BLENDING CORRELATION
OF
BIO-DIESEL WITH PETRO-DIESEL

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BLENDING CORRELATION
OF
BIO-DIESEL WITH PETRO-DIESEL

A thesis submitted in partial fulfilment of the requirements for the
Degree of
Bachelor of Technology

By
Suchitra Chandrashekar
Under the guidance of

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Approved

....
Dean

College of Engineering
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Dehradun
May, 2008

CERTIFICATE

This is to certify that the dissertation report on "Blending Correlation of Bio-diesel with Petro-diesel" completed and submitted to the University Of Petroleum & Energy Studies, Dehradun by Miss Suchitra Chandrashekar in partial fulfillment of the requirements for the award of degree of Bachelor of Applied Petroleum is a bonafide work carried out by her under my supervision and guidance.

To the best of my knowledge and belief the work has been based on investigation made, data collected and analyzed by her and this work has not been submitted anywhere else for any other University or Institution for the award of any degree/diploma.

Bhavna 13.05.08.

Mrs.Bhavna Lamba Yadav

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Acknowledgement

This report bears imprints of many people.

I am thankful to ***University of Petroleum & Energy Studies*** *for giving me this opportunity to carry out my major project on "****Blending Correlation of Bio-diesel with Petro-diesel****"*

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DEHRADUN

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1. INTRODUCTION

Bio-diesel is an organic compound made up methyl or ethyl fatty acids obtained from vegetable oil and animal fats. Raw material for bio-diesel is *Jatropha curcas, Pongamia Pinnata or rubber*. Bio-diesel being environmentally friendly is considered as an important alternative fuel keeping in view the pollution level that has been increased over the past few years. Bio-diesel, in some developed countries like Europe and United States have been worked upon for it's performance in various engines. Depending upon the results obtained in the R&D centers, new technologies have been developed so that bio-diesel can be used efficiently in any of the vehicles in order to minimize the carbon content in the atmosphere.

The project "Blending correlation of bio-diesel with petrol-diesel" deals with analyzing the different blends of bio-diesel in given sample of petroleum diesel for their properties and comparing them with the standard ASTM charts.

The results are then utilized to check there performance of a blend in a C.I. engine (test rigs)and hence predicting the best blend that can be used up which are both environmentally as well economically feasible

2. BIODIESEL – summary

Biodiesel is a diesel fuel or fuel additive derived from a renewable resource such as plants that can be grown domestically. It can be made from many different oils and fats such as soy, canola, tallow, mustard, and restaurant greases. Generally the fuel's final properties are not dependent on the feedstock but on the refining process. Biodiesel is produced to meet industry standards.

Biodiesel is made by chemically reacting alcohol with vegetable oils, fats, or greases. It's most often used in blends of 2% (partly for lubricity) or 20% (B20) biodiesel. It may also be used as pure biodiesel (B100). For the BioBus research project, the City of Saskatoon Transit Services is using a 5% blend of biodiesel with regular petrodiesel.

Fig1Bio-diesel sample

Usually this fuel is derived from soy beans but for the Saskatoon Transit experiments Canola oil is used as the feedstock for the refining process.

2.1 SOURCES OF BIO-DIESEL

- Jatropa plant
- Soyabean
- Castor seeds
- Rape seeds

2.2 BASIC TRANSESTERIFICATION TECHNOLOGY

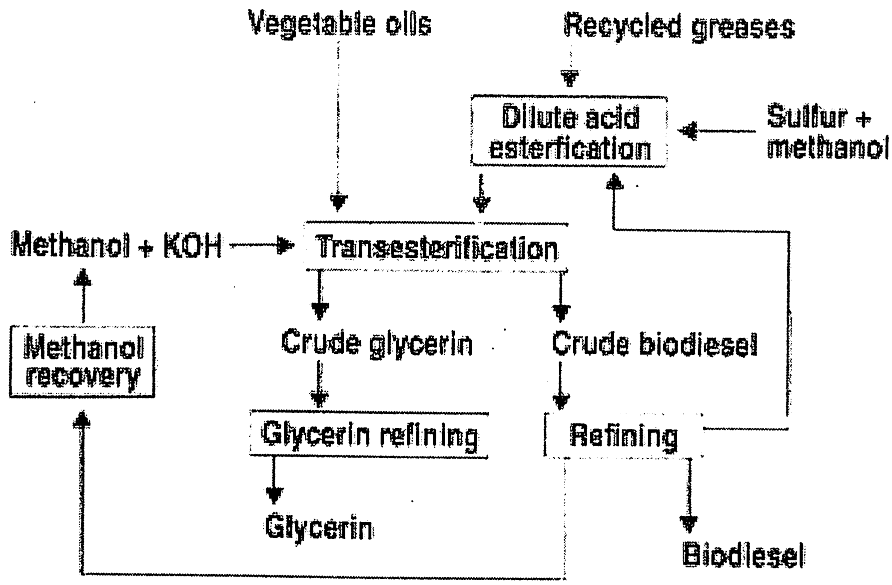


Fig.2Bio-diesel production

2.3 WHY BIODIESEL?

It is safe, biodegradable, and reduces serious air pollutants such as soot, particulates, carbon monoxide, hydrocarbons and ground level ozone. These are the main contributors to smog. Performance, storage requirements, and maintenance are similar for biodiesel blend fuels and petrodiesel. It contains no aromatics or sulfur, and is a superior sulfur-free lubricant.
Bio-diesel works with existing petrodiesel engines, and offers an immediate and seamless way to move existing petrodiesel vehicles into a cleaner burning fleet.

Biodiesel has a natural lead for its development in comparison with diesel fuel. Its high cetane index, its almost complete lack of sulfur, is significantly higher lubricating capability and its built-in oxygen proportion of around 11 percent make it an intrinsically modern hi-tech fuel.

- *Cetane Improvement*:

The higher the cetane index of a diesel fuel, the better the ignition and combustion and the more regular and smoother the engine runs. Commonly available diesel fuels have a cetane index of 50 to 52, and values of 53 to 54 are achieved by the addition of ignition accelerators. In this, biodiesel has a natural advantage. Its primary components are similar to cetane and this fuel therefore has a natural cetane index of 56 to 58 and can easily fulfill the requirements of engine manufacturers for high-quality fuels with high inflammability without additives.

- ***Ultra low sulphur level:***

Whereas the sulphur content of low sulphur diesel fuel is reduced in the refinery in a high-energy process with additional CO2 emission and a loss of the intrinsic lubricating capability, biodiesel is naturally almost free of sulphur (max. 0.001 percent and thereby at the limit of its detectability). This characteristic of biodiesel also allows the simple and optimum use of an oxidation catalytic converter.

- ***Significant Lubrication Capability:***

Biodiesel has a very good intrinsic lubrication capability. Trials have shown that biodiesel lies far below the values specified in the standard for mineral oil diesel. The so-called HFRR value is a measure of the lubrication capability. In general, the lower the HFRR value, the better the fuel. Highly desulphurised mineral oil diesel fuel has an HFRR value of 500 or higher without additives, but the limit specified by the standard for diesel fuel is 450. Mineral oil diesel fuel therefore requires additives. In contrast, the HFRR value of biodiesel is approx. 200. Biodiesel is therefore suitable as a good lubricating additive to conventional diesel when added in proportions of only 1 percent. In the operation of an engine approved for biodiesel, the engine wear is significantly reduced.

The Biodiesel molecule contains around 11 percent of oxygen. This oxygen contingent leads to an improved combustion and thereby to substantially less soot. The residues left inside the engine by the fuel are significantly reduced.

Although the density of biodiesel is slightly different from that of mineral diesel fuel, both fuels can be mixed in any ratio due to their similar chemical structure. The mixture is stable and cannot be separated by mechanical methods. It is therefore also impossible to extract biodiesel which has escaped to the engine oil with partial flow filters. The subject of mixing will have more importance in the future in view of the more stringent emission requirements

Biodiesel compliant with EN 14124 has a flashpoint of over 110 °C and other properties which indicate a lower potential hazard. For this reason, it is not a hazardous material and its handling is not subject to the operational safety rules. This is a great advantage over mineral oil diesel in storage and handling.

With the development of the European standard EN 14214, the minimum requirements on the quality of biodiesel were specified mutually at a European level by engine manufacturers and the biodiesel industry. The European standard for biodiesel has now become internationally acknowledged and is a guideline for the standardization activities conducted by other countries.

Apart from all the technical advantages and features of biodiesel, there is another more significant aspect in its favor: its environmental friendliness. Biodiesel and its use are the origin of local and global effects. Its rapid biodegradability and its almost closed CO2 cycle set out the enormous bandwidth of its ecological value.

Numerous independent institutes have now confirmed the advantages of the emissions from biodiesel in comparison with conventional diesel. For example, when biodiesel is used with a catalytic converter, only one third of the quantity of particles is emitted in comparison with low-sulfur diesel fuel. Unburnt hydrocarbons are also reduced. Only slightly higher NOx values have been noted when biodiesel is used. However, this increase, which is caused by the higher combustion temperature of biodiesel, is an effect not typical of the fuel, but of the engine.

In contrast, mineral oil diesel fuel is classified as water-endangering and EN14214 Biodiesel is rapidly biodegradable. It has been demonstrated that biodiesel is biologically degraded by over 98 % within 21 days whereas mineral oil diesel fuel is degraded by only 70 %.

Since biodiesel became a serious alternative, there have been intensive discussions of the pros and cons of its use. Important aspects such as the material balance, the energy and CO2 balance has been extensively analyzed. The fundamental advantage of all regenerative energy sources is their almost completely closed CO2 cycle. CO2 is released in all combustion processes. However, the CO2 produced in the combustion of biodiesel has been absorbed beforehand from the atmosphere by the rape plant during the photosynthesis process. In contrast to the use of fossil fuels, the combustion of biodiesel does not make a new addition. In this way, every liter of biodiesel which replaces fossil diesel reduces the greenhouse effect.

However, it cannot be denied that future developments in Biodiesel fuels new potentials for the use of native vegetable oils and these oil wells will never run dry.

3. BLENDS OF BIO-DIESEL

Bio-diesel of different blends has been used depending upon the availability of bio-diesel. Common blends are 5%, 10%, 15%, and 20% along with 100% biodiesel (pure biodiesel).

3.1 USING BIODIESEL AS A B5 BLEND:

Biodiesel as a 5% blend in Derv is fully accepted within the EN590 diesel specification.

As said:

"Australia's escalating need for fuel is posing a major health problem. Our research found that the particulate matter from diesel exhaust stimulated a "death pathway" response that the body uses to dispose of damaged cells. This response caused the airway cells to fuse together and die. saw hardly any cell death after treatment with biodiesel particulates. This study provides clear evidence that diesel exhaust is more harmful to our health than bodies"

-Leigh Ackland

3.2 BIODIESEL DISTRIBUTION

Biodiesel is distributed from the point of production via truck, train, or barge. Pipeline distribution of biodiesel, which would be the most economical option, is still in the experimental phase. Biodiesel is distributed to retail fueling stations and directly to end users such as large vehicle fleets. Most biodiesel distributors will deliver pure or pre-blended (with petroleum diesel) biodiesel depending on the customer's preference.

Global scenario

United States of America uses B20 (20% biodiesel & 80% petrodiesel) and 100% biodiesel. France uses B5 as mandatory in all diesel fuel. European countries use 5 to 15% blends.

3.3 B20 AND B100: ALTERNATIVE FUELS

The interest in biodiesel as an alternative transportation fuel stems mainly from its renewable, domestic production; its safe, clean-burning properties; and its compatibility with existing diesel engines.

Biodiesel can be legally blended with petroleum diesel in any percentage. The percentages are designated as B20 for a blend containing 20% biodiesel and 80% petroleum diesel, B100 for 100% biodiesel, and so forth. B100 and blends of B20 or higher qualify for alternative fuel credits under the Energy Policy Act of 1992.

- ***B20***

Twenty percent biodiesel and 80% petroleum diesel—B20—is the most common biodiesel blend in the United States. Using B20 provides substantial benefits but avoids many of the cold-weather performance and material compatibility concerns associated with B100.

B20 can be used in nearly all diesel equipment and is compatible with most storage and distribution equipment. B20 and lower-level blends generally do not require engine modifications. Not all diesel engine manufacturers cover biodiesel use in their warranties, however. See the National Biodiesel Board's Standards and Warranties page to learn more about engine warranties. Because diesel engines are expensive, users should consult their vehicle and engine warranty statements before using biodiesel. It is similarly important to use biodiesel that meets prescribed quality standards ASTM D6751-07b

Biodiesel contains about 8% less energy per gallon than petroleum diesel. For B20, this could mean a 1 to 2% difference, but most B20 users report no noticeable difference in performance or fuel economy. Greenhouse gas and air-quality benefits of biodiesel are roughly commensurate with the blend; B20 use provides about 20% of the benefit of B100 use and so forth. Low-level biodiesel blends also provide benefits.

- ***B100***

B100 or other high-level biodiesel blends can be used in some engines built since 1994 with biodiesel-compatible material for parts such as hoses and gaskets. However, as biodiesel blend levels increase significantly beyond B20, a number of concerns come into play. Users must be aware of lower energy content per gallon and potential issues with impact on engine warranties, low-temperature gelling, solvency/cleaning effect if regular diesel was previously used, and microbial contamination.

B100 use could also increase nitrogen oxides emissions, although it greatly reduces other toxic emissions. All these issues can be handled, but currently B100 use might be best for professional fleets with maintenance departments prepared to deal with this fuel.

3.4 DESCRIPTION OF BIO-DIESEL

Slightly yellow in color, oily in liquid with some aromatic odor and a bitter taste.

Chemistry of bio diesel

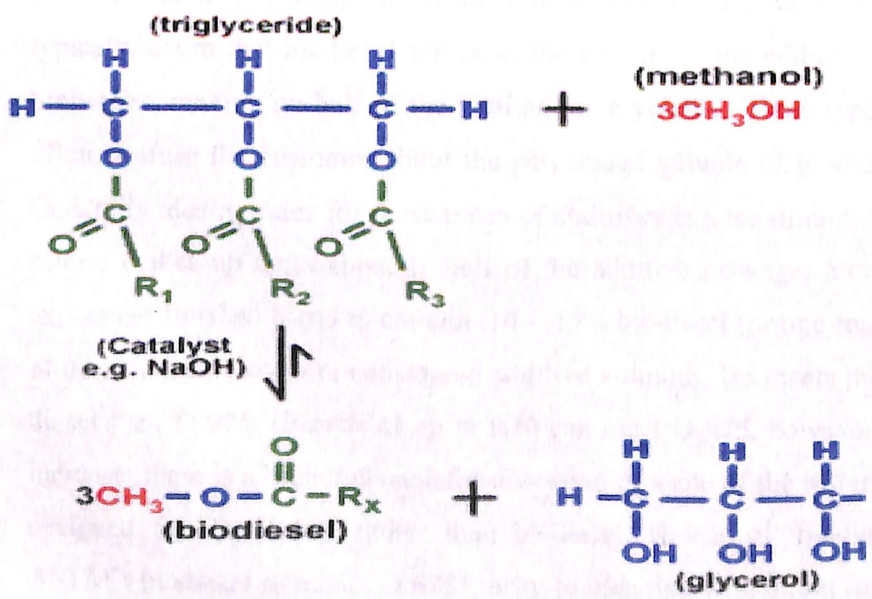


Fig3 Reaction Mechanism

3.5 PROCEDURE FOR BLENDING

Blending is the preferred method of vehicle owners and equipment operators to maximize the benefits of biodiesel and offsetting the cost differential with petroleum diesel. Blends of 20% biodiesel and 80% petroleum diesel, commonly known as B20 is being sold at gas stations and marinas nationwide. Common method for blending fuels is known the splash method where as you add biodiesel over petroleum diesel and with little agitation you have blended fuel. One can blend at any percentage as anyone's wish. Obviously a richer blend of biodiesel maximizes environmental benefits. It is recommended that you start with a 20% blend and slowly increase to a richer blend, because biodiesel is a biological solvent and will dissolve and dislodge any petroleum sludge or carbon deposits in your fuel system. Changing the fuel filter will likely be necessary after you initial few uses of Biodiesel.

