A DISSERTATION ON

AN EXPERIMENTAL STUDY OF BIODIESEL AND DEE BLENDED DIESEL IN A CONSTANT SPEED CI ENGINE

Submitted in the partial fulfillment of the requirement for the
Award of degree of

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in

Thermal Engineering

Submitted by:

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CANDIDATE'S DECLARATION

I hereby declare that the project entitled "**AN EXPERIMENTAL STUDY OF BIODIESEL AND DEE BLENDED DIESEL IN A CONSTANT SPEED CI ENGINE**" submitted by me is an authentic work carried out under the supervision of **Dr. Amit Pal**, Associate Professor, Mechanical Engineering Department, Delhi Technological University, Delhi. This is also certified that this dissertation has not been submitted to any other Institute/University for the award of any degree or diploma.

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CERTIFICATE

This is to certify that the dissertation entitled **"AN EXPERIMENTAL STUDY OF BIODIESEL AND DEE BLENDED DIESEL IN A CONSTANT SPEED CI ENGINE"** submitted by Mr. Mohit Kumar (2K14/THE/12) in partial fulfilment of the requirement for the award of the Degree of Master of Technology in Thermal Engineering from Delhi Technological University, Delhi, is an authentic record of student's own work carried out by him under my guidance and supervision.

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ABSTRACT

Our nation is a developing country, it requires huge amount of energy resource for transportation and agriculture sector. At present diesel is the back bone of transportation and agriculture in India.

India imports up to 80% of its total requirement of crude oil from abroad, hence India is dependent upon gulf country for crude oil supply. So, the whole world is focusing on non-conventional energy source now a day because of depleting fuel reservoirs and increasing pollution.

The solution of these biggest problems of the whole world is alternative fuels. Di-ethyl ether (DEE) and biodiesel (BD) are considered two of the prospective transportation fuels recently. These are environmentally benign and have good safety. Di-ethyl ether is such a fuel of ethyl group having much similar fuel properties to diesel. High heating value of DEE is further plus point over other alternative fuels. Di-ethyl ether also has a high cetane number which makes it suitable for compression ignition engines.

The current study aims to analyse the use of waste cooking oil as an alternate fuel for CI engine, to know performance characteristics of mixed bio-diesel samples (blended with DEE) and to know the best fuel sample for the C.I engine as a fuel. The experiments were done with blends of Di-ethyl ether, waste cooking oil as a biodiesel and diesel in 10%, 15% and 20% ratio by volume. On comparing the performance and emission parameters using various blends, there was reduction in the major pollution agents CO, HC, NOx and negligible increase in CO_2. Further, combustion quality is improved when diesel is blended with Di-ethyl ether and waste cooking oil biodiesel because of extra oxygen availability. The performance parameters that measured are torque, power, brake specific fuel consumption, brake specific energy consumption, exhaust gas temperature and brake thermal efficiency. The results were comparable to Petro-diesel operation.

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INTRODUCTION

Diesel engines today have become a major source of transportation, power generation and marine applications, etc. Therefore, diesel is being used extensively in every place, but because of the gradual decrease in fossil fuel-reserves and the impact of huge environmental pollution; there is today an urgent need for suitable different fuels for C.I. engines. Because of this situation, Vegetable oils have become more attractive recently as a result of their environmental benefits as well as the undeniable fact that these are made from renewable resources. Vegetable oils are renewable, potentially inexhaustible source of energy with energy content almost close to diesel. More than 100 years ago, Rudolf Diesel tested vegetable oil as the fuel in a CI engine. With the advent of low cost petroleum, appropriate crude oil fractions were then refined to serve as fuel for engines and other motors. During 1930s and 1940s vegetable oils were also used as diesel fuel from time to time, but only in emergency conditions. Now, there has been a renewed focus on the use of each vegetable oil and biodiesel fuel.

A different kind of vegetable oil and bio-diesel have been timely tested in diesel engines. Its characteristics for reducing greenhouse emissions, its assistance on reducing a country's reliance on fossil fuel imports, and its supportive characteristic for giving a new marketplace for domestic crops in agriculture, additionally its effective lubricating property that eliminates the requirement of any lubricating additive and its wide acceptance to vehicle makers may be listed as the most important benefits of the bio-diesel fuel. There are over 350 oil-bearing crops identified, out of which only sunflower, safflower, soya bean, cottonseed, rapeseed, waste cooking oil and peanut oils are only being thought of potential alternative fuels for diesel engines.

