Experimental Analysis of Using Neem Oil as an Alternative Fuel

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ABSTRACT

Neem oil can be directly used in compression ignition engine. However, the performance is inferior to diesel. This is due to its high viscosity and carbon residue. The performance of the neem oil fuelled engine can be improved by esterifying, preheating or using dual fuel mode with petrol carburetion. In this experimental work, performance and emission characteristics of a single cylinder, water cooled ,direct injection diesel engine operating on neem oil, its ester, preheated neem oil and neem oil-petrol dual fuel mode were evaluated and compared with diesel operation. The brake thermal efficiency of the engine with neem oil is 24.9%,neem oil ester is 26.39%, preheated neem oil at 160 deg Celsius (temperature at which neem oil viscosity equals to diesel viscosity) is 29.1 % and that of diesel is 31.4% at full load. At knock limited point (60% full load,1500 rpm), brake thermal efficiency increases from 24% to 30.5% at 33.7% of energy share of petrol with neem oil, and from 26.8% to 32.3% at 30.3% of energy share of petrol with neem oil ester, Smoke, HC/CO decrease with esterification and preheating but increase with petrol carburetion.

Keywords - vegetable oil, diesel engine, bio-diesel, neem oil.

I. INTRODUCTION

Vegetable oils are promising alternative fuels for diesel engines, since they are easily handled liquid fuels with properties close to those of diesel in many respects (1) They are renewable in nature, can be produced in rural areas by well known agricultural practices Research findings (2) have revealed that engine durability is adversely affected by the use of vegetable oils as a fuel for long term. These problems can be attributed to the high viscosity, low volatility, and reactivity of unsaturated hydrocarbon chains.

Of these factors, the high viscosity of vegetable oils is the predominant hurdle as it causes excessive carbon deposit, ring sticking, plugging of injector orifices, improper injection and atomization and hence incomplete combustion .Transesterification(3) and preheating(4) are effective methods to reduce the viscosity of the vegetable oils. The performance of vegetable oil fuelled engine can be improved to some extent using petrol induction. In this work, performance of a single cylinder, water cooled, CI engine was evaluated using preheated neem oil, neem oil ester and neem oil-petrol dual fuel mode and the results are compared with that of base diesel engine.

II. PROBLEMS ASSOCIATED WITH USE OF NEEM OIL IN DIESEL ENGINE

Vegetable oils have generally more complex structure than normal hydrocarbons found in diesel fuel. The diesel fuel molecule is a saturated non-branched hydrocarbon with carbon numbers about 12 to 18. Vegetable oil molecules are triglycerides, generally with non-branched chains of different degrees of saturation. The high viscosity of neem oil (as seen in Table 1) leads to poor atomization during injection, resulting in inefficient mixing with air, which contributes to incomplete combustion. The poor volatility makes the neem oil difficult to evaporate and ignite. Hence, it is difficult to use neem oil without further processing as a fuel in a direct injection diesel engine. Either the neem oil has to be further processed or the engine has to be modified to render the use of neem oil practicable. In the present work methods such as transesterification, preheating and petrol carburetion were investigated to improve the performance.

Transesterification involves making the triglycerides of vegetable oil react with methyl alcohol in the presence of a catalyst (NaOH) to produce glycerol and fatty acid ester. Which results in a vegetable oil ester. The byproduct is glycerol, which has its own industrial application. Preheating of vegetable oil reduces the viscosity considerably. The reduction in viscosity improves the formation of the air fuel mixture, resulting in good combustion .Engine can be operated on gasoline-neem oil (or its esters) dual fuel mode. It is expected that the engine performance will improve because of many ignition centers, low viscosity and good mixing characteristics of petrol in the dual fuel mode.

