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Effect of Eucalyptus - Mahua oil on performance and emission characteristics on a dual fuel engine operation

Arul Selvan Subramaniyan* and Senthilkumar Masimalai
Department of Automobile Engineering, Madras Institute of Technology, Anna University, Chennai-600 044, (T.N), India
***Corresponding author: E-Mail: arul.automobile@gmail.com**

ABSTRACT

Vegetable oil combustion in unmodified diesel engine results in increased smoke and inferior thermal efficiency. One of the effective methods to reduce smoke and increase thermal efficiency is use of in dual fuel combustion with primary (high octane fuel) and pilot (high cetane number) fuels . Primary fuel is premixed with air in the modified intake system and Pilot fuel act as a ignition source for combustion. The experimental work reported here is caried out in a single cylinder constant speed diesel engine with the modification in the intake system to study the effect of varying proportion of primary fuels(eucalyptus oil) with injected Pilot fuel (mahua vegetable oil). Performance and emission parameters are discussed for different energy share of eucalyptus oil . First baseline reading with diesel and neat mahua oil is taken for full load (100 %) . Subsequently experiements were repeated with full load condition operated using neat mahua oil in the modified engine to vary the proportion of eucalyptus oil till engine could tolerate. It was found that there is a significant increase in the brake thermal efficiency of neat Mahua oil-Eucalyptus dual fuel mode compared to Diesel-Eucalyptus dual fuel mode. A drastic reduction in smoke and nitric oxide are observed with the mahua-eucalyptus dual fueling. The total hydrocarbon emision and carbon monoxide emission increases significantly for eucalyptus induction compared to neat mahau oil.

KEY WORDS: Eucalyptus, Mahua oil, Fossil fuel

1. INTRODUCTION

Growing demand for energy using fossil fuel operated diesel engines with their higher heat efficiency, fuel economy and durability increases day by day through the world. However, depletion in petroleum resources and environmental concern has raised interest in the global community and researcher for sustainable and environment friendly alternative fuels. The use of vegetable oil based alternative fuels derived from renewable sources is very attractive for reducing the dependence on fossil fuel derived from petroleum refineries. Most of the properties of vegetable oil is close with standard diesel with higher viscosity, lower volatility and lower heating value. Vegetable oil can be used directly in diesel engine with reduced thermal efficiency and increased smoke emission. There are other ways of using the vegetable fuel in diesel engine i.e blending, heating, thermal cracking, transesterification, emulsion etc. Each method has its own significance and limitations. However, dual fuel mode of operating the internal combustion engines to improve performance and reduce emission is attractive due to their clean combustion characteristics.

In this research work, engine is modified to operate in the dual fuel mode with mahua oil as pilot injected fuel and eucalyptus oil as inducted primary fuel. The fuels used in this research work are 100% pure non-edible mahua oil derived from Madhuca Indica seed and pure eucalyptus oil extracted from forest eucalyptus tree. The neat Mahua oil is procured from a remote village of Kanchipuram district of Tamil Nadu in India and eucalyptus oil from Kodaikannal hills of Tamilnadu in India.

