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Performance of C.I Engine by Using Biodiesel-Mahua Oil.

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Abstract: - India is looking at renewable alternative fuel sources to reduce its dependence on foreign imports of oils. As India imports 70% of the oil, the country has been hit hard by increasing cost and uncertainty. Recently the biomass resources are being used as alternative fuels and effective use of those fuels is gaining prominence as a substitute way to solve the problem of global warming and the energy crisis. Among all the alternative fuels existing mahua oil is also one. In this work, conventional laboratory equipment has been used for the transesterification of mahua oil. Various properties of esterified mahua oil have been tested for comparison with diesel fuel; further the investigations are carried out on a laboratory based diesel engine to study its performance.

An attempt has been made in the present work to find out the suitability of transesterified mahua oil as a fuel in C.I. engine. Experimental work was carried out on 7B.H.P single cylinder four stroke and vertical, water cooled Kirloskar diesel engine at rated speed of 1500rpm different blends of transesterified mahua oil with diesel were tested at 200bar injection pressure.

From the performance characteristics of transesterified mahua oil diesel blends the efficiencies obtained were found to be better with 75% transesterified mahua oil. The thermal efficiencies of transesterified mahua oil are higher at 25% diesel blends. The cost of transesterified mahua oil is low compared to the cost of diesel. Hence mahua oil blended with diesel is more economical and this can provide an immediate, though partial solution to the growing diesel scarcity in developing countries like ours.

i. INTRODUCTION

When Rudolf diesel first enunciated the concept of diesel engine, about a century back, the experimental evaluation was demonstrated on peanut oil indicating that the vegetable oils will be the prospective future fuels in diesel engines. In the context of fast depletion of fossil fuels and ever increasing diesel vehicle population, use of renewable fuels like vegetable oils has become more pertinent.

The various biomass based resources, which cab be used as an extender, or a complete substitute of diesel fuel may have very significant role in the development of agriculture, industrial and transport sectors in the energy crisis situation. The role of diesel fuel in these sectors cannot be denied because of its ever-increasing use. In fact agricultural and industrial sectors are almost diesel dependent.

Need for shifting towards alternative fuels

Probably in this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. Although fuel economy of engines is greatly improved, increase in the number of automobiles alone dictates that there will be a great demand for fuel in the near future. Alternative fuel technology, availability, and use must and will become more common in the coming decades.

Another reason motivating the development of alternative fuels for the IC-engine is concerned over the emission problems of gasoline engines. Combined with other air polluting systems, the large number of automobiles is a major contributor to the air quality problem of the world. A third reason for alternative fuel development is the fact that a large percentage of crude oil must be imported from other countries which control the larger oil fields.

Energy consumption as a measure of prosperity

Energy is an important input in all sectors of any countries economy. The standard of living of a given country can be directly related to the per capita energy consumption.

Energy crisis is due to the two reasons:

1. The population of the world has increased rapidly.
2. The standard of living of human beings has increased.

Supply and demand of energy

The energy plays an important role in everyday life. Growth of an economy is largely dependent on adequate supply of energy. Energy available in its original form in nature such as crude oil, natural gas, coal, solar heat, etc. is called primary energy sources. Many of these sources are not directly usable and can be used only after processing of or conversion. Crude oil is refined in a petroleum refinery and resulting petroleum products include petrol are termed as **secondary energy sources.**

Present demand and supply

World energy future in present trend countries, the world in the next 50 years will be more crowded than that of today. The world population may reach 10 billions. The conventional sources of energy are depleting and may be exhausted by the end of the century or at the beginning of the next century.

The various alternative fuel options researched for diesel are mainly bio-gas, producer gas, methanol, ethanol, and vegetable oils. Out of all these vegetable oils offer an advantage because of its comparable fuel properties with diesel. The various edible vegetable oils like sunflower, soyabean, peanut, cotton seed etc. have been tested successfully in diesel engine. Research in this direction with edible oils yielded encouraging results. But as India still imports huge quantity of edible oils, therefore, the use of non-edible oils of minor oilseeds like mahua (madhuca indica) oil has been tested as a diesel fuel extender.

The advantages of vegetable oils as diesel fuel are:

- Liquid nature-portability
- Ready availability
- Renewability
- High Cetane number
- Lower sulfur content
- Lower aromatic content
- Biodegradability

The disadvantages of vegetable oils as diesel fuel are:

- Higher viscosity
- Lower volatility
- The reactivity of unsaturated hydrocarbon chains

II. IMPORTANCE OF BIO-DIESEL

What is Bio-diesel?

Bio-diesel is a renewable fuel, biodegradable and non-toxic. It is an ester based oxygenated fuel made form any vegetable oil (edible or non-edible) or animal fat. Bio-diesel is produced by a simple chemical reaction between vegetable oil and alcohol in the presence of an acid or base as catalyst. It contains around 10% built-in oxygen by weight and has no sulphur and has excellent lubricity properties. Built-in-oxygen makes it more efficient fuel than petro-diesel hence its cetane number is higher than that of petro-diesel. It can be blended with petro-diesel in any proportion.

Bio-diesel is the name of the clean burning alternative fuel, produced from domestic, renewable resources. Bio-diesel contains no petroleum, but it can be blended at any level with petroleum diesel to create a bio-diesel blend. It can be used in compression-ignition (diesel) engines with little or no modifications. Bio-diesel is simple to use, biodegradable, nontoxic, and essentially free of sulphur and aromatics. It is defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which confirm to ASTM D6751 specifications for use in diesel engines. Bio-diesel refers to the pure fuel before blending with diesel fuel.

Statistical report:

The National Bio-diesel Board (NBA) in the US reported that an estimated 5 million gallons of Bio-diesel were sold in 1999, followed by 2 million gallons in 2000, 5 millions gallons in 2001, 15 million gallons in 2002 and an estimated 25 million gallons in 2003 respectively. It is estimated that during 2004-2005, an estimated 35 million gallons of bio-diesel is made in the US and it is likely to reach 70 million gallons in the US in 2006. Bio-diesel operates in conventional engines. Just like petroleum diesel, bio-diesel operates in compression-ignition engines. Essentially no engine modifications are required, and bio-diesel maintains the payload capacity and range of diesel.

Pure bio-diesel is not compatible with natural rubber, sometimes found in pre 1994 vehicles. Because it is a solvent. It can degrade natural rubber hoses and gaskets. This is not a problem with B20 blends (20 percent biodiesel/80 percent diesel) and below. Bio-diesel does not require special storage. In fact, in its pure form or in blends, Bio-diesel can be stored wherever petroleum diesel is stored, except in concrete-lined tanks. It is handled like diesel and uses the same infrastructure for transport, storage and use. At higher blend levels, bio-diesel may deteriorate natural rubber or polyurethane foam materials. Bio-diesel exhaust is less offensive. The use of bio-diesel and bio-diesel blends results in a noticeable, less offensive change in exhaust odour, which can be a real benefit in confined spaces. In fact, equipment operators have compared it to the smell of French fries. Users also report having no eye irritation. Since bio-diesel is oxygenated, diesel engines have more complete combustion with bio-diesel than with petroleum. Bio-diesel is safer to use than petroleum diesel. The flash point (the point at which fuel ignites) for bio-diesel in its pure form is a minimum of 260 degrees versus about 125 degrees Fahrenheit for regular No.2 diesel. This makes bio-diesel one of the safest fuels to use, handle and store. Bio-diesel reduces emissions significantly.

Bio-diesel is the first alternative fuel to have fully completed the health effects testing requirements of the US Clear Air Act. The use of bio-diesel in a conventional diesel engine results substantial reduction of unburnt hydrocarbons, carbon monoxide, and particulate matter. Emissions of nitrogen oxides are either slightly reduced or slightly increased depending on the duty cycle and testing methods. The use of bio-diesel decreases the solid carbon fraction of particulate matter (since the oxygen in bio-diesel enables more complete combustion to CO_2), eliminates the sulfate fraction (as there is no sulfur in the fuel), while the soluble, or hydrocarbon, fraction stays the same or is increased. Bio-diesel works well with new technologies such as catalysts, particulate traps, and exhaust gas recirculation. So bio-diesel reduces carbon dioxide by 78 percent on a life cycle basis. No engine modifications are required up to 20 percent blend.

Bio-diesel is made from Rapeseed (UK), Soybean (USA, Brazil), Sunflower (Italy and Southern France), Oil palm (Malaysia), Linseed, Olive (Spain), Cotton seed (Greece) and tree borne, non-edible oilseeds like Mahua,Jatropha (Ratanjot) and Pongamia (Karanja) in India. Bio-diesel is produced from more than 20 countries in the world. Like USA, Australia, France, Italy, Hungary, Germany and Czechoslovakia. No tax is being levied on the production of bio-diesel by Germany and Italy. More than 100 bio-diesel plants were established in the world. Bio-diesel could be made from crude/natural vegetable oils, crude/refined fats, high acidity oil/fats, recovered fried oils, animal fats and waste oils.

Bio – Diesel Scenario in the World:

Bio-fuel used for school buses in the US

Pollution from school diesel buses has health implications to children. The use of Bio diesel can reduce such health risks. In view of this, several thousand school buses in the US are using blends of bio-diesel. In 1997, Medford, New Jersey school district used bio-diesel buses for transport of children to school. In August 2002, Olympia, Illinois school district used bio-diesel for 33 schools buses and travels around 4000 miles per day with 6 lakhs miles per annum. Clark country, Nevada school district used bio-diesel buses in May 2003 for 1200 schools. Similarly, Arlington County, Cirginia school district used bio-diesel buses for 200 schools, and in July 2004, Arkansas school district used bio-diesel buses for 149 schools respectively.

Bio-diesel passenger Cars & trucks in the US

America’s big 3 Auto makers – general Motors, Ford and Daimler Chrysler each introduced new generation of vehicles with diesel electric hybrids. Diesel engines are about 30 percent more efficient than gasoline engines. This means that the diesel engine of the same displacement will produce about 30 percent more horse power or give 30 percent better fuel economy for 30 percent less carbon dioxide emissions. Today’s diesel engines are quieter, cleaner burning and more responsive than earlier diesels. In Europe, where the cost of owning and operative of a passenger vehicle is significantly higher than in the US, stringent laws adopted by California and four north West States have slowed the introduction of diesel vehicles to the market. However, increasing fuel prices, the introduction of ultra low sulphur diesel, and new emissions, technology are making passenger diesel vehicles more attractive to customers leading to diesel option offerings by auto manufacturers.

Bio-diesel further enhances the advantages of diesel by reducing vehicle emissions. B20 reduces emissions of 12 percent. It reduces sulphur on average by 20 percent. Hundreds of US flights, representing over 25,000 vehicles for commercial, government, utility and transit use, currently run on bio-diesel blends nationwide. Bio-diesel blends are also used increasingly in the farming, mining and marine industries, as well as for heating oil and electrical generation applications. Most auto manufacturers approve Upto the use of B 55% percent bio-diesel for the diesel engines.

Bio-diesel in Indonesia from Castor Oil

Indonesia's scientists claimed to have developed bio-diesel from castor oil plant at Bogor Institute of Agriculture (IPB) and at the Ban dung Institute of Technology. They are currently developing bio-diesel oil from the castor oil plant in 400 ha of land in Bireun, Aceh. Each 400 ha of Castor oil plants can produce 4000 liters of bio-diesel.

Bio-diesel from Oliplam in Malaysia

Palm oil prices have been showing wide variation over the last 4 years despite rising production of the oil with in Malaysia, Palm oil (30 million tones) accounts for about 35 percent of global vegetable oil production (110mt) and close to 60 percent of world trade of (40 mt in vegetable oils. The industry estimates that up to five lakhs tones of crude palm oil will be used up annually for bio-fuel purposes, a development that would act as a stabilizing factor for the palm oil market; any quantity in excess of one million tones in stocks will be diverted for bio-diesel.

