Effect of Fuel Injection Pressure on Diesel Engine Performance and Emission using Blend of Mahua Oil

[1]Sukumar Puhan, [2]B.B.Sahu, [3]Raghu Ram Pradhan, [4]J.Siva Nagaraju

[1,2,3,4]Department of Mechanical Engineering, PACE Institute of Technology and Sciences, India

ABSTRACT : In the present investigation, tests were conducted using a blend of Mahua oil and Diesel in a single cylinder, four stroke air cooled light duty direct injection diesel engine at different injection pressures as injection pressure is one of the main characteristics which effects the performance and emissions of a diesel engine. The injection pressure was increased from 150bar to 210bar (In steps of 30bar). Two test fuels were used during experiments including neat 100 % diesel fuel and a blend of 20% Mahua oil by volume in the diesel. The tests were carried out for the above proportion of Mahua oil and diesel. The performance tests were conducted at 1500 rpm with loading of 20,40,60,80, and 100 percent of maximum load.

KEYWORDS–Engine, Diesel, Mahua oil

I. INTRODUCTION

The diesel engine is a type of internal combustion engine; more specifically, it is a compression ignition engine, in which the fuel ignited solely by the high temperature created by compression of the air-fuel mixture. The engine operates using the diesel cycle. The diesel engine is more efficient than the petrol engine, since the spark-ignition engine consumes more fuel than the compression-ignition engine. The used of diesel engines have extended in the last years to vehicles area due to their high efficiency also by economic fuel cost. In present diesel engines, fuel injection systems have designed to obtain higher injection pressure. So, it is aimed to decrease the exhaust emissions by increasing efficiency of diesel engines. When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation leads to increase pressure. Engine performance will be decrease since combustion process goes to a bad condition. When injection pressure increased of fuel particle diameters will become small. Since formation of mixing of fuel to air becomes better during ignition period, engine performance will be increase. If injection pressure is too higher, ignition delay period becomes shorter. Possibilities of homogeneous mixing decrease and combustion efficiency fall down. The fuel injection system in a direct injection diesel engine is to achieve a high degree of atomization in order to enable sufficient evaporation in a very short time and to achieve sufficient spray penetration in order to utilize the full air charge. The fuel injection system must be able to meter the desired amount of fuel, depending on engine speed and load, and to inject that fuel at the correct time and with the desired rate. Further on, depending on the particular combustion chamber, the appropriate spray shape and structure must be produced. Usually, a supply pump draws the fuel from the fuel tank and carries it's through a filter to the high-pressure injection pump.

Dependent on the area of application and engine size, pressures between 100 and 200 MPa generated. The high pressures injection pump carries the fuel through high-pressure pipes to the injection nozzles in the cylinder head. Excess fuel transported back into the fuel tank. The functionality of the so-called unit pump system is practically identical to that of the unit injector system and offers the same advantages and disadvantages. However, the pump and nozzle not combined into one unit. The camshaft driven a high pressure pump and thus directly coupled with the engine speed. The injection nozzle is located inside also-called nozzle holder in the cylinder head and connected via a high-pressure pipe with the pump. An advantage of this system is that the pump and nozzle not installed at the same place. This reduces the size of the components that have integrated into the cylinder head and simplifies the assembly of the injection system.

Effects of injection pressure on engine performance have investigated on a unit pump system direct injection diesel engine. The diesel engine performance and fuel consumption have been measured at constant speed with varying loads by changing the fuel injection pressure. In the investigation is the effect of injection pressure are conducted using Mahua oil diesel blend ratio (20:80) which is called as B-20 is used at the different fuel injection pressures (150 to 210 bar).

When fuel injection pressure is low, fuel particle diameters will enlarge and ignition delay period during the combustion will increase. This situation leads to inefficient combustion in the engine and causes the increase in NOx, CO emissions. When the injection pressure is increased fuel particle diameters will become small. The mixing of fuel and air becomes better during ignition delay period which causes low CO emission. But, if the injection pressure is too high ignition delay become shorter. So, possibilities of homogeneous mixing decrease and combustion efficiency falls down.