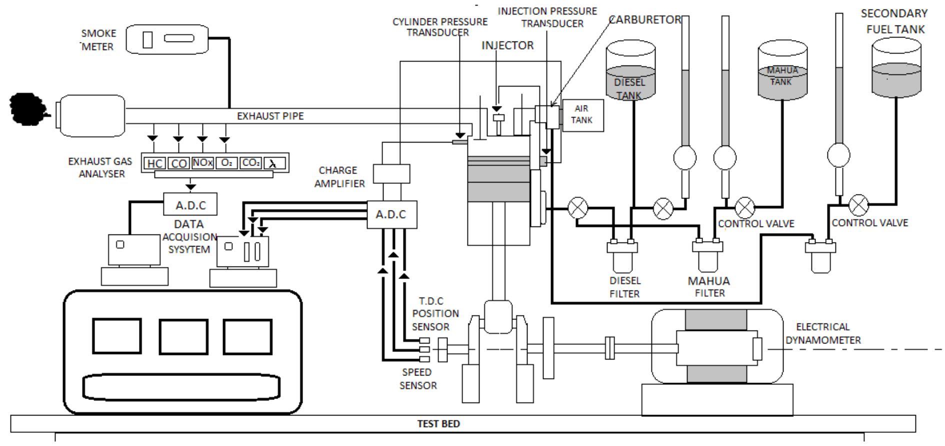

Figure.1. Schematic of test engine set-up

2. EXPERIMENTAL SETUP AND TEST PROCEDURE

A schematic diagram of experimental engine setup is shown in Fig. 1 and the specifications of the test engine are provided in Table1.Test were done on 100 % load at constant speed in naturally aspirated condition in direct injection diesel engine. All the reading were taken out after reaching the steady state operation at full load. Exhaust gas temperature were measured using 'K type' thermocouples from exhaust side. Separate fuel tank and burette measurement arrangement was done for primary fuel induction.

Table.1. Engine Specifications

General Details	Single Cylinder, Four Stroke, Compression Ignition, Constant Speed, Vertical, Water Cooled, Direct Injection
Rated Power (KW)	3.7 @1500 rpm
Bore / Stroke (mm)	80/110
Compression Ratio	16.5
Connecting Rod Length (mm)	235
Swept Volume (CC)	550
Clearance Volume (CC)	36.87
Nozzle Opening Pressure (Bar)	200,240
Injection Timing (BTDC)	27

3. RESULTS AND DISCUSSION

The variation of brake thermal efficiency of neat mahua oil and standard diesel at different eucalyptus energy share can be seen in Fig. 2. Brake thermal efficiency is the measure of how efficiently the primary and pilot fuel is burned inside the cylinder and generates heat. It depends on number of factors like combustion phasing and combustion duration and heat transfer losses etc. Due to higher viscosity, mixture formation inside the cylinder is affected for neat mahau oil compared to base diesel. This results in the lower brake thermal efficiency for neat mahua oil. The brake thermal efficiency with mahua oil is about 25.18 % and 30 .80 % for diesel at zero percentage eucalyptus energy fuel. As eucalyptus energy share is increased, there is a drastic rise in brake thermal efficiency of neat mahua oil compared to standard diesel, due to efficient combustion inside the cylinder. The Maximum values are 32.26 % and 33.52 % when mahua oil and diesel are used as pilots respectively. The maximum admittable limit of eucalyptus oil is 53.6 % and 70.1% in mass basis, beyond that engine gets knock.