Energy Scenario in India

India's incremental energy demand for the next decade is projected to be among the highest in the world. With increasing growth rate of GDP, total primary commercial energy consumption has increased from 350 million metric tones of oil equivalent (MMToE) during 2003-04 to 380 MMToE at present.

Consumption of petroleum has increased form 3.5 million metric tones (MMT) in 1950-51 to 17.9 MMT in 1970 and 843 MMT in 1997-98 and to more than 120 MMT at present. It is estimated that the demand for petroleum is 234 MMT in 2019-20. Domestic production of oil in 2004-05 is 33 MMT. Diesel consumption in 2004-05 for import of petroleum products and it is estimated to cost approximately Rs. 1, 75, 000 .00 crores in 2005 respectively.

There is increase in the growth rate of expenditure on import of petroleum to the tine of 46 percent from 2004-05 and 2005-06. More than 70 percent of India's total petroleum consumption is imported from international market, which itself has become more volatile than ever. International crude prices are soaring to new highs. Petroleum is predominately (46 percent) consumed in transport sector. The fuel-mix in transport sector shows that about 80 percent consumption in this sector is a High Speed Diesel (HSD). The projected demand for HSD in the country by 2005-07 is 52 MMT and on present indications, by 2011-12, it could increase to 67 MMT. Petroleum resources are finite and therefore search for alternative fuels is continuing all over the world. Bio-diesel is a renewable fuel and it can be made from any edible, non-edible vegetable oil including waste oil development of Bio-diesel as an alternative and renewable source of energy for transport sector has become important in the national effort towards self-reliance, an important component of the strategy for energy security.

Bio-diesel Society of India (BDSI) formed

Keeping in view of the depleting oil reserves, increasing crude prices and rising global temperature, a group of like minded entrepreneurs, scientists, bureaucrats and social workers have formed a society to promote the use of bio-diesel. The objective of the society is to promote the consumption of bio-diesel. Due to availability of high yielding varieties, this may also results in reduction in import of petroleum products.

III. ALTERNATIVE FUELS

The selection of alternative fuels for IC-engines include the following factors

- Should be available in plenty and derived continuously from renewable sources.
- They should have high specific energy content.
- Should permit easy transportation and storage.
- Should cause less environmental pollution.
- Should be safe in handling.

The various alternative fuels for compression ignition engines are as follows.

ALCOHOLS:

Alcohol is an important renewable energy sources that can substitute petroleum products to certain extent. The two alcohols that are of main interest are

ETHANOL:

Ethanol is a convenient liquid fuel and can act as a substitute for petrol and diesel. Usually 95% (hydrous) ethanol can be directly used in modified engines. 100% (anhydrous) ethanol can be mixed with dry petrol to produce gasohol comprising 10% anhydrous ethanol with 90% petrol. The excellent combustion properties of ethanol enable an engine to produce up to 20% more power. Mass, density and calorific value of ethanol are less than that of petrol but on account of its improved combustion properties of ethanol fuel consumption from for ethanol, gasohol or petrol is more or less than the same. Ethanol as petrol additive raises the octane rating of the mixture, as anhydrous ethanol is an octane fuel. Distinctive advantage of ethanol is that it can be produced by renewable sources unlike nonrenewable fossil fuels.

METHANOL:

Methanol like ethanol possesses octane enhancing capability when blended with unleaded petrol. Methanol has high toxicity, which makes it a less desirable fuel than ethanol. Methanol, in blends with petrol, up to a 10% can be used in existing S.I.engines without any modification. In view of its particular solubility, characteristics, methanol can not be blended with diesel for use in C.I engines. Methanol has a value of 15.5*10^6 to 17.7*10^6 joules per liter, which about half the heat value of petrol and 75% of ethanol. Apart from having higher flame speed, methanol possesses superior anti knocking properties that enable us to achieve a higher output. The concentration of carbon monoxide, unburnt hydrocarbons and oxides of nitrogen in the engine exhaust is less with methanol and methanol-petrol blends as compared to that of petrol. It is to be noted that methanol burns cleaner than petrol.

Table 1: important properties of methanol and ethanol

S.no	Property	Methanol	Ethanol
1	Chemical formula	CH_3OH	C_2H_5OH
2	Composition by weight %		
	Carbon	37.5	52
	Hydrogen	12.5	13
	Oxygen	50	35
3	Specific gravity at 15.5^{o}c	0.796	0.794
4	Boiling point	65	78
5	Lower calorific value (K cal/Kg)	4700	6400
6	Self ignition temperature (^{o}C)	478	420
7	Octane numbers		
	(a) research	114	111
	(b) motor	94	94
8	Cetane number	03	08

BIO-MASS:

Biomass is produced in nature through photo synthesis achieved by solar energy conversion. Bio-mass can be obtained from different sources comprising

1. Organic wastes that accumulate at specific locations such as municipal solid wastes (MSW), timber wastes and sewage sludge.
2. Bio-mass in non traditional form (converted in to liquid fuels).
3. Fermenting the biomass aerobically to obtain a gaseous fuel called biogas.

Bio-mass is a renewable energy so long as it is grown at a rate at least equal to the rate of its consumption.

BIO-GAS:

Bio-gas can be produced by fermenting organic materials in the absence of air or oxygen with the help of bacteria (micro organisms) to break down the materials into intermediates like alcohols and fatty acids and finally to methane, carbon dioxide and water. This process is called anaerobic fermentation. The appropriate fermentation. The appropriate composition of biogas produced is as follows: methane 50-60%, CO2 30-40%, hydrogen 5-10%, nitrogen 4-6%, oxygen 1-2% and hydrogen sulfide in traces. Methane and hydrogen when burnt with oxygen give energy in the form of heat.

1. $CH_4 + 2O_2 \rightarrow 2H_2O + CO_2 + 978.6\ KJ$

2. $2H_2 + O_2 \rightarrow 2H_2O + 572.6448\ KJ$

The CO2 in bio-mass does not contribute to the heat energy; indeed it is unfavorable to any burning process. The amount of heat energy generated is 36476.804 KJ/m^3 for methane and 11712.428 KJ/m^3 for hydrogen. It is impracticable to store large volumes of biogas at low pressure. It is therefore more economically used as it is produced, for example, to meet space and water heating or cooking needs in forms.

NATURAL GAS:

Natural gas is generally associated with petroleum and coal deposits. It consists of mainly methane with small percentages of ethane, propane, butane and CO2 and nitrogen. Natural gas is nearly odorless and colorless. The usual range of consumption is 68% to 96% of methane and 3% to 30% of ethane in natural gas. The range of calorific value of the natural gas is 37674-46046 KG/m^3. Gaseous fuel has number of advantages over solid or liquid fuels as they burn without any smoke and ash. The control of gases relatively easy and main disadvantage is its storage.

HYDROGEN:

Hydrogen can play an important role as an alternative to conventional fuels provided, its technical problems of production, storage and transportation can be resolved satisfactorily and cost could be brought to the acceptable limits. One of the most attractive features of hydrogen as an energy carrier is that it can be produced from water, which is abundantly available in nature. Hydrogen has the highest energy content per unit if mass than any chemical fuel and can be substituted for hydrocarbons in a broad range of applications, often with increased combustion efficiency. Its burning process is non- polluting and it can be used in fuel cells to produce both electricity and useful heat.

METHANE:

Methane is clear gas with high calorific value. It can be used on site, and into the gas mines. Natural gas is 955-methane or converted into methanol by treatment with a catalyst at high temperature and pressure. It can also be compressed and used in limited range vehicles like tractors and forklift trucks. However, to store or transport the energy equivalent of a single gallon of petrol as compressed requires a large tank. At 115bar pressure the tank dimensions would need to be 0.45m in diameter and 1.45m in height.

LIQUIFIED PETROLEUM GAS:

During the refining of petroleum, large quantities of butane are liberated from the top of the column and from the other refining processes. These gases can be compressed and liquefied at atmospheric temperature. Butane and propane are also present in natural gas and can be separated and removed. Thus large volumes of the gas can be stored under pressure in steel cylinders. It is an ideal fuel for domestic and mobile use. LPG contains some fraction of methane and unsaturated hydro carbons in addition to butane and propane.

VEGETABLE OILS:

Vegetable oils can be classified as edible and non-edible oils. In India the consumption of edible oils is more than the production. Hence, we can depend on non-edible oils for use in CI engines. Edible oils such as sunflower, coconut, rice bran etc. can be used. Non-edible oils such as mahua, karanji, rapeseed, cottonseed etc. can be substituted in CI engines.

PROPERTIES OF VEGETABLE OILS:

If fuel shall be used in the existing engines, some required properties of the fuel such as kinematic-viscosity, the self ignition response, the net heating value, the grass heating value and density must be considered.

VISCOSITY:

The direction injection in open combustion chamber trough nozzle and pattern of fuel spray decides the case of combustion and thermal efficiency of the engine. Viscosity plays a vital role in the combustion. Low viscosity can lead to excessive internal pumping leakage where as high viscosity can increase system pressure to unacceptable levels and will effect injection during spray atomization. This effect is critical particularly at low speed or light load condition as pure vegetable oils have high viscosity. The derivatives of vegetable oils are called monsters and have low kinematics viscosity than that of oils. The monoesters are able to give stable solutions in wide range of proportions with diesel fuel, vegetable oils and with alcohol too. They can be solubilizers and can also make it possible to influence the viscosity of blended oils.

SELF-IGNITION RESPONSE:

It is expressed by the cetane number and for a good diesel fuel the value has to be not lower than 45. The cetane number of vegetable oils is less than the diesel. The cetane number of monoesters, on an average, is above that of vegetable oils. For example neem and karanji oils with diesel blends of 10% level have cetane number about 40-45 and at 20% level have cetane number about 35-40.

THE ENERGY CONTENT or HEATING VALUE:

The specific heating values of the different vegetable oils are nearly the same.

They range from 30.5-40.5MJ/Kg and for fuels it are approximately 42.4MJ/Kg. if calorific or heating value of vegetable oils is more, it helps to reduce the quantity handled and to maximize equipment operating range. It is always desirable for vegetable fuels to have heating value nearer to diesel oil.

DENSITY:

Density of the vegetable oils is 0.91-0.94gm/cc at 15^{o}C. In comparison to the density of diesel fuel (0.81-0.86gm/cc)the density of vegetable oils 10% higher, and for ester about 5% higher. For example mahua oil-0.92, neem oil-0.921 & karanji oil-0.95 while the density of ethyl and methyl ester of rape oil is 0.87 and 0.88gm/cc respectively.

POUR POINT, CLOUD POINT AND FLASH POINT:

First two properties are important for cold weather operation. For satisfactory working, the values of both are well below freezing point of oil used. Flash point is important from safety point of view. The temperature should be practically as high as possible. Typical values of vegetable fuels range between 50 & 110 c addition of vegetable oil with diesel to form a blend should not decrease the flash point temperature.

SEPERATION OF VEGETABLE OIL FUELS:

Solution to the viscosity problem has approached in at least four ways:

1. by dilution
2. by preparation of methyl esters transesterification
3. by micro emulsification
4. by Pyrolosis(or)thermal cracking

(a)DILUTION:

Dilution or blending of vegetable oil with neat diesel fuel, to improve fuel property of vegetable oil, is one of the well known methods. Dilution of sunflower oil with diesel fuel (1.3v/v) provides a fuel with a viscosity of 4.88 at 40 c, which is higher than the specified ASTM value of 4.0 at 40c. The viscosity is moderately less than that of neat sunflower oil. However Ziejewsks concluded that the blend could not be recommended for long term use in the direction diesel, engine because of closing of injector nozzle.

(b) METHYL ESTER TRANS ESTERFICATION:

The second method for reducing the viscosity is the conversion of the triglyceride oil to simple esters, which reduces the molecular weight of the original oil to 1/3 of its former value and so reduces the viscosity. Transesterification is a chemical reaction that aims at substituting the glycerol of the glycosides with their molecules of mono alcohols such as methanol and ethanol there by obtaining three molecules of methyl ester of the vegetable oil. A mixture of anhydrous alcohol and reagent (NaOH) in proper proportions is combined with moisture free vegetable oil. The materials are maintained at 65 to 75 c and allowed to settle by gravity for 24 hours.

