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EFFECT OF ENGINE MODIFICATIONS ON PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINES WITH ALTERNATIVE FUELS

K.Venkateswarlu
Department of Mechanical engineering,
K.L University, GreenFields,Vaddeswaram,Guntur(Dist). AndhraPradesh,India.
Pincode: 522 502, E-mail: chaitu9903@yahoo.co.in
B.S.R Murthy
Madhira Institute of technology & Science, Kodad, Nalgonda(dist)
Andhra pradesh-India, E-mail: bsrm54@gmail.com

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Abstract

Performance and emission characteristics unmodified diesel engines operating on different alternative fuels with smaller blend proportions are comparable with pure diesel operation. But with increased blend proportions due to the associated problems of vegetable oils like high viscosity and low volatility pollution levels increase which however is accompanied by operating and durability problems with the long term usage of engine. This paper discusses the necessary modifications required to overcome the problems associated with unmodified diesel engines like Low heat rejection (LHR),dual fuel mode of operation, Turbocharged engines and EGR engines (exhaust gas recirculation) with different alternative fuels . The energy of the biodiesel can be released more efficiently with the concept of low heat rejection (LHR) engine. LHR engine can be used for improving engine performance when biodiesel is used as an alternative fuel. Low heat rejection engines with vegetable oils may give better performance and lower smoke emissions. Exhaust emissions (NOx and smoke) were improved in dual fuel operation. If direct injection diesel engine is modified to operate with dual fuel operation a reduction of exhaust emissions from diesel engines were investigated.

Keywords: Compression ignition, Alternate fuels, Exhaust emissions**,** Low heat rejection, performance.

1. Introduction

Compression ignition (CI) or diesel engines are widely used for transportation, automotive, agricultural applications and industrial sectors because of their high fuel conversion efficiencies and easy operation. The existing CI engines operate with conventional diesel fuel derived from crude oil. It is well known that the world petroleum resources are limited and the production of crude oil is becoming more difficult and expensive. On the other hand, the pollutants including unburned hydrocarbons (UHCs), carbon monoxide (CO), nitrogen oxides (NOx) and smoke opacity emissions have been regulated by the laws in many countries. A naturally aspirated diesel engine wastes a high proportion of heat energy released in the cylinder by exhausting to the ambient. Some of the wasted heat energy in the exhaust gas can be recovered by a turbocharger and converted to useful work. In fact, the turbocharger is widely employed in current diesel engines. The turbine of a turbocharger is driven by the energy available in the exhaust gas and its compressor, which is connected to turbine with a shaft, increases the pressure of the air supplied to the engine. This leads to more incoming air in the cylinder and also increases the temperature of the air.

2. Performance and Emission Characteristics of Diesel Engines with Alternate Fuels

Crude-Jatropha oil, a non-edible vegetable oil shows a greater potential for replacing Conventional diesel fuel quite effectively, as its properties are compatible to that of diesel fuel P.V. Krishna Murthy et al.[1]. But low volatility and high viscosity of jatropha oil call for low heat rejection (LHR) diesel engine, which is constructed with the provision of air gap of 3-mm in the threaded piston and in the liner, with superni-90 (a low thermal conductivity nickel allow material) inserts, and ceramic coating (500µ) on inside surface of cylinder head. Pollution levels decreased with insulated engine with vegetable oil in comparison with conventional engine with pure diesel operation. High degree of insulation in LHR engine decreased smoke levels with vegetable oil operation. Increase of injection pressure decrease of smoke levels with vegetable oil operation. Increase of injection pressure decreased pollution levels in LHR engine. However, the NOx levels increased in conventional engine due to increase of gas temperature. High degree of insulation in LHR Engine decreased smoke levels with vegetable oil operation. Increase of injection pressure decrease of smoke levels with vegetable oil operation. Increase of injection pressure decreased pollution levels in LHR engine. However, the NOx levels increased in conventional engine due to increase of gas temperature in the conventional engine. Table 1 shows data of smoke levels with conventional engine and Low Heat Rejection Engine at peak load operation with different test fuels.

