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Gravity Assisted Heat Pipe (Closed Thermosyphon) As a Biodiesel Preheating Device

S. L Nadaf[1], P. B Gangavati[2]
[1]Mechanical Engineering Department, Government Engineering College Haveri, India.
[2]Mechanical Engineering Department, Basaveswar Engineering College Bagalkot, India.

***Abstract* - Gravity assisted wickless heat pipes (Closed Thermosyphons) are the two-phase heat transfer devices with extremely high thermal conductivity, are suitable devices to transfer heat between two streams. Recently, Thermosyphon have attracted more interest in the shift towards smaller, lighter and cheaper heat exchangers because of their compactness, low thermal resistance, high heat recovery effectiveness, safety and reliability. The present paper deals with the design and development of wickless heat pipe arrangement for pongamia biodiesel preheating. The experiments conducted with different heat input at the evaporator of 50W, 100W, 150 W and 200 W. The pongamia biodiesel blends (20B, 40B, 60B and 100B) used as condenser fluid and heated. The results of work insight into the effect of parameter variations on the effectiveness, thermal resistance, temperature difference, heat capacity, flow rate and rise in temperature of pongamia biodiesel blends.**

At 200W heat input the temperature of all blends varies from 75-79° C. Thus, the gravity assisted heat pipe can be used as biodiesel preheating device, using which the biodiesels blends of 40 % and above, and even 100 % biodiesel can be used directly.

Keywords : Thermosyphon, Pongamia Pinnata, biodiesel, Viscosity, Preheating.

1. INTRODUCTION

The world is presently confronted with the twin crises of gradual depletion of world petroleum reserves and the impact of environmental pollution of increasing exhaust emissions. *(S K Acharya, 2011)*

The biodiesels are the right choice alternative fuels. Replacing fossil fuels with biodiesels could reduce the world dependence of fossil fuel. They are abundant worldwide and largely environment-friendly and can be used in existing engine without any modification. But use of biodiesel creating new challenges of reducing the viscosity and atomization issues .In this paper a critical analysis on preheating the biodiesel and the preheating device (***gravity assisted heat pipe***) related are discussed.

1.1Biodiesels and their scope

India's demand for diesel fuels is roughly six times that of gasoline hence seeking alternative to mineral diesel is a natural choice fulfill the energy security needs without sacrificing engine operational performance. *(Acharya S K et al. 2009)*

Biodiesel has many advantages include the following: its renewable, safe for use in all conventional diesel engines, offers the same performance and engine durability as petroleum diesel fuel, non-flammable and nontoxic, reduces tailpipe emissions, visible smoke and noxious fumes and odors. The use of biodiesel has grown dramatically during the last few years. *(www.naturfuels.com)*

- 99% of transport still uses fossil fuel sources. Because of this, many countries in the world have committed to increasingly search for alternative fuels using renewable energy sources.
- Biodiesel is 100% biodegradable – leaving behind a cleaner environment – a cleaner future.
- Biodiesel is environmental friendly and economical.
- Processed biodiesel meets the International standards of quality for use in diesel driven automobiles and trucks.
- Biodiesel can be used with little or no modifications required for most diesel engines.
- Biodiesel can even be mixed together with fossil diesel, in any blend, from 1% to 100%.
- Biodiesel even provides enhanced lubrication compared to running fossil diesel.

The use of Biodiesel reduces greenhouse gas emissions compared to fossil diesel and is therefore a better choice when working in pollution sensitive environments, (www.naturfuels.com)

1.2 Some serious problems with biodiesel

There are many problems associated with direct use of biodiesel in engines.

- With changes of outside temperature, fats can precipitate out of bio-fuel. These fats block fuel filters. The heating re-melts any fats and ensures that fuel filters stay clear.
- Poorer cold-flow properties and shorter shelf life compared with petroleum diesel.
- Due to their high viscosity (about 11–17 times higher than diesel fuel) and low volatility, they do not burn completely and form deposits in the fuel injector of diesel engines. *(Demirbas A,2003)*
- The fuel injection system of new technology engines is sensitive to fuel viscosity changes. High viscosity of the vegetable oil leads to poor fuel atomization which in turn may lead to poor combustion, ring sticking,

injector cocking, injector deposits, injector pump failure and lubricating oil dilution by crank-case polymerization.

- Increased exhaust gas temperature and increased oxides of nitrogen and other emissions, with increased blending of biodiesel with diesel and 100 % Biodiesel.

1.3 Pongamia Pinnata (Karanja) biodiesel

Vegetable oil is one such source. India has about 86 types of oilseed-bearing perennial trees of which Karanja seed (Pinnata); mahua (Madhuca indica), neem (Azadirachta) and Jatropha (Jatropha curcas) are the important ones. *(Mandal B, 1984) (Mitra, C.R, 1963)*

Vegetable oils have comparable properties with diesel fuel. However, using straight vegetable oil lead to the clogging of the fuel injectors and there is a problem of starting, especially when the engine is cold. To avoid these problems, the straight vegetable oils can be chemically treated to enhance its properties, after which the vegetable oil is known as methyl ester (ME) or biodiesel. *(Mitra, C.R, 1963)*

Figure 1: Pongamia tree, leaves, seeds and biodiesel. *(Vivek et al., 2003)*

Pongamia, a medium sized glabrous tree grown in many parts of India and Australia. Pongamia is popularly known as Karanja in India. The oil content of karanja seed is about 33%. The fresh extracted oil is yellowish orange to brown and rapidly darkens on storage as shown in Figure 1. *(Vivek et al., 2003).*

1.4 Preheating of biodiesel

The fuel modification is mainly aimed at reducing the viscosity to eliminate flow or atomization related problem *(Deepak Agarwal, 2007).* Preheating the fuel before the combustion, to reduce the viscosity and physical delay of combustion. *(Suresh R, 2009).*

However, the use of higher biodiesel blending more than 20 % will increase the viscosity problems and increased exhaust temperatures. If they are heated so that it will perform in a similar fashion to diesel fuel. Heated bio-fuel is thinner than cold bio-fuel.

