Investigations on a Neat Mahua Oil Fuelled C.I Engine with Hydrogen Peroxideas Additive

[1]Guduru VNSR Ratnakara Rao, [2]V Ramachandra Raju, [3]Richa Rani Dewangan

[1]Professor, Mechanical Engineering Department, Sri Vasavi Engineering College,
[2]Professor, JNT University, Kakinada.
[3]Asst. Engineer, Chhatisgarh State Electricity Board, Raipur

Abstract : The present work deals with the investigation of different methods to improve the performance of a variable compression ratio direct injection C. I engine using Mahua oil. In the first stage of experimentation neat mahua oil is used as a fuel and the performance and emission characteristics were obtained. In the next stage of experimentation 5% hydrogen peroxide was added to Mahua oil and the performance is analysed. Further all the results were compared with neat mahua oil operation for various performance parameters like brake thermal efficiency (BTE), exhaust gas temperature and the emission parameters like smoke density, HC, CO and NO.

From the results, it is found that the addition of 5% hydrogen peroxide to Mahua oil also resulted in improved brake thermal efficiency and better emission characteristics. However the percentage addition of hydrogen peroxide is limited to 5%, due to its corrosive nature and presence of water.

Key words: mahua oil, blends of mahua oil, hydrogen peroxide, performance characteristics.

I. INTRODUCTION

Energy is the prime mover of economic growth and is vital to the sustenance of a modern economy. Future economic growth depends entirely on the long term availability of energy from sources that are affordable, accessible and environmental friendly.

Vegetable oils are the chief alternatives to the petroleum based fuels like Diesel. The properties of various vegetable oils are almost close to Diesel leaving apart few exceptions. The vegetable oils have reasonably high cetane number and are oxygen enriched. Vegetable oils are free from sulphur and heavy metals. The vegetable oils have high flash and fire points making them safe to use and carry. The heating value is about 90% of that of Diesel. The viscosities of vegetable oils are high which makes it difficult to atomise and mix them in the engine cylinder.

Among the vegetable oils used as an alternative to Diesel, Mahua oil occupies a commendable position. Mahua is an Indian tropical tree found largely in north Indian plains and forests. It is adapted to arid environments, being prominent tree in tropical deciduous forests in central India. The dryings and decortification yield 70% kernel on the weight of seed. The kernel of seed contains about 50% oil. The oil yield in an expeller is nearly 34%-37%. The fresh oil from properly stored seed is yellow in colour.

Low volatility and high viscosity of the vegetable oils can be overcome by various methods like

1) Transesterification with alcohols,

2) Pre heating,

3) Blending,

4) Use of semi adiabatic engine components,

5) Dual fuelling with superior fuel,

6) Use of additives etc.

II. LITERATURE REVIEW

Several experiments were carried out on C. I engines using additives to analyze the performance and other characteristics.

Song et al. (2003) found that the structure of an oxygenated compound blended with diesel fuel could affect the particulate emissions. 5% oxygen by mass of fuel was added to ethane using DME and ethanol. It has been reported that a significant reduction in aromatic species relative to pure ethane was observed with the addition of DME to ethanol, but DME was found to be more effective in reducing aromatic species than ethanol. Moreover additions of DME lead to higher final temperature.

Cheng et al. (1999) conducted engine tests using oxygenates (DMC and DEE) blended with diesel. His studies revealed the reduction in particulate matter at higher loads. No change has been observed at low loads. Higher fuel consumption and increase in CO_2 emissions were reported with addition of oxygenates.

Kajitani et al. (1997) conducted performance and emission tests on a direct injection Yammar diesel engine with neat DME. In addition, they analysed injector needle lift and heat release and compared with conventional diesel. They reported that the engine operated by DME exhibited remarkable high energy conversion efficiency with low exhaust temperature. The injection period was found much longer than diesel. They observed higher NO emissions with DME with reduced HC and CO emissions. They noted injector wear with DME and suggested that lubricating additives must be added in small quantities when DME is used as fuel.

