Performance and Emission Characterization of Mahua Methyl Ester

U.Ravindranath [#1], M.V.Jagannadha Raju [*2], Ugandhar Puli [$3], Dhanunjaya Naidu[$4]

[#]*Government Polytechnic, Visakhapatnam*

**Department of Mechanical Engineering, Andhra University, Visakhapatnam.*

[$]*Government Polytechnic, Vizianagaram*

Abstract *As crude oil price reach a new high, the need for developing alternate fuels has become acute. Alternate fuels should be economically attractive in order to compete with currently used fossil fuels. In this research work, biodiesel (ethyl ester) was prepared from Mahua oil. Ethyl alcohol (Methanol) with potassium hydroxide as a catalyst was used for the transesterification process. The biodiesel was characterized by its physical and fuel properties including density, viscosity, flash point according to ASTM standards. Production of biodiesel from Mahua oil for diesel substitute is particularly important because of the decreasing trend of economical oil reserves, environmental problems caused due to fossil fuel use and the high price of petroleum products in the international market. The performance evaluation of a single cylinder four stroke diesel engine has been done when fuelled with different blends of diesel and biodiesel made of Mahua oil. The present experimental results show that the performance of the biodiesel blend is comparable as that of diesel and Methyl esters of Mahua oil and can be used as an alternative fuel in diesel engine. Exhaust gas analysis indicates that with the use of biodiesel, the percentage of CO, CO_2 and HC decreases which is a good sign as far as ecological conservation is concerned. The other important benefit is biodiesel certainly promotes rural economy*

Keywords — *Bio-diesel, Variable Compression Ratio, Exhaust analysis.*

I. Introduction

(Biodiesel is prepared by base catalyzed reaction which is the most effective process due to high conversion of 98% without any intermediate steps. The following steps are involved in preparing the biodiesel from Mahua oil.

A. Retrieving Mahua oil

Mahua oil (Vippa Noone in Telugu) is obtained from the well dried seeds of a tree named Madhuca longifolia (Vippa chettu in Telugu) which is an Indian tropical tree and found largely in tribal areas. The oil was allowed to settle for 2-3 days and filtration was done to separate unnecessary impurities.

B. Pre-heating of Mahua oil

Before transesterification process, to remove water in the oil, the filtered Mahua oil was subjected to pre-heating to 100 ^{0} C for 15 minutes with continuous stirring using magnetic stirrer. This helped in drying the oil.

C. Alkali catalysed transesterification of Mahua oil

The alkali catalyzed transesterification was performed due to presence of majority of free fatty acids in Mahua oil. For transesterification of Mahua oil in laboratory, oil was heated in a flat bottom conical flask upto 59 ^{0} C. To ensure the prevention of methanol to reach its boiling point 60 ^{0} C), the optimum reaction temperature was set to be 59 ^{0}C. Now, 1litre of filtered Mahua oil is poured into the reaction vessel and is stirred and simultaneously heated with the help of magnetic stirrer apparatus. First the methanol (MeOH) and the catalyst are mixed which forms Methoxide. Generally 200 ml of methanol is added with 5 gms of NaOH. This is stirred continually on magnetic stirrer for forming Methoxide.

This Methoxide is added to Mahuaoil at temp of 50 ^{0}C. After the methanol and catalyst are mixed, they go into a reactor, where the Mahua oil is added to the mix. Mahua oil is first run through a filter to remove the fatty acids. This mixture is agitated continuously for 1 to 4 hours and heated. The oil is converted to esters during this stage. Glycerin and methyl esters are the two major products created after the reaction is complete and the excess methanol has been removed from the mixture. Gravity is used to separate the two products, since they have different densities. Glycerin is the denser of the two products. The glycerin is then drawn off the bottom of the tank.

This biodiesel is then blended with diesel and various blends such as 5BD, 10BD and 20BD are prepared for conducting CI engine experiment for performance and emission characteristics. Proper characterization of biodiesel blends and diesel is also done in laboratory as per ASTM norms and presented in Table -1. Specific gravity of blends and kinematic viscosity is measured using Red Wood Viscometer.