- Heated bio-fuel will atomize better in the engine leading to cleaner, more complete and therefore more economical combustion.
- There is short time available for the mixing, vaporization and distribution. Where the vaporization is controlled by the temperature.
- The vaporized fuel makes a homogeneous mixture of fuel and air, and improves the combustion and to reduce noxious content of the engine exhaust.
- The rate of chemical reaction depends to a great extent on temperature; small at low temperatures but increases rapidly with increase in temperature. The ignition lag therefore decreases with increases in the temperature.
- The lower and upper ignition limits of the mixture depend upon mixture ratio and temperature. The ignition limits are wider at increased temperatures because of higher rates of reaction and higher diffusivity co-efficient of the mixtures
- Increases in intake temperature increases the flame speed.
- It reduces the specific fuel consumption by providing better combustion and reduces the pollutants. *(Heywood John B, 1988).*

These difficulties could be overcome by different ways to reduce the high viscosity of biodiesels:

- Dilution with diesel fuel
- Thermal decomposition, which produces alkanes, alkenes, carboxylic acids, i.e. preheating before burning preheating *(Demirbas A, 2003)*

2. PREHEATING OF BIODIESEL BLENDS: RELATED RESEARCH WORK

Many investigations have proved that biodiesels and vegetable oils are feasible substitutes for diesel fuel. The present conventional fuel crisis inspired the authors to compare the performance and emission characteristics of compression ignition engine using oils of preheated.

High viscosity of the plant oils is considered to be the major constraint, adversely affects the engine performance. To reduce the viscosity number of method has been tried by researcher such as; Blending or dilution, transesterification, micro emulsion, heating or pyrolysis or thermal cracking, engine setup modification. *(Pramanik, 2003), (Wilson Parawira, 2010)*

2.1 Blending and preheating:

Blending is the method in which Vegetable oil can be directly mixed with diesel fuel and may be used for running an engine without any modification. The blending of vegetable oil with diesel fuel in different proportion were experimented successfully by various researchers. Blend of 20% oil and 80% diesel have shown same results as diesel and also properties of the blend is almost close to diesel. The blend with more than 40% has shown appreciable reduction in flash point due to increase in viscosity. Some researchers suggested for heating of the fuel lines to reduce the viscosity. *R.Sarala et al., (2011) and Satyanarayana Murthy Y.V.V et al., (2010)* conducted experiments on MOME and Tobacco oil(TME) and suggested blending to reduce the viscosity problems, and found that NO_x increased with increased % of biodiesel blending. Higher the percentages blending, the performance & engine emissions drastically effected. *Z.M. Hasib et al., (2011)* shown that the preheating is must for the blends more than 40 %. *Mehta et al., (2007)* stated that the use of straight vegetable oil encounters problem due to its high viscosity, poor volatility and cold flow. The purpose of this study is to reduce the viscosity of oil by effectively utilization of waste heat from exhaust gases before fed to inlet and favorable properties compared to diesel can be obtained.

Chi. Nagaprasad (2009) concluded that the heating temperature of the blends increases with the increase in the percentage of neat oils with diesel and the range used was 70° C to 120° C before entering into the combustion chamber. *Dinesha P et al., (2012)* concluded that increase of biodiesel fraction in the blends will increase the viscosity and decrease performance. To increase the fraction of biodiesel in blends, it is required to reduce the viscosity by preheating. *S K Acharya et al., (2011)* acquired engine data and were analyzed; the engine performance with kusum and karanja oil (preheated) was found to be very close to that of diesel.

2.2 Preheating components:

Dinesha P et al., (2012) carried out experimentation on preheated B40 blend of Pongamia biodiesel and B20 biodiesel. The B40 blend is preheated at 60, 75, 90 and 110°C temperature using waste exhaust gas heat in a shell and tube heat exchanger. S K Acharya et al.*, (2011)* attempts to study the effect of reducing kusum and karanja oil's viscosity by preheating the fuel, using a shell and tube heat exchanger. *Dhrubatara Mitra et al., (2011)* presented the performance of a 5 KW diesel generator (DG) set using 100 % oil of karanja (pongamia pinnata). The tests were carried out by preheating karanja oil at 50-200° C using electric heater. The significance improvements observed in the energy conversion (50-80%) under different load conditions, leading to the lower pollution of exhaust. *Kamal Kishore Khatri et al., (2010)* studied the effect of injection timing on the preheated Karanja-Diesel blend is investigated and the optimal injection timing is determined for Karanja-Diesel blend, which is found to be 19º BTDC. *Sagar Pramodrao Kadu et al., (2010)* used a separate heater arrangement made to preheat the Karanja oil before it is injected into the engine. A resistance controlled a thermostat was installed around a fuel reservoir. The thermostat was used for keeping the temperature of the Karanja oil in the reservoir at the required temperatures. S K Acharya et al.*, (2011)* investigated the effect of temperature on the viscosity of Karanja oil. Fuel preheated in the experiments for reducing viscosity of Karanja oil and blends has been done by a specially designed heat exchanger, which utilizes waste heat from exhaust gases. *K. Hossain et al., (2012)*, directed the engine hot jacket water to preheat the neat plant oil prior to injection. Their study concludes that the engine can be efficiently operated with neat jatropha (or karanja) oil preheated by jacket water. *Mehta et al., (2007)* incorporated a device heat exchanger that used to decrease the viscosity of straight vegetable oil and thus provide smooth running of engine.

V. Vara Prasad et al., (2011) focuses on the use of pongamia seed based oil as fuel in diesel engine by blending it with diesel for dilution of viscosity and preheating it for reduction of viscosity. *P. V. Rao, (2011)* studied the effect of properties of Karanja (*Pongamia pinnata*) methyl ester on combustion, and NOx (oxides of nitrogen) emissions of a diesel engine. The engine tests were conducted with karanja methyl ester (with and without preheating), and baseline fossil diesel. A significant reduction in oxides of nitrogen emission is observed with preheated methyl ester. *Sagar Pramodrao Kadu, et al., (2010)* deals with preheated neat Karanja oil from 30° C to 100° C. Found the lower thermal efficiency with preheated neat Karanja oil at higher speed. The power developed and NO_x emission increase with the increase in the fuel inlet temperature and the specific fuel consumption is higher than diesel fuel operation at all elevated fuel inlet temperature. *Ch. Satyanarayana1et al., (2009)* examined the influence of Pongamia biodiesel (with and without preheating), and petroleum diesel as fuels. A significant improvement in thermal efficiency was observed with preheated biodiesel. There is a significant reduction in all exhaust gaseous emissions. Also a considerable reduction in nitric oxide emission is observed with preheated biodiesel due to change in premixed combustion phase. *A K Agarwal et al.,(2009)* conducted a series of engine tests, with and without preheating gives significant improvements in the performance and exhaust emissions, and conclude that the Karanja oil blends with diesel (up to 50% v/v) with preheating can replace diesel.