3.6 A GUIDE TO DIFFERENT BLEND LEVELS

Biodiesel has become a valuable blending component with diesel fuel at low percentage blends because of biodiesel's "premium" aspects. Pure biodiesel has high lubricity, high cetane, and a high flash point. "Low blend" can be defined as blends of 5% and below. Even low blends of biodiesel are highly effective at enhancing the lubricity of diesel fuel. The typical blend used for lubricity enhancement is 2% biodiesel mixed with 98% diesel (B2).Several commercial "premium diesel" products have incorporated the positive benefits of biodiesel as a component of their multi-functional additive packages. These products typically claim that biodiesel serves as the carrier for the additive and delivers the lubricity properties, making up half of the total additive volume. These types of marketing messages often confuse the customer about the percentage volume of biodiesel in the finished blend. Generally, dosing rates for these types of additives is a maximum .25%. If biodiesel (methyl esters) makes up approximately half of the additive package, a customer could reasonably expect the finished blend to contain .10 - .15% biodiesel (or one-tenth of one percent).Blends of up to 5% biodiesel are considered additive volumes, B5 meets the ASTM specification for diesel fuel, D 975. (Blends of up to B20 can meet D 975, however, as blend concentrations increase; there is a higher chance for distortion of some of the test method results which were designed for diesel fuel rather than biodiesel. Hence, all biodiesel (B100) should meet ASTM's biodiesel standard, D 6751, prior to blending with diesel fuel at any level.)

3.7 WHY B2?

Lubricity data indicates that 2% blends of biodiesel offer the highest amount of lubricity benefit for the least incremental cost. Testing has shown that 2% blends of biodiesel can provide any type of distillate fuel with sufficient lubricity. Many independent petroleum distributors have embraced biodiesel as a liquid fuel that can be complimentary to their conventional petroleum products, and integrated profitably into their operations and product lines.

The National Biodiesel Board believes that the success of biodiesel as a fuel will depend upon the extent to which it can be successfully integrated into the existing national liquid fuel energy infrastructure. NBB is a Platinum Partner of the Petroleum Marketer's Association of America (PMAA), and has committed to work cooperatively with petroleum distributors and marketers on technical, marketing, and regulatory issues pertaining to biodiesel. NBB and its member organizations have also begun outreach efforts to cooperate on regional technical, regulatory, and educational initiatives with state petroleum

***Recommended Blending Ratios for Biodiesel in Boat Fuel*:**

Biodiesel mixes easily with diesel as a fuel additive for use in blends of up to 20% with regular petroleum diesel. Add 5 gallons (one 5-gallon container) of Biodiesel to every 20 gallons of petrodiesel to achieve a 20% blend, or use the blending chart printed on the container back label. Biodiesel mixes quickly with petrodiesel once the boat is moving. Biodiesel is a little heavier than the petroleum with has a specific gravity of 0.87 compared to 0.79-0.80 typical of reformulated petrodiesels.

Higher concentrations, up to 100% (neat) Biodiesel, are used in Europe to operate diesel engines in boats and vehicles with good performance results and excellent emissions reductions. However, until new Federal and State laws defining diesel fuel specifications are mandated to accommodate the unique properties of vegetable methyl esters. Biodiesel will only be sold as an additive for use in boat engines at ratios not to exceed 20%. In France, all diesel sold for vehicle fuel in the entire country ranges from 1% up to 5% rapeseed Biodiesel in a blend and some urban buses routinely operate on a 30% blend. In Germany, where the price of Biodiesel (tax exempt) is similar to petroleum diesel (with taxes), over 350 fuel stations offer Biodiesel for sale to motorists and Biodiesel is used in tour boats on their lakes.

3.8 BIO-DIESEL ON ATMOSPHERE:

- Sulphur dioxide emissions are eliminated (Biodiesel contains no sulphur)
- Biodiesel fuel burns up to 75% cleaner than conventional diesel fuel made from fossil fuels
- Biodiesel substantially reduces unburned hydrocarbons, carbon monoxide and particulate matter in exhaust fumes
- Biodiesel can be mixed with ordinary diesel fuel in any proportion. Even a small amount of Biodiesel means cleaner emissions and better engine lubrication: 1% Biodiesel will increase lubricity by 65%
- Biodiesel can be produced from any fat or vegetable oil, including waste cooking oil.
- Bio-diesel adds up no carbon dioxide as it is plant based

4. PRODUCT DESCRIPTION & USES

The proposed product is bio-diesel which is domestically produced, renewable fuel that can be manufactured from vegetable oil, animal fats. Blends of 20% bio-diesel can generally be used in unmodified diesel engines. Bio-diesel can also be used in its pure form but it may require certain engine modifications to avoid maintenance and performance problems.

Biodiesel is a cleaner burning diesel replacement fuel. Just like petroleum diesel, bio-diesel also operates in compression engines. Blends up to 20% can be used in nearly all bio-diesel equipment and are compatible with most storage and distribution equipment. These low level blends generally do not require any engine modifications. Bio-diesel can provide the payload capacity as diesel. Using bio-diesel in a conventional engine substantially reduces emissions of unburned hydrocarbons and particulate matter. These reductions increase as the amount of blending increases. The best emission reduction can be seen in B100.

The use of bio-diesel decrease the solid carbon fraction of particulate matter since the oxygen in biodiesel enable more complete combustion to carbon dioxide and reduces sulfate fractions. Thus bio-diesel works well with new technologies such as diesel oxidation catalyst. Emission of nitrogen oxides increases with the concentration of bio-diesel in a fuel. Some bio-diesel produces more nitrogen oxides than others and some additives have shown promise in modifying the increase. More R&D are needed to resolve the issue

A physical property of bio-diesel is similar to a diesel:

Table1: Physical property of B100

Specific gravity	0.87 to 0.89
Kinematic viscosity @ 40°	3.7 to 5.8
Cetane number	46 to 70
Higher heating value (btu/lb)	16,928 to 17,996
Sulfur , wt%	0
Cloud point,°	-11 to 16
Pour point	-15 to 13
Iodine number	60 to 135
Lower heating value	15,700 to 16,735

4.1 STANDARDS AVAILABLE FOR BIO-DIESEL

- Standard specification for bio-diesel fuel (B100) blend stock for distillate fuels, provided by ASTM international.
- Bio-diesel Production & Quality
- Bio-diesel Handling & use guidelines
- Pure bio-diesel needs to meet the requirement of ASTM D6571 to avoid engine operational problems.

4.2 GENERAL INFORMATION ON BIO-DIESEL

- Biodiesel is an alternative fuel which can be made using a simple chemical process from waste vegetable oil. It can be used directly in any diesel engine, either neat or mixed in any ratio with petroleum diesel.
- It is a green fuel, does not contribute to the carbon dioxide (CO_2) burden and produces drastically reduced engine emissions. It is non-toxic and biodegradable.
- Biodiesel has a much higher lubricity than petroleum diesel and its use can prolong engine life...

4.3 GREEN FUEL

Renewable - Biodiesel is derived from vegetable oil which is essentially grown - a sustainable resource that will not run out. Petroleum diesel is derived from crude oil, which is finite and will eventually run out.

- Carbon Neutral - Biodiesel use does not lead to any overall change in the amount of CO2 in the atmosphere. The vegetables from which the oil has been extracted remove CO2 from the atmosphere to grow. When biodiesel is burned the CO2 is released back into atmosphere.
- Less noxious, non-toxic - Biodiesel lacks the unpleasant odour of petroleum diesel and exhaust emissions smell like a barbecue! Users can expect a near 100% reduction in Sulphur dioxide (SO2), 40-60% reduction in soot & particulates, 10-50% reduction in Carbon monoxide, and a reduction in all Poly Aromatic Hydrocarbons PAHs - Phenanthren -97%, Benzofluoroanthen -56%, Benzapyren -71%, Aldehydes & Aromatics -13%.

5. BENEFITS OF BIO-DIESEL

Bio-diesel is a substitute or extender for traditional petroleum diesel and don't need special pumps or high pressure equipment for fueling. In addition, it can be used in conventional diesel engines so don't need any special vehicles or engines to run bio-diesel. Scientist believes carbon dioxide is one of the main green house gases contributing to global warming. Neat bio-diesel reduces carbon dioxide emission by 75% or more. Using a blend of 20% can reduce carbon dioxide emission by 15%.Bio-diesel also reduces particulate matter and sulfur emission.

Bio-diesel offers safety benefits over diesel because it is much less combustible having higher flash point, over $110^{O}C$ compared to diesel having flash point of $77^{o}C$. It is safe to handle, store and transport. Bio-diesel can help reduce our dependence on foreign oil and help us leverage our fossil fuel supplies. It can also help reduce green house gases emissions. It is non toxic and bio degradable. Bio-diesel contains only trace amount of sulfur and can be stored in diesel tanks and pumped with regular equipment except in cold weather where tank heaters maybe required. Bio-diesel mixes readily with petroleum diesel and hence makes it a very flexible fuel additive. Bio-diesel is an oxygenated fuel, so it contributes to a complete burn and greatly improves emission profile. One of the greatest benefit of bio-diesel is reduces air toxic which is suspected of causing cancer and other health problems. Nitrogen emissions are exceptional and tend to increase with increase in % of bio-diesel.Special precautions to be taken in cold weather conditions as seals and gaskets may tend to get damaged.

To avoid such problems, common blending proportion is 20%.Every gallon of bio-diesel displaces 0.95 gallons of petroleum based diesel over its life cycle. It is also energy efficient.

For every unit of fossil energy used to produce bio-diesel, 3.37 units of bio-diesel energy are created. It releases less fossils and carbon dioxide and acts as a suitable fuel for use in fragile environment

5.1 BIO-DIESEL AS AN AUTOMOBILE FUEL

- ***Toxicity of Biodiesel***

Impacts on human health represent significant criteria as to the suitability of the fuel for commercial applications. Health effects can be measured in terms of fuel toxicity to the human body as well as health impacts due to exhaust emissions. Tests conducted by the WIL Research Laboratories investigated the acute oral toxicity of pure biodiesel fuel as well as B20 in a single dose study on rats, which concluded that biodiesel is not a toxic and there is no hazards anticipated from ingestion incidental to industrial exposure. The acute oral LD50 (lethal dose) is greater than 17.4-g/kg-body weight, which by comparison is far safer then even table salt. According to NIOSH (National Institute for Occupational Safety & Human Health), a 96-hr. lethal concentration of biodiesel for bluegills was greater than 1000 mg/l and this aquatic toxicity is deemed as insignificant. Other related effects of biodiesel are given below:

- Very mild human skin irritation. It is less than the irritation produced by 4% soap and water solution.
- It is biodegradable. It degrades at least 4 to 5 times faster then conventional diesel fuel.
- Biodiesel has a flash point of about 300 F well above conventional diesel fuel.
- Spills of biodiesel can decolorize any painted surface if left for long.
- There is no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on biodiesel (20%RSME80% diesel).

- ***Storage & Infrastructure***

In general, the standard storage and handling procedures used for petroleum diesel may be used for biodiesel. It is preferable to store the fuel in clean, dry and dark environment. Biodiesel may gel at low temperatures and care needs to be taken to avoid temperature extremes. Acceptable storage tank materials include mild steel, stainless steel and fluorinated polypropylene. Biodiesel has a solvent effect, which releases the deposits accumulated on tanks and pipes, which previously have been used for diesel. These deposits can be expected to clog filters initially and precautions should be taken for this.

- ***Materials Compatibility***

Biodiesel over time will soften and degrade certain types of elastomers and natural rubber compounds. Materials like bronze, brass; copper, lead, tin and zinc may oxidize the diesel or biodiesel fuels and create sediments. Moreover, lead solders and zinc linings should be avoided, as should copper pipes, brass regulators and copper fittings. It is desirable to change all components, which are not biodiesel compatible to aluminum or stainless steel. The effect of B20 on vulnerable materials is diluted compared to higher blends. It may also be noted that most of the new generation vehicles can take biodiesel without any materials compatibility problems as they are already tuned to using low sulphur diesel, biodiesel etc.

Table 2 *Compatibility of some materials with biodiesel*

Material	Biodiesel Type	Effect compared to petrodiesel
Teflon	B100	Little change
Nylon 6/6	B100	Little change
Nitrile	B100	Hardness reduced 20%
	B100	Swell increased 18%
Viton A401-C	B100	Little change
Viton GFLT	B100	Little change
Fluorosilicon	B100	Little change in hardness
	B100	Swell increased 7%
Fluoroethane	B100	Little change in hardness
	B100	Swell increased 6%
Polypropylene	B100	Hardness reduced 10%
	B100	Swell increased 8-15%
	B100	Much worse

	B50	Worse
	B40	Worse
	B30	Worse
	B20	Comparable
	B10	Comparable
Tygon	B100	Worse

Source: National Renewable Energy Laboratory (NREL)

- ***Solvency of Biodiesel***

Biodiesel is a mild solvent. On prolonged contact with painted surfaces, it may deface some paints. Always wipe up spills and dispose of rags in a safe manner. Biodiesel soaked rags may self-combust if not handled properly. The most commonly encountered problem with solvency is biodiesel's tendency to "clean out" storage tanks, including the vehicle fuel tanks and systems. Some type of diesel tends to form sediments that stick to and accumulate in storage tanks, forming layers of sludge or slime in the fuel systems. The older the system, and the poorer the maintenance, the thicker the accumulated sediments become. Biodiesel will dissolve these sediments and carry the dissolved solids into the fuel systems of the vehicles. Fuel filters will catch most of it, but in severe cases, the dissolved sediments have caused fuel injector failure. Few problems have been encountered with B20 in typical diesel storage situations. However, the solvency effect of the biodiesel in B20 is sufficiently diluted so that most problems encountered are minor and in general the problem goes away after the first few tanks of fuel.

- ***Lubricity of Biodiesel***

Biodiesel blends offer superior lubricating properties, which may reduce engine wear and extend the life of fuel injection systems. Tests with two leading lubricity measuring systems- the BOCLE machine and the HFRR machine-show biodiesel blends offer better lubricating properties then conventional petroleum diesel. Lubricity is especially important for rotary/distributor type fuel injection pumps in which parts are lubricated by the fuel itself and not by the engine oil. The result of a lubricity test done by Exxon with petro diesel and biodiesel blends is given in Table

Lubricity Results (HFRR Machine)

Table 3 *Effect of bio-diesel on lubricity*

Fuel Type	Scar	Friction	Film %
Conventional low sulfur diesel	492	0.24	32
Blend (80% petro diesel + 20% biodiesel)	193	0.13	93
Blend (70% petro diesel + 30% biodiesel)	206	0.13	93
Petro diesel + 1000 ppm lubricity additive	192	0.13	82
Petro diesel + 500 ppm lubricity additive	215	0.14	94
Petro diesel + 300 ppm lubricity additive	188	0.13	93

Source: Exxon & Interchem Environmental Inc.

6. IMPORTANT PROPERTIES CONSIDERED FOR BLENDING

A general understanding of the various properties of bio-diesel is essential to study their Implication in engine use, storage, handling and safety.

- ***Density***

  Bio-diesel is slightly heavier than conventional diesel fuel (s.g= 0.88 compared to s.g. = 0.84 for diesel). This allows use of splash blending by adding bio-diesel on top of diesel fuel for making bio-diesel blends.

