Analysis of Performance and Emission Characteristics of a LHR CI Engine Fuelled with Biodiesel Derived from Neem Oil at Various Injection Pressures

N. Malleswara rao[1] Gosangi Narasa Raju[2] Alapati Ramakrishna[3] Nasar Shaik[4]

[1] PG Student, Mechanical Engineering Department,. B.V.C Engineering college, , Amalapuram East Godavari ,A.P India

[2]Associate professor, Department of Mechanical Engineering. B.V.C Engineering college, Amalapuram East Godavari,A.P India

[3] professor, Department of Mechanical Engineering, B.V.C Eengineering college, Amalapuram East Godavari,A.P India

[4]Assistant professor, Department of Mechanical Engineering, Tirumala engineering college,Narasaraopet,Guntur,, A.P India.

Abstract:

Increasing the performance of an internal combustion engine requires the transformation of total fuel energy to useful energy at the highest as possible. Increase of inner cylinder heat plays important role in the increase of engine performance and decrease of exhaust emissions. It is understood that coating combustion chamber elements with thermal barriers contributes a lot to the increase of inner cylinder heat. This study includes an evaluation of experimental studies and its results carried out upon the methods applied on coating with thermal barrier in diesel engines, the effects of coating on the performance of engine using neem oil biodiesel blend of B100. By using neem biodiesel result showed that brake thermal efficiency of Biodiesel fuel is less as compared to conventional diesel.

***Keywords*: Biodiesel, neem seed based biodiesel, alternative fuel, diesel engine, performance, Emission characteristics, and blend.**

1. Introduction

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petrol-diesel in combustion properties. Increasing environmental concern,

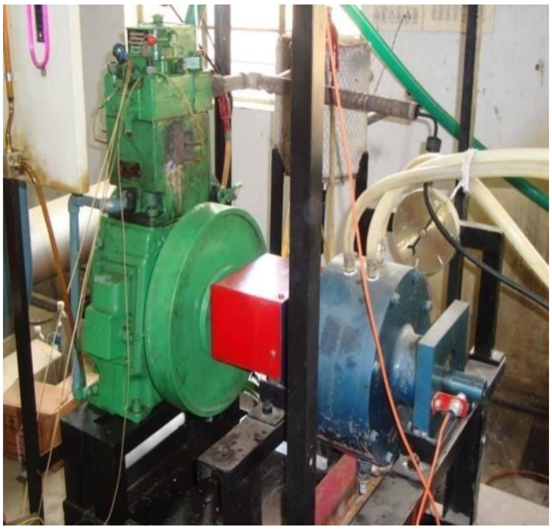
diminishing petroleum reserves and agriculture based economy of our country are the driving forces to promote biodiesel as an alternate fuel. While search for alternate fuels is continuing, researchers are also attempting to find different techniques of efficient fuel utilization in diesel engines. These fuels are fossil in nature, leads to the depletion of fuel. Pollution levels are increasing with the fossil fuels. And also there is burden on Govt. of India in importing crude oils. In the context of depletion of fossil fuels, the search for alternate and renewable fuels has become pertinent. It has been found that the vegetable oil is a promising fuel, because of its properties are similar to those of diesel fuel and it is a renewable and can be easily produced It is well known fact that about 30% of the energy supplied is lost through the coolant and the 30% is wasted through friction and other losses, thus leaving only 30% of energy utilization for useful purposes. The concept of LHR engine is to provide thermal insulation in the path of heat flow to the coolant and increase thermal efficiency of the engine. LHR engines are classified into low grade, medium grade and high grade engines depending on degree of insulation. Low grade engines consist of thermal coatings on piston, liner, cylinder head and other engine components, medium grade engines provide an air gap in the piston and other components with low-thermal conductivity materials like cast iron and mild steel etc and high grade engines are combination of low and medium grade engines[2]. Thermal barrier coatings are duplex systems, consisting of a ceramic topcoat and a metallic intermediate bond coat. The topcoat consists of ceramic material whose function is to reduce the temperature of the underlying, less heat resistant metal part. The bond coat is designed to protect the metallic substrate from oxidation and corrosion and promote the ceramic topcoat adherence. Ceramic coatings are widely used in industry for providing valuable improvements against wear, corrosion, erosion, and heat in designs. The bottle neck is that coatings must maintain intended performance during their life cycles. Although coatings exhibit excessive variability and unpredictability in nature, thermal barrier coating in internal combustion engine is a subject of research for many investigations especially reducing in-cylinder heat rejection of adiabatic engines because ceramic coatings demonstrates good thermal barrier properties. Therefore, thermal barrier coating (TBC) technology is successfully applied to the internal combustion engines, in particular to the combustion chamber. Insulation of the combustion chamber components of low heat rejection (LHR) engines can reduce the heat transfer between the gases in the cylinder and the cylinder wall and thus increase the combustion temperature. The LHR engine concept is based on suppressing this heat rejection to the coolant and recovering the energy in the form of useful work. Thermal barrier coatings on the elements of combustion chamber of internal combustion engine offer advantages including fuel efficiency, multi fuel capacity and high power density. Insulation of the combustion chamber may provide not only reduced heat rejection but also thermal fatigue protection of the underlying metallic surfaces in engines as well as possible reduction of engine emissions. However, the insulation of the combustion chamber influences the combustion process and the exhaust emission characteristics.