Rasmus Christensen and Sorenson (1997) conducted studies on a naturally aspirated direct injection diesel engine with DME as fuel. They studied the effects of injection timing and injection system as well as exhaust gas recirculation (EGR). Due to differences in density and viscosity between DME and diesel, they set the fuel injection pump in such a way that the volume of DME injected was 1.8 times that of diesel for the same power. They also used a pressurized fuel system to deliver DME with a transfer pump of 10bar output pressure to eliminate vapour lock. They noted reduction in NO emission by over 70% as compared to diesel. Even with advanced timings they observed reduction in NO. Particulate emissions were low and about 90% of diesel values. They observed low cylinder peak pressure, rate of pressure rise, reduced premixed combustion rate with DME than base diesel operation.

Alam et al. (1999) investigated the performance of a direct injection diesel engine operated with neat dimethyl ether (DME). In their experiments they added DME for reducing NO in the exhaust. They reported higher NO emissions with DME than diesel under the engine manufacturers recommended injection timing. However, NO in the exhaust reduced with increase in DME content. Soot emission with DME was not observed through the entire engine operational region. At around 200^0C, large amount of methanol and formaldehyde formation was observed. Total hydrocarbon emission was much less than the conventional diesel engine. They also observed low HC emissions with DME. They concluded that greater NO reduction can be achieved if the exhaust gas contains a suitable amount of reducing agent.

Wang et al. (2000) conducted experiments to study the performance and emission characteristics of a compression ignition engine fuelled with dimethyl ether (DME) and dimethyl carbonate (DMC). They investigated the effect of exhaust gas recirculation on engine performance and emissions. From the experimental results they found that the DME engine with Exhaust Gas Recirculation could simultaneously reduce smoke and NO emissions. NO reduced to 20% for every 10% of EGR introduction, while smoke was very low. The BSFC showed a slight decrease when DMC was added. It was found that, the smoke reduction rate showed a linear relationship with DMC percentage. CO level reduced when DMC was added, while NO showed an increase. This difference was pronounced at a high BMEP. CO reduced by 20% while NO increased by 20% for every 10% addition of DMC.

They also carried out a study on performance and emission characteristics of a water cooled single cylinder naturally aspirated diesel engine using dimethyl ether (DME) as sole fuel. They used a pressurized fuel supply system by compressed nitrogen and installed a supply pump before the fuel pump to avoid vapour lock. They studied the effect of main parameters of the combustion system, such as plunger diameter, nozzle type, fuel delivery angle, protruding distance of the nozzle tip and swirl ratio on the performance of DME engine. They observed smooth engine operation with DME over wide range of speeds and loads. The efficiency of the engine is increased by 3% as compared to diesel operation. They suggested that by increasing the plunger diameter and the number of orifices, one can achieve higher thermal efficiencies. They also reported that DME needs low injector opening pressure since it is highly volatile. They found lower peak cylinder pressure, shorter ignition delay and low rate of pressure rise with high thermal efficiency. They found smokeless combustion with reduced NO, CO and HC emissions.

III. EXPERIMENTAL SETUP

An experimental setup was made with necessary instruments to analyze the performance, emission and combustion parameters of the engine at different operating conditions. Overall view of the experimental setup is shown in the plate

3.1 EXPERIMENTAL TEST RIG

A four stroke single cylinder diesel engine with an auxiliary water cooled head is coupled to an eddy current dynamometer with the use of star coupling (genuine part from Kirloskar) mounted on a sturdy mild steel channel base as shown in the plate 3.1. Table 3.1 shows specifications of the selected engine test rig.

Table 3.1 Specifications of the engine

Make	Kirloskar
Type	Single cylinder, vertical, water cooled, variable compression ratio
Bore	70mm
Stroke	110mm
Rated speed	1500 rpm
Rated power	3.2kW
Compression ratio	Variable from 13.2 to 20.2

3.2 CONTROL PANEL WITH COMPLETE SET OF INSTRUMENTATION

Digital indicators are mounted on the control panel for indicating air-rate, fuel-rate, torque, temperature, water flow, and speed & signal conditioner for P-V, P-θ (interface unit). Burette & a manometer are connected as stand-by option. A load controller is mounted on the same panel for varying loads.