The current study aims to analyse the use of waste cooking oil as an alternate fuel for CI engine, to know performance characteristics of mixed biodiesel samples (blended with DEE) and to know the best fuel sample for the CI engine as a fuel.

DEE, also known as Diethyl ether, sulphuric ether, simply ether, or ethoxy-ethane, is an organic compound in the ether class with the formula $(C_2H_5)O$. It is a colourless, extremely volatile combustible liquid. It's generally used as a solvent and was once used as a general anaesthetic. It also has narcotic properties and has also been noted to cause temporary psychological addiction, namely referred to as ether mania. It is having the properties, Density: 713.40 kg/m³, Formula: $(C_2H_5)O$, Boiling point: 34.6 °C, Molar mass: 74.12 g/mole, Melting point: -116.3 °C, IUPAC ID: Ethoxy-ethane.

These days the automobiles have become an integral part of our life, specially the IC engine. Every one of us uses IC engine for transportation purpose, for the electricity production use in different fields like agriculture etc. or to run a mechanical machine. The conventional fuels in the IC engine are diesel and gasoline. Di-Ethyl ether is also such a kind of fuel which can be easily blended with biodiesel as well as diesel and can also be used to run a SI engine. Many research scholars reported that DEE has very good fuel properties and its blending with any biodiesel and diesel improves the combustion properties of the diesel and may additionally improve the emission characteristics of the diesel.

To test the mix of the biodiesel, diesel and the DEE here, we are using one cylinder diesel engine which has the facility to change the fuel, has fuel consumption indicator and emission analyser. A software Engine-soft is used to record the data on the computer and to improve the accuracy level.

1.1 OBJECTIVES

- Optimization of the molar ratio in biodiesel production.
- To investigate the performance characteristics of WCO biodiesel, diesel and DEE blends.
- To investigate the emission characteristics of WCO biodiesel, diesel and DEE blends.

1.2 NEED OF ALTERNATIVE FUELS

The motivation for development and production of the alternative fuel are following:

1.2.1 Depleting oil reservoirs:

The gasoline and diesel are obtained from petroleum. These are explored from the crust of the earth. But the amount of petroleum in the crust of the earth is limited and approximately non-renewable, hence these oil reserves are depleting with a very high rate. When these reservoirs would completely extinct, at that time we would have neither gasoline nor diesel to run automobiles so an alternative fuel should be there to decrease dependence on gasoline and diesel. In a country like ours, the 80% of fuel country using is imported which is one of the main reasons of such a high trade deficit. In the present situations of increased terrorism and arm rebellion, it is very difficult to have assurance about the regular supply of oil. Also, the price of oil may fluctuate. So it becomes much important for us to switch to non-conventional fuel and solve these problems permanently. Oil depletion is the decline in oil production of a well, oil field, or geographic area responsible for its production. Hubbert curves predict that the production curve of non-renewing resources is approximate a bell curve. Thus, according to this theory, when the peak of production is passed, production rates enter an irreversible decline.

The United States energy information administration predicted in 2006 that world consumption of oil would increase to 98.3 million barrels per day (15,630,000 m3/d) (mbd) in 2015 and 118 million barrels per day in 2030. With 2009 world oil consumption at 84.4 mbd, reaching the projected level of consumption of 2015 would represent an average annual increase of 2.7% per year between 2009 and 2015.

Individual oil wells are usually within multi-well oil fields. As with individual wells, the production curves for oil fields vary depending on geology and how they are developed and produced. Some fields have symmetric bell-shaped production profiles, but it is more common that the period of inclining production is briefer and steeper than the subsequent decline. More than half the production usually occurs after a field has reached a peak or plateau. Production profiles of many fields show distant peaks, but for giant oil fields, it is more common for production to reach and maintain a plateau before declining. Once a field declines, it usually follows an exponential decline. As this decline levels off, productions can continue at relatively low rates. A number of oil fields in the U.S. have been producing for over 100 years.

Most oil is found in a small number of very large oil fields. According to Hubbert peak theory, production starts off slowly, rises faster and faster, then slows down and flattens until it reaches a peak, after which production declines. In the late stage, production often enters a period of exponential decline in which the decline become less and less steep. Oil production may never actually reach zero, but eventually becomes very low.

