Effect of EGR Rates on NOx and Smoke Emission of LHRE Diesel Engine Fuelled with Blends of Diesel and Neem Biodiesel -A Review

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Abstract— For the developing country like India dependent on imports of fossil fuels, there is a huge crisis in the making. The real sustainable solution for India lies in a well-planned transition to alternative sources of energy. Among the proposed alternative fuels, biodiesel have received much attention in recent years for diesel engines and could be one remedy in many countries to reduce their oil imports. An attempt has been made to study the performance of twin cylinder water-cooled diesel engine using Neem oil as the fuel was evaluated for its performance of exhaust emissions. For the present study the biodiesel was prepared in laboratory from non-edible vegetable oil (Neem oil) by transesterification process with methanol, where potassium hydroxide (KOH) was used as a catalyst. The stationary diesel engine was run in laboratory at a medium speed, variable load condition experienced in most urban driving conditions and various measurements like fuel flow, exhaust temperature, exhaust emission measurement and exhaust smoke test were carried out. The results indicate improved fuel economy and reduced pollution levels. During performance test it showed reasonable efficiencies, lower smoke, SO2, PM (particulate matter) and CO with some increase in emission of oxides of nitrogen (NOx). Exhaust gas recirculation (EGR) is one of the techniques being used to reduce NOX emission from diesel engines; because it decreases both flame temperature and oxygen concentration in the combustion chamber.

Key words**:** LHRE, EGR, Blending, Bio-diesel

I. INTRODUCTION

Internal combustion engines, which form an essential part of the transportation as well as mechanized agricultural system, have been badly affected by the twin crisis. Diesel engines are used in wide range because their advantages such as greater efficiency, durability, and good fuel economy compared to gasoline engines. The applications of diesel engines are in electric power generation, agricultural, construction, industrial fields, and transportation sector. These wide uses of diesel engines lead to increase the requirement for petroleum derived from fossil fuel. The depletion of fossil fuel and the impact of increasing environmental pollution from exhaust gas emissions have led the search for alternative fuels. From the point of view of protecting global environment and concerns for long-term energy security, it becomes necessary to develop alternative fuels with properties comparable to petroleum based fuels. Unlike the rest of the world, India's demand for diesel fuels is roughly six times that of gasoline, hence seeking alternative to mineral diesel is a natural choice. The rapid depletion of petroleum reserves and rising oil prices has led to the search for alternative fuels. Non edible oils are promising fuels for agricultural applications. Vegetable oils have properties comparable to diesel and can be used to run CI engines with little or no modifications. Usage of biodiesel will allow a balance to be sought between agriculture, economic development and the environment.

A. Neem biodiesel:

Neem Tree, a multipurpose plant, contains high amount of oil in its seeds which can be converted to biodiesel. Neem tree is probably the most highly promoted oilseed crop at present in the world. Neem seed oil has about 72% unsaturated fatty acids. The viscosity of Neem oil is considerably lower than soybean, cottonseed, and sunflower and Cetane number of Neem biodiesel is higher than other biodiesel. So, pointing to its suitability for use as diesel fuel.

The proximate analysis of Neemseeds revealed that the percentage of crude protein, crude fat and moisture were 24.60, 47.25 and 5.54% respectively.[9] The seeds can be transported without deterioration and at low cost due to its high specific weight. The seeds of the Neemcontain 30 - 40% oil that can be easily expressed for processing (transesterification) and refinement to produce biodiesel[9]. *Neem* tree gives higher oil yield per hectare than peanuts, sunflower, soya, maize or cotton when grown under optimum conditions. The processed oil can be used directly in diesel engines after minor modifications or after blending with conventional diesel. The byproducts of the biodiesel processing plant are nitrogen-rich press cake and glycerol, which are said to have good commercial value as fertiliser and as a base for soap and cosmetics, respectively [9].

Biodiesel produced from Neem has advantages compared to conventional diesel fuel (DF).

