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Research Paper

PERFORMANCE INVESTIGATIONS OF EGR IN CI ENGINES USING BIODIESEL

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Fossil fuels are limited in nature. The increase in the fuel consumption rate creates the future need for alternate fuels. This paper aims at usage of the biodiesel as a fuel along with standard fuel The characteristics of performance, combustion and emissions of the diesel engine are investigated for the mixture The results of engine characteristics with biodiesel were compared with standard baseline petroleum diesel. During the combustion of the fuel in any engine, when the peak temperatures are high enough for long periods of time, the nitrogen and oxygen combined to form the nitrogen oxides, referred to as NOx. These compounds are one of the chief constituents of smog, which have an adverse effect on ecological systems. NOx emissions can be reduced by lowering the cylinder temperatures This is possible by recirculating some percentage of exhaust gas and mixing it into the engine inlet air. This process is known as Exhaust Gas Recirculation (EGR). The EGR valve recirculates gases into the intake stream. These gases displace some of the normal intake charge. This chemically slows and cools the combustion process by several hundred degrees thus reducing NOx formation. This paper studies the effect of EGR on various characterstics, when the Biofuel mixed with standard fuel is used in diesel engines.

Keywords: Bio diesel, EGR, Emissions, Efficiency

INTRODUCTION

Fossil fuels currently meet 80% of global energy demand. Even if current policy commitments and pledges made by countries to tackle climate change and other energy-related challenges were to be put in place, global energy demand in 2035 is projected to rise by 40%-with fossil fuels still contributing 75%. Demand over the coming decades will stem mainly from energy needs of emerging markets such as China and India. The use of coal, gas and oil to fuel the power, industry, buildings and transport sectors is set to rise. Although environmental concerns have led to a significant increase in lower-carbon options, these are not yet deployed widely enough to meet current or future demand for energy.

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Fossil are still classified as resources and not yet as reserves. This distinction is important as it reflects the likelihood that the fossil fuels will be brought to the market. Resources are those volumes that have yet to be fully characterized, or that present technical difficulties or are costly to extract, for example where technologies that permit their extraction in an environmentally sound and cost-effective manner are still to be developed.

A quick summary of known hydrocarbon reserves and resources demonstrates the potential supply:

Proven reserves of conventional oil are estimated to be around 1.3 trillion barrels, with remaining recoverable oil resources representing about 2.7 trillion barrels. The global reserves-to-production ratio, based on current consumption levels, is in the range of 40 to 45 years. As resources are successfully converted into reserves, this period will be extended.

Reserves of unconventional oil are around 400 billion barrels (bb), with estimated recoverable resources of 3.2 trillion barrels.

Reserves of conventional gas are estimated at around 220 trillion cubic meters (tcm)-the equivalent of around 1.4 trillion barrels of oil-with remaining recoverable resources of 460 tcm. Reserves of unconventional gas, because of the heterogeneity of the rock formations, are very difficult to assess. Remaining recoverable resources (excluding methane hydrates) are estimated at 330 tcm.

Exhaust Gas Recirculation

The first EGR systems was as simple as an orifice jet between the exhaust and intake tracts which admitted exhaust to the intake tract whenever the engine was running. Difficult starting, rough idling, and reduced performance and fuel economy resulted. By 1973, an EGR valve controlled by manifold vacuum opened or closed to admit exhaust to the intake tract only under certain conditions.

EGR in Spark-Ignited Engines

A part of exhaust gases which is added to the fuel and oxygen increases the specific heat capacity of the cylinder contents, which lowers the adiabatic flame temperature. These are the advantges of EGR in SI engines

- Reduced throttling losses.
- Reduced heat rejection.
- Reduced chemical dissociation.
- Reduced specific heat ratio..

But, EGR is not employed at high loads as it would reduce peak power output due to reduce in the intake charge density. EGR is also omitted at idle (low-speed, zero load) because it would cause unstable combustion, resulting in rough idle. The EGR valve also cools the exhaust valves and makes them last far longer

EGR in Diesel Engines

Exhaust gas-largely carbon dioxide and water vapor—has a higher specific heat than air, can serve to lower peak combustion temperatures. However, adding EGR to a diesel reduces the specific heat ratio of the combustion gases in the power stroke. This reduces the amount of power that can be extracted by the piston. EGR also tends to reduce the amount of fuel burned in the power stroke. This is evident by the increase in particulate emissions that corresponds to an increase in EGR.Particulate matter (mainly carbon) that is not burned in the power stroke is wasted energy stricter regulations on Particulate Matter (PM) call for further emission controls to be introduced to compensate for the PM emissions introduced by EGR.

