Extraction and Testing of Biodiesel From Almond and Mustard Seed's

Mr. G Balaji[1], Dr. J Murali Naik[2]
[1]Assistant Professor, Dept of Mechanical Engineering
[2]Associate Professor & HOD, Dept of Mechanical Engineering
[1, 2] Holy Mary Institute of Technology and Science (An autonomous Institute), Hyderabad, India

Abstract- *Due to scarcity of fossil fuels in earth's crust efforts are being made throughout the planet to reduce the consumption of petroleum products. Biodiesel is recently gaining prominence as a substitute for petroleum fuels mainly due to environmental considerations. Bio-diesel has become more attractive recently because of the fact that it is made from renewable resources. Although short-term tests using vegetable oil showed some promising results, longer tests led to choking of injector, engine deposits and thickening of lubricant oil. Although there are many ways and procedures to convert vegetable oil into Diesel like fuel, the transesterification process was found to be the most viable process. Biodiesel have been produced from different edible and non-edible oil and the properties of biodiesel produced are measured and compared with those of biodiesel. As in India the mustard and almond seeds are available in abundance, from which we have extracted oil by using Bligh-Dyer method and by performing transesterification reaction on these respective oils, we got biodiesels. By using the blends of these biodiesels with that of conventional diesel, we performed C.I. engine testing. The blends used were B10 (10% biodiesel and 90% conventional diesel) and B20 (20% biodiesel and 80% conventional diesel)*

Keywords- Almond, Biodiesel, Blending, Bligh-Dyer Method, Mustard, Transesterification.

I. INTRODUCTION

Recent survey on the World Energy Consumption, which highlights that a major portion of the total energy consumed is derived from the combustion of fossil fuels. Among the fossil fuels, liquid petroleum based fuels contributes a maximum because of their chemical and combustion properties. Unfortunately, the reserves of fossil fuels, specially the liquid fuels are limited and may exhaust soon, if not utilized economically, within few decades. Efforts are being made throughout the world to reduce the consumption of fossil fuels. Two general approaches are in use. First is to switch over the energy consumption devices on alternative energy source which are either abundant or are reproducible. The second is to improve the efficiency of combustion devices. This can be achieving by understanding the physicochemical processes involved during the combustion. Such knowledge is also important in view of propulsion, reduction of combustion generated pollution and control of fire hazard in handling combustibles.

Recently, there has been a growing concern about the rapid increase in air pollution caused by the combustion of petroleum products. In addition, depleting resources of conventional fuels has caused an increase in its price. Biodiesel is a renewable fuel which is generated from vegetable oil or animal fat through a chemical process and can be used as substitute, extender or as an additive to fossil diesel fuel in C.I engines.

The most promising feature of biodiesel is that it can be used in existing design of compression ignition engines with no or very little modifications. It has a proven performance for air pollution reduction. Biodiesel is produced through the chemical reaction of vegetable oils or animal fat with methanol or ethanol in the presence of catalyst to yield glycerol as by product (biodiesel chemically called methyl or ethyl ester). However, the price of biodiesel is presently more as compared to petrol &diesel. Higher cost of biodiesel is primarily due to the raw material cost.

II. NECESSITY AND NEED OF THE PROJECT

As the crude oil are depleting day by day, there is a need to find out an alternative fuel to fulfill the energy need of the world. Biodiesel is one of the best present available sources to fulfill the energy demand of the world. The fossil fuel plays a very important role in the development of industries, transportation, agricultural and to meet many other basic human needs. However, these fuels are limited and depleting day by day as the consumption is increasing very rapidly. Moreover, their use is alarming the environmental problems to society. Hence, the scientists are looking for alternative fuels. India is importing more than 85% of its fuel demand and spending a huge amount of currency on fossil fuel. Biodiesel is gaining more and more importance as an attractive alternative fuel due to the depleting nature of fossil fuel resources.

The very basic step is to extract oil from the almond seeds. This is done by a chemical reaction named as Bligh-Dyer method. This method is performed by using a device called as rotary evaporator.