(1) NBD molecules are simple hydrocarbon chains, containing no sulphur, or aromatic substances associated with fossil fuels.
(2) The presence of oxygen in the structure of NBD reduces emission of particulate matter (PM), hydrocarbon (HC) and carbon monoxide (CO), as compared to DF.
(3) It is much safer than DF, because of its higher flash point and fire point, or ignition temperature compared to DF.
(4) It has excellent lubricity; extending diesel engine life.
It has bulk modulus higher than that of DF. Bulk modulus results in advance of injection timing in biodiesel fuelled engine. The higher bulk modulus of NBD leads to a more rapid transfer of pressure waves from fuel pump to lift the needle of the injector much earlier. This advance results in more fuel accumulation before the start of combustion and leading to higher peak temperature and pressure in the premixed phase and subsequently higher nitrogen oxides (NO_X) emission.
(5) Boiling point of NBD is higher than that of DF. Because of higher boiling point, NBD maintains its liquid phase for an increased duration, facilitating more droplet penetration into the combustion

chamber. This feature can lead to increase the fuel consumption, peak temperature and higher NOX emission.

Although NBD has many advantages, but it still has several disadvantages, one of them is higher NOx emission compared to DF. The higher NOX emission is a common disadvantage of most biodiesel oils. Previous researches achieved reduction in NOX using exhaust gas recirculation (EGR) technique with different biodiesel oils.

B. Processing Techniques:

Natural vegetable oils and animal fats are pressed to obtain crude oil which contains free fatty acids, phospholipids, sterols, water, odorants and other impurities.[9] Because of these compounds, high viscosity, low volatility and the polyunsaturated character of the vegetable oils, they cannot be used as fuel directly in compression engines.[9] To overcome the problems highlighted above of using the vegetable oils directly, the oils require chemical modification so that they can match the properties of fossil diesel.

The processing techniques that are mainly used to convert vegetable oils including Neemoil into fuel form are direct use and blending, pyrolysis, micro-emulsification and transesterification.

C. Low Heat Rejection Engine (LHRE):

The overall energy use by vehicles depends on two factors, vehicle load and power train efficiency. The former depends on speed and acceleration and key vehicle characteristics such as mass. The latter depends on heat-engine thermodynamic efficiency, and engine and transmission frictions.

Energy conservation and efficiency have been the quest of engineers concerned with internal combustion engines. The diesel engine generally offers about two thirds of the heat energy of the fuel, one-third to the coolant, and one-third to exhaust, leaving only about one third as useful power output. Theoretically, if the heat rejected could be reduced, then the thermal efficiency would be improved, at least up to the limit set by the second law of thermodynamics. Low Heat Rejection engines aim to do this by reducing the heat lost to the coolant.

The diesel engine with its combustion chamber walls insulated by ceramics is referred to as Low Heat Rejection (LHR) engine. The LHR engine has been conceived basically to improve fuel economy by eliminating the conventional cooling system and converting part of the increased exhaust energy into shaft work using the turbocharged system. A large number of studies on performance, structure and durability of the LHR engine have been carried out. In low heat rejection engine reduced heat transfer, improves thermal efficiency, and increases energy availability in the exhaust.

An adiabatic engine is one type of adiabatic engine. An adiabatic engine is a system where, Q=0 when the system is working. Generally, it is difficult to have adiabatic engine in practice. However, an adiabatic engine has no conventional cooling and strives to minimize heat loss. The adiabatic engine combustion chamber is made of material which allows the operation of the engine combustion with minimum heat loss.

1) Engine Coatings:

There are three main types of coatings, and their names are self-explanatory. Thermal-barrier coatings hold heat in, heat-dissipating coatings let heat out, and low-friction coatings remove power-robbing and heat-inducing friction.

The most commonly used TBC is a ceramic-based material that’s applied to the top of the piston and to the combustion chamber and valve faces in the cylinder head. The TBC holds more heat in the chamber, instead of letting it dissipate through the piston, valves and head (where it is then absorbed by the cooling system). The TBC also protects the aluminum piston from the intense heat, so the air/fuel mixture can be leaned slightly for maximum power without burning through the piston. And, since the amount of heat radiated into the rest of the engine is reduced. This is also beneficial to the piston rings, improving their radial tension and sealing ability. TBCs are also used on intake and exhaust ports and headers to improve scavenging and lower the under hood temperature. They are also used on the underside of an intake manifold to keep hot oil from elevating the intake charge temperature.

