Research Article

# PERFORMANCE ANALYSIS OF CI ENGINE USING JATROPHA OIL AND THEIR ESTERS

Ram Prakash[1], S.P.Pandey[2], S.Chatterji[3]

**Address for Correspondence**

1 Research Scholar, Uttarakhand Technical University, Dehradun Uttarakhand India
2 Professor, MED, Kumaon Engineering College, Dwarahat –Almora (Uttrakhand), India
3 Professor, EED, NITTTR Chandigarh, India
Email: prakashweb1@rediffmail.com

**ABSTRACT**

This paper deals with the experimental work carried out for the performance analysis of Compression Ignition (C I) engine using alternative fuel/ vegetable oils from renewable oil, seed can be use when mixed with diesel fuels. Pure vegetable oils however cannot be used in direct-injection diesel engines, such as those regularly used in standard engines. There are more than 350 oil bearing crops identified among which only sunflower, soybean, cottonseed, rapeseed and peanut oils are considered as potential alternative fuels for diesel engines. The major problem associated with the use of pure vegetable oils as fuels for diesel engines are caused by high fuel viscosity in compression ignition engine. These problems can be minimized by the process of transesterification. In this study experimental investigation have been carried out to examine the performance parameters in terms of Brake Specific Fuel Consumption(BSFC) and Brake Thermal Efficiency ( BTE) for different engine load from 1.8 kg to 6.6 kg and different blending ratios like B0,B25,B50,B75,B100 of soya oil and their esters . Result indicated that B25 have closer performance to diesel oil and B100 had lower performance mainly due to high viscosity compared to diesel. However its diesel blends showed reasonable lower smoke CO, and HC.

**KEYWORDS** Alternative Fuels, BSFC, Soya oil, soya oil blends,Performance,CI Engine

## 1. INTRODUCTION

The major part of all energy consumed worldwide comes from fossil sources (petroleum, coal and natural gas). However these sources are limited and will be exhausted by the near future. Thus looking for alternative sources of new and renewable energy such as hydro, bio-mass, wind, solar, geothermal, hydrogen and nuclear is of vital importance. Alternative new and renewable fuels have the potential to solve many of the current social problems and concerns, from air pollution and global warming to other environmental improvements and sustainability issues [1]. Vegetable oils have become more attractive because of its environmental benefits and the fact that it is made from renewable resources. Vegetable oils are a renewable and potentially inexhaustible source of energy with an energetic content close to diesel fuel. The vegetable oil fuels were not acceptable because they were more expensive than petroleum fuels. However, with recent increase in petroleum prices and uncertainties concerning petroleum availability, there is renewed interest in vegetable oil fuels for diesel engine [2]. Bio-fuels are generally considered as offering many properties, including sustainability, reduction of greenhouse gas emission regional development, social structure and agriculture, security of supply [3]. In developed countries there is growing trends towards employing modern technology and efficient bio-energy conversion using a range of bio-fuels, which are becoming cost wise competitive with fossil fuels[4]. Conversion of the vegetable oils and animal fats into bio-diesel has been undergoing further development over the past several years [5-10]. Bio-diesel represents an alternative to petroleum-based diesel fuels and it is a mixture of mono-alkyl esters of fatty acids, most often obtained from extracted plant oils and/or collected animal fats. Commonly accepted biodiesel raw materials include the oils from soya, canola, corn, rapeseed and palm. New plant oils that are under consideration include mustard seed, peanut, sunflower and cottonseed. The most commonly considered animal fats include those derived from poultry, beaf and pork [11].