Authors experimented on different vegetable oils and biodiesels with and without preheating and found that the per-heat of vegetable oil up to 80-120° C brings the viscosity similar diesel and same viscosity at fuel injector. The expected outcomes are higher brake thermal efficiency up as compared to diesel and highest brake power with minimum brake specific fuel consumption. The emission of HC, CO_2 and NO_2 to be significantly lesser or at least closer compared to diesel.

Table: 2.1 Blending/ Pre-heating device for various vegetable oil and their derivatives.

Authors	*Vegetable. oil /Biofuel*	*Blending/ Pre-heating device*	*Remarks/ Preheated temperature*
R.Sarala, et.al (2011)	MOME	Blending	NO_x increased with increased % of biodiesel blending
Satyanarayana Murthy, et al (2010)	Tobacco oil(TME)	Blending	Higher the percentages blending, the performance & engine emissions drastically effected.
N. Tippayawong, et.al (2002)	Palm and soybean oils	Heater	40 – 100°C
Vijittra Chalatlon, et.al (2011)	Jatropha oil	Heating and Blending	Viscosity close to ASTM limits (ASTM D6751) for 100°C or more.
P.B.Ingle ,et.al (2011)	COME	Heater	Preheated to 50, 70 and 90°C, appreciable results with 90°C.
S K Acharya, et.al (2011)	Kusum and Karanja oil's	Shell and tube heat exchanger	Viscosity very close to that of diesel, by preheating to 100–130°C.
M. C. Navindgi,et.al(2011)	Neem, Mahua, Linseed and Castor oil.	Heat exchanger	Viscosity very close to that of diesel at 80°C of neat Neem, Mahua and linseed oil, and that at @120°C for Castor.
Sagar Pramodrao Kadu, et.al(2010)	Karanja oil	Electric heater	Preheated at 30°C to 100 °C
R. Raghu, et.al(2011)	Rice bran oil(RBME)	Heat exchanger using exhaust gas	Raised to 158°C to bring its viscosity closer to diesel
A.K.Agarwal, et.al(2009)	Karanja oil	Heat exchanger	---
Lutfia, et.al(2009)	Petrol	Heat pipe	Preheated at 30°C to 100 °C
Z.M. Hasib, et.al (2011)	MOME	Gas burner.	Preheating required for B40 and emits cleaner emission (except for NO_x)
Kamal Kishore Khatri, et.al (2010)	Karanj	Heat exchanger	---
Chauhan, et.al (2010)	Jatropha	Heat exchanger,	Optimal fuel inlet temperature was found to be 80°C
Yilmaz and Morton, et. al(2011)	Peanut, sunflower and canola oils	---	---
Hazar and Aydin, et.al (2010)	Raw rapeseed oil (RRO)	---	The effects of fuel preheating to 100°C, lowered its viscosity and provided smooth fuel flow
M.V Mallikarjun , et.al (2011)	Madhuca Indica oil	Exhaust gases/heater	30°C to 135 °C
Suresh R, B, et.al(2009)	Coconut oil	heater	Preheated (50%) coconut oil blends and Without preheating 20% coconut oil blends gave optimum results
Canacik, et al (2010)	LPG,CNG,LNG and CCNG	Heat exchanger	Fuel consumption reduced by 5-40%
Dhrubatara Mitra, et al.(2011)	Karanja oil	Heater	50°C to 200 °C, Best performance at 122 °C.
K. Pramanik , et.al (2003)	Jatropha curcas oil	Heater	25–75 °C.
L. Labecki, et.al(2009)	RSO	----	Temperature maintained at 70 °C for all runs for RSO.
Agarwal D, et.al (2007)	*Jatropha* oil	---	---
Murat Karabektas, et.al(2008)	COME	---	30, 60, 90 and 120 °C.
O.M.I. Nwafor,et.al (2004)	Neat vegetable oils	---	The heated fuel showed a comparative reduction in delay period over the unheated.
S. Bari ,et al (2002)	CPO	---	92 °C is needed shorter ignition delay of 2.6°,no benefits in terms of engine performance.
M.Martin, et.al (2011)	CSO	---	Blend containing 60% of cottonseed oil with diesel, heated to a temperature of 70°C.
Pugachev , et.al (2001)	Petrol	Heat exchanger	Increased fuel saving and reduced exhaust gas toxicity and enable the use of cheaper low octane fuel.
V.R. Sivakumar , et.al (2009)	Jatropha oil	---	Preheated temperature of 35° C to 47°C.
T. Venkateswara Rao , et.al 2008)	Pongamia (PME), Jatropha (JME) and Neem (NME)	---	The high density of methyl esters (B25, B30, B60 etc.) Can be reduced by heating of fuel.
M.Prabhakar , et.al (2011)	Pungamia methyl ester (PME)	---	B5, B10,B15 and B20 blends can be used without any heating
M. Nematullah Nasim, *et.al* (2010)	Neat jatropha oil	---	The preheating done from 30° C to 100°C.
Ch .S. Naga Prasad , et.al (2009)	Castor oil	Electric heating	The heating temperature of the blends increases with the increase in the percentage of neat oils , 70° C to 120° C before entering into the combustion chamber.
Oza Nityam P , et.al (2012)	Karanj, Jatropha and Neem	---	Preheating the fuel to overcome problem of higher viscosity and lower volatility associated with bio-diesel.
Md A. Hossain, et al.(2012)	Coconut Oil	---	B40 at 55° C. B60 at 60° C, B100 requires preheating at 65° C to attain similar flash point as that of diesel fuel.
Hevandro , et.al (2010)	Soybean oil	---	Pre-heated (65 °C) 50% (v v-1) of soybean oil in petro diesel
Bhupender singh chauhan., et.al (2010)	Pre-heated jatropha oil	Shell and tube heat exchanger	The optimal fuel inlet temperature was found to be 80ºC
R. Raghu, et.al.(2011)	Rice bran oil(RBME)	Heat exchanger using exhaust gas	Raised to 158°C to bring its viscosity closer to diesel
H Masjuki, et al.(1996)	Palm Methyl Esters	---	---
P V Rao(2011)	Karanja methyl ester	Heater	---

Although there are number of fuel preheating devices like electric heating, shell and tube heat exchangers, heating coils, gas burners, fuel inline heating and other manual heating methods but, still a lot of work that needs to be done to apply for preheating the biodiesels effectively. Till now no such effective works carried using gravity assisted heat pipe to preheat the biodiesels, which is more compact, low cost, superconductive and no need of energy to run.