  Bio-diesel should always add at the top. If bio-diesel is first put at the bottom and then diesel is added, it will not mix properly. Density is controlled according to ASTM specifications.

- ***Cetane Number***

  Cetane number of a diesel fuel is indicative of it's ignition characteristics. Higher the cetane number better is its ignition properties. Cetane number affects a number of engine performance parameters like combustion, stability, drive ability, white smoke, noise and emissions of carbon monoxide and hydrocarbons. Bio-diesel has higher cetane number than conventional diesel fuel. This results in higher combustion efficiency and smoother combustion. Cetane index commonly used to indicate the ignition characteristics of diesel fuels does not give correct result for bio-diesel. Hence cetane index is not specified and a cetane number test is important. Even for a bio-diesel blend, cetane index is not indicated.

- ***Viscosity***

  In addition of lubrication of fuel injection system of fuel injection system components, fuel viscosity controls the characteristics of the injection from the diesel injector (droplet size, spray characteristics etc.). The viscosity of methyl esters can go to very high level and hence it is important to control it within an acceptable limit to avoid negative impact on fuel injection system performance. Therefore, the viscosity specifications proposed are the same as for diesel fuel.

- ***Distillation Characteristics***

The distillation characteristics of bio-diesel are quite different from that of bio-diesel. Bio-diesel does not contain any highly volatile components; the fuel evaporates only at higher temperature. This is the reason that sometime sump lubrication oil dilution observed in many tests. The methyl esters present in bio-diesel generally have molecular chains of 16 to 18 carbons which have close boiling points. In other words, rather than showing the distillation characteristics, bio-diesel exhibits a boiling point. Boiling point of bio-diesel generally ranges between 330 to 357^{O}C. The limit of 360^{O}C is specified mainly to ensure that boiling point components are not present in bio-diesel as adulterants or contaminants.

- ***Flash Point***

Flash point of a fuel is defined as the temperature at which it will ignite when exposed to flame or spark. The flash point of bio-diesel is higher than the petroleum based diesel. Flash point of bio-diesel blends is dependent on the flash point of the base diesel. The flash point of bio-diesel blend depends upon the flash point of the base diesel fuel used and increase with increase in % of bio-diesel blends. Thus it's blends are safer than conventional diesel. The flash point is around 160^{O}C but it can reduce drastically if the alcohol used in manufacture of bio-diesel is not properly. The residual alcohol in bio-diesel reduces it's flash point drastically and is harmful to fuel pump, seals, elastomers, etc. It also reduces the combustion quality.

A minimum flash point for bio-diesel is specified more from the point of view of restricting the alcohol content rather than fire hazard. A minimum flash point of 100^{0}C is specified to ensure that excess alcohol used for esterification is removed. Another point of consideration is that the test method used to find out the flash point – ASTM D93, gives high scatter in results at the flash point near 100^{0}C. Due to this reason, the ASTM D6751 standard issued in Feb, 2002, calls for flash point of min 130^{0}C though the min value is 100^{0}C .

- ***Cold Filter Plugging Point***

  At low temperature, fuel may thicken and not flow properly affecting the performance of the fuel lines, fuel pumps and injectors. Cold filter plugging point of bio-diesel reflects it's cold weather performance. It defines the fuel limit of filterability. CFPP has better correlation than cold point for diesel fuel. Bio-diesel thicken at low temperature so need cold flow improver additives to have acceptable CFPP

- ***Pour Point***

  Normally either pour point or CFPP is defined. French and Italian bio-diesel specifications specify pour point whereas others specify CFPP. Since CFPP reflects more accurately the cold weather conditions operation of fuel, it is proposed not to specify pour point for bio-diesel. Pour point is defined as the lowest temp.at which oil ceases to flow. It is an important consideration to be taken care off in cold weather regions, where if pour point is not maintained then plugging of flow lines & pumps may occur due to ceasing of oil to flow. Pour point depressants commonly used for diesel may not work for bio-diesel

- ***Cloud Point***

  Cloud point is the temperature at which a cloud or haze of crystals appear in the fuel under test conditions and thus becomes important for low temperature operations. Bio-diesel generally has higher cloud point than conventional diesel. Cloud point is not specified but ASTM D6571 calls for reporting of the cloud point to alert the user of possible problem under cold climatic conditions.

- ***Aromatics***

  Bio-diesel does not contain any aromatics therefore not at all carcinogenic. So aromatics limits are not specified. It may be noted that conventional aromatics determination tests used for petroleum fuel does not give correct results for bio-diesel. Hence, aromatics in a bio-diesel blend can be determined only by testing the base diesel fuel before blending.

- ***Stability***

  Bio-diesel ages more quickly than fossil fuel due to the chemical structure of fatty acids and methyl esters present in bio-diesel. Typically there are upto 14 types of fatty acid & methyl esters in the bio-diesel.

  The individual proportion of presence of these esters in the fuel affects the final properties of bio-diesel. Saturated fatty acid methyl esters increase the cloud point, cetane number and improve the stability whereas poly-saturates reduce the cloud point, cetane number & stability.

6.1 STABILITY CRITERIA:

1. Oxidation Stability
2. Storage Stability
3. Thermal Stability

- ***Oxidation Stability***

Poor oxidation stability can cause fuel thickening, formation of gums and sediments which in turn can cause filter clogging and injector fouling. Iodine number indicates the tendency of a fuel to be unstable as it measure the presence of C=C bonds that are prone to oxidation. Generally, instability increase by factor of 1 for every C=C bond on the fatty acid chain. Thus C18 = 3 are three time more unstable than C18=O fatty acids. Oxidation stability of bio-diesel varies greatly depending upon the feedstock used. In one study of 22 bio-diesel samples taken from 7 European production sites, the induction period was found to vary from 1 to 10 hours.

- ***Thermal Stability***

Current knowledge in this area is inadequate but research is going on to study the thermal stability of oil which is important to analyze the affect of high temperature on given sample.

- ***Storage Stability***

Very little data is available on the long term storage stability of bio-diesel. Effect of presence of water, sediments and additives on storage stability need to be investigated. Based on the data available so far it is recommended that bio-diesel and it's blend should not be stored in a storage tank or vehicle tank for more than 6 months. Depending upon the storage temperature and other conditions use of appropriate antioxidants, e.g.Tenox 21, t-butyl hydroquinone, etc.is suggested. The antioxidants must be properly mixed with the fuel for good effectiveness. To avoid growth of algae, water contamination need to be minimized and if necessary some biocide to be used.

Currently not all of the bio-diesel standards issued, mention oxidation stability, iodine number, viscosity and Neutralization number indirectly assesses it. Higher value is indicative of poor oxidation stability. Iodine number test does not pick up the stability additives if used. There is need to develop tests methods for oxidation and storage stability of bio-diesel. ASTM D2274 is a good candidate test method.

- ***Iodine Number and Poly unsaturated Methyl Ester***

In diesel engines, methyl esters have been known to cause engine oil dilution by the fuel. A high content of unsaturated fatty acid in the ester indicated by iodine number increases the danger of polymerization in the engine oil. Oil dilution decreases oil viscosity. Sudden increase in oil viscosity as encountered in several engine tests is attributed to oxidation and polymerization of unsaturated fuel parts entering into oil through dilution.

In saturated fatty acids all the carbon is bound to two hydrogen atoms by hydrogen atoms by double bond. More the double bond, the lower is the cloud point of oil. The tendency of the fuel to be unstable can be predicted by bromine number.

Different bio-diesel has different stability performance. When iodine is introduced in the oil, the iodine attaches itself over the double bond to form single bond. Thus iodine number refers to the amount of iodine required to convert unsaturated oil into saturated oil. It does not refer to amount of iodine in oil but to the presence of amount of fatty acids in the oil. ASTM D1520 method indicates the oxidation stability. Iodine number is well suited to indicate the influence of methyl ester on engine. One value of iodine number may be obtained from different grades of unsaturated fatty acid. So an additional parameter, the linolenic acid content is specified and limited to 15% in Austrian Standard ON.

- ***Free and Total Glycerol***

The degree of conversion completeness of the vegetable oil is indicated by the amount of free and total glycerol present in the bio-diesel. If the actual number is higher than the specified values, engine fouling filter clogging can occur. Manufacturing process controls are necessary to ensure low free and total glycerin. Free glycerol if present can build up at the bottom of the storage and vehicle fuel tanks.

- ***Mono-, Di-, and Triglycerides***

Most of the bio-diesel standards, except Austrian and ASTM, specify a maximum limit of 0.08 for monoglyceride. Draft EU standards calls for same limit. Di- and triglycerides are also controlled in most of the standards. High level of these glycerides can cause injector fouling, filter clogging etc.

- ***Ester Content***

France (96.5%), Italy (98), and Sweden (98) specify minimum ester content whereas Austrian and ASTM standards do not specify any limit.

- ***Alkaline Matter***

Sodium and potassium: alkaline matter is controlled mainly to ensure that the catalysts used in the esterification process are properly removed.

- ***Total Contamination***

Left over impurities at the time of manufacture such as fire proteins may form solid impurities and particles and clog the fuel lines. Filtration and washing treatments at the manufacturing level need to be robust.

- ***Sulfur Content***

Bio-diesel generally contains less than 15ppm sulfur. ASTM D5453 test is a suitable test for such low level sulfur. ASTM D2622 used for sulfur determination of diesel fuels gives falsely results when used for bio-diesel. More work need to be done to assess suitability of ASTM D2622 application to B20 bio-diesel blend. The increase in oxygen content of the fuel affects precision of this test method.

- ***Lubricity***

Wear due to excessive friction resulting in shortened life of diesel fuel pumps and injectors, has some times ascribed to lack of lubricity in the fuel. Numerous premature breakdown and in some case, catastrophic failures have occurred failures. All diesel fuel injection equipment of the engine have reliance on diesel fuels for it's lubrication especially the rotary and common rail type systems. The lubrication of the pump is not provided by viscosity alone but also by lubricity property of the fuel.

Even when the viscosity of the fuel is correct, several parts of the pump can wear out due to lack of lubricity. The lubricity of the fuel depends upon the crude source, refining process to reduce sulfur content and the type of additives used. BOCLE and HFFR are commonly used for evaluating the lubricity of the fuel. BOCLE is normally used for finding the lubricity without using additives.

HFRR method has been adopted by fuel injection manufacture for lubricity evaluation and they recommend a limit of 460 microns wear scan diameter. Lower the WSD better the lubricity. In case of BOCLE method, a higher value is better. Even with 2% bio-diesel blend mixed in diesel fuel, the WSD value comes down to around 325 microns and is sufficient to meet the lubricity requirements of the fuel injection pump. B100 performs still better, with a WSD value of about 314 microns. With further reduction of sulfur content for diesel for Euro II and Euro III, the lubricity loss due to sulfur removal can be easily compensated by the addition of appropriate amount of the bio-diesel in diesel. 2% addition into any conventional diesel fuel is sufficient to address the lubricity problem. It also eliminates the inherent variability associated with use of the other additives to make fuel fully lubricious.
Secondly, the bio-diesel is a fuel component itself, any addition of it does cause any adverse consequences. When bio-diesel is used as blended, its lubricity characteristics has to meet the specification for the base fuel. Lubricity improves somewhat with the chain length and the presence of double bonds. An order of oxygenated moieties enhancing lubricity (COOH > CHO > OH > $COOCH_3$ > C=O > C-O-C) was obtained from studying various oxygenated C_{10} compounds. Results on neat C_3 compounds with OH, NH_2, and SH groups show that oxygen enhances lubricity more than nitrogen and sulfur. Adding commercial biodiesel improves lubricity of low-sulfur petrodiesel more than neat fatty esters, indicating that other biodiesel components cause lubricity enhancement at low biodiesel blend levels. Adding glycerol to a neat ester and then adding this mixture at low blend levels to low-lubricity petrodiesel did not improve petrodiesel lubricity. However, adding polar compounds such as free fatty acids or monoacylglycerols improves the lubricity of low-level blends of esters in low-lubricity petrodiesel. Thus, some species (free fatty acids, monoacylglycerols) considered contaminants resulting from biodiesel production are responsible for the lubricity of low-level blends of Biodiesel in (ultra-)low-sulfur petrodiesel. Commercial biodiesel is required at a level of 1%-2% in low-lubricity petrodiesel, which exceeds the typical additive level, to attain the lubricity-imparting additive level of biodiesel contaminants in petrodiesel.

- ***Sulfated Ash***

Sulfated ash is controlled to ensure that all the catalyst used in transesterification process is removed. Presence of ash can cause filters plugging and injector deposits. Soluble metallic soap, un-removed catalyst and other solids are possible sources of sulfated ash.

- ***Acid Number & Neutralization Number***

Acid number or neutralization number is specified to ensure proper aging properties of the fuel or good manufacturing process. Acid number reflects the presence of free fatty acids or acids used in manufacturing of bio-diesel. It also reflects the degradation of bio-diesel due to thermal effects. For e.g. during the injection process several times more fuel returns from the injector than the injected into the combustion chamber of the engine. The temp.of this return fuel can sometimes be as high as 90°C and thus accelerate the degradation of bio-diesel. The resultant high acid number can cause damage to injector and also result in deposits in fuel system and affect life of life of pump and filters. Sodium hydro peroxide and sulfuric acid are highly corrosive and can cause serious injuries.

- ***Water Content***

Bio-diesel blends are susceptible to growing microbes when water is present in fuel. The Solvency properties of bio-diesel can cause microbial slime to detach and clog fuel filter

- ***Phosphorous Content***

Phosphorous can come as impurity and affect oxidation catalyst and cause injector fouling. As more and more OEM's are going to use catalytic converters in diesel engines, it is necessary to keep the level low. Usually bio-diesel has < 10 ppm phosphorous content. The specification to minimum phosphorous is intended to ensure compatibility with catalytic convectors irrespective of the source of bio-diesel.

- ***Methanol & Alcohol Content***

High levels of free alcohol in bio-diesel cause deterioration of natural rubber seals and gaskets. Damage to fuel pumps and injectors which have natural rubber diaphragms has been very common type of failure. Methanol is membrane –permeable and can cause nerve damage. Therefore control of alcohol is important

- ***Conradson Carbon Residue(CCR)***

Carbon residue of the fuel is indicative of carbon depositing tendencies of the fuel. CCR for bio-diesel is more important than that in diesel fuel because it shows a high correlation with presence of free fatty acids, glycerides, soaps, polymers, higher unsaturated fatty acids, inorganic impurities and even on the additives used for pour point depression.

Two methods are used to measure carbon residue:

- 100% residual
- 10% residual

6.2 GUIDANCE ON BLENDS ABOVE B20

Background:

Due to the renewable, domestic, and clean burning attributes of biodiesel there is interest by some individual users and fleets that use diesel fuel to utilize blends of biodiesel above 20 percent by volume (B20), up to and including pure biodiesel (B100). For a variety of reasons, some consumers prefer to use blends higher than B20, up to B100.

Current Situation: The American Society of Testing and Materials (ASTM) have approved a standard for pure biodiesel when used in blends at 20% by volume (B20) or lower: ASTM D6751Standard Specification for Biodiesel Fuel (B100) Blend Stock for Distillate Fuels. This is a consensus standard, developed in cooperation with vehicle, engine, and fuel injection equipment companies; petrodiesel and biodiesel producers and distributors; and state and federal regulators and third parties through the ASTM standard development process.