Table 1. Some levels with different test fuels

Smoke levels (Hartridge smoke units, HSU)						
Engine Version	Pure Diesel operation			Crude oil operation		
	Injection Pressure (bar)			Injection Pressure (bar)		
	190	230	270	190	230	270
Conventional Engine	48	38	34	66	62	55
Low Heat Rejection Engine	68	53	58	50	48	46

The high viscosity, poor volatility and cold flow characteristics of vegetable oils can cause some problems such as injector coking, severe engine deposits, filter gumming, piston ring sticking and thickening of lubrication oil from long-term use in diesel engines Can Has-imog lua [2]. These problems can be eliminated or minimized by transesterification of the vegetable oils to form monoesters. These monoesters are known as biodiesel. The important advantages of biodiesel are lower exhaust gas emissions and its biodegradability and renewability compared with petroleum-based diesel fuel. Although the transesterification improves the fuel properties of vegetable oil, the viscosity and volatility of biodiesel are still worse than that of petroleum diesel fuel. The energy of the biodiesel can be released more efficiently with the concept of low heat rejection (LHR) engine. The aim of this study is to apply LHR engine for improving engine performance when biodiesel is used as an alternative fuel. For this purpose, a turbocharged direct injection (DI) diesel engine was converted to a LHR engine and the effects of biodiesel (produced from sunflower oil) usage in the LHR engine on its performance characteristics have been investigated experimentally. The results showed that specific fuel consumption and the brake thermal efficiency were improved and exhaust gas temperature before the turbine inlet was increased for both fuels in the LHR engine Environmental degradation and depleting oil reserves are matters of great concern round the V. Pradeep et al.[12] globe.

Developing countries like India depend heavily on oil import. Diesel being the main transport fuel in India, finding a suitable alternative to diesel is an urgent need. Jatropha based bio-diesel (JBD) is a non-edible, renewable fuel suitable for diesel engines and is receiving increasing attention in India because of its potential to generate large-scale employment and relatively low environmental degradation. Diesel engines running on JBD are found to emit higher oxides of nitrogen, NOx. Hot EGR, a low cost technique of exhaust gas recirculation, is effectively used in this work to overcome this environmental penalty. Practical problems faced while using a COOLED EGR system are avoided with HOT EGR. Results indicated higher nitric oxide (NO) emissions when a single cylinder diesel engine was fuelled with JBD, without EGR. NO emissions were reduced when the engine was operated under HOT EGR levels of 5–25%. However, EGR level was optimized as 15% based on adequate reduction in NO emissions, minimum possible smoke, CO, HC emissions and reasonable brake thermal efficiency. Smoke emissions of JBD in the higher load region were lower than diesel, irrespective of the EGR levels. However, smoke emission was higher in the lower load region. CO and HC emissions were found to be lower for JBD irrespective of EGR levels. Combustion parameters were found to be comparable for both fuels.

Higher NOx is one of the major problems to be overcome in a low heat rejection (LHR) diesel engine as insulation leads to an increase in combustion temperature about 200–250 0C compared to an identical standard (STD) diesel engine, Adnan Parlak et al. [3]. High combustion temperatures alter optimum injection timing of a LHR engine. With the proper adjustment of the injection timing, it is possible to partially offset the adverse effect of insulation on heat release rate and hence to obtain improved performance and lower NOx. However, the injection timing and brake specific fuel consumption (BSFC) trade-off must be considered together in performance and NOx emission point of view. In this study, optimum injection timing was found with 40 crank angle (34_ CA) retarded before top dead centre (BTDC) in LHR diesel engine in comparison to that of STD diesel engine (38_ CA BTDC). When the LHR engine was operated with the injection timing of the 380 crank angle, which is the optimum value of the STD engine, it was shown that NOx emission increased about 15%. However, when the injection timing was retarded to 34_ CA in the LHR case, it was observed a decrease on the NOx emissions with about 40% and the brake specific fuel consumption (BSFC) with about 6% compared to that of the STD case. Thus, by retarding the injection timing, an additional 1.5% saving in fuel consumption was obtained. As a result of the ceramic coating, as commonly reported by the most researchers, combustion temperature increase and ignition delay time decrease. This increase in combustion temperature enables lowering injection timing of the LHR engines to some extent without degrading the power and torque in a big scale at full loads. However, as an engine is generally operated for a short time intervals at full load condition, the power reduction at these extreme points can be omitted when improvements in BSFC and decrease in NOx is considered together when NOx/BSFC trade-off is considered for all operating regions. Adding any inert gas as diluent to the inlet air reduces oxides of nitrogen (NOx) emissions Can Cinar et al.[4]. In this study, carbon dioxide (CO2) was used as diluent and introduced to the intake manifold of a diesel engine at a ratio of 2%, 4% and 6% respectively. The investigation was conducted on a four stroke, four-cylinder, indirect injection (IDI), turbocharged diesel engine and was concerned with the effect of using diluting CO2 in the intake manifold and injection pressure on engine torque, power, brake mean effective pressure, specific fuel consumption, carbon monoxide, smoke and NOx emissions. The tests have demonstrated that NOx is reduced by the introduction of CO2 in the inlet charge. The engine tests have demonstrated that while