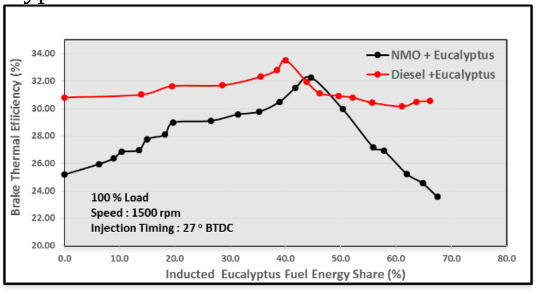

Figure.2. Variation of Brake Thermal Efficiency with Eucalyptus oil Energy Share

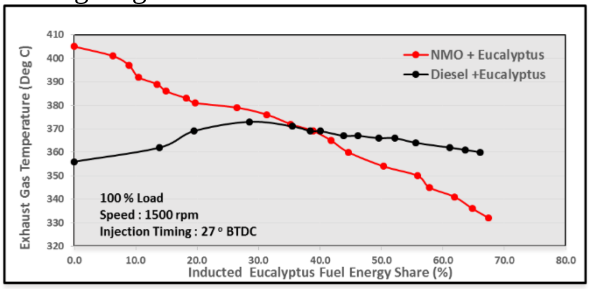

Figure.3. Variation of Exhaust Gas Temperature with Eucalyptus oil Energy Share

The variation of exhaust gas temperature versus eucalyptus energy share percent at full load operating condition was shown in figure 3. The exhaust gas temperature decreases with eucalyptus oil enrichment from 405ºC at zero percent to 360ºC at 67.5% (maximum efficiency flow). At 6.3%, 10.4%, 19.7%, 31.4%, 41.8%, 50.4%, 61.9%, 67.5% eucalyptus energy share, the measured exhaust gas temperature was 401ºC, 392ºC, 381ºC, 376ºC, 365ºC, 354ºC, 341ºC, 332ºC respectively. Decrease in cylinder temperature and improvement in thermal efficiency, shows the volatility of the fuel and it aids in reducing the viscosity of the sprayed mahau oil from fuel injector and making overall mixture to combustible. But in the case of standard diesel, it initially increase and drops after maximum efficiency thermal efficiency point.

Figure 4. Shows that for two fuels namely standard diesel and mahau, smoke was reduced drastically by the effect of premixing the eucalyptus oil with intake air. The smoke value reduced with eucalyptus induction from 78% at zero percent to 41 at 67.5% (maximum efficiency flow). At 6.3%, 10.4%, 19.7%, 31.4%, 41.8%, 50.4%, 61.9%, 67.5% eucalyptus energy share, the measured smoke percentage was 72, 62, 48, 45, 42, 40, 36, and 28 respectively.

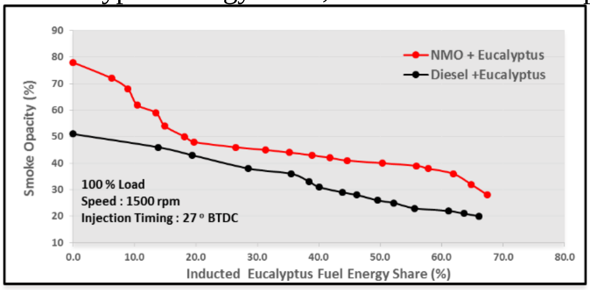

Figure.4.Variation of Smoke with different percentage of Eucalyptus oil Energy Share

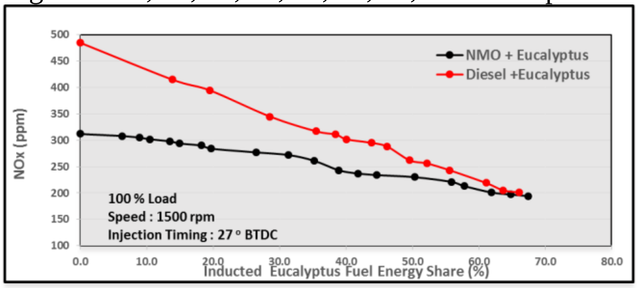

Figure.5.Variation of Nitric Oxide emission with Eucalyptus oil Energy Share

Decrease in smoke is mainly due to break down of large hydrocarbon molecule from mahua injected fuel by high volatility (i.e no heavy hydrocarbon) and vaporization characteristics of inducted eucalyptus oil.

The variation of NOx emissions formed in the cylinder for standard diesel and neat mahau oil for different energy share of eucalyptus oil are plotted in figure.5. It can be seen that, as the eucalyptus fuel percentage is increased, substantial reductions in NOx are achieved. NOx formation depends on cylinder temperatures, and it is combination of nitric oxide and nitrogen dioxide. The addition of eucalyptus fuel keeps on increase the ignition delay, due to higher self-ignition temperature, hence combustion temperature drops, which would result in reduced NOx. NOx emission for standard diesel and neat mahau oil with zero percent eucalyptus oil is 485 ppm and 312 ppm. The NOx drops to 234 ppm at the maximum thermal efficiency condition (i.e 44.6% of eucalyptus energy share), which is lesser than standard diesel operation at full load.