3.3 TEST PARAMETERS

The selection of various parameters to be measured from the engine is essential in analyzing the performance of the engine. The main parameters required are listed below:

a) Power developed by the engine

b) Fuel consumption rate

c) Speed of the engine

d) Exhaust gas composition.

3.4 METHODS OF MEASUREMENT AND SELECTION OF INSTRUMENTS

The measurement of various performance parameters includes measurement of brake torque, cylinder pressure, fuel flow, speed, crank angle, temperature, fuel flow, smoke density, exhaust gas composition etc.

Torque is measured by means of a load cell connected to the loading arms of an eddy current dynamometer.

The cylinder pressure is measured using a piezo transducer plugged into the cylinder head. The fuel consumption is measured by means of a load cell on which the fuel tank is placed. The airflow rate is measured using an orifice connected to the air box. The smoke density is measured using a Hartridge smoke meter, while a Horiba make exhaust gas analyser is used to know the composition of exhaust gases.

Plate 3.1 Overall view of the experimental setup

IV. RESULTS AND DISCUSSION

Hydrogen peroxide by 5% was added to neat Mahua oil to analyze performance and emission parameters of the selected engine. The tests were carried out at a constant speed of 1500rpm while keeping the compression ratio constant at 15.7 which is the optimum compression ratio for Mahua oil. The optimum compression ratio of the engine with neat mahua oil as fuel has been arrived at as a result of previous experimentations carried out on the engine [7]. The blend is limited to 5% due to the corrosive nature and excess water presence in hydrogen peroxide. Water present in the hydrogen peroxide helps in improved intermixing of fuel and air in the combustion chamber to certain extent. The oil being less dense forms an envelope over the inner core of the water droplet during the process of atomization. As the cylinder temperatures increase, the inner core expands and the droplet explodes. This results in better mixing of fuel with air present in the engine cylinder. This is evident from the improvement in brake thermal efficiency by more than 1%.

Fig.4.1 shows 4.2% increase in brake thermal efficiency from 26.14% with neat Mahua oil to 27% with hydrogen peroxide. This may be due to the better oxidation characteristics of hydrogen peroxide and increased volatility of the mixture.

The smoke density is also much less compared to neat Mahua oil. From Fig.4.2, it can be noted that the addition of hydrogen peroxide resulted in the reduction of smoke density by 33% from 45 HSU to 30HSU.

Fig.4.3 predicts the reduced exhaust gas temperatures with the 5% hydrogen peroxide blend at full loads. This indicates decreased ignition delay due to the presence of hydrogen peroxide. Once the ignition delay is reduced, major amount of fuel burns during the controlled combustion phase thus, leading to reduced exhaust temperatures.

HC, CO and NO emissions were also found to be reduced by 5.18%, 15.38% and 0.67% with the hydrogen peroxide blend. This is evident from the Fig.4.4, Fig.4.5 and Fig.4.6 respectively.

The HC emission is reduced from 135ppm to 128ppm, CO emissions reduced from 0.26% to 0.22% while the NO reduced to 735ppm from 740ppm due to the addition of 5% hydrogen peroxide to Mahua oil.

Fig.4.7 shows the increased cylinder pressure and the Fig.4.8 shows the improved heat release with the addition of hydrogen peroxide to neat Mahua oil.

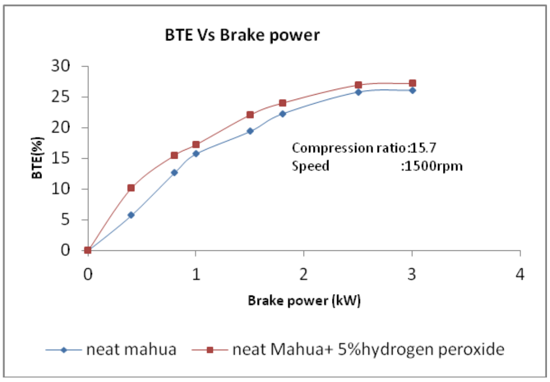

Fig.4.1 Variation in brake thermal efficiency with the addition of hydrogen peroxide to Mahua oil