NOx emission improves with CO2 admission, other parameters have deteriorated. With 6% CO2 admission engine torque, power, BMEP and SFC have deteriorated approximately 5.9%, 5.5%, 6%, 3.3% respectively, smoke emission and CO2 increased approximately 60% and CO emission increased approximately 8.5 times from its base level. In spite of this NOx emission was reduced approximately 50% with 6% CO2 admission. As the performance parameters did not vary too much with CO2 admission, emission parameters had changed extremely. The positive effects of increasing injection pressure on performance and emissions were isolated by CO2 admission especially on smoke and CO emission.

Karabektas [5] investigates the effects of turbocharger on the performance of a diesel engine using diesel fuel and biodiesel in terms of brake power, torque, brake specific consumption and thermal efficiency, as well as CO and NOx emissions. For this aim, a naturally aspirated four-stroke direct injection diesel engine was tested with diesel fuel and neat biodiesel, which is rapeseed oil methyl ester, at full load conditions at the speeds between 1200 and 2400 rpm with intervals of 200 rpm. Then, a turbocharger system was installed on the engine and the tests were repeated for both fuel cases. The evaluation of experimental data showed that the brake thermal efficiency of biodiesel was slightly higher than that of diesel fuel in both naturally aspirated and turbocharged conditions, while biodiesel yielded slightly lower brake power and torque along with higher fuel consumption values. It was also observed that emissions of CO in the operations with biodiesel were lower than those in the operations with diesel fuel, whereas NOx emission in biodiesel operation was higher. This study reveals that the use of biodiesel improves the performance parameters and decreases CO emissions of the turbocharged engine compared to diesel fuel. In the NA operation the use of biodiesel yields slightly higher BTEs, while in TU operation the use of biodiesel improves BTE further compared with the use of diesel fuel. The NOx emission with biodiesel is higher than that with diesel fuel, while CO emission is lower for both fuels. A noticeable increase in the NOx emissions was observed in TU operation for both fuels. The TU operation with biodiesel yields a higher ratio of decrease in CO emission compared to diesel fuel. The use of biodiesel improves the performance and exhaust emissions of the turbocharged engine better compared with the use of diesel fuel.

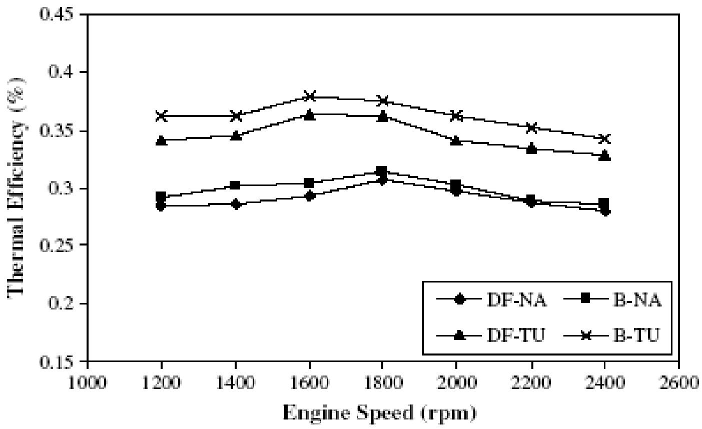

Fig. 1. Thermal efficiency vs. engine speed for fuels tested at full load.