Table 1.1 properties of Mahua oil:

Properties	Diesel	Mahua oil
Kinematic viscosity at 40 ^{0}C (cSt)	4.59	5.47
Density at 15 ^{0}C (kg/m^3)	850	876
Flash point (^{0}C)	52	150
Calorific value (kJ/kg)	42000	39900
Sp.Gravity	0.85	0.876
Ash (% by mass)	0.01	0.14

Sukumar Puhan(2005)et al. In this investigation, Mahua Oil Ethyl Ester was prepared by trans etherification using sulfuric acid (H2SO4) as catalyst and tested in a 4-stroke direct injection natural aspirated diesel engine. Tests were carried out at constant speed of 1500 rev/min at different brake mean effective pressures. Results showed that brake thermal efficiency of Mahua Oil Ethyl Ester (MOEE) was comparable with diesel and it was observed that 26.36% for diesel whereas 26.42% for MOEE. Emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and Bosch smoke number were reduced around 58, 63, 12 and 70%, respectively, in case of MOEE compared to diesel. Based on this study, MOEE can be used a substitute for diesel in diesel engine.

SukumarPuhan(2007)et al.methyl and ethyl ester of mahua oil was prepared by trensesterification, using sulfuric acid (H2SO4) as a catalyst, and tested in a 4-stroke direct injection naturally-aspirated diesel engine. Tests were conducted at a constant speed of 1500 rev/min at varying brake mean effective pressures. Results showed that brake thermal efficiency of mahua oil ethyl ester was comparable to diesel. It was observed that the thermal efficiency at full load for diesel was 26.36%, whereas it was 28.3% for mahua oil methyl (MOME) and 26.42% for ethyl ester (MOEE). Emissions of hydrocarbon (HC), carbon monoxide (CO) and Bosch smoke numbers (BSN) were comparatively lower than that of diesel fuel. The highest reduction in HC emission observed in methyl ester was 60%, compared to 49% for ethyl ester. In the case of CO emission, 79% reduction was observed with methyl ester and 67% for ethyl ester. Oxides of nitrogen emission were comparatively lower and the data observed was 9% for methyl ester and 27% for ethyl ester, at full load. Based on this study, it has been observed that esters of mahua oil could be used as a substitute for diesel.

II EXPERIMENTAL SETUP & PROCEDURE

2.1 Experimental set up

The experimental set up consists of engine, an alternator, top load system, fuel tank along with immersion heater, exhaust gas measuring digital device and manometer.

Engine:

The engine which is supplied by M/s. Alimgar Company the engine is single cylinder vertical type four strokes, Air-coo1ed, compression ignition engine. The engine is self-governed type whose specifications are given in Appendix 1.is used in the present work.

2.2 Reasons for selecting the engine

The above engine is one of the extensively used engines in industrial sector in India. This engine can with stand the peak pressures encountered because of its original high compression ratio. Further, the necessary modifications on the cylinder head and piston crown can be easily carried out in this type of engine. Hence this engine is selected for the present project work.

Dynamometer

The engine is coupled to a generated type electrical dynamometer which is provided for loading the engine.

Fuel injection pump

The pump is driven by consuming some part of the power produced by the engine; it will provide the required pressure to the injector. The pump is BOSCH fuel injection pump.

Fuel injector (BOSCH)

A cross sectional view of a typical BOSCH fuel injector

The injector assembly consists of

i. A needed valve

ii. A compression spring

iii. A nozzle

iv. An injector body

U-tube manometer

The one of end of the U-tube manometer is connected to the orifice of the air tank and the other end is exposed to the atmosphere, the manometer liquid used is water.