Due to concerns of the US engine and fuel injection equipment manufacturers regarding influence of biodiesel fuels on cold flow properties, material compatibility, and maintenance intervals, fuel stability, biological growth, energy content, and emissions influence with higher concentration blends, ASTM standard has only been approved for blends of biodiesel of B20 and lower. D6751 states the following:

"A considerable amount of experience exists in the U.S. with a 20 % blend of biodiesel, primarily produced from soybean oil, with 80 % diesel fuel (B20). Experience with biodiesel produced from animal fat and other oils is similar. Although biodiesel (B100) can be used, blends of over 20 % biodiesel with diesel fuel (B20) should be evaluated on a case by case basis until further experience is available."

B20 has been used in millions of road miles, and has proven to be a practical fuel that can be used in any diesel engine with few precautions or changes compared to the use of petrodiesel. The National Biodiesel Board and the diesel engine, fuel injection, and vehicle companies have formed the B20 Fleet Evaluation Team (B20 FET) to develop an informed, fact-based position on the use of B20.

Based on the available field experience the B20 FET has developed a set of recommendations for users of B20, "Technical Recommendations for B20 Fleet Use Based on Existing Data," which describes specific advice for users of B20. Most auto, engine, and fuel injection equipment companies doing business in the US strongly discourage the use of blends over B20 due to the impacts of higher blends on equipment and fuel systems which have not been thoroughly tested with these high blends, and the higher likelihood of known problems or issues with high blends that are not present or are of lesser importance when using B20 or lower blends. Blends higher than B20 can not be considered a direct replacement for petroleum diesel fuel and may require significant additional precautions, handling, and maintenance considerations as well as potential fuel system and engine modification. Problems specifically caused by any fuel, including biodiesel or biodiesel blends, are not considered manufacturing defects and generally will not be covered by any engine or fuel injection equipment manufacturer's warranty.

6.3 SUMMARY OF THE KNOWN CONCERNS AND ISSUES WITH BLENDS OVER B20:

1. The ASTM specification for pure Biodiesel was approved only for blends up to B20, not for higher blends. There may need to be additional specifications, or different values of existing specifications, that is necessary if blends higher than B20 are used to assure satisfactory long term engine performance.

2. *Cold flow properties:* When Biodiesel made from soybean oil is blended at 2% by volume with average No. 2 petrodiesel; the cold flow properties of the finished B2 blend are similar to those of the petrodiesel alone. With B20, the cold flow properties of the blend can be 3-10degrees F higher than average No. 2. There can be more Biodiesel impact when usingbiodiesel from different feed stocks or with lower gelling diesel fuel. In some cases, the increased gel temperature of B20 is within the variability seen with petrodiesel from

supplier to supplier and no further precautions are needed in cold weather but it is always good to measure the cold flow properties of a Biodiesel blend to insure it will perform adequately for the geography and climate the fuel will be used in.

As Biodiesel components greater than B20are added, the cold flow properties become more like the B100. B100 made from soybean oil typically starts to gel around 32 degrees Fahrenheit or higher, with high biodiesel blends being more similar to B100 than the petrodiesel. Great care must be taken to be sure the blend will not gel and clog fuel filters in cold conditions (climate or altitude). This is especially a concern for someone who may be using a high blend of biodiesel in the warm conditions and precautions are not taken before colder conditions are encountered.

3. *Materials compatibility:* B100 will soften and degrade certain types of elastomers and rubber compounds over time. Using high percent blends can impact fuel system components (primarily fuel hoses and fuel pump seals) that contain compounds incompatible with B100.Manufacturers recommend that natural or butyl rubbers not be allowed to come in contact with pure Biodiesel or Biodiesel blends higher than B20. Over the past 15 years of use, blends of B20 or lower have not exhibited problematic elastomers degradation and no changes are recommended. If a fuel system does contain these materials and users wish to fuel with blends over B20, replacement with compatible elastomers is needed. In many instances, especially with older equipment, the exact composition of elastomers can not be obtained and it is recommended they be replaced if using blends over B20.

4. *Cleaning effect of B100 and high blends:* In some cases the use of petrodiesel, leaves a deposit in the bottom of fuel lines, tanks, and delivery systems over years of time. Biodiesel acts as a cleaning agent and can dissolve these sediments and result in fuel filter becoming clogged and the need to change filters more frequently until the whole system has been cleaned of the sediments left by the petrodiesel. This phenomenon has not been observed with B5 and lower blends, and occurs when first using B20 in about 2% of the cases, requiring 2 or 3 additional filter changes when first using the fuel. The cleaning effect of B20 and lower blends appears to increase the need for filter changes only with systems that have significant amounts of sediment. Although experience is limited, with higher blend levels than B20 if any sediment is present it is brought up quickly and clogs filters immediately. The engine may be starved for fuel and stall. If the filter ruptures, this can cause a significant

amount of debris and sediment to move into fuel lines, pumps and injectors resulting in an expensive repair that is not covered by warranty as the problem is not caused by an equipment defect but a ruptured fuel filter.

5. *Fuel stability:* Industry experts recommend that Biodiesel be used within six months of manufacture to ensure that the quality of the fuel is maintained. Fuel degradation pathways for Biodiesel are more likely with higher concentration blends due the higher presence of the Biodiesel, so stability concerns and issues (fuel system deposits, clogged filters, etc.) are likely to be higher and may occur faster as the blend level is increased. There have been very few field reports of stability related problems with B20 and lower blends in the US when the Biodiesel meets D6751 prior to blending and the fuel is used within six months.

6. *Energy Content:* B100 on average has 7-9% lower energy content (BTU per gallon) than average diesel fuel. Conventional diesel engines convert the energy in Biodiesel into work with the same efficiency as petrodiesel, so impacts on fuel economy, peak horsepower and peak torque are all directly rel\at\\ed to the energy content of Biodiesel. The energy content of conventional diesel fuel can vary over 15% from supplier to supplier or from summer to winter. On average, B20 will decrease BTU content 1-2% vs. petrodiesel, and BTU changes with B2 are imperceptible. While BTU changes of 1-2% can be picked up in lab tests for horsepower, torque, and fuel economy normal variability in the field make it very difficult to detect any impact with B20 and lower blends for these parameters. Some fleets have even shown fuel economy increases with B20, although this is unexpected based on the BTU content. With blends higher than B20, the impact on power or fuel economy may be great enough it will become noticeable by the user and the penalty in fuel economy may offset any fuel cost reduction.

7. *Engine Oil Dilution:* Blends higher than B20 may cause a larger amount of unburned fuel to make its way past the piston rings and into the oil pan. This is due to the slightly higher viscosity and the slightly higher density of Biodiesel vs. petrodiesel. High levels of Biodiesel present in the engine oil may polymerize over time and cause serious engine oil sludge problems. Engine oil change intervals may need to be shortened significantly if using high blends of Biodiesel. The viscosity and density of B20 and lower blends are very similar to that of the pure petrodiesel, and this phenomenon has not been problematic with blends of B20 or lower so no changes in engine oil intervals are needed with B20 or lower.

7. ENVIRONMENT & HEALTH EFFECTS OF BIO DIESEL

The use of bio-diesel in a conventional diesel engine results in substantial reduction in unburned hydrocarbons, carbon monoxide and particulate matter. However, emissions of nitrogen dioxides are either slightly reduced or slightly increased depending upon the duty cycle or testing methods. The use of bio-diesel decreases the solid fraction of particulate matter and eliminates sulfur fractions, while soluble or hydrogen fraction stays the same or increased. Therefore bio-diesel works well with new technologies such as oxidation catalyst.

As per U.S. EPA bio-diesel has been comprehensively evaluated in terms of emissions and potential health effects under the Clean Air Act Section. These programs include stringent emission testing protocols required by EPA for the certification of fuels in U.S. The data gathered through these tests include thorough inventory of the environmental and human health effects attributes that current technology will allow.

Table 4 Emissions results:

Emissions	B100	B20
Total unburned hydrocarbons	-93%	-30%
Carbon monoxide	-50%	-20%
Particulate matter	-30%	-22%
NOx	+13%	+2%
Sulphates	-100%	-22%

From the table we come to know that bio-diesel gives a distinct emission benefit almost for regulated and non regulated pollutants when compared to conventional diesel. The increase in NOx content with increase in bio-diesel can be neutralized by efficient use of NOx control technologies which fits better with bio-diesel with almost nil sulfur.

It may also be noted that emission of NOx varies with different family of feedstock for bio-diesel. Moreover, the problem of NOx can be solved by tackling by retarding the fuel injection pump.

7.1 COMPARISON OF PARTICULATE COMPOSITION

Diesel vs. Biodiesel

When the engine is operated on RSME (Rape seed methyl ester), soot emissions are dramatically reduced but the proportion of emission composed of fuel derived hydrocarbons, condensed on the soot, is much higher. This implies that the RSME may not burn to complete combustion as readily as diesel fuel. It should however be noted that gaseous HC emissions were reduced with RSME in the test. Since concern over particulate matter arises partly from potential harmful effects of the soluble fraction, it might be suspected that emissions from RSME would be more harmful. However data shows no tendency for the mutagenicity of exhaust gas to increase for a vehicle running on 20% RSME and 80% diesel blends

Table 5 Comparison of particulate emission between diesel and organic fuel

Test	Fuel	Total PM (g/mile)	Insoluble (g/mile)	Fuel soluble (g/mile)	Lube soluble (g/mile)	Soluble inorganic (%)
Cold FTP	Diesel	0.311	0.259	0.021	0.0301	17
	RSME	0.0258	0.118	0.104	0.0306	54

7.2 TOXICS & SAFETY ISSUES

Bio-diesel is non toxic. There is no tendency of mutagenicity of exhaust gases to increase for vehicle running on bio-diesel. Bio-diesel is considered as fairly a safe fuel. This product bio-diesel is non toxic under EPA ratings. The safety concerns are same as for diesel.

7.3 GREEN HOUSE EFFECT

Using vegetable oils or animal fats as fuel for motor vehicles is in effect running them on solar energy. All bio-fuels including ethanol are derived from conversion of sunlight to energy that takes place in the green leaves of plants. Plants take up carbon dioxide from the atmosphere, burning plant or animals products in an engine releases the CO_2 uptake back into the atmosphere to be taken up by other plants. The CO_2 is recycled, atmospheric CO_2 levels remain constant. Thus biofuels do not increase the green house effect. Infact bio-diesel reduces the carbon dioxide level in the atmosphere.

7.4 IMPORTANT CONSIDERATIONS DURING USAGE OF BLENDS

- Ensure the biodiesel meets the ASTM specification for pure biodiesel (ASTM D 6751) before blending with petrodiesel.The specification for biodiesel is designed to ensure that consumers will not experience Operational problems from the fuel's use. Make sure that biodiesel meets this specification and that the fuel supplier will warrant this fact. Quality fuel will provide the consumer with improved air quality and enhanced operability. Purchase fuel only from a reputable source

- Check fuel filters on the vehicles and in the delivery system frequently• upon initial biodiesel use, and change them as necessary.

  Biodiesel and biodiesel blends have excellent solvent properties. In some cases the use of petrodiesel, especially petrodiesel, leaves a deposit in the bottom of fuel lines, tanks, and delivery systems over time. The use of biodiesel can dissolve this sediment and result in the need to change filters more frequently when first using biodiesel until the whole system has been cleaned of the deposits left by the petrodiesel.

- Be aware of biodiesel's cold weather properties

- A 20 percent blend of biodiesel with petrodiesel raises the cold weather properties at least 3° F (pour point, cloud point, cold filter plugging point). In most cases, this has not been an issue.

- Wipe painted surfaces immediately when using biodiesel. Since biodiesel is a good solvent, it can, if left on a painted surface long enough, dissolve certain types of paints. Therefore, it is recommended to wipe any biodiesel or biodiesel blend spills from painted surfaces immediately.

- Store biodiesel or biodiesel blend soaked rags in a safety can to avoid spontaneous combustion. Biodiesel soaked rags should be stored in a safety can or dried individually to avoid the potential for spontaneous combustion. Biodiesel is made from vegetable oils or animal fats that can oxidize and degrade over time. This oxidizing process can produce heat. In some environments a pile of oil soaked rags can develop enough heat to result in a spontaneous fire.

- Use stored biodiesel within six months.

7.5 GLOBAL ASPECT

Table 5 ***Comparison of feasibility of Bio-diesel as an alternative source by European & Asian Countries***

European and American Countries	**Asian and Developing Countries**
• These countries follow bio-diesel route. This is because they are using soyabean or rapeseed for manufacture of bio-diesel. These oils cannot be blended directly.	In India, we follow Jatropha and Karanj route. All other edible oil cannot be used as fuel as these are expensive compared to Jatropha. Climatic conditions are favorable for growth of Jatropha & Karanj.
• Viscosities of these oil are high and these increase the viscosity of mix by significant level. The problems of cloud point and pour point are severe in winters.	Viscosity of Jatropha is less and does not increase the viscosity of mix significantly. Cloud point & pour point are not a problem
• Production of bio-diesel requires methanol to an extent of 15% by volume. Methanol production base in India is small and hence need to be imported if used for bio-diesel. If it is manufactured locally it will be manufactured from fossil fuels. The by-product glycerin has now flooded the market and hence fetches low value. Manufactured process produces it s a byproduct which needs to be disposed off.	By product glycerin of bio-diesel manufacture from Jatropha and Karanj oil may have some toxic component and will not be suitable for human consumption and will have to be used as fuel. The only is oil cake which can be used as bio-fertilizer.
• In these countries, farming is mechanized and low in employment generation. Hence only those crops which can be mechanized are grown	In India, Jatropha & Karanj farming is manual. This will generate employment.
• Most of the production and storage of oil seeds will be largely centralized operations. These oil do not decompose and can be crushed in oil fields and oil can be transported to bio-diesel plants	Jatropha & Karanj plantation are scattered in rural areas. Carrying bio-diesel seeds to plant is a problem and seeds must be crushed in processing unit
• Seed production not a seasonal job as rainy throughout the year	These seeds available only during fruiting season, therefore large stock to be maintained

8. PROJECT DESCRIPTION

8.1 STANDARD CHART FOR 100% BIO-DIESEL AND CONVENTIONAL DIESEL

This is a chart depicting the ASTM standards numerical values for 100%bio-diesel (B100) and ASTM standards for conventional diesel. These values are standard based on which my experimental work would be compared. These values have been experimentally derived at standard international laboratory at standard temperature (25°C)

The experimental work of my project where I would take different blends of bio-diesel with petrodiesel has been carried at University of Petroleum & Energy Studies, Dehradun. This experimental value obtained has then been analyzed and interpretated using graphical methods and compared on the basis of standard ASTM values which are given below. Hence, these ASTM values would help us know the extent of the blending and therefore obtain the best blend at optimum temperature with best results. Further the selected blend are examined in a C.I. engine to correlate the above results and evaluate the performance of engine on the basis of the various properties like flash point, HC emissions, carbon deposits, engine efficiency and fuel consumption of different blends at particular load.

Table 6: ***ASTM standard Chart***

SNo.	Property	ASTM method for Biodiesel	ASTM method for diesel	Limits	Units
1	Flash Point	D93	D93	130 min.	Degree C
2	Water & Sediment	D2709	D2709	0.050 max.	% vol.
3	Kinematic Viscosity 40 C	D445	D445	1.9-6.0	mm^2/sec.
4	Sulfated Ash	D874		0.020 max.	% mass
5	Sulfur	D5453	D5453	0.05 max.	% mass
6	Copper Strip Corrosion	D130	D130	No. 3 max.	
7	Cetane	D613	D4737	47 min.	
8	Cloud Point	D2500		Report	Degree C
9	Acid Number	D664		0.80 max.	Mg K/gm
10	Carbon Residue 100% sample	D4530**	D4530	0.050 max.	% mass
11	Free Glycerin	D6584		0.020 max.	% mass
12	Total Glycerin	D6584		0.240 max.	% mass
13	Phosphorus Content	D4951		0.001 max.	% mass
14	Distillation Temp, Atmospheric Equivalent Temperature, 90% Recovered	D1160	D86	360 max.	Degree C

9. CASE STUDY

9.1 TRIAL ON SHATABDI EXPRESS

On 31st December 2002, a field trial was done on Delhi-Amritsar Shatabdi express using B5 biodiesel blend as fuel. It was noted that no problem was experienced in locomotive haulage, and acceleration while running the train. . The specific fuel consumption was also found comparable to the petro diesel.