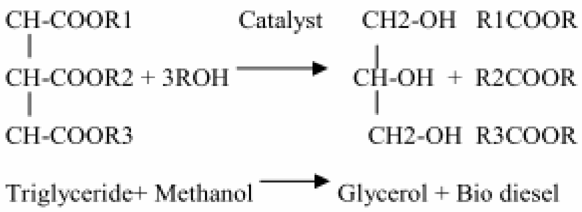
Energy is an essential factor for economic growth; however from oversea effect the countries has incurred the expenses in terms of US$ for importing petroleum and its products, this can be avoided. After the crises of World's oil in balance oil in 1971, every country have tried to find a new energy that can replace petroleum diesel by using their district energy specially Bio fuels. The World's economy to a much extent the burning of fossil fuel. Fossil fuel equivalent to some 180 million barrels of oil is being burnt each day. The fuel consumption rate works out to be is equivalent to an annual burning of fuel mass what nature took about one million years to accumulate as fossil deposits. The world at present is confronted with the twin crises viz (i) fuel depletion and (ii) environment degradation. Indiscriminate extraction and lavish consumption of fossil fuel have lead to the reduction in underground carbon resources. The search for alternative fuels which promises a harmonious correlation with sustainable development, energy conservation, management efficiency and environment preservation, has become highly pronounced and need of the world. For the developing countries of the world like India, fuels of bio origin can provide a feasible solution of the crises. The fuels of bio-origin may be alcohol, vegetable oil, biomass and biogas. Some of these fuels can be used directly while others need to be formulated to bring the relevant properties close to conventional fuels. The power used in the agricultural and transportation sector is essentially based on diesel fuels and it is therefore, essential that alternatives to diesel fuels be developed urgently.

## 2. Vegetable oils and their derivatives used as an alternative fuels

The use of vegetable oils directly in CI engine is associated with problem due to its high viscosity (about 11-17 times higher than diesel fuel) and low viscosity; they do not burn completely and form deposits in the fuel injector of diesel engine [2]. This problem is to be minimized by the transesterification process.

## 3. Transesterification

The formation of methyl esters by transesterification of vegetable oil requires raw oil, 15% of methyl and 5%of sodium hydroxide on mass basis. However, transesterification is an equilibrium reaction in which excess alcohol is required to derive the reaction with an alcohol in presence of a catalyst to produce methyl esters. Glycerol was produced as a by-product of transesterification reaction.




Where R1, R2 and R3 are long chain hydrocarbons.

The mixture was stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24 hrs. The upper layer was of ester and lower was of glycerol. The lower layer was separated out. The separated ester was mixed with some warm water (around 10% volume of ester) to remove the catalyst present in ester and allowed to settle under gravity for another 24 hrs. The catalyst got dissolved in water, which was separated and removed the moisture. The methyl ester was then blended with mineral diesel in various concentrations for preparing biodiesel blends to be used in CI engine for conducting various engine tests [12, 13, 14].

## 4. Experimental Setup

The present study was carried out to investigate the performance characteristics of soya oil and their esters in a constant speed, single cylinder, and four stroke, naturally aspirated, water cooled, direct injection diesel engine of 3.75kW rating Kirlosker was chosen for doing the experimental work. The detailed specifications of the engine are given below in table1:

**Table.1. Specification of engine**

| | |
|---|---|
| **Make Type** | Kirlosker engine |
| **EngineType** | Single cylinder, Direct injection water cooled |
| **Stroke** | 100mm |
| **Bore** | 80mm |
| **Rated power** | 3.75kw |
| **Compression ratio** | 16.5:1 |
| **Total displacement volume** | 552.64cc |
| **Rated speed** | 1500rpm |
| **Loading device** | Hydraulic dynamometer |
| **Fuel injection timing** | $23^0$ BTDC |

To measure the brake power hydraulic dynamometer was employed. Neptune make exhaust gas analyzer was used to measure the concentration of emissions of carbon mono-oxide and hydrocarbons. A smoke meter of Netel make was employed to measure the smoke density of exhaust gas emitted from the diesel engine. Temperature gauge was used to measure the temperature of the exhaust gases. Experimental setup diag. as sshown in fig.1.