To increase the thermal efficiency or to reduce the fuel consumption of engines leads to the adoption of higher compression ratios in order to reduce in-cylinder heat rejection. Both of these factors cause increases in mechanical and thermal stresses of materials used in the combustion chamber. In particular, durability concerns for the materials and components in the engine cylinders, which include pistons, rings, liners and the cylinder heads, limit the maximum in-cylinder temperatures. The application of TBC on the surfaces of such components enhances high temperature durability by reducing the heat transfer and lowering the temperature of the underlying metal.

2.0 Performance analysis

2.1 Experimental setup

The Performance test is conducted on a high speed, four stroke, vertical, water cooled diesel engine. The loading is by means of an electrical dynamometer. The fuel tank is connected to burette to measure the quantity of fuel consumed in unit time. An orifice meter with U-tube manometer is provided along with an air tank on the suction line for measuring air consumption. An AVL15 smoke meter is provided for measuring FSN of exhaust gases. The test rig is installed with AVL software for obtaining various data and results during operation. A five gas analyzer is used to obtain the exhaust gas composition.



Photograph 1: single cylinder Diesel Engine used for neem seed Based Biodiesel Testing

2.2 Engine specifications

Computerized Single Cylinder Diesel Engine Test Rig:

Description	Value
Manufacturer	Kirlosker oil engines Ltd .,Pune
Engine Type	Single Cylinder, 4 Stroke, vertical water cooled Diesel engine.
Cylinder	Single
Stroke	110mm
Cubic capacity	3.68 kW (0.661 ltr.)
Bore	80 mm
Net Power	3.68 kW @ 1500 rpm
Compression Ratio	17.5 :1

2.2 Engine Performance Analysis:

The performance of an internal combustion engine is mainly studied with the help of operating Characteristics. These characteristics obtained by using diesel and neem seed based biodiesel in single cylinder, four stroke diesel engine are discussed below.

Measured results recorded by conducting trials using diesel and neem seed based biodiesel are represented in the following graphs .These graphs are used to study various operating characteristics of engine such as specific fuel consumption brake thermal efficiency, etc.

2.2.1 Comparison of the specific fuel consumption for the insulated (TBC) engine run with diesel and biodiesel and standard engine run with diesel and biodiesel is shown in Fig.1. Because of the higher surface temperatures of its combustion chamber, the SFC values of the LHR diesel and biodiesel were lower than those of standard diesel and biodiesel engine. The relative reduction in the SFC is seen to be within the range of 3–7%. Lower heating value of the biodiesel caused an increase in specific fuel consumption of the biodiesel. As if this reduction would be eliminated particularly in LHR engine, the specific fuel consumption of the biodiesel with TBC coincides at 100% load with standard diesel engine.

2.2.2 In the above fig: 2, it is observed that the SFC of LHR biodiesel was slightly higher than those of diesel at every percent of load (no load to full load). At no load LHR diesel was relatively decreased when compared with biodiesel.

2.2.3 Comparison of the Brake thermal efficiency for the insulated (TBC) engine run with diesel and biodiesel and standard engine run with diesel and biodiesel is shown in Fig.3. The Brake thermal efficiency values of the LHR biodiesel engine were slightly higher than those of the LHR diesel engine. This is attributed to the higher surface temperature with complete combustion due to higher percent of oxygen present in biodiesel. The relative improvement in the Brake thermal efficiency is within the range of 1-11% for partially stabilized zirconia coated engine.

