Experimental Investigation to Evaluate the Performance, Emission and Combustion Characteristics of Diesel Engine with Neem Oil Biodiesel

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Abstract The world is confronted with the twin crises of fossil fuel depletion and environmental degradation. The indiscriminate extraction and consumption of fossil fuels have led to a reduction in petroleum reserves. Alternative fuels, energy conservation and management, energy efficiency and environmental protection have become important in recent years. The increasing import bill has necessitated the search for liquid fuels as an alternative to diesel, which is being used in large quantities in transport, agriculture, industrial, commercial and domestic sectors. Biodiesel obtained from vegetable oils has been considered a promising option. India is looking at renewable alternative fuel sources to reduce its dependence on foreign imports of oils. As India imports 70% of the oil, the country has been hit hard by increasing cost and uncertainty. Recently the biomass resources are being used as alternative fuels and effective use of those fuels is gaining prominence as a substitute way to solve the problem of global warming and the energy crisis. Among all the alternative fuels existing neem oil is also one. In this work, conventional laboratory equipment has been used for the transesterification of neem oil. Various properties of esterified neem oil have been tested for comparison with diesel fuel further the investigations are carried out on a laboratory based diesel engine to study its performance. An attempt has been made in the present work to find out the suitability of transesterified neem oil as a fuel in C.I. engine.

In this thesis, an attempt has been made to review the work done on biodiesel production and utilization, resources available, process(es) developed/being developed, performance in existing engines, environmental considerations, the economic aspect, and advantages in and barriers to the use of biodiesel.

***Keywords*: Biodiesel, Performance, Emissions, Neem Oil, Load, BSFC, NOx, Incylinder Pressure.**

I. INTRODUCTION

Biodiesel is a clean-burning, renewable fuel made from vegetable oils, animal fats and recycled cooking oil and greases. The manufacturing process for biodiesel combines oils and fats with methanol and a catalyst to produce fatty acid methyl esters, which is commonly referred to as biodiesel. Vegetable oils such as rapeseed, canola, soybean and palm oil are the most common raw material for commercial-scale biodiesel production. Biodiesel is an environmentally-friendly, efficient alternative to conventional petroleum-based diesel and can be used in a variety of ways. Biodiesel has physical and chemical properties similar to conventional petroleum-based diesel. The current specification for biodiesel fuel is ASTM D6751. ASTM is a standards group comprised of engine and fuel injection equipment manufacturers, fuel producers, and fuel users whose standards are recognized in the U.S. by governmental entities, including state agencies responsible for ensuring fuel quality. So called “biofuels” that do not meet the ASTM standard are not legally biodiesel fuels and should not be used in diesel engines. Biodiesel is typically used as an additive to conventional diesel fuel, ranging in content from 2% to 50% or more. Consequently, biodiesel fuel is often referred to by the percentage of biodiesel in the fuel. For example, B20 is a blended fuel that contains 20% biodiesel and 80% conventional diesel. B20 is a common blend because it provides a good balance between costs, performance, and environmental benefits. Biodiesel is a legally registered fuel and fuel additive with the U.S. Environmental Protection Agency.

II. EXPERIMENTAL WORK

For this study a single cylinder, four stroke diesel engine, Kirloskar, Model TV1, connected to eddy current type dynamometer for loading, smoke meter to measure smoke and five gas analyzer for exhaust gas evaluation, is employed. It is provided with necessary instruments for combustion pressure and crank-angle measurements. These signals are interfaced to computer through engine indicator for Pθ−PV diagrams. Provision is also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup has stand- alone panel box consisting of air box, fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator Rotameters are provided for cooling water and calorimeter water flow measurement. The setup enables study of engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency etc.

