Feasibility Testing of VCR Engine using various blend of Neem Oil

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Abstract - Biodiesel production is a valuable process which needs a continued study and optimization process because of its environmentally advantageous attributes and its renewable nature. In India Neem tree is a widely grown crop, termed as Divine Tree due to its wide relevance in many areas of study. The present study is intended to consider aspects related to the feasibility of the production of biodiesel from neem oil. This report deals with biodiesel obtained from neem oil which are mono esters produced using transesterification process. The optimum conditions to achieve maximum yield of biodiesel were investigated at different temperatures and with different molar ratio of neem oil and methanol. The temperature increases yield of methyl ester at 55 0C and a molar ratio of 1:12 were found to be beneficial. From the obtained results it was apparent that the produced biodiesel fuel was within the recommended standards of biodiesel fuel. The fuel properties of biodiesel including kinematic viscosity and acid value were examined. The engine power and pollutant emissions characteristics under different biodiesel percentages were also studied. Experiments demonstrated that the biodiesel produced using neem oil could reduce smoke and Carbon monoxide emissions, significantly while the Nitrogen oxide emission changed slightly. Thus, the ester of this oil can be used as environment friendly alternative fuel for diesel engine.

Keywords: Neem Oil, Bio-diesel, Transesterifications, Combustion Characteristics, Engine performance.

I. INTRODUCTION

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petrol-diesel in combustion properties. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of our country are the driving forces to promote biodiesel as an alternate fuel.

Biodiesel derived from vegetable oil and animal fats is being used in USA and Europe to reduce air pollution, to reduce dependence on fossil fuel. In USA and Europe, their surplus edible oils like soybean oil, sunflower oil and rapeseed oil are being used as feed stock for the production of biodiesel. Since India is net importer of vegetable oils, edible oils cannot be used for production of biodiesel. India has the potential to be a leading world producer of biodiesel, as biodiesel can be harvested and sourced from non-edible oils like Jatropha Curcus, Pongamia Pinnata, Neem (Azadirachtaindica), Mahua, castor, linseed, Kusum (Schlecheratrijuga), etc. Some of these oils produced even now are not being properly utilized. Out of these plants, India is focusing on Jatropha Curcas and Pongamia Pinnata, which can grow in arid and wastelands. Oil content in the Jatropha and Pongamia seed is around 30-40 %. India has about 80-100 million hectares of wasteland, which can be used for Jatropha and Pongamia plantation.

India is one of the largest producer Neem oil and its seed contains 30% oil content. It is an untapped source in India. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction independence on imported crude oil and reduction in air pollution. Prydeetal (1982) reviewed the reported successes and shortcomings for alternative fuel research. However, long term engine test results showed that durability problems were encountered with vegetable oils because of deposit formation, carbon buildup and lubricating oil contamination. Thus, it was concluded that vegetable oils must either be chemically altered or blended with diesel fuel to prevent premature engine failure. Blending, cracking/ pyrolysis, emulsification or transesterification of vegetable oils may overcome these problems. Heating and blending of vegetable oils may reduce the viscosity and improve volatility of vegetable oils but its molecular structure remains unchanged. Hence, poly unsaturated character remains. Blending of vegetable oils with diesel, however, reduces the viscosity drastically and the fuel handling system of the engine can handle vegetable oil-diesel blends without any problems.

On the basis of experimental investigations, it is found that converting vegetable oils into simple esters is an effective way to overcome all the problems associated with the vegetable oils. Most of the conventional production methods for biodiesel use basic or acidic catalyst. A reaction time of 45min to 1h and reaction temperature of55-65° C are required for completion of reaction and formation of respective esters. Biodiesel consists of alkyl esters of fatty acids produced by the tranesterification of vegetable oils. The use of biodiesel in diesel engines requires no hardware modification. In addition, biodiesel is a superior fuel than diesel because of lower sulphur content, higher flash point and lower aromatic content. Biodiesel fuelled engine emits fewer pollutants. Biodiesel can be used in its pure form or as a blend of diesel. It can also be used as a diesel fuel additive to improve its properties.

