CHAPTER 1

INTRODUCTION

1.1 GENERAL

The ever increasing demand for petroleum based fuels and the uncertainty in their availability has been a matter of concern world over. The huge outflow of foreign exchange on one hand and increasing emissions causing environmental hazards on the other, have triggered interest in alternatives to gasoline and diesel. Oil provides energy for 95% of transportation and the demand continues to rise, particularly in rapidly developing countries like India and China. The requirement of gasoline and diesel is expected to be about 13 MMT and 66 MMT by 2011-2012. The domestic supply of crude oil in India will satisfy only about 22% of the demand and the rest will have to be met from imported crude oil. Crude oil prices and availability are subject to great volatility depending upon the international situation and relationships between the countries. Moreover, import of petroleum is a major strain on a country’s foreign exchange resource. Hence, steps are being taken to reduce dependence on oil imports.

Diesel engines are the best for power plants today because of their high thermal efficiency, good torque characteristics and ability to cater to a wide range of applications. In India, majority of the power plants for heavy transportation, agriculture as well as industries use diesel engines and hence the consumption of diesel is almost six times higher than that of petrol. The cost of diesel is going up in an uncontrollable way and so is the cost of
transportation. Costs of transportation affect the price of all commodities and in turn the economic progress of the country. A nation’s development is strongly dependant on the availability of fuels for transportation, agriculture and power generation. Thus, India, like many developing countries faces the major challenge of meeting the high demand for oil. Only by using the renewable sources of fuel with clean combustion, we can reduce emissions and also the dependence on conventional petroleum sources. Therefore, there is a need to stimulate the use of renewable energy sources to increase the rate of economic growth and national development. This is particularly significant for a country like India with plenty of wastelands where plants to produce bio-fuels can be cultivated. This activity also will generate employment for the poor. If the energy need of rural areas can be met by locally available fuels, then the problem of large imports of crude oil can be eased out a little.

Fuels suitable for rural applications should have the capability to be used with little processing. Several alternative fuels are being considered for use in engines. The potential alternatives fuels are gaseous fuels and liquid fuels.

1.2 LIQUID FUEL

Liquid fuels are preferred for IC engines because they are easy to handle, transport, store and have reasonably good calorific value. The liquid fuels are alcohol and vegetable oils.

1.2.1 Alcohol

Many countries like Brazil, Mauritius, U.S and few European countries are using ethanol blended fuel in automobiles. Ethanol is produced from sugar molasses, wood, maize beet etc. Ethanol is processed from any feed stock such as corn, wheat, sugar cane, tapioca, and other grains. The grain is first ground and cooked with water to convert the starch to sugar with
enzyme. The sugar is then fermented with yeast to produce raw ethanol and a high protein material. The raw ethanol is distilled to get anhydrous ethanol.

Methanol is produced from coal, natural gas, farm waste, municipal waste etc. The municipal wastes are first shredded and then passed under a magnet to remove ferrous materials and then gasified with oxygen. The synthesis gas is cleaned by water scrubbing and other means to remove any particulates, \( \text{H}_2\text{S} \) and \( \text{CO}_2 \). Further CO-shift conversion for \( \text{H}_2\text{-CO-CO}_2 \) adjustment, methanol synthesis and methanol purification are accomplished.

1.2.2 Vegetable Oil

The concept of using vegetable oil as fuel for diesel engine is nothing new. As early as 1910, Rudolf Diesel demonstrated his engine with peanut oil in France and said that the diesel engine can be fed with vegetable oils that would help considerably in the development of agriculture of the countries. It has also been said that the use of vegetable oils as engine fuels would become significant in the long run, when the demand for petroleum products goes up. Vegetable oils as alternative fuels offer an advantage because of their comparable properties with that of diesel. But a serious objection for the use of vegetable oils is their high cost. The present scenario is that the market prices of vegetable oils are higher than petroleum fuels. However, it is anticipated that the cost will come down as the developments in agriculture and oil extraction methods improve. There are about 350 varieties of oil seeds identified. Out of these, India has more than 200 types of oil seed varieties. The vegetable oils may be classified into edible and non-edible oil. India being agriculture based country, the agricultural lands are plants or trees viz. Jatropha, Pongamia pinnatta, Madhuca Indica, Cashew, and Neem etc. can be cultivated / planted in the wasteland / barren lands with lesser cost and labor.
1.3 VEGETABLE OIL AS FUEL

Countries like Europe, South America and East Asia started using vegetable oils as fuel in diesel engine. If the engine is started with diesel, run with vegetable oil and stopped with diesel, the fuel system of the engine will function for long time, while engine components are deposited with severe carbon build up.