Fuels	Calorific value(MJ/kg)	Density (Kg/m^3) at 30°C	Viscosity at 30°C(cSt)	Flash point °C	Cetane number
diesel	43.5	835	4.3	50	52
neem oil	39.9	938	87.66	350	38
neem oil methyl ester	38.5	882	15	180	47

Table.1.Properties Of Neem Oil

III EXPERIMENTAL SETUP

A single cylinder 4-stroke water-cooled diesel engine developing 3.7kW at 1500rpm was used. The schematic diagram of the experimental set up is shown in Fig.1. A swinging field electrical dynamometer was used for loading the engine. A carburetor was fitted in the intake port of the engine for supplying petrol. The petrol supply could be varied. A turbine type meter connected to a large tank was attached to the engine to make air flow measurements. The fuel flow rate was measured on the volumetric basis. An infrared exhaust gas analyzer was used for the measurement of HC/CO in the exhaust. Smoke levels were obtained using a standard Bosch Smoke Meter.

In order to reduce the viscosity of neem oil, an electrical oil heater incorporating a relay circuit with electronic controller was designed. Fig.2 shows the details of the fuel heating system in the tank. Neem oil is preheated over a period of time in the preheating tank prior to injection and reduction in viscosity is accomplished. The electric heater (2kW, 230V) submerged in the fuel tank was connected to a.c. power supply. The relay controller with an auto reset function, on - off action; operating range of 0-600° C, k type thermocouple and digital display were employed to regulate fuel temperature.

- Initially, the tests were conducted at a constant speed of 1500 rpm with variable load for diesel, neem oil and its esters as fuels.

- Then the tests were conducted with neem oil, at different fuel temperatures. The temperature was increased till the viscosity of neem oil becomes equal to diesel viscosity.

- Engine was operated on dual fuel mode namely gasoline-diesel oil, gasoline-neem oil and gasoline-neem oil ethyl ester. Petrol has low viscosity and high self ignition temperature. So at full load condition the engine knocks even for a little amount of petrol carburetion. So experiment was conducted at 60% of full load. At constant speed of 1500 rpm the amount of petrol carbureted was varied from 0% to 40% of the total input energy.

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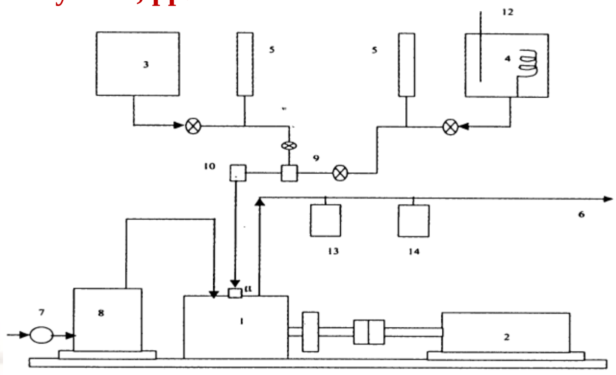

Fig.1 Engine setup

1. ENGINE
2. DYNAMOMETER
3. FUEL TANK
4. FUEL TANK WITH HEATER
5. BURETTES
6. EXHAUST PIPE
7. AIR FLOW METER
8. AIR TANK
9. FUEL FILTER
10. FUEL PUMP
11. FUEL INJECTOR
12. THERMOCOUPLE IN THE FUEL TANK
13. SMOKE PUMP
14. HC/CO ANALYSER