2.2.4 In the above fig: 4, Brake thermal efficiency of biodiesel is comparably closer to diesel, mostly at 100% of load all are closer to each other. Due to increase in temperature inside the cylinder the intake of air reduced which intern reduces the efficiency of biodiesel.

2.2.5 Comparison of the Volumetric efficiency for the insulated (TBC) engine run with diesel and biodiesel and standard engine run with diesel and biodiesel is shown in Fig.5. The volumetric efficiency of the LHR biodiesel was

observed to be higher than LHR diesel at part loads (20, 40 and 60%) and was decreasing with the increase in the load. This can be attributed to the presence of oxygen in the biodiesel which helps in complete combustion of fuel even at maximum loads thereby releasing more heat which intern causes in the heating up of intake manifold and thereby, in the reduction of volumetric efficiency.

As, the in-cylinder combustion temperatures are lowered due to the lower heating value of the biodiesel fuel, less heat will be transferred to the engine parts, so the intake air temperatures decreases. This enhances the volumetric efficiency when the biodiesel was used as fuel.

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2.2.6 Figure.6 shows, the volumetric efficiency of the LHR biodiesel was observed to be higher than LHR diesel at part loads (20 and 40%) and was decreasing with the increase in the load.

2.2.7 Comparison of the Exhaust temperatures for the insulated (TBC) engine run with diesel and biodiesel and standard engine run with diesel and biodiesel is shown in Fig.7. Exhaust gas temperatures of LHR biodiesel is found to be lower at 40,60 and 80% of load than that of LHR diesel , but at 100% load it found slightly higher due to the higher specific fuel consumption of biodiesel. Even though the heating value of the bio diesel is lower than that of diesel, higher exhaust temperatures are attributed to the presence of 11% oxygen in the fuel which helps in complete combustion of the fuel.

2.2.8 The variation of exhaust gas temperature with respect to the load is indicated in Fig. 8. The exhaust gas temperature for all the fuels tested increases with increase in the load. The amount of fuel injected increases with the engine load in order to maintain the power output and hence the heat release and the exhaust gas temperature rise with increase in load. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber.

3.0 Emissions analysis

3.1 Unburned Hydrocarbon (HC):

The variation of HC emission with load is shown in below fig 11.HC emissions are reduced when engine is fueled with diesel with TBC. This reduction is mainly contributed to the efficient combustion of diesel. The plot reveals that as the load increases the HC emission increases. Biodiesel without TBC has more HC emissions than others. Diesel with TBC has lowest HC emissions than diesel without TBC.

3.2 Oxides of nitrogen (NO_x):

The variation of NO_x emission with load is shown in fig 12.Nox formation increases as load is increased, which is a result of higher combustion temperature due to higher engine load; i.e. No_x concentration varies linearly with load. As the load increases the overall fuel air ratio increases which results in an increase in the average gas temperature in the combustion chamber and No_x formation which is sensitive to temperature change increases. The plot reveals that as the load increases the NO_x emissions increases. Diesel with TBC has highest Nox formation at 80 and 100% load conditions.biodiesel without TBC has lowest nox emissions.

3.3COemissions :

The variation of CO emission with load is shown in fig 9.Generally CO emissions reduces with biodiesel due to the higher oxygen content and the lower carbon to hydrogen ratio in biodiesel compared to diesel. Another reason for decrease in CO emissions in biodiesel is it has higher cetane number which results in the lower possibility of formation of rich fuel zone which reduces CO emissions. Biodiesel without TBC has has more CO emission at 75% and full load condition. Diesel with and with out TBC has same co emissions at all load conditions.

3.4 CO_2 emissions The variation of CO2 emission with load is shown in Fig 10 Diesel with TBC and Diesel without TBC has same Co 2 emissions at all load conditions. Biodiesel with and wi9th out TBC are also having same Co2 emissions except at 80 and100% load conditions.