Digital thermometer

It consists of a temperature sensing element connected to the electronic digital display which is operated by battery

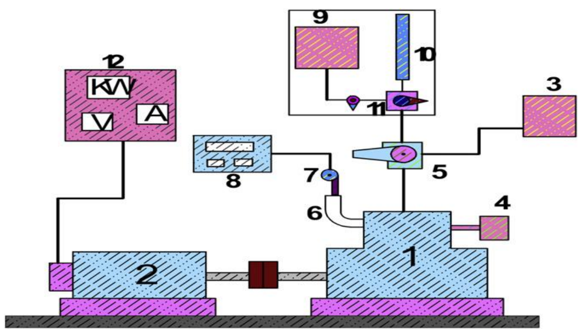

Figure 2.1

2.3 Experimental Procedure

Before starting the engine, the fuel injector is separated from the fuel system. it is clamped on the fuel injection pressure tested and operates the tester pump. Observe the pressure reading from the dial. At which the injector starts spraying. In order to achieve the required pressure by adjusting the screw provided at the top of the injector .This procedure is repeated for obtaining the various required pressures.

As first said, diesel alone is allowed to run the engine for about 30 min, so that it gets warmed up and steady running conditions are attained. Before starting the engine, the lubricating oil level in the engine is checked and it is also ensured that all moving and rotating parts are lubricated.

The various steps involved in the setting of the experiments are explained below

1. The Experiments were carried out after installation of the engine
2. The injection pressure is set at 150 bar for the entire test.
3. Precautions were taken, before starting the experiment.
4. Always the engine was started with no load condition
5. The engine was started at no load condition and allowed to work for at least 10 minutes to stabilize.
6. The readings such as fuel consumption, spring balance reading, cooling water flow rate, manometer reading etc., were taken as per the observation table.
7. The load on the engine was increased by 20% of FULL Load using the engine controls and the readings were taken as shown in the tables.
8. Step 3 was repeated for different loads from no load to full load by varying injector pressures (such as 180bar and 210 bar).
9. After completion of test, the load on the engine was completely relieved and then the engine was stopped.
10. The results were calculated as follows.

Finally the engine is run by Mahua oil diesel blend at various injection pressures the corresponding observations are noted.

The test is carried on the Alamgir Engine for the following fuel blends:

1. 100% Diesel
2. 20% Mahua Oil + 80% Diesel

III CALCULATIONS AND GRAPHS

3.1 Calculations

The parameters that are determined at different loads are as fallows

1. Brake Power, B.P $= \frac{VIcos\,\emptyset}{\eta_{tran}\ x\ \eta_{gen}\ x\ 1000}$ kw

Where,

V = voltage, volts

A = current, amperes

Cos $\emptyset$ = Power factor = 1

η_{tran}=Transmission Efficiency = 0.98

η_{gen}=Generator Efficiency = 0.9

Brake Power, B.P

2. T.F.C = $\frac{20\ x\ 0.85\ x\ 3600}{t\ x\ 1000}$Kg/h

Where,

T.F.C= Total Fuel Consumption, Kg/h

Specific gravity of diesel =0.85

t=Time taken for 20 c.c fuel, seconds

3. Brake Specific Fuel Consumption,

bsfc=$\frac{T.F.C}{B.P}$ Kg/kwh

4. Brake Specific Fuel Consumption,

bsfc = Kg/kwh

5. Heat Input = T.F.C X C.V kW

Where,

C.V=Calorific Value of Fuel, kJ/kg

6. Frictional Power, F.P = kW (from graph by William's line method)

7. Indicated Power =B.P + F.P

8. Indicated Power= kW

9. Mechanical efficiency η_{mech}=$\frac{B.P}{I.P}$x 100 %

10. Brake thermal efficiency =$\frac{B.P}{Heat\ Input}$ x 100 %

12. Indicated thermal efficiency=$\frac{I.P}{Heat\ Input}$ x 100 %

13. Brake Mean Effective Pressure, bmep $= \frac{B.P\ x\ 60}{L\ x\ A\ x\ n\ x\ k}$

Where L = length of the stroke, m n = speed of the engine = 1500/2

A = Area of the cylinder, m^2 k = no. of cylinders= $\frac{3.1188\ x\ 60}{0.116\ x\ \frac{\pi}{4} x (0.102)^2\ x\ \frac{1500}{2}\ x\ 1}$