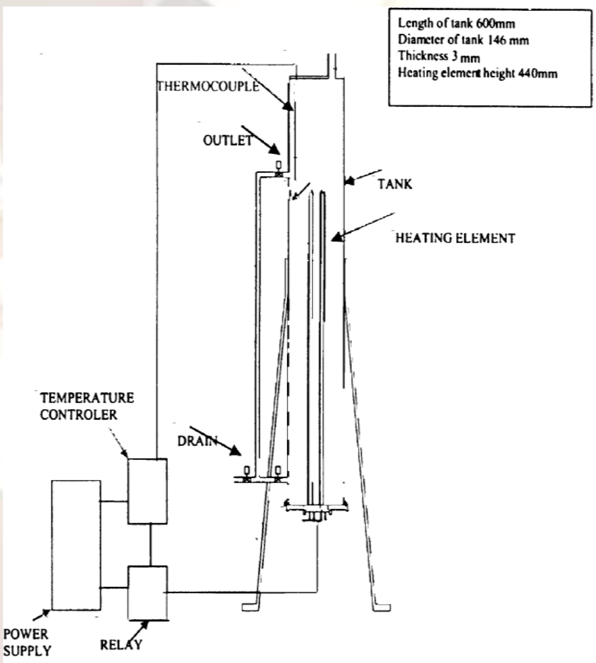

Fig.2 Fuel heating system in the tank

IV. RESULTS AND DISCUSSION

Tests with Neem Oil, Neem Oil Methyl Ester and Diesel

Brake Thermal Efficiency

As seen in Fig 3, at maximum load, brake thermal efficiency with neem oil is 24.9%, which increases to 26.39% in neem oil methyl ester operation. However these values are low compared to diesel operation (31.4%).The lower brake thermal efficiency with neem oil is due to poor mixture formation as a result of low volatility, higher viscosity and density. But slight improvement in brake thermal efficiency with neem oil ester is due to improved combustion as a result of reduced viscosity.

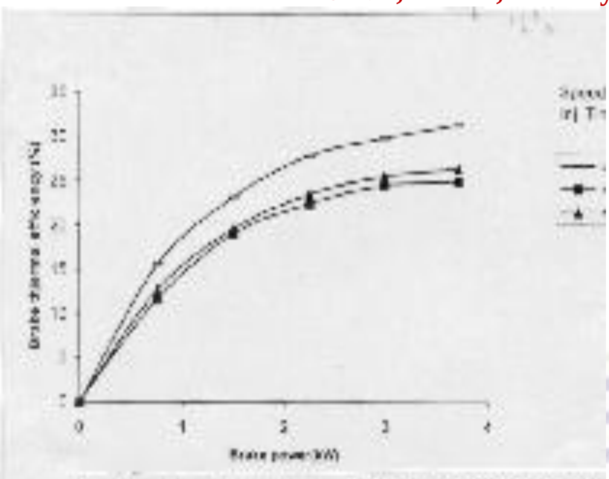

Fig.3 Variation of brake thermal efficiency with brake power

Smoke Emission

Fig.3 compares the smoke emission of neem oil, neem oil ester with that of diesel operation. At maximum load smoke emission of neem oil is 4.1 BSU, which decreases to 3.6 BSU in neem oil methyl ester operation. The smoke emission with diesel operation is 2.8 BSU. The high viscosity and low volatility of neem oil leads to larger droplet sizes with consequent sluggish combustion, which results in increased smoke levels. But with its ester, it is reduced, due to its reduction in viscosity and density.

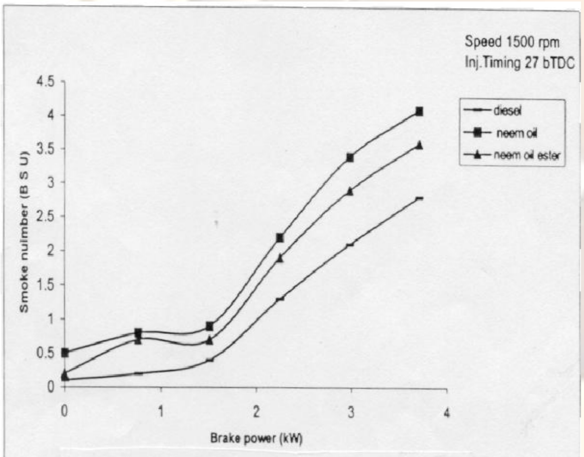

Fig.4 Variations of smoke emission with brake power

CO Emission

It is evident from Fig.4 that the CO emissions of neem oil and its ester are higher than diesel operation. A possible explanation for higher CO emission is the presence of local mixture at core of injection spray, with insufficient air during the combustion process. The reduction in CO emission with neem oil methyl ester is due to improved air fuel mixture as a result of reduction in viscosity.