Alkali catalyzed transesterification is known to proceed much fatter than acid catalyzed transesterification. Fatty acid methyl esters are considered as a possible substitute for a conventional automotive diesel engine.

Vegetable oil + alcohol -------------> glycerin + esters

(c)MICRO EMULSIFICATION:

Another method of reducing vegetable oil viscosity has been discovered through the formation micro emulsion with short chain as methanol (or) ethanol. A micro emulsion is defined as colloidal equilibrium dispersion of optically isotopic fluid micro
structures, with dimension generally in 1 to 150 square meter range, formed spontaneously from two normally immiscible liquids and one or more amhophilous.

The preliminary engine tests gave the following results for micro emulsions.

1. Lower exhaust temperature, and reduced emissions. Lower carbon monoxide/nitrogen oxide emissions than that is observed for diesel fuel.
2. Heat release4 patters indicated that the micro emulsion fuels burned faster than diesel fuel and had higher levels of pre mixed burning and lower levels of diffusion flame burning.

(d) PYROLYSIS OR THERMAL CRACKING:

Thermal and catalytic decomposition of vegetable oils to produce substitutes for diesel fuel has been studied by a number of researchers using a variety of methods. The method involves cleavage of chemical bonds to yield smaller molecules. Essentially two different methods of processing vegetable oils to obtain fuel have been used.

1. Passing of the oil over a heated catalyst in a tube.
2. Distillation of the oil while in the presence of metallic salts.,

PROPERTIES OF VEGETABLE OIL ESTER:

The physical characteristics of vegetable oil esters are close to those of diesel oil. A very positive gain by this process is the cetane number of esters. The fact that the cetane number of esters is in the range of 50 and above indicates their superiority in this respect. Viscosity is considerably reduced and is brought down to the level of what is usual for diesel oil. They heating value is slightly lower than that of the parent oil. The cloud point, though considerably reduced, is still high enough to cause flow problem in certain climates. The carbon residue of the esters is also low. There is only a marginal improvement in the volatility as a result of esterification. However this is not sufficient to eliminate starting problems in cold conditions. They mix easily with diesel oil. The characteristics being so close to those of the diesel oil that the esters become strong candidates to replace the diesel oil when need arises.

Table 2: vegetable oil properties

Oil	Flash point (^{o}c)	Density gm/cc	Kinematic Viscosity At 37.8^{o} c Sq.mm/sec	Cetane number	Cloud point (^{o}c)	Lower heating Value MJ/liter
Diesel oil	46	0.832	1.62	45.0	-17.8	35.3
Peanut oil	235	0.921	41.2	41.5	+3	34.1
Methyl ester peanut oil	176	0.883	4.9	54.0	+5	33.6
Soya bean oil	219	0.923	36.8	38.5	-4	34.0
Babassu oil	150	0.946	30.3	38.0	+20	33.4
Methyl babassu oil	127	0.879	3.6	63.0	+4	31.8
Palm oil	267	0.918	39.6	42.0	+31	35.0
Methyl ester of palm oil	164	0.880	5.7	62.0	+13	33.3
Sunflower oil	232	0.924	37.1	35.5	-5	34.0
Methyl ester of sunflower oil	183	0.880	4.6	49.0	+1	33.5

VEGETABLE OIL FUEL PERFORMANCE:

The vegetable oil based fuels are renewable biomass derived fuels. Further these fuels can be readily mixed with standard diesel and can be used in blends at any proportion. As far as the impact engine is concerned, there has been no evidence of material compatibility, problems using vegetable oil fuel when it is used in the proportion of 20 to 30% blend with diesel. A test in this regard was carried out by national Soya diesel.

According to NSDB(Development board USA) reports 100%esters of Soya bean oil indicated immersion incompatibility with certain rubbers and plastics, but not with metals. As far is durability is concerned most studies have shown no appreciable difference between vegetable oil based diesel and petrol. Vegetable oils based fuel can be substituted for diesel fuel with essential no engine modifications particularly at lower blending levels. Further, vegetable oil based fuel has a flash point of 64 c. vegetable oil fuel also has the advantage of not producing explosive fuel air mixtures.

PROBLEMS ASSOCIATING WITH VEGETABLE OIL FUEL:

1. Viscosity of vegetable oils is much higher than that of diesel. It can cause problems in fuel handling, pumping, atomization and fuel injection, incomplete combustion, poor cold startup, deposit formation and ring sticking.
2. Slower burning rate: vegetable oil gives rise to exhaust smoke, fuel impingements of oil on cylinder walls and lubricant oil contamination.
3. *VOLATALITY* of vegetable oils is very less which preclude their use in spark ignition engine.
4. *FLOW PROPERTIES* of the vegetable oils are poor which limit their utilization during cold weather in moderate temperature climates.

MODIFICATIONS:

The problems associated with viscosity can be reduced by heating the oil before entering into the engine.

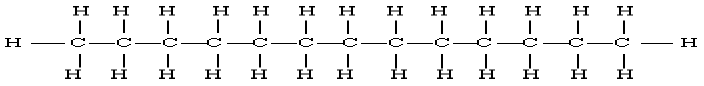
1. Further the fuel injection problem can be increasing the injection pressure.
2. The problems associated with late/slow burning can be avoided by advancing fuel injection and preheating the fuel.
3. All the above problems can be eliminated up to certain extent by blending vegetable oils with diesel.
4. Low problems can be eliminated by winterization (popular technique for reducing high melting point by freezing them over a prescribed time period and drawing the liquid portion off separately)

POLLUTION ASPECT OF VEGETABLE OILS:

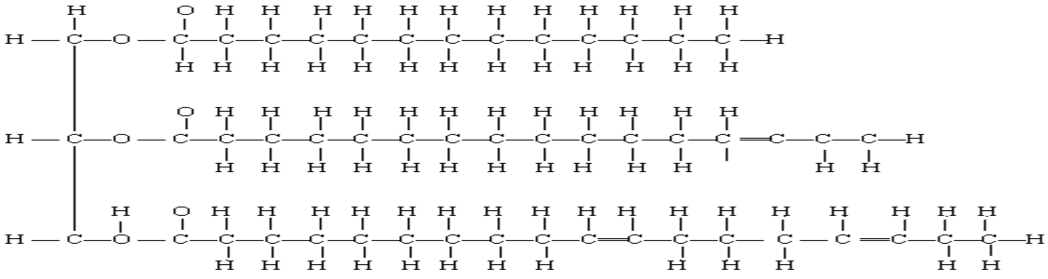
Vegetable oils have high carbon residue. Vegetable oil based fuel contribute less green house gases to the atmosphere and its use results in reduced air pollution to local levels. The parameters, which improve with vegetable oil based fuel, include smoke, polyrometric hydrocarbon, unburned hydrocarbon, sulphurdioxide, and acetaldehyde. One more important thing is that vegetable oil based fuels are biodegradable and non toxic. If spilled, it is at least 90% biodegradable with in three weeks. Therefore, its spill and leaks in mines and other sensitive areas will have less impact on disturbed aquifers. These characteristics make it a valuable fuel particularly in environmentally sensitive areas. Vegetable oil has good ignition qualities than lighter alcohols for diesel engines, since their cetane number is above 30.

ECONOMICAL ASPECT OF VEGETABLE OIL FUELS:

Vegetable oil based fuel is currently more expensive than petrol & diesel. But by increasing the production and by providing subsidies, the prices can be lowered down. Further, by using glycerin as bi-product, the prices can be brought down. While considering about cost factor, we have to think about petroleum sources. They will become scarce with in next 25-30 years, and by that time we must have some alternative sources to run out millions of vehicles with out disturbance. The alternative fuels available are LPG, alcohol, and vegetable oils etc., further these LPG sources are also limited. They may serve 30-40 years. So, next choice is to go for vegetable oils. These vegetable oil based fuels are promising once. Their use doesn't requiring major engine, vehicle or infrastructure modification in existing facilities. Because, these vegetable oils are renewable, the promising feature of vegetable oil based fuel cannot be over looked.



DIESEL FUEL STRUCTURE



VEGETABLE OIL FUEL STRUCTURE

IV. MAHUA OIL – LITERARY SURVEY

Introduction:

Two species of the genus madhuca indica and madhuca longifolia are found in India. Mahua is known as *Illupai maram* in Tamil and *Hippi* in Kannada, which can be successfully grown in the wastelands and dry lands. The seeds of the tree, popularly known as `Indian butter tree. The specific gravity of mahua oil was 9.11% higher than that of diesel. The kinematic viscosity of mahua oil was 15.23times more than that of diesel at temperature of 40c. The kinematic viscosity of mahua oil reduced considerably with increase in temperature to 80c and by increasing the proportion of diesel in fuel blends.

Mahua oil tree plantations and seeds shown
at the top right corner

Leaves and flowers of mahua oil tree

Edible oil:

The seeds contain 30-40 per cent fatty oil called mahua oil, which is edible and is also used in the manufacture of various products such as soap and glycerin. The oil cake is used as bio fertilizer, organic manure and as feed for fish and cattle. The leaves are used as fodder and as green manure. The flowers are used for extracting ethanol, which is used in making country liquor.

Potential income:

The tree is found in abundance in Thanjavur, Tiruchi and Perambalur regions of Tamil- Nadu and along the Cauvery River basin. About 30-40 percent of the tribal economy in north India such as in Bihar, Madhya Pradesh and Orissa is dependent on the mahua seeds and flowers. The tree has a potential of enhancing rural income. Being an evergreen variety, it reaches a height of 45-60 feet, and is well adapted to varied weather conditions. With its wide spreading branches and circular crown the trees present a visually appealing structure. Though the tree starts bearing seeds from the seventh year of planting, commercial harvesting of seeds can be done only from the tenth year. Seed yield ranges from 20-200 kg per tree every year, depending on its growth and development. Being hardy and pest resistant, the tree requires little attention once it has taken root.

Propagation technique:

Elaborating on the technique for propagating the trees, he said the variety can be propagated through seeds and transplanted seedlings. Seeds are sown at a depth of 1.5-2.5 cm on raised beds. The seeds germinate in about ten days. One-month-old seedlings are transplanted in plastic containers of 15 x 25 cm. Six to twelve-month old-seedlings are used for planting in the main field.

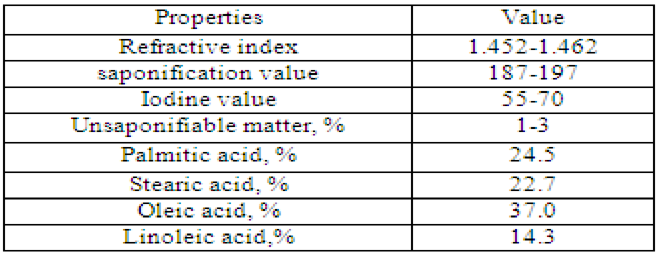
Comparison of mahua oil with diesel oil:

(a) **Calorific Value and Carbon Residue:** The calorific value of mahua oil was observed as 88.26% of diesel on weight basis and 96.30% on volume basis. The calorific value of mahua oil was found nearer to diesel fuel in comparison with other liquid fuel options like ethanol and methanol. The carbon residue of mahua oil was found higher than that of the limit specified for gradeA diesel and this may increase the chances of carbon deposition in the combustion chamber. The higher carbon residue may be due to the difference in chemical composition and molecular structure of mahua oil.

(b) **Flash point:** the flash point of mahua oil was very high as compared to diesel thus indicating its low volatile nature. The results of increase in concentration of mahua oil in diesel revealed that the power output decreases at all compression ratios.