The engine and the fuel were modified to obtain optimum performance of the C.I. engine by using vegetable oil and its blend with diesel. The modification ensures the operation of the engine safely for long-term. Two fuel tanks were installed one holds the vegetable oil and its blends with diesel and the other tank holds the diesel oil. The C.I. engine has been modified as duel fuel engine. The fuel system was modified by adding an additional filter and a three way, hand operated, two-position directional control valve, which allowed rapid switching between the vegetable oil blend and the diesel fuel. Fuel was fed to the injector pump under gravity and the volumetric flow rate was measured by the use of 10cc graduated burette and a stopwatch. The speed was measured by tachometer. The engine was started on the diesel tank and runs on diesel for the first few minutes. While the vegetable oil was heated to lower the viscosity which has provided engine durability improvements. Exhaust gases were used as heat source. When the fuel reaches the required temperature the engine is switched over to the second tank and runs on the blended fuel. The engine was switched back to diesel before stopping the engine and fuel system "purged" of vegetable oil before switching off, so that there is no cold veg-oil left to coke-up the injector next time when the engine is started. Starting and stopping the engine with diesel oil while running with vegetable oil eliminates filter clogging. Injector was optimized for vegetable oil as well as fuel heating to have adequate characteristics of fuel jet, which has provided the deep penetration and dispersion of fuel droplets. Periodic cleaning of nozzle tip has helped to ensure adequate spray characteristics.