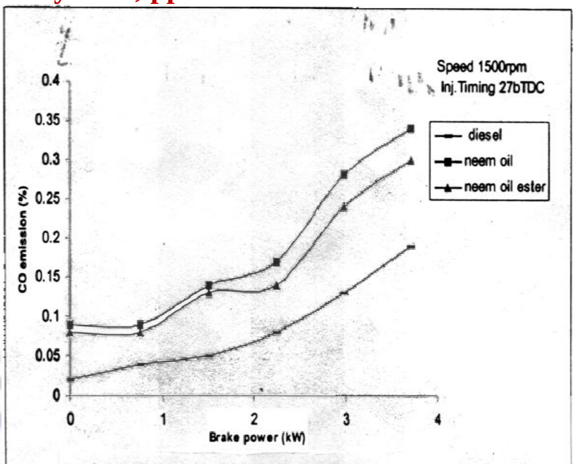

Fig.5 Variation of CO emission with brake power

HC Emission

Fig.5 shows the variation of HC emission with brake power. The HC emissions of neem oil and its ester are higher than diesel operation. The higher density and viscosity of the neem oil cause poor mixture formation, which results in partially burned hydrocarbons during combustion process. So the hydrocarbon emission is higher for the neem oil. After converting neem oil to neem oil methyl ester, the HC emission decreases, indicating improved combustion with esters.

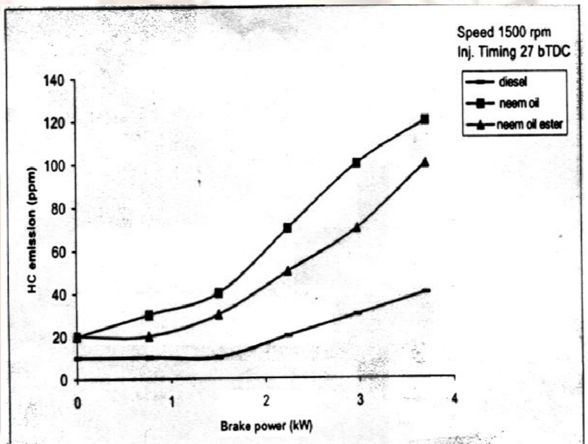

Fig.6 Variation HC emission with brake power

Tests with Preheated Neem Oil at Various Temperatures

In these tests the diesel engine was operated with preheated neemoil at various fuel temperatures like 50°C, 90°C, 120°C and 160°C

Brake Thermal Efficiency

It is evident from Fig.6 that the maximum brake thermal efficiency at full load increases by preheating the fuel because of lower viscosity. When operating with neem oil at 160°C (temperature at which neem oil viscosity is equal to diesel viscosity at ambient temperature) the maximum brake thermal efficiency at full load increases from 24.5% to 29.1%, which is close to diesel operation 31.4%. Higher fuel temperature helps to reduce the viscosity of neem oil, which improves the fuel spray characteristics; atomization proves the fuel spray characteristics, atomization, resulting in better combustion.

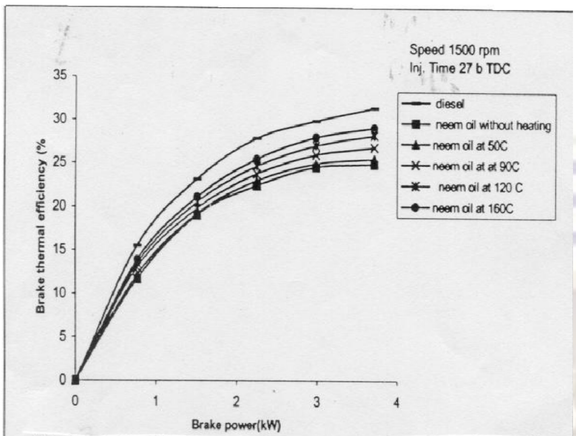

Fig.7 Variation of brake thermal efficiency with power for various fuel temperatures

Smoke Emission

Fig.7 shows the comparison of smoke emission at various fuel temperatures. The smoke emission with neem oil is higher than diesel. When fuel temperature increases the smoke tends to reduce. While neem oil is operating at 160°C smoke reduces from 4.1 to 3.1 BSU, which is near to diesel operation with a smoke intensity of 2.8 BSU at maximum load. The reduction in smoke emission is due to more complete combustion of preheated neem oil.

