CHAPTER 1

INTRODUCTION

1.1. REVIEW ON DEMAND OF ENERGY

Consumption of energy is increasing worldwide in various forms for a variety of purposes. The amount of consumption is directly proportional to a society’s growth. Today developing countries are prospering through economic reforms and are becoming technologically advanced.

Fuel is critical to any tactical plan for economic growth and national security. In developing countries like India the fuel has implicit economic cost in the forms of budget deficits caused by imports of oil and ecological dreadful conditions caused by pollution. The imports statement on these items is around Rs.18000 crores and the intensification rate of diesel consumption is more than 15% per annum (36).

When it comes to world, energy consumption which is drastically increased for last decade. People still depends mostly on fossil fuels to fuel their vehicles, in spite of the environment problem that flow from burning coal oil and natural gas. So many research works are carried out in many nations like India to search an appropriate fuel source such as solar and the wind as the great alternatives which are neat copious and on the edge of mass production in a upcoming days that always seems around the corner yet eternally out of reach.

Nowadays, renewable energy sources of the world’s supply, fossil fuels provide about 85% technologically higher which have damped the cost of renewable power sources, but technology has also kept down the price
using fossil fuels and some cases reduced their unsafe effects on the environment.

It is estimated that by 2020, the world may be consuming the energy 15 times higher when compared to the usages of energy in 1980. Possibly as much as many environmentalists, the oil companies are willing to find alternatives to fossil fuels, because they understand that over the next century they will see their supply diminishing.

The major oil companies like, IOCL (Indian Oil Corporation Limited) in India are doing their research towards renewable energy sources. The possibility of substituting some alternatives for petrol and diesel has become aware of the automobile industry over the last decade.

Here is a list of fuels that are being used in automobiles.

- Compressed natural gases (CNG)
- Liquefied petroleum gas (LPG)
- Alcohol fuels such as methanol, ethanol, and other alcohols
- Hydrogen (including fuel cells)
- Coal-derived liquid fuels
- Biodiesel prepared from vegetable oils, animal fats
- Biodiesel prepared from animal fats
1.2. VEGETABLE OIL AS FUEL IN DIESEL ENGINES

Compression ignition (CI) engines are more far and wide used compared to spark ignition (SI), greater thought is being committed to expand an alternative source of fuel for the CI engine. When vegetable oils are fueled with a CI engine, the CI engine’s safety should be considered as a major factor. Vegetable oils and their suitability as an alternative to diesel fuel have been considered as a topic of research. Though, their higher viscosity and ability of storage problems detaint their direct use as alternate fuel. The use of vegetable oils in I.C engines dates back to 1900 when Rudolph diesel, the inventor of compression ignition engines, used peanut oil as an engine fuel. The energy crisis of 1947 brought stress on various countries to search for non petroleum based alternate fuels. Many vegetable oils for the purpose of commercial and non commercial have been investigated and possible difficulties are reported (55).

The observed major differences between diesel fuel and vegetable oil are higher viscosities, reasonably higher densities; lower heating values, rise in the stoichiometric air / fuel ratio due the presence of molecular oxygen and the opportunity of thermal cracking at the temperatures encountered by the fuel spray of vegetable oil in naturally aspirated diesel engines (55). These differences lead to the poor atomization, carbon deposits on combustion chamber and various parts of engine, exhaust emissions and wear that were usually experienced and which unfavorably affect the resilience of the engine.

1.2.1 Advantages of using vegetable oil as diesel fuel

From literature review available in the field of vegetable oil usage, a lot of advantages are observed (55). The following are the some of the advantages of utilizing vegetable oil as fuel in India.
1. Vegetable oils are produced domestically which helps to reduce the cost of petroleum products.

2. Growth of the bio-diesel industry would make stronger the domestic, and for the most part the rural, agricultural economy of agricultural based countries like India.

