CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION TO ENERGY SCENARIO

Energy is one of the most significant inputs for growth of all sectors including agricultural, industrial services and transport sectors. Energy has been at the centre stage of national & global economic development since several decades. The demand for energy, around the world is increasing exponentially, specifically the demand for petroleum-based energy. Petroleum derived fuels, actually, exceeds the demand of any other fuels or energy resources. The world consumption for petroleum and other liquid fuel will grow from 85 million barrels/day in 2006 to 107 million barrels/day in 2030. Under these growth assumptions, approximately half of the world’s total resources would be exhausted by 2030. Also, as per many studies, the world oil production would peak sometime between 2007 and 2030. Therefore, the future energy availability is a serious global concern. Another, major global concern is environmental degradation or climate change such as global warming. Global warming is related with the greenhouse gases which are mostly emitted from the combustion of petroleum fuels. In order to control the emissions of greenhouse gases, Kyoto Protocol targets to reduce the greenhouse gas emission by a collective average of 5% below 1990 level of respective countries. The Intergovernmental Panel on Climate Change (IPCC) concludes in the Climate Change 2007 that, because of global warming effect the global surface temperatures are likely to increase by 1.1°C to 6.4°C between 1990 and 2100.
1.1.1 Energy Crisis

There is a realization throughout the world that the petroleum resources which are non-renewable, are limited and are being consumed at an alarming rate. The growing demand for energy and gradual extinction of fossil fuels has lead to an energy crisis. Most of the power in industries and transportation is derived from oil and coal. Special mention is needed for automobiles where almost all of the fuels for combustion engine today are derived from petroleum, a non-renewable source of energy, which is nearing its end at an unprecedented pace. The globe today uses about 147 trillion kWh of energy which is expected to rise in the coming future. The expected rise in the world consumption of energy up to 2030. A major chunk of this rise will be due to the developing countries, which are bound to grow by leaps and bounds.

1.1.2 Indian scenario in biodiesel

The country's energy demand is expected to grow at an annual rate of 6.8 per cent over the next couple of decades. Most of the energy requirements are currently satisfied by fossil fuels – coal, petroleum based products and natural gas. Domestic production of crude oil can only fulfil 25-30 per cent of national consumption rest we are importing from other countries. In these circumstances bio fuels are going to play an important role in meeting India’s growing energy needs. Bio fuels offer an attractive alternative to fossil fuels, but a consistent scientific framework is needed to ensure policies that maximize the positive and minimize the negative aspects of bio fuels.

The government of India has formulated an ambitious National Biodiesel Mission to meet 20 per cent of the country’s diesel requirements by 2016-2017. A commercialization period during 2007-2012 will continue Jatropha cultivation and install more transesterification plants which will position India to meet 20 per cent of its diesel needs through biodiesel.
The main problem in getting the biodiesel program rolling has been the difficulty in initiating the large-scale cultivation of Jatropha because farmers do not consider Jatropha cultivation rewarding enough. Therefore government needs to sponsor confidence-building measures such as establishing a minimum support price for Jatropha oilseeds and assuring farmers of timely payments. The plantations under this mission will be established by NGOs, public and private sectors. The Ministry of Forests and Environment (MoEF) and the National Oilseed and Vegetable Oil Development (NOVOD) Board will serve as responsible agencies for the cultivation in the forest and non-forest areas, respectively by providing the necessary information and financial assistance.