II. NEEM OIL (MELLIAAZADIRACHTA, FAMILY: MELIACEAE)

The fat content of the kernels ranges from 33-45%. Neem oil is usually opaque, bitter and inedible but it has recently been shown that it can be processed into non bitter edible oil with 50% oleic acid and 15% linoleic acid. The major fatty acid composition of oil includes Palmitic acid 19.4%, Stearic acid 21.2%, Oleic acid 42.1%, Linoleic acid 14.9% and Arachidic acid 1.4%. Neem seeds are usually crushed prior to extraction in expellers. Good quality kernels (50% oil) yield 40% oil. Its oil is better than the conventional fossil fuel as it does not emit harmful fumes and is a cheaper source for generating fuels. Neem trees are being grown on commercial basis for their possible and effective use in manufacturing biodiesel. A blend of up to 20% of biofuel in diesel will not require much modification in automobile engines. Neem trees are found in abundance in tropical and semi-tropical forest regions.

Properties of Neem Oil:

- **Colour –** Greenish Brown
- **Odour –** Garlic Repulsive
- **Refractive Index at 40° C –** 1.4617–1.4627
- **Specific Gravity at 30° C –** 0.9087-0.9189
- **Iodine Value –** 68.0-75.8
- **Saponification Value** – 193 to 204
- **Unsaponifiable Matter** – 0.8% - 2.4%

III. PROCESS OF EXTRACTION AND TRANSESTERIFICATIO:

Source:

Neem oil can be obtained from various methods either from extraction process or by direct source (i.e. from shops or factories where it is easily available).

IV. EXTRACTION OF NEEM OIL FROM NEEM SEEDS:

- *Material preparation :*

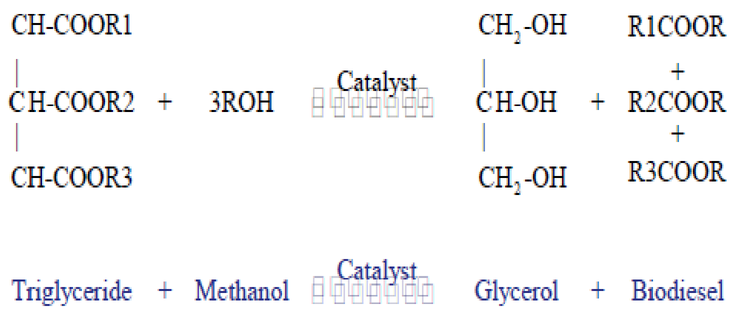
  Neem seeds used in this study were obtained from Bali. This raw material has water content of 7.8% and oil content of 49.58%. Prior to use, the Neem seeds were repeatedly washed to remove dirt and other impurities material, and subsequently dried in oven at 50°C until it reached constant moisture content. Then, Neem seeds were ground to get three different particle sizes (0.85-1.40 mm, 0.71-0.85 mm, and 0.425-0.71 mm).

- *Oil extraction :*

  Neem seeds were extracted using two solvent (n-hexane and ethanol) for 3 hours with ratio Neem seed powder weight to solvent volume of 1:5. In certain time intervals, the samples were taken and centrifuged to separate the solid fraction from solution. Filtrate was heated and evaporated to obtain solvent-free oil. Then the oil was weighed to calculate the concentration of oil in the solution. Extractions were conducted at 5 temperature level (30^o, 35^o, 40^o, 45^o and 50^{o}C).