2.3 Thermosyphon (gravity assisted wickless heat pipe)

A heat pipe is a device that efficiently transports thermal energy from its one point to the other. It utilizes the latent heat of the vaporized working fluid instead of the sensible heat. As a result, the effective thermal conductivity may be several orders of magnitudes higher than that of the good solid conductors.

A heat pipe consists of a sealed container, a wick structure, a small amount of working fluid that is just sufficient to saturate the wick and it is in equilibrium with its own vapor. The operating pressure inside the heat pipe is the vapor pressure of its working fluid. If the wick is not used in the construction of heat pipe, it is called thermosyphon. In thermosyphon, return of the working fluid from condenser to evaporator is caused by gravity. *(Shaikh Naushad., 2013).*

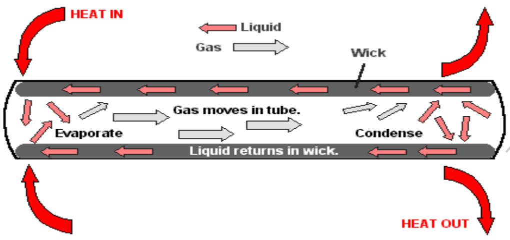

Figure 2.1: Heat pipe

The length of the heat pipe can be divided into three parts viz. evaporator section, adiabatic section and condenser section. In a standard heat pipe, the inside of the container is lined with a wicking material. Space for the vapor travel is provided inside the container. A heat pipe can transfer up to 1000 times more thermal energy, than copper, the best known conductor. *(Shaikh Naushad., 2013).*

One of the amazing features of the heat pipes is that they have no moving parts and hence require minimum maintenance. They are completely silent and reversible in operation and require no external energy other than the thermal energy they transfer. The present work deals with the gravity assisted heat pipe for preheating.

2.4 Gravity assisted Heat Pipe

- In thermosyphon, return of the working fluid from condenser to evaporator is caused by gravity.
- Gravity is used to force the condensate back into the evaporator.
- Therefore, condenser must be above the evaporator in a gravity field.

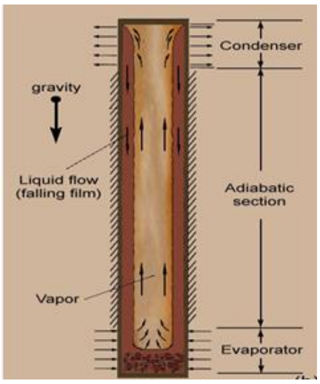

Figure 2.2: Gravity assisted heat pipe

The idea of heat pipes was presented first by Gaugler in General Motor Company in 1942. The first heat pipe was designed and manufactured by *Grover (1966*) in National Lab, Los Alamos, in the US in 1964. Since then, heat pipes are being used in many applications such as: heat exchangers (air pre-heaters or systems that use economizers for waste heat recovery), cooling of electronic components, solar energy conversion systems, spacecraft thermal control, cooling of gas turbine rotor blades, etc.,

MD Anwarul Hasan et al., (2003) discussed the performance of a gravity assisted heat pipe of diameter 12.5 mm and length 0.50 m using water as working fluid with different heat flux from 25 to 40 W and a fill charge ratio of 0.20. The best performance of heat pipe is achieved at its vertical position where gravity serves to assist return of condensate from condenser to evaporator. *Y. Cao et al.*, (2002) designed, fabricated, and tested two flat-plate wickless heat-pipes under different working conditions and orientations relative to the gravity vector, with water and methanol as the working fluids. *M. Karthikeyan et al.*, (2010) developed copper thermosyphon with a length of 1000 mm long, an inner diameter of 17 mm and an outer diameter of 19 mm was employed. Each thermosyphon was charged with 60% of the working fluid and was tested with an evaporator length of 400 mm and condenser length of 450 mm. The thermosyphon was tested for various inclinations of 45°, 60° and 90° to the horizontal. Flow rate of 0.08Kg/min, 0.1 Kg/min and 0.12 Kg/min and heat input of 40 W, 60 W and 80 W were taken as input parameters. *Amornkitbumrung et al*., (1995) designed and fabricated two phase closed thermosyphon using copper water combination. Their study show the effect of the inclination angle on the heat transfer rate and the highest heat transfer rate occurred at 22.5° with a filling ratio of 30%. *Wang and Ma*, (1991) studied condensation heat transfer inside vertical and inclined thermosyphons. *Rudra Naik, et al.*, tested a heat pipe with an axial grooved wick for horizontal and gravity assisted orientations. In their analysis three different working fluids i.e. methanol, acetone and distilled water were used. The maximum heat transfer coefficient for methanol, acetone and distilled water were found to be

3550 W/m^2 °c for horizontal orientation, 1700 W/m^2°c for vertical orientation and 2400 W/m^2 °c for vertical orientation respectively.

The author's investigations insist the appropriate orientation, working fluid, container material and filling ratio to optimize the preheating.

3. MATERIALS AND METHODS

It has been concluded from the above literature review that, preheating of biodiesels is required before admitting into the engine cylinder and also the heat pipe (closed Thermos phone) can be used effectively and economically as a device for preheating the biodiesel.

3.1 Objectives of investigation

- To study the variation of viscosity with temperature.
- To study the effect of heat input at evaporator.(50, 100, 150, and 200 W)
- To study the temperature difference (gradient) between evaporator and condenser.
- To analyze the thermal resistance and Effectiveness of the heating device.
- study the of flow rate at different temperatures
- To demonstrate biodiesel temperature suitable for the engines.

  Blends of POME with petro diesel (20%, 40%, 60 %, 80 % and 100 %)

3.2 Viscosity of POME and its blends with petro diesel

The viscosity at different temperatures studied in the laboratory. The viscosity of Pongamia biodiesel blends with petro diesel measured using Redwood viscometer and the flash and fire point temperature using Cleveland open cup apparatus.

The figure 3.1 indicates the variations of viscosity with temperature measured in the laboratory**.** However with the increased % blend ratio of biodiesel the viscosity increases. It's also come to know that the blending up to 20 % with biodiesel will yield the properties near to diesel but, the blending above 20 % needs a preheating device for the biodiesels before the fuel admit in to the engine cylinder.