1.2.2 High emissions:

A very large amount of CO_2 is emitted by automobiles using gasoline and diesel as fuel. Other gases are also emitted like NOx, CO and unburned hydrocarbons which are very injurious to health. To reduce the emission of these harmful gases a much cleaner fuel is needed which has good combustion properties as well as low emission characteristics. Air pollution is the introduction of particulates, biological molecules, or other harmful gases into Earth's atmosphere, causing disease, death to humans, damage to other living organisms such as food crops, or the natural or built environment. Air pollution may come from anthropogenic or natural sources.

The atmosphere is a complex natural gaseous system that is essential to support life on planet Earth. Stratospheric depletion due to air pollution has been recognized as a threat to human health as well as to the Earth's ecosystems. Indoor air pollution and urban air quality are listed as two of the world's worst pollution problems in the 2008 Institute World's Worst Polluted Places report. According to the 2014 WHO report, air pollution in 2012 caused the deaths of around 7 million to people worldwide.

An air pollutant is a substance in the air that can have adverse effects on humans arid the ecosystem. The substance can be solid particles, liquid droplets, or gases. A pollutant can be of natural origin or man-made. Pollutants are classified as primary or secondary. Primary pollutants are usually produced from a process, such as ash from a volcanic eruption. Other examples include monoxide gases from motor vehicle exhaust or the Sulphur dioxide released from factories. Secondary pollutants are not emitted directly. Rather, they form in the air when primary pollutants react or interact. Ground level ozone is a prominent example of a secondary pollutant. Some pollutants may be both primary and secondary: they are both emitted directly and formed from other primary pollutants.

Particulates, alternatively referred to as particulate matter (PM), atmospheric particulate matter, or fine particles, are tiny particles of solid or liquid suspended in a gas. In contrast, aerosol refers to combined particles and gas. Some particulates occur naturally, originating from volcanoes, dust storms, forest and grassland fires, living vegetation, and sea spray. Human activities, such as the burning of fossil fuels in vehicles, power plants and various industrial processes also generate significant amounts of aerosols.

Averaged worldwide, anthropogenic aerosols, those made by human activities currently account for approximately 10 percent of our atmosphere. Increased levels of fine particles in the air are linked to health hazards such as heart disease, altered lung function and lung cancer.

1.2.3 Performance and maintenance of engine:

The diesel fuel needs some additives and if these additives are not added to the diesel the performance of engine decreases. The problem of knocking is a major problem that is caused if no additive is added into diesel. Some alternative fuels like Diethyl ether have the ability to solve these problems.

1.3 ALTERNATIVE FUELS

The major alternative fuels for an internal combustion engine are Biodiesels, Alcohols and Hydrogen. Renewable type of fuel can be used in an internal combustion engine. These all are:

1.3.1 Bio diesel:

Now, the present time Biodiesel is attracted for all as an alternative fuel, non-toxic, bio-degradable. Biodiesel is generally produced by the process of transesterification of vegetable oil or animal fat or waste cooking oil and many renewable resources with short chain alcohol such as methanol or ethanol. In the Biodiesel, found the percent of oxygen content is more as compared to the petroleum or diesel. Due to its use in internal combustion engines, diesel engines have to show great reductions in the emission of particulate matter, carbon monoxide, sulphur, poly-aromatics, hydrocarbons, smoke, nitrogen oxide, and noise. Since vegetable oil base fuel is made from agricultural used or raw materials which are produced by the process of photosynthetic carbon fixation, these do not contribute to net atmospheric carbon-dioxide levels on burning.

The Biodiesel can be differentiated into two categories on the basis of their source.

- Biodiesel from plants: Plants like jatropha have an ability to produce bio-diesel. After some synthesis, this fuel can be used as diesel in internal combustion engine. But our country has a very large population and we have very limited agricultural land. If we utilize this land to grow these plants, then food supply will be affected so this is not much suitable in a country like India.
- Biodiesel from eatable oils: after some chemical and physical reactions, the eatable oils can be converted into the biodiesel. But our country imports a large amount of eatable oil annually to fulfil its demand so we can't even think of this conversion.