V. TRANSESTERIFICATION

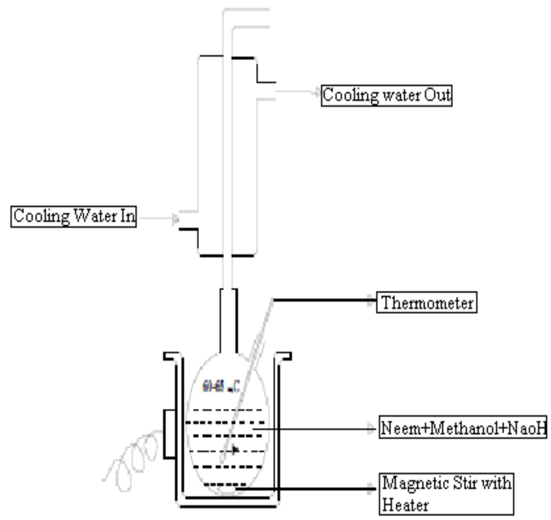
The formation of methyl esters by transesterification of vegetable oil requires raw oil, 15% of methanol & 5% of sodium hydroxide on mass basis. However, transesterification is an equilibrium reaction in which excess alcohol is required to drive the reaction very close to completion. The vegetable oil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



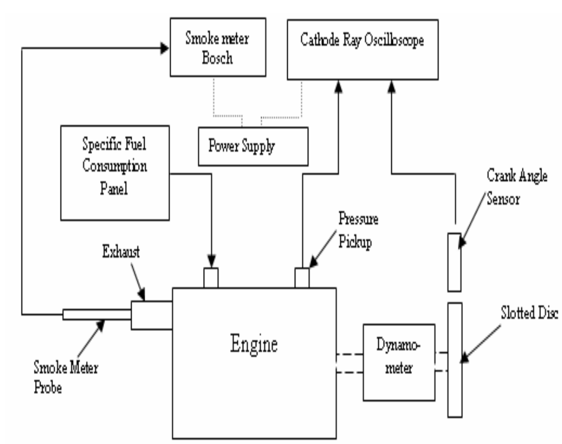
Where R1, R2, & R3 are long chain hydrocarbons. The mixture was stirred continuously and then allowed to settle under gravity in a separating funnel. Two distinct layers form after gravity settling for 24 h. The upper layer was of ester and lower layer was of glycerol. The lower layer was separated out. 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 h. 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.

VI. EXPERIMENTAL SETUP OF TRANSESTERIFICATION PROCESS

Biodiesel fuel blend can be conventionally prepared by using alkali or acid as catalyst.100gm of refined neem oil is mixed with 12gm of alcohol and 1gm of sodium hydroxide (NaOH) which acts as catalyst. This mixture is taken in a 500ml round bottomed flask .The amount of catalyst that should be added to the reactor varies from 0.5% to 1% w/w. Using magnetic stirrer and heater equipment the above mixture is thoroughly mixed and maintained at a temperature of 50-55 ^{0}C for two hours. The mixture is now allowed to settle for 24 hours at which two separate layers are obtained. The top layer will be methyl ester of neem oil (fatty acid methyl ester (FAME) i.e, .biodiesel) and the bottom one glycerin. Using a conical separating funnel the glycerin is separated at the bottom. To separate the FAME (fatty acid methyl ester) from glycerol, catalyst (NaOH) and methanol, washing was carried out with warm water. Further water and methanol will be removed by distillation. Then the NaOH, Glycerol, methanol and water was treated with phosphoric acid for neutralizing the catalyst. Finally glycerin is obtained as a byproduct in case of alkali transesterification process. Fig.1. shows the experimental set up of the process.



VII. EXPERIMENT SET-UP:



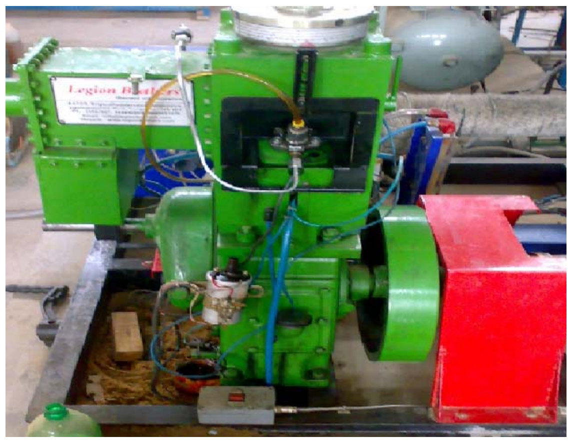
VIII. VARIABLE COMPRESSION ENGINE:

Variable compression ratio engines are those engines that have varied compression ratios at different engine speeds used mostly in the diesel engine, these engines have high values of economy compared to the ordinary engines.