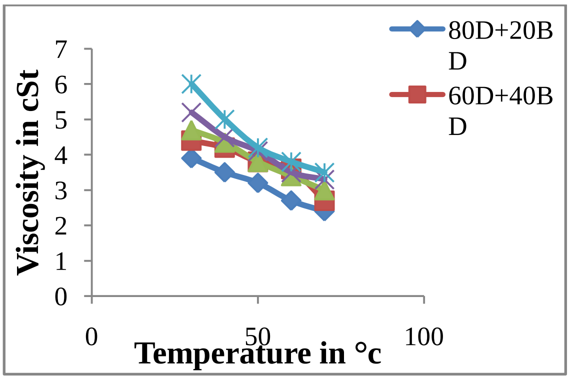

Figure 3.1: Viscosity temperature behavior of different blends

3.3 Experimental Set Up

The experiments were conducted on closed thermosyphon which is fabricated as per mentioned dimensions. The power input to the thermosyphon is gradually raised to the desired power level keeping thermosyphon in vertical position.

The surface temperatures at different locations along heat pipe sections are measured at regular time intervals until the heat pipe reaches the steady state condition. Simultaneously the evaporator wall temperatures, condenser wall temperatures, oil inlet and outlet temperatures in the condenser zone are measured. Once the steady state is reached, the input power is turned off and cooling oil is allowed to flow through the condenser to cool the heat pipe and to make it ready for further experimental purpose. Then the power is increased to the next level and the heat pipe is tested for its performance.

Experimental procedure is repeated for different heat inputs (50, 100, 150, and 200 W) and at different blending ratios of diesel and biodiesel.

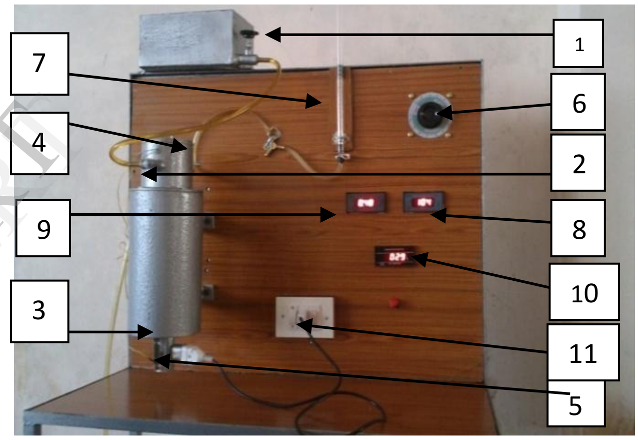

Figure 3.2: experimental set up

1. Oil tank
2. Inlet to condenser
3. Thermosyphon
4. Condenser out
5. Heater
6. Variator
7. Burette
8. Ammeter
9. Voltmeter
10. Temperature Indicator
11. Main power input

Table 3.3: Details of thermosyphon device

Container	Copper
Working fluid	Distilled water
Diameter of thermosyphone	Do=22 mm
Length of thermosyphone	460 mm
Thickness of tube	1.2 mm
Evaporator length	80 mm
Condenser length	80 mm
Adiabatic length	300 mm
Filling ratio	60 % of EVO volume
Thermocouples	type K-08 no
Heat source	Φ45X65 mm stainless steel vessel with heater

4. RESULTS AND DISCUSSIONS

The following section details the data recorded from the extensive experimentation carried for varied parameters as per the matrix defined. Since the viscosity of biodiesel is a function of temperature, the effect of following parameters studied.

Effectiveness of heat pipe
Thermal gradient
Rise in biodiesel temperature
Thermal resistance
Flow rate

Temperature difference: Figure 4.1 shows the decreasing trend of temperature difference between the cold and hot end which decides the effectiveness and the heat capacity of heat pipes, as the input power increased from 50 W to 200 W the decreased temperature difference results the faster response. The graph shows decreased temperature difference for lower heat input and also at higher blends due to reduced flow rate because of higher viscosities.

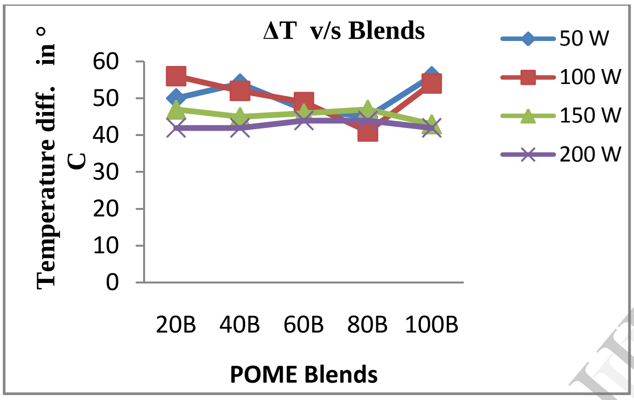

Figure 4.1: Temperature difference for POME blends at different heat input

Efficiency (Effectiveness of heat pipe): Figure 4.2 shows the reduced effectiveness for 60B POME blends at different heat input

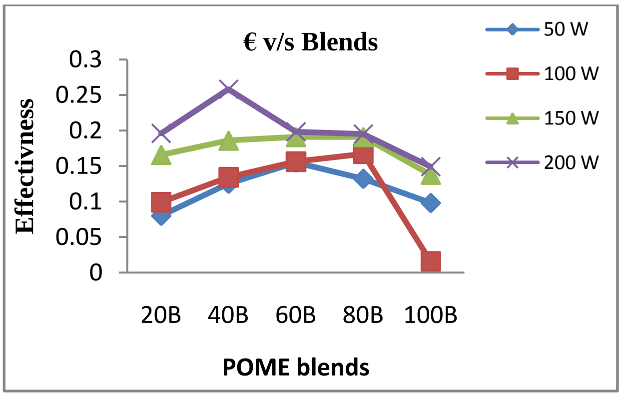

Figure 4.2: Thermosyphon effectiveness for POME blends at different heat input

The efficiency increases with increases in heat input from 50 to 200 W, it's because of reduced temperature difference between the evaporator and condenser section with increased heat input and time as well there is increased flow of fluid. The optimum value of 25.8 % effectiveness recorded at 200 W heat input.

Thermal resistance: Thermal resistances condense quickly to its minimum value when the heat load is increased.