1.3.2 Hydrogen:

No doubt hydrogen is the best available fuel on earth. Hydrogen has the highest calorific value and it is more clean fuel, produces pure water as the emission. But the process of combustion of hydrogen requires very high-quality equipment so the cost becomes so high which is not suitable from automobile point of view. Hydrogen fuel is a zero-emission fuel which uses electrochemical cells to provide combustion in internal engines, to power vehicles and electric devices. It is also used for propulsion of spacecraft and might potentially be mass-produced and commercialised for passenger vehicles and aircraft. Hydrogen lies in the first group and first period in the periodic table, i.e. it is the first element on the periodic table, making it the lightest element. Since hydrogen gas is so light, it rises in the atmosphere and is therefore rarely found in its pure form, H_2. In a flame of pure hydrogen gas burning in air, the hydrogen (H_2) reacts with oxygen (O_2) to form water (H_2O) and releases energy. If carried out in atmospheric air instead of pure oxygen (as is usually the case), hydrogen combustion may yield small amounts of nitrogen oxides, along with the water vapour.

The energy released enables hydrogen to act as a fuel. In an electrochemical cell, that energy can be used with relatively high efficiency. If it simply is used for heat, the usual thermodynamic Carnot limits on the thermal efficiency apply.

Since there is very little free hydrogen gas, hydrogen is in practice only an energy carrier like electricity, not an energy resource. Hydrogen gas must be produced, and that production always requires more energy than can be retrieved from the gas as a fuel later on. This is a limitation of the physical law of the conservation of energy. Hydrogen production induces environmental impacts.

1.3.3 Alcohols:

Throughout history, alcohols have been used as a fuel. The first four aliphatic alcohols (methanol, ethanol, butanol and propanol) are of interest as fuels because they can be synthesized chemically or biologically, and they have characteristics which allow them to be used in internal combustion engines. The general chemical formula for alcohol fuel is $C_nH_{2n+1}OH$.

Most methanol is produced from natural gas, although it can be produced from biomass using very similar chemical processes. Ethanol is commonly produced from a biological material through fermentation processes. However, ethanol that is derived from petroleum should not be considered safe for consumption as the mixture contains about 5% methanol and may cause blindness or death. Bio-butanol has the advantage in combustion engines in that its energy density is closer to gasoline than the simpler alcohols (while still retaining over 25% higher octane rating); however, bio-butanol is currently more difficult to produce than ethanol or methanol. When obtained from biological materials and/or biological processes, they are known as bio-alcohols (e.g. "bioethanol"). There is no chemical difference between biologically produced and chemically produced alcohols.

One advantage shared by the four major alcohol fuels is their high octane rating. This tends to increase their fuel efficiency and largely offsets the lower energy density of vehicular alcohol fuels (as compared to petrol/gasoline and diesel fuels), thus resulting in comparable "fuel economy" in terms of distance per volume metrics, such as kilometres per litter, or miles per gallon.

Alcohols are basically extruded from waste biomass like an agricultural waste. Alcohols have good fuel properties and can easily blend with gasoline. As these are extruded from waste so they help in waste management. The combustion of alcohols doesn't need any extra arrangement so these fuels are cost-effective. Also, the storage and transportation are also very easy.

1.3.4 Butanol:

Butanol is a four-carbon alcohol. The chemical formula of Butanol is C_4H_9OH. The butanol is present in four type of isomeric structure. The butanol produced by the biological process is known as bio-butanol.

The most of the butanol is produced commercially from fossil fuels. The mostly used reaction is the hydroformylation reaction, to form butyraldehyde. This reaction starts with propane (propylene), but dehydrators produced are then reacted with hydrogen and form 1-butanol and or 2-butano1.The reaction with isobutene produces the propylene oxide along with tert-butanol.

Another way of butanol production is by fermentation reactions. In fermentation, bacteria reduce the biomass into butanol. This method is mostly used before 1950 and at that time Clostridium acetobutylicum was used for fermentation processes to produce Butanol at the industrial level. There are some other microorganisms that can produce butane.

The butanol can be used as a fuel in an IC engine without any modification because its properties are much similar to diesel. The butanol has a four link hydrocarbon chain and possesses the good fuel properties.

The butanol is toxic in nature but not much toxic like other alcohols so it is safe to work with butanol as compared to other alcohols. The exposes to butanol are only minor skin irritation and minor eye irritation. So butanol can be used without much security concern.