14. Indicated Mean Effective Pressure, Imep = $\frac{I.P\ x\ 60}{L\ x\ A\ x\ n\ x\ k}$

$= \frac{4.6688\ x\ 60}{0.116\ x\ \frac{\pi}{4} x (0.102)^2\ x\ \frac{1500}{2}\ x\ 1}$

15. Volumetric efficiency, $\eta_{vol} = \frac{\text{actual volume flow rate of air}}{\text{the rate at which volume is displaced}} \times 100\ \%$

$$= \frac{\text{area of inlet pipe} \times \text{velocity of air}}{\begin{bmatrix}\text{are of}\\ \text{the cylinder}\end{bmatrix} \times \begin{bmatrix}\text{length of}\\ \text{the stroke}\end{bmatrix} \times \begin{bmatrix}\text{revolutions}\\ \text{per second}\end{bmatrix}} \times 100\%$$

3.2 Graphs

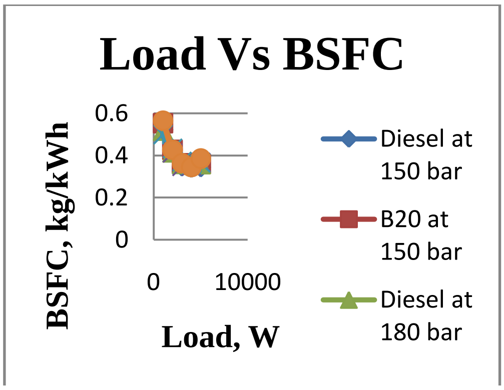

Fig. 3.1 Load Vs Brake Specific Fuel Consumption

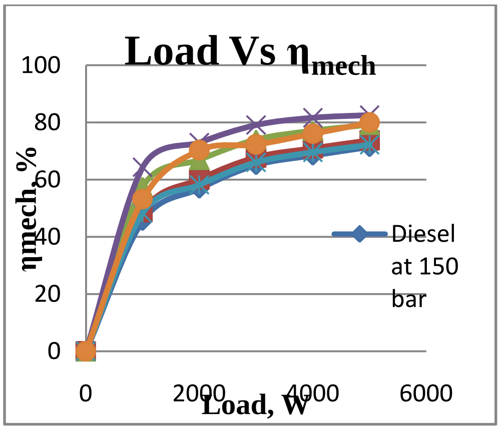

Fig. 3.2 Load Vs Mechanical efficiency

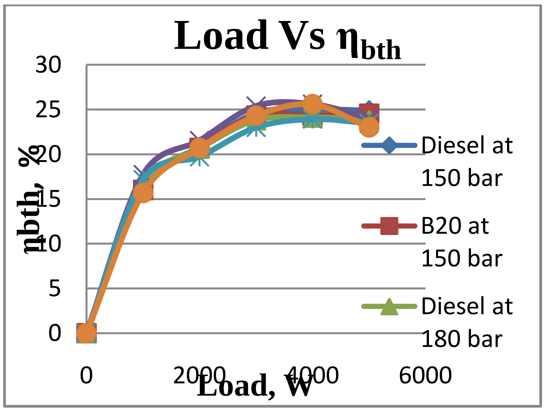

Fig. 3.3 Load Vs Brake Thermal Efficiency

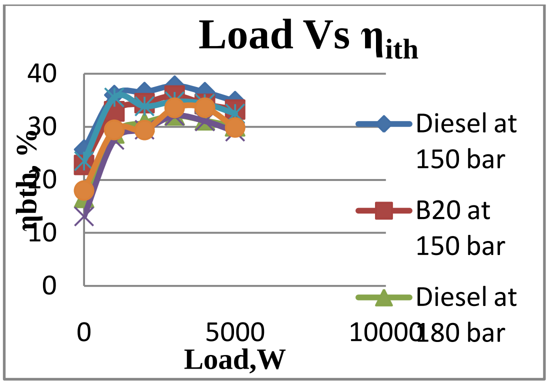

Fig. 3.4 Load Vs Thermal Efficiency

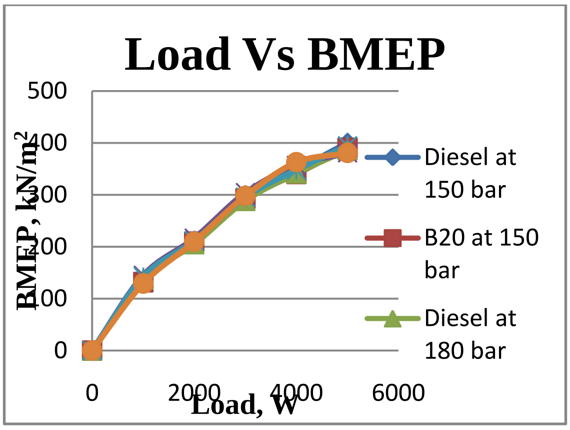

Fig. 3.5 Load Vs Brake Mean Effective Pressure

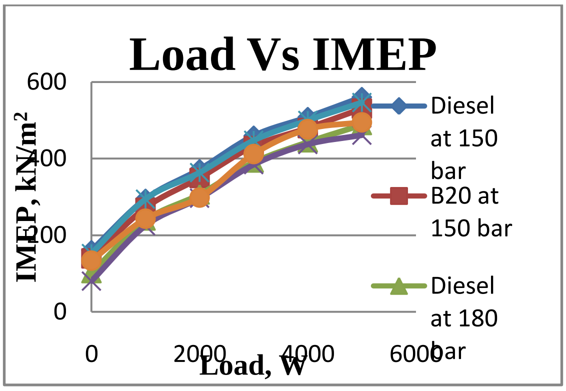

Fig. 3.6 Load Vs Indicated Mean Effective pressure

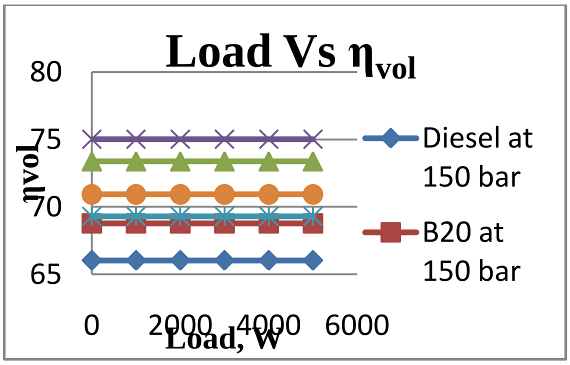

Fig. 3.7 Load Vs Volumetric Efficiency