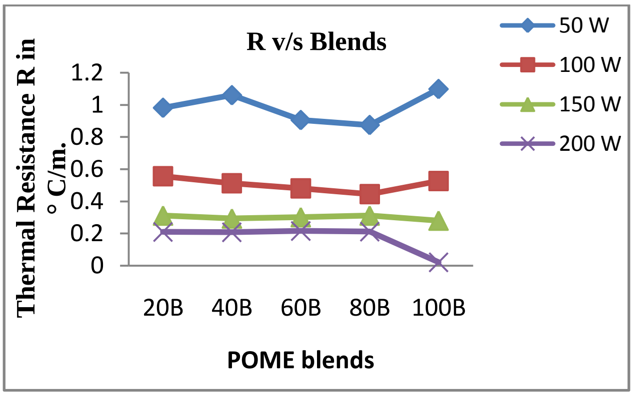

Figure 4.3: Thermal resistance for POME blends at different heat input

The above Figure 4.3 cleared that the decreases in thermal resistance increased the effectiveness of heat pipes, and the thermal resistance decreased with increased heat input. And it has been observed that there is no much difference with varied blends on thermal resistance of heat pipe.

Rise in biodiesel temperature: It is observed in Figure 4.4 that the temperature difference between the evaporator and the condenser increases for increasing values of heat input, leads to increased condenser outlet temperature. The main objective of the paper is to demonstrate the increase in temperature of biodiesel blend, fortunately for all blends the temperature varies from 74-79° C.

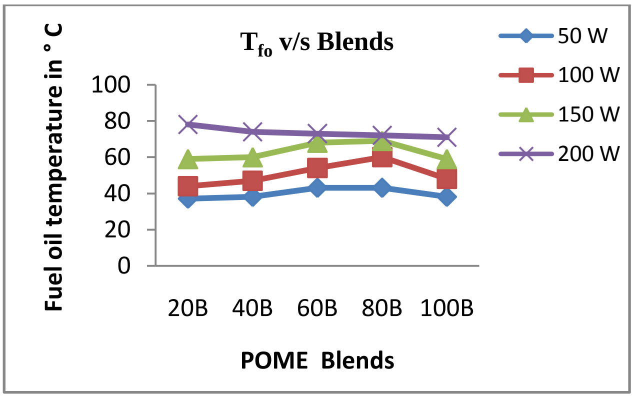

Figure 4.4: Rise in biodiesel Temperature for various blends

For all the blends with heating at 100 and 150 W will yield the blends suitable for engines and the viscosity close to diesel. Even 100 % biodiesel can be directly used if heated.

Flow rate: It is clear from the Figure 4.5 that thermal resistance exhibited a decreasing trend as the heat input is increased. It could be mentioned here, as the heat input is raised, heat transfer rate is increased due to the increase of vapor density Since the viscosities decreased with the heat input, there is increased flow rate and decreased time for flow of oil as shown in the below graphs.

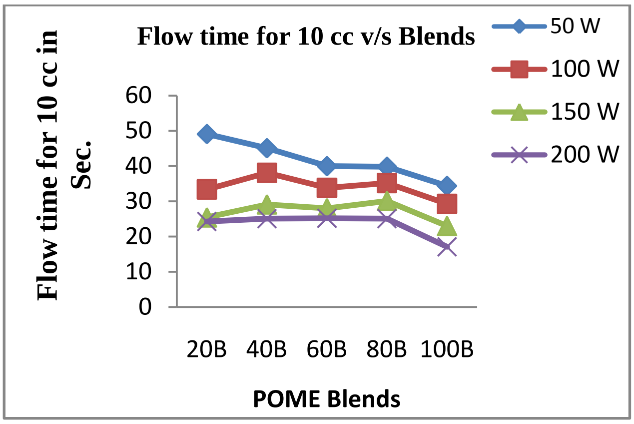

Figure 4.5: Flow rate for various blending ratios

CONCLUSIONS

The results of work insight into the study the effect of parameter variation on the effectiveness, thermal resistance, temperature difference, temperature distribution, heat capacity of heat pipe, viscosity, flow rate and rise in fuel temperature for different blending ratios of pongamia biodiesel with diesel.

The following are the conclusions remarked from the results and discussions.

1. The heat pipe has been fabricated and the instrumentation carried for the measurement required, like heat input, thermocouples, flow measurement e.t.c.,
2. The experiments conducted at different heat input of 50W, 100W, 150 W and 200 W.
3. The temperature difference, thermal resistance reduced with increased heat input from 50- 200 W indicating the faster heat transfer.
4. The efficiency of heat pipe, fuel outlet temperature, flow rate increased with increased heat input from 50-200 W.
5. Increasing the flow rate makes the flow smooth without clog in the path and the
6. Heating at 100 and 150 W will yield the blends suitable for engines and with viscosity close to diesel.

Thus, the gravity assisted heat pipe can be used as biodiesel preheating device, using which the biodiesels blends above 40 % and even 100 % biodiesels can be used directly.