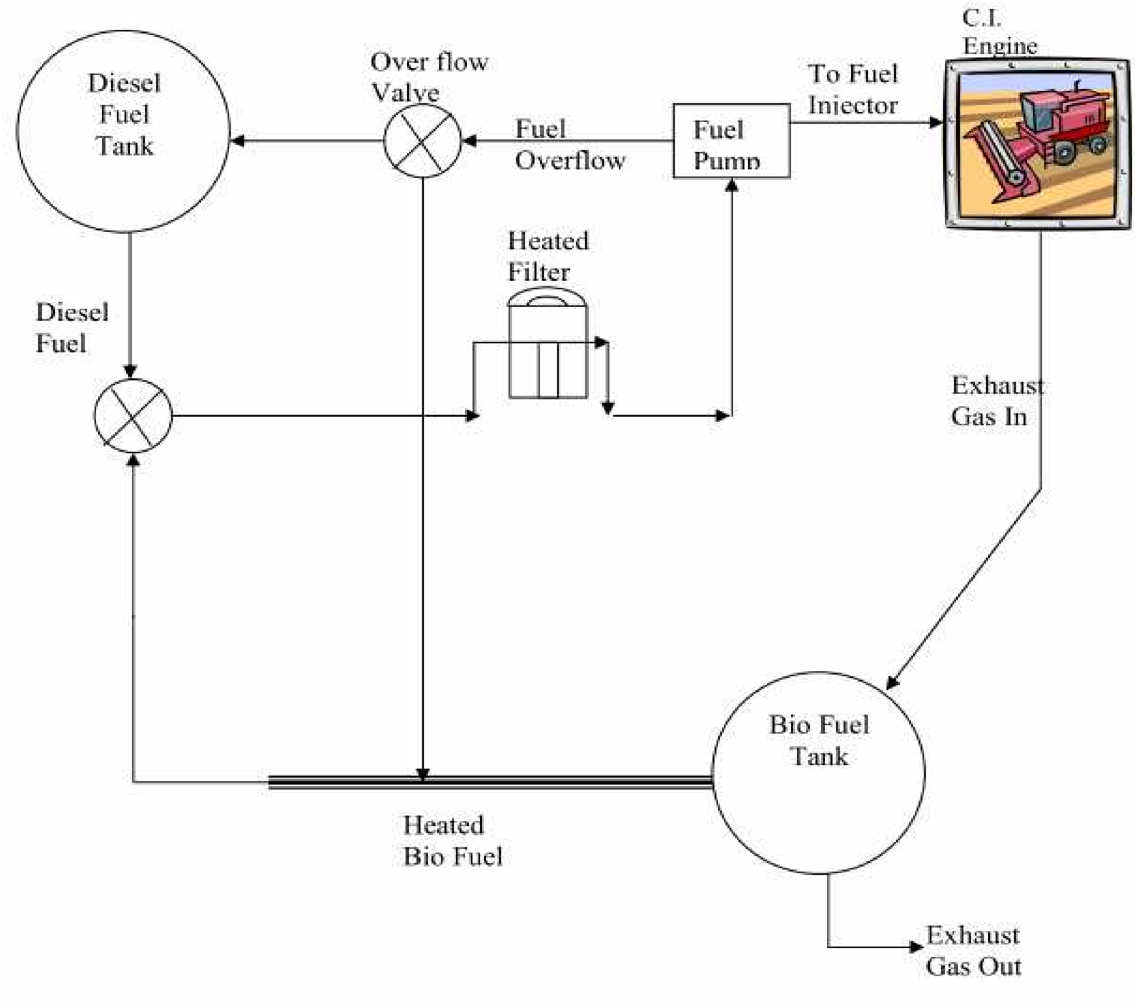



**Fig.1 Scematic Diagram of theexperimental setup**

## 5. Testing of the engine using blends of Jatropha oils with diesel

The use of vegetable oils as an alternative substitute in a system, designed to run on diesel fuel will undoubtedly impose problems. Vegetable oil has an ignition quality equivalent to diesel fuel and their combustion characteristics are much the same, but there viscosity is too high for the modern fuel pumps. Higher viscosity results in incomplete atomization of neat vegetable oil fuel, which in turn prevents complete combustion of large fuel droplets, resulting in carbon deposits. Fuel modification may, however, improve the viscosity of vegetable oil fuel. The vegetable oils used as the fuel were soybean oil, Rice Bran oil and Jatropha Curcas oil. Three blends of each vegetable oil were obtained by mixing diesel and soybean oil, Rice Bran oil and Jatropha oil in the following proportion by volume.

100% Vegetable Oil (B100)
75% Vegetable Oil + 25% Diesel (B75)
50% Vegetable Oil + 50% Diesel (B50)
25% Vegetable Oil + 75% Diesel (B25)
100% Diesel (B0)

## 6. Observations

The engine was run using blended fuel and mineral diesel and experiments were carried out. Properties of jatropha oil and their blending with diesel oil is shown in following table 2, Which is used for testing of engine performance and various performance data's can be obtained during test runs of the engine, and data tabulated in table form in table 3(a) and 3(b). With the help of observation obtained in above table 3(a) and 3(b) plots were drawn for BSFC and BTE for different engine load and various mixing ratios as shown in Fig.2(a), and Fig.2(b)

**Table.2. Properties jatropha oil, diesel oil and blended fuel**

| Properties/BR | B0 | B25 | B50 | B75 | B100 |
|---|---|---|---|---|---|
| Specific Gravity | 0.835 | 0.856 | 0.8768 | 0.8977 | 0.9186 |
| Calorific value(kJ/Kg) | 42500 | 41819 | 41137 | 40456 | 39774 |

**Table. (3a). BSFC (kg/kwH) for different blend ratio and different engine load (kg)**

| Load(kg)/BR | B0 | B25 | B50 | B75 | B100 |
|---|---|---|---|---|---|
| 1.8 | 0.4589 | 0.4778 | 0.5010 | 0.5212 | 0.5377 |
| 3.5 | 0.3370 | 0.3533 | 0.3702 | 0.3791 | 0.3924 |
| 4.8 | 0.3009 | 0.3170 | 0.334 | 0.3469 | 0.3712 |
| 5.5 | 0.2944 | 0.3065 | 0.3458 | 0.3730 | 0.3959 |
| 6.6 | 0.3374 | 0.3609 | 0.3955 | 0.4246 | 0.4688 |

**Table.(3b). BTE (%) for different blend ratio and different engine load (kg)**

| Load(kg)BR | B0 | B25 | B50 | B75 | B100 |
|---|---|---|---|---|---|
| 1.8 | 18.46 | 18.02 | 17.47 | 17.07 | 16.83 |
| 3.5 | 25.13 | 24.37 | 23.64 | 23.47 | 23.07 |
| 4.8 | 28.15 | 27.15 | 26.20 | 25.65 | 24.39 |
| 5.5 | 28.77 | 28.09 | 25.31 | 23.85 | 22.86 |
| 6.6 | 25.11 | 23.85 | 22.13 | 20.96 | 19.31 |