Compression ratio is defined as ratio of volume before compression to volume after compression. It can also be defined as ratio between the volume of the cylinder, when the piston is at the bottom of its stroke, and the volume when the piston is at the top of its stroke. The compression ratio is a single number that can be used to predict the performance of any engine.

High Specific Output means when maximum amount of fuel can be burnt efficiently. This comes with many problems for ex, increasing engine speed imposes dynamic loads and wear. High speed also increases pumping losses. Use of high pressure turbo charging also results in higher thermal loads and high peak pressure problems. These problems are encountered when compression ratio is reduced at full load and at same time keeping it high for starting condition. High compression ratio for low load operation and low compression ratio at full load to allow turbocharger to boost intake pressure without increasing peak pressure.

At starting, turbocharger output is zero. As load increases engine exhaust temperature increases and boost available from turbocharger increases. At full load turbocharger capacity is high and utilize without increasing peak cycle pressure lowering compression ratio as needed.



IX. EXHAUST GAS ANALYZER:

Exhaust gas analyzer is a functional tool that used to check the emissions of the vehicle which are within regulations, find leaks in the exhaust system, and also to measure the engine efficiency. Exhaust gas analyzer is a modern as advanced tool that offers you with a range of functionality. It means that this tool is becoming an essential part of the mechanic's arsenal in tracking down any maintenance issues with cars and truck, and also making the first step towards to get the problem fixed.

Moreover, exhaust gas analyzer is able to simply measure the types of gas that are present in a sample, and provide a reading to the operator in a way to show them its finding. This exhaust gas analyzer is commonly used to search for the leaks in the vehicle exhaust system and measure the emissions. Furthermore, exhaust gas analyzer can work well in finding various gases in the vehicle exhaust that include carbon monoxide, as well as being able to locate the potential sources of fire where unburned fuel is released and can combust on contact with hot areas. This exhaust gas analyzer comes in a range of forms, and at many different price points, so it can be a complicated tool to buy. However, the most important aspect to choose this analyzer is to make sure that it does everything that you want it to.

Exhaust gas analyzer

Carbon Dioxide (CO_2):-

CO_2 is a desirable by product that is produced when from the fuel is fully oxidized during the combustion process. As a general rule, the higher the carbon dioxide reading, the more efficient the engine is operating. Therefore, air/fuel imbalances, misfires, or engine mechanical problems will cause CO_2 to decrease.

Oxygen (O_2):-

Oxygen (O_2) readings provide a good indication of a lean running engine, since O_2 increases with leaner air/fuel mixtures. Generally speaking, O_2 is the opposite of CO, that is, O_2 indicates leaner air/fuel mixtures while CO indicates richer air/fuel mixtures. Lean air/fuel mixtures and misfires typically cause high O_2 output from the engine.

Other Exhaust Emissions:-

There are a few other exhaust components which impact drive ability and emissions diagnosis, which are not measured by shop analyzers. They are:

- Water vapor(H_2O)
- Sulfur Dioxide(SO_2)
- Particulate carbon soot(C)

Sulfur dioxide (SO_2) is sometimes created during the combustion process from the small of sulfur present in gasoline. During certain condition the catalyst oxidizes sulfur dioxide to make SO_3, which then reacts with water to make H_2SO_4. Finally, when sulfur and hydrogen react, it forms hydrogen gas. This process creates the rotten egg odor when following vehicles on the highway

X. EDDY CURRENT DYNAMOMETER

A dynamometer can also be used to determine the torque and power required to operate a driven machine such as a pump. In that case, motoring or driving dynamometer is used. A dynamometer that is designed to be driven is called an absorption or passive dynamometer. A dynamometer that can either drive or absorb is called a universal or active dynamometer.