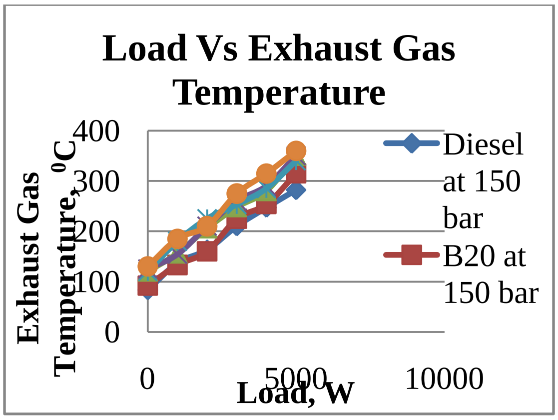

Fig. 3.8 Load Vs Exhaust Gas Temperature

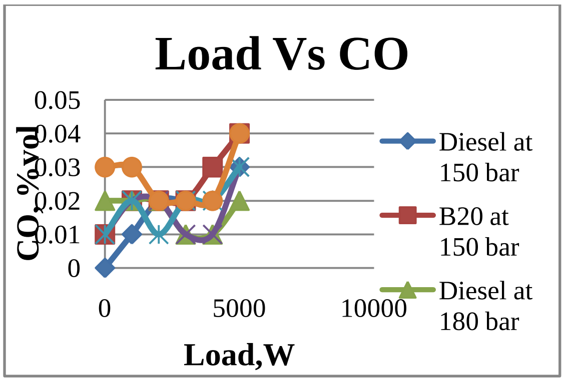

Fig. 3.9 Load Vs Carbon monoxide

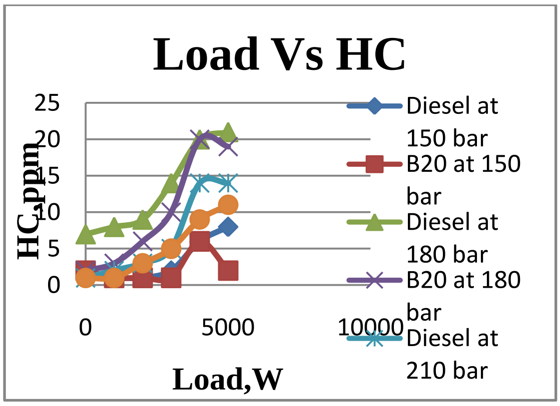

Fig. 3.10 Load Vs Hydro carbons

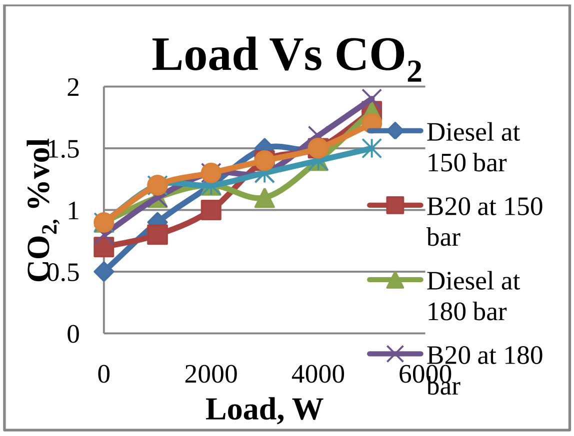

Fig. 3.11 Load Vs Carbon dioxide

III. CONCLUSION

The engine was made to run on diesel fuel mode, and Mahua oil –diesel mode. The experiments were conducted at 3 different fuel injection pressures of 150 bar, 180 bar and 210 bar. The performance and emission of the engine at full load were investigated. The following results were obtained.

- Brake specific fuel consumption for Mahua oil-diesel blend ishigher than the BSFCat 210 bar.(0.345 kg/kWhr at 150 bar, 0.367 kg/kWhr at 180 bar, 0.384 kg/kWhrand 0 kg/kW at 210 bar.)
- The brake thermal efficiency of the engine for Mahua oil- Diesel blend of is high compared to diesel mode at 180 bar and 210 bar.
- The exhaust gas temperature of diesel fuel mode is less compared to Mahua oil-diesel mode at fuel injection pressures of 150 and 180 bar.
- CO emission of Mahua oil-diesel mode is higher compared to that of diesel fuel mode at all fuel injection pressures.