The major differences between diesel and vegetable oils are:

- The viscosities are significantly higher, approximately 10 times that of diesel.
- Vegetable oils have lower heating values than diesel.
- Vegetable oils raise the stoichiometric fuel / air ratio due to the presence of molecular oxygen.
- Vegetable oils undergo thermal cracking at the temperatures encountered by the fuel spray in diesel engines.

1.3.1 Properties of Vegetable Oil

The properties of vegetable oils fall within a narrow band and are close to those of diesel fuel. Vegetable oils have about 10 percent lesser heating value than diesel because of the presence of oxygen in their molecule. The kinematics viscosity is several times higher than diesel. This leads to pumping and atomization problems. They have a high carbon residue, indicated by the Conradson value and high viscosity, which are due to the large molecular mass and their chemical structure. They have poor volatility characteristics and hence are not suitable for spark ignition engines. By their properties, vegetable oils are suitable fuels only for compression ignition
engines. In India, only non-edible oils can be considered seriously since the others are in great demand and are too expensive.

The cost of vegetable oils of the non-edible type can be reduced if the production of oil seeds can be stepped up. The production of vegetable oil is very easy in an agricultural country like India and can be made quite economical by growing the right crops. Geographical location and the available type of oil-bearing plants play an important role in the choice of the most suitable type. From the ecological point of view, use of vegetable oils has yet another advantage to combat the green house effect. Since all the carbon dioxide given off in to the atmosphere when it is burned is absorbed by photosynthesis, the carbon dioxide balance is neutral. India has the third position among the largest oil seed producers in the world. It is first in the production of groundnut, sesame and castor and second in the production of sunflower and third in rapeseed, mustard, coconut and linseed oils. Others include neem, rubber seed, cottonseed, rice bran and maize etc. These oils can be directly used in diesel engines on the short term basis.

A number of vegetable oils have been tested all over the world to evaluate their performance and emission characteristics in diesel engines. Sunflower and rapeseed oils are used in Europe whereas soybean is used in USA. Thailand uses Palm oil. The production of sunflower seed is mainly confined to Eastern Europe and USSR. The oil content of the seed ranges from 22 to 36% and the kernel contains 45-55% oil. Rapeseed oil is a general term applied to seeds of Olieiferous Brassica, cultivated in many parts of the world as oil seed crops. A few important rapeseed producing countries are Poland, Sweden, France, Germany, Canada and India. The seed yields 40-45% of oil. Soybean (Glycine max) is a native of south-eastern Asia. The seeds have been used as an article of food in China, Japan and Korea. Since thirties it has attained great importance in USA. Other countries in which
soybean are grown in Philippines, Indonesia, Thailand, India, Canada, Brazil and Argentina.

Jatropha curcas is a native of tropical America, occurring almost throughout India and in Andaman Islands. It is propagated easily by seeds or cuttings and it grows rapidly. The oil content of the kernel is about 46-58% and the kernel forms 60-68% of the weight of the seed. Jatropha oil has its heating value and cetane number close to diesel. Its flash point is 248°C as compared to 50°C for diesel, hence it is easy to store and handle. Freshly extracted oil is yellowish orange to brown in colour. The kinematic viscosity of Jatropha oil is very high as compared to that of diesel.