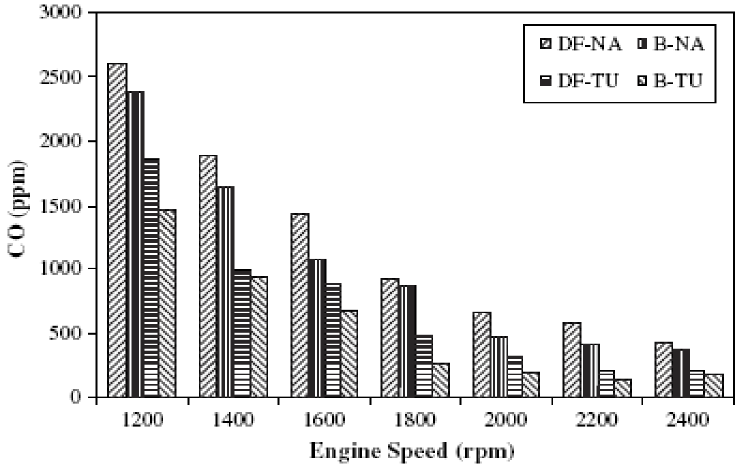

Fig. 2. Carbon monoxide emissions vs. engine speed for fuels tested at full load.
NA : naturally aspirated, TU :turbocharged conditions, DF: diesel fuel, B: biodiesel.

Use of alternative fuel is a way of emission control Salman et.al [6]. A single cylinder, direct injection diesel engine was modified to operate with dual fuel operation (30% LPG and 70% diesel fuel by weight) and a reduction of exhaust emissions from diesel engines was investigated. During the experiments engine speed was kept constant (1650 rpm) and load was changed. It was obtained that; NOx and smoke emissions were reduced with dual fuel operation in the experiments. The experimental results showed that exhaust emissions (NOx and smoke) were improved in dual fuel operation. This indicates that fuel property is one of the most important parameters, which affects the exhaust emissions. Diesel powered forklifts which work in warehouses can be converted to operate with dual fuel. So the air quality in the workplace will be better. LPG can be injected to the intake manifold to obtain the precise control of the amount of fuel, admitting to the cylinder. Also, by increasing the LPG proportion in dual fuel operation a further improvement in exhaust emissions can be obtained. Dual fuel systems can be used in vehicles, and in public and cargo transportation. Thus motor vehicle sourced air pollution would decrease.

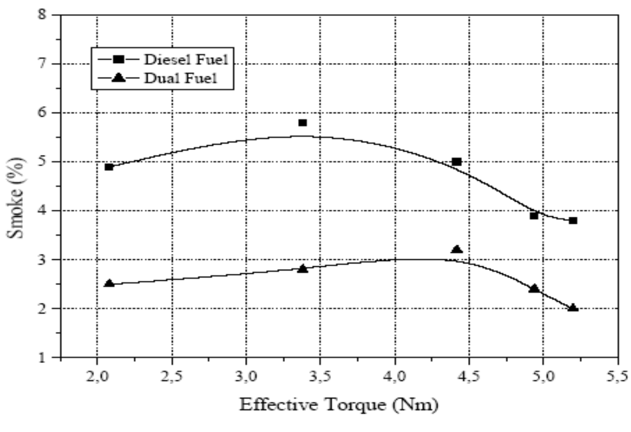

Fig. 3. Variations Of Smoke Emissions With Effective Torque(Ref1)

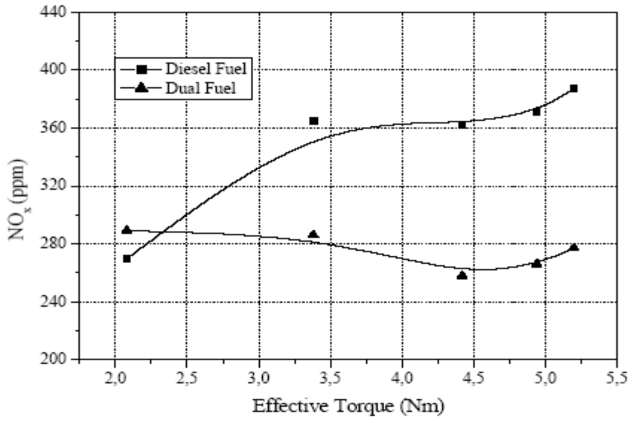

Fig. 4. Variations of Nox Concentration With Effective Torque (Ref1)