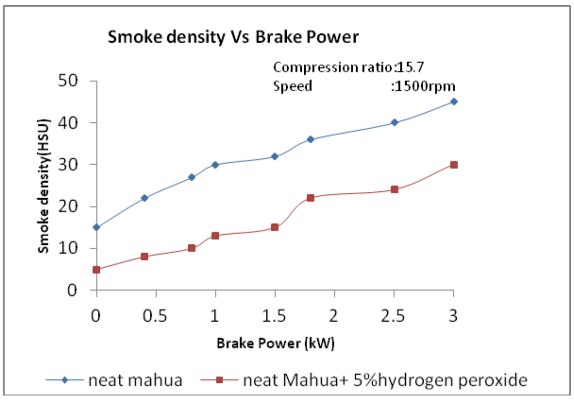

Fig.4.2 Variation in smoke density with the addition of hydrogen peroxideto Mahua oil

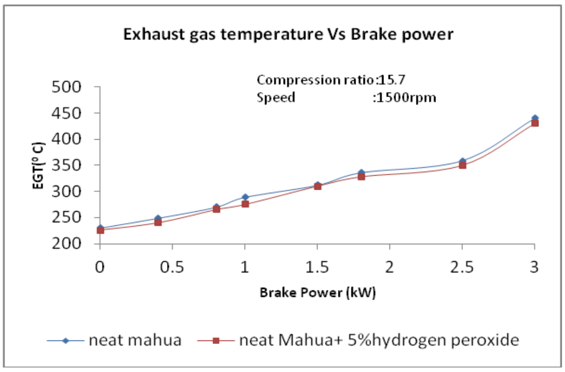

Fig.4.3 Variation in exhaust gas temperature with the addition of Hydrogen peroxideto Mahua oil