Table-1 Properties of Mahua oil, Mahua methyl esters and its blends

Fuel	Viscosity mm^2/s at 40^oC	Calorific value MJ/kg	Density kg/m3 at 40^oC	Flash point ^oC
Diesel	3.8	42.8	830	58
Mahua oil	18.4	36.1	918	207
5 BD	16	38	901	192
10 BD	9	39	883	160
20 BD	4.2	40	810	91

II. EXPERIMENTAL SET- UP

The setup consists of single cylinder, four stroke, Multi-fuel VCR research engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The set up has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package "Engine soft" is provided for on line performance evaluation. Diesel engine test rig used for investigations comprised of a single cylinder, water cooled, constant speed, four stroke, variable compression ratio diesel engine connected to an eddy current dynamometer for loading. The set up and its schematic are shown in Fig. 1 and Fig.2 respectively includes necessary instruments for measuring temperatures at various points, load, speed and fuel consumption. Rota meter was used for measuring cooling water and calorimeter water flow. Thermocouples were used for measurement of temperature of exhaust gas, cooling water and calorimeter inlet and outlet. These signals were sent to data acquisition system and to computer for further processing. The specifications of engine and sensors used are given in Table 2. The engine was coupled with Indus five gas exhaust analyser which is used for measuring exhaust gas emissions like HC, CO, CO_2 and NO_x.

.

Fig.1 Test Setup

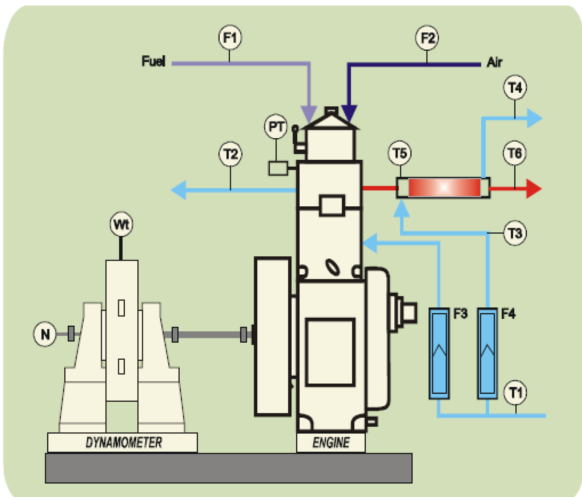

Fig.2 Schematic of Test Setup

III.EXPERIMENTAL PROCEDURE

The condition of the engine oil is checked and availability of water is ensured before starting the engine. Initially, engine was allowed to run at constant speed of 1500 rpm with pure diesel fuel at no load till engine condition stabilizes. The engine was then tested for different loads at compression ratio of 18. For each load the engine was run for 4-5 minutes till engine parameters stabilizes. At every load, fuel consumption and temperatures were recorded. Simultaneously the values of CO_2, CO, HC and NO_x were recorded by using exhaust gas analyzer. The engine then tested with blends of diesel and biodiesel (Easter of Mahua oil) at same setting to obtain base line data. The performance of the engine at different loads was evaluated in terms of brake power (BP), indicated power (IP), brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and mechanical efficiency. CO_2, CO, HC and NO_x were recorded by using exhaust gas analyzer while evaluating the performance of engine fuelled with different blends of diesel and Easter of Mahua oil by using exhaust gas analyzer.

Table 2 Specifications of engine and sensors

Specifications	
Product	Research Engine test setup 1 cylinder, 4 stroke, Multi-fuel (Computerized)
Product code	240
Engine	Type 1 cylinder, 4 stroke, water cooled, stroke 110 mm, bore 87.5 mm. Capacity 661 cc. Diesel mode: Power 3.5 KW, Speed 1500 rpm, CR range 12:1-18:1. Injection variation:0- 25 Deg BTDC Petrol mode: Power 4.5 KW @ 1800 rpm, Speed range 1200-1800 rpm, CR range 6:1-10:1, Spark variation: 0-70 deg BTDC
Dynamometer	Type eddy current, water cooled, with loading unit
Propeller shaft	With universal joints
Air box	M S fabricated with orifice meter and manometer
Fuel tank	Capacity 15 lit, Type: Duel compartment, with fuel metering pipe of glass
Calorimeter	Type Pipe in pipe
Piezo sensor	Combustion: Range 5000 PSI, with low noise cable Diesel line: Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Make-Cuadra, Model AX-409.
Digital voltmeter	Range 0-20V, panel mounted
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, Range 0–1200 Deg C, Output 4–20 mA
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"Enginesoft" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Pump	Type Monoblock
Overall dimensions	W 2000 x D 2500 x H 1500 mm