As seen in the below figure 6. , the hydrocarbon emission formed inside the cylinder, increases with standard diesel and neat mahau oil for different percentage of eucalyptus oil. HC formation depends on complete combustion in the cylinder, and it is combination of premixed and pilot fuel. The addition of eucalyptus fuel keeps on reduces the ignition capability of the premixed eucalyptus oil, hence in-complete combustion, which would result in increased HC emission. HC emission for standard diesel and neat mahau oil with zero percent eucalyptus oil is 110 ppm and 172 ppm. The HC increases to 260 ppm at the maximum thermal efficiency condition (i.e 44.6 % of eucalyptus energy share), which is nearly two and half times the standard diesel operation at full load.

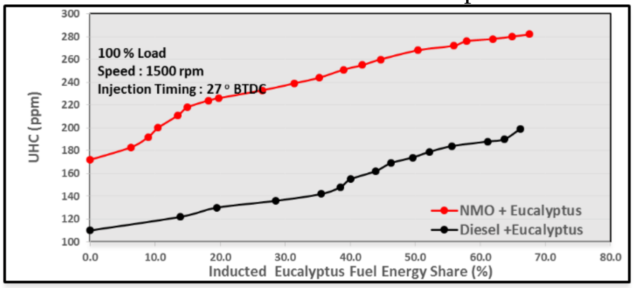

Figure.6.Variation of Unburned hydrocarbon emission with Eucalyptus oil Energy Share

The variation of carbon monoxide emission at full load for standard diesel and neat mahau oil for different energy share of eucalyptus oil are plotted in figure.7. CO emission was noted about 0.18% and 0.26% for zero percent admission of eucalyptus oil for diesel and mahua oil. It can be observed from the graph, as eucalyptus fuel percentage increased, there is a significant rise in CO value. CO formation depends on air fuel ratio, and hence over-rich mixture would result in increased CO value. The CO increase from 0.26% to 0.45% at the maximum thermal efficiency condition (i.e 44.6% of eucalyptus energy share), which is more than standard diesel operation at full load. As eucalyptus share increased further, there is drop CO due to oxidation of carbon content, which is reflected in the heat release rate.

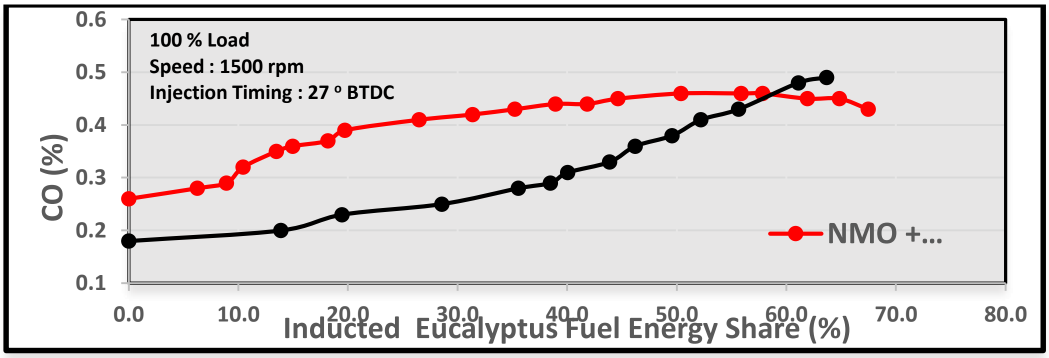

Figure.7. Variation of Carbon Monoxide emission with Eucalyptus oil Energy Share

The variation of heat release rate with crank angle at full load condition for zero percent i.e Neat Mahau oil, maximum efficiency energy share (44.6%) and maximum possible energy share (67.5%) are shown in the Figure 8. The heat-release analysis is estimated based on first law of thermodynamics, from the change in the cylinder pressure value and cylinder volume during the cycle. Also few engine dimensional values is needed. It is observed that the premixed combustion increases and diffusion combustion decrease in heat release rate with increases in energy share percentage of eucalyptus oil. The reason for this trend is the use of oxygenated fuels to improve the combustion stably inside the cylinder. The maximum possible eucalyptus energy share is 67.5% and remaining 32.5% is supplied by mahua oil, beyond this energy share engine knocks.