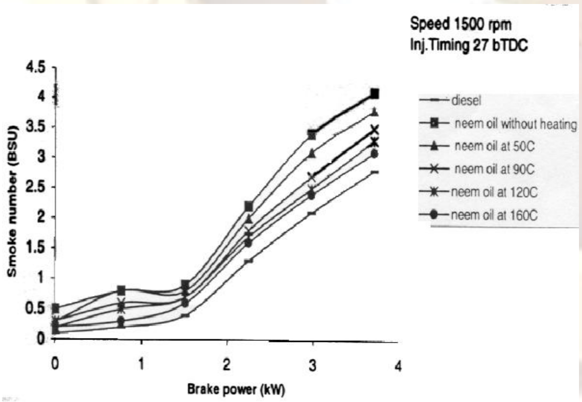

Fig.8 Variation of smoke number with brake power at various fuel temperatures

CO Emission

Fig.8 shows the comparison of carbon monoxide emission of neem oil at different fuel temperatures. The CO emission of neem oil without heating is 0.34% at maximum load, which decreases to 0.22% at fuel temperature 160°C. The CO emission of diesel is 0.19% at maximum load. When the fuel temperature increases, the CO emission decreases. The fall in CO emission is an outcome of improved oxidization of carbon monoxide to carbon dioxide. The increase in fuel temperature of preheated neem oil helps to increase the combustion temperature, thus reduction in CO emission is obtained.

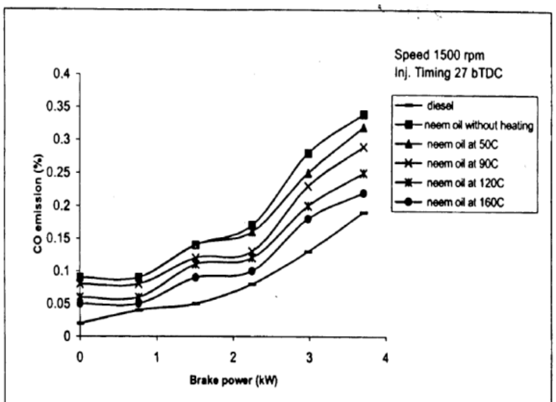

Fig.9 Variation of CO emission with power at various fuel temperatures

HC Emission

Fig.9 shows the comparison of HC emission of neem oil at different fuel temperatures. The HC emission of neem oil decreases with increase in fuel temperature. The HC emission of neem oil without heating is 120 ppm, which reduces to 60 ppm at 160°C. The HC emission of diesel is 40 ppm at maximum load. When fuel temperature increases, there will be some thermal dissociation of fuel particles, which increases concentration of chemically active fuel radicals. The pre-activated fuel radicals will ignite and combust much more rapidly upon injection in to the cylinder than fuel at conventional temperature. So the unburned hydrocarbon decreases with increase in fuel temperature.

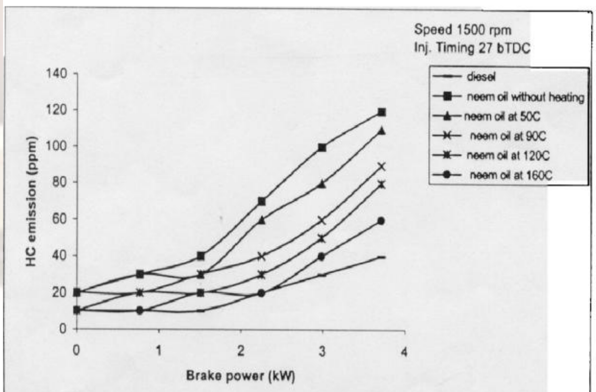

Fig.10 Variation of HC emission with power at various fuel temperatures

Neem Oil- Gasoline Dual Fuel Mode- Brake Thermal Efficiency

The variation of the break thermal efficiency is shown in Fig.10. With zero percentage of energy share of petrol, the values of brake thermal efficiency are 28.4% for diesel, 24% for neem oil and 26.8% for neem oil ester. The brake thermal efficiency increases with the increasing amount of petrol carbureted at constant loads. This happens because of the better combustion of the petrol-air mixture. At 60% of full load, the break thermal efficiency increases up to 35.2% from 28.4% at 24.4% energy share of petrol in petrol-diesel fuel mode. For the same load, brake thermal efficiency increases up to30.5% from 24% at 33.7% energy share of petrol in petrol-neem oil fuel mode and brake thermal efficiency increases up to 32.7% from 26.8% at 30.3% energy share of petrol in petrol-neem oil ester fuel mode. When petrol is inducted into combustion chamber, a homogeneous mixture is formed, resulting in better combustion, thus causing an increase in the brake thermal efficiency.