The purpose of transesterification process is to lower the viscosity of the oil. The main downside of vegetable oil is because of their high viscosity and low volatility, which causes poor combustion in diesel engines. The transesterification is the process in which the glycerides is removed and combining oil esters of vegetable oil with alcohol. This process effectively reduces the viscosity to a value comparable to that of diesel and hence improves combustion. Biodiesel emits lesser pollutants over the whole range of air–fuel ratio when compared to diesel. Biodiesel can be produced by using different methods such as ultrasonic cavitation, hydrodynamic cavitation, microwave irradiation, two-step reaction process, response surface technology etc. Experiments had been conducted for different types of combustion chambers. It was found that spherical combustion chamber gives better results than other type of combustion chambers. The scientists tested a number of different raw and processed vegetable oils like rapeseed oil, sunflower oil, palm oil, soybean oil, mustard oil and almond oil.

Biodiesel is produced from vegetable oils. The main components of vegetable oil are triglycerides. Triglycerides are esters of glycerol with long chain acids, commonly named fatty acids. Bio-diesel can be defined as mono alkyl esters of long chain fatty acids derived from renewable feedstock such as vegetable oil or animal fats, for use in compression ignition (CI) engines. This name is given to the esters when they are for use as fuel.

Problems associated with using straight vegetable oil (SVO) in diesel engine can be classified in two groups, operational and durability problems. Operation problems are related to starting of engine, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injection tip, ring sticking and dilution of lubricant. The problems associated by using straight vegetable oil can be listed as below:

- It has been observed that Straight Vegetable Oils when used for long hours, tend to choke the fuel filter because of high viscosity and insoluble present in the Oils.
- High viscosity of Straight Vegetable Oils causes poor fuel atomization, large droplet size, and thus high spray jet penetration. The jet also tends to be a solid thick stream instead of a spray of small droplets. As a result, the fuel is not distributed and mixed with the air required for burning in the combustion chamber. This result in poor combustion accompanied by loss of power and efficiency.
- Straight Vegetable Oils has lower energy density than fossil diesel. Therefore, this leads to higher Brake Specific Fuel Consumption of the engine.
- To use Straight Vegetable Oils efficiently in diesel engine, modification of fuel supply system and engine redesign is required which is very costly.

Blending, Cracking/Pyrolysis, Emulsification or Trans-esterification of vegetable oil may overcome these problems. Due to heating and blending vegetable oil reduces the viscosity and improve volatility, but its molecular or atomic structure remains unchanged hence, polyunsaturated character remains. Blending or mixing of vegetable oils with diesel reduces the viscosity drastically and the fuel handling system of engine can handle the vegetable oil mixed with diesel without any major problems. Based on experiments, it is found that transfiguring vegetable oils into simple esters is an effective way to overcome all the problems associated with the vegetable oils.

III. METHODOLOGY

Materials and methods used in various studies discussed in the following chapter of the thesis are described in this chapter. Various experiments, experimental procedure, experimental set-up, analytical tools used to characterize and to undergo various engine performance tests of different blends and their property.

Extraction Of Oil From Almond Seeds:

Almonds (Prunus dulcis) are believed to be the widely spread among tree nuts all over the world. Almond oil could be extracted from the almond seeds, which contain a good percentage of oil. Firstly, almonds were collected. The total weight of the collected almonds was 8 kg. After splitting of shells of almond, we got 2 kg of almond seeds. Later, we dried those almond seeds in sunlight for 20-25 days. After which we peeled almond seeds.

Fig. No. 1: Peeling of Almond Seeds

After peeling the almond seeds, they were dried at nearly 30°C then blended and crushed in a blender. Powdered seeds were kept at 5°C in polyethylene bags before analysis. The Bligh-Dyer method is used to extract almond oil. Ground seeds were harmonized with a ($CHCl_3$/MeOH) mixture (1:1) chloroform methanol and water. Two phases were formed and obtained, aqueous layer (MeOH-water) and organic layer ($CHCl_3$). A rotary evaporator was used for evaporating off the solvent ($CHCl_3$) for the recovery of oil. A residual solvent was separated by oven drying for 1 hour at 60∘C. The selected engine fuel was a commercial diesel fuel. A laboratory preparation of mixing of blends of biodiesel made up of almond seed with diesel fuel was performed to operate a diesel engine and to make measurements of emissions and performance parameters. The ratios of blends selected were B10 and B20 on volume basis of almond biodiesel in an almond biodiesel-diesel fuel mixture. They are referred to as B10 (10% almond biodiesel 90% diesel fuel) and B20 (20% almond biodiesel 80% diesel fuel), respectively.