- CO_2 emission increased up to the fuel injection pressure of 180 bar for Mahua oil- diesel mode and then decreased slightly at 210 bar injection pressure.
- CO emission decreased with increase in fuel injection pressure from 180 bar to 210 bar for fossil diesel mode of operation.
- HC emission of Mahua oil-Diesel fuel operation is less than the diesel fuel mode at all fuel injection pressures.

From the above analysis the main conclusion is Mahua oil blends are suitable substitute for diesel at high injection pressure(value), whichproduces lesser emission and better performance then diesel.

REFERENCES

[1] Sukumar Puhan, N. Vedaraman Boppana, V.B. Ram G.Sankarnarayanan,K.Jeychandran. Mahua oil (Madhuca Indica seed oil) methyl ester as biodiesel-preparation and emission characterstics. Volume 30, Issue 8, July 2005, Pages 1269-1278

[2] Sukumar Puhan, N.Vedaraman Boppana, V.B. Ram G. Sankarnarayanan. Performance and emission study of Mahua oil (madhuca indica oil) ethyl ester in a 4-stroke natural aspirated direct injection diesel engine, Volume, sep 2007, Pages 19-28

[3] Bhattacharya .S and Reddy C.S, 1994. Vegetable oils as Fuel for Internal combustion Engines: A Review, Journal of Agricultural Engineering Research. 57, pp. 157-166.