9.2 INTENSIVE PERFORMANCE EVALUATION OF BIO DIESEL

- ***Detailed Testing & Evaluation Of Bio Diesel***

Detailed testing and evaluation of biodiesel has been conducted during April-May 2004 at RDSO on the 3100hp Diesel Engine Test Bed. Five KL of pure bio diesel (B100) was arranged through Indian Oil Corporation. The objective of the detailed testing was to carry out the performance evaluation as well as some optimization of 10%, 20%, 50% and 100% blends of bio diesel on the 3100 hp engine bed.

- ***Engine Configuration***

The engine configuration used for the testing was a 16 cylinder, V type, water cooled, supercharged engine. The configuration is as follows:

Table 7 *Engine Configuration*

Engine	16 cylinder
Rated HP	3100 hp
Engine RPM	400-1050
Manifold	Streamlined 3 entry
Camshaft	140 degrees overlap
Fuel injection pump	17mm plunger dia, 157 degree nozzle spray angle having 0.35mm dia holes

- *Test Procedure*

Necessary instrumentation was provided for measuring the exhaust gas temperature, engine oil temperature, fuel consumption and various other engine parameters. The performance of biodiesel was evaluated in terms of fuel consumption, exhaust emissions, and power. Fuel consumption and power was measured for each of the power notches. The engine was run for a sufficiently long duration to ensure thermal stabilization before conducing the specific fuel consumption test.

- *Quality Assurance*

To test the properties of bio diesel, which was of imported origin; the sample was sent to the IOC-R&D facility in Faridabad. The test results obtained for the various properties by carrying out the testing with the ASTM methods is given above in the project description.

9.3 TEST RESULT ANALYSIS

Results obtained in this study with petro diesel, neat biodiesel and different biodiesel blends are deliberated upon with respect to engine performance and emissions. The testing was carried out in the 16-cylinder test bed. A test matrix was designed with petro diesel and biodiesel in various volume proportions. Initially, the base line data was generated by testing with petro diesel and carrying out the measurement of all the requisite parameters. Subsequently, bio diesel blends of B10, B20, B50 and pure biodiesel B100 were used as fuel and the various parameters of the engine performance were noted.

Major Engine Performance Parameters:

As can be seen from the table above, the engine maintained full horse power with all the bio diesel blends including pure bio diesel i.e. B100.

	Regular diesel	**Bio diesel blends with regular diesel**			
		B10	**B20**	**B50**	**B100**
Horse power(HP)	3140	3116	3156	3153	3128
SFC,(gms/bhp-hr)	153.68	155.37	156.11	162.15	173.6
Exhaust gas temp.(^{0}C)	517	511	-	483	486
Firing pressure (psi)	1648	1650	1644	1631	1655

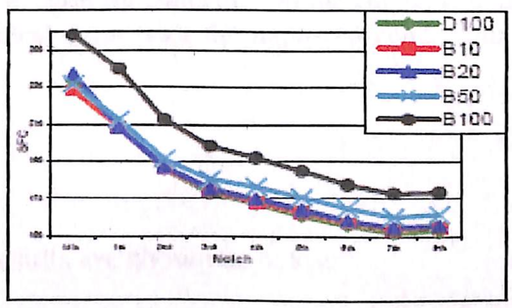
The specific fuel consumption of the engine increased from 153.68 g/bhp-hr to 173.6 g/bhp-hr, an increase of 12.5%. The exhaust gas temperature in general showed a down ward trend. The firing pressure did not change significantly.

- **Specific Fuel Consumption**

In general the specific fuel consumption increases with the increase in bio diesel percentage as has been shown in the summary table before. However a more detailed analysis of the data is also recorded and deliberated upon to observe the effect of engine rpm on the specific fuel consumption.
The observations of the specific fuel consumption (gms/hphour) for all the power notches and various blends are tabulated below:

Power Notch	Regular diesel	Bio diesel blends with regular diesel			
		B10	B20	B50	B100
8th	153.68	155.37	156.11	162.15	174.00
7th	152.43	154.04	155.27	160.94	173.25
6th	156.34	157.62	158.98	165.24	177.71
5th	161.62	163.33	164.79	171.37	185.20
4th	167.86	168.58	170.31	176.93	192.37
3rd	173.64	174.71	176.14	181.18	198.76
2nd	186.29	186.79	187.60	191.73	213.00
1st	209.89	209.25	208.76	212.88	240.23
Idle	233.94	229.08	237.46	232.29	258.54

It can be seen that in general, SFC increases for higher blends of bio diesel. This is logically explained by the fact that the bio diesel has a lower calorific value when compared to petro diesel.
However, at lower notches (Idle, 1st, 2nd), SFC for bio diesel blends is comparable and even better than petro diesel.



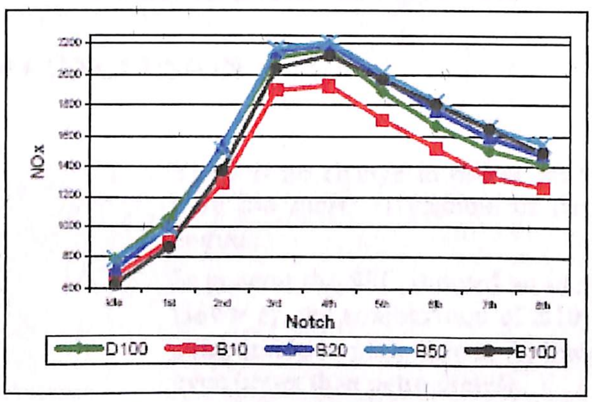
Graph1 - SFC vs Notches for various blends

- **Exhaust gas temperature**

- **NOx emission**

There is an increase in concentration of NOx with increase in bio-diesel blend

Notch	Regular diesel	Bio diesel blends with regular diesel			
		B10	B20	B50	B100
8th	1422	1266	1480	1553	1491
7th	1511	1337	1590	1658	1647
6th	1669	1522	1769	1826	1804
5th	1891	1711	1980	2015	1970
4th	2166	1931	2201	2215	2127
3rd	2133	1900	2148	2173	2043
2nd	1521	1295	1537	1511	1376
1st	1056	904	1007	1001	870
Idle	789	683	726	791	627

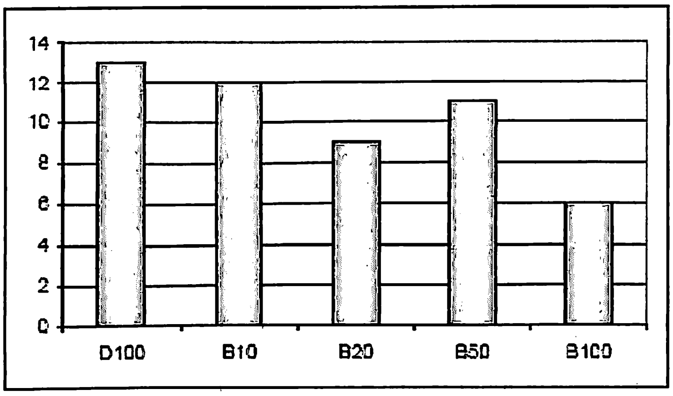


Graph3 - NOx versus Notches

It may be seen that the NOx emissions increased with the increase in notch or speed of the engine. The maximum NOx value was obtained for the 4th notch when the engine RPM was 650. For further increase in the notches upto 8th notch (RPM 1050), the NOx emissions tended to decrease. This may be due to the lower energy content associated with bio diesel fuel, which may result in lower peak temperature than the petro diesel.

Another important observation is the lower Nox values obtained for bio diesel blends at lower notches viz. idle, 1st,2nd and 3rd when compared to petro diesel. Normally an increase in NOx is expected and is mainly attributed to the oxygen content of bio diesel. At elevated temperature this oxygen reacts with Nitrogen and tended to form NOx. However the reduced Nox formation at lower notches is probably due to the reduced temperatures and pressures, which occur due to the improved combustion and which inhibit the combining of nitrogen and oxygen.

- **Hydrocarbon Emissions**



Graph4 - Hydro Carbon emissions in ppm

The hydrocarbon content in emission has shown an over all down ward trend. For B100, there is reduction of 54% in hydrocarbon emission as compared to petro diesel

- **Fuel Filter**

The fuel filters fitted on the engine test bed were instrumented by naustran pressure gauge before and after the filter. The differential pressure developed across the filter were carefully monitored and it was seen that there were no unusual increase in the differential pressure during the test.

9.4 CONCLUSION

1. There is no change in power for various blends of bio diesel. Even B-100 i.e. pure bio diesel is capable of developing full horsepower on the Alco DLW engine.
2. In general the SFC showed an increased trends with higher blends of bio diesel. However, the combination of B10 with the optimized injection timing was quite comparable to petro diesel. At lower notches (lower engine speeds) the SFC was even better than petro diesel).
3. The NOx emissions in general increase with higher blends of bio diesel. However, at lower notches (1^{st}, 2^{nd} & 3^{rd}), bio diesel blends showed lower NOx readings compared to petro diesel.
4. The hydrocarbon emission also revealed a decreasing trend with high blends of bio diesel with as much as 54% reduction with B-100 as compared to regular diesel.
5. The exhaust gas temperature showed the decreasing trend for increasing blends of bio diesel. This also resulted in lower booster air pressure. The exhaust gas temperature was further reduced on optimizing the injection timing.

Trial Scheme

- Lab testing
- Test bed testing scheme
- Objective is to measure the effect of 10%, 20%, 50%, & 100% on high speed diesel
- Parameters to be measured:
- Specific fuel consumption, exhaust gas temperature, firing pressure, RPM
- Methology :

Stage 1: A base line test data would be generated with regular petro diesel.

Stage 2: A 10% blend of biodiesel with petro diesel would be used on the engine and data as per the above mentioned parameters would be generated.
Stage 3: A 20% blend of biodiesel with petro diesel would be used on the engine and data as per the above mentioned parameters would be generated.
Stage 4: A 50% blend of biodiesel with petro diesel would be used on the engine and data as per the above mentioned parameters would be generated.
Stage 5: 100% Biodiesel would be used on the engine and data as per the above mentioned parameters would be generated.
Stage 6: Optimisation studies – by advancing the injection timing 1 degree at a time to ascertain impact on firing pressures and SFC.
Stage 7: The base line test would be repeated with regular petro diesel

- Duration of blending

Each blend is tested for 5 hours. The readings are taken at each notch.

- Blending procedure :

The blending of bio diesel shall be done in the overhead tanks of engine development directorate. For this purpose 2 tanks of 5 Kl have already been cleaned and kept in readiness. These shall first be filled with petro diesel. Then the required amount of bio diesel shall be pumped into the tanks to create the blend.
e.g. for creating a blend of 5% bio diesel, initially 2850 litres of petro diesel shall be pumped into the tank. Subsequently the 150 litres of bio diesel shall be pumped into the tank. This procedure is as per the norms and will make a homogenous blend of 5 % bio diesel in petro diesel.

FURTHER WORK

The case study and the live data revealed earlier shows that bio-diesel is an important additive as well as an important blending compound to be used in petro-diesel.

Many countries including India and other developing nations are started working on the positive aspects of using bio-diesel as an important blend even though some of the developed countries like Europe & United States are trying and working hard to prepare bio-diesel as a complete fuel itself due to various environmental regulations. It is important at such critical situation where the entire world is facing green house effect, to find an alternative solution to rising pollution and population.

A new strategy called " carbon credits" have come up where all the oil companies would be provided with some credits and it is the responsibility of the market and the retail sector to market such fuel which will minimize the pollutant level in the atmosphere so that they can earn credits for there company.

Bio-diesel therefore is a promising agent at the current scenario and India needs to develop more R&D centers to work on the type of blending agent that can be used without much affecting the structure of the engine. The best blends with optimum cost needed to be found out through rigorous experiments. The next portion of this project deals with the performance evaluation of various blends through experiment in the laboratory and studying the different properties of the fuel and there alteration with the addition of bio-diesel.

This is followed by working on one of the most suitable blend and their effect on the performance of a C.I. engine. The experiment is performed on four different blends namely, pure straight vegetable oil, SVO10, SVO50 & pure diesel. The comparison with different blends is shown along with the performance & emission table obtained on experimentation work.

10. EXPERIMENTAL WORK & PROCEDURE

10.1 PHYSIO-CHEMICAL PARAMETERS

- ***Density***

Density is obtained through Densitometer. The apparatus is first brought at zero mode and then calibrated. The calibration is as follows: Initially the weight of the empty bottle is measured, followed by which water is completely filled in the bottle and weighed again. This completes the calibration of the apparatus. Then the bottle is completely dried out so that no moisture remains in the walls of the bottle as well. Finally, the sample (fuel sample) is filled in the bottle and the density is measured. Similar procedure is carried out for different samples.

Formula used: $((w_3 - w_1) / (w_2 - w_1))*D_1 = D_2$

Where, w_3 is weight of the sample fuel

w_2 is the weight of bottle with water

w_1 is the weight of empty bottle

- ***Flash point***

Flash point is estimated through Pensky Martin apparatus. Flash point is defined as that temperature at which the vapors on the surface of the surface of fuel flashes or catches fire on introduction of external source of flame Pensky martin apparatus consist of brass cup which is 5cm in diameter and 5.5cm in depth. The level upto which oil has to be filled is marked at about 1cm below the top of the cup. The cover for the cup is provided with four openings of standard dimensions which is meant for thermometer and an inlet device for introducing flame. The shutter provided at the top is based on lever mechanism and when is turned on, flame and air are opened and flame exposure dips in the opening over the surface on the oil. The assembly is kept on a electric heater.

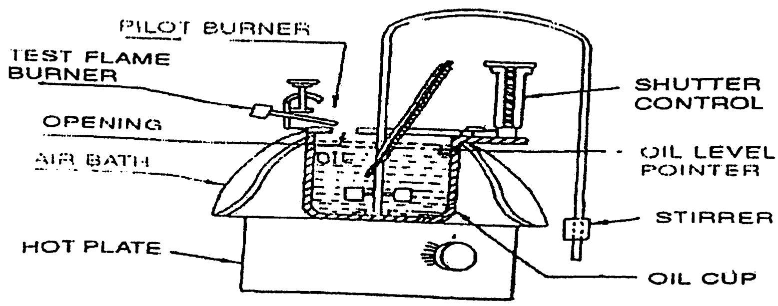


Fig4 Pensky Martin apparatus

Procedure:

1. Thoroughly clean and dry all parts
2. Support the tester on level
3. Fill the cup with sample to be tested wrt to mark
4. Flame exposure device is brought on top and thermometer is kept
5. Insert the thermometer and light the flame with matchstick
6. The apparatus is heated so that oil temperature increases
7. Test flame is applied at every degree rise in temp
8. Record the flash point at the time when test flame applied causes a distinct flash in the interior of cup. Oil sample is further heated and application of flame is brought again.

- **Viscosity Measurement**

This is based on the principle of laminar flow through capillary tube of standard dimensions under falling head. It consists of a vertical cylinder with orifice at centre. The cylinder is surrounded by a water bath which can maintain the temp of liquid to be tested at required temperature. The water bath is heated with heater and cylinder which is filled upto certain height with liquid whose viscosity is to be determined is heated by water bath to desired temperature. Then orifice is opened to pass standard quantity and the time is noted. With this the variation of viscosity with temp is noted.