3. It is biodegradable and non toxic.

4. It is renewable fuel that can be made from agricultural crops and other feed stocks that are considered as waste.

5. It has 80% calorific value compared to diesel.

6. It has a reasonable cetane number and hence possess less knocking tendency.

7. It contains low aromatics.

8. Low sulphur content and hence eco friendly.

9. Better lubricity, by this means no major modification is required in the engine.

10. Personal safety is enhanced.

1.2.2. Challenges and difficulties

The major challenges that face the use of vegetable oil as C.I. engine fuels are listed below (55).

1. The cost of vegetable oil depends on the feed stock price.

2. Feed stock homogeneity, uniformity and reliability are questionable.

3. Composition of the product depends on the feed stocks and production methods.

4. Storage and handling is difficult and flash point in blends is unreliable.

5. Wear and tear needs to be studied further.

6. Cold weather operation of the engine is not easy with vegetable oils because viscosity is higher for vegetable oil.
7. Acceptance by engine manufacturers is another major difficulty.
8. Continuous availability of the vegetable oils needs to be assured before embarking on the major use of it in I.C. engine.

1.2.3. Technical difficulties

The major technical areas (with respect to use of vegetable oils as in I.C. engines) which need further attention are the following (55):

1. Development of less expensive quality tests for the vegetable oils.
3. Emission testing with a wide range of feed stocks.
4. Studies on developing specific markets such as mining, municipal water supplies etc., which can specify bio-diesel as the fuel choice for environmentally sensitive areas.
5. Co-product development such as glycerol at reduced cost.
6. Efforts to be focused on responding to fuel system performance, material compatibility, petroleum additive compatibility and low fuel stability under long term storage.
7. Continued engine performance, emission and durability testing in a variety of engine types and sizes need to be developed to increase consumer and manufacturer confidence.
8. Environmental benefits offered by vegetable oil over diesel fuel needs to be popularized.
9. Studies are needed to reduce the production cost, develop low cost feed stocks and identify potential markets in order to balance cost and availability.
10. Research on the effect of glycerol on engine durability, emission and material compatibility and prevention of oxidation in storage, etc.
1.2.4. Disadvantages of using vegetable oil as fuel in diesel engine

Vegetable oil has slightly lower calorific value than diesel oil. Vegetable and diesel differs greatly in their properties. Their kinematic viscosity is several times higher than the diesel. (55, 57).

1. Thick and viscous vegetable oil leads to pumping and atomization problems in the normal diesel fuel injection systems.
2. High carbon residue causes heavy smoke emission and carbon deposition in the injection nozzle tips and in the combustion chamber.
3. It also has some problems of incompatibility with engine lubricants.
4. The poor volatility makes the vegetable oil difficult to vaporize and ignite. This leads to thermal cracking resulting in the heavy smoke emission and carbon deposits in the combustion chamber. This tendency is partly due to higher fuel viscosity.
5. Vegetable oils dilute the lubricant oil and forms sludge on the parts of engine, where it comes in contact with lubrication oil.

1.2.5. Remedies

1. Filter plugging is minimized if crude degummed oils are passed through a four micrometer filter.
2. Starting problems should be overcome by starting aids such as glow plugs and fuel heaters.
1.3. ALTERNATIVE FUELS FOR CI ENGINES

The alternative fuels must be technically and environmentally acceptable, and economically spirited. From the viewpoint of these requirements, triglycerides of vegetable oils or animal fats and their derivatives may be considered as viable alternatives for diesel. The problems with their high viscosity, low volatility and polyunsaturated character have been mitigated by developing vegetable oil derivatives that approximate the properties and performances and make them compatible with the hydrocarbon based diesel fuels through pyrolysis, micro-emulsification, dilution and transesterification (38).

1.3.1. Pyrolysis

Pyrolysis refers to a chemical change by the application of thermal energy in the absence of air or nitrogen (57). The liquid fractions of the thermally decomposed vegetable oil are likely to approach fuels. The properties of oil has been changed as lower viscosity, flash point and pour point than diesel fuel and equivalent calorific values when the oil is undergone the pyrolysis. The cetane number of pyrolyzate was lower. The pyrolyzed vegetable oils contain adequate amounts of sulphur, water, reasonable copper corrosion values and also undesirable ash, carbon residue and pour point.