D. Exhaust Gas Recirculation (EGR):

Diesel engines naturally benefit from high thermal efficiencies as a consequence of lean combustion and rather high compression ratio. Their high compression ratio can provide appropriate conditions required for auto-ignition. High flame temperature is a predominant issue in diesel engines which originates from the non-homogeneous nature of diesel combustion caused by locally stoichiometric air to fuel ratios. As a consequence of high temperature of diesel combustion and use of jetropha biodiesel available oxygen and nitrogen from inlet combine and form nitrogen oxides like Nitric Oxide (NO) and Nitrogen dioxide (NO_2) which are categorized as NOx emissions. Also abundant oxygen presented during diesel combustion greatly contributes to the NOx formation.

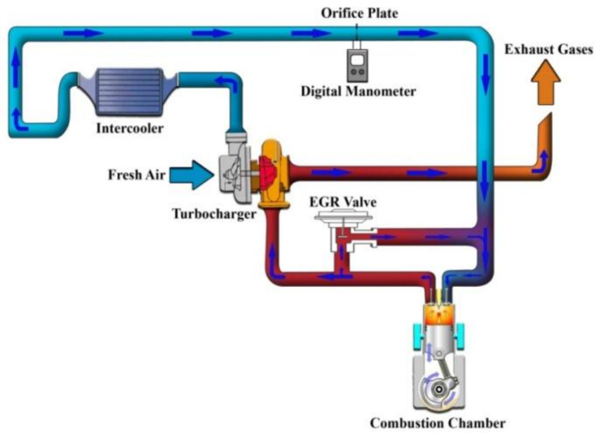

Fig. 1: Egr System

In the last decades, reduction of soot and NOx emissions from diesel engines was extensively perused by the researchers and also new stricter emission control policies like EURO-V highlight the importance of NOx and soot emission level control. In order to meet future emission regulations, use of high EGR is known as an efficient method. Increasing the EGR ratio can change the shape of heat release rate during premixed combustion which can greatly suppress NOx formation.

EGR influences diesel engine combustion in three different ways: thermal, chemical and dilution. The thermal effect is related to the increase of inlet charge temperature that affects volumetric efficiency (thermal throttling) and the increase of charge specific heat capacity due to the presence of CO_2 and H_2O. On the other hand the chemical effect is related to the dissociation of species during combustion, while dilution is related to the reduction of O_2 availability.

While EGR is effective in reducing NOx, it also has adverse effects on the engine efficiency and may cause pollution of lubricating oil and corrosion of inlet manifold and moving parts as exhaust gas contains a lot of particulate matter.

It also increase the specific fuel consumption and decreased heat transfer from cylinder contents to the surrounding surface. The application of the EGR also adversely the lubricating oil quality and engine durability. The quantity of EGR is limited to a point beyond which the combustion temperature and the flame speed are low enough to prevent successful engine operation. And found in some case that as the carbon dioxide level are increased. The combustion noise level also increase at certain engine speeds.

II. LITERATURE REVIEW

Baitiang et al. study the effects of neat biodiesel (B100) and pure jetropha oil on engine performance, black smoke density, fuel consumption and durability of engines. Two 14-horse power, single cylinder diesel engines were dedicated for the experiment using those fuels. From the performance test, when comparing BDF and jetropha oil with diesel, the engine performances were slightly different with a small increase of fuel consumption. It is noticeable that black smoke measured from the engines using both biodiesel and jetropha oil can be hugely reduced. However, in the case of field test when each engine was connected to power water pumps in order to determine the long term effects, the engine that was fueled with jetropha oil presented some problems. The injector and fuel filter were clogged enough to cause engine malfunction. The parts were then replaced and petroleum diesel fuel was added at an increment of 20% in the blended fuel to reduce the concentration of jetropha oil until the engine could run continuously again. It was found that the highest amount of jetropha oil could be used was a blend between jetropha oil and diesel fuel of 60:40 by volume for practical running time before failure.