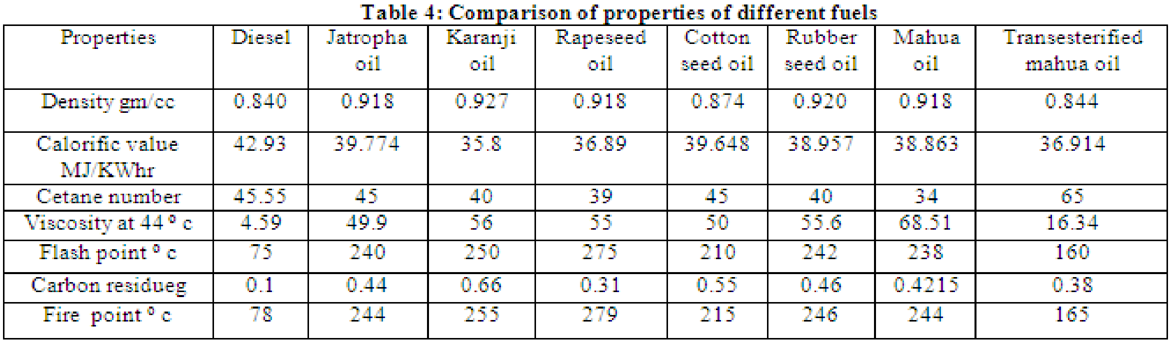
(c) **Brake thermal efficiency and a/f ratio:** Brake thermal efficiency decreased with the increase of mahua oil in diesel at all three compression ratio in comparison with pure diesel. Exhaust gas temperature increased with the increase in concentration of mahua oil in diesel. The air-fuel ratio and volumetric efficiency decreased with increase in concentration of mahua oil in diesel.

Table 3: characteristics of mahua oil



Properties	Value
Refractive index	1.452-1.462
saponification value	187-197
Iodine value	55-70
Unsaponifiable matter, %	1-3
Palmitic acid, %	24.5
Stearic acid, %	22.7
Oleic acid, %	37.0
Linoleic acid,%	14.3

Table 4: Comparison of properties of different fuels



Properties	Diesel	Jatropha oil	Karanji oil	Rapeseed oil	Cotton seed oil	Rubber seed oil	Mahua oil	Transesterified mahua oil
Density gm/cc	0.840	0.918	0.927	0.918	0.874	0.920	0.918	0.844
Calorific value MJ/KWhr	42.93	39.774	35.8	36.89	39.648	38.957	38.863	36.914
Cetane number	45.55	45	40	39	45	40	34	65
Viscosity at 44 ° c	4.59	49.9	56	55	50	55.6	68.51	16.34
Flash point ° c	75	240	250	275	210	242	238	160
Carbon residueg	0.1	0.44	0.66	0.31	0.55	0.46	0.4215	0.38
Fire point ° c	78	244	255	279	215	246	244	165

V. TRANSESTERIFICATION

Introduction:

Transesterification is the process of using an alcohol (methanol, ethanol, proponol, or butanol) in the presence of catalyst to chemically break the molecule of the raw renewable oil into methyl or ethyl esters of the renewable oils with glycerol as by-product.

Transesterification of vegetable oils and fats:

The transesterification reaction proceeds with catalyst or without catalyst by using primary or secondary monohydric aliphatic alcohols having 1-8 carbon atoms as follows:

Triglycerides + monohydric alcohol ↔ glycerin + mono-alkyl esters

Transesterification means taking a triglyceride molecule or a complex fatty acid, neutralizing the free fatty acids, removing the glycerin, and creating an alcohol ester. Theoretically, transesterification reaction is an equilibrium reaction. In this reaction, however more amount of methanol was used to shift the reaction equilibrium to the right side and produce more methyl esters as the proposed product. A catalyst is usually used to improve the reaction rate and yield.

Alcohols are primary or secondary monohydric aliphatic alcohols having 1-8 carbon atoms. Among the alcohols that can be used in the transesterification reactions are Methanol, ethanol, proponol, or butanol or amyl alcohol. Methanol and ethanol are most frequently used. Ethanol is a preferred alcohol compared to methanol because it is derived from agricultural products and is biologically less objectionable in the environment. However methanol is preferable because if it's low cost and its physical and chemical advantages (polar and shortest chain alcohol). The transesterification can also be catalyzed by alkalis, acid or enzymes.

In the conventional transesterification of animal fats and vegetable oils for biodiesel production, free fatty acids and water always produce negative effects, since the presence of free fatty acids and water causes soap formation, consumes catalyst and reduces catalyst effectiveness, all of which resulting in a low conversion.

The transesterification reaction based on the catalyst usage is divided into two types namely

1. catalytic transesterification method
2. non- catalytic transesterification method

Reaction mechanism of transesterification:

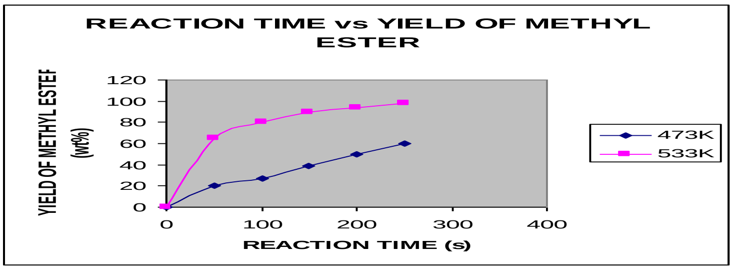
Tranesterification consists of a number of consecutive, reversible reactions. Triglyceride is converted stepwise to diglyceride, monoglyceride and finally glycerol. The formation of alkyl esters form monoglycerides is believed as a step which determines the reaction rate, since monoglycerides are the most stable intermediate compound.

$$\textit{Triglyceride} + ROH \leftrightarrow \textit{diglyceride} + RCOOR_1$$
$$\textit{Diglyceride} + ROH \leftrightarrow \textit{glycerol} + RCOOR_2$$
$$\textit{Monoglyceride} + ROH \leftrightarrow \textit{glycerol} + RCOOR_3$$

Several aspects, including the type of catalyst (alkaline, acid or enzyme), alcohol/vegetable oil molar ratio, temperature, water content and free fatty acid content have an influence on the course of the tranesterification. In the tranesterification of vegetable oils and fats for bio-diesel production, free fatty acids and water always produce negative effects, since the presence of fatty acids and water causes soap formation, consumes catalyst and reduces catalyst effectiveness, all of which result in a low conversion. When the original ester is reacted with an alcohol, the transesterification process is called alcoholysis. The transesterification is an equilibrium reaction and the transformation occurs essentially by mixing the reactants. In the transesterification of vegetable oils, a triglyceride reacts with an alcohol in the presence of a strong acid or a base, producing a mixture of fatty acids alkyl esters and glycerol. The stoichiometric reaction requires 1mol of a triglyceride and

3mol of the alcohol. However an excess alcohol is used to increase the yield of the alkyl esters and to allow its phase separation from the glycerol formed.

In the below graph various reaction times are plotted against various percentage yields of methyl esters at two different temperatures.



Based on the type of catalyst used the transesterification process is classified as follows:

1. Acid-catalyzed process
2. Alkali- catalyzed process
3. Enzyme- catalyzed process

Acid-catalyzed process:

The transesterification process is catalyzed by acids, preferably by sulphonic and sulphuric acids. These catalysts give very high yields in alkyl esters, but the reactions are slow**.** The alcohol/vegetable oil molar ratio is one of the main factors that influence the transesterification. An excess of alcohol favors the formation of products. On the other hand, an excessive amount of alcohol makes the recovery of glycerol difficult, so that the ideal alcohol/oil ratio has to be established empirically considering each individual process.

Alkali-catalyzed process:

The reaction mechanism for alkali-catalyzed transesterification was formulated in a simple manner. This reaction proceeds faster than that of the former one. The reaction mechanism will be explained in the later part.

Enzyme-catalyzed process:

This process is not yet commercially developed and also the reaction yields as well as the reaction times are still unfavorable compared to the base-catalyzed systems.

Transesterification procedure:

Table 5:

Sl.no	Chemical	Proportions
1	Mahua oil	500ml
2	Catalyst- NAOH	5.2gram
3	Methanol	225ml
4	Acetic acid + water	150ml + 850ml

- The catalyst is dissolved into methanol by vigorous stirring in a flask.
- The oil is transferred into a round bottomed flask and is heated in a water bath at 70c in water the prepared catalyst and alcohol mixture is added at first by constant stirring.
- The final mixture is stirred vigorously for 2hours at 340K in ambient pressure.
- A successful transesterification produces two liquid phases: ester and crude glycerol. Crude glycerol being heavier liquid is collected at the bottom of the flask after several hours of settling.
- Phase separation can be observed within 10min and can be completed within 2hours of settling in the separating funnel. Complete settling can take as long as 20hours.
- Before collecting the oil in the separating funnel it is mixed with acetic acid and water for distillation and easy phase separation.
- The separating funnel should be shaken well for two to three times while the mixture is allowed for phase separation.
- Finally, after 20hours, complete settling of oil and glycerol will take place.

VI. TRANSESTERIFICATION PROCESS

step1: weighing NaOH

step2: mixing methanol and NaOH

step3: heating sodium methoxide with 100ml mahua oil

step4: heated mahua oil in water bath and colour change appeared

step5: preparing dilute acetic acid solution (approx 130ml)

step6: mixing and shaking heated mahuaoil with acetic acid in a separating funnel

step7: finally obtained layers of biodiesel and glycerol after settling

step8: testing glycerol with acidified potassium permanganate solution

Precautions:

- The vegetable oil should have an acid value less than one and all materials should be substantially anhydrous. If acid value is more than one, more NaOH is injected to neutralize the free fatty acids.
- Water can cause soap formation and frothing. The resulting soaps can induce an increase in viscosity, formation of gels and foams, and made the separation of glycerol difficult.
- The stochiometric ratio for transesterification reaction requires 3mol of alcohol and 1mol of triglyceride to yield 3mol of fatty acid ester and 1mol of glycerol.
- Higher molar ratios result in greater ester production in a shorter time.
- Stirring plays a vital role in transesterification process. Constant stirring should be done for yielding of oil else it will be solidified.

Test for glycerol:

- The glycerol is tested for whether it is unsaturated or saturated fatty acid. For that it is taken in a flask.
- Then acidified potassium permanganate solution is added to that glycerol drop wise and observed carefully
- In this experiment it is observed that the acidified potassium permanganate solution decolorized the glycerol taken in the glass flask indication that it is unsaturated fatty acid.

FLOW CHART:

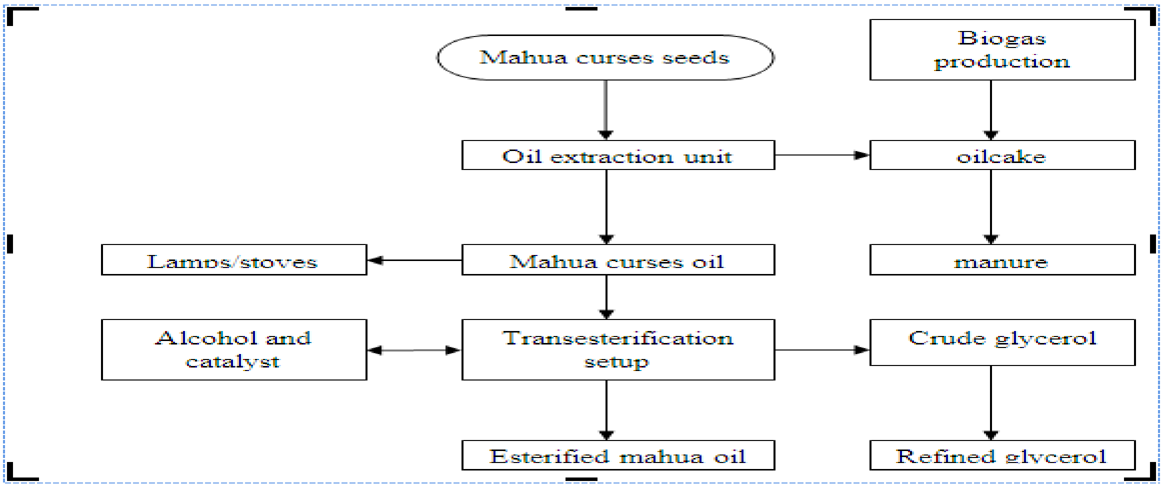


fig: **flow chart for preparation of esterified mahua oil**

VII. ACID AND HYDROCARBONS TEST

TEST WITH NaHCO3:
The esterified mahua oil is partially soluble in NaHCO3 and regeneration with dil.Hcl to this the oil contains "acidic groups".