1.3.5 Di-Ethyl ether (DEE):

The research on diethyl ether (DEE) as an alternative fuel produced great enlightenment. DEE contains oxygen element and has no C–C bonds, which therefore helps to achieve smokeless combustion that is superior to with a diesel fuel even without high-pressure injection or turbocharger .DEE can be produced by dehydration of bio-ethanol, a renewable fuel. DEE has long been recommended as a cold starting additive in diesel engines and gasoline engines due to its low autoignition temperature and high volatility. The properties of DEE permit it to be used as a compression ignition engines either as a neat fuel or as a blend with diesel. The autoignition temperature of DEE is lower than diesel. DEE has a high cetane number of greater than 125. Its heating value is comparable to that of diesel. The latent heat of vaporization is higher than diesel. DEE is liquid at room temperature which reduces handling and storage problems. DEE is also non-corrosive compared to alcohols. The properties which need concern are high flammability and poor storage stability. DEE also poses human health problems due to its anaesthetic effect. DEE has low heat release rates during early cool flame generation but has typical heat release rates for mid-stage blue flame oxidation. Experiments suggested that DEE may interact with aromatics in diesel fuel, delaying the onset of ignition. A mixture of 4% toluene in DEE resulted in an ignition delay of 4 to 5 milliseconds before the ether ignited. Used as a cold starting aid, DEE apparently acts as a neat fuel and not in combustion with the diesel fuel.

Chapter - 2

LITERATURE SURVEY

Before carrying out any experiment it is very important to know each and everything about the process, experimental setup, important parameters and the important properties which affect the result of the experiment. For this purpose research paper published by other authors in this area are the best sources. These sources are authentic and reliable, and provide a global perspective over the concerned area. In this chapter, the important outcomes of the various research journals are mentioned which I have referred to understand this experimental work.

2.1 FUEL PROPERTIES

Table 2.1 Comparison of properties of potential CI engine fuel components[3,6,14]

Property	Diesel	Dimethyl Ether	Diethyl Ether	Biodiesel
Boiling point ^{0}C	146-374	-25	34.44	182-337
Cetane number	40-55	>55	>125	46-55
Autoignition temperature ^{0}C	315.55	350	160	373-448
Flash point^{0}C	56-75	-41	-45	165
Stoichiometric Air/fuel Ratio	15.0	8.9	11.1	13.8
Lower heating Value, kJ/kg	43000	28191.12	35400.14	37500
Kinematic Viscosity 40 ^{0}C cSt	3.2	-	0.24	4.5
Density , kg/L	820-950	713	714	815-890
Energy Density (MJ/L)	35.8	19.3	20.6	23.4

2.2 BIODIESEL PRODUCTION

Biodiesel is generally produced by the process of trans-esterification of vegetable oil or animal fat or waste cooking oil and many renewable resources with short chain alcohol chemical process such as methanol or ethanol. Since vegetable oil base fuel is made from agricultural used or raw materials which are produced by the process of photosynthetic carbon fixation do not contribute to net atmospheric carbon-dioxide levels on burning.

2.2.1 Biodiesel synthesizing process:

There are different processes which can be used to synthesize biodiesel are given below:

1. **Direct Use and Blending:** The direct use of vegetable oils in IC engine is not favourable and problematic because it has many inherent failings in doing that. Even though the vegetable oils have familiar properties same as biodiesel fuel, it require some chemical modification before same can be used into the engine. It has only been researched extensively for the last couple of decades, but has been experimented with for almost hundred years. Although some diesel engine can run pure vegetable oils, turbocharged direct injection engine such as trucks are prone to many problems. Energy consumption with the use of pure vegetable oils was found to be similar to that of diesel fuel. For short term use, ratio of 1:10 to 2:10 oil to diesel has been found to be successful.
2. **Emulsion Process:** The problem of the high viscosity of vegetable oils was solved by microemulsions with solvents such as methanol, ethanol, and 1-butanol. Micro-emulsion is defined as a colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1-150 nm range formed spontaneously from two normally immiscible liquids and one or more ionic or non-ionic amphiphiles. The components of a biodiesel microemulsion include diesel fuel, vegetable oil, alcohol, and surfactant and cetane improver in suitable proportions. Alcohols such as methanol and ethanol are used as viscosity lowering additives, higher alcohols are used as surfactants and alkyl nitrates are used as cetane improvers. Microemulsions can improve spray properties by explosive vaporisation of the low boiling constituents in the micelles. Micro-emulsion results in a reduction in viscosity, increase in cetane number and good spray characters in the biodiesel. However, continuous use of micro-emulsified diesel in engines causes problems like injector needle sticking, carbon deposit formation and incomplete combustion.
3. **Pyrolysis:** Pyrolysis can be defined as the conversion of one substance into another by means of heat in the absence of air (or oxygen) or by heat in the presence of a catalyst which results in cleavage of bonds and formation of a variety of small molecules. The pyrolysis of vegetable oil to produce biofuels has been studied and found to produce alkanes, alkenes, alkadienes, aromatics and carboxylic acids in various proportions. The