Biodiesel Vs. Straight Vegetable Oil (Svo):

Biodiesel is produced from vegetable oils. The main components of vegetable oil are triglycerides. Triglycerides are esters of glycerol with long chain acids, commonly named fatty acids. Bio-diesel is defined as mono alkyl esters of long chain fatty acids derived from renewable feedstock such as vegetable oil or animal fats, for use in compression ignition (CI) engines. This name is given to the esters when they are for use as fuel.

Problems associated with using straight vegetable oil (SVO) in diesel engine can be classified in two groups, operational and durability problems. Operation problems are related to starting of engine, ignition, combustion and performance. Durability problems are related to deposit formation, carbonization of injection tip, ring sticking and dilution of lubricant. The problems associated by using straight vegetable oil can be listed as below:

- It has been observed that Straight Vegetable Oils when used for long hours, tend to choke the fuel filter because of high viscosity and insoluble present in the Oils.
- High viscosity of Straight Vegetable Oils causes poor fuel atomization, large droplet size, and thus high spray jet penetration. The jet also tends to be a solid thick stream instead of a spray of small droplets. As a result, the fuel is not distributed and mixed with the air required for burning in the combustion chamber. This result in poor combustion accompanied by loss of power and efficiency.
- Straight Vegetable Oils has lower energy density than fossil diesel. Therefore, this leads to higher Brake Specific Fuel Consumption of the engine.
- To use Straight Vegetable Oils efficiently in diesel engine, modification of fuel supply system and engine redesign is required which is very costly.

Blending, Cracking/Pyrolysis, Emulsification or Trans-esterification of vegetable oil may overcome these problems. Due to heating and blending vegetable oil reduces the viscosity and improve volatility, but its molecular or atomic structure remains unchanged hence, polyunsaturated character remains. Blending or mixing of vegetable oils with diesel reduces the viscosity drastically and the fuel handling system of engine can handle the vegetable oil mixed with diesel without any major problems. Based on experiments, it is found that transfiguring vegetable oils into simple esters is an effective way to overcome all the problems associated with the vegetable oils.

Transesterification Reaction:

Transesterification, also called as alcoholysis is the dis- placement of alcohol from an ester by another alcohol in a process similar to hydrolysis except that an alcohol is used instead of water. This has been widely used to reduce the viscosity of the triglycerides. The transesterification is expressed by the following reaction. Experimental study reveal that the major variables affecting the trans-esterification reaction are:

- The free fatty acid (FFA) and the moisture content.
- Type of Catalyst.
- A literature (Freedmen et al. 1984) has revealed that, the rate of reaction is strongly influenced by the reaction temperature.

- Murugesan et al. reported that, after completion of the reaction, the product is kept for a certain time interval for separation (approx. 25 h+) of bio-diesel and glycerol separation.
- Murugesan et al. reported that, washing is a process to remove catalyst, soap and excess methanol.

Synthesis Of Biodiesel From Mustard Oil And Almond Oil:

For the transesterification of mustard oil, Dr. Peepers style has been followed in our work. Firstly 250 ml (90% pure) of methanol was mixed with 150 ml (1N) of NaOH. This mixture was swirled in a glass container until NaOH is completely dissolved in methanol. As this is an exothermic reaction, so the mixture would get hot (temperature increases). This solution is known as methoxide, which is powerful corrosive base and is injurious for human skin. Therefore, safety precautions should be taken to avoid skin injuries during meth- oxide producing.