REFERENCES

1. Acharya S K, Mohanty M K, Swain R K. "Kusum oil as fuel for small horse power diesel engine". International Journal of Engineering and Technology, 2009; 1(3): 219–223.
2. A. Demirbas. "Biodiesel fuels from vegetable oils via catalytic and non-catalytic supercritical alcohol transesterifications and other methods: a survey". Energy Conversion and Management. 2003 44: 2093–2109.
3. Agrwal D, Agrwal A K. "Performance and emission characteristics of jatropha oil (Pre heated and Blends) in a direct compression ignition engine". Applied Thermal Engineering, 2007; 27: 2314–23.
4. Alpesh Mehta, Mehul Joshi , Ghanshyam Patel , Mohammad Juned Saiyad "Review article performance of single cylinder diesel engine using jatropha oil with exhaust heat recovery system" International Journal of Advanced Engineering Technology E-ISSN 0976-3945 IJAET/Vol.III/ Issue IV/Oct.-Dec., 2012/01-07.
5. A. K. Hossain and P. A. Davies "Performance, emission and combustion 1 characteristics of an indirect injection (IDI) multi-cylinder compression ignition (CI) engine operating on neat jatropha and karanja oils preheated by jacket water" Manuscript. Sustainable Environment Research Group, School of Engineering and Applied Science, Aston 7, 2012.
6. Amornkitbamrung M, Wangnippanto S and Kiatsirirote T, "Performance studies on evaporation and condensation of a thermosyphon heat pipe", Proc 6th ASEAN Conference of Energy Technology, 28-29 August, Bangkok, Thailand, pp 27-34, (1995).
7. Arif CANACIK, Ahmet DONMEZ "Fuel preheating system" United States patent (19) September 1988. Patent No.0167221 Al. July 2010.
8. Avinash Kumar Agarwal, K. Rajamanoharan "Experimental investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel engine" Applied Energy 86 (2009) 106-12.
9. Bhupendra Singh Chauhan, Naveen Kumar and Haeng Muk Cho "Performance and emission studies on an agriculture engine on neat Jatropha oil" Journal of Mechanical Science and Technology 24 (2) (2010) 529~535.
10. CH. Satyanarayana, and P. V. Rao "Influence of Key Properties of Pongamia Biodiesel on Performance Combustion and Emission Characteristics of a DI Diesel Engine" WSEAS TRANSACTIONS on HEAT and MASS TRANSFER ISSN: 1790-5044 Issue 2, Volume 4, April 2009.
11. Ch .S. Naga Prasad , K. Vijaya Kumar Reddy, B.S.P. Kumar, E. Ramjee, O.D. Hebbel and M.C. Nivendgi "Performance and emission characteristics of a diesel engine with castor oil" Indian Journal of Science and Technology Vol.2 No.10 (Oct 2009).
12. Dinesha P, Mohanan P "Experimental investigations on the performance and emission characteristics of diesel engine using preheated pongamia methyl ester as fuel" International Journal of Advances in Engineering & Technology, Nov. 2012. ©IJAET ISSN: 2231-1963 591 Vol. 5, Issue 1, pp. 591-600.
13. Dhrubatara Mitra,A K Basu "Techno economic study on using non edible oil as a diesel substitute for electricity generation in remote villages and forest areas" Journal of Scientific and Industrial Research. Vol.70, August 2011,pp. 699-702.
14. Grover, G. M. (1964). Evaporation-condensation heat transfer device. US Patent, No.3229759.
15. Hazar, H. and Aydin, H., 2010, "Performance and emission evaluation of a CI engine fueled with preheated raw rapeseed oil (RRO)–diesel blends", Applied Energy, 87: 786–790.
16. Hevendro colonhese delali bera, et al,"Performance of a diesel engine fuelled with preheated blend of Soy bean Oil and Petrol Diesel".
17. Heywood John B "Internal Combustion Engines Fundamentals", New York, McGraw-Hill. 1988.
18. H Masjuki, M Z Abdulmuin, H S Sii, "Investigations on Preheated Palm Oil Methyl Esters in the Diesel Engine" Proceedings of the Institution of Mechanical Engineers, Part A: Journal of Power and Energy April 1996 vol. 210 no. 2 131-138
19. Kamal Kishore Khatri A, Dilip Sharma A, S. L. Soni A, Satish Kumar A,Deepak Tanwar B "Investigation of Optimum Fuel Injection Timing of Direct Injection CI Engine Operated on Preheated Karanj-Diesel Blend" Volume 4, Number 5, November 2010 ISSN 1995-6665 Pages 629 – 640 Jordan Journal of Mechanical and Industrial Engineering.
20. K. Pramanik "Properties and use of jatropha curcas oil and diesel fuel blends in compression ignition engine"Journal of Renewable Energy, 2003, Vol 28, issu-2,239-248.
21. L. Labecki, L.C. Ganippa "Soot reduction from the combustion of 30% rapeseed oil blend in a HSDI diesel engine" Towards Clean Diesel Engines, TCDE2009.
22. Lutfia. Essia. Ramadan "Designing a heat pipe to improve the exhaust emissions from petrol engines" Ecologic vehicles. Renewable energies MONACO- March.2009, Copyright 2009 MC2D MITI.