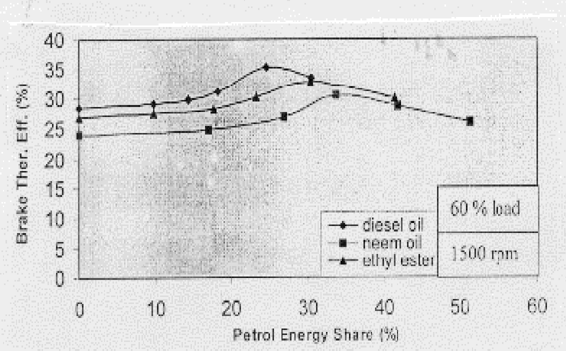

Fig.11 Variation of brake thermal efficiency with petrol energy share

When the petrol flow rate is higher, the flame propagation is enhanced so the combustion becomes very rapid and engine starts knocking after a particular amount of petrol admission for all fuels mode at constant load. Engine starts knocking just after the point, where the maximum brake thermal efficiency is obtained.

Smoke Emissions

The variation of smoke emissions is shown in the Fig.12 for all three fuel modes. The smoke emission decreases considerably, with the increase in carburetion of petrol, for constant load condition. The petrol air mixture is more homogeneous and pilot fuel quantity is reduced so the combustion process is accelerated resulting in less smoke emission. Smoke intensity reduces, from 3.1 BSU to 2.3 BSU for (neem oil + petrol) at 33.7% energy share of petrol; from 2.4 BSU to 1.5 BSU for (neem oil ethyl ester + petrol) at 30.3% energy share of petrol and 2.1 BSU to 1.3 BSU for (diesel+ petrol) at 24.4% energy share of petrol.

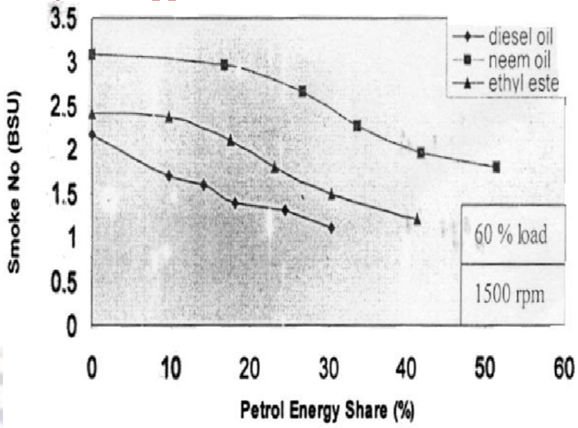

Fig.12 Variation of smoke intensity with petrol energy share

HC and CO Emissions

The variation of HC and CO emissions are shown in the Figs.13 and 14 for constant load. The HC emissions increase with the increase in the carbureted amount of petrol. The diesel quantity decreases as a result of which some quantity of the carbureted fuel does not burn completely due to flame quenching. The CO emissions also increase with the increase in the petrol carburetion. This is again due to fuel flame quenching in a duel fuel engine.. At 60% of full load the HC emission increases up to 90 ppm from 70 ppm and CO emission increases up to 0.38% from 0.3% at 24.4% energy share of petrol in petrol-diesel fuel mode. For same load condition, HC emission increases up to 140 ppm from 90 ppm and CO emission increases up to 0.7% from0.6% at 33.7% energy share of petrol in petrol-neem oil fuel mode and HC emission increases up to 120 ppm from 80 ppm, CO emission increases up to 0.57% from 0.39% at 30.3% energy share of petrol in petrol-neem oil ester fuel mode