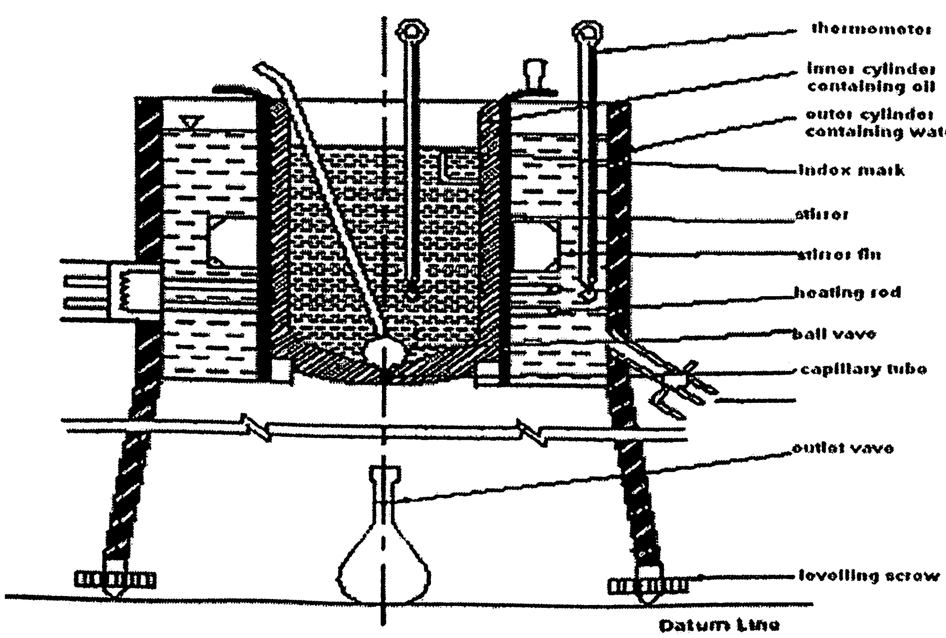


Fig 5 *Viscositimeter*

Procedure:

1. Clean the oil cup, jet and ball valve
2. Level the instrument with the help of circular bubble and leveling the screws
3. Fill the water bath
4. Close the orifice with ball valve and fill the cylinder upto index mark
5. Record steady temp of oil
6. On lifting the ball valve, collect the sample upto the mark and measure the time required for the same
7. Report the time in seconds
8. Repeat the experiment three times for each blend and take the average value and consistency in reading is to be noted
9. Formula used: c*t
10. Where c is calibrated Viscositimeter constant and the value is = 0.02666, t is the time in seconds
11. Viscosity is evaluated in lab at 400C standard.

- **Pour point & cloud point apparatus**

Pour point is that temperature at which oil ceases to flow. After preliminary heating, the sample is cooled and examined at interval of 3^0C for flow characteristics. Cloud point is defined as that temperature at which the first cloud is observed at the bottom of the test jar.

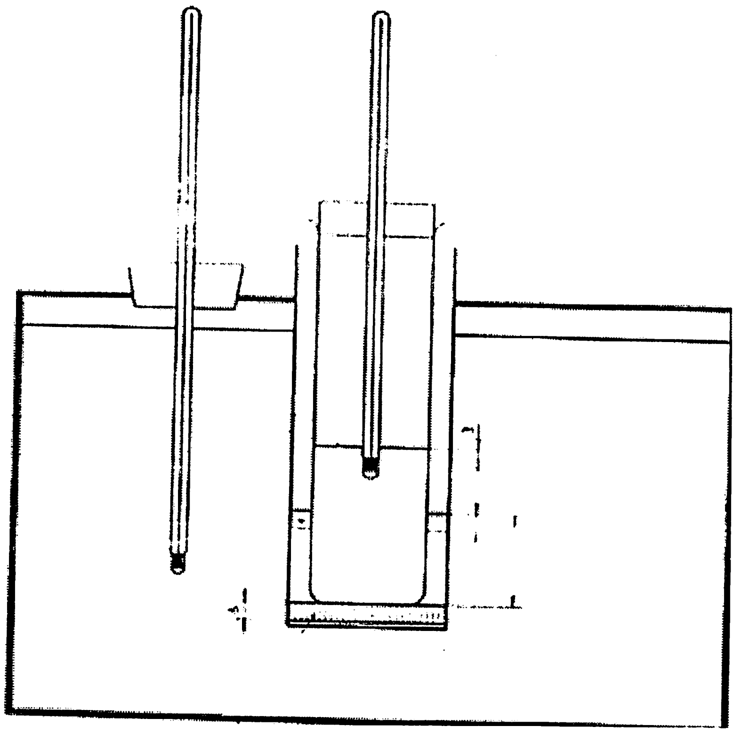
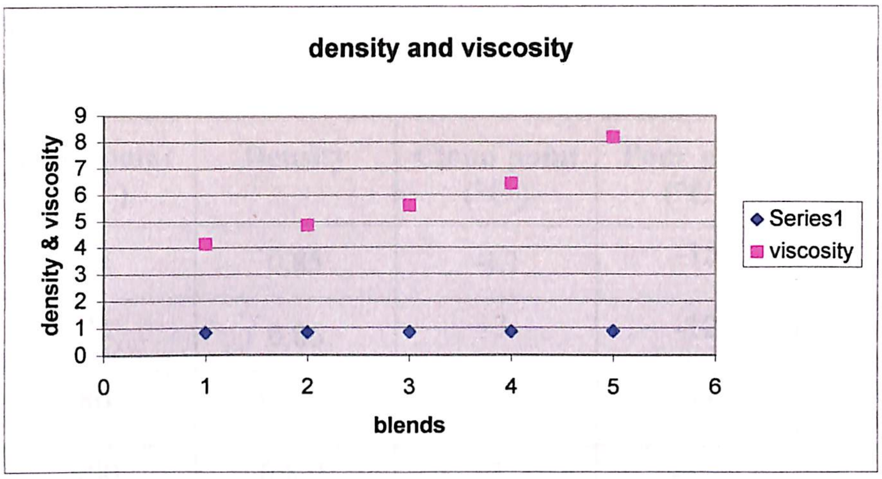


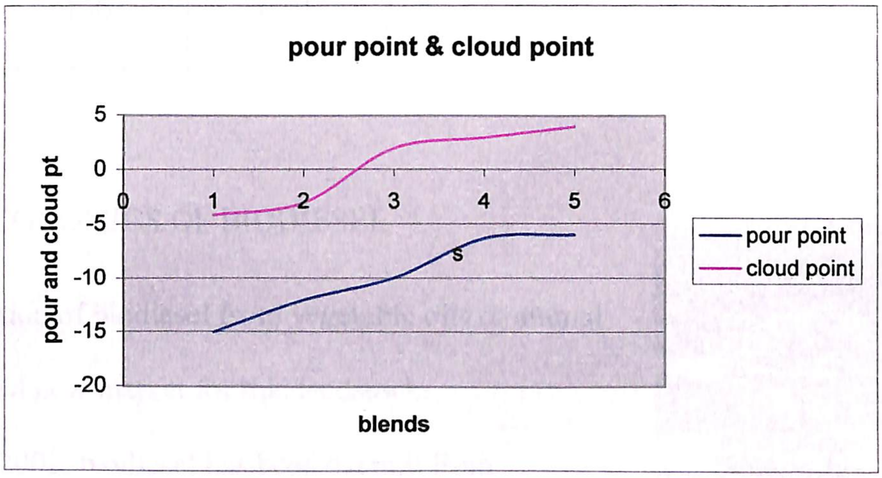
Fig 6 *Pour point & cloud point meter*

Procedure:

1. Bring the apparatus to 40^0C
2. Sample jar and the reference jar is kept adjacent to each other in a water bath.
3. Observe the temp decrease and analyze the condition of the sample to be tested at every 1^0C and the temp at which the cloud start forming is the cloud point and further cool it to observe the solidification of sample when completely stops flowing and is the pour point.
4. Pour point is generally observed as in multiple of 3 and cloud point in multiple of 1.

Blends	Flash point	Density	Cloud point	Viscosity	Pour point
B20	65	0.85	-4.1	4.18	-15
B40	72	0.86	-3	4.9	-12
B60	80	0.871	2	5.63	-9.9
B80	100	0.878	3	6.46	-6.3
B100	130	0.91	4	8.2	-6


density and viscosity
density & viscosity
blends
Series1
viscosity


pour point & cloud point
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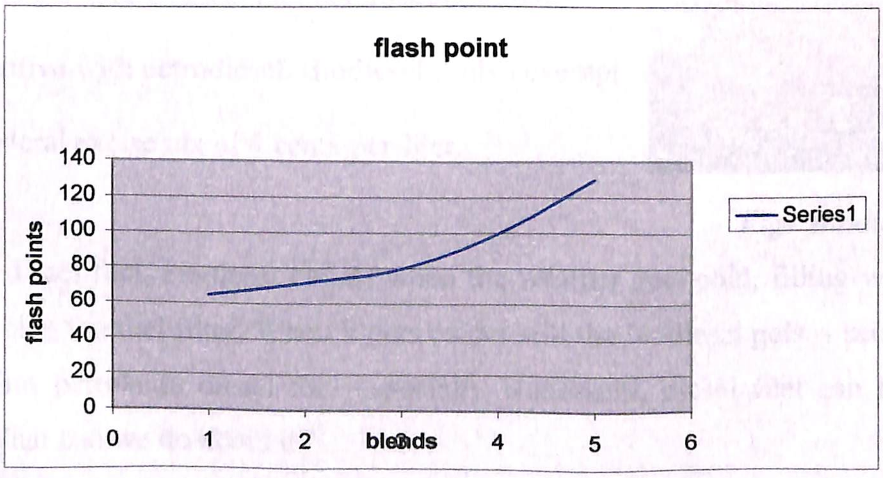

flash point
flash points
blends
Series1

10.2 EXPERIMENTAL RESULTS

Table 8 ***Results***

Blends	Flash point (°C)	Density	Cloud point (°C)	Pour point (°C)	Viscosity (stokes)
B-20	65	0.85	-4.1	-15	4.18
B-40	72	0.86	-3	-12	4.9
B-60	80	0.871	2	-9.9	5.63
B-80	100	0.878	3	-6.3	6.47
B-100	130	0.91	4	-6	8.23

10.3 THE ECONOMICS OF BIODIESEL

- The production of biodiesel from vegetable oils or animal fats creates a new market for this feedstock.
- Since June 2002, biodiesel has been exempt from the 14.3 cents-per-liter Ontario fuel tax, making it more
- cost-competitive with petrodiesel. Biodiesel is also exempt from the Federal excise tax of 4 cents-per-liter.

Fig7 Biodiesel in cold temp

The problem

Like petroleum diesel fuel, biodiesel clouds when the weather gets cold, filling with little crystals of wax that can clog the fuel filter. When it gets colder still the biodiesel gels -- sets solid and won't flow or pour. But petroleum diesel fuel especially winterized, diesel fuel can take colder than biodiesel can. What can we do about it?

Depending on the oils used, biodiesel made from virgin oil has a lower pour-point (or CFPP -- Cold-Filter Plugging Point) than biodiesel made from used cooking oil. These bottles were kept at very low temp to figure out the cloud formations. The additives to the solution or sample can be a solution.

11. ENGINE PERFORMANCE

This part of my project deals with using different blends of vegetable oil and diesel on different test engines present at the University laboratory. The samples used were SVO10, SVO50, SVO20, and SVO100. They were run on the test engines. The properties that were mainly focussed upon were smoke emissions, % of hydrocarbon emitted, efficiency with different loads, break specific fuel consumption evaluation,nitrogen oxide emissions and oxygen consumption.Performance evaluation on engine helped me with getting a clear picture of how a particulart blend can effect the working condition of an engine keeping in view the emission level of different blends at different loads.It is assumed that higher blending can be useful in getting lesser pollutants but it does not improve upon the efficiency to a larger extent and as well even though the hydrocarbon level is seen reducing but nitrogen content is seen to be higher in higher blend of bio-diesel.

11.1 INTRODUCTION TO ENGINES

Definition

An engine is a device which transforms one form of energy into another. In conversion efficiency plays an important role. Heat engine is a device that transforms the chemical energy into thermal energy and utilizes this thermal energy to perform useful work. It can be classified into two main parts:

1. Internal combustion engine
2. External combustion engine

Basic engine components are & nomenclature:

- ***Cylinder block:*** This is the main supporting structure for various components. The cylinders of a multicylinder engine are cast as a single unit called cylinder block. The cylinder head is mounted on cylinder block. They are enclosed in water jacket\s in case of water cooling or with cooling fins in case of air cooling. Bottom portion of the cylinder block is crankcase. The inner surface is well machined and finished accurately to cylindrical shape called bore.

- ***Cylinder:*** It is the cylindrical vessel or space in which makes a reciprocating motion. The varying volume created in the cylinder during operation of the engine is filled with working fluid and subjected to thermodynamics processes.
- ***Piston:*** It is the cylindrical component fitted into the cylinder forming the moving boundary of the combustion engine. It fits perfectly into the cylinder providing a gas tight space with piston rings and lubricants. It forms the first link in transmitting the gas force to the output shaft.
- ***Combustion chamber:*** The space enclosed in the upper part of the cylinder by cylinder head and piston top during the combustion process called combustion chamber. The combustion of fuel and the consequent release of thermal energy results in building up of pressure in this part of cylinder.
- **Inlet manifold:** The pipe which connects the intake system to the inlet valve of the engine and through which air or air-fuel mixture is drawn into cylinder

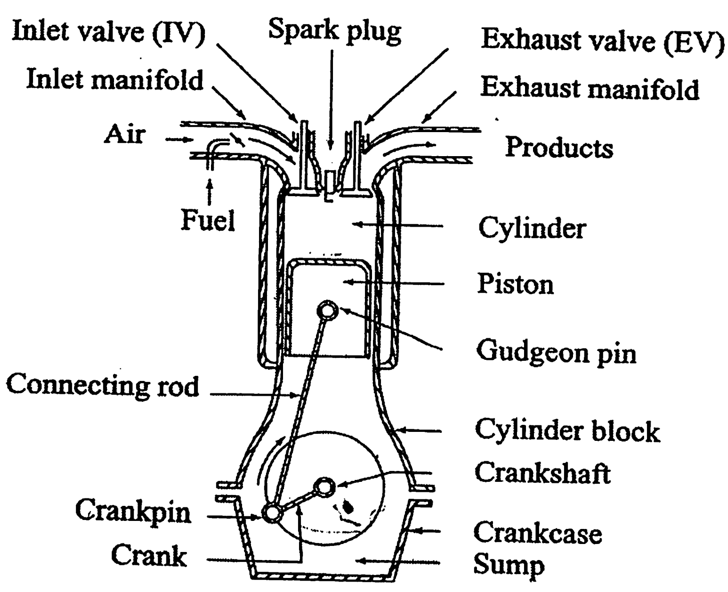


Fig8 Parts of engine

- ***Exhaust Manifold:*** The pipe which connects the exhaust system to the exhaust valve of the engine and through which the products of combustion escape into the atmosphere is called the exhaust manifold.
- ***Inlet and Exhaust Valves:*** Valves are commonly mushroom shaped poppet type. They are provided either on the cylinder head or on the side of the cylinder for regulating the charge coming into the cylinder (inlet valve) and for discharging the products of combustion (exhaust valve) from the cylinder

- ***Spark Plug:*** It is a component to initiate the combustion process in Spark-Ignition (SI) engines and is usually located on the cylinder head.
- ***Connecting Rod:*** It interconnects the piston and the crankshaft and transmits the gas forces from the piston to the crankshaft. The two ends of the connecting rod are called as small end and the big end. Small end is connected to the piston by gudgeon pin and the big end is connected to the crankshaft by crankpin.
- ***Crankshaft:*** It converts the reciprocating motion of the piston into useful rotary motion of the output shaft. In the crankshaft of a single cylinder engine there are a pair of crank arms and balance weights. The balance weights are provided for static and dynamic balancing of the rotating system. The crankshaft is enclosed in a crankcase.
- ***Piston Rings:*** Piston rings, fitted into the slots around the piston, provide a tight seal between the piston and the cylinder wall thus preventing leakage of combustion gases.
- ***Gudgeon Pin:*** It forms the link between the small end of the connecting rod and the piston.
- ***Camshaft:*** The camshaft and its associated parts control the opening and closing of the two valves. The associated parts are push rods, rocker arms, valve springs and tappets. This shaft also provides the drive to the ignition system. The camshaft is driven by the crankshaft through timing gears
- ***Cams:*** These are made as integral parts of the camshaft and are designed in such a way to open the valves at the correct timing and to keep them open for the necessary duration.