[4] Bhatt, Y. C. and A.N. Mathur. 2002. Biodiesel-an alternative diesel fuel. The Institution of

Engineers (India) Souvenir and Annual Bulletin, 10: 29-31.

[5] Das, Sankha Subhra. 2005. Use of some non-edible vegetable oil blends as an alternative source of energy for a compression ignition engine. Unpublished M.Tech. Thesis, C.A.E.T, O.U.A.T., Bhubaneswar, Aug 2005.

[6] Fontaras G, Tzamkiozis T, Hatziemmanouil E, Samaras Z., 2007. Experimental study on the potential application of cotton seedoil-diesel blends as fuels for automotive diesel engines, Trans I Chem E Part B Process Safety Environ Protect, 85(B5),pp. 396–403.

[7] Fontaras G, Samaras Z, Miltsios G, 2007. Experimental evaluation of cottonseed oil- diesel blends as automotive fuels via vehicleand engine measurements. SAE paper,No. 2007-24-0126.

[8] Gattamaneni LNR, Subramani S, Santhanam S and Kuderu R, 2008. Combustion and emission characteristics of diesel enginefuelled with rice bran oil methyl ester and its diesel blends, Thermal Science, 12(1), pp. 139-150.

[9] Ghobadian B, Rahimi H, Nikbakht AM, Najafi G and Yusaf TF, 2009. Diesel engine performance and exhaust emission analysisusing waste cooking biodiesel fuel with an artificial neural network, Renewable Energy, 34, pp. 976–982.

[10] Giannelos P.N., Zannikos F., Stournas S., Lois E., Anastopoulos G., 2002, Tobacco seed oil as an alternative diesel fuel: physicaland chemical properties, Industrial Crops and Products, 16, pp. 1– 9.

[11] Hazar H., 2010. Cotton methyl ester usage in a diesel engine equipped with insulated combustion chamber, AppliedEnergy, 87, pp.134–40.

[12] Jeffrey SG and Nancy AM, 2009. The impacts of combustion emissions on air quality and climate–From coal to biofuels andbeyond, Atm. Environment, 43, pp. 23–36.

[13] Karabektas M, Ergen G, Hosoz M. 2008. The effects of preheated cotton seed oil methyl ester on the performance and exhaustemissions of a diesel engine, Applied Thermal Engineering, 28, pp. 2136–43.

[14] Nabi N, Rahman M and Akhter S, 2009. Biodiesel from cotton seed oil and its effect on engine performance and exhaustemissions, Applied Thermal Engineering, 29 (11-12), pp 2265-2270.

[15] Naga P. Ch. S, Vijaya K.R.K, Kumar B.S.P., Ramjee.E, Hebbel O.D. and Nivendgi M.C., October 2009. Performance and emissioncharacteristics of a diesel engine with castor oil, Indian Journal of Science and Technology, 2 (No.10), pp.25-31.

[16] Narayana R.J. and Ramesh A., 2004. Effect of injector opening pressure on the performance of a Jatropa oil fueled CompressionIgnition Engine, National Conference on State of the art of technologies in Mechanical Engineering, NCSAME- 2004.

[17] Nazar .J, Sandesh G., Ramesh A. and Nagalingam B., Use of Vegetable Oils in Diesel Engines, National conference on State of theart of technologies in Mechanical Engineering, NCSAME- 2004.

[18] No S.-Y., 2010. Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines: A review, Renewable and Sustainable Energy Reviews, (In Press)

[19] Nurun N. Md., Mustafizur R. Md., Shamim A. Md., 2009. Biodiesel from cotton seed oil and its effect on engine performance andexhaust emissions, Applied Thermal Engineering. 29, pp. 2265–2270

[20] Oman H, 2003. Energy sources for the worlds post petroleum era, IEEE Aerospace Elec. Sys. Vol. 18, pp. 35–39.

◈◈◈