Pongamia pinnata is medium sized tree and is found throughout India. The tree is drought resistant. Major producing countries are East Indies, Philippines, and India. The oil content varies from 27-39%. Its cake is used as pesticide and fertilizer. A thick yellowish-orange to brownish oil is extracted from seeds. Yields of 25% of volume are possible using a mechanical expeller. The oil has a bitter taste and a disagreeable aroma, thus it is not considered edible. In India, the oil is used as a fuel for cooking and lamps. The oil is also used as a lubricant, water-paint binder, pesticide, and in soap making and tanning industries. The oil is known to have value in herbal medicine for the treatment of rheumatism, as well as human and animal skin diseases. It is effective in enhancing the pigmentation of skin affected by leucoderma. The oil of Pongamia is also used as a substitute for diesel. Its flash point is 248°C as compared to 50°C for diesel, hence it is easy to store and handle. The kinematic viscosity of Pongamia oil is very high as compared to that of diesel.
1.4 DIESEL ENGINE PERFORMANCE WITH VEGETABLE OIL

When used in diesel engines the high viscosity and low volatility of vegetable oils causes problems in spray penetration, atomization and mixture formation, which results in high fuel consumption, high smoke and gummy deposits on engine components. These problems associated with vegetable oils can be overcome by adopting suitable methods like:

1. Blending
2. Transesterifying with alcohols and converting to biodiesel
3. Thermal cracking
4. Heating to reduce viscosity
5. Air preheating
6. Use of insulated combustion chambers
7. Micro-emulsification
8. Using additives and ignition improvers and
9. Dual fuel operation with other gaseous and liquid fuels

Most of the vegetable oils are easily mixed with diesel fuel in all proportions. Hence, one of the possible methods is to use mixtures of vegetable oils and diesel in existing diesel engines without any modification. Significant improvement was observed with blends in comparison to neat vegetable oil. Transesterification is an effective way to reduce the viscosity and carbon residue of vegetable oils by modifying their structure. Technically, esterified vegetable oil is called biodiesel. Thermal cracking (pyrolysis) refers to chemical change caused due to the application of heat. Cracking is generally defined as the process of breaking one compound into simpler compounds by heating, as in the case of crude oil cracking process, which produces diesel fuel. Cracking of vegetable oil reduces its molecular size. Normally, by cracking different types of products can be produced with
regard to their structure and molecular composition. Heating can considerably reduce the viscosity of the vegetable oils. The fuel viscosity at the injector is important for atomization, penetration and combustion. Hence vegetable oils can be heated prior to injection. Air pre-heating will cause considerable increase in the fuel temperature of air at the end of compression and in turn accelerate evaporation and mixing of the vegetable oil and hence combustion. Low heat rejection diesel engines lead to increased temperatures and have better combustion with vegetable oils.

A micro emulsion of vegetable oil with a low boiling point constituent can improve the spray characteristics due to explosive vaporization of the low boiling point constituent in the emulsion. The ignition quality of vegetable oils can also be improved by using additives which accelerate combustion to reduce smoke emission. It is found that the addition of dimethyl carbonate (DMC) to diesel results in improved thermal efficiency and lower carbon monoxide, hydrocarbon and smoke emissions.

Gaseous fuels are clean burning and they can be used with vegetable oils in the dual fuel mode. A dual fuel engine is a modified engine in which usually a gaseous fuel called the primary fuel is inducted along with air and is ignited by a small amount of liquid fuel called the pilot fuel at the end of the compression stroke. Varying the amount of primary gaseous fuel added to the inlet manifold normally controls the power output of the engine. The major advantage of dual fuel engine is its ability to use a wide range of gaseous fuels and also to produce smoke levels lower than that of conventional diesel engines. Vegetable oils have been used in dual fuel role along with some gaseous and liquid fuels.

In the present research work, the experiment is conducted on a direct injection diesel engine with Pongamia methyl ester and its diesel blends like B10, B20 and B100 with different nozzle opening pressures like 180 bar,
200 bar and 220 bar, 500 micron thickness of TiO$_2$ coating on the piston crown and 10\% Di-ethyl ether (DEE). The setup has been developed for analyzing the performance, combustion and emission characteristics of DI diesel engines with Pongamia methyl ester. The combustion characteristics like cylinder pressure and heat release rate, peak heat release rate, ignition delay, combustion duration and the exhaust gas emissions of NO$_x$, CO, CO$_2$, HC, smoke and O$_2$ have been analyzed under different load conditions.

The main advantages of the present work is that the performance of a biodiesel fuelled diesel engine is increased and reduction in CO, HC and smoke emissions with marginal increase in NO emissions. The discussion on the existing literature concerning these aspects is presented in the next chapter, prior to the details of the work carried out during the investigation.