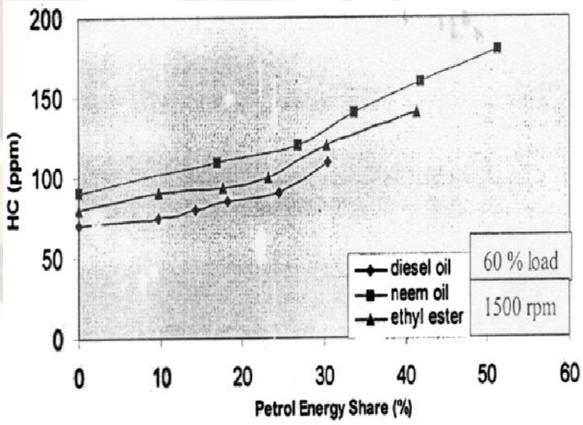

Fig.13 Variation of HC emission with petrol energy share

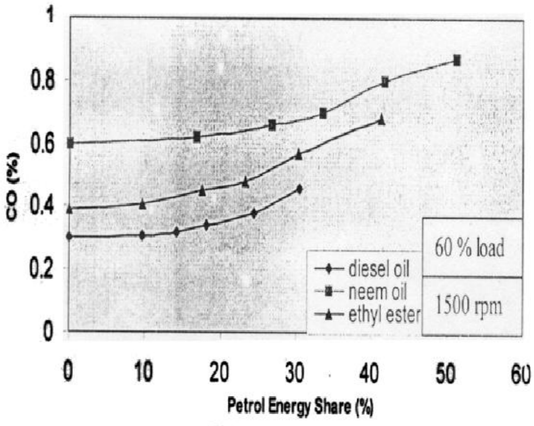

Fig.14 Variation of CO emission with petrol energy share

V. CONCLUSION

The following conclusions are given based on the present work

- The break thermal efficiency of neem oil is 24.9%, neem oil ester is 26.39% and that of diesel is 31.4% at full load. The reduced break thermal efficiency of neem oil is due to poor combustion as a result of high viscosity and density.
- The smoke number of neem oil is 4.1 BSU, neem oil ester is 3.6 BSU and diesel is 2.8 BSU. The high viscosity and low volatility of neem oil leads to larger droplet sizes, poor mixture formation, sluggish combustion and increased smoke levels.
- When neem oil operating with fuel temperature at 160°C (fuel temperature at which its viscosity is equal to diesel viscosity), the maximum brake thermal efficiency obtained is closer to the brake thermal efficiency of diesel. There is a drastic reduction in smoke emission also.

	diesel	neem oil without heating	neem oil 160°C
BTE (%)	31.4	24.9	29.1
Smoke NO (BSU)	2.8	4.1	3.1

- The increase in brake thermal efficiency and reduction in smoke emission with increase in fuel temperature of neem oil are due to better combustion of fuel air mixture as a result of improved atomization during injection. At 60% of full load and 1500 rpm with petrol carburetion, brake thermal efficiency increases from 24% to 30.5% at 33.7% of energy share of petrol for neem oil and from26.8% to 32.3% at 30.3% of energy share of petrol for neem oil ester. Smoke intensity decreases from 3.1 BSU to 2.2 BSU for neem oil, from 2.4BSU to 1.5BSU for neem oil ester at the same operating condition. HC/CO emissions increase with increase in petrol energy share.

REFERENCES

[1]. Gerhard Vellguth, "Performance of vegetable oil and their monoesters as fuel for diesel engine", *SAE Paper* No: 831358, 1983.

[2]. Barsic, N.J. and Humke, A.L, "Performance and emission characteristics of naturally aspirated diesel engine with vegetable oil fuels", *SAE Paper* No: 810262, 1981

[3]. M.Senthil Kumar, A.Ramesh and B.Nagalingam, "Investigations on the use of Jatropha oil and its methyl ester as a fuel in a compression ignition engine", *Journal of Institute of Energy*, March 2001, 74, pp24-28

[4]. A.Ramesh, "Study of Engine Performance and Emission characteristics of a diesel engine using preheated vegetable oil as a fuel," *M.Tech Thesis*, Jan 2003, Dept of Mech Engg., IIT Madras.