- ***Fly Wheel:*** The net torque imparted to the crankshaft during one complete cycle of operation of the engine fluctuates causing a change in the angular velocity of the shaft. In order to achieve a uniform torque an inertia mass in the form of a wheel is attached to output shaft and this wheel is called the flywheel.

11.2 NOMENCLATURE

- ***Cylinder Bore (d):*** The nominal inner diameter of the working cylinder is called the cylinder bore and is designated by the letter d and is usually expressed in millimeter (mm).

- ***Piston Area (A):*** The area of a circle of diameter equal to the cylinder bore is called the piston area and is designated by the letter A and is usually expressed in square centimeter (cm^2).

- ***Stroke (L):*** The nominal distance through which a working piston moves between two successive reversals of its direction of motion are called the stroke and is designated by the letter L and is expressed usually in millimeter (mm).

- ***Stroke to Bore Ratio:*** L/d ratio is an important parameter in classifying the size of the engine. Ifd $< L$, it is called under-square engine. If $d = L$, it is called square engine. If $d > L$, it is called over-square engine. An over-square engine can operate at higher speeds because of larger bore and shorter stroke.

- ***Dead Centre:*** The position of the working piston and the moving parts which are mechanically connected to it, at the moment when the direction of the piston motion is reversed at either end *of* the stroke is called the dead centre. There are two dead centres in the engine.

  They are:

  (i) Top Dead Centre

  (ii) Bottom Dead Centre

(i) Top Dead Centre (TDC): It is the dead centre when the piston is farthest from the crankshaft. It is designated as *TDC* for vertical engines and Inner Dead Centre *(IDC)* for horizontal engines.

(ii) ***Bottom Dead Centre (BDC):*** It is the dead centre when the piston is nearest to the crankshaft. It is designated as *BDC* for vertical engines and Outer Dead Centre *(ODC)* for horizontal engines.

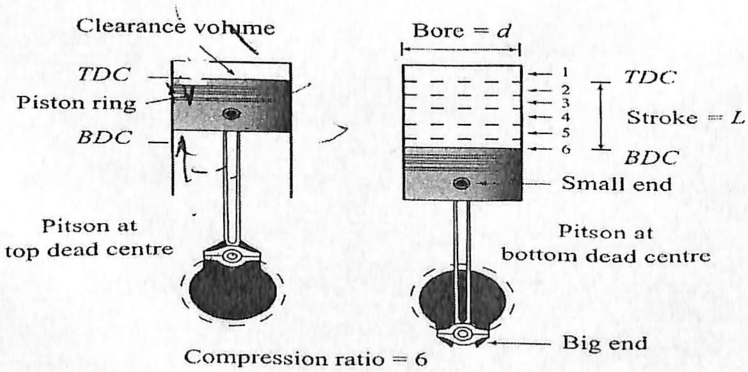


Fig 9 Positions of moving piston

- ***Displacement or Swept Volume (VS):*** The nominal volume swept by the working piston when traveling from one dead centre to the other is called the displacement volume. It is expressed in terms of cubic centimeter (cc) and given by $V_S = AxL = 4d^2L$

- ***Cubic Capacity or Engine Capacity:*** The displacement volume of a cylinder multiplied by number of cylinders in an engine will give the cubic capacity or the engine capacity. For example, if there are K cylinders in an engine, then Cubic capacity = V_S x K

- ***Clearance Volume** (VC)*: The nominal volume of the combustion chamber above the piston when it is at the top dead centre is the clearance volume. It is designated as VC and expressed in cubic centimeter (cc).

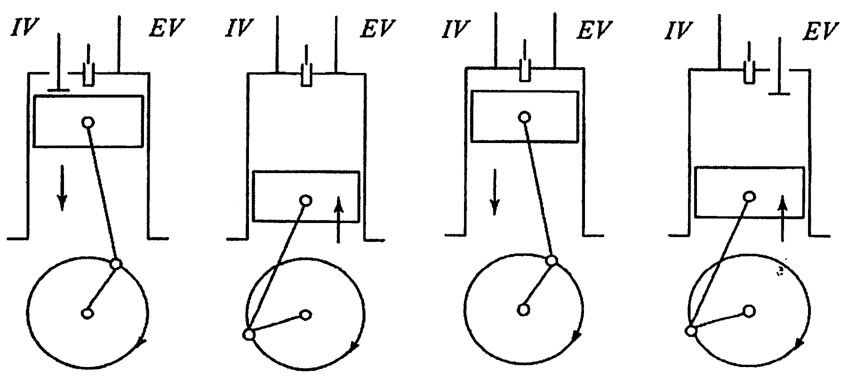
- ***Compression Ratio** (r)*: It is the ratio of the total cylinder volume when the piston is at the bottom dead centre, *VT,* to the clearance volume, VC. It is designated by the letter *r*.

$$r = V_T/V_C = (V_C+V_S)/ V = 1+ (V_S/V_C)$$

11.2 FOUR-STROKE COMPRESSION-IGNITION ENGINE

The four-stroke CI engine is similar to the four-stroke SI engine but it operates at a much higher compression ratio. The compression ratio of an SI engine is between 6 and 10 while for a CI engine it is from 16 to 20. In the CI engine during suction stroke, air, instead of a fuel-air mixture, is inducted. Due to the high compression ratio employed, the temperature at the end of the compression stroke is sufficiently high to self ignite the fuel which is injected into the combustion chamber. In CI engines, a high pressure fuel pump and an injector are provided to inject the fuel into the combustion chamber. The carburetor and ignition system necessary in the SI engine are not required in the CI engine.

The ideal sequence of operations for the four-stroke CI engine is as follows:



(a) Suction (b) Compression (c) Expansion (d) Exhaust

Fig.10 Strokes of engine

(i) ***Suction* Stroke** : Air alone is inducted during the suction stroke.

(ii) ***Compression Stroke:*** Air inducted during the suction stroke is compressed into the clearance volume. Both valves remain closed during this stroke

(iii) ***Expansion Stroke:*** Fuel injection starts nearly at the end of the compression stroke. The rate of injection is such that combustion maintains the pressure constant in spite of the piston movement on its expansion stroke increasing. the volume. Heat is assumed to have been added at constant pressure. After the injection of fuel is completed.

(iv) ***Exhaust Stroke:*** The piston traveling from *BDC* to *TDC* pushes out the products of combustion. The exhaust valve is open and the intake valve is closed during this stroke.

Due to higher pressures in the cycle of operation the C.I. engine is sturdier than S.I engine. This results in a C.I. engine to be much heavier than the S.I. engine. However it has higher thermal energy on account of high compression ratio.

11.3 COMPARISON OF C.I. AND S.I. ENGINE:

In four strokes, there is one power stroke for every two revolutions of the crankshaft. There are two non-productive strokes of exhaust and suction which are necessary for flushing the products of combustion from the cylinder and filling it with fresh air. If this purpose could be served by an alternative arrangement, without the movement of the piston, it is possible to obtain a power stroke for every revolution of the crankshaft increasing the output of the engine. However, in both SI and CI engines operating on four-stroke cycle, power can be obtained only in every two revolution of the crankshaft. Since both SI and CI engines have much in common, it is worthwhile to compare them based on important parameters like basic cycle of operation, fuel induction, compression ratio etc.

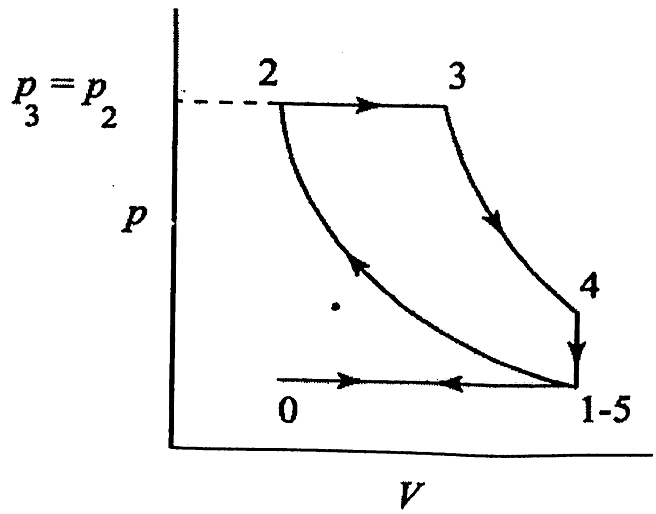


Fig11 Ideal P-V diagram for four stroke engine

11.4 ENGINE SPECIFICATIONS:

Engine type

Table 9: **Engine Specifications**

Power, hp/Kw	10hp, 7.35Kw
No. of cylinder	1
Bore, mm	120
Stroke, mm	139.7
Speed, rpm	1000
Specific fuel consumption, gm/Kwh Specific fuel consumption, gm/bhp/hr	265 195
Compression ration	17:1
Displacement, cm^3	1580
Fuel	High speed diesel
Lubrication	SAE 30/40
Bare weight of engine, kg(app.)	335
Gross weight of engine, kg(app.)	490
Packed case size, L*W*H, mm	1070*780*1145
Packing case volume, m^3	0.86

DIESEL

LOAD(%)	LOAD(KW)	VOLTAGE(V)	CURRENT(I)	GEN SPEED(RPM)	ALT SPEED(RPM)	Tfuel(sec)	T1	T2	T3	T4	T5	OPACITY(%)	CO(%)	CO2(%)	O2(%)	Nox(ppm)	HC(ppm)	λ
0	0	257	0	1000	1500	117	28	29	44	171	12	0	0.01	2	17	11	5	9.76
20	1.2	208	4.5	1000	1500	80	29	34	46	214	90	1	0.02	2	16.9	270	10	7.21
40	2.4	214	10.5	1000	1500	71	29	35	47	270	11	1.2	0.02	3.4	15.7	383	13	5.583
60	3.6	212	15.7	1000	1500	54	29	36		300	12	1.7	0.02	4.2	14.7	536	14	4.488
80	4.8	213	23	1000	1500	47	30	37		300	11	10.4	0.02	4.9	13.65	510	21	3.77
100	6	213	30	1000	1500	38	31	38		300	12	48	0.17	4.9	13.1	410	25	3.568

ALT EFFICIENCY	ENGINE OUTPUT(KW)	TORQUE	MASS OF FUEL	BSFC(kg/kwh)	BSEC(KJ/Kwh)	BTE	BMEP(MPA)
0	0	0					
62.40000	1.923076923	12.67127338	0.95625	0.49725	11377.08	16.4541341	0.97213473
74.90000	3.204272363	21.11314977	1.077464789	0.336258803	4617.393794	24.33190778	1.619791913
73.96444	4.867203461	32.07030614	1.416666667	0.291063786	2631.245373	28.11005207	2.460420312
81.65000	5.878750765	38.7354542	1.627659574	0.276871676	2072.269128	29.55093968	2.97176765
85.20000	7.042253521	46.40184617	2.013157895	0.285868421	1786.105895	28.6209234	3.559929998

SVO100

LOAD(%)	LOAD(KW)	VOLTAGE(V)	CURRENT(I)	GEN SPEED(RPM)	ALT SPEED(RPM)	Tfuel(sec)	T1	T2	T3	T4	T5	OPACITY(%)	CO(%)	CO2(%)	O2(%)	Nox(ppm)	HC(ppm)	λ
0	0	222	0	1000	1500	98	31	35	36	132	57	0.6	2.4	0.04	17.4	101	10	8.139
20	1.2	219	4.4	1000	1500	85	32	37	40	161	65	0.8	0.04	3.1	16.6	198	7	6.28
40	2.4	221	9.3	1000	1500	69	33	40	41	219	69	1.2	0.03	4.1	15.46	344	7	4.73
60	3.6	228	15	1000	1500	49	44	56	63	209	72	2.4	0.02	5.01	14.04	471	6	3.7
80	4.8	229	20	1000	1500	42	50	56	68	241	85	4.4	0.02	5.5	13.6	549	5	3.4
100	6	229	27.8	1000	1500	38	60	58	70	244	100	8.56	0.02	5.8	13	550	2	3.24

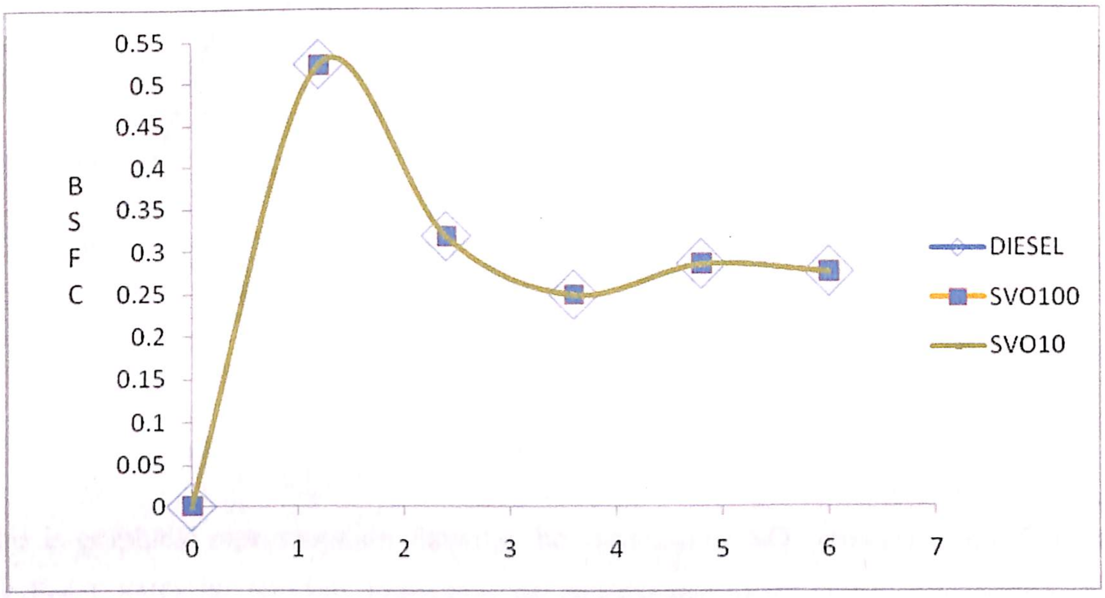
ALT EFFICIENCY	ENGINE OUTPUT(KW)	TORQUE	MASS OF FUEL	BSFC(kg/kwh)	BSEC(KJ/Kwh)	BTE	BMEP(MPA)
0	0	0			0	0	
64.24000	1.867995019	12.30833529	0.952941176	0.510141176	19385.36471	18.57071071	0.944290273
68.51000	3.503138228	23.08239553	1.173913043	0.335103261	12733.92391	28.27094009	1.770871615
76.00000	4.736842105	31.21134706	1.653061224	0.348979592	13261.22449	27.1468144	2.394521335
76.33333	6.288209607	41.43340396	1.928571429	0.306696429	11654.46429	30.8894507	3.178753214
84.88267	7.068580943	46.57531919	2.131578947	0.301556842	11459.16	31.4159153	3.573238774

