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1.1 GENERAL

Industrialization and globalization have increased the automobile population in the recent years. Huge usage of fossil fuels reduced the carbon sources within a short span of time [1]. During 1970’s the Organization of Petroleum Export Countries (OPEC) implemented a series of price hike due to heavy demand for fuel which increases the cost of fuel, due to this reason the vehicles have to meet the increasingly stringent emission norms. By using various fossil fuels the carbon dioxide level has been increased from 250PPM to 380PPM. These emission levels are increasing drastically by burning the fuel which leads to greenhouse effect, acid rains, smog and global warming thought the world. These factors have made the researches to focus their attention on alternative and eco-friendly fuels that would help to reduce the import of crude oil, which will reduce the emission significantly.

The use of vegetable oil in diesel engine had been done by the father of diesel engine named Rudolf Diesel. He run his first diesel engine using peanut oil in 1900 [2, 3]. In early periods low cost of fossil fuel did not lend the hand to a large extent on utilizing vegetable oil or biodiesel. The whole consumption of the fossil fuel cannot be replaced by the vegetable oil. Rapid growth of pollution from vehicles makes the scientists to concentrate on pollution free fuels. Statistical data reveals that the available fossil fuels can withstand for about sixty years. The alternative fuels, have better characteristics like energy conservation, efficiency and environmental preservation. The bio fuels are an alternative solution for the worldwide petroleum crisis. Researchers in the world are working on several alternative sources in order to make a pollution free environment because diesel engines are the major sources for pollution. Some of the
energy sources are biomass, biogas, primary alcohols, vegetable oils and biodiesel are eco-friendly and they can be used directly in diesel engines by bringing the properties closer to diesel.

1.2 BIO-MASS

It is an organic matter produced by plants and aquatic derivatives. It can be considered as a renewable energy source because plant life renews and adds to itself every year. The word clearly signifies, biomass means organic matter. Biomass is classified into two categories, in which biomass in its traditional solid mass and biomass in its nontraditional form. The first type of biomass is to generate energy by direct conversion method. The second category is to convert the biomass into ethanol and methanol which can be used as a liquid fuel. The thermal plants run by biomass have advantages over coal and diesel fuel plants because the rate of emission gradually reduces when using bio fuels. When biomass is used directly in energy application without chemical processing it is combusted. Biomass can be converted into biofuels such as bioethanol, biodiesel and thermo chemical conversion products such as syn-oil, bio-syngas and biochemical’s.

Bio-mass has been a source of fuel used traditionally for many centuries in underdeveloped countries. In the developed countries, the application of bio-mass is increasing significantly and it plays an important source for combined heat and power generation. Our country accounts for one third of the total bio-mass consumption in the world, in which for household purpose nearly 80% of the rural people and 20% of the urban are using biomass. According to the present scenario about 3400MW of power could be
generated from sugar mills in India. Around 290 MW capacity power plants have already been commissioned and some more are under construction.

1.3 BIO-OIL

Bio-oil is formed by the process called pyrolysis. The input feed stock undergoes heating in the absence of oxygen to produce bio fuels. The raw materials are solid mass such as wood, house hold waste or agro waste. The end products such as gases and bio oil can be utilized as a fuel for generating energy when it undergoes combustion.

1.4 BIO-FUELS

Environmental pollution takes place mainly by transportation and agricultural sector which consumes more amounts of fossil fuels and it can be reduced by replacing mineral-based fuels by bio-origin. Bio-fuel is any fuel that is derived from bio-mass such as waste fruits, vegetables, living organism or their metabolic byproducts. In the next few years, due to its less pollution content the biofuel playas a vital role in the automobile area. The merits of bio-fuels are the following

- It can be generated easily from bio sources.
- Eco friendly.
- Free from pollution.
- Biodegradable.

Bio-fuels namely ethanol, methanol, bio-gas and vegetable oils are being used as an alternative to fossil fuels partially or fully in diesel engines.

1.5 BIO GAS

The generation of Biogas is by an aerobic digestion or fermentation process. The input material is plant waste, animal waste, agro waste, kitchen waste etc are utilized as
an input for the generation of biogas. In the gasifier these feed stock is undergone fermentation process in the absence of oxygen which liberates biogas, in which its major composition is methane.

Biogas can be produced by feeding energy crops such as maize silage or biodegradable wastes including sewage sludge and food waste. The process takes place in an air-tight tank which helps in the production of methane. The generation of biogas may varies depending upon the raw material which is used as an input. Biogas also contains water vapor. Highly compressed biogas is has been used in countries such as Sweden, Switzerland, and Germany. In early 2006 bio gas powered trains has been in service in Sweden.

1.6 VEGETABLE OIL

The father of diesel engine Dr. Rudolf planned to run the engine with different fuels like vegetable oils. But his first trial becomes a failure in the exhibition held at Paris when running with 100% vegetable oil. By using the vegetable oil as fuel the development of agriculture gives the employment for the farmers. Due to high viscosity of vegetable oil the combustion efficiency has been reduced when compared with the diesel. The fluctuating prices of crude oil focused the vegetable oils and animal fats to generate biodiesel for future generation.