A dynamometer consists of an absorption (or absorber/driver) unit, and usually includes a means for measuring torque and rotational speed. An absorption unit consists of some type of rotor in housing. The rotor is coupled to the engine or other equipment under test and is free to rotate at whatever speed is required for the test. Some means is provided to develop a braking torque between dynamometer's rotor and housing. The means for developing torque can be frictional, hydraulic, electromagnetic etc. according to the type of absorption/driver unit.

One means for measuring torque is to mount the dynamometer housing so that it is free to turn except that it is restrained by a torque arm. The housing can be made free to rotate by using trunnion connected to each end of the housing to support the dynamo in pedestal mounted trunnion bearings. The torque arm is connected to the dynamo housing and a weighing scale is positioned so that it measures the force exerted by the dynamo housing in attempting to rotate. The torque is the force indicated by the scales multiplied by the length of the torque arm measured from the center of the dynamometer. A load cell transducer can be substituted for the scales in order to provide an electrical signal that is proportional to torque. Another means for measuring torque is to connect the engine to the dynamometer through a torque sensing coupling or torque transducer. A torque transducer provides an electrical signal that is proportional to torque. With electrical absorption units, it is possible to determine torque by measuring the current drawn (or generated) by the absorber/driver. This is generally a less accurate method and not much practiced in modern times, but it may be adequate for some purposes. When torque and speed signals are available, test data can be transmitted to a data acquisition system rather than being recorded manually. Speed and torque signals can also be recorded by a chart recorder or plotter.

XI. SMOKE METER

The Smoke meter is a partial flow opacity meter suitable for Free Acceleration and Full Load testing of all sizes and types of diesel vehicles. It consists of two main items, a smoke sampling head and an interface unit.

The smoke sampling head operates at low voltage (24V DC for DX260-1 Smoke head, 30v DC for DX260-1BT Smokehead), and is suitable for use in all weather conditions and at temperatures down to -15ºC. It consists of a green LED and a photodiode mounted at opposite ends of a measuring tube, such that the effective light path length through the smoke is 250 mm. The measuring tube and the LED / Photodiode assemblies are heated such that their minimum temperature is 70ºC, thereby preventing condensation of the oil and water content of the smoke. The temperature of the smoke is measured at the inlet to the measuring tube so that, if necessary, an automatic correction can be applied to the opacity readings for smoke temperatures other than 100ºC.

The smoke sampling head contains a fan to draw the smoke sample into the measuring tube via a by-pass system, so that the pressure inside the tube cannot normally exceed ambient by more than 7.5 mbar. This provides for rapid response and fast clearance of the smoke sample after testing.

Smoke analyzer

The lenses are protected by an air curtain which reduces sooting. In addition, the sampling head has an auto range feature which can provide a step change in LED intensity to compensate for dirtiness and the sampling head has its serial number stored in permanent memory and the sampling head contains a clock that provides information for the printout and also to control the calibration interval.

XII. RESULTS

Properties of vegetable oils as compared with diesel

Properties	**Diesel**	**Neem**
Before Blend		
Cetane number (CN)	45-55	31
Specific gravity	0.83	0.968
Viscosity (20°C) mm^2/sec	4.7	37.42
Calorific value (MJ/kg)	42	29.97
Carbon (%)	86	78.92
Hydrogen (%)	14	13.41

After Blend (20% by volume with diesel)		
Cetane number (CN)	45-55	48
Specific gravity	0.83	0.934
Viscosity (20°C) mm^2/sec	4.7	6.3
Calorific value (MJ/kg)	42	31.142
Carbon (%)	86	83
Hydrogen (%)	14	15

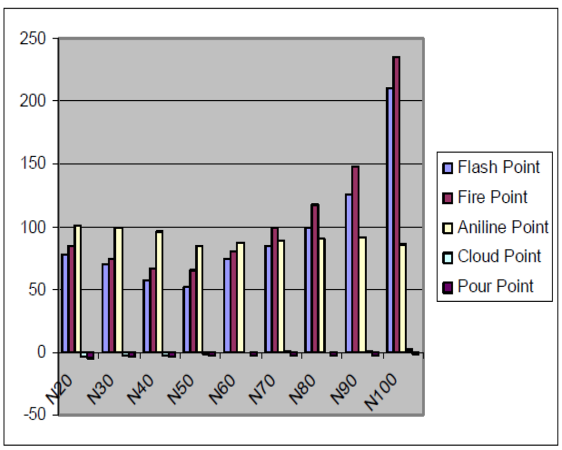
In the following table the properties of Neem Oil of various blends (with diesel) have been shown. Blends of Neem Oil starts from N20 and then go high upto N100 at an interval 10% increase of blends of NeemOil.