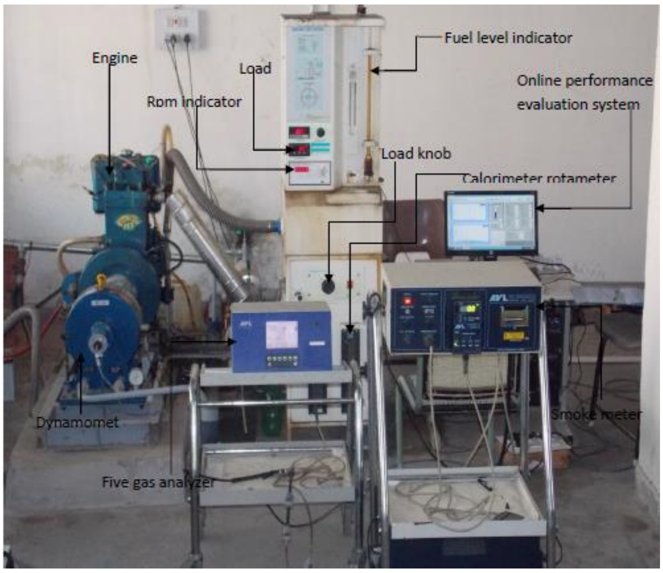

Fig. 1 Engine Setup

The engine was fuelled with pure diesel and mixtures containing 10%, 20%, 30%, and 50% of Castor oil biodiesel. Relative effects of engine operation, emission characteristics and combustion characteristics of the different blends of Castor oil biodiesel with that of diesel under variable loads (0%, 25%, 50%, 75% and 100%) at a constant velocity of 1500 RPM are measured. The main specifications of engine are shown in Table1.

Table 1: Specifications of Test Engine

Product	Engine test setup 1 cylinder, 4 stroke, Diesel Engine.
Maximum Power	5.2kW @1500rpm
Bore × Stroke	87.5 × 110
Compression Ratio	17.5:1
No of Cylinder	1
Dynamometer	Type Eddy Current
Software	EnginesoftLV
Pump	Type Monoblock
Fuel tank capacity	15 litres

III. RESULTS AND DISCUSSIONS

Regarding the engine performance in terms of BTE, BSFC is as follows: Figure 2 shows that the variation of brake thermal efficiency (BTE) with load for different blends. It has been observed that the brake thermal efficiency for all test fuel is increasing with increase in applied load. It happens due to reduction in heat loss and increase in power developed with increase in load. The maximum brake thermal efficiency is obtained 25.09% for B30 among all other blends, which is only 2.80% lower than that of diesel on an average bases. At 60% load B30 has been shown little higher BTE than diesel otherwise there is no other case in which diesel fuel is given lower efficiency than blends. By increasing the load on engine, the brake thermal efficiency also increases for all the fuel types tested. Initially, efficiency was found to be increased with increased blend ratio up to B30 and after that it got decrease as shown in figure 3. The decrease in brake thermal efficiency for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption. In spite of this increasing viscosity may be the other reason for decreasing efficiency with higher blend ratio of fuel thereby, poor spray and poor atomization occurred due to which charge was not properly burned.

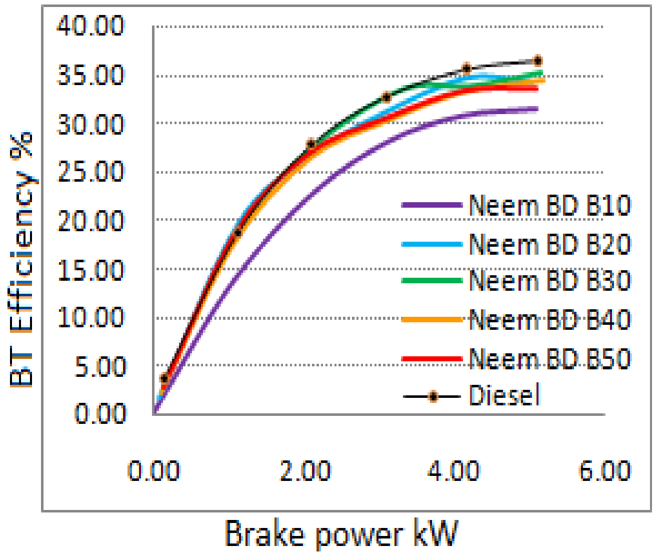

Fig. 2 Variation of Brake power with BT Efficiency

The variation of brake specific fuel consumption with respect to load is presented in figure 3. It is obvious from the figure that the BSFC of the engine gradually decreases with increase in load and then becomes constant up to full load condition. Same trend in brake specific fuel consumption (BSFC) can be seen as it was seen in efficiency, B30 has given lowest brake specific fuel consumption to all other blends however, it was slightly higher than that of diesel.