The engine performance fueled with Jetropha blend and biodiesel is not much different from that with petroleum diesel, with slightly inferior fuel consumption and significantly improved black smoke.

Significant reduction in black smoke is observed for engine running on biodiesel while slightly higher black smoke at high speed is observed for engine running on Jetropha oil blends. The injector and fuel filter were clogged. [1]

G.H.Abd-Alla et al. conducted investigation on a high speed indirect injection (richardo-E6) dual fuel engine and was concerned with the effect of exhaust gas recirculation (EGR) on the dual fuel engine combustion and emission, in particular effect of intake air temp. and diluent admission. This study is shows "effect of intake air temp. And diluents admission on the performance and emission of engine.
From this study it is found that

(1) The introduction of CO_2 in the inlet charge resulted in reduction in NOx and an increase in the unburned hydrocarbons.
(2) Increase the inlet charge temp. Resulted in an increase in NOx and a reduction in unburned hydrocarbons emission.
(3) Increasing the inlet charge temp. Resulted in improved combustion characteristics due to reduction in ignition delay. Therefore, brake horse power and thermal efficiency were increased, and carbon monoxide and unburned hydrocarbons emissions were decreased.[2]

M. K. Duraisamy shows that biodiesel-fueled engines produce less carbon monoxide, unburned hydrocarbon, and smoke emissions compared to diesel fuel but higher NOx emissions. Exhaust gas recirculation (EGR) is effective to reduce NOx from diesel engines because it lowers the flame temperature and the oxygen concentration in the combustion chamber. The objective of this work is to investigate the usage of biodiesel from Jetropha Seed Oil and EGR simultaneously in order to reduce the emissions of all regulated pollutants from diesel engine. A fully automated single-cylinder, water-cooled, constant speed direct injection diesel engine was used for experiments. HC, NOx, CO, and smoke of the exhaust gas were measured to estimate the emissions. Various engine performance parameters such as thermal efficiency, and brake specific fuel consumption were calculated from the acquired data. Application of EGR with biodiesel blends resulted in reductions in NOx emissions without any significant penalty in smoke emissions.

Based on the exhaustive engine tests, it can be concluded that Biodiesel and EGR both can be employed together in CI engines to obtain simultaneous reduction of NOx and smoke. Other emissions such as HC and CO are also found to have decreased. 15% EGR is found to be optimum, which improves the thermal efficiency, reduces the exhaust emissions and the BSFC. Biodiesel is an oxygenated fuel and it undergoes improved combustion in the engine due to the presence of molecular oxygen which also leads to higher NOx emissions. This higher NOx emission can be effectively controlled by employing EGR. EGR increases the HC and CO emissions. Also, higher BSFC and particulate emissions were observed.[3]

Alain Maiboom et al has been conducted experimental study on a HSDI automotive diesel engine under low-load and part load conditions.

In this study, ROHR (rate of heat release) is unchanged and AFR (air fuel ratio) is also maintained, then changing in inlet temperature and EGR rate this experiment is conducted and data will be taken. This paper shows "effect of different EGR rates and inlet temperature on the engine performance and emission.

Based on the exhaustive engine tests, it shows that the increase of inlet temperature at constant EGR rate, NOx emissions is reduced with increased inlet temperature. At low-load conditions, very low NOx and PM emissions can be obtained with high EGR rates, because the combustion is delayed due to the high dilution. This is accompanied with an increase of BSFC (that can be higher that 10%) and CO and hydrocarbon emissions.EGR at constant AFR is a way to drastically reduce NOx emissions without important penalty on BSFC and soot emissions.[4]

H.E. Saleh used jojoba methyl ester in two-cylinder, naturally aspirated, four-stroke direct injection diesel engine.The tests were made in two sections. First, the measured performance and exhaust emissions of the diesel engine operating with diesel fuel and JME are determined and compared. Second, tests were performed at two speeds and loads to investigate the EGR effect on engine performance and exhaust emissions including nitrogenous oxides (NOx), carbon monoxide (CO), unburned hydrocarbons (HC) and exhaust gas temperatures. Third, effect of cooled EGR with high ratio at full load on engine performance and emissions was examined.