1.3.2. Micro-emulsification

The formation of micro emulsions is one of the potential solutions for solving the problem of vegetable oil’s viscosity. Micro-emulsions are defined as transparent, thermo dynamically stable colloidal dispersions (55, 57). The droplet diameters in micro-emulsions range from 100 Å to1000 Å. A micro-emulsion can be made of vegetable oils with ester and dispersant that is co-solvent, or of vegetable oils, an alcohol and a surfactant and a cetane
improver, with or without diesel fuels. Water (from aqueous ethanol) may also be present in order to use lower proof ethanol, thus increasing water tolerance or the micro-emulsions.

### 1.3.3. Dilution

Dilution of vegetable oils can be accomplished with such materials as diesel fuels, solvent or ethanol (55).

### 1.3.4. Transesterification

Transesterification is also called alcoholysis is the displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis (57). This process has been widely used to reduce the viscosity of triglycerides. The transesterification reaction is represented by the general equation.

The methanol is used in the above reaction, it is termed as methanolysis.

Triglycerides are readily transesterified in the presence of alkaline catalyst at atmospheric pressure and at a temperature of approximately 55 to 65 °C with an excess of methanol (66). The mixture at the end of the reaction is allowed to settle. The lower glycerol layer is drawn off while methyl ester layer which is known as biodiesel is washed to remove entrained glycerol and
is then processed further. The excess methanol is recovered by distillation and sent to a rectifying column for purification and recycled. The transesterification works well if the vegetable oil is of good quality. On the other hand frequently low quality oils are used as raw materials for preparing the biodiesel. In case were the free fatty acid content of the oil is above 1%, difficulties arise due to the formation of soap which promotes emulsification during the water washing stage and at FFA content above 2% the process does not produce methyl ester (66).

1.4. EFFECT OF FATTY ACIDS AND MOISTURE

The free fatty acid and moisture content are important parameters for determining the viability of the vegetable oil transesterification process (22). To carry the base catalyzed reaction to complete the free fatty acid (FFA) value lower than 3% is needed. If the acidity of oil is higher, the efficiency of conversion is reduced. Both, excess as well as inadequate amount of catalyst may cause glycerol formation (14).

The materials used for base catalyzed alcoholysis should meet cetane specifications. The lower acid value of triglycerides should be substantially anhydrous. The addition of more sodium hydroxide (NaOH) catalyst compensates for increasing acidity but the resulting glycerol causes a raise in viscosity or creation of gel that interferes in the reaction and also the separation of glycerol (22).

When the reaction circumstances do not meet the above necessities, yields of methyl ester are significantly reduced. The methoxide and hydroxide of sodium and potassium should be maintained in anhydrous state, extended contact with air would maintained in anhydrous state, would reduce the effectiveness of these catalysts through interaction with moisture CO₂ (22).
1.5. BIODIESEL

1.5.1. Definition of biodiesel

- Biodiesel is a natural and renewable domestic fuel alternative for diesel engines made from vegetable oil and animal fat.
- It is not a petroleum based fuel. It is nontoxic and biodegradable. Biodiesel is mostly produced through the chemical reaction of a vegetable oil or animal fat with methanol in the presence of catalyst which is called as transesterification process and resulting yield of methyl esters (biodiesel) and glycerine.

1.5.2. Advantages of biodiesel

The following are the advantages of biodiesel have been listed from the literature review (55).

- It has better fuel burning characteristics when fueled with CI engine.
- When the bio diesel blends are fueled with CI engine, the exhaust comes out from an engine emits lower CO, lower HC, very less particulate matter but slightly higher NOx.
- They are biodegradable.
- They are obtained from renewable source (vegetable oil).
- It is not needed to modify the availed engine.
- They are safe to handle.
- They act as lubricating oil as well.
- The fuel consumption is not much higher than diesel.
- The maximum torque is practically same.
- Their viscosity is far less than pure vegetable oil.
1.5.3. Fuel properties and specification of biodiesel

The biodiesel is produced in quite differently scaled plants from oil of varying origin and quality, it is compulsory to have a standardization of fuel quality to assure engine performance to avoid errors. The parameters which describe the quality of biodiesel can be divided into two groups. One group contains general parameters, which are also used for mineral oil based fuel and other group particularly describe the chemical composition and purity of fatty alkyl esters.