equipment for thermal cracking and pyrolysis is expensive for modest biodiesel production, particularly in developing countries. Furthermore, the removal of oxygen during the thermal processing also removes any environmental benefits of using an oxygenated fuel. Another disadvantage of pyrolysis is the need for separate distillation equipment for separation of the various fractions. Also, the product obtained is similar to gasoline containing sulphur which makes it less eco-friendly. Pyrolytic chemistry is difficult to characterize because of the variety of reaction path and the variety of reaction products that may be obtained from the reaction occur. The pyrolyzed material can be vegetable oils, animal fats, natural fatty acids and methyl esters of fatty acids.

4. **Trans-esterification:** The most common way to produce biodiesel is the transesterification method, which refers to a catalyzed chemical reaction involving vegetable oil and alcohol to yield fatty acid alkyl esters (i.e., biodiesel) and glycerol. The reaction requires a catalyst, usually a strong base, such as sodium and potassium hydroxide or sodium methylate. A catalyst is usually used to improve the reaction rate and the yield. Since the reaction is reversible, excess alcohol is used to shift the equilibrium to the product side. Especially methanol is used as alcohol because of its low cost and its physical and chemical advantages. Methanol can quickly react with vegetable oil and NaOH can easily dissolve in it. To complete a transesterification reaction stoichiometrically, a 3:1 molar ratio of alcohol to triglycerides is necessary. In practice, the ratio needs to be higher to drive the equilibrium to a maximum ester yield (Sarıbıyık et al., 2012; Antony Raja et al., 2011). The triglycerides are reacted with a suitable alcohol (Methyl, Ethyl, or others) in the presence of a catalyst under a controlled temperature for a given length of time. The final products are Alkyl esters and Glycerin. The Alkyl esters are the main product and the Glycerin, is a byproduct.

2.2.2 Factors Affecting Biodiesel Production by Trans-esterification:

1. **Temperature:** The reaction temperature is the important factor that will affect the yield of biodiesel. For example, higher reaction temperature increases the reaction rate and shortened the reaction time due to the reduction in viscosity of oils. However, the increase in reaction temperature beyond the optimal level leads to a decrease of biodiesel yield, because higher reaction temperature accelerates the saponification of triglycerides and causes methanol to vaporize resulting in decreased yield. Usually, the trans-esterification reaction temperature should be below the boiling point of alcohol in order to prevent the alcohol evaporation. The range of optimal reaction temperature may vary

from 50°C to 60°C depends on the oils or fats used. Therefore, the reaction temperature near the boiling point of the alcohol is recommended for faster conversion by various works of literature. At room temperature, there is up to 78% conversion after 60 minutes.

2. **Reaction Time:** The increase in fatty acid esters conversion observed when there is an increase in reaction time. The reaction is slow at the beginning due to mixing and dispersion of alcohol and oil. After that, the reaction proceeds very fast. However, the maximum ester conversion was achieved within < 90 min. Further increase in reaction time does not increase the yield product i.e. biodiesel/monoalkyl ester. Besides, longer reaction time leads to the reduction of the end product (biodiesel) due to the reversible reaction of transesterification resulting in loss of esters as well as soap formation.
3. **Methanol to Oil Molar Ratio:** One of the most important parameters affecting the yield of biodiesel is the molar ratio of alcohol to triglyceride. Stoichiometrically 3 moles of alcohol and 1 mole of triglyceride are required for transesterification to yield 3 moles of fatty acid methyl/ethyl esters and 1 mole of glycerol is used. It is varied from 5.6 – 7.8:1 for both the catalyst systems. Biodiesel yield could be elevated by introducing an excess amount of methanol to shift the equilibrium to the right-hand side.
4. **Type of Catalyst:** Biodiesel formation is also affected by the concentration of catalyst. Most commonly used catalyst for biodiesel production is sodium hydroxide (NaOH) or Potassium hydroxide (KOH). The type and amount of catalyst required in the trans-esterification process usually depend on the quality of the feedstock and method applied for the trans-esterification process. The yield of fatty acid alkyl esters generally increases with increasing amount of catalyst.
5. **Free Fatty Acid:** The value of free fatty acid is less than 2 it directly trans-esterification in single stage and when the value of free fatty acid is more than 2 it trans-esterification in two stages. The process of find the value of trans-esterification we make the solution of sodium hydroxide and distilled water. After this process methanol is added into the mixture and two three drop of phenolphthalein in the mixture. The chemical reaction occurs by the help of catalyst concentration to the mixture till it turns into pink colour and checks the free fatty acid contents into the table. Then after this process filter the impurities. The solution of methyl alcohol and potassium hydroxide is now mixed into the vegetable oil. And then after it can be solved by different separation methods and at last wash with water to obtain purest form of biodiesel.