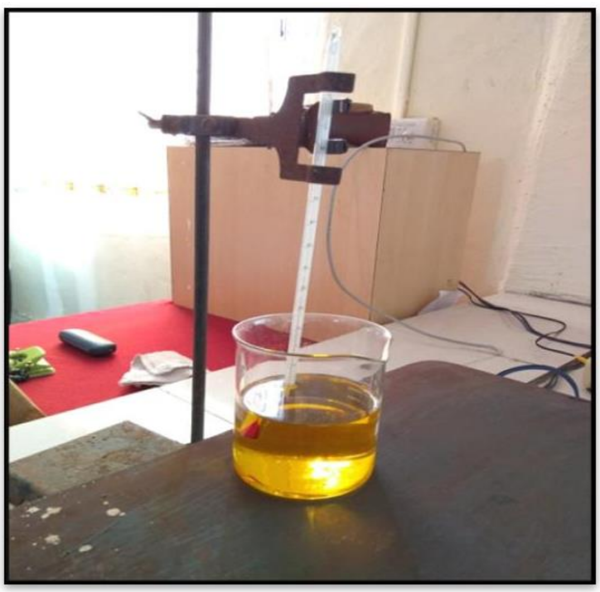

Fig. No. 2: Preheating of Oil

Next, methoxide was added with 1 liter of mustard oil, which was preheated about 55ºC. Then the mixture was stirred for 5 minutes in a glass container. After that, the mixture was left for 24 hours (the longer is better) for the separation of glycerol and ester. This mixture then gradually settles down in two distinctive layers. The upper transparent layer is 100% biodiesel and the lower concentrated layer is glycerol. The heavier layer is then removed by gravity separation. In some cases, if the mustard oil contains impurities, then a thin white layer is formed in space between the two layers. This thin layer comprises of soap and some other impurities.

Fig. No. 3: After jerking the solution

Fig. No. 4: Solution after 3 hours

Biodiesel produced in the above process contains moisture (vaporization temperature 100ºC) and methanol (vaporization temperature 60ºC) and usually some soap. If the soap level is low enough (300 ppm - 500 ppm), the methanol can be removed by vaporization and the methanol will usually be dry enough to directly recycle back to the reaction. Methanol tends to act as a co-solvent for soap in biodiesel; so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed. Anyway, heating the biodiesel above 100 Degree Celsius would cause the removal of both the moisture and methanol as well.

Fig. No. 5: Solution after 25 hours

Fig. No. 6: By products of transesterification reaction after separation

i) Soap ii) Glycerol iii) Biodiesel.

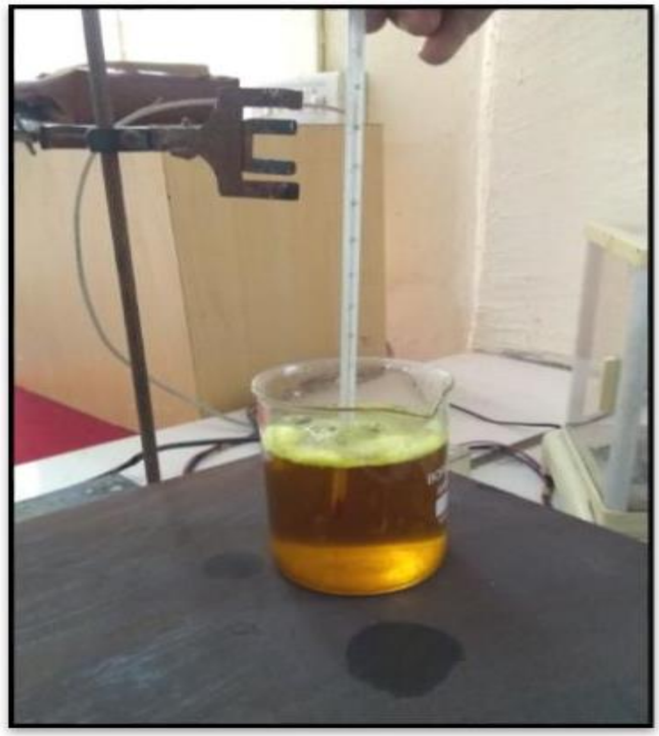

Fig. No. 7: Biodiesel after heating at 100^{o}C

Characterization of Biodiesels From Almond Oil And Mustard Oil:

After obtaining the three different layers from transesterification reaction, the top most layers are of biodiesel. By separating the layers, we got biodiesel which heated at 100ºC for vanishing off the moisture content in it. At 60ºC, methanol evaporates and we got pure form of biodiesels. For describing and characterization of the final product, we have given the samples of both almond biodiesel and mustard biodiesel to a well-established laboratory Insta Pollutech Lab, Pune. They tested our samples and obtained result is stated in a report. The procedure to obtain following values are given as follow:

Acid Value:

Procedure:

1. A certain amount of vegetable oil was added to 30 mL of mixed solvent (ethanol and petroleum ether).
2. Then, 2-3 drops of phenolphthalein were added into the mixed solution and stirred for a while. 0.1 mol/L potassium hydroxide solution was also used for calibration on the above solution.
3. The acid value of the vegetable oil could be determined on the basis of the following formula:

Acid value = (V×C×5.6)/m

where,

V is the consumption of titration KOH solution volume, mL; C is the concentration of KOH solution, mol/L; m is the quality of the oil is potassium hydroxide molar mass, g/mol. All experiments were measured three times in parallel, and then averaged.