1.1.3 Development of Biodiesel in India

Biodiesel is a relatively new product in India. In 1912, the use of vegetable oils for engine fuels may seem insignificant today. But such oil may in the course of time become as important as petroleum and the coal tar products of present time. Biodiesel is alternative fuel that can be used in diesel engines and provides power similar to conventional diesel fuel. It reduces the countries dependence on foreign oil imports. As per its end use it is classified with petroleum products industry more particularly with diesel. This industry is known to everybody in world whether literate or illiterate. Contribution of this industry in economy of India or rather we can say world can be understood, simple in one sentence that any price change in products related to this industry affects almost all the commodities, services of every industry. Cost of petroleum products is directly proportional to the living cost of common man. Although biodiesel is new product but it is going to replace product of petroleum industry i.e. diesel in future. In India, however, continuing research work on renewable energy sources, including vegetable oils, is underway in various
laboratories starting from the classic work of Prof. H.A. Javemann and his associates at the Indian Institute of Science from the early 1940’s. Now national mission for biodiesel is proposed and in this regard planning commission has taken decision to blend 5% ethanol with petrol effective in eight major cities from 01.01.2003 as per phase I and has decided that this ratio gradually be increased to 10% and 20% over a period of time upto 2011-2012 in phase II. Daimler Chrysler India Ltd. has declared the commercial launch of biodiesel cars in five to ten years as a part of its biodiesel project. The National Oilseeds and Vegetable Oil Development (NOVOD) board has prepared Rs. 1,430 crore project for biodiesel production from Jatropha seeds and state governments are providing various incentives to promote integrated Jatropha oil extraction in their state e.g. Tamil Nadu. The southern railway adopted a three pronged strategy of large scale plantation of these trees, processing the oil into biodiesel and making use of it for its large fleet of road vehicles and locomotives. Awareness in India is only now giving shape to projects. In Andhra Pradesh four companies viz. Southern Online Biotechnology (SBT), Tree Oils Ltrs (Zaheerabad) Natural Bio Energy and the GMR group have seriously entered into this project. Others include Vrideshwar SSK Ltd. (Ahmednagar, Maharashtra) the Simbhioly Sugar Mills (Ghaziabad, Uttar Pradesh), Mewar Sugar Mills (Jaipur) SM Dyechem (Thane, Maharashtra) R.S. Petrochemicals (Punjab) and Progressive Petroleum (Mumbai) The Aditya Birla group proposed a project in Malaysia, which did not come off. All of them feel that government should offer incentives to offset risk of a Greenfield area.

1.2 ALTERNATE FUELS

The power used in the agricultural and transportation sector is based on diesel fuel and hence it is essential to develop alternatives for diesel. A
number of steps have been taken for promoting the conservation of petroleum products. These include improving energy efficiency of refineries and increasing fuel efficiency in the transport sector. Moreover the engine exhausts accumulate the pollution into the atmosphere. Alternative fuels especially for diesel are needed to diminish the impacts of exhaust gas pollution on the environment and depleting fossil fuel reserves. Such alternatives should be compatible with existing engines, associated equipments like fuel injector etc. and fuel transportation, storage and delivery. There are some important properties to be considered while deciding alternative fuel for the existing engines.

(i) Investment cost: Additional investment on existing engine must be small to ensure that the operation is competitive with petroleum fuel.

(ii) Modification of existing engines: Engine modification should be simple, inexpensive and easily reversible. Such modification should not affect the use of traditional diesel fuel in order to preserve engine compatibility for the use of two fuels. Switch over of operation from alternative fuel mode to diesel mode should be easy.

(iii) Environmental compatibility: While using alternative fuel the engine performance is expected to improve significantly with regard to regulated emissions and unregulated emissions.

(iv) Manufacturer’s warranty: The alternative fuel must guarantee that the lifetime of the equipment, its reliability and operational capability is not modified. Maintenance, repair and fuel costs must be similar to that of conventional fuel and the alternative fuel must be readily available.

1.3 VEGETABLE OILS

The concept of using oil as fuel for diesel engine is nothing new. In 1911, Rudolf Diesel demonstrated his engine with peanut oil in France and
said that the diesel engine can be fed with vegetable oils would help considerably in the development of agriculture of the countries which use it. He also said that the use of vegetable oils for engine fuels would become significant in the long run as the demand for petroleum products go up.

Presently, vegetable oil fuel has gained importance due to the following factors.

1. High cetane number
2. Renewable
3. Carbon neutral
4. Abundant production at low cost
5. Not harmful to engine
6. Eco friendly
7. Aims at reduction in crude import

The demerits are:

1. High viscosity of oil results in ring sticking, stuffing of cylinder links
2. Unfavorable spray atomization and evaporation
3. High flash point resulting in slow combustion
4. Severe gum deposits lead to clog in the fuel system
5. Unsaturated components cause deposits in combustion chamber

The methods of use of vegetable oil are

- Preheated vegetable oil
- Blend
- Vegetable oil as ester

1.4 **Jatropha Curcas**

Jatropha oil has a high cetane number, very close to diesel. This makes it an ideal alternative fuel compared to other vegetable oils. The flash point of
Jatropha oil is around 160°C compared to 75°C for diesel. Due to its higher flash point, Jatropha oil has certain advantages over petroleum crude, like greater safety during storage, handling and transport. However, the higher flash point may create problems in engine starting.