IV. RESULTS AND ANALYSIS

I Performance Parameters

(A) Brake Thermal Efficiency: It decreases slightly with the increase in % of biodiesel due to poor combustion, low volatility, high viscosity and density

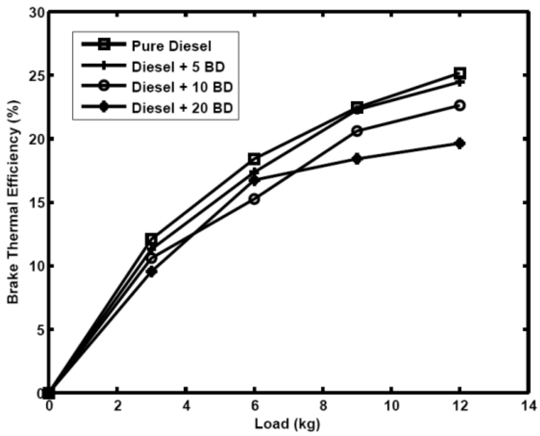

Fig. 3 Brake Thermal Efficiency at various loads and blends

(B) Brake Specific fuel consumption (BSFC): It increases with the increase in % biodiesel due to lower calorific value of biodiesel.

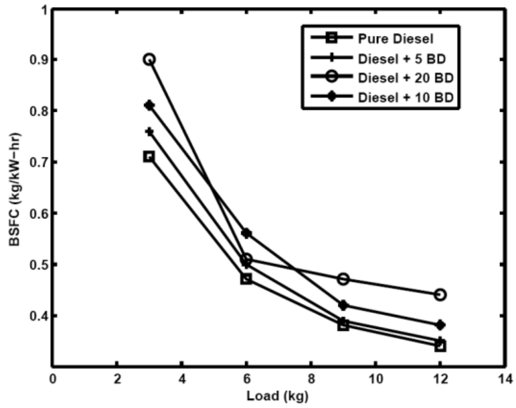

Fig.4 BSFC at various loads and blends

(C) Fuel Consumption: It increases with the increase in % biodiesel due to its low calorific value. As concentration of biodiesel increases, the fuel consumption tends to increase.

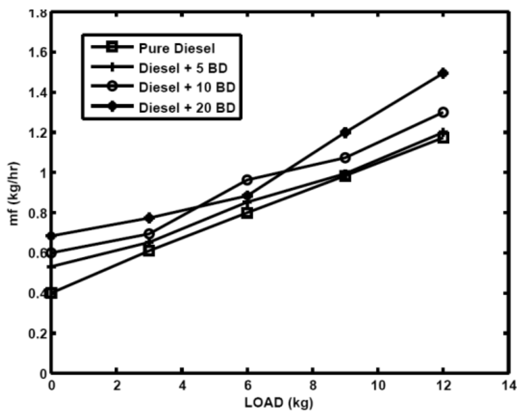

Fig.5 Fuel Consumption at various loads and blends

II. Emission Parameters

(a). % of CO: It decreases with % increase in biodiesel due to better combustion.

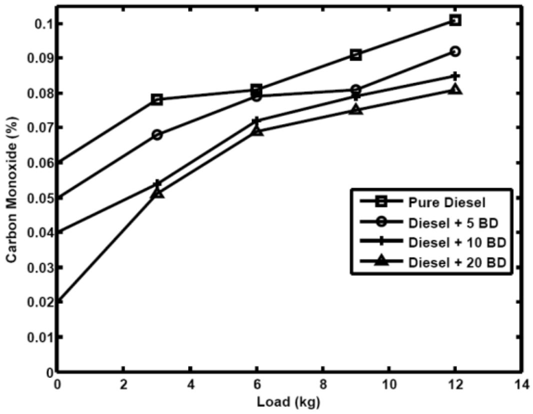

Fig. 6 % CO at various loads and blends

(b) % of CO_2: It decreases with the % increase in biodiesel due to better combustion.