In the following table the viscosity property (in centi-strokes) of various blends

of Neem Oil with Diesel is shown.

Various Blends	N20	N30	N40	N50	N60	N70	N80	N90	N100
Viscosity	16.93	19.2	25.2	27.0	37.3	55.9	57.7	70.9	105.6

Variation of physical Properties of Diesel Blended Neem Oil with Temperature (0C)



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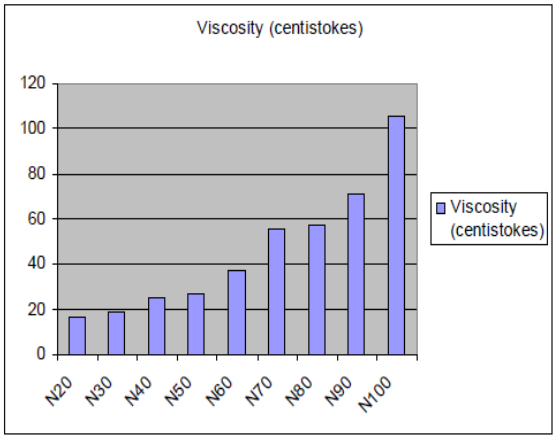
Viscosity	16.	19	25	27	37	55	57	70	10

	9	.2	.25	.06	.32	.9	.74	.9	5.66

Variation of Viscosity with temperature of Diesel Blended Neem Oil.



XIII. CONCLUSION

In general, this model is useful for predicting the trends of pressure, temperature, heat release, heat transfer, work done, thermal efficiency, specific fuel consumption, power and harmful pollutants such as CO, HC, NO_x and Smoke of all vegetable oil esters and diesel fuel. Heat release is reduced only about 4 % to 8 % for vegetable oil esters compared to diesel fuel. This value is nearly closer to diesel. The pressure of vegetable oil esters are reduced about 4 %, 5% and 7% respectively for Neem oil esters when compared to diesel. The brake thermal efficiency is reduced about 5% for Neem oil ester when compared to diesel. The brake specific fuel consumption is increased about Neem oil ester it is increased about 11% to 13% when compared to diesel fuel. The brake power is reduced about 12% for neem oil ester when compared to that of diesel. The carbon monoxide is reduced for Neem oil ester it is reduced about 16 % when compared to that of diesel. It is concluded that the carbon monoxide for vegetable oil ester is less when compared to diesel fuel. The concentration of hydrocarbon is decreased 15 % for Neem oil ester when compared to diesel fuel. The formation of nitric oxides is decreased about 3 % for Neem oil ester when compared to that of diesel fuel. The smoke level is decreased about ester 10 % for Neem oil ester when compared to diesel fuel. Thus multizone combustion model can be an efficient tool to calculate the effect of design and operating parameter. Hence it is concluded that in terms of performance characteristics and emission vegetable oil esters can be regarded as a potential substitute for diesel fuel.

Following are the conclusions based on the experimental results obtained while operating single cylinder diesel engine fuelled with biodiesel from Neem seed oils and their diesel blends.

- Neem based methyl esters (biodiesel) can be directly used in diesel engines without any engine modifications.
- Brake thermal efficiency of B10, B20 blends are better than B100 but still inferior to diesel.
- Properties of different blends of biodiesel are very close to the diesel and B20 is giving good results.
- It is not advisable to use B100 in CI engines unless its properties are comparable with diesel fuel.
- Smoke, HC, CO emissions at different loads were found to be higher for diesel, compared to B10, B20 blends.