The viscosity of Jatropha oil is less compared to other vegetable oils but is higher than diesel. The higher viscosity of Jatropha oil could pose problems related to flow of oil in the fuel supply pipes and nozzle. The fatty acid composition of Jatropha oil as shown in table 1.1

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Fatty acids</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Palmitic (C16:0)</td>
<td>12-17</td>
</tr>
<tr>
<td>2</td>
<td>Stearic (C18:0)</td>
<td>5-9.7</td>
</tr>
<tr>
<td>3</td>
<td>Oleic (C18:1)</td>
<td>37-63</td>
</tr>
<tr>
<td>4</td>
<td>Linoleic (C18:2)</td>
<td>19-41</td>
</tr>
<tr>
<td>5</td>
<td>Arachidic (C20:0)</td>
<td>10.3</td>
</tr>
<tr>
<td>6</td>
<td>Myrstic (C14:0)</td>
<td>0.5-1.4</td>
</tr>
</tbody>
</table>

1.5 SUNFLOWER OIL

Sunflower oil also contains lecithin, tocopherols, carotenoids and waxes. Sunflower oil's properties are typical of vegetable triglyceride oil. Sunflower oil is produced from oil type sunflower seeds. Sunflower oil is light in taste and appearance and has high vitamin E content. It is a combination of monounsaturated and polyunsaturated fats with low saturated fat levels.

Sunflower oil contains predominantly linoleic acid in triglyceride form. Fatty acids composition of Sunflower oil as shown in table 1.5
Table 1.2 Fatty acids composition of Sunflower oil

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Fatty acids</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Palmitic (C16:0)</td>
<td>4 – 9</td>
</tr>
<tr>
<td>2</td>
<td>Stearic (C18:0)</td>
<td>1 – 7</td>
</tr>
<tr>
<td>3</td>
<td>Oleic (C18:1)</td>
<td>14 – 10</td>
</tr>
<tr>
<td>4</td>
<td>Linoleic (C18:2)</td>
<td>48 – 74</td>
</tr>
</tbody>
</table>

1.6 PALM OIL

Palm oil like all natural fats and oils comprises mainly Triglycerides, mono and diglycerides. Free fatty acids, moisture, dirt and minor components of non oil fatty matter referred to collectively as unsaponifiable matter.

Palm oil is composed of fatty acids, esterified with glycerol just like any ordinary fat. It is high in saturated fatty acids. Palm oil gives its name to the 16-carbon saturated fatty acid palmitic acid. Monounsaturated oleic acid is also a constituent of palm oil. Fatty acids composition of palm oil as shown in table 1.3

Table 1.3 Fatty acids composition of Palm oil

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Fatty acids</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Palmitic (C16:0)</td>
<td>44</td>
</tr>
<tr>
<td>2</td>
<td>Stearic (C18:0)</td>
<td>4.5</td>
</tr>
<tr>
<td>3</td>
<td>Oleic (C18:1)</td>
<td>39.2</td>
</tr>
<tr>
<td>4</td>
<td>Linoleic (C18:2)</td>
<td>10.1</td>
</tr>
<tr>
<td>5</td>
<td>Lauric C12:0</td>
<td>0.2</td>
</tr>
<tr>
<td>6</td>
<td>Myristic (C14:0)</td>
<td>1.1</td>
</tr>
<tr>
<td>7</td>
<td>Others</td>
<td>0.9</td>
</tr>
</tbody>
</table>
1.7 WASTE COOKING OIL (WCO)

Used cooking oil refers to oil that has been hydrogenated after cooking. It can be converted to biodiesel by transesterification. It might be the most practical alternative of all sources due to its availability. The overall cost of biodiesel is greatly reduced if used cooking oils are used as the source and hence such biodiesels might be able to compete with petroleum derived diesels in the market. Once refined oil is subjected to frying it becomes hydrogenated and is not recommended for further use.