TEST WITH NITRATION:
The esterified mahua oil and Nitration mixture (1:1 ratio of sulphuric acid and nitric acid) is collected in ice for about 15min and then heated in water bath for 20min and then poured into crushed ice then yellow precipitate is formed due to this the oil contains "hydrocarbons".

TEST WITH dil.Hcl:
The oil is insoluble in dil.Hcl due to this property the oil does not contain "basic groups".

VIII. DISTILLATION

What is distillation?
The process in which a liquid (or) vapour mixture of two (or) more substances is separated into its component factions of desired purity by the application and removal of heat. Distillation is the most common separation technique.

Introduction
Distillation Experiment

One of the major tasks of the synthetic organic chemist is the purification of starting materials and the isolation and purification of products. It is of particular importance to free a compound of impurities when its structure is to be established or its physical properties are to be precisely determined.

Distillation is a very old technique which is frequently used to purify compounds and to determine their boiling points. The boiling point is a useful molecular constant for the characterization and identification of pure compounds. Furthermore, the boiling point range is usually a good indicator of the purity of a liquid.

In this experiment you will perform several distillations. You will compare distillations of a mixture of methanol and water using the glassware set-up for a simple distillation and one for fractional distillation. You will also measure the boiling point-range for an unknown compound and use this information as an aid in its identification

Set Up
Distillation Experiment

The distillation flask, fractionation column and distillation head make up the part of the apparatus where the liquid components are volatilized and separated. (This unit should be constructed high enough on a ring stand to permit raising and lowering of the heating unit and assembled using the clamped flask as the foundation for the apparatus.) The rest of the apparatus serves to condense the hot vapor back to a liquid as it flows out the side-arm of the distillation head into the water-cooled condenser. (Caution: water should always flow from bottom to top of the condenser) Liquid flows down the condenser and through the adapter into a collection vessel. A thermometer is attached to the top of the distillation head by an adapter in order to determine the temperature of the vapor being collected. The animation shows the step-by-step assembly of a fractional distillation set-up.

A simple distillation apparatus is less efficient than a fractional distillation apparatus, but is used to purify materials containing only small amounts of impurities with much higher or lower boiling points.

IX. DISTILLATION PROCESS

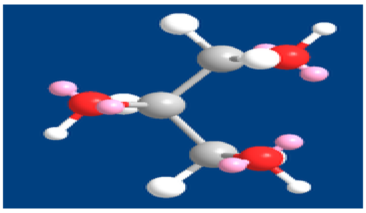
Experiment

Distillation Experiment

The distillation flask is charged with the mixture of liquids and a couple of boiling chips. (Caution: never heat a liquid without boiling chips and always add new chips to a cooled solution before reheating.) After reattaching the flask, the liquid is heated to its boiling point to cause distillation. As the liquid travels up the fractionating column, there is constant contact of the vapor and condensed liquid flowing back down the column setting up equilibration all along the column. This results in the equivalent of a number of simple distillations, depending on the particular column being used. As the liquid is removed, the sample is depleted of the lower boiling component which is highly enriched at the top of the column until most of it is gone. An intermediate fraction consisting of the two components is usually collected until all of the lower boiling component is removed, at which point the pure higher boiling component is distilled. The progress of the distillation is followed by measuring the temperature of the vapor at the top of the column. In a reasonably efficient distillation, a fraction of each of the pure components will be obtained which boil over a small temperature range near the boiling points of the components with an intermediate fraction, whose boiling range is broad and between those of the pure components.

X. GLYCEROL REPRESENTATIONS:

chemical structure of glycerol



glycerol 3D model

GLYCEROL:

Glycerol, also well known as **glycerin** and **glycerine**, and less commonly as **propane-1,2,3-triol**, **1,2,3-propanetriol**, **1,2,3-trihydroxypropane**, **glyceritol**, and **glycyl alcohol** is a colorless, odorless, hygroscopic, and sweet-tasting viscous liquid. Glycerol is a sugar alcohol and has three hydrophilic alcoholic hydroxyl groups (OH^-) that are responsible for its solubility in water. Glycerol has a wide range of applications. Glycerol has a prochiral spatial arrangement of atoms.

Glycerol – uses and applications:

Glycerol literally has thousands of uses. However, those uses are in constant flux as new technologies are adapted. Here is an overview of the most common uses.

Foods and Beverages

Glycerol is used to moisten, sweeten and preserve foods and drinks.

Examples:

- Soft drinks
- Candies
- Cakes
- Casings for meats, cheese and dry pet foods

As an intermediate, glycerol also is used in margarine, salad dressings, frozen desserts and food coatings.

Drugs

Glycerol is one of the most widely used ingredients in drugs and pharmaceuticals, Uses include:

- Capsules
- Ear infection remedies
- Anesthetics
- Cough remedies
- Gargles
- As a vehicle for antibiotics and antiseptics

Cosmetics and Toiletries

Because glycerol is nontoxic, non-irritating and odorless, it is used as a moisturizing agent and emollient (softening agent) for cosmetics and toiletries, including:

- Toothpaste
- Skin creams and lotions
- Pre-shaving lotions
- Deodorants
- Make up
- Lipstick

Tobacco

Glycerol keeps tobacco moist and soft to prevent breaking and crumbling during processing; it also adds flavor to chewing and pipe tobaccos. Glycerol also is used to manufacture cigarette filter tips.

Paper and Printing

Glycerol is used to soften and reduce shrinkage during paper manufacturing.

Related uses:

- Grease-proof paper
- Food wrappers
- To manufacture printing ink

Textiles

Glycerol is used to size and soften yarn and fabric and to lubricate many kinds of fibers in spinning, knitting and weaving operations.

Other common uses:

- As a lubricant for food processing machinery
- To manufacture resin coatings
- To add flexibility to rubber and plastic
- As a building block in manufacturing flexible foams
- To manufacture dynamite
- To create a component used in radios and neon lights

XI. EXPERIMENTAL SETUP AND PROCEDURE

The schematic diagram of the experimental setup to test the performance of the engine with esterified mahua oil is shown in figure. The engine is rigidly fixed to engine bed by bolts and nuts. A surge tank is fixed to the stand and air enters into the surge tank through air filter and passes through an orifice plate. The difference in water column in two legs of U-tube manometer gives the pressure drop across orifice plate. This pressure drop is used to calculate the mass flow rate of air.

The dynamometer used here is brake dynamometer. It has a brake drum connected to the crankshaft. A belt runs over the brake drum one end connected to the spring balance and another end to the load carrying plate. The reading of the spring balance is taken as the net load on the engine.

EXPERIMENTS:

For better homogenization of the blends, they were prepared by mixing the required proportions in the fuel tank. The compressed air at 2-3 atmospheres from a compressor was bubbled through the mahua oil blend. This ensures a thorough mixing and homogenization of the blend. The blended fuel was then injected into the combustion chamber with the standard fuel injection system of the engine. The injection timing was optimized for the fuel at the rated load and this injection timing is maintained constant through the test.

The experimental setup consists of

1. Setup for investigation of the performance characteristics of C.I.engine using diesel and mahua oil blends.
2. Setup for the investigation of fuel properties.
3. Setup for the transesterification of mahua oil.
4. Setup for changing the pressure of the injector of the engine.

Kirloskar Single Cylinder 4-Stroke Diesel Engine

Experimental Setup For Investigation Of Performance Characteristics:

The experimental setup consists of single cylinder, 4-stroke, and water cooled KIRLOSKAR diesel engine. It is provided with accessories for the measurement of the load, fuel consumption, exhaust gas temperature, volume of air inducted. The experimental setup is shown in the figure.

Specification Of The Engine:

Name of the engine : KIRLOSKAR
General details : 4-stroke C.I, vertical, water cool
Number of cylinders : 1
Bore : 80mm
Stroke : 110mm
Rated power : 5bhp at 1500rpm
Brake drum diameter : 310mm
Belt thickness : 6mm

Arrangement For Measuring Load:

A rope runs over the brake drum one end connected to the spring balance and another end to the load carrying plate. The reading of the spring balance is taken as the net load on the engine. In the operation of the rope brake drum dynamometer, the engine is made to run at constant speed. The frictional torque due to the rope must be equal to the torque transmitted by the engine.

Apparatus For Measurement Of Fuel Consumption:

The fuel tank is attached with a graduated burette. The valve at the bottom of the tank is closed when fuel consumption rate is to be measured so that fuel is consumed only from the burette. The time taken for “X” amount of fuel consumption is recorded to measure the fuel consumption rate.

Experimental Set Up For The Investigation Of Fuel Properties:

For determination of properties of esterified mahua oil and diesel blends, the experimental setup consists of

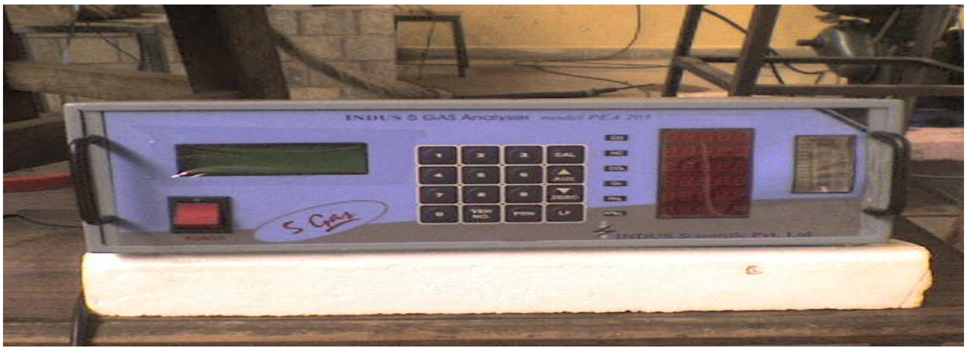
(a) Apparatus to determine emission gases
(b) Apparatus to determine viscosity
(c) Apparatus to determine density
(d) Determination of aniline point and cetane number

Description Of Apparatus For Measuring Emission Gases:

(a) DC-5 GAS ANALYZER:

DC- 5 gas analyzer measures five emission gases, including hydrocarbons (HC), Carbon Monoxide (CO), Carbon Dioxide (Co2), Oxygen (O2) and oxides of Nitrogen (NOX).

It will also provide a read-out for an optional Tachometer that handles up to 30,000 r.p.m.



DC-5 GAS ANALYZER

(b)SMOKEMETER:

Many stationary sources discharge visible emissions into the atmosphere; these emissions are usually in the shape of plume. This smoke meter involves to determination of plume opacity.

SMOKE METER

Description Of Apparatus For Measuring Viscosity:

The viscosity of the vegetable oil blends is determined by using redwood viscometer. The description of apparatus is given below. The redwood viscometer consists of a copper cup, which is used to fill the liquid whose viscosity, is to be determined. The cylinder cup is surrounded by a water jacket. To maintain a uniform temperature throughout the volume of a stirrer is provided. A ball valve is provided to control the flow of liquid through the small hole located at the bottom of copper cup. A collecting flask and stopwatch are required to collect 50cc of oil and to determine the corresponding time.

Apparatus To Determine Density:

For measuring the density of fuel blends, the apparatus consists of gravity bottle is determined accurately with the help of physical balance and weight. A 50cc of trans esterified mahua oil is taken in the bottle and its weight is determined. From the readings obtained, the density of esterified mahua oil is determined

Apparatus For Determing Aniline Point And Cetane Number:

To determine the aniline point of fuel blends the apparatus consists of a water container in which a test tube with the aniline mixture placed. The setup is heated using the Bunsen burner and the heat is distributed to the stem by using a stirrer. Thermometer is placed in the mixture to, read the aniline mixture.