The plantation of soybean in United States of America, Sunflower oil in India and palm oil in Malaysia are being considered as a substitute for Diesel fuel. The bio fuel must satisfy the operating conditions by giving better efficiency and it may fulfill the environmental protection. Bio diesel can give better efficiency than diesel fuel by
making minor modification in engine like dual fuelling, fuel injection modification and in fuel supply system like blending, microemulsion, cracking and viscosity reduction.

1.6.1 Jatropha Curcas

Jatropha is derived from the greek word which has been used for medical purpose. The plant can grow on hard soils where there is low rainfall, and it makes good income for the village people who involved in agriculture sector [4, 5, 6]. Rapid growth can be seen in terrestrial soils and it can prevent from erosion of soil. When jatropha is cultivated under optimum conditions, the grown trees produced about five kilogram of seed per year. Jatropha curcas gives yield for very long years on an average of 30 -60 years [7, 8].

Jatropha curcas belongs to spurge family which has been originated from Central America. It is a poisiouness species of flowering plant and cultivated in tropical and subtropical regions around the world reaching a height of 5.5m and has a resistance to with stand the heat, so it can be grown in deserts. The jatropha seeds contain 25 - 44% oil which can undergo esterification process to produce biodiesel, and can be substituted as a fuel in diesel engines [86]. Oleic, linoleic, palmitic and the stearic fatty acids are the major fatty acids present in jatropha seeds [9, 10]. The highest percentage of composition of oleic acid is 42.8% and linoleic acid is 32.8%.

1.6.2 Pongamia Pinnata

Pongamia pinnata is normally mentioned as Karanji in Hindi [11]. It grows about 12-30m height which spreads equally wide. In summer the leaves are soft and shiny. It starts flowering after 2 - 5 years. The flowers are purple in colour and finally it gives seeds which appear in brown colour. It’s a traditional Ayurvedic medicine which can be
used for treating various diseases. It is a medicinal plant native to Western Ghats and chiefly found in tidal forests of India [12, 13]. The tree has large number of uses, and it can be utilized for preparing medicines, but its major contribution is in production of biodiesel. The seeds have an average of about 30–38% oil with high percentage of polyunsaturated fatty acids [14]. If you analyze the medical history the karanji plays a vital role in Ayurvedha and Siddha systems of Indian medicine [15]. The entire plants are used for treating various diseases such as tumours, piles, skin diseases, itches, abscess, painful rheumatic joints wounds, ulcers, diarrhea etc [16].

1.6.3 Neem oil

It is an ever green tree which gives the vegetable oil from the seeds of Neem. The seeds are pressed and the oil is extracted by screw pressing. The oil is generally red in colour and it gives a bad odour. The oil has high triglycerides and it contains steroids. Neem oil is not used for cooking purposes but it plays a vital role in medical applications [17, 18]. The percentage oil received from the neem seeds vary from 25% to 45% and the oil is extracted by pressing the kernels under the standard temperature.

1.6.4 Rapeseed oil

It belongs to the family Brassicaceae, which is a flowering plant gives beautiful yellow flowers. The latin word named Brassicacea family of plants includes similar crops, such as mustard and cabbage. The seeds contain high oil content and it is rich in protein. Most of the world's rapeseed is grown in China, Canada and India [19]. Mainly rapeseed is grown for the production of biodiesel in addition to that it can be used for animal feed. In our country plantation is done in 15% of dry lands. Agriculture department has announced in the year 2000, in which rapseed takes its third place for producing huge
amount of vegetable oil in the world. The trucks and cars in European countries are expected to run with biodiesel in 2015.

1.7 BIODIESEL

It was introduced in the year 1990 by the United States of America which makes awareness for the whole world. It has been commercialized in various countries after its introduction. Methyl ester is a long chain fatty acid derived from vegetable oils and animal fats. The biodiesel is produced from different feed stocks in our country. The European country has implemented 95% tax reduction for using biodiesel in Diesel engines in order to reduce the emission from the year 1992. Major countries give suggestions to blend a small percentage of biodiesel with diesel for reducing the pollution when it undergoes combustion process. Now-a-days countries like India take necessary steps for the production of biodiesel for pollution free environment and mainly for rural employment.

The Planning Commission committee submitted its report in 2002, to generate methyl esters from non-edible oil which increase the economy in rural areas [20, 21, 22]. The committee suggested the government to blend 20% of biodiesel with diesel which can save over 12 million tons of diesel fuel. Methyl esters of biofuel have high energy, cetane number, heat of vaporization and stoichiometric air/fuel ratio with mineral diesel. Due to high viscosity large molecular components rises from triglycerides when it is compared with diesel. During combustion poor atomization occurs due to high viscosity which leads to larger droplets, which reduces the engine power output and fuel efficiency. The vegetable oils must undergo transesterification to remove the triglycerides which reduces the viscosity.
1.7.1 Biodiesel characteristics

The major difference when comparing with diesel and biodiesel is its presence of oxygen content. Normally biodiesel has large amount of oxygen content because of the presence of carbon in its molecular structure. The methyl ester normally contains of about 12 to 14% of oxygen [23, 24]. The boiling point of biodiesels is around 340°C, which makes close to diesel fuel. The flash and fire points of methyl esters are higher than the normal diesel fuel because of its increase in viscosity.