The WCO samples used in this study were of palm oil, since its most commonly used oil in the restaurants and hostel kitchens. The fatty acid composition of palm oil is dominated by palmitic, oleic, and stearic fatty acids and in addition to it much less proportions of myristic, lauric, linolenic, and capric acids. Fatty acids composition of waste cooking oil as shown in table 1.4

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Fatty acids</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Palmitic (C16:0)</td>
<td>16</td>
</tr>
<tr>
<td>2</td>
<td>Stearic (C18:0)</td>
<td>5.21</td>
</tr>
<tr>
<td>3</td>
<td>Oleic (C18:1)</td>
<td>34.28</td>
</tr>
<tr>
<td>4</td>
<td>Linoleic (C18:2)</td>
<td>40.76</td>
</tr>
</tbody>
</table>

1.8 KARANJA OIL

Karanja is a medium sized tree is found almost throughout India. Karanja tree is wonderful tree almost like neem tree. The plant is also said to
be highly tolerant to salinity and can be grown in various soil textures viz.
stony, sandy and clayey. The present production of karanja oil approximately
is 200 million tons per annum. The time needed by the tree to mature ranges
from 4 to 7 years and depending on the size of the tree the yield of kernels per
tree is between 8 and 24 kg.

Table 1.5 Fatty acids composition of Karanja oil

<table>
<thead>
<tr>
<th>Sl.No.</th>
<th>Fatty acids</th>
<th>Composition (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Palmitic (C16:0)</td>
<td>11.6</td>
</tr>
<tr>
<td>2</td>
<td>Stearic (C18:0)</td>
<td>7.5</td>
</tr>
<tr>
<td>3</td>
<td>Oleic (C18:1)</td>
<td>51.5</td>
</tr>
<tr>
<td>4</td>
<td>Linoleic (C18:2)</td>
<td>16</td>
</tr>
<tr>
<td>5</td>
<td>Linolenic(C18:3)</td>
<td>2.6</td>
</tr>
<tr>
<td>6</td>
<td>Arachidic</td>
<td>1.7</td>
</tr>
<tr>
<td>7</td>
<td>Eicosenoic</td>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
<td>Behenic</td>
<td>4.3</td>
</tr>
<tr>
<td>9</td>
<td>Lignoceric</td>
<td>1.0</td>
</tr>
</tbody>
</table>

1.9 ADVANTAGES OF BIODIESEL

There are numerous advantages of bio-diesels. Some of the most
important are listed:

- Biodiesel runs in any conventional, unmodified diesel engine. No
  engine modifications are necessary to use bio-diesel and there is no
  “engine conversion.” In other words, “you just pour it into the fuel
tank.”
• Biodiesel can be stored anywhere that petroleum diesel fuel is stored. All diesel fuelling infrastructure including pumps, tanks and transport trucks can use bio-diesel without any major modifications.

• Biodiesel reduces carbon dioxide emissions, the primary cause of the greenhouse effect, by up to 100%. Since bio-diesel comes from plants and plants breathe carbon dioxide, there is no net gain in carbon dioxide from using bio-diesel.

• Biodiesel is more lubricating than diesel fuel, it increases the engine life and it can be used to replace sulfur, a lubricating agent that, when burned, produces sulfur dioxide. The primary component in acid rain. Instead of sulphur, all diesel fuel sold in France contains 5% bio-diesel.

• Biodiesel is safe to handle because it is biodegradable and non-toxic. According to the national bio-diesel board, “neat diesel is as biodegradable as sugar and less toxic than salt.”

• Biodiesel is safe to transport. Bio-diesel has a high flash point, or ignition temperature, of about 150°C compared to petroleum diesel fuel, which has a flash point of 52°C.

• Engines running on bio-diesel run normally and have similar fuel mileage to engines running on diesel fuel. Auto ignition, fuel consumption, power output, and engine torque are relatively unaffected by biodiesel.