LITERATURE REVIEW

Gurumoorthy *et al.* (2013) in their study, they addressed about the application of EGR for reduced NOx emissions from naturally aspirated direct injection stationary diesel engine. EGR is an attractive method to reduce combustion temperature. EGR temperature is an important factor while admitting higher percentage of EGR. As High temperature EGR, obtained due to increase in loads, limits the conduct of higher EGR ratios. Cooling of EGR can be done when higher ratios of EGR need to be admitted. The effect EGR temperature on NOx reductions and thermal efficiency were found to be better for hot EGR up to about 30% EGR and thereafter EGR cooling shows better results. Mukesh *et al.* (2012) conducted an experimental study on a naturally aspirated 4 cylinders, 4 stroke diesel engine with modification to run with EGR. Engine performance and emission was tested at varying EGR Rate (0-40%) and optimum EGR Rate for the naturally aspirated engine is found out by taking the performance and emission readings at varying load conditions (0-120%) and at 1500 RPM. Brake power was measured with electric dynamometer. The evaluation of experimental data showed that NOx emission was reduced by about 80% because of EGR.

Avinash Kumar *et al.* (2003) conducted an experimental study on a INDEC Engines Ltd make two cylinder, direct injection, rated capacity 9.3 kW at speed 1500 rpm, air-cooled diesel engine. The objective is to investigate and demonstrate the effects of various EGR rates on exhaust emissions from the engine. A long route partially cooled EGR system was choosen. Experiments were carried out by using a setup to prove the efficiency of EGR as a technique for NOx reduction. It is seen that the exhaust gas temperatures are reduce drastically by employing EGR.

Hussain *et al.* (2012) conducted an experimental study on a two cylinder 4 Stroke, 52 HP, 1500 rpm constant speed diesel engine generator set to study the effect of EGR on the performance and emissions of diesel engine components. The results were shown that UHC can be reduced by 20 to 25% from this method.

Manieniyan *et al.* (2013) used EGR technique in the diesel engine with B20 biodiesel as fuel. Madhua oil is used to prepare the biodiesel for investigation of a four stroke, water cooled, single cylinder, Direct-Injection (DI), vertical diesel engine running at a rated power of 5.2 kW and at a rated speed of 1500 rpm coupled to an Eddy current dynamometer with EGR and without EGR at various level (5%, 10%, 15%, and 20%). The result shows that NOx emission is reduced using EGR for diesel and bio diesel.

Murthy et al. (2011) conducted an experimental study on a Kirloskar Oil Engines with naturally aspirated single cylinder 3.7 kW at 1500 rpm, water cooled diesel engine with D.C shunt dynamometer is selected for experimentation. Modifications are made for the original engine set up to work with option EGR. They found that effect of EGR is to increase the fuel consumption of the engine; EGR is the best method to reduce the NOx emission.

Brusca *et al.* (2014) studied on the possibility to run a spark ignition engine on acetylene and alcohol. Test engine was single cylinder, four stroke and modified with electronic injection control system and two standard injectors. They observed that engine performance decreased about 25% with acetylene and alcohol in comparison gasoline. Acetylene and alcohol brake specific fuel consumption is lower than gasoline in almost all engine speed. They stated that exhaust emissions CO, HC and NOx decreased using acetylene and alcohol fuel in comparison gasoline

BIO DIESEL PREPARATION

Biodiesel is a renewable, biodegradable and nontoxic fuel for diesel engines. As alternative fuel biodiesel has attracted considerable attention during the past decades. Various possible bio diesels that could be effectively used as alternatives to diesel. The parameters that were considered for the selection of the oil are density, viscosity, calorific value, flash point, fire point, pour point etc. The bio fuels that were considered for the study are:

1. Dimethyl ether
2. Fischer trope diesel
3. Mustard oil
4. Castor oil
5. Cashew nut oil (shell)
6. Vegetable oil

Bio Diesel from Waste Cooking Oil

The main hurdle to the commercialization of biodiesel is the cost of raw materials. The biodiesel used for the present work is prepared through the following procedure.

1. First stage (Acid catalyzed transesterification);
2. Second stage (Base catalyzed transesterification);
3. Final stage (Base catalyzed transesterification).

Fuel Properties

According to ASTM biodiesel Standards (Reference A.B.M.S. HOSSAIN). Fuel characteristics of biodiesel as given in Table.

Table: Properties of Biodiesel

Property	Units	Standard method	Standard value	Biodiesel (WCME)
Viscosity	mm^2/s at 40°C	ASTMD 6751	1.9–6.0	9.5
density	Kg/m^3	ASTMD 6751	0.87	0.68
Group I metals(Na+K)	mg/kg	EN 14214	5.0 max	2.8
Group II metals(Ca+ Mg)	mg/kg	EN 14214	5.0 max	2.6
Phosphorus content	mg/kg	EN 14214	10.0 max	3.1
Acid number	mgKOH/g oil	ASTMD 6751	0.50 max	0.44

Figure 1: (a) Pure Waste Cooking Oil, (b) Biodiesel After the Final Wash

(a)

Figure 1 (Cont.)