Formula: Acid Value= Mean burette reading×5.6 Wt. of sample taken

Calculations:

I. For biodiesel (Yellowish) Acid Value= (0.9666×5.6)/5 =1.0825

II. For biodiesel (Reddish) Acid Value= (14.566×5.6)/5 =16.3139

III. For Plain diesel Acid value = (0.4666×5.6)/5 =0.52259

FLASH POINT AND FIRE POINT:

Procedure:

The jar was filled approximately 54 mm above the bottom of the jar with the test fuel blend rich was approximately 40 ml of test fuel. This jar then had a cork inserted into the top of the flask: which had a thermometer in it. A piece of cork has applied to the outside of the jar to act as a washer so the sides of the special jar would not touch the sides of the air bath.

The thermometer was inserted such that it was just barely above the bottom surface of the jar. The jar then was inserted into an air bath. The temperature of the fuel then decreased and once the fuel reached approximately 35 ^{0}F the fuel was then moved into the next air bath which was at 0^0F.
The specimen was then checked nearly every degree the temperature decreased. The fuel sample as checked for the first crystal to form in the jar. When the first crystal was observed, this temperature was recorded as the cloud point. The thermometer was then pulled up until it was approximately in the center of the fuel blend. The jar was reinserted into the 0^0F air bath and the temperature was allowed to decrease once more. The sample as checked periodically until the sample was clearly in crystal form reached.

The pour point was noted when the jar could be turned on its side for 5 seconds and no more liquid in the fuel was noticed. If the sample had not yet reached its pour point at 0^0F, the sample could be moved once more in the air bath temperature decrease to -30^0F.

CALORIFIC VALUE:

Bomb calorimeter:

The calorific value of solid and liquid fuels is checked in the laboratory by „Bomb calorimeter". It is named because its shape resembles that of a bomb. Fig.No.8 shows the schematic sketch of a bomb calorimeter. The calorimeter is made of austenitic steel which provides considerable good resistance to corrosion and enables it to withstand high pressure. In the calorimeter there is a strong cylindrical bomb in which combustion occurs. The bomb has two valves at the top. One supplies oxygen to the bomb and another releases the exhaust gases. A crucible in which a weighted quantity of fuel sample is burnt is arranged between the two electrodes as shown in Fig.No.8 The calorimeter is fitted with cooled water jacket which surrounds the bomb. To reduce the losses due to radiation, calorimeter is further provided with a jacket of water and air.

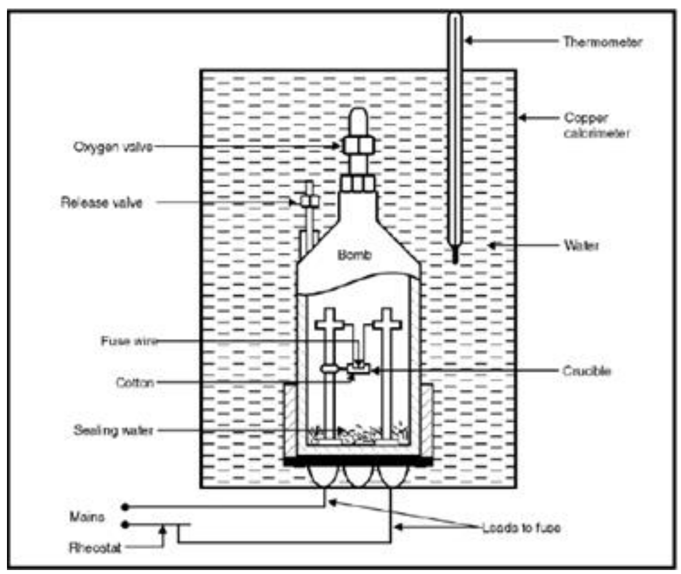

Fig. No. 8: Bomb Calorimeter

A stirrer is used for keeping the temperature of water constant and a thermometer to measure the temperature up to an accuracy of 0.001°C.