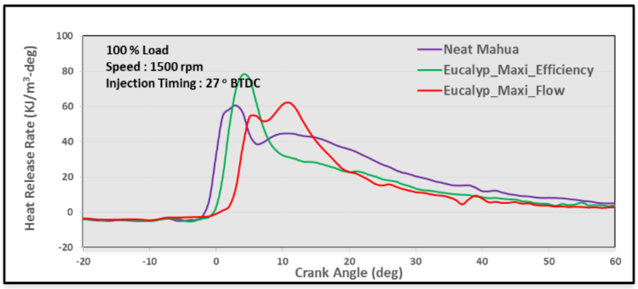

Figure.8.Variation of Heat Release rate with different Eucalyptus oil Energy Share (Zero Percent Energy Share, Maximum Efficiency energy Share, Maximum Possible Share)

4. CONCLUSION

The present research work reveals that it is possible to induct eucalyptus oil as a primary fuel in dual fuel mode to improve the performance of a neat mahau oil at full load in a single cylinder compression ignition engine. The maximum energy share of eucalyptus oil that can be inducted is limited by knock. It is found that the brake thermal efficiency increases from 25.18% to 32.26% with neat mahua-eucalyptus dual fuel mode operation, whereas for diesel-eucalyptus dual fuel mode it increases from 30.8% to 33.52%. The increase in heat release rate substantiate this rise in brake thermal efficiency due to eucalyptus oil induction. The maximum amount of energy share of eucalyptus oil that can be inducted along the intake air is 67.5% and maximum rise of 32.32% is attained at an energy share basis of 44.6%. A drastic reduction in smoke level from 78 to 41 at maximum efficiency point (44.6%) and from 78 to 28 at maximum induction point (67.5%) is achieved. Also significant drop in NO_x level from 312 ppm to 234 ppm is obtained at maximum efficiency point (44.6%) and to 194 ppm at maximum induction point (67.5%). The drop in exhaust gas temperature is significant compared to neat mahau operation and standard diesel operation. Thus this research in dual fuel mode, will allow to use eucalyptus oil in neat vegetable oil (mahau oil), to operate with improved performance, reduced smoke and NO_x level. But hydrocarbon and carbon monoxide increases due to inducted eucalyptus oil is drawback.

REFERENCES

Lata D.B, Ashok Mishra, and Medhekar S, Effect of hydrogen and LPG addition on the efficiency and emissions of a dual fuel diesel engine, International Journal of Hydrogen Energy, 37, 2012, 6084-6096.

Qian Xiong, Kazuki Inaba, Influence of fuel properties on operational range and combustion characteristics of premixed diesel combustion with high volatility fuel, International Journal of Engine Research, 15 (5), 2014, 557-564.

Raheman H, and Ghadge S.V, Performance of Compression Ignition Engine with Mahua (Madhuca Indica) Biodiesel, Fuel, 86, 2007, 2568-2573.

Sangita Yadav, Poonam Suneja, Zakir Hussain, Prospects and Potential of Madhuca Longifolia (Koenig) J.F. Macbride for nutritional and industrial purpose, Biomass and Bioenergy, 35, 2011, 1539-1544.

Senthilkumar Masimalai, Ramesh A, and Nagalingam B, Experimental Investigations on a Jatropha oil Methanol Dual Fuel Engine, SAE Technical Paper, 2001.

Sharanappa Godiganur, Suryanarayana Murthy C.H, and Rana Pratap Reddy, 6BTA 5.9 G2-1 Cummins engine Performance and emission tests using methyl ester mahua (Madhuca indica) oil/diesel blends, Renewable Energy, 34, 2009, 2172-2177.

Sukumar Puhan, Vedraman N, Boppana VB Ram, Sankaranarayanan G, Jeyachandran K, Mahua oil (Madhuca Indica seed Oil) methyl ester as bio-diesel-preparation and Emission Characteristics, Biomass and Bioenergy, 28, 2005, 87-93.