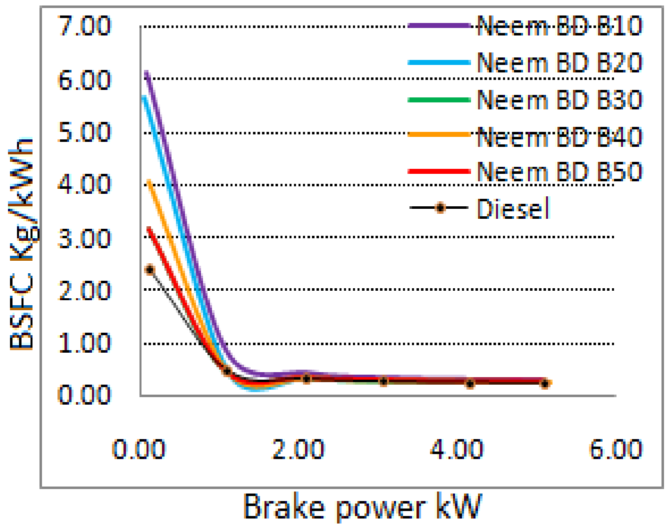

Fig. 3 Variation of Brake power with BSFC

NBD blend B30 and conventional diesel are given 0.79 kg/kWh and 0.65 kg/kWh of BSFC respectively, on an average bases. For higher percentage of biodiesel blends, the SFC increases. This may be due to high density, high viscosity and lower heating value of the fuels. B30 has optimal viscosity than B10, B20, B40 and B50 that is way it gives low BSFC among them.

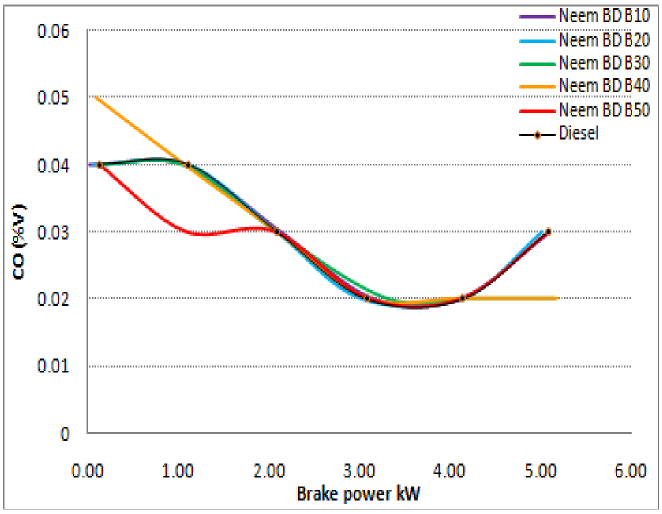

Fig. 4 CO (%V) Vs BP (KW) emission

Figure 4 shows that the variation of carbon monoxide emission of the blends and diesel under various loads. The emission of CO is found to be decrease with increasing load. More fuel accumulates at higher load to produce more power due to which higher temperature occurs in exhaust. This increased temperature helps in the oxidation of CO on account of that its value decreases. However at full load air-fuel ratio was decreased up to that much limit when sufficient oxygen was not available to oxidize completely that is way higher CO is obtaining. The CO emission of all blends is close to that of standard diesel except B30 which has given 0.028% compare to diesel 0.03%, on an average bases.

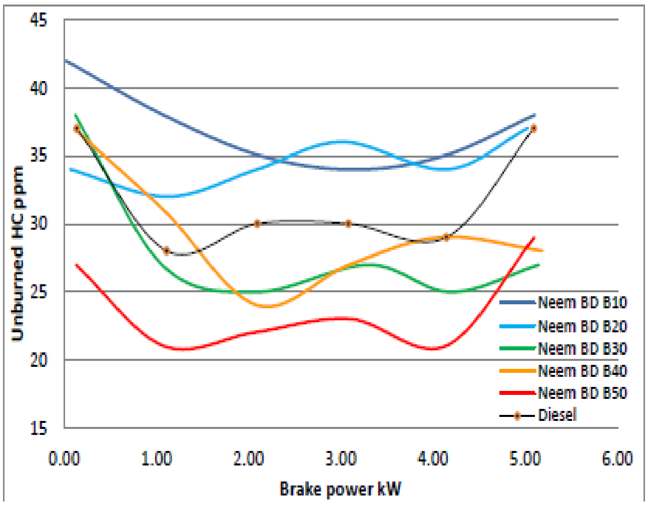

Fig. 5 Unburned HC Vs BP

Figure 5 shows the significant reduction in HC emission has been found with increasing blend ratio of biodiesel in fuel. All blends except lower blends such as B10 and B20 have given high HC. Other blend like B30, B40, B50 and diesel has been given 28.11ppm, 29.33ppm, 23.66ppm and 31.83ppm of HC emission respectively on an average bases. These reductions indicate that the better combustion of fuels and thus, HC level decreased significantly.