Procedure:

To start, about 1 gm of fuel sample is accurately weighed into the pot and a fuse wire (whose weight is known) is stretched between the electrodes. It should be ensured that wire is in close contact with the fuel. To soak up the

combustion products of Sulphur and nitrogen 2 ml water is poured in the bomb. Bomb is then supplied with pure oxygen through the valve to an amount of 25 atm. The bomb is then neatly placed in the weighed quantity of water, in the calorimeter. The stirring is started after making complete electrical connections, and when the thermometer indicates a steady-constant temperature, fuel is fired and temperature readings are recorded after 1/2 minute intervals until maximum temperature is reached. The bomb is then taken off, the pressure slowly releases through the exhaust valve and the contents of the bomb are weighed for further analysis.
The heat when released by the fuel on combustion is absorbed by the surrounding water and the calorimeter. From the above data the calorific value (C.V) of the fuel can be found in the following way:

Let W_f = Weight of fuel sample (kg), W = Weight of water (kg),
C = Calorific value (higher) of the fuel (kJ/kg), We = Water equivalent of calorimeter (kg),
T1 = Initial temperature of water and calorimeter, T2 = Final temperature of water and calorimeter,
Tc = Radiation corrections, and c = Specific heat of water.

Heat released by the fuel sample = $W_f \times C$
Heat received by water and calorimeter = $(W_W + We) \times c \times [(T2 - T1) + Tc]$. Heat lost = Heat gained
$W_f \times C = (W + We) \times c \times [(T2 + T1) + Tc]$

$$\text{i.e. } C = \frac{W+We \times c \times [\,T2-T1+Tc\,]}{Wf}$$

[Value of c is 4.18 in SI units and unity in MKS units.]

The following are results evaluated by the above mentioned laboratory. They used various protocols to find out the results, protocols mentioned in the report.

Table No. 1: Characterization of Almond Biodiesel

SR. NO.	PARAMETER	UNIT	SPECIFICATION AS PER IS: 1460-2005	RESULT
01	Cetane Number	-	Min. 46	52.10
02	Flash Point	°C	Min. 66°C	142
03	Density at 15°C	Kg/m^3	820-860	875
04	Water Content	% by volume	Max 0.05	Nil
05	Flash Point	°C	-	167
06	Gross Calorific Value	Kcal/kg	-	9673.23

Table No. 2: Characterization of Mustard Biodiesel

SR. NO.	PARAMETER	UNIT	SPECIFICATION AS PER IS: 1460-2005	RESULT
01	Cetane Number	-	Min. 46	66.4
02	Flash Point	°C	Min. 66°C	128
03	Density at 15°C	Kg/m^3	820-860	900
04	Water Content	% by volume	Max 0.05	Nil
05	Flash Point	°C	-	140
06	Gross Calorific Value	Kcal/kg	-	8638.48

Procedure And Experimental Setup

Fig. No. 9: C.I. Engine Testing Rig

Various Experiments were performed to study biodiesel from almond oil as a substitute or alternative fuel to operate a diesel engine and the performance data were recorded. The percentage of exhaust gases contaminant emissions were also measured and investigated. The experimental setup consists of a one cylinder, water-cooled, naturally aspirated, direct-injection (DI) and variable compression engine. Swept volume of the engine was 583 cm3 with a 95 mm bore and 82 mm bore by stroke. The injection system consists of an in-line fuel injection pump and throttle nozzle. The combustion chamber is direct injection type with a design of bowl- in piston type. The injection timing and injection pressure were set at 21°crank angle TDC and 20MPa, respectively. At each crank angle the cylinder pressure was measured and stored. It consisted of a flush mounted piezoelectric pressure transducer in conjunction with charge amplifier for converting electric charge to voltage. It could measure and store more than 200 cycles engine pressure histories. The measured data can be analyzed online or stored for post processing. A Chromel-Alumel (k-type) thermocouple with a calibrated digital display was used to record exhaust gas temperature. Load was applied by connecting engine to an electrical generator dynamometer and could be varied by changing the voltage with the help of control panel. To measure the flow rate of cooling water rotameter was used. Difference in the measured performance and exhaust emission parameters from the "baseline" operation of the engine and all fuels tested were determined and also compared. The experimental work started with a preliminary investigation of the engine running on pure diesel fuel, to determine the engine"s operating characteristics and exhaust emission levels constituting the "baseline". The data gathering was made at five engine torques from 4 to 20 N-m at an increment of 4 N-m each time.