The properties of various biodiesel are indicated in Table 1.1. Due to low heating value and high viscosity the diesel fuel injection system affects the combustion when it is fuelled with biodiesel. When the engine under goes combustion with biodiesel higher temperature and pressure are generated, this produces more amount of nitric oxide emission in the engine exhaust. The cetane number of biodiesel is higher which causes the ignition delay between the start of injection and ignition when it undergoes combustion.

The investigations have been done in several countries including India show significant reduction in brake specific fuel consumption and brake thermal efficiency shoots up, which leads to considerable changes in exhaust gas emissions for different engine operating conditions when biodiesels were used as fuel in place of conventional diesel in direct injection diesel engines. For example, the literatures [25, 26] reported significant increase in brake specific fuel consumption, ignition delay and combustion duration, reduced power output, reduced brake thermal efficiency, reduced volumetric efficiency, higher exhaust gas temperatures, increased soot, CO₂, NOx, and smoke emissions when biodiesel was replaced with the conventional diesel fuel in diesel
The emissions of unburned hydrocarbons and CO were significantly reduced with the use of biodiesel. Some studies on biodiesel reported increased CO emissions at rated operating conditions. Vegetable oil is free from sulphur, so when it undergoes combustion sulphur oxide emission can be eliminated [27, 28]. The pollutants emitted from the engine exhaust when fuelled with biodiesel are due to combustion chamber design, operating conditions and fuel characteristics.
1.7.2 Rubber seed oil as bio-fuel

Our country plays a vital role in the production of rubber, in which Kerala is the leading state for rubber plantation. The rubber tree comes under the family of Euphorbiaceae [29]. The tree grows to a height of 25 to 35 meters which grows straight and has a light brownish straight bark. The leaf of the rubber tree divided into three segments with long stalks shown in Fig.1.1.

The tree gives latex on daily basis which is extracted from its trunk. The latex is of high cost. It is white in color with a high viscous liquid. The collected latex is solidified by using acid as a catalyst. The thickness of the latex is reduced by sending it in two rollers and finally it is dried. The latex plays a vital role in automobile industry for the manufacture of tiers and some rubber parts. The plant sheds their leaf in every year during the month of January and it starts growing from March which yields flowers. Flowers are small but appear in large clusters. However, the rubber tree also produces large volumes of seed, which is underutilized.
Fig. 1.1 Rubber plantations in farm with its seeds.

In our country 2.5 lack hectare of rubber plantation is available and it produces about thirty five thousand tones of seeds per year which generates oil of about five thousand four hundred tons per year. When the tree attains about three years it start flowering and gives seeds which is enclosed by a shell. The shell gets hard with increase in days. Initially it is green in color and at the final stage its color is in brown. When the seed gets matured the shell breaks out and the rubber seeds fall on the ground. The weight of the seed may vary about five gram and it gives a shining appearance which is indicated in Fig.1.2. The seeds are crushed and the kernels are separated and the oil is extracted by pressing and then it is filtered to remove the impurities. After the extraction of oil the husk which has high amount of protein can feed the cattle. Vegetable oils cannot be used directly in engines, because of high viscosity, so it must undergo transesterification process to bring the properties close to diesel fuel. Biodiesel is an oxygenated fuel made from vegetable oils and animal fats. It can be blended with diesel with any proportion with diesel to form a diesel blend and can be used as a fuel in diesel engines without any modification.
1.8 ORGANIZATION OF THESIS

The thesis comprises six main parts. The first part is a review of the literature on experimental studies of diesel engine running with biodiesels and its blends (Chapter 2). The second part provides a description of the experimental setup, and equipments with necessary instrumentation which is utilized for biodiesel production and optimization technique using Design of Experiment is carried out (Chapter 3). The third part describes the experimental setup and its technical specifications to study the influence of engine operating parameters and emissions parameters at different compression ratios (Chapter 4). The fourth part deals with the combustion and performance characteristics of diesel biodiesel blends in a single-cylinder four stroke direct injection engine for a compression ratio of 16:1, 18:1,20:1 & 22:1 (chapter 5). The fifth part deals with minor engine modification with the effect of injection pressure on performance and emission characteristics at different nozzle opening pressure (chapter 6). The sixth part deals with the improved engine performance and emission reduction by coating the piston with Copper, magnesium oxide and Nickel (chapter7). The conclusions drawn from this research and a list of recommendations for further work are presented in Chapter 8.

1.9 SUMMARY

In this chapter different types of biofuels such as Jatropha curcas, Pongamia pinnata, Neem, Rapseed, etc has been discussed in detailed, in addition to that the rubber seed oil which is used as an nonedible oil in this research has been explained in an elaborate manner. The various physico – chemical properties of biodiesel derived from different feed stock is shown in this chapter. The higher oxygen content of biodiesel
improves the combustion efficiency which compensates the lower calorific value.