Among the general parameters for biodiesel the viscosity of fatty acid methyl esters are higher and hence it is important to control it within a tolerable level to avoid unconstructive impacts on fuel injector system performance.

Flash point of a fuel is the temperature at which fuel will ignite when exposed to flame. The flash point of bio diesel and its blends are higher than the diesel (48).

Cold filter plugging point (CFPP) of the fuel reflects its cold weather performance. At low operating temperature the fuel may thicken and might not flow properly affecting the performance of fuel lines, fuel pumps and injectors. Normally either pour point or CFPP is specified (48).

Cetane number is indicating the ignition characteristics of biodiesel which is higher and resulting better engine performance. Cetane number affects the engine performance characteristics such as combustion, drive ability, noise, smoke, and emissions of CO and HC. Bio-diesel has higher cetane number than diesel fuel, which results in higher combustion efficiency (48).
Neutralization number is specified to guarantee proper ageing properties of the fuel. It reflects the presence of free fatty acids. Carbon residue of the fuel is the pinpointing of carbon depositing tendencies of the fuel. The concentration of high level of alcohol in bio-diesel cause accelerated deterioration of natural rubber seals and gaskets. Therefore control of alcohol content is required.

1.5.4. Biodiesel economics

Biodiesel plants are not capital-intensive plants. The majority of the cost is expended for production of biodiesel from the oil. The cost associated with catalysts such as KOH or NaOH and neutralizing acid is not important. On the other hand, there are so many indirect benefits that are possible in India (4). For example in India considerable waste land is available. The energy farming by cultivation of oil bearing plants can generate employment in tree plantations; seed picking, in oil mills where extraction is carried out and then the biodiesel plant itself. There is considerable scope for export of biodiesel.

The oil cake can be used as bio-fertilizer or its formulation, fetching some revenue. The tree plantation can result in more green coverage resulting in restoring ecological balance and socio-economic benefits. Thus, this “energy farming” concept becomes catalyst to sustainable development.

The economics of the process can be improved by recovering glycerol of a good quality. The good quality glycerol may fetch value order of which could be much more (5 to 10 times) biodiesel. It should be noted that 90% of the product will be sold at a price which is equal to diesel price having no duties. The other industrial applications such as lube oil, solvent, paint stripper can also help in generating revenue.
1.6. CATALYTIC CONVERTER

Automotive industry plays a major role in the economic growth and prosperity of developing countries. In our country, for a long time, personal transport has been regarded as a luxury and requirement of the elite. But now, as personal transport has become a necessary and universal part of modern life, automotive industry in India is all set to take off in a big way. Most of the automobile giants in the world are setting their production units in India. Such high acceleration in the automotive industry brings to focus many problems and one of the major issues is the vehicular emission. There is no need to emphasize the importance of clean air, which is so vital to sustain good and healthy life. Hence it is clear that the levels of emissions have to be reduced drastically, to ensure a reasonable safe environment for the future generations.

The environmental degradation all over the world has led the researchers to work towards the development of Low Emission Vehicle (LEV) and Ultra Low Emission Vehicle (ULEV). Automobile vehicles emit substantial quantities of hydrocarbons (HC), carbon monoxide (CO) and particulate matter.

Catalytic exhaust controls are generally recognized to be the most cost-effective way to reduce emission. Catalyst exhaust control technology uses a precious metal catalyst to convert chemically the harmful components of the vehicle’s exhaust to harmless gases. This technology is capable of reducing HC and CO emission in the range of 60 to 80 percent respectively and particulate matter more than 50 percent.