The experimental setup consisted of engine test bed with fuel supply system and different metering and measuring devices with the engine. A water brake dynamometer was coupled to the engine. Load was varied by means of flow control of the dynamometer. Fuel was supplied from an external source. Preheating of fuel was done manually with the help of gas burner. B40 blend was preheated at 55°C and B50 blend was preheated at 60°C. However, B100 was not possible to use directly as it causes more engine vibration. Engine speed was measured by digital tachometer. Lube oil temperature and exhaust gas temperature was measured by K-type thermocouple.

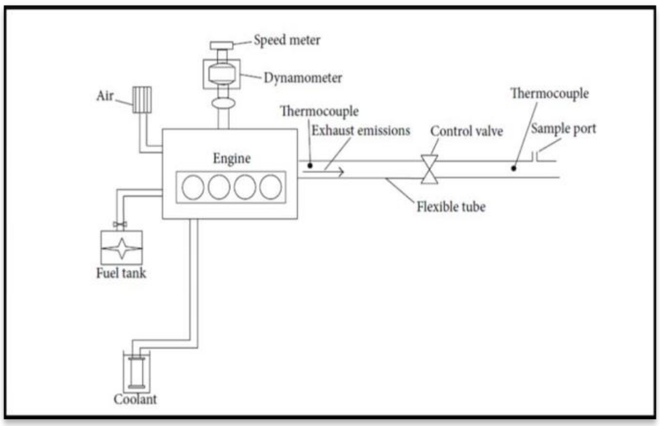

Fig. No. 10: Layout of Engine Performance Testing

Engine Specification:

Table No. 3: Specification of Engine Testing Rig

MODEL	Comel (Diesel Engine)
Method of Starting	Hand Starting
Type	Horizontal, 4-stroke, 1 cylinder
Cylinder Diameter	70mm
Piston Stroke	75mm
Nominal Speed	1500 rpm
Nominal Power	5 BHP
Cooling System	Water Cooled
Rotation	Anti-clockwise
Fuel Filter	Present
Oil Filter	Present

Performance Analysis:

Performance testing of Compression Ignition engine by using two different blends of biodiesels with that conventional diesel. The blends are B10 (10% biodiesel and 90% conventional diesel) and B20 (20% biodiesel and 80% conventional diesel). Procedure and experimental setup has already described above. The following values were obtained after performance testing.

Table No. 4: Engine Performance Readings

Sr. No.	Performance Characteristics	Different Blends		
		B0	B10	B20
01	Torque (Nm)	8.93	9.01	8.87
02	Brake power (kw)	2.06	2.07	2.33
03	Brake mean effective pressure (KN/m^{2})	38.68	39.30	41.85
04	Specific fuel consumption (g/KW-h)	81.15	89.21	88.15
05	Brake thermal efficiency (%)	32.43	29.50	29.85
06	Air fuel ratio	12.51	12.30	10.64

IV. RESULT AND CONCLUSION

After completion of the project, the following results and conclusions are obtained. They are as follows:

- Biodiesel can be produced from almond oil and mustard oil.
- It is possible to run diesel engine by using biodiesel blends.
- In terms of engine performance, it was found that after blending of biodiesel with that of conventional diesel, the Break Specific Fuel Consumption (BSFC) has increased.
- Brake power has increased in case of blends.
- Brake thermal efficiency and air-fuel ratio has decreased in case blends.
- Brake mean effective pressure is also increased in case of blends.
- The moisture content in both biodiesels from almond and mustard oils is nil i.e. 0.
- Gross calorific value of the biodiesel from both almond and mustard oils is less than that of conventional diesel.