Experimental Technique:

The important fuel properties of esterified mahua oil where determined according to standard procedure. The kirloskar 5bhp, single cylinder, 4stroke, water cooled engine having a bore(80mm) and stroke (10mm) was used for this stud as shown in the figure 7.1.the experiments were conducted at constant speed of 1500rpm as applicable for stationary engine. The engine was coupled with a belt brake dynamometer. The standard instrumentation was used to measure the fuel consumption, exhaust temperature, coolant temperature(fig 1)for the stabilization of measuring parameters at each load setting and at the start of each test, time period of 10 min and 30min were allowed. Three blends of esterified mahua oil with diesel and pure oil were tested in the engine. The fuel blends were prepared in the proportion of 80% and 60% volume be volume with diesel, respectively. Pure esterified mahua oil (100%) is also used as another blend to run the engine. The base line test was conducted with diesel only. In the process of testing with esterified mahua oil – diesel fuel blends, no change was made in the engine. The engine was directly started on the fuel blends with out a change over from diesel fuel. The engine performance was compared on the basis of parameter, i.e. power output, specific fuel consumption, brake thermal efficiency, and exhaust gas temperature, air/fuel ratio and volumetric efficiency.

The values of power output, specific fuel consumption (SFC) and brake thermal efficiency was calculated using the standard formula and compared with that of diesel.

Experimental Procedure:

The experimental procedure consists of

1. Tests for determination of fuel properties
2. Tests for finding out the performance characteristics

Test To Determine The Properties Of Blends:

A Procedure To Determine The Viscosity:

The apparatus is cleaned thoroughly. The ball valve is placed in position thus closing the orifice. The sample is poured into the cup up to gauge point. The standard 50 ml flask is kept under the orifice of the cup. The sample is heated to the required temperature, which is noted from the thermometer immersed in the oil. After heating to the desired temperature the ball valve is lifted off. The oil drains in to the flask placed beneath. The time taken to collect the oil up to the mark is measured using stop watch.

The kinematic viscosity of the sample is determined using the formula.

Kinematic viscosity = A*t – B/t in centistokes.

Density (Dt) = Dr-0.000675(T-Tr) in gm/cc.

Where t = Redwood seconds to collect the 50 ml sample.

A and B are constants given below

A = 0.26 and B = 171.5.

PROCEDURE TO CALCULATE CETANE NUMBER:

The aniline point is the lowest temperature at which equal parts of volume of freely distilled aniline and test sample are completely miscible in each other.

It is determined by mixing in jacketed test tube to clear solution and recording the temperature at which turbidity appears as mixture cools.

$$\text{Cetane number} = -\frac{\text{Aniline temperature in } {}^{o}\text{C}}{1.95} - 31.5$$

for pure esterified mahua oil, diesel blends that are mixable with aniline at room temperature, the mid boiling point is determined. From mid boiling point, the cetane number is determined.

The aniline point indicates the possible deterioration of rubber sealing, pacing, etc, in contact with the oil. The aniline point, the lower the percentage of aromatic hydrocarbons and higher the content of paraffin lower the aromatic content.

Procedure To Measure Density:

The gravity bottle is thoroughly cleaned and dried. The bottle is placed in the left pan of the balance and mass of bottle is determined b placing weights from the weight box in the right pan so the weights of the masses in the pans are balanced. The bottle is filled with the sample up to the mark, it is again placed on the pan and its mass is also determined. The volume of the sample in the bottle is 'X 'cc

Density of the sample = (b – a)/ X g/cc

Where

b = mass of fuel + bottle in g.

a = mass of bottle in g.

XII. PROCEDURE TO CHANGE INJECTOR PRESSURE:

Higher fuel-injection pressure increases the degree of atomization. The fineness of atomization reduces the ignition delay, due to higher surface volume ratio. Smaller droplet size will have low depth of penetration due to less momentum of the droplet and less velocity relative to air from where it has to find oxygen after vaporization. Because of this air utilization factor will be reduced due to fuel spray path being shorter. Also with smaller droplets, the aggregate area of inflammation will increase after ignition, resulting in higher pressure rise during the second stage of combustion. Thus, lower injection pressure, giving larger droplet size may give lower pressure rise during the second stage of combustion and probably smoother running.

Generally mean droplet size decreases with increase in the injection pressure. Also the rate of injection increases with the increase in injection pressure and there by the load on the injector push rod and cam increases which may affect the durability of the engine.

Injector to be pressure changed should be placed in the pressure changing setup. The lever is pulled down such that the nozzle sprays the fuel and the pressure reading is shown in the indicator in bar. Pressure can be changed by removing the head nut of the nozzle and by adjusting the screw, by operating the lever the pressure can be changed. The pressures we have used for injector is 200bar. The following steps show the procedure of pressure changing of the injector.


Step: 1


Step: 2


Step: 3


Step: 4


Step: 5


Step: 6

Experimental Procedure For The Determination Of Performance Characteristics

The procedure comprises of determining Brake Horse power, Brake Thermal efficiency, specific energy consumption, and Exhaust gas temperature. Before the actual tests are carried out the engine is checked for lubrication and fuel supply. Rotating the flywheel manually and operation the decompression lever start the engine. If the engine starting is difficult for blends, the engine is run on diesel initially. The nozzle injection pressure is set at 200 kg/cm2.

Determination of Brake Power

The equivalent load 'W' is recorded from the calibrated circular scale incorporated in the dynamometer setup.

B.P = W*N/1500 KW

Where,

N is speed of engine in rpm,

W is load applied in kg

Determination Of Brake Thermal Efficiency

Brake thermal efficiency = (B.P * 3600)/ (F.C.H * C.V)

Where,

C.V = calorific value of the blend in kJ/kg

F.C.H = fuel consumption in kg/hr

Determation Of Specific Fuel Consumption

. S.F.C = F.C.H / B.P kg / KW-hr

Procedure To Obtain Exhaust Gas Temperature

The Exhaust gas temperature is measured using a Dail thermometer. The indicator on a graduated Dail directly reads the temperature in ^{o}C

Table: 6 Engine performance with 100 % diesel at an injection pressure of 200bar

Gas Analyser Readings					Smokometer Readings	
Co (%)	HC(ppm)	Nox(ppm)	Co2 (%)	O2 (%)	Opacity(N)	K
0.049	15	74	2.03	18.12	1.1	0.03
0.040	18	351	3.98	15.26	1.5	0.03
0.036	22	615	5.34	13.4	1.4	0.035
0.039	19	840	6.53	11.6	4.1	0.09
0.033	12	831	6.58	11.57	8	0.21
0.033	8	865	7	10.9	13.5	0.35
0.086	29	829	6.61	11.38	16.5	0.35

S.No	Load (Kg)	Speed (rpm)	Fuel Consumption (mf),Kg/hr		Exhaust Gas Temp.(°C)	B.P (kw)	F.C (kg/hr)	F.P (kw)	I.P (kw)	S.F.C (kg/kw-hr)	B.T.E (%)	I.T.E (%)	M.E (%)
			X(cc)	T(Sec)									
1	0	1500	30	187	105	0	0.49	5.2	5.2	∞	0	87.9	0
2	1	1490	30	141	140	0.99	0.66	5.2	6.19	0.66	12.58	78.6	15.99
3	2	1480	30	110	175	1.97	0.84	5.2	7.17	0.43	19.67	71.6	27.47
4	3	1460	30	97	205	2.92	0.96	5.2	8.12	0.33	25.51	70.1	35.96
5	4	1452	50	145	225	3.87	1.06	5.2	9.07	0.27	30.62	70	42.67
6	5	1440	50	129	240	4.8	1.2	5.2	10	0.25	33.54	69.8	48
7	6	1416	50	113	265	5.66	1.37	5.2	10.86	0.24	34.64	66.47	52.12

Table: 7 Engine performance with 25% esterified oil and 75% diesel at an injection pressure of 200bar

S.No	Load (Kg)	Speed (rpm)	Fuel Consumption (mf),Kg/hr		Exhaust Gas Temp.(°C)	B.P (kw)	F.C (kg/hr)	F.P (kw)	I.P (kw)	S.F.C (kg/kw-hr)	B.T.E (%)	I.T.E (%)	M.E (%)
			X(cc)	T(Sec)									
1	0	1500	30	176	110	0	0.54	4.5	4.5	∞	0	73.17	0
2	1	1493	30	141	130	0.99	0.67	4.5	5.49	0.68	12.97	71.94	18.03
3	2	1486	30	114	155	1.98	0.82	4.5	6.48	0.41	21.20	69.39	30.55
4	3	1474	30	99	175	2.94	0.95	4.5	7.45	0.31	27.26	68.86	39.59
5	4	1464	50	140	195	3.9	1.12	4.5	8.4	0.29	30.57	65.85	46.43
6	5	1451	50	123	215	4.84	1.27	4.5	9.34	0.26	33.46	64.57	51.82
7	6	1427	50	107	255	5.71	1.46	4.5	10.21	0.25	34.34	61.40	55.92

Gas Analyser Readings					Smokometer Readings	
Co (%)	HC(ppm)	Nox(ppm)	Co2 (%)	O2 (%)	Opacity(N)	K
0.048	10	169	3.12	16.46	0.4	0.01
0.045	13	307	3.72	15.37	0.7	0.01
0.039	17	616	5.20	13.63	1.6	0.02
0.037	19	710	5.68	12.96	3.4	0.05
0.035	13	897	6.49	11.78	6.8	0.17
0.041	13	951	8.16	10.5	10.5	0.25
0.069	33	1492	9.83	7.05	19.5	0.48

Table: 8 Engine performance with 50% esterified oil and 50% diesel at an injection pressure of 200bar

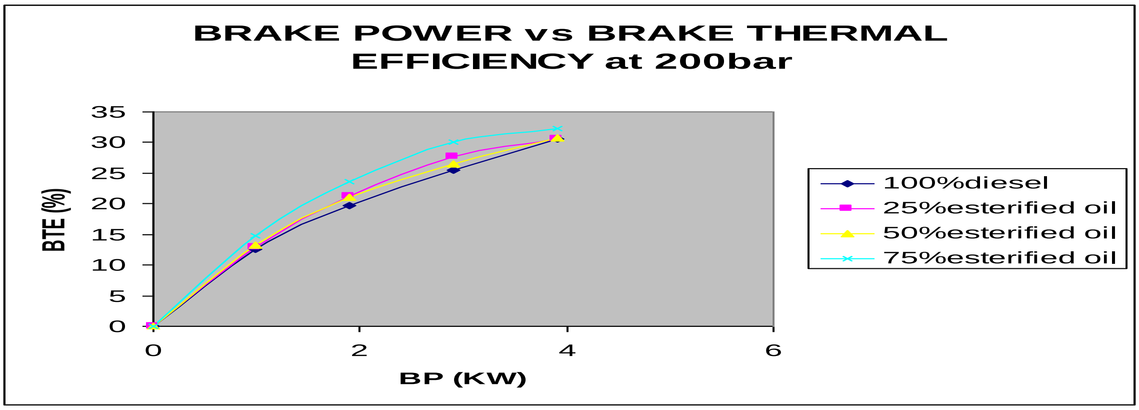
S.No	Load (Kg)	Speed (rpm)	Fuel Consumption (mf),Kg/hr		Exhaust Gas Temp.(°C)	B.P (kw)	F.C (kg/hr)	F.P (kw)	I.P (kw)	S.F.C (kg/kw-hr)	B.T.E (%)	I.T.E (%)	M.E (%)
			X(cc)	T(Sec)									
1	0	1500	30	191	90	0	0.5	4.1	4.1	∞	0	73.98	0
2	1	1496	30	141	140	0.99	0.67	4.1	5.09	0.68	13.33	68.54	19.45
3	2	1488	30	112	165	1.98	0.85	4.1	6.08	0.43	21.02	64.54	32.56
4	3	1478	30	94	185	2.96	1.01	4.1	7.06	0.34	26.44	63.07	41.92
5	4	1464	50	139	205	3.91	1.15	4.1	8.01	0.29	30.67	62.84	48.81
6	5	1451	50	120	230	4.84	1.32	4.1	8.94	0.28	33.08	61.11	54.14
7	6	1434	50	102	265	5.74	1.55	4.1	9.84	0.27	33.41	57.28	58.33