1.10 CARBON CYCLE

It is appropriate to mention here that the CO₂ releases by petroleum diesel was fixed from the atmosphere during the formative years of the earth,
whereas the CO₂ releases by biodiesel get continuously fixed by plants and may be recycled by the next generation crops (Fig.1.1). The carbon cycle time (i.e. for the fixation of CO₂ and release after combustion) of biofuel is quite small (few years) as compared to that of petroleum oils (few million years). A comparative assessment of the level of CO₂ released due to fuel combustion shows that the natural resource has deteriorated considerably due to the rapid growth in fossil fuel consumption. On complete combustion, the hydrocarbon molecule is converted into carbon dioxide and water. Replacing the petroleum diesel with biofuels could reduce the accumulation of CO₂ in the atmosphere. It is estimated that each litre of biofuels released 1.1 to 1.2 times the CO₂ released in the atmosphere by one litre of petroleum diesel. But CO₂ released from combustion of biofuels, will be recycled by future crops. That is, growing trees absorb the CO₂ in the atmosphere for photosynthesis. Oxygen and water are created as secondary products and are released back into the atmosphere. The plant uses glucose, in combination with nutrients absorbed from the soil, for growth and development. The following equation describes the carbon-based process in terms of a balanced chemical formula.

\[ 6\text{CO}_2 + 12\text{H}_2\text{O} \rightarrow C_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 + 6\text{H}_2\text{O} \]

Figure 1.1: Carbon cycle
1.11 OBJECTIVE OF THIS WORK

In the context of escalating problems of fuel (energy) crisis and environmental pollution, the renewable fuels such as biodiesels derived from vegetable oils are tried as substitutes/alternatives for diesel.

The oils selected for the study are Karanja, Jatropha, Sunflower, Palm and Waste cooking oil. All the oils were converted into their methyl esters by the transesterification process are karanja methyl esters (KME), jatropha methyl esters (JTME), sunflower methyl esters (SFOME), palm methyl esters (POME) and waste cooking methyl esters (WCOME).

An experimental set up was configured with necessary instruments to evaluate the performance, emission and combustion parameters of the compression ignition engine at different operating conditions and also prediction of cetane number for all methyl esters.

A single cylinder air-cooled four-stroke direct injection diesel engine (Kirloskar Engine) compression ratio of 17.5:1, developing 4.4 kW at 1500 rpm was used for this work. Experiments were conducted for the five different vegetable oils selected. The engine was run with five different blend ratios Viz. B20, B40, B60, B80 and B100 (% volume). The optimal values for performance, combustion and emission were determined for each of the oil and also effect of variation of cylinder pressures and combustion chamber design on performance, combustion and emission analysis.

1.12 ORGANISATION OF THE THESIS

Chapter 1 gives the introduction to various alternative fuels with a focus on biodiesel as fuel for diesel engines. Different types of vegetable oils, transesterification process, advantages and disadvantages of biodiesel and the present work are also briefly discussed.
Chapter 2 presents the review of the literature on the experimental work carried out in diesel engines by the researchers. A brief description of the work done on diesel engines giving emphasis on biodiesel and their corresponding findings are reported here.

Chapter 3 presents the preparation of biodiesel by transesterification process. The details of the esterification process and the properties of the oils selected are presented this chapter.

Chapter 4 presents the details of the experimental set up developed for the present work. The details of the experimental setup and the different instruments used for the evaluation of performance and measurements of emission are also discussed.

Chapter 5 presents about the development of correlations to predict cetane number for selected bio fuels. The bio fuels considered were karanja methyl esters (KME), jatropha oil methyl esters (JTME), sunflower methyl esters (SFOME), palm oil methyl esters (POME) and waste cooking oil methyl esters (WCOME).

Chapter 6 gives the discussion on the results of all the tested fuels. The important performance parameters such as specific fuel consumption, brake thermal efficiency, cylinder pressure, heat release rate and the emissions such as NOx, smoke density, carbon dioxide, carbon monoxide, hydrocarbons are discussed. This chapter also discuss about the variation of cylinder pressures and combustion chamber design on performance, combustion and emission analysis.

Chapter 7 presents the conclusions based on the experimental study. The optimum blend for each of the oils tested and the various emission levels are reported. It also provides the scope for further work.