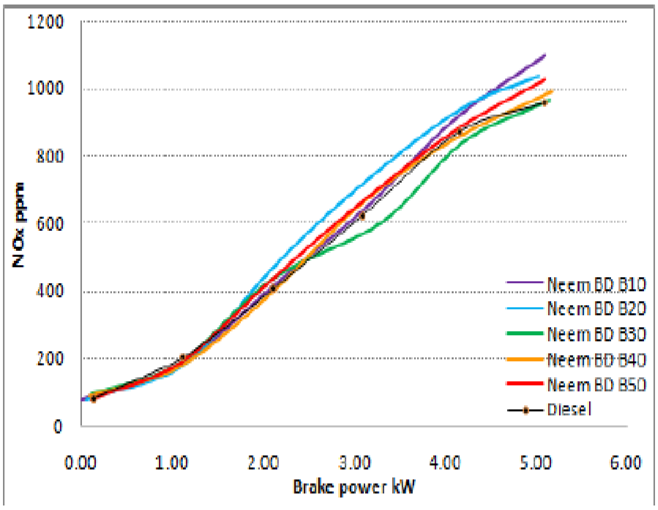

Fig. 6 NOx Vs BP

Figure 6 shows the NOx emission for biodiesel blends is higher than that of conventional diesel except B30 from partial to high load condition. In general, vegetable based fuel contains a small amount of nitrogen that contributes towards NOx production. This figure shows that from nearly 45% to 100% load, NOx emission from the CNBD blend B30 is fairly lesser than that of diesel. But for full load the NOx emission from the blend B30 is higher than that of diesel. While other blends closely follow standard diesel or even gives higher level of NOx than diesel. The reason of higher NOx emission for blends is due to the higher peak temperature. Reduction of NOx is the main achievement of this study. The NOx emission for diesel and blend B30 at 40% and 60% loads is (621 ppm and 870 ppm) and (602 ppm and 839 ppm) respectively.

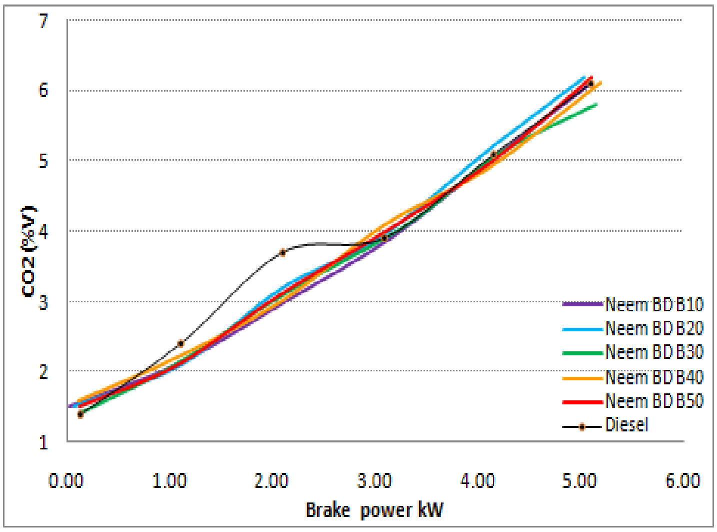

Fig. 7 CO2 Vs BP

Figure 7 shows the variation of CO_2 under varying load for different biodiesel blends. All test fuels show increasing trends CO_2 emission with increase in load due to increase in accumulation of fuel. CO_2 emission level can related to the increase in exhaust gas temperature therefore more emission of CO_2 means high temperature is there. CO_2 emission of the blend B30 for full load is less than diesel this may be due to some lack of complete combustion and inadequate supply of oxygen due to which same one showed less NOx out of all. On the contrary, B30 has not been showed less temperature than diesel thus it needs further scientific investigation to understand the reason behind it.