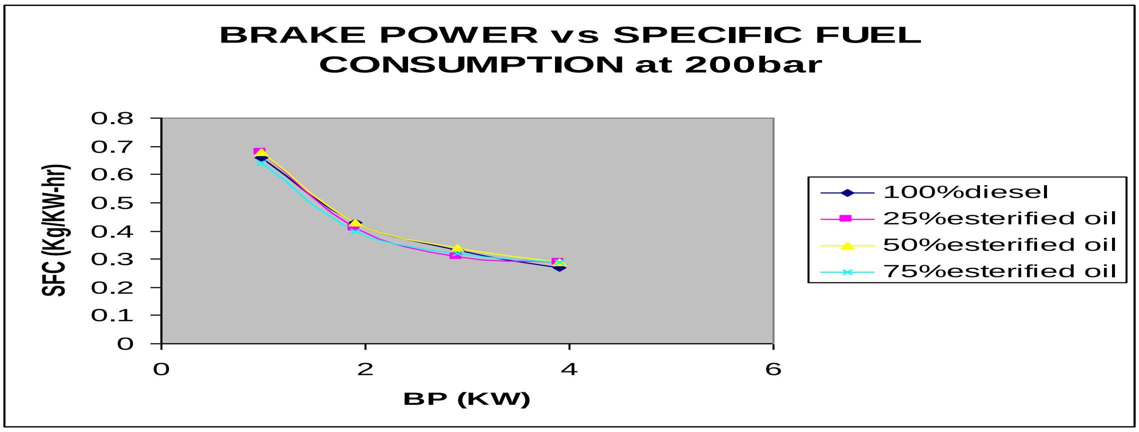
Gas Analyser Readings					Smokometer Readings	
Co (%)	HC(ppm)	Nox(ppm)	Co2 (%)	O2 (%)	Opacity(N)	K
0.043	10	97	2.61	17.28	0.8	0.02
0.038	11	344	4.17	15.11	1.2	0.03
0.037	12	518	4.9	14.01	1.4	0.03
0.033	13	778	5.91	12.67	2.5	0.05
0.031	15	1002	6.85	11.37	3.3	0.10
0.028	15	1142	8.09	9.56	9.6	0.25
0.061	23	1323	9.22	7.24	23.5	0.72

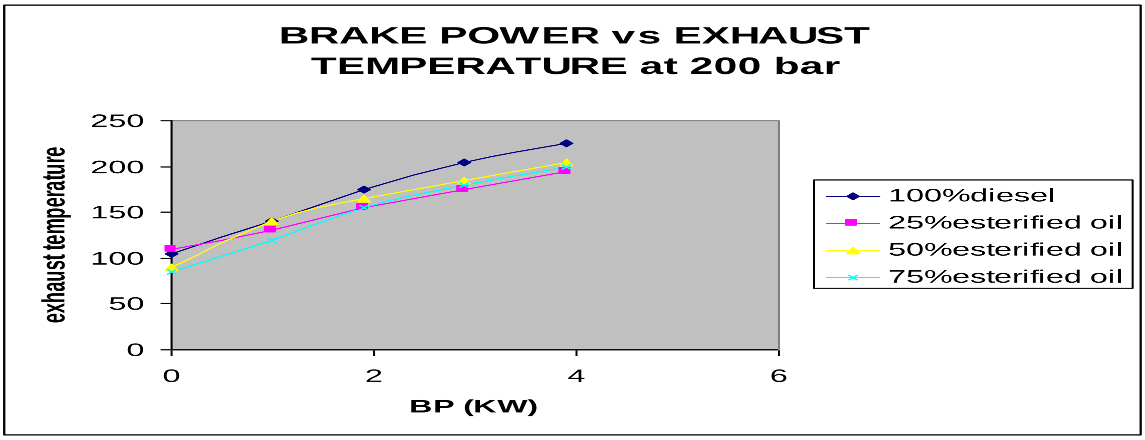
Table: 9 Engine performance with 75% esterified oil and 25% diesel at an injection pressure of 200bar

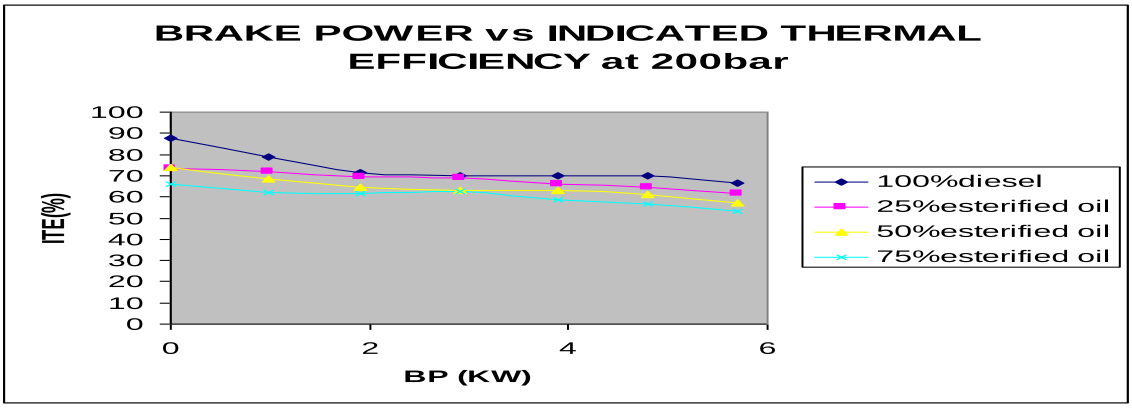
S.No	Load (Kg)	Speed (rpm)	Fuel Consumption (mf),Kg/hr		Exhaust Gas Temp.(°C)	B.P (kw)	F.C (kg/hr)	F.P (kw)	I.P (kw)	S.F.C (kg/kw-hr)	B.T.E (%)	I.T.E (%)	M.E (%)
			X(cc)	T(Sec)									
1	0	1500	30	210	85	0	0.46	3.2	3.2	∞	0	65.9	0
2	1	1499	30	151	120	.99	0.64	3.2	4.2	0.64	14.83	62.17	23.81
3	2	1494	30	121	155	1.99	0.8	3.2	5.19	0.4	23.57	61.46	38.34
4	3	1474	30	104	180	2.95	0.93	3.2	6.15	0.32	30.06	62.84	47.97
5	4	1466	50	141	200	3.91	1.15	3.2	7.11	0.29	32.21	58.57	54.99
6	5	1452	50	121	225	4.84	1.34	3.2	8.04	0.28	34.22	56.84	60.19
7	6	1434	50	102	250	5.74	1.59	3.2	8.94	0.27	34.30	53.27	64.21

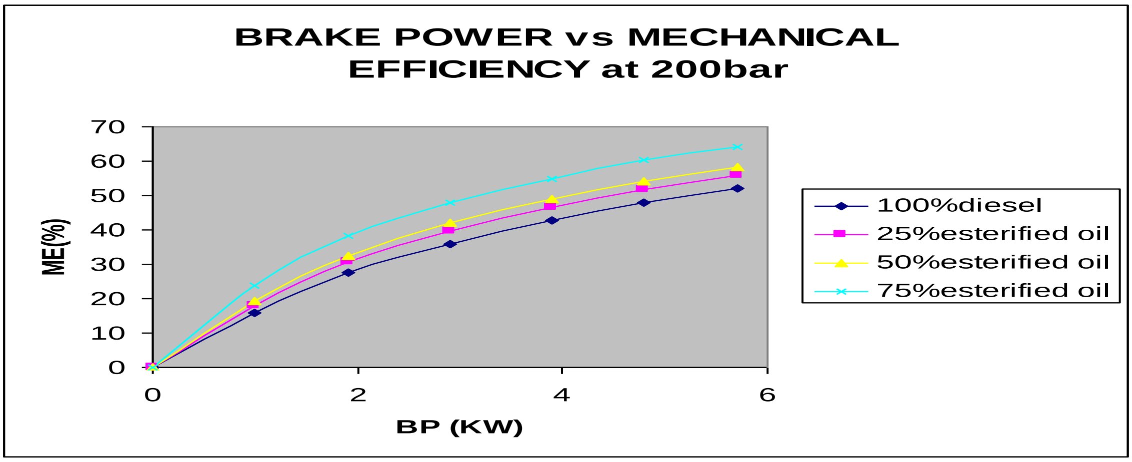
Gas Analyser Readings					Smokometer Readings	
Co (%)	HC(ppm)	Nox(ppm)	Co2 (%)	O2 (%)	Opacity(N)	K
0.041	8	90	2.26	17.75	0.4	0.01
0.040	9	270	3.73	16.14	1.1	0.03
0.038	11	520	4.84	14.38	1.3	0.04
0.031	11	819	6.04	12.42	2.3	0.07
0.028	10	983	6.86	11.47	3.1	0.09
0.02	8	1036	7.86	10.61	8.9	0.23
0.058	19	1332	9.39	8.15	16.1	0.38

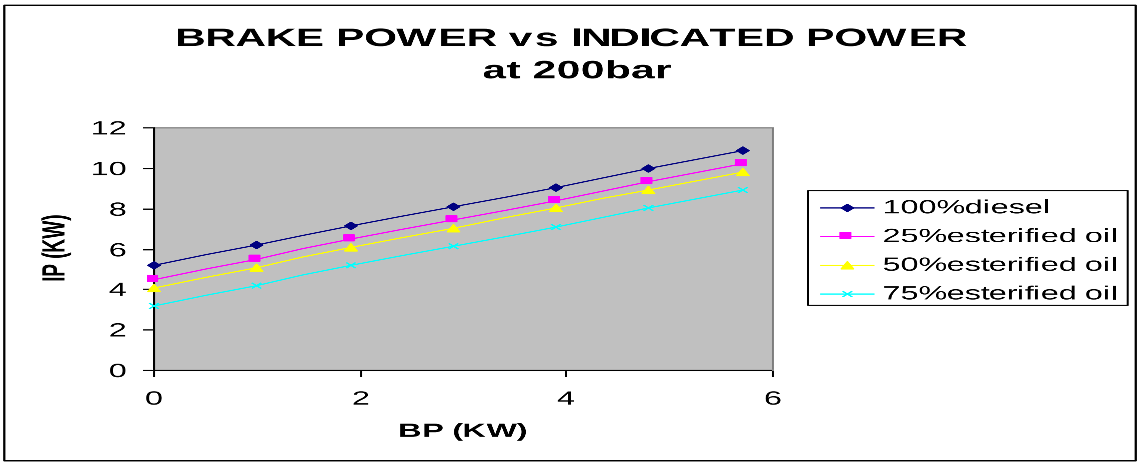

BRAKE POWER vs BRAKE THERMAL EFFICIENCY at 200bar
BTE (%)
35
30
25
20
15
10
5
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