Good mixture formation and lower smoke emission are the key factors for good CI engine performance. These factors are highly influenced by viscosity, density, and volatility of the fuel. For bio-diesels, these factors are mainly decided by the effectiveness of the transesterification process. With properties close to diesel fuel, bio-diesel from Neem seed oil can provide a useful substitute for diesel.

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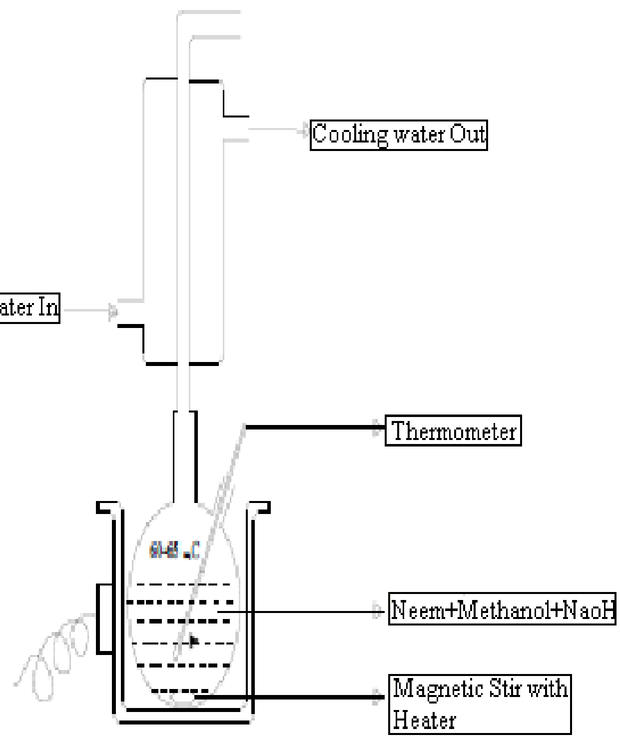
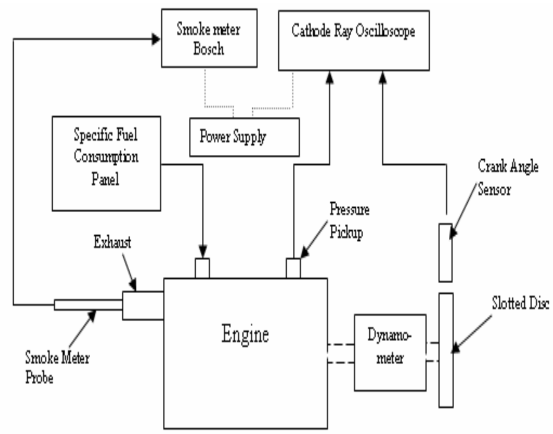
Figures, tables and graghs shown above are as follow for seeing it properly

$$\begin{array}{lcccccc} CH\text{-}COOR1 & & & & CH_2\text{-}OH & & R1COOR \\ | & & & & | & & + \\ CH\text{-}COOR2 & + & 3ROH & \xrightarrow{\text{Catalyst}} & CH\text{-}OH & + & R2COOR \\ | & & & & | & & + \\ CH\text{-}COOR3 & & & & CH_2\text{-}OH & & R3COOR \end{array}$$

$$\text{Triglyceride} + \text{Methanol} \xrightarrow{\text{Catalyst}} \text{Glycerol} + \text{Biodiesel}$$





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Various Blends	N20	N30	N40	N50	N60	N70	N80	N90	N100
Flash Point	78	70	58	52	75	85	99	125	210
Fire Point	85	75	67	65	80	99	118	148	235
Aniline Point	101	99	96		87	89	90	92	86
Cloud Point	-4	-3	-2	-1.2	0	1.1	1.3	1.5	1.9
Pour Point	-4.4	-4	-3.4	-2.9	-2	-2	-2	-2	-1.5

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Aniline Point	101	99	96		87	89	90	92	86
Cloud Point	-4	-3	-2	-1.2	0	1.1	1.3	1.5	1.9
Pour Point	-4.4	-4	-3.4	-2.9	-2	-2	-2	-2	-1.5