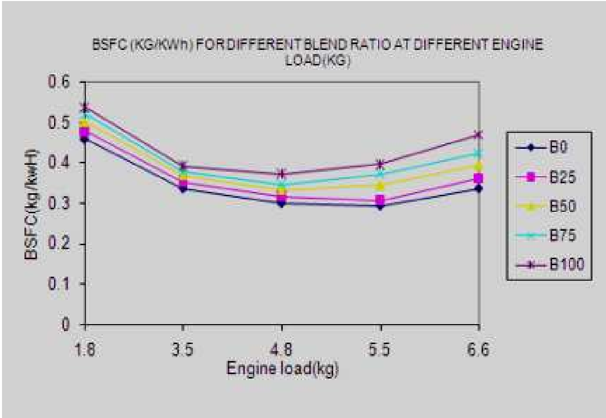



**Fig. 2(a) BSFC for different blending ratio with the variation of engine load**

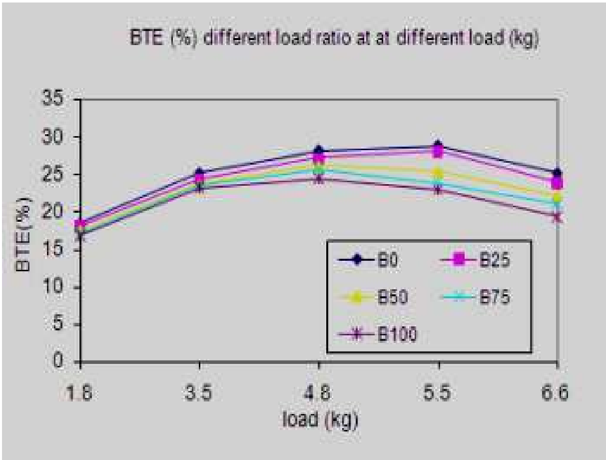



**Fig. 2(b) BTE for different blending ratio with the variation of engine load**

Further engine was run using blended fuel and mineral diesel and experiments were carried out. Properties of jatropha oil esters(after esterification) and their blending with mineral diesel oil is shown in following table 4, Which is used for testing of engine performance and various performance data's can be obtained during test runs of the engine, and data tabulated in table form in table 5(a) and 5(b)

**Table 4 Properties for jatropha oil Ester, diesel oil and blended fuel (BSO)**

| Properties/BR | B0 | B10 | B20 | B50 | B75 | B100 |
|---|---|---|---|---|---|---|
| Specific Gravity | 0.835 | 0.8395 | 0.844 | 0.8575 | 0.86875 | 0.88 |
| Calorific value(kJ/Kg) | 42500 | 42350 | 42200 | 41750 | 41375 | 41000 |

**Table: 5(a) BSFC (kg/kHz) for different blend ratio and different engine load (kg)**

| Load(kg) /BR | B0 | B10 | B20 | B50 | B75 | B100 |
|---|---|---|---|---|---|---|
| 1.8 | 0.4589 | 0.4497 | 0.4508 | 0.5028 | 0.5178 | 0.5176 |
| 3.5 | 0.3370 | 0.3185 | 0.3312 | 0.3469 | 0.3311 | 0.3759 |
| 4.8 | 0.3009 | 0.2899 | 0.2931 | 0.3324 | 0.3468 | 0.3599 |
| 5.5 | 0.2944 | 0.2713 | 0.2822 | 0.3326 | 0.3462 | 0.358 |
| 6.6 | 0.3374 | 0.3131 | 0.3197 | 0.3922 | 0.39 | 0.4025 |