SVO10

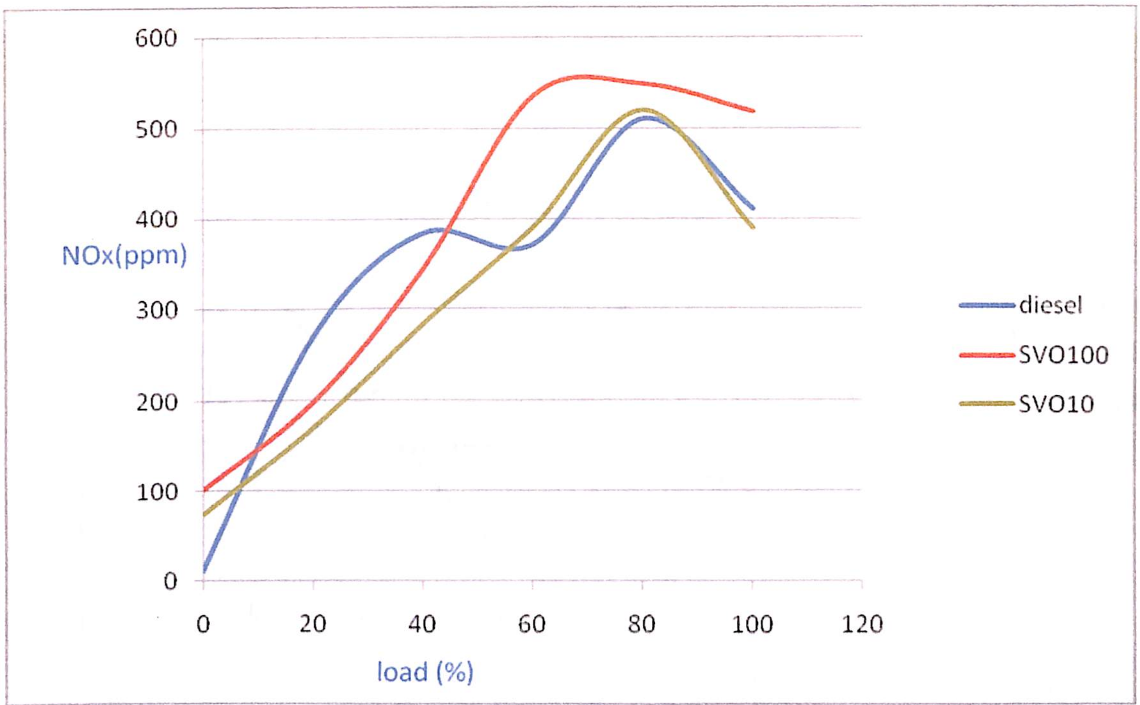
LOAD(%)	LOAD(KW)	VOLTAGE(V)	CURRENT(I)	GEN SPEED(RPM)	ALT SPEED(RPM)	Tfuel(sec)	T1	T2	T3	T4	T5	OPACITY(%)	CO(%)	CO2(%)	O2(%)	Nox(ppm)	HC(ppm)	λ
0	0	219	0	1000	1500	117	28		44	171	42	2.8	0.05	2.1	17.52	74	17	9.094
20	1.2	215	4.7	1000	1500	80	29		46	214	48	3.4	0.03	2.9	16.56	170	9	6.634
40	2.4	217	9.9	1000	1500	71	29		47	270	50	4.1	0.02	3.7	15.42	284	1	5.141
60	3.6	218	15.5	1000	1500	54	29			300	51	15	0.02	4.8	14.25	346	2	3.527
80	4.8	212	17.2	1000	1500	47	30			300	51	23	0.01	5.41	13.68	389	1	3.53
100	6	208	29	1000	1500	38	31			300	52	38	0.02	6.23	12.21	389	0	2.93

11.6 CALCULATION & GRAPHS

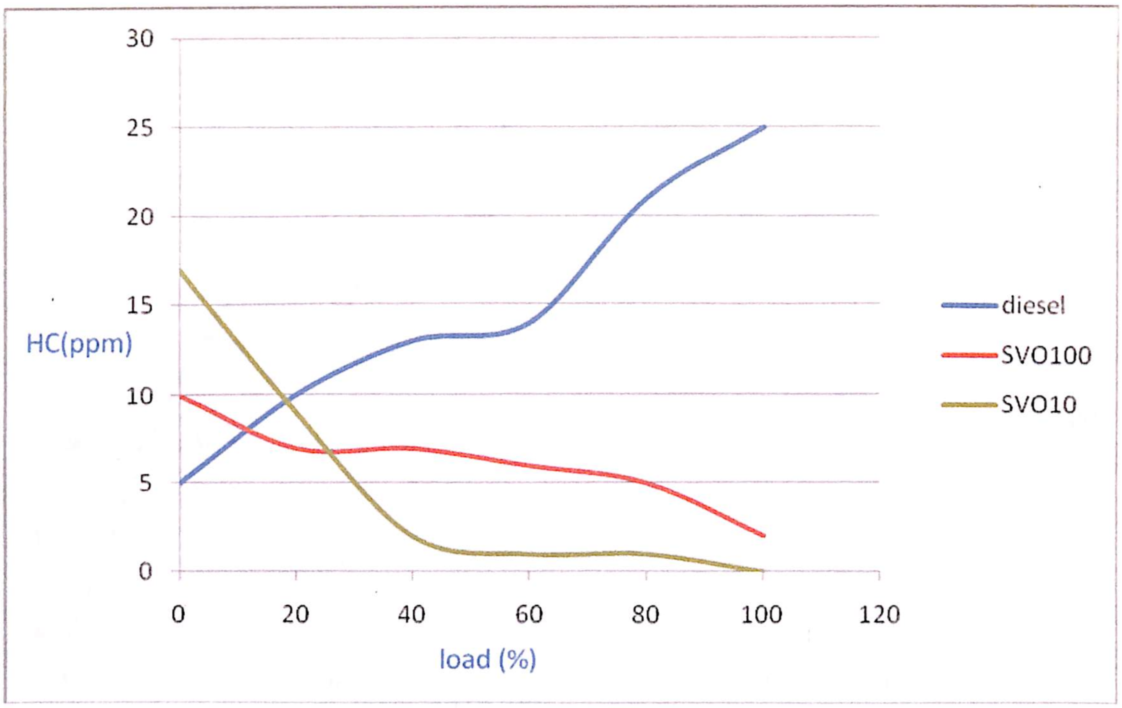
The following graphs show the comparison of different parameters for different samples with respect to its corresponding load.



- This graph shows the variation in Break specific fuel consumption with different blends. According to standards, it is seen that BSFC should increase with increase in %blend, as the calorific value of pure bio-diesel is much less than pure diesel but in the lab, even though a increase in BSFC occurs at SVO10 but diesel and SVO100 showing the same value of BSFC due to slight % error as reported.

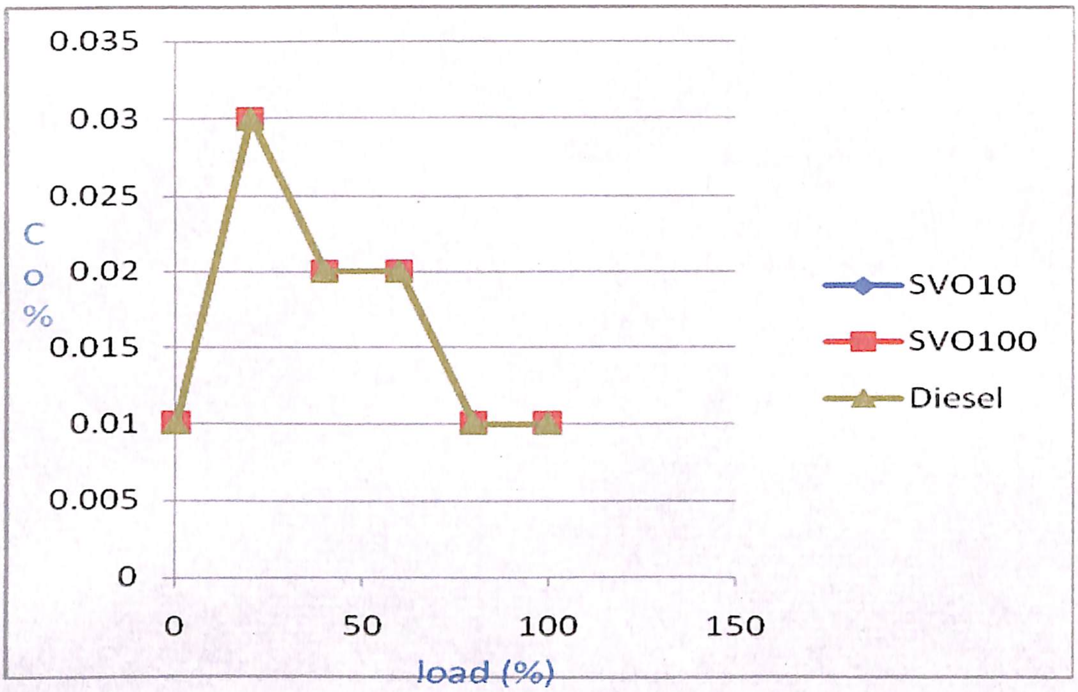


- This is graphical representation showing the variation of NOx emissions at different loads for diesel, SVO100, SVO10. From this, we can see that as the % blend of organic content, that is the bio-diesel increases, the % of NOx also shows an upward trend. This is the major problem associated with increasing the content of vegetable oil in engines



- This is a graph showing the variation of hydrocarbon emissions for three different samples. From this, we can see that as the percentage of blend increases, the hydrocarbon emissions decreases. Even though there might be a small increase in its emission with increase in % of load.

➢ Similar is the case with CO emission, where there is not much difference between the emission values even if the level of organic blend is higher.



11.7 CONSTANTS TAKEN IN CALCULATION

- $\cos\Phi = 0.8$
- Π (pie) = 3.14
- Engine speed = 1000 r.p.m
- Alternator speed = 1450 r.p.m
- Density of pure diesel = 850kg/m^3
- Calorific value of diesel = 44,000 KJ/kg
- Calorific value of pure SVO100 = 38,000 KJ/kg
- Calorific value of SVO10 (assumed) = 42,000 KJ/kg
- Number of cylinder = 1

- Speed = 1500 r.p.m
- Length of the stroke = 0.14 meter
- Bore diameter = 0.12 meter
- *Conversion factors*
- $1m^3 = 10^6$ cc
- 1 minute = 60 seconds
- 1 kilowatt = 1000 watts
- 1 hour = 3600 second

11.8 FORMULAS USED

- Alternator Efficiency = (Actual output)/(Theoretical output)
- Engine output (KW) = (Rated output)/(Alternator efficiency)
- Torque = (Engine output*60*1000)/(2*Π*alternator speed)
- Mass of fuel = (25cc*3600*d_f)/(T_{Fuel}*10^6)
- Break Specific Fuel Consumption(Kg/Kwh) = m_f/output of engine
- Break specific energy consumption(KJ/Kw) = (m_f*calorific value)/(engine output)
- Break Thermal Efficiency = (engine output*3600)/(m_f*calorific value)
- Break mean effective pressure = (engine output*1000)/((K* Π/4*L*D^2*(N/2*60)*10^5))

where, m_f is mass of fuel, d_f is density of fuel in kg/m^3, K is no. of cylinder, N is the speed in rpm, L is the stroke length and D is the bore diameter

12. BIO-FUEL AS A POTENTIAL ENERGY ALTERNATIVE

From the desk of Chairman of CII National Biofuels Committee

Biofuels have been recently been attracting the global spotlight for their potential as alternative energy. Though increasing environmental concerns have led to a simultaneous cost benefit analysis, the scales are still favoring towards bio-fuels. As per Goldman Sachs's data, the estimated cost of a barrel of fuel made from sugarcane is $45and of Jatropha is $43. Jatropha has the capability to grow on land which cannot support crops and is known to survive drought too. It generates, from the fourth year of cultivation onwards, a net income of about Rs10,000 per acre for 35-40 years and also improves the fertility of the soil after its life span of 50 years. Ethanol is a widely used fuel nowadays. Brazil has almost replaced petrol- only engines with engines that pure ethanol or 78:22 petrol-ethanol blend. Ethanol contains about 35% oxygen and hence and good environmental friendly similar to bio-diesel. There is an argument that energy crop battles with the food crop and cause food shortages and price may be affected. The argument need to be analyzed against the India's real food situation of supply and demand and the advantages and disadvantages of producing bio-fuels. Adoption of agricultural practices should evolve efficient methods of utilizing available land and other resources to meet both food and fuel from agro forestry systems.

From India's perspective, both ethanol and jatropha are the potential feed stocks. According to R.P.S Katwal, director general, Indian council of Forestry Research and Education, the Govt has plans to plant jatropha trees on 50,000 hectares, at a cost of Rs14.3 lakh. Other projects being funded from Abroad include a proposed $2.5 million pilot plant project in Hyderabad and Rajasthan, which will produce 10tonnes of bio-diesel per day. Raw oil from pongamia, jatropha and other plants will be sourced from local farmers who will be the major beneficiaries in the above project. Nandan Biomatrix and Labland Biotech are buying land in Malaysia to grow Jatropha. Shapoorji Pallonji & Co is looking to purchase land in South America and Africa for bio-fuels. As global reserves of fossil fuel shrink, the bio-fuel industries have to put their act together and India is in good position to step up to this opportunity. India pursues an energy growth of 8-10% and imports about 70% crude so the govt is looking committed to use bio-fuel as a fuel.

13. CONCLUSION

The paper on blending correlation mainly dealt an overview of bio-fuel as good option for fuel in the coming futures, though it is true that not much analysis on the feasibility part is done in India till now. Pilot plants have been developed across the country to perform experiments with the perspective of achieving satisfactory results.

Jatropha, the main feedstock for bio-diesel production have been planted with the land been governed by Indian Government as well as some private players. Bio-fuel as an alternative source of energy seems to be promising in the near future. As predicted by various meteorological data it is seen that the temperature of the earth has increased by around 1^0C over the past few years which gives an alarming message for all countries across the globe about the extent upto which various pollutants have contributed to the environmental disaster and is still continuing and would continue if strong measures are not taken at the right moment. A right decision and implementation at this point of time would be effective enough with the view of protecting the life of all habitats of next generations.

This project helped me get into the insight of the topic and explore the ways and procedures in which such efforts of bringing alternative energy into picture can prove to be beneficial.

The project started with literature survey which dealt with an overview of bio-diesel and the blends of bio-diesel with petro-diesel, with its pros and cons taken into account.

Second phase of the project focused on the interpretation of various important blends that were prepared in the laboratory and tested for some physio-chemical properties. This part helped me in evaluating the appropriate blend at particular conditions and the variation in properties as different blends are tested.

Third phase of the paper dealt with using the blends prepared to be run it on test engines available in the campus laboratory and analyze the important parameters that are actually considered while running an engine such as extent of smoke by each blend, hydrocarbon emissions, variation of nitrogen emissions with the change in blend, the amount of fuel that was consumed during the overall operation and there variation with change in load & blend samples, etc.

In the end, I would conclude by saying that blends like B20, B10 and B50 can hold as potential blend keeping in view all the parameters even though B100 is beneficial to the environment but currently cannot be accepted due to higher nitrogen emissions involved with pure bio-diesel and as well the engine modifications that is required as the percentage of vegetable oil keeps on increasing which may prove to be much more costlier than emissions that are contributed while running on pure diesel as till date.

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