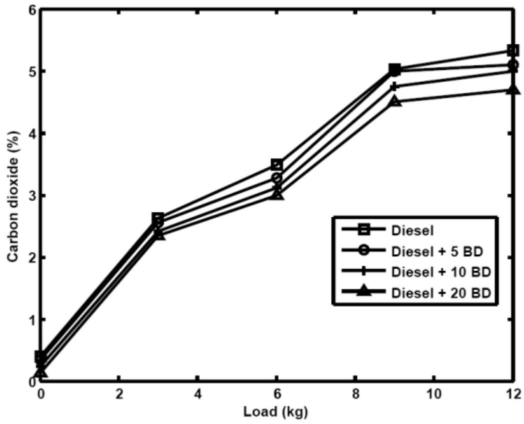

Fig. 7 % CO_2at various loads and blends

(c) Hydrocarbons: With the increase in % of biodiesel, Hydrocarbons are reduced which is due to complete combustion of fuel due to more oxygen content.

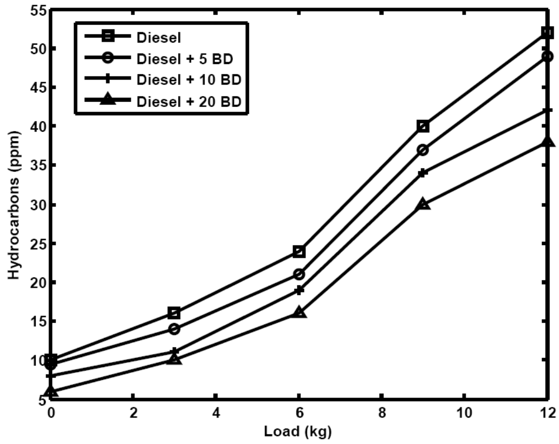

Fig. 8 Hydrocarbons at various loads and blends

(d) Nitrogen Oxide: With the increase in % of biodiesel, NO_x is increased which is due to generation of higher exhaust temperatures and also due to lower cetane number.

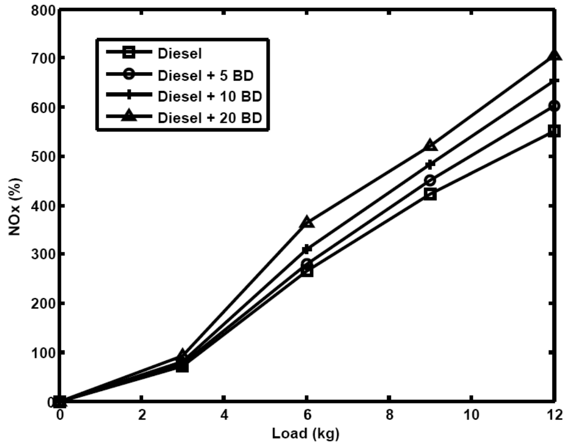

Fig.9 % of NO_xat various loads and blends

V. CONCLUSIONS(SIZE 10 & BOLD)

It is concluded from this research work that, by using various blends of biodiesel of Mahua oil

1. The brake thermal efficiency decreases.
2. The SFC increases.
3. The percentage of CO reduces.
4. The percentage of CO_2 reduces.
5. The percentage of NO_X increases.
6. The performance evaluation indicates that use of biodiesel of Mahua oil is certainly beneficial to environment due to reduction in emissions of green house gasses though it slightly reduces the performance of given engine.

This experiment proves that biodiesels are popular and promising environment friendly alternative fuels due to their renewable nature, clean burning characteristics, less greenhouse effect.

REFERENCES

1. Gerhard Vellguth., Performance of vegetable oils and their monoesters as fuels for diesel engines, *SAE Int.J. paper No*.831358.
2. Murayama T, Oh Y, Miyamoto N, Chikahisa T, Takagi N, Itow K., Low carbon flower buildup, low smoke, and efficient diesel operation with vegetable oils by conversion to mono-esters and blending with diesel oil or alcohols, *SAE paper* No.841161.
3. Nakom Tippayawong , Anusan Permsuman, Nat vorayos, Tanongkiat kiatsiriroat, Srithorn Uppakam, Manu Panyacum., Long term direct injection diesel engine operation on vegetable oils / diesel blends, *JSAE* 2003-01-1932.
4. Recep Altin, Selim Cetinkaya, Huseyin Serdar Yucesu, The potential of using vegetable oils as fuel for diesel engines, *Energy Conversion and Management, 42 (*2001), pp.529-538.
5. Fangrui Ma, and Milford A Hanna, Biodiesel Production: a Review, *Bioresource Technology, 70 (*1999), pp.1-15.