**Table.5 (b) BTE (%) for different blend ratio and different engine load (kg)**

| Load(kg) /BR | B0 | B10 | B20 | B50 | B75 | B100 |
|---|---|---|---|---|---|---|
| 1.8 | 18.46 | 18.90 | 18.92 | 17.15 | 16.80 | 16.96 |
| 3.5 | 25.13 | 26.46 | 25.75 | 24.86 | 26.28 | 23.36 |
| 4.8 | 28.15 | 29.31 | 29.11 | 25.94 | 25.08 | 24.40 |
| 5.5 | 28.77 | 31.33 | 30.23 | 25.93 | 25.13 | 24.53 |
| 6.6 | 25.11 | 27.78 | 26.68 | 21.98 | 22.31 | 21.81 |

With the help of observation obtained in above table 5(a) and 5(b) plots were drawn for BSFC and BTE for different engine load and various mixing ratios as shown in following Fig.3(a), and Fig.3(b)-

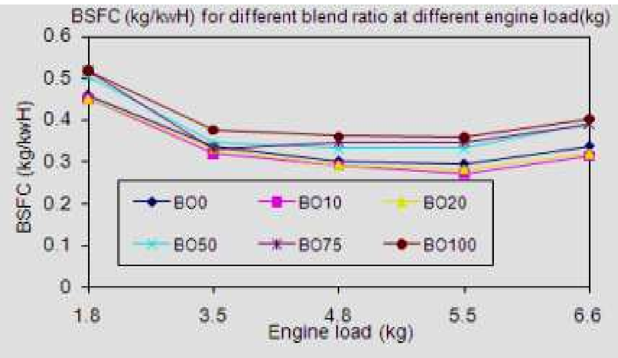



**Fig. 3(a) BSFC for different blending ratio with the variation of engine load**

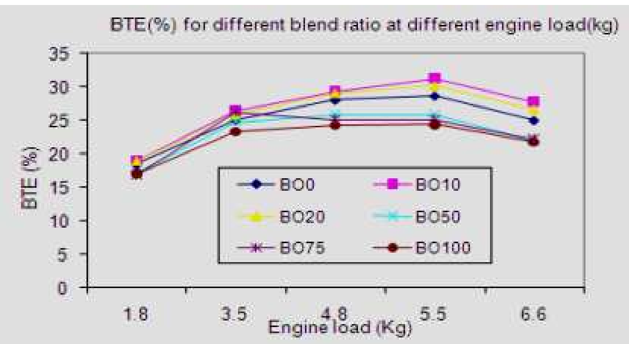



**Fig. 3(b) BTE for different blending ratio with the variation of engine load**

## 7. RESULT AND DISCUSSION

The result in table 2 shows that pure biodiesel from jatropha oil has a specific gravity 0.9186 is greater than that of mineral diesel oil of specific gravity 0.835 means specific gravity of blended fuel is to be increases . In case of calorific value is to be decreases when blending percentage is to be increases. The table 4 shows same pattern also follow when jatropha oil ester blended with mineral diesel oil regarding specific properties and calorific value. BSFC at minimum load (1.8 kg) for mineral diesel is found to be 0.4589 kg/kwh and 0.5577 kg/kwh for pure jatropha oil used as biodiesel. For mineral diesel when engine load is to be increases BSFC is to be decreases. BSFC of jatropha methyl ester is found to be optimum for blending ratio of 20% (B20) of biodiesel. BTE for jatropha oil and jatropha oil ester is to be optimum for blending ratio of 20% and 25% of biodiesel is very close to the performance of diesel oil.

## 8. CONCLUSION

Performance Analysis of Compression Ignition Engine using alternative fuels as jatropha oil and their ester after esterification has successfully compared and the responses observed were basic specific fuel consumption, brake thermal efficiency. These responses obtained from the vegetable oils and its blends were compared to the diesel fuel. Different comparative graph is obtained and successfully compared and author will suggest for replacement of the conventional fuel i.e. diesel by appropriate alternative fuels.