23. Mandal B., Majumdar S. G., Maity, C.R., "Chemical and Nutritional Evaluation of Pongamia glabra Oil and Acacia uriculaeformis Oil", J. American Oil Chemists Society, Vol. 61, No. 9, 1984, pp. 1447-1449.
24. Mitra, C.R., "Development of Minor and Nonedible Oils", Report of the Indian Central Oilseeds Committee, Hyderabad, 1963, p.29.
25. M. C. Navindgi, Dr. Maheswar Dutta "Performance Evaluation and Emission Characteristics of Different Vegetable Oils on a Single Cylinder Agricultural Diesel Engine" Proc. of Int. Conf. on Advances in Mechanical Engineering 2011.
26. Md A. Hossain, Shabab M. Chowdhury, Yamin Rekhu, Khandakar S. Faraz, Monzur Ul Islam, "Biodiesel From Coconut Oil: A Renewable Alternative Fuel For Diesel Engine", World Academy Of Science, Engineering And Technology Vol.68, Pp. 1289-1293, 2012.
27. MD Anwarul Hasan, Chowdhury MD Feroz and A.K.M. Sadrul Islam "performance of a gravity assisted heat pipe" Proceedings of the International Conference on Mechanical Engineering 2003 (ICME2003) 26- 28 December 2003, Dhaka, Bangladesh.
28. M.Karthikeyan, S.Vaidyanathan, B.Sivaraman "Thermal performance of a two phase closed thermosyphon using aqueous solution". International Journal of Engineering Science and Technology Vol. 2(5), 2010, 913-918
29. M. Nematullah Nasim, Ravindra Babu Yarasu and Jehad Yamin, "Simulation of CI engine powered by neat vegetable oil under variable fuel inlet temperature", Indian Journal of Science and Technology, Vol. 3 No. 4,387- 392, 2010.
30. M. Martin ,A, D. Prithviraja "Performance of Pre-heated Cottonseed Oil and Diesel Fuel Blends in a Compression Ignition Engine" Jordan Journal of Mechanical and Industrial Engineering Volume 5, Number 3, June 2011 ISSN 1995-6665 Pages 235 – 240.
31. Murat Karabektas, Gokhan Ergen, Murat Hosoz "The effects of preheated cottonseed oil methyl ester on the performance and exhaust emissions of a diesel engine" Applied Thermal Engineering Volume 28, Issues 17-18, December 2008, Pages 2136-2143.
32. M.V. Mallikarjun,Venkata Ramesh Mamilla, G Lakshmi Narayana Rao"Investigations on the performance and exhaust emissions of a diesel engine using preheated Madhuca indica as a fuel" International journal of mechanical and production engineering research and development, Vol.1 Issue 1(2011) 1-15.
33. Nadir Yilmaz, Byron Morton"Effects of preheating vegetable oils on performance and emission characteristics of two diesel engines" Biomass and Bioenergy , Volume 35 (5) – May 1, 2011.
34. N. Tippayawong, T. Wongsiriamnuay and W. Jompakdee "Performance and Emissions of a Small Agricultural Diesel Engine Fueled with 100% Vegetable Oil: Effects of Fuel Type and Elevated Inlet Temperature" Asian J. Energy Environ., Vol. 3, Issues 3-4, (2002), pp. 139-158.
35. O.M.I. Nwafor "Emission characteristics of diesel engine running on vegetable oil with elevated fuel inlet temperature" Biomass and Bioenergy 27 (2004) 507 – 511.
36. Oza Nityam P, Dr. Rathod Pravin P. Prof. Patel Nikul K "Review article a review of recent research on non edible vegetable oil as fuel for CI engine" Journal of Engineering Research and Studies E-ISSN0976-7916 JERS/Vol.III/ Issue I/January-March, 2012/84-86.
37. P.B.Ingle,R.S.Ambade, R.V.Paropate, S.Bhansali "Comparisons of Diesel Performance Neat and Preheated Transesterfied Cotton Seed Oil" (IJAEST) international journal of advanced engineering sciences and technologies vol no. 5, issue no. 1, 067 – 071-2011.
38. Pugachev "Method for preparing an air fuel mixture for an internal combustion engine, device for realizing the same and heat exchanger." United States Patent. Patent No.6314919 B1. November 2001.
39. P. V. Rao "Effect of properties of Karanja methyl ester on combustion and NOx emissions of a diesel engine" Journal of Petroleum Technology and Alternative Fuels Vol. 2(5), pp. 63-75, May 2011.
40. R.Sarala, Dr.M.Rajendran, Dr.S.R.Devadasan "Emission characteristics of mustard oil methyl ester (MOME)–diesel fuel blends on a C.I engine" International Journal of Green Chemistry and Bioprocess 2012, 2(1): 6-10.
41. R. Ragu, G. Ramadoss, K. Sairam, A.Arulkumar "Experimental Investigation on the Performance and Emission Characteristics of a DI Diesel Engine Fueled with Preheated Rice Bran Oil" ISSN 1450-216X Vol.64 No.3 (2011), pp. 400-414© Euro Journals Publishing, Inc. 2011.
42. Rudra Naik, Venugopal Varadarajan,G Pundarika."Design, fabrication and performance evaluation of axially grooved wick assisted heat pipe". International Journal of Emerging trends in Engineering and Development ISSN 2249-6149 Issue1, Vol. 2.
43. Sagar Pramodrao Kadu, Rajendra H. Sarda "Experimental Investigations on the Use of Preheated Neat Karanja Oil as Fuel in a Compression Ignition Engine" World Academy of Science, Engineering and Technology 7-2- 2010.
44. S. Bari, T. H. Lim and C. W. Yu, "Effects of Preheating of Crude Palm Oil (CPO) on Injection System, Performance and Emission of a Diesel Engine", Renewable Energy, Vol. 27, No. 3, Nov.2002, pp. 339-351.
45. Shaikh Naushad "HEAT PIPES" Excel Journal of Engineering Technology and Management Science (An International Multidisciplinary Journal) Vol. I No. 3 December – January 2012-13 (Online) ISSN 2277-3339.
46. S K Acharya, A K Mishra, M Rath, C Nayak "Performance analysis of karanja and kusum oils as alternative bio-diesel fuel in diesel engine" International Journal of Agric & Bio Eng, June, 2011 Vol. 4 No.2 23-28.
47. S Prabhakar,K Annamalai,Issac Joshua Ramesh Lalvani "Experimental study of using hybrid vegitable oil blends in diesel engine "Journal of scientific and industrial research Vol.71,September 20112,pp.612-615
48. Suresh R, B. Durga Prasad, S. Muthu Raman and T. Nibin "Emission control for a glow plug direct injection C I engine using preheated coconut oil blended diesel" vol. 4, no. 8, October 2009 ISSN 1819-6608 ARPN journal of engineering and applied sciences.
49. T. Venkateswara Rao a, G. Prabhakar Rao , and K. Hema Chandra Reddy "Experimental Investigation of Pongamia, Jatropha and Neem Methyl Esters as Biodiesel on C.I. Engine" Jordan Journal of Mechanical and Industrial Engineering Volume 2, Number 2, Jun. 2008 ISSN 1995-6665 Pages 117 – 122.
50. Vijittra Chalatlon, Murari Mohon Roy, Animesh Dutta and Sivanappan Kumar "Jatropha oil production and an experimental investigation of its use as an alternative fuel in a DI diesel engine" Journal of Petroleum Technology and Alternative Fuels Vol. 2(5), pp. 76-85, May 2011.
51. Vivek, Gupta AK (2004) "Biodiesel production from Karanja oil". J. Sci. Ind. Res., 63: 39-47.
52. V.R. Sivakumar, V.Gunaraj, P.Rajendran "Statistical analysis on the performance of engine with jatropha oil as an alternate fuel" International Journal of Engineering Science and Technology Vol. 2(12), 2010, 7740-7757.
53. V. Vara Prasad, M. Lava Kumar and B. Madhusudhan Reddy "Modeling, analysis and optimization of the total fuel consumption and brake thermal efficiency of diesel engine with pongamia oil as an alternate fuel" Science Insights: An International Journal 2011; 1 (1): 11-16.
54. Wang J C Y and Ma Y "Condensation heat transfer inside vertical and inclined thermosyphons", Journal of Heat transfer, vol 113, pp 777-780, August (1991).
55. Wilson Parawira, "Biodiesel production from Jatropha curcas: A review". Scientific Research and Essays Vol. 5(14), pp. 1796-1808, 18 July, 2010.
56. www.naturfuels.com
57. Y. Cao , M. Gao "Wickless network heat pipes for high heat flux spreading applications" International Journal of Heat and Mass Transfer 45 (2002) 2539–2547.
58. Y. V. V. Satyanarayana Murthy "Performance of tobacco oil-based bio-diesel fuel in a single cylinder direct injection engine" Journal of the Physical Sciences Vol. 5(13), pp. 2066-2074, 18 October, 2010.
59. Z.M. Hasib "Use of mustard oil as an alternative and renewable substitute of fossil diesel" BRAC University Journal, vol. VIII, no. 1&2, 2011, pp. 55-62.