PERFORMANCE OPERATING CHARACTERISTICS GRAPHS:

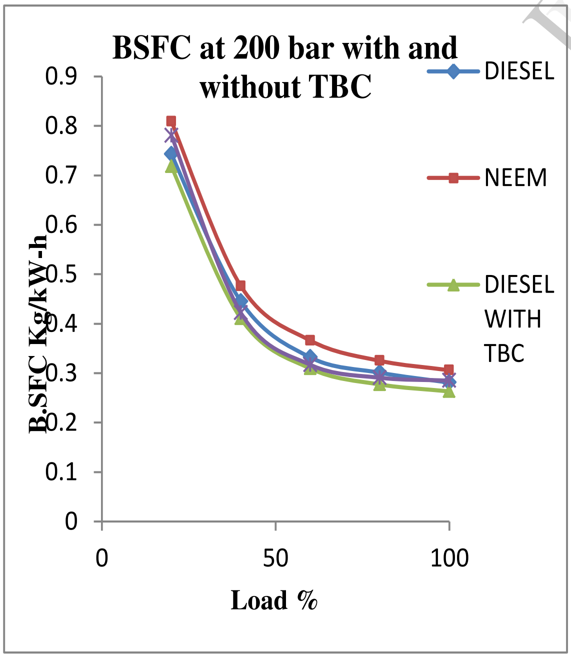

Fig: 1 Load vs. B.S.F.C At 200 bar

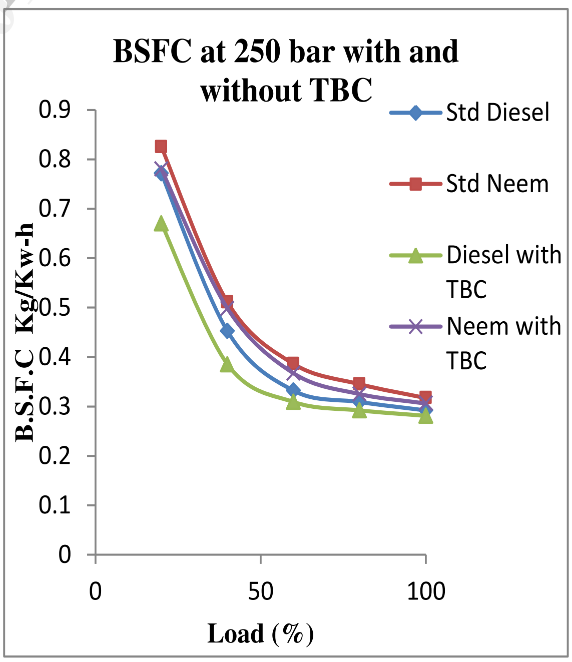

fig: 2 Load vs. B.S.F.C At 250 bar

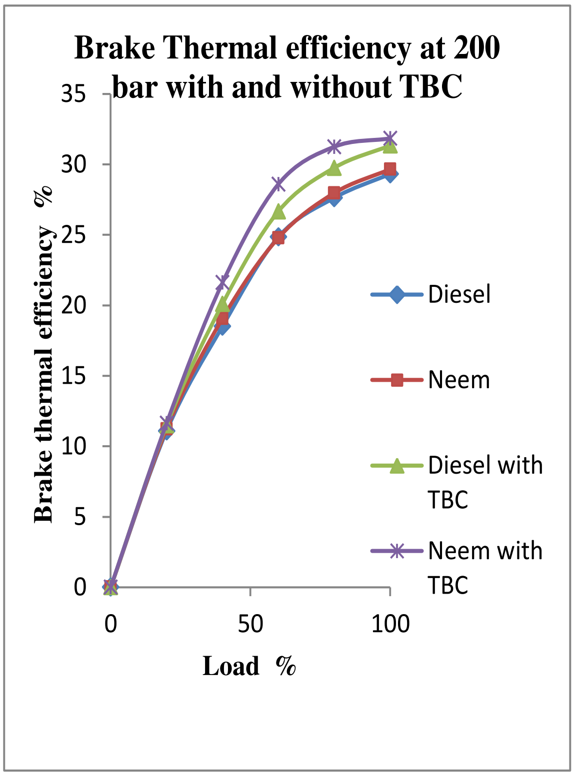

Fig: 3 Load vs. Brake Thermal efficiency

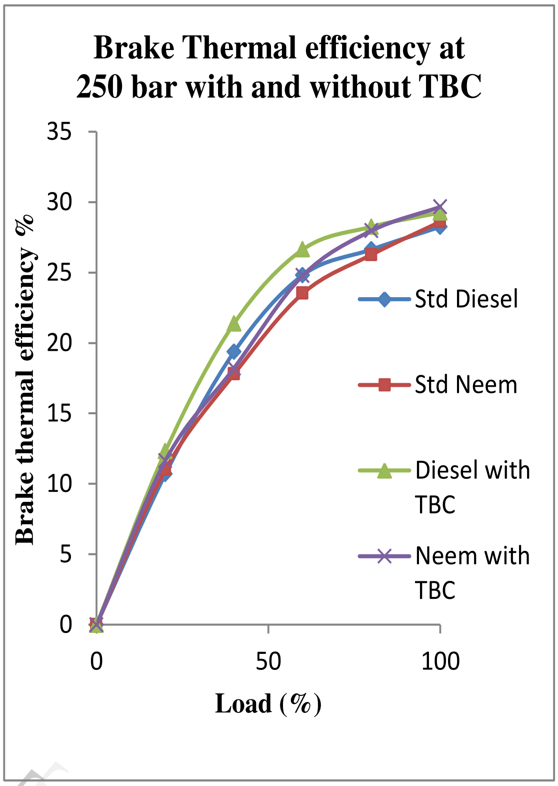

fig: 4 Load vs. Brake Thermal efficiency

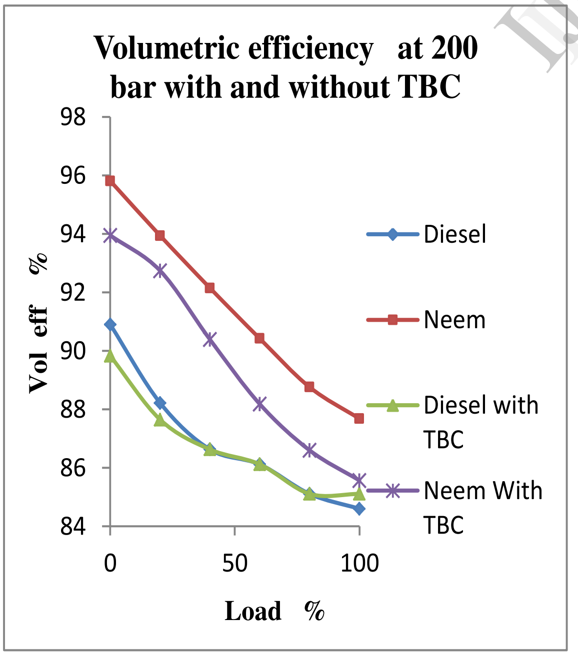

Fig: 5 Load vs. Volumetric efficiency

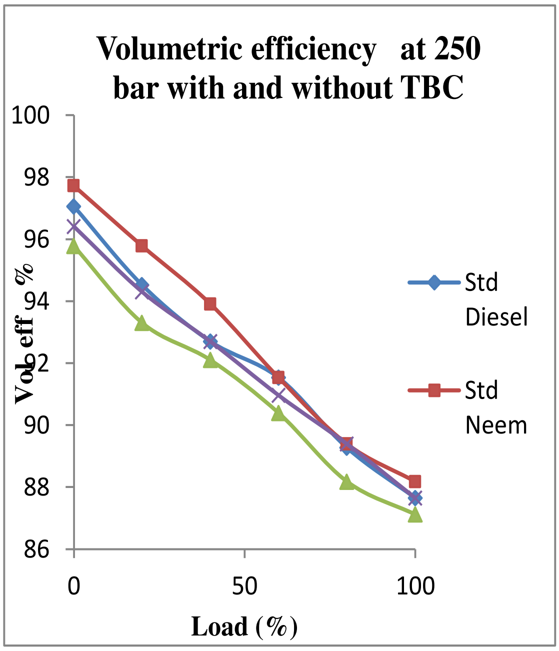

Fig: 6 Load vs. Volumetric efficiency

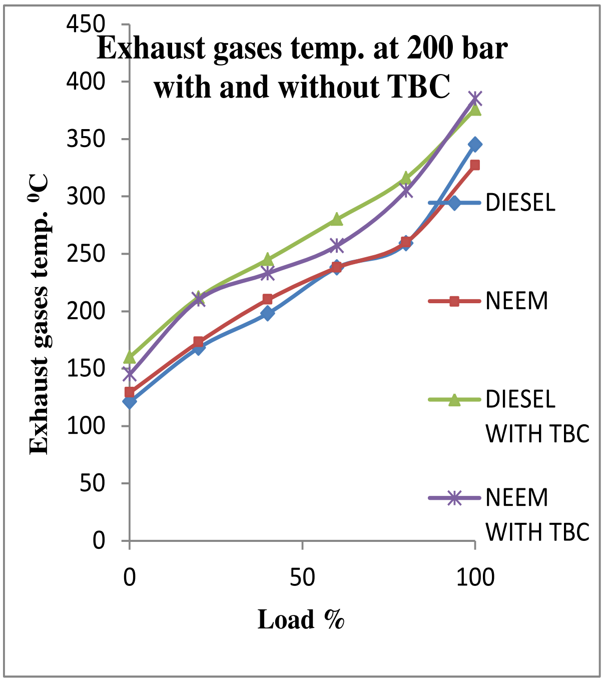

Fig: 7 Load vs. Exhaust gases temp