(b)

EXPERMINENTAL SETUP AND PROCEDURE

The experimental setup of test rigi with Single cylinder Diesel engine four strokes, water-cooqled diesel engine coupled to eddy current dynamometer, engine analysis software. The setup entirely mounted on a centrally balanced base frame made of ms channels the help of flexible rubber couplings as shoiwn in Figure 2.

Engine Description

The following are the test rig specifications.

ENGINE: 4 stroke 1 cylinder water cooled diesel Engine Make: kirloskar

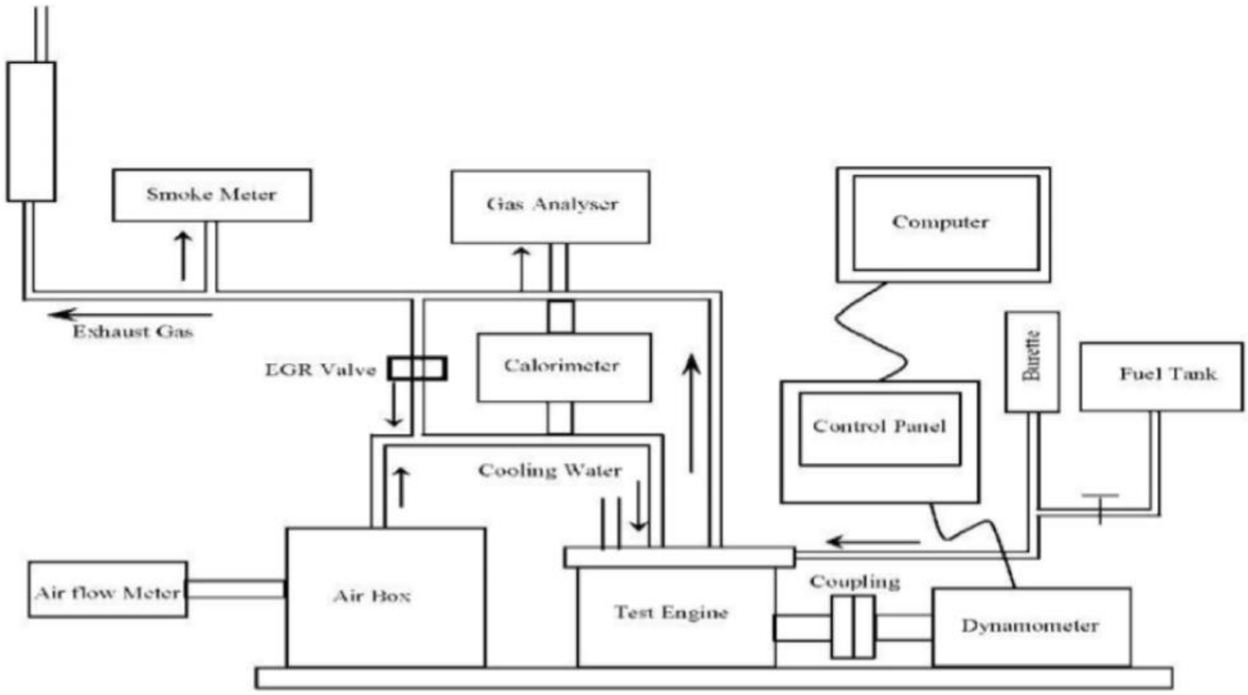
Rated power: 5 HP

Bore dia: 80 mm

Stroke length: 110 mm

Compression ratio: 16.5:1

Figure 2: Experimental Set Up



Rated speed: 1500 rpm

Dynamometer: eddy current dynamometer.

Sensors provided with transmitters for combustion pressure and crank angle measurements. All these signals are interfaced to computer through signal conditioner and signal converter for computerization.

Exhaust Gas Recirculation Setup

The EGR setup consists of The exhaust gases are tapped from exhaust pipe and connected to an inlet airflow passage. A system is devised consisting of a control valve and a manometer set up to control the rate of EGR by manually operating the control valve as shown in Figure 3.

For experimentation the engine is run at a rated speed of 1500 rpm. Then the engine is loaded in terms of 0%, 25%, 50%, 75% and 100%. At each load, the engine is run at a constant speed with different EGR with various blends of biofuel. The exhaust gases are tapped from exhaust pipe and connected to an inlet airflow passage. After attaining the steady state, the observations are made for various parameters such as exhaust gas temperature, airflow rate, fuel consumption, brake specific fuel consumption, combustion characteristics like pressure rise which are recorded through the data acquisition system which converts analog to digital at various loads. Exhaust emissions CO, HC and NOx are recorded simultaneously by the flue gas analyzer. At each load the experiment is conducted by varying EGR rates such as 0%, 5%, 10% and 15%. The first stage of the experiment is performed.