The present generation of gasoline vehicles tested according to the Federal Test Procedure emits 70-80 percent of exhaust emission during the first one or two minute following cold-start. This is primarily due to the
ineffectiveness of catalytic converter till it reaches light-off temperature. Thus, rapidly increasing the temperature of catalytic converter under vehicle cold-start condition is of paramount importance in reducing HC and CO emission. Tremendous improvements were made in the past couple of years to reduce power consumption to the 2 to 3 kilowatt level. To provide 2 to 3 kilowatts from a 12-volt battery requires large wire diameters and a sophisticated power switching mechanism. Even a 2-kilowatt power requirement has a substantial impact on battery life.

A more practical solution may be to utilize the various sources of energy such as electrical energy, sensible energy and chemical energy of the exhaust available to heat the catalyst. Observing any of the following measures could optimize this technique:

- Positioning of the heated catalyst close to the main converter.
- Positioning of the heated catalyst and the main converter, close to the engine.

Positioning the heated catalyst close to the main converter increases the backpressure of the engine. Positioning of the heated catalyst and the main converter, close to the engine increases thermal degradation of catalyst and also backpressure. Reduction of the heated catalyst mass reduces the high electrical power requirement and the time required for heat-up. The rate of temperature rise is proportional to the mass of the converter. By optimizing the heated mass, rate of temperature rise can be increased to a greater extent followed by exothermic reaction. Once the exothermic reaction begins, an abundance of chemical energy is released which acts to heat up the main converter. So that the time required activating the catalyst is reduced marginally.
The Low Mass Electrically Heated Metal Catalytic Converter (LMEHMC) quickly reaches high temperature levels, and the heat generated by the exothermic oxidation is carried by the exhaust gas down to the main converter, which attains faster light off, resulting in low emissions at power levels as low as 1.5 kW.

1.7. AIM OF THE STUDY

Most research on biodiesel has focused on using plant based oils as feed stocks. One potential source of oil is Used Vegetable Oil (UVO). It has been retrieved from waste oil after cooking. From this UVO, the bio diesel can be produced through transesterification process.

The aim of the study is to investigate the used vegetable oil methyl ester (UVOME) as a substitute for diesel in compression ignition engine. Used vegetable oil was converted into their methyl ester using transesterification process. The properties of the fuels were determined using standard methods. The study was carried out to investigate the performance, combustion and emission characteristics of used vegetable oil methyl esters and their blends with diesel in varying proportions. A single cylinder, water cooled, four stroke diesel engine was used for this work. Experiments were conducted when the engine was fueled with used vegetable oil methyl ester and their blends with diesel in proportions of 20:80, 40:60, 60:40, 80:20 and 100% (by volume), which are generally called as B20, B40, B60, B80 and B100 respectively. The experiments covered a range of loads. An AVL smoke meter was used to measure the smoke density in HSU. The exhaust emissions were measured using exhaust gas analyzer. High volume sampler was employed to measure the particulate matter in exhaust.

The performance of the engine was evaluated in terms of brake specific fuel consumption, brake thermal efficiency. The combustion characteristics of the engine were studied in terms of cylinder pressure, rate of pressure rise
respect to crank angle. The emission characteristics of the engine were studied in terms exhaust gas temperature, concentration of NOx, CO, particulate matter and smoke density. The results obtained for UVOME, and their blends with diesel were compared with the results of diesel.

1.8. SCOPE OF THE RESEARCH

The problem of increasing demand of fuel, engine performance and emissions characteristics are greater threat to the field of automobiles. The hike in fuel cost has caused many to re-evaluate alternative fuel that has huge potential globally. On the other hand, the use of used vegetable oil methyl ester in diesel engines brings into focus the various challenges that might be faced by public usage. The main aim of this research is to demonstrate how capably an engine can be run by using used vegetable oil methyl ester (biodiesel) and its blends when compared to diesel.

1.9. REASONS FOR SELECTING THE TOPIC

In a country like India, where agriculture is the main profession and kirloskar engine are mostly used by the farmers for various applications like water pumping etc. The main problems are the increasing demand of fuel, cost and emission. The biodiesel is considered as an alternate fuel for diesel engines especially, during the periods of diesel scarcity. The biodiesels and their blends have better engine performance characteristics and the exhaust exhibited lower CO, lower HC, lower particulate matter emission but slightly higher NOx.