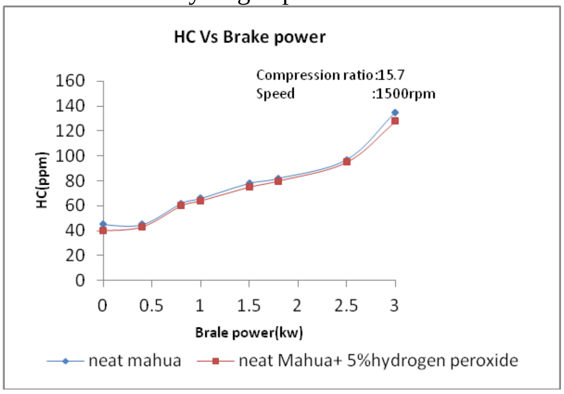

Fig.4.4 Variation in HC with the addition of hydrogen peroxideto Mahua oil

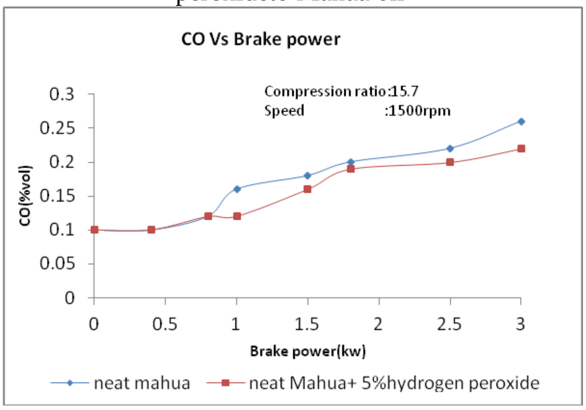

Fig.4.5 Variation in CO with the addition of hydrogen peroxideto Mahua oil

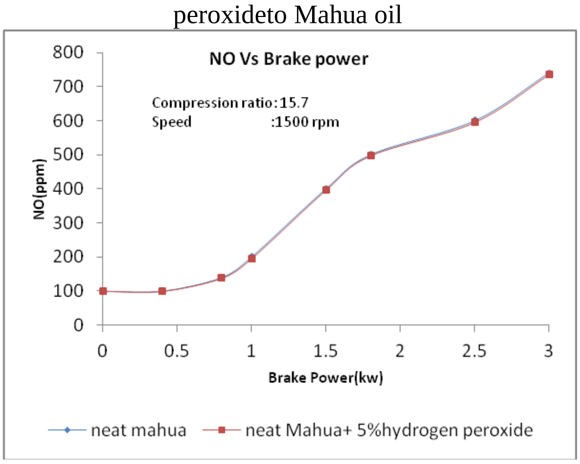

Fig.4.6 Variation in NO with the addition of hydrogen peroxideto Mahua oil

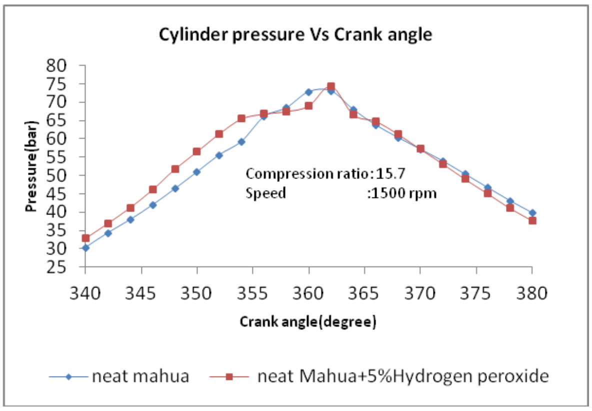

Fig.4.7 Variation in cylinder pressure with the addition of hydrogen peroxideto Mahua oil

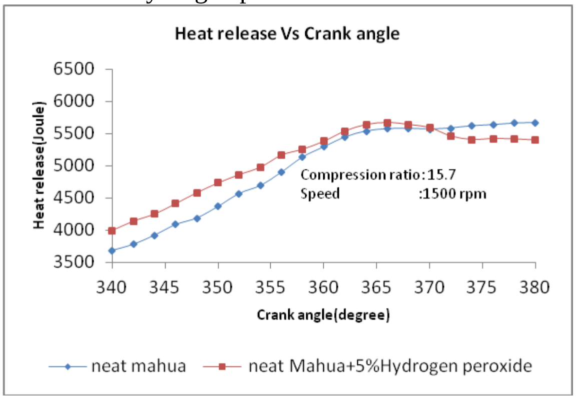

Fig.4.8 Variation in heat release with the addition of hydrogen peroxideto Mahua oil

V. CONCLUSIONS

Following are the summary of results obtained by the addition of 5% of H_2O_2 to neat Mahua oil.

1. There is a rise in BTE by 4.19%.
2. Exhaust gas temperatures were decreased by 2.27%.
3. There is a 33.3% reduction in smoke density.
4. HC and CO in the exhaust were decreased by 5.18% and 15.38% respectively.
5. NO in the exhaust is reduced by 0.6756%.

REFERENCES

[1] A.S. Cheng, D. W. Dibble (1999), Emissions Performance of oxygenate-in-diesel blends and Fischer-Tropsch diesel in a Compression Ignition Engine, SAE 1999-01-3606.

[2] Alam M., O. Fujita, and K. Ito (1999), Performance of NO Catalyst in a DI diesel engine operated with neat dimethyl ether, Society of Automotive Engineers, Paper No. 1999-01-3599, USA.

[3] K. H. Song, P. Nag, T. A. Litzinger, D. C. Haworth (2003), Effects of oxygenated additives on aromatic species in fuel-rich premixed ethane

combustion: a modeling study, Combustion and Flame, 135, 9, 341-349.

[4] Kajitani, S., Z. L. Chen and M. Konno (1997), Engine Performance and Exhaust Characteristics of Direct Injection Diesel Engine Operated with DME. Society of Automotive Engineers, paper No. 972973, USA.

[5] Rasmus Christensen and S.C. Sorenson (1997), Engine Operation on dimethyl ether in a naturally Aspirated DI Diesel engine Society of Automotive Engineers, paper No. 971665, USA.

[6] Wang H. W, Z. H. Huang, and L. B. Jiangand, Z. I. Yang(2000), Investigation on Emission Characteristics of a Compression Ignition Engine with Oxygenated Fuels and Exhaust Gas Recirculation. Proceedings of Institute of Mechanical Engineers, 214, Part D, 2000, 503-508, London.

[7] GNSR Ratnakara Rao, V. Ramachandra Raju, Muralidhara Rao (2009), Optimising the compression ratio for a Mahua oil fuelled C.I engine", JEAS, Vol 4, No.3, May 2009.