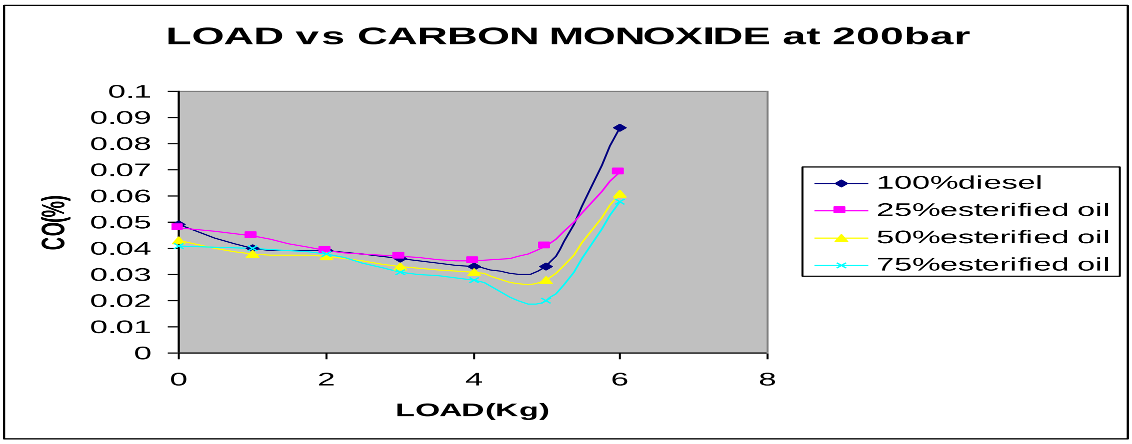

BRAKE POWER vs SPECIFIC FUEL CONSUMPTION at 200bar
SFC (Kg/KW-hr)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

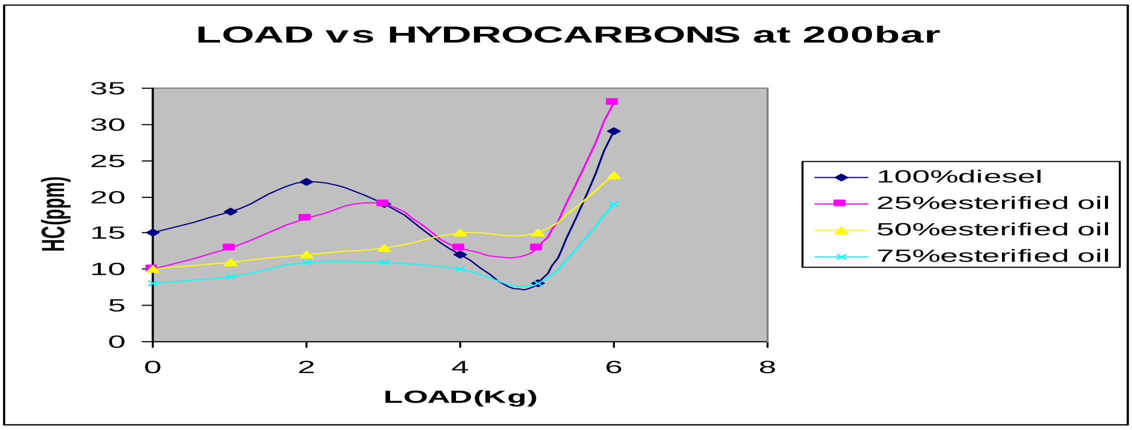

BRAKE POWER vs EXHAUST TEMPERATURE at 200 bar
exhaust temperature
250
200
150
100
50
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

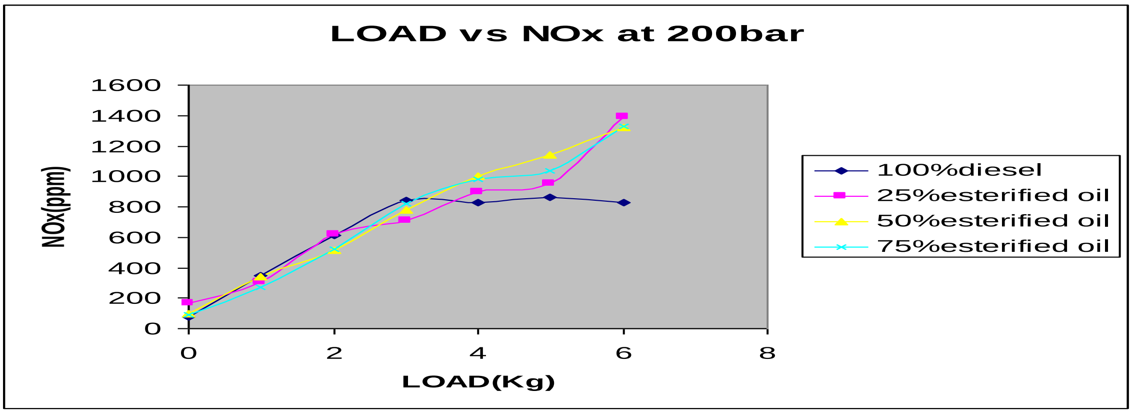

BRAKE POWER vs INDICATED THERMAL EFFICIENCY at 200bar
ITE(%)
100
90
80
70
60
50
40
30
20
10
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

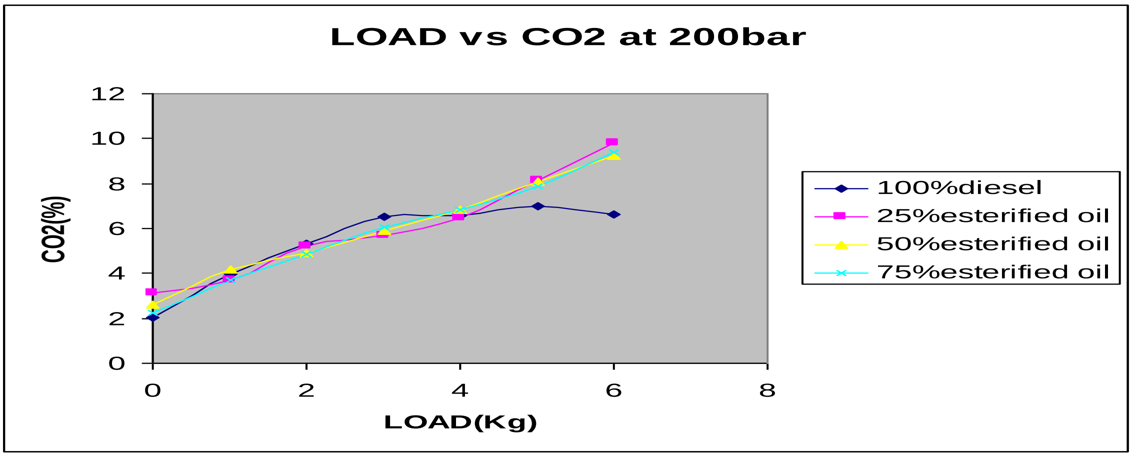

BRAKE POWER vs MECHANICAL EFFICIENCY at 200bar
ME(%)
70
60
50
40
30
20
10
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

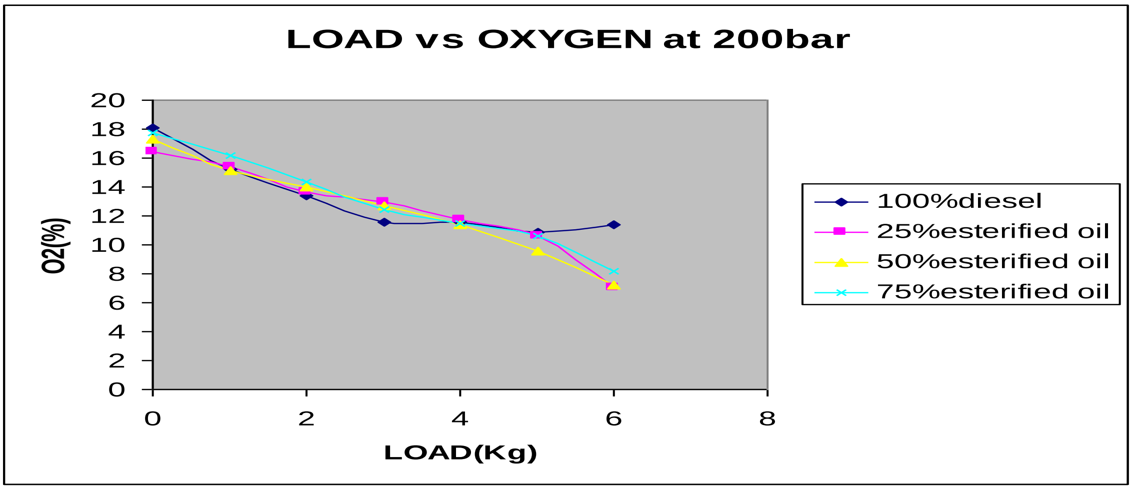

BRAKE POWER vs INDICATED POWER at 200bar
IP (KW)
12
10
8
6
4
2
0
0
2
4
6
BP (KW)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil

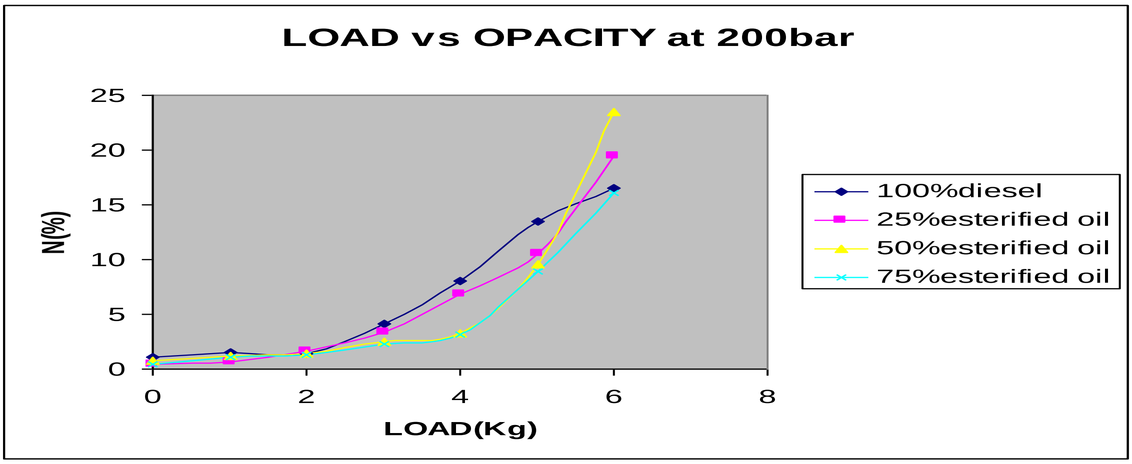

LOAD vs CARBON MONOXIDE at 200bar
CO(%)
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
2
4
6
8
LOAD(Kg)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil


LOAD vs HYDROCARBONS at 200bar
HC(ppm)
35
30
25
20
15
10
5
0
0
2
4
6
8
LOAD(Kg)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil


LOAD vs NOx at 200bar
NOx(ppm)
1600
1400
1200
1000
800
600
400
200
0
0
2
4
6
8
LOAD(Kg)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil


LOAD vs CO2 at 200bar
CO2(%)
12
10
8
6
4
2
0
0
2
4
6
8
LOAD(Kg)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil


LOAD vs OXYGEN at 200bar
O2(%)
20
18
16
14
12
10
8
6
4
2
0
0
2
4
6
8
LOAD(Kg)
100%diesel
25%esterified oil
50%esterified oil
75%esterified oil



XIII. CONCLUSIONS

- 800-850ml of esterified mahua oil is extracted from 1000ml of mahua oil during esterification.
- Percentage increase in esterified mahua oil increases the viscosity of diesel.
- Increase in percentage of mahua oil increases the cetane number of the blend.
- Smooth running of engine is observed with esterified mahua oil compared with that of diesel.
- Slight increase in brake thermal efficiency and decrease in specific fuel consumption is observed in the case of esterified mahua oil (all blends especially 75% mahua oil) compared to that of diesel.
- Particulate matter is some what less in the case of esterified mahua oil than that of diesel which is observed by keeping a tissue paper at the outlet of the exhaust pipe.
- Among the injection pressures tested 200bar is the optimum pressure for esterified mahua oil.
- Observing the particulate matter esterified mahua oil is an eco-friendly fuel.

SCOPE FOR FUTURE WORK:

- Attempts are to be made to extract more pure esterified oil during esterification.
- Attempts are to be made to extract pure bio diesel of esterified mahua oil by using distillation process.
- Increase in production of mahua oil reduces the cost of fuel.

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