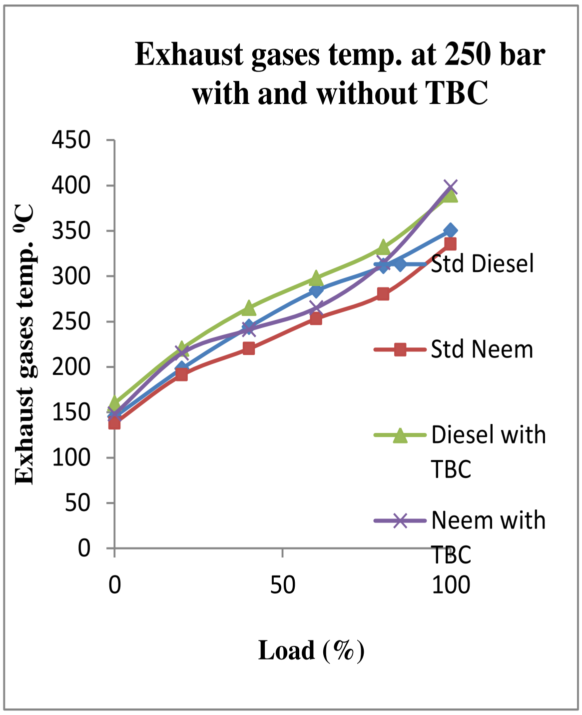

Fig: 8 Load vs. Exhaust gases temp

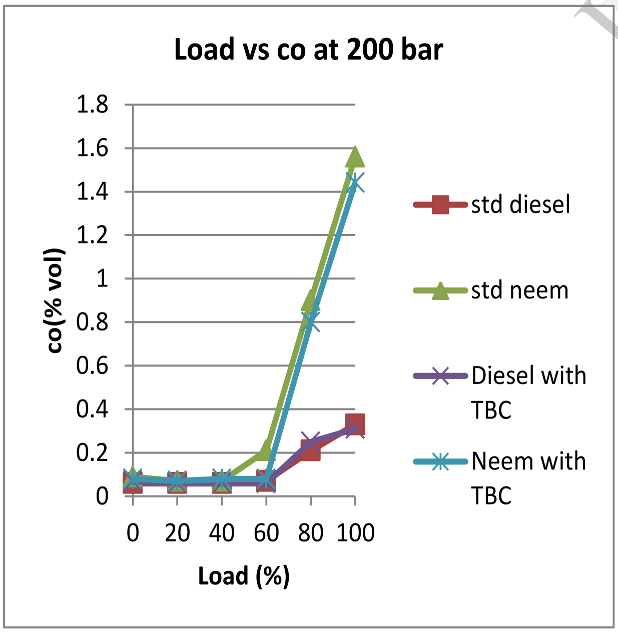

Fig: 9 Load vs. Co

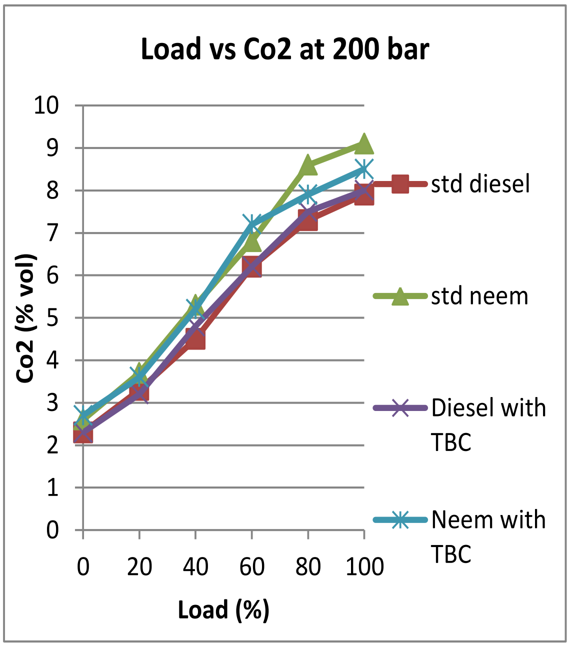

Fig: 10 Load vs. Co2

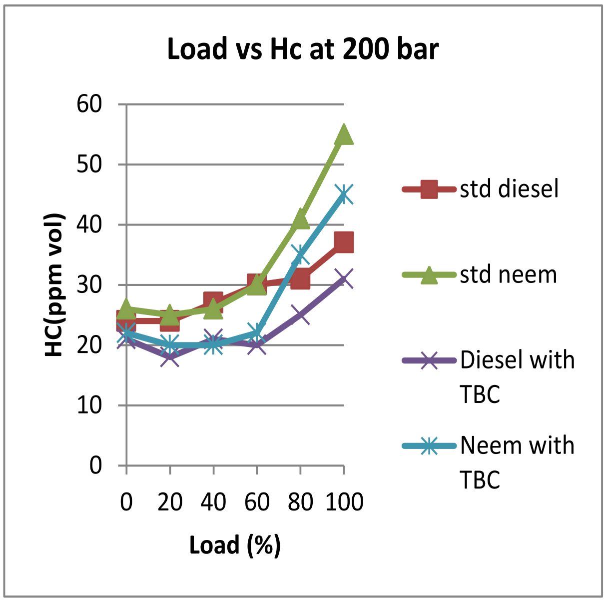

Fig: 11 Load vs. HC

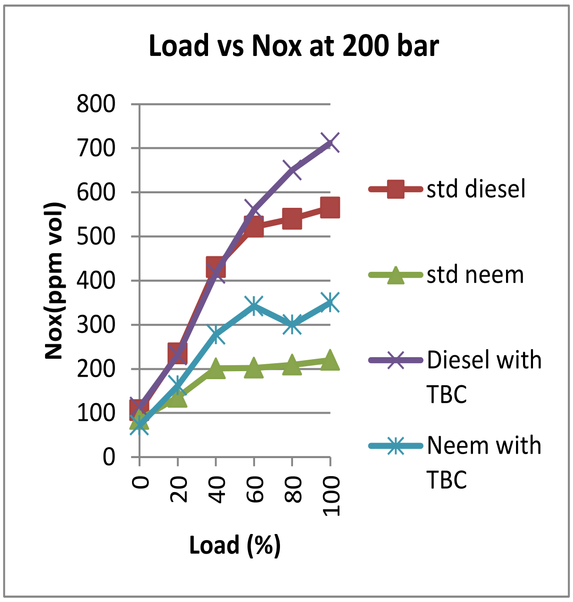

Fig: 12 Load vs. Nox

5 Conclusions

When biodiesel was used as fuel, increments in the engine efficiency were mainly caused by the higher mixture heating value of the biodiesel. The deterioration of the engine efficiency for biodiesel fuel was caused by the higher viscosity of the biodiesel. By the application of the thermal barrier coating, the engine efficiency was improved mainly due to better combustion of fuel.

Lower heating value of the biodiesel caused an increase in specific fuel consumption of the biodiesel. As if this reduction would be eliminated particularly in LHR engine, the specific fuel consumption of the biodiesel is still higher than that of diesel fuel. Lower heating value of the biodiesel also reduced the exhaust gas temperature when biodiesel was used in standard diesel engine. With the application of the thermal barrier coating the exhaust gas temperature increases for both fuels in LHR engine.

The brake thermal efficiency of the biodiesel improved due to the engine power and torque did not deteriorate too much according to diesel fuel. By the application of the thermal barrier coating, the improvement in the specific fuel consumption caused an increase of the brake thermal efficiency for both fuels in LHR engine.

As, the in-cylinder combustion temperatures are lowered due to the lower heating value of the biodiesel fuel, less heat will be transferred to the engine parts, so the intake air temperatures decreases. This enhances the volumetric efficiency when the biodiesel was used as fuel.

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