From this experimental work he was found that the NOx emissions decreased with increasing the EGR rate. Also, at all engine speeds and loads, the JME produced a higher CO and HC emissions when the EGR rate is increased.Using high levels of EGR (in excess of 40%) at low load condition, reduced NOx emissions of 50% with increase in BSFC of 5%.[5]

Ekrem buyukkaya and muhammet cerit studied onlow heat rejection (LHR)turbocharged direct injection diesel engine.This study shows “effect of injection timing on brake specific fuel consumption (BSFC) and NO*x* emissions.

The brake specific fuel consumption values of the LHR engine were found to be approximately 6% lower than the original engine at especially medium speeds.For 18˚ BTDC of injection timing, fuel consumption was decreased about 8%.

NOx emissions was decreased by 21%, when original injection timing was retarded by 2˚ BTDC for the LHR engine [6].

Modi A.J. and Gosai D.C. used Multi cylinder vertical, water cooled, self-governed diesel engine for their study. Piston top surface, cylinder head and liners were fully coated with Partially Stabilized Zirconia (PSZ).The engine was run at a constant medium speed variable load condition. The SFC was 5-10% lower than that is in the base engine.The mechanical efficiency of the TBC engine is found to be 10-16% higher than the base engine.The brake thermal efficiency of the TBC engine is found to be 10-15% higher than the base engine.The smoke emission from the TBC engine was 45.74% lower than that in the base engine[7].

Modi A.J. and Gosai D.C. carried out experimental investigation of the performance of a ceramic coated engine was carried out with palm bio-diesels and its blends, the results were compared to the experiment done with the conventional petroleum diesel. In this study Multi cylinder vertical water cooled self-governed diesel engine used in which piston, top surface of cylinder head and liners were fully coated with Partially Stabilized Zirconia (PSZ).

Results indicated that Bio-diesels had lower brake thermal efficiency mainly due to its high viscosity compared to diesel .The use of palm biodiesel resulted in lower emissions of unburned hydrocarbons, carbon monoxide, and particulate matter, with some increase in emissions of oxides of nitrogen. The results indicate improved fuel economy and reduced pollution levels for the Thermal Barrier Coated (TBC) engine [8].

Kevadia P. J. and Modi A.J. carried out experimental investigation of the performance of a TBC diesel engine for investigation of effect of EGR technique using Jetropha biodiesel. Results indicate that Jetropha biodiesel blends produced higher brake thermal efficiency (BTE) than that of pure diesel, at all operating conditions. As increased in EGR %, BTE is reduced for both biodiesel-diesel blends. Also derived that NOx emission decreased with increase EGR rates, CO and CO_2 and smoke opacity emission increased with increasing EGR [9, 10].

III. CONCLUSION

From the literature survey it is concluded that with increase in biodiesel content emission of oxide of nitrogen increased. 100% biodiesel gives more NOx emission compared to other blends. In this case 100% petroleum fuel gives lower NOx emission. Biodiesel also increase efficiency in reducing efficiency of engine. It also shows reduction in CO, SO_2, CO_2 in emission.

The purpose of this study is to study the effect of EGR rates on NOx and smoke emission on thermal barrier coated diesel engine fueled with blends of diesel and Neem biodiesel.

For experimentation multi cylinder vertical water cooled self governing diesel engine piston, top surface of cylinder head, valves and liners are fully coated with partially stabilised Zirconia in form of ZrO_2 as ceramic material attending adiabatic condition. Previous studies have reported that combustion of Neem biodiesel emitted higher NOx, while hydrocarbon and smoke emission were lower than conventional diesel fuel. Exhaust gas recirculation (EGR) is one of the techniques being used to reduce NOx emission from diesel engine; because it decreases both flame temperature and oxygen concentration in the combustion chamber.

For the present study the biodiesel was prepared in laboratory from non-edible vegetable oil (Neem oil) by transesterificationprocess with methanol, where potassium hydroxide (KOH) was used as a catalyst.

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