Figure 3: EGR in Single Cylinder Diesel Engine

The performance anlaysis done various blended fuels for Break power, Specific fuel consumption, Volumetric efficiency, Indicated power, Indicated thermal efficiency, Mechanical efficiency. A heat balance is prepared for the experiments.The combustion analysis is done for crak angle, heat release and burnt mass fraction.

RESULTS AND DISCUSSION

In this experiment performance parameters such as specific fuel consumption and brake thermal efficiency, were determined, combustion parameter cylinder pressure, heat release rate were determined, and emissions such as oxides of nitrogen, carbon monoxide, hydrocarbon, smoke density and exhaust gas temperature were measured.

With increase in EGR levels, CO emissions also increase for biodiesel. In Full load condition HC emission was measured as 18 ppm in diesel and 19 ppm in biodiesel without EGR. At the same full load condition with higher EGR level HC emission varies from 22 to 25 ppm in diesel and 22 to 26 ppm in bio diesel. This is due to richer mixture at full load and oxygen deficiency might have dominated as EGR was applied.

CO_2 emissions are decreased diesel as fuel at 0% EGR about 6 ppm. The reduction of CO_2 emissions are 5 ppm with B10 fuel with 5% EGR rate, which are the lowest. O_2 was reduces with increasing with EGR rates. In diesel O_2 emissions are around 12 ppm without EGR. Maximum reduction in O_2 levels observed at B10 fuel at 15% EGR rate is 11 ppm.

NOx value was found to be 1700 ppm for diesel and 1000 ppm for biodiesel without EGR at full load condition. This was due to peak combustion temperature inside the cylinder. With increases in EGR level, the NOx value gets reduced. With 15% EGR, NOx levels were 1700 ppm for diesel and 1000 ppm for biodiesel. With increase in EGR level, NOx level was reduced. Also reduction in brake thermal efficiency and large increase in smoke density were observed.

Brake thermal efficiency with and without EGR was found to be comparable for diesel and bio diesel. Full load brake thermal efficiency of 41% was obtained for diesel without EGR whereas it was 38.8% using biodiesel without EGR. Brake thermal efficiency of 15% EGR was maximum for full load when compared. with diesel and biodiesel. IMEP with diesel is 18.85 at 0% EGR rates.

It was observed that with increase in EGR rate, exhaust gas temperature also increases. Exhaust gas temperature was higher in biodiesel compare with diesel at full load condition. The possible reason for this temperature increased may be relatively higher availability of oxygen in biodiesel for combustion.

Cylinder pressure at full load and without EGR condition was found to be comparable for diesel and bio-diesel. Peak pressure was found to be 69.392 bars for diesel and 68.252 bars for bio-diesel under these conditions. This is because the EGR serves as a heat absorbing agent, which reduces the cylinder charge temperature in the combustion chamber during the combustion process.

At full load condition heat release rate was 65 J/°CA for diesel and 63.331 J/°CA for biodiesel with EGR. There is a reduction in peak heat release rate for EGR operation. Decrease in heat release rate is indicative of incomplete combustion due to presence of less oxygen content when using EGR. The Combustion process was generally done in between the crank angle 360°-400°.

CONCLUSION

In this experimental investigation on single cylinder diesel engine, the performance and emission characteristics of bio diesel blends with exhaust gas recirculation were investigated. The following conclusions are made on the basis of experimental results.

- Lower SFC was found in 10% EGR with diesel and 15% EGR with B10 fuel.
- Brake thermal efficiency of biodiesel was found to be comparable with diesel, at all EGR rates and highest BTE is found maximum with diesel at lower EGR, whereas the blends will give slightly lower at higher EGR.
- The EGR level was increased HC emission also increased for biodiesel. This was due to oxygen content in biodiesel compensating for oxygen deficiency and facilitating complete combustion.
- With increases in EGR level, the NOx value gets reduced for both diesel and biodiesel blends.
- CO emissions slightly increases due to oxygen deficient operation in EGR, but still at low level compared to diesel operation without EGR.

- Brake Mean Effective Pressure (BMEP) and Indicated Mean Effective Pressure (IMEP) increases with increasing the rates of EGR with diesel and biodiesel.
- Fuel Consumption is constant at all EGR levels for diesel and biodiesel.
- Analysis of combustion parameters have also indicated comparable heat release rates cylinder pressures, and with and without EGR at different blends of diesel.

Thus the present experimental analysis on a single cylinder diesel engine with diesel biodiesel blend has minimized pollution and improved performance. EGR technique is used for reduction of NOx concentration.

Measurement errors and uncertainties are arisen from devices used to measure the data of the experiment. Total Percentage uncertainty of the experiment has been calculated as 6.2%.

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