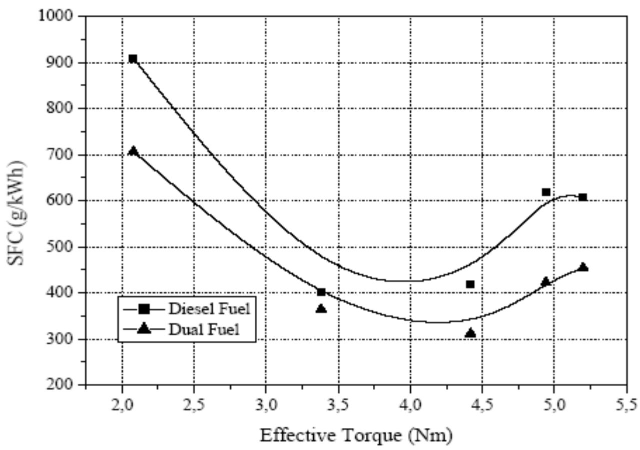

Fig. 5. Variations of SFC With Effective Torque (Ref1)

Crude palm oil (CPO) is one of the vegetable oils that have potential for use as fuels for diesel engines. CPO is renewable, and is safe and easy to handle. However, at room temperature (30–32□C) CPO has a viscosity about 10 times higher than that of diesel. To lower CPO's viscosity to the level of diesel's viscosity, a heating temperature of at least 92 □C is needed. At this temperature, there is a concern that the close-fitting parts of the injection system might be affected. Study of S. Bariey et al. [7] focused on finding out the effects of preheating of fuel on the injection system utilizing a modified method of friction test, which involves injecting fuel outside the combustion chamber during motoring. Results show that preheating of CPO lowered CPO's viscosity and provided smooth fuel flow, but did not affect the injection system, even heating up to 100 □C. Nevertheless, heating up to such a high temperature offered no benefits in terms of engine performance. However, heating is necessary for smooth flow and to avoid fuel filter clogging. Both can be achieved by heating CPO to 60 □C. Combustion analyses comparisons between CPO and diesel found that CPO produced a higher peak pressure of 6%, a shorter ignition delay of 2.6□, a lower maximum heat release rate and a longer combustion period. Over the entire load range, CPO combustion produced average CO and NO emissions that were 9.2 and 29.3% higher, respectively, compared with those from diesel combustion. Hanbey Hazar[8] studied engine performance and exhaust emissions of a diesel engine, with the cylinder head, exhaust, and inlet valves coated the ceramic material MgO–ZrO2 by the plasma spray method, while the piston surface was coated with ZrO2. Thus, a thermal barrier was provided for the elements of the combustion chamber with these coatings.

Using identical coated and uncoated engines, the effects of canola methyl ester produced by the transesterification method, and ASTM No. 2D fuel on engine performance and exhaust emissions were studied. Tests were performed on the uncoated engine, and then repeated on the coated engine and the results were compared. An increase in engine power and decrease in specific fuel consumption, as well as significant improvements in exhaust gas emissions and smoke density, were observed for all test fuels used in the coated engine compared with that of the uncoated engine.

