Emissions

The variations of NOx emission as a function of load at various EGR compositions is presented in Fig 8. It can be seen from the Fig that NOx emission increases with increase in the load. Under full load conditions, NOx emission with 5%, 10% and 15% EGR were recorded as 447, 364 and 378 ppm respectively. As compared with diesel, NOx emission is found to be lower by 13.53%, 29.59% and 26.88% for 5%, 10% and 15% EGR composition respectively. NOx emission with 10% EGR is lower than all other conditions. This may be due to dilution of fresh charge and in turn decrease in in-cylinder temperature during the combustion process. In this regard the available oxygen reacts with the carbon and hydrogen molecules present in fuel rather than with nitrogen present in air.

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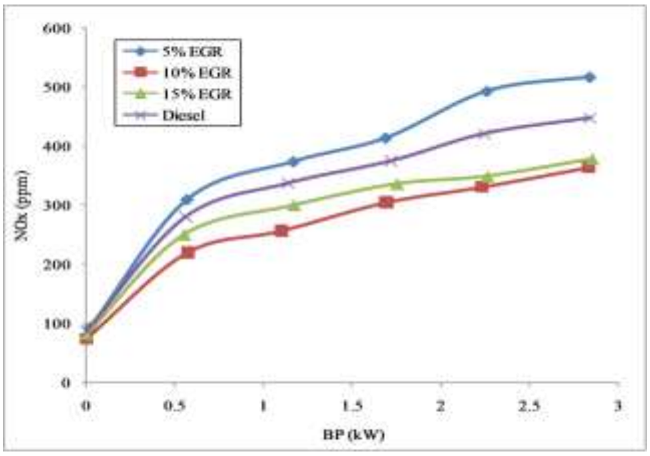

Fig: 8 Brake Power Vs NOX Emissions

The variations of HC emission as a function of load for various EGR compositions are presented in Fig 9. It can be seen from the Fig that, HC emission increases with increase in the load and also with increase in EGR composition. In general, at reduced EGR composition, the exhaust gas temperature and recirculated exhaust gas temperature is high which promotes better atomization of diesel fuel and reduced HC emissions. Whereas, higher EGR ratios results in lean and very lean fuel/air mixtures and lower flame temperatures. As compared with diesel, HC emission with 5% and 10% were found to be lower by 13.37% and 4.45% respectively and with 15% EGR, HC emission increased by 11.79%. The increased HC emission with 15% EGR may be attributed to the formation of flame quenching at places in combustion chamber and also due to incomplete combustion.

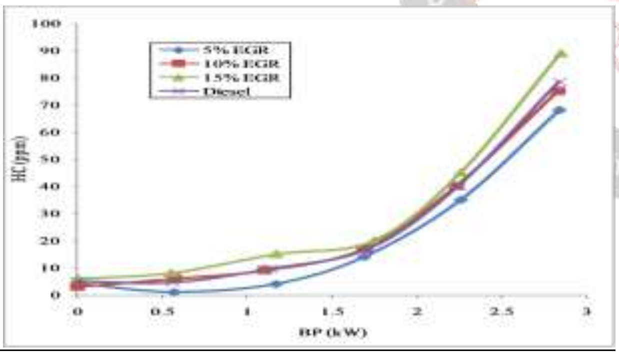

Fig: 9. Brake Power Vs HC Emissions

IV. CONCLUSION

In this study, the experimental investigation was carried out to analyze the performance and emission characteristics of single cylinder diesel engine fuelled with jute biodiesel and exhaust gas recirculation rates of 5%, 10% and 15%. The following conclusions are derived from the study:

- The physical and chemical properties of jute biodiesel are adequate and favourable to be used as fuel on diesel engine. The engine could run with jute biodiesel without any hardware modifications on the engine.
- At lower EGR rates, as the exhaust gases were introduced into the combustion chamber the heat loss in the combustion chamber was reduced and hindered the normal combustion which is seen as reduced brake thermal efficiency.
- The ignition delay first increased and the decreased with increase in EGR rate. The combustion duration increased owing to the deterioration in combustion quality. In order to obtain the rated power, the engine consumed more fuel as the load on engine increased.
- The NOx emissions are lower for all EGR rates as the in-cylinder combustion temperature lower as compared to diesel without EGR. As the recirculated gases contain more amount of high heat capacity gases such as CO2 and H2O, reduced the peak combustion temperature owing to the heat absorption by these gases.
- The dilution of charge in the combustion chamber lowered the local oxygen concentration which is seen as increased CO emission. At smaller EGR rate, the temperature of recirculated exhaust gases is high which promotes the atomization of diesel fuel benefitting the combustion and reduction in HC emission.

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