**REFERENCES**


1. [1] Mac Leana HL, Laveb L B. Evaluating automatic fuel/propulsion system technologies. Progress of energy combustion Science 2003; 29; 1-69.
2. [2] Demirabs A. Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterification and other methods: a survey energy conversion management 2003; 44:2093-2109.
3. [3] Reijnders L. Conditions for the sustainability of biomass based fuel use. Energy policy 2006; 34:863-76.
4. [4] Puhan S Vedaraman N, Rambrahaman BV, Nagarajan G. Mahua ( Mahua indica ) seed oil; a source of renewable energy in india. J Sci. Ind Res 2005; 64:890-96.
5. [5] Hass M J, Mc Aloon A J Yee WC, Foglia TA. A process model to estimate biodiesel production costs. Bioresearch Technology 2006; 97: 671-78.
6. [6] Prakash C B. A critical review of biodiesel as transportation fuel in Canada. A technical report. Canada: GCSI-Global change strategies international Inc; 1998.
7. [7] Demirabas A. Diesel fuel from vegetable oil via transesterification and soap pyrolysis. Energy sources 2002; 24:835-41.
8. [8] Meher LC, sagar DV, Naik SN. Technical aspects of biodiesel production by transesterification – a review renewable sustainable energy rev 2006; 10; 248-68.
9. [9] Madras G. Kolluru C Kumar R. synthesis of biodiesel in supercritical fluids. Fuel 2004; 83: 2029-33.
10. [10] Aliy, Hanna MA Cuppett SL. Fuel properties of tallow and soybean oil esters. JAOCS 1995;72:1557-64.
11. [11] Usta N, Ozturk E, Can O, Cankur ES, Nas S, Can AH, et al. Combustion of biodiesel fuel produced from hazelnul soapstock/waste sunflower oil mixture in a diesel engine. Energy conversion management 2005; 46:741-55.
12. [12] D. Agrawal, L.Kumar, A.K.Agrawal , " Performance evaluation of vegetable oil fuelled CI engine ". Renewable Energy,accepted 29$^{th}$ june 2007.
13. [13] M.A. Fangrui, M.A. hanna, " Biodiesel Production:Areview," Biosource Technology, vol.70,1999, 1-15.
14. [14] A.K. Agrawal, L.M. Das," Biodiesel development and characterization for use as a fuel in CI Engine," Journal of Engineering, Gas Turbine and power( ASME), vol.123,2000, 440-47.
15. Pryor, R.W., Hanna, M.A., Schinstock, J.L., Bashtord, L.L. "Soybean oil fuel in small diesel engine", Transaction on American Society of Agricultural Engineers, Vol. 26, pp.333-338,July 1982.
16. Siti Zullaikah, Chao-Chin Lai, Shaik Ramjan Vali, Yi-Hsu Ju "A two-step acid-catalyzed process for the production of Bio-Diesel from rice bran oil" , Department of Chemical Engineering, National Taiwan University of Science and Technology*,* 43 Sec.4, Keelung Road, Taipei 106-07, Taiwan, 29 January 2005.
17. Chanoknun Sookkumnerd, Nobutaka Ito, Koji Kito "Financial viabilities of husk-fueled steam engines as an energy-saving technology in Thai rice mills" , Department of Environmental Science and Technology, Faculty of Bioresources, Mie University, 1515, Kamihama-cho, Tsu *514-8507*
18. O.M.I. Nwafor & G. Rice "Performance of Rapeseed Oil Blends in a Diesel Engine", Department of Engineering, University of Reading, Whiteknights, Box 225, Reading, UK, RG6 2AY, 22 January, 2006
19. A.S. Ramadhas, S. Jayaraj, C. Muraleedharan "Theoretical modeling and experimental studies on biodiesel-fueled engine", Department of Mechanical Engineering, National Institute of Technology Calicut, Calicut – 673 601, India. 10 september, 2005.
20. G. Nafaji, B.. Ghobadian, T. Yusuf,Hadi Rahimi " Combustion Analysis of a CI Engine Performance using waste cooking Biodiesel fuel with an Artificial Neural Network Aid" , American Journal of Applied Sciences, Vol.4, pp. 756-764, October 2007.