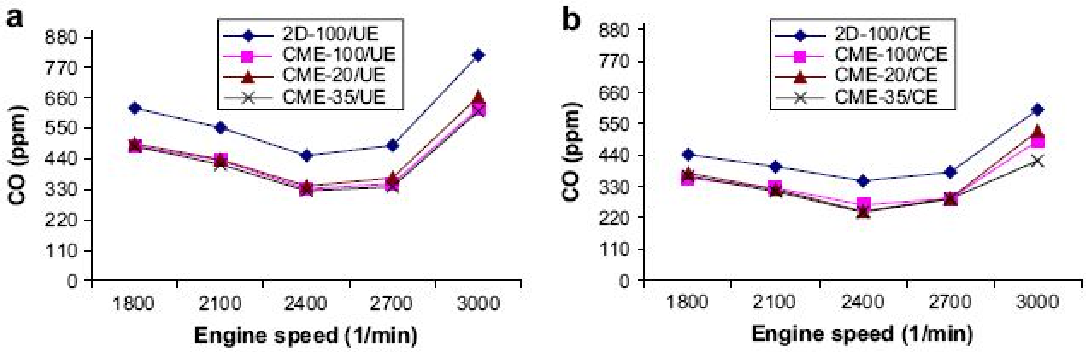

Fig. 6 Comparison of CO of test fuels at different speeds in UE (a) and CE (b) engines.

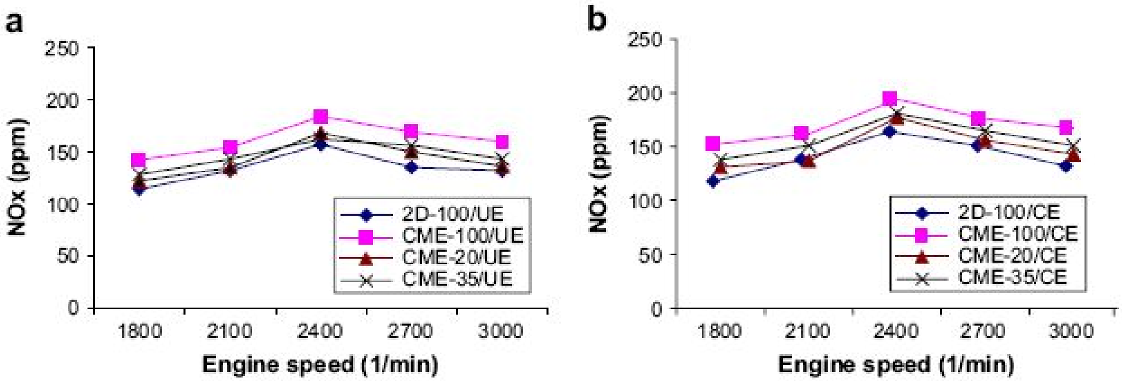

Fig. 7. Comparison of NOx of test fuels at different speeds in UE (a) and CE (b) engines.

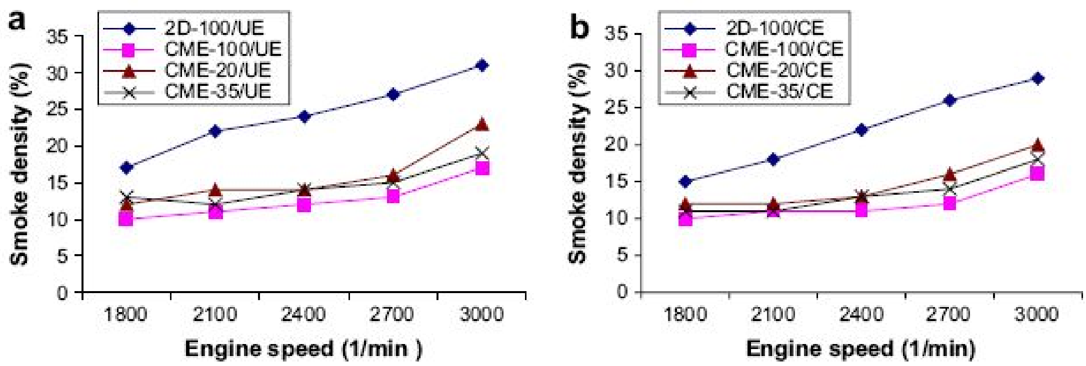

Fig.8. Comparison of smoke density of test fuels at different speeds in UE (a) and CE (b) engines. UE: uncoated engine, CE: coated engine, canola methyl ester (CME)