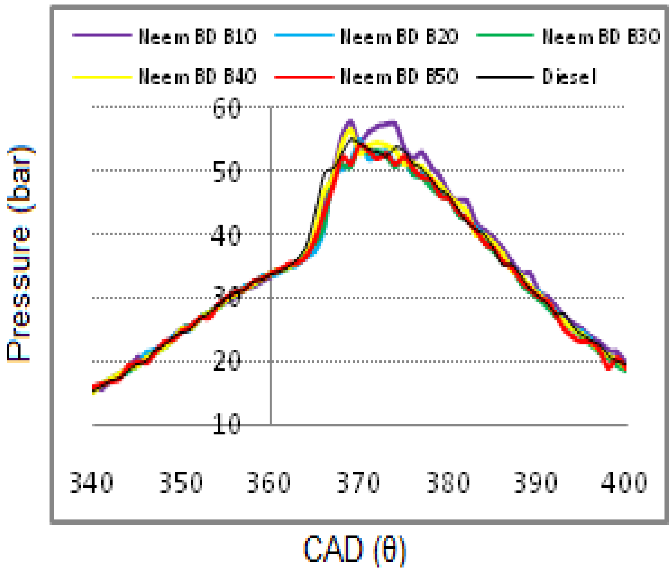

Fig. 8 Incylinder pressure vs. crank angle

Figure 8 shows the variation of incylinder pressure with crank angle for blends B10, B20, B30, B40 and B50 in comparison of base line data obtained from standard diesel. Figure 8 also shows the increasing trend of incylinder pressure with 20% load. At no load condition all blends shows high peak pressure compare to standard diesel but as the load increases gradually from no load to full load with equal interval of 20% load, all test fuels shows earlier pressure rise. Lower blend B10 always shows the higher peak pressure in comparison with other blends and mineral diesel. This result of B10 indicates optimum condition for combustion exhibited by mixing of diesel and biodiesel. Combined effect of presence of inherited oxygen in biodiesel and lower viscosity of diesel ensures optimum air fuel mixing. At full load highest blend B50 shows earlier start of combustion than diesel while other blends show delay in combustion than diesel. Higher cylinder gas temperature exists at high engine load due to which viscosity of fuel decreases however fuel pump injector setting is always remain same. That is way B50 experienced fewer falls in viscosity compared to other fuels and showed earlier start of combustion.

Figure 9 shows the heat release rate for biodiesel blends in comparison of standard diesel at different engine operating conditions. Because of the after combustion of fuel variation of heat release occurs. From figure 9 it is cleared that the biodiesel blends show identical combustion stages for all loads as diesel. In general, premixed fuel- air mixture burns rapidly after an ignition delay of fuel. Generally, lower blends as B10, B20 and B30 shows the delay in the start of premixed combustion heat release than higher blends as B50 and B100 in comparison of diesel. This is because, in of low blend the concentration of biodiesel is low, that is way fuel does not cause a significant force on certain number, but it touches the air fuel mixture formation due to changes in viscosity and evaporation properties of the fuel. Premixed combustion heat release rate is higher especially for blend B100 at approximate all engine loads that indicates optimum conditions for mixture formation.

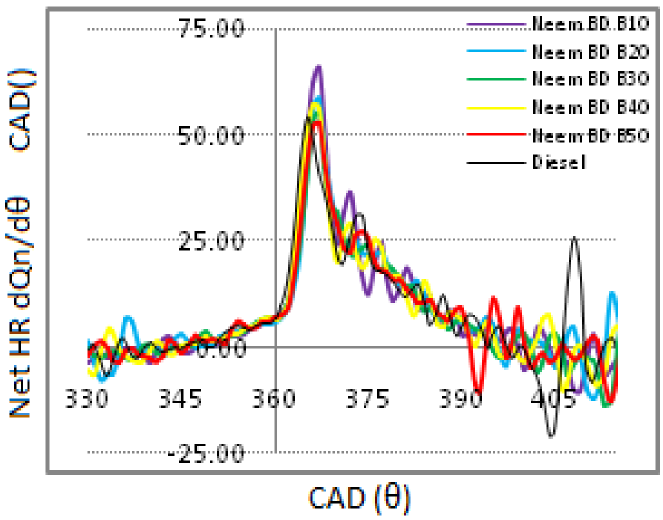

Fig. 9 Heat release rate vs. crank angle

IV. CONCLUSIONS

- The performance, emission and combustion characteristics of engine fuelled with Neem oil biodiesel and diesel blends was investigated and compared with that of standard diesel.

- The experimental results confirm that the BTE, BSFC, are the function of biodiesel blend and load. For similar operating conditions, a particular blend gave better engine performance and reduced emissions compared to other blends in comparison of standard diesel.
- B30 of NBD gave the better overall performance among all other blends in comparison of diesel however it showed slightly reduced BTE (.82% less than diesel), increased value of BSFC (21.5% more than diesel due to lower calorific value), reduced CO, HC, NOx and CO2 emissions with high value smoke which indicates better combustion of fuel, which can be considered as acceptable results in overall performance with biodiesel without any modification of engine.
- In combustion characteristics higher blends showed earlier start of combustion and for lower blends start of combustion was slightly delayed in comparison of standard diesel. Almost identical trends were to be seen for all the biodiesel blends in heat release rate.
- Very negligible difference was seen in combustion duration for blends and diesel however under full load condition, blends showed insignificant shorter duration of combustion than diesel.
- Therefore, in Neem oil biodiesel blends, B30 can be used in unmodified CI engines or to reclaim its performance better than this we can do fuel as well as engine modification also.

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