V. FUTURE SCOPE

1. High-quality biodiesel fuel that is properly cared for should result in a lifetime of excellent performance. In general, it can be used same as petroleum diesel fuel.
2. The one notable exception is during cold-weather conditions, when biodiesel tends to “gel up” sooner than traditional diesel fuel. Many additives are available on the market that can help safeguard the quality and improve the cold-weather performance of biodiesel, and their use is one option for improving the performance of the fuel when using biodiesel.
3. Solar irradiation is used to perform the esterification of free fatty acids in vegetable oils for the efficient production of biodiesel by using Cr/Sio_2 (Photo catalyst).
4. The studies report slight increases in NOx Emissions, when using biodiesel fuels. The reason most frequently pointed out is that, the injection process is slightly advanced with biodiesel. The physical properties of biodiesel or the response of the electronic unit could cause such an advance. Delaying or postponing injection as a mean to eliminate the increase in NO emissions, with a minor penance in

particulate emissions. Antioxidant additives in biodiesel can reduce the prompt NO (by up to 43.3%) with increasing CO and HC emissions. biodiesel- fueled engine shows positive impacts on engine performance and NO emissions. However, it increases CO, HC, and smoke.

REFERENCES

[1] Nidal H. Abu-Hamdeh et.al (2015), "A Comparative Study of Almond Biodiesel-Diesel Blends for Diesel Engine in Terms of Performance and Emission", Hindawi Publication Corporation, BioMed Research International, Research Article

[2] E.G. Bligh and W.H. Dyer (1959), "A Rapid Method of Total Lipid Extraction and Purification", Canadian Journal of Biochemistry and Physiology, The National Research Council of Canada, Volume 37

[3] B. Freedmen et.al (1984), "Variables Affecting the Yields of Fatty Esters from Transesterified Vegetable Oils", Northern Regional Research Center, Agricultural Research Service, United States

[4] Zannatul Moiet Hasib et.al (2011), "Bio-Diesel from Mustard Oil: A Renewable Alternative Fuel for Small Diesel Engines",
Modern Mechanical Engineering, Volume 1

[5] Agarwal AK, Tate M, Garpen J. The specific gravity of biodiesel and its blends with diesel fuel. J Am Oil Chem Soc 2000;77(2):115–9.

[6] V.K. Shahir, Rahman MM, Akhter MS. Biodiesel from cottonseed oil and its effect on engine performance and exhaust emissions. App l Therm Eng 2009;29(11-12):2265–70.

[7] Hasimoglu C, Ciniviz M, Ozsert I, Ic-ingur A, Parlak Y, Salman MS. Perfor- mance characteristics of a low heat rejection diesel engine operating with biodiesel. RenewableEnergy2008;33(7):1709–15.

[8] Raheman H, Ghadge SV. Performance of compression ignition engine with mahua (Madhucaindica) biodiesel. Fuel 2007;86(16):2568–73.

[9] Jon H. Van Gerpen, Song J, Alam M, Boehman AL. Biodiesel combustion, emissions and emission control. Fuel Process Technol 2007;88(7):679–91.

[10] Hanifa Taher,, Miguez JL, Porteiro J, Granada E, Moran JC. Performance and exhaust emissions in the use of biodiesel in out board diesel engines. Fuel 2007;86(12-13):1765–71.

[11] Matt Johnston1 .The characteristics of performance and exhaust emissions of a diesel engine using a biodiesel with antioxidants Bioresour Technol 2010;101 (1):78–82.

[12] Piyanuch Nakpong and Sasiwimol Wootthikanokkhan. An experimental study on the effects of oxygenated fuel blends and multiple injection strategies on DI diesel engine emissions. Fuel 1999;78:1303–17.

[13] S.L.Sinha And R.K.Yadav, Eckstrom JC, Wolf LR. The emissions performance of oxygenated diesel fuels in a prototype DI diesel engine. SAE paper 2001-01-0650.

[14] Das LM. Biodiesel development and characterization for use as a fuel in compression ignition engines. J Eng Gas Turb Power 2001;123:440–7.

[15] Yii-Der You, Kusdiana D. Biodiesel fuel from rapeseed oil as prepared in supercritical methanol. Fuel 2001;80:225–31. [16].Murayama T, Fujiwara Y, Noto T. Evaluating waste vegetable oils as a diesel fuel. P I Mech Eng D-J Aut 2000;214:141–8.