Jatropha based biodiesel (JBD) is a non-edible, renewable fuel suitable for diesel engines and is receiving increasing attention in India because of its potential to generate large-scale employment and relatively low environmental degradation. Diesel engines running on JBD are found to emit higher oxides of nitrogen, NOx. HOT EGR, a low cost technique of exhaust gas recirculation, is effectively used in the work of V. Pradeep et.al [9] to overcome this environmental penalty. Practical problems faced while using a COOLED EGR system are avoided with HOT EGR. Results indicated higher nitric oxide (NO) emissions when a single cylinder diesel engine was fuelled with JBD, without EGR. NO emissions were reduced when the engine was operated under HOT EGR levels of 5–25%. However, EGR level was optimized as 15% based on adequate reduction in NO emissions, minimum possible smoke, CO, HC emissions and reasonable brake thermal efficiency. Smoke emissions of JBD in the higher load region were lower than diesel, irrespective of the EGR levels. However, smoke emission was higher in the lower load region. CO and HC emissions were found to be lower for JBD irrespective of EGR levels. Combustion parameters were found to be comparable for both fuels.

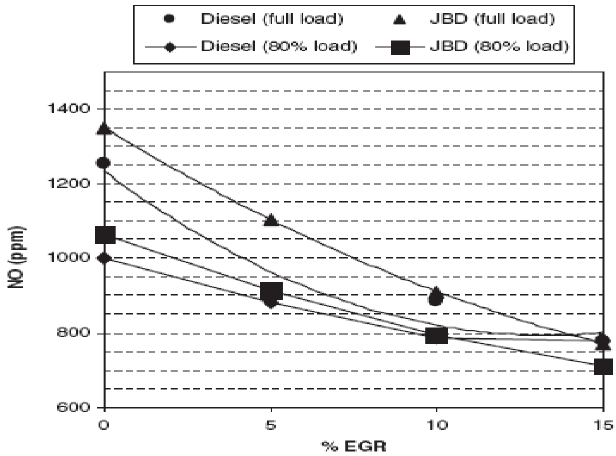

Fig. 9. Variation of NO with EGR (full load and 80%).

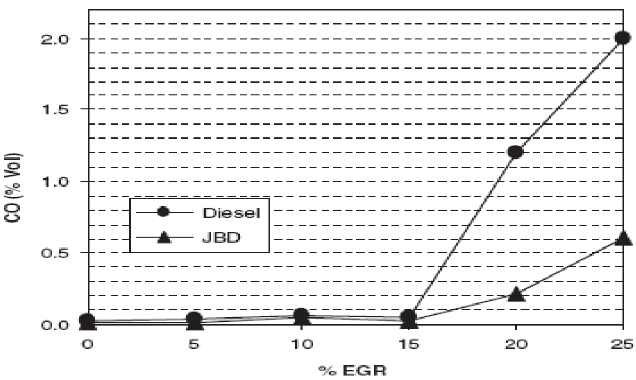

Fig. 10. Comparison of CO with EGR (full load).

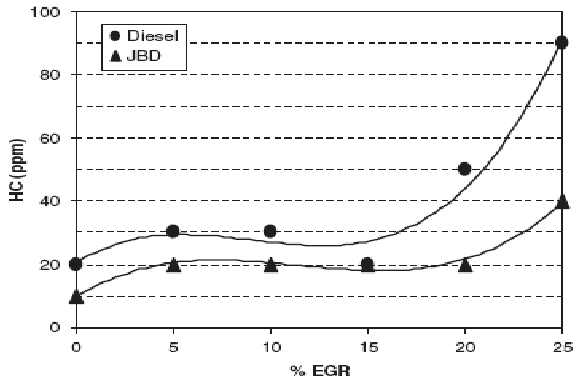

Fig. 11. Comparison of HC with EGR (full load).

3. Conclusion

Low heat rejection engines with vegetable oils may give better performance and lower smoke emissions when compared to pure diesel operation. Exhaust emissions NOx and smoke were improved in dual fuel operation. HOT EGR, a low cost technique of exhaust gas recirculation, is effectively used to reduce NO emissions when a single cylinder diesel engine was fuelled with Jatropha biodiesel. NO emissions were reduced when the engine was operated under HOT EGR levels of 5–25%. However, EGR level was optimized as 15% based on adequate reduction in NO emissions, minimum possible smoke, CO, HC emissions and reasonable brake thermal efficiency.

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