2.3 UTILIZATION OF WASTE COOKING OIL BIODIESEL IN CI ENGINES

Waste cooking oils are one of the alternative sources than other higher grade oils or refines oils. Waste cooking oil can easily be collected from industries such as domestic usage, chips maker factories, hotels, marriage places and restaurant and also cheaper in cost than other oils. We can reduce the cost of biodiesel production by using these oils as the raw material. The advantages of using waste cooking oils are to produce biodiesel at low cost and control the environment pollution. Due to the high cost of disposal, many individuals dispose waste cooking oils to the environment in the rural area. So that, the use of waste cooking oils is an effective way to reduce the cost of biodiesel production. Use of the cooking oil has sufficient potential to be used as fuel that is its flash point, cetane number, viscosity and many physical properties to the compression ignition engines. The kinematic viscosity of used cooking oil is about 10 times greater and its density is about 10% higher when compared to diesel and gasoline. These properties play an important role in the combustion so that they must be modified primarily to the use of cooking oil in the engine. Many of techniques have been developed for reducing the properties of kinematic viscosity and specific gravity of vegetable oils in which include pyrolysis, emulsification, leaning and trans-esterification. Above these techniques trans-esterification is the best and easy technique because of the fact that this method is easy to carry out under normal conditions and the best conversion efficiency and faster technique is achieved.

Fuel modification, modification of combustion chamber design and exhaust after treatments are the important means to alleviate such emissions. In this context, engine researchers are hunting for suitable alternative fuels to the diesel engine. These fuels can either be used as a blend with conventional diesel/biodiesel fuel or as an additive or as a neat fuel. The presence of oxygen in the fuel molecular structure plays an important role to reduce PM and other harmful emissions from the diesel engine. Particulate matter (PM) or smoke emission and oxides of nitrogen (NO emissions) are the two important harmful emissions in the diesel engine. Fuel companies and the researchers around the world are devoted to reduce such emissions with different ways.

2.4 UTILIZATION OF DI ETHYL ETHER (DEE) IN CI ENGINE

DEE is the simplest ether, and it has been considered as an automotive fuel. It has been used in a low-pressure gaseous state as ignition improver of Ethanol. DEE properties are similar to that of LPG in that it is a gas at ambient temperature and atmospheric pressure. It became a colourless, clear liquid at ambient temperature or at atmospheric pressure. Thus, DEE can be transported and stored as a liquid at low temperature. DEE is a clean fuel that contains no sulphur or nitrogen compounds, has extremely low toxicity for humans and has no corrosive effects on metals.

In the 1990s, DEE was produced worldwide in quality of 100,000 to 150,000 tons per annum. DEE can be used as a replacement for diesel fuel as DEE has a high cetane value, contains oxygen so that its combustion is not accompanied by black smoke or soot. This property has attracted considerable interest in DEE as a clean fuel. DEE can also be used in the same domestic application as LPG as well in an extremely wide range of industrial applications, such as a high-efficiency power generation fuel, for example, gas turbine powered generators.

DEE contains oxygen and no carbon molecules, thus seriously limiting the possibility of forming carbonaceous particulate emissions during combustion. When used as a CI engine fuel, DEE provides reduced NOx and PM emissions. Its unique auto-ignition qualities due to the very high cetane number could be best utilized by high-pressure ignition of liquid DEE directly into the CI engine cylinders.

2.5 LITERATURE SURVEY

Various literature that has been taken as reference for this study is as follows:

Geo et al. [1] conducted experiments on a Kirloskar single cylinder cool, direct injection, four-stroke diesel engine that run at a constant speed and variable load conditions used for agricultural purpose with rated output of 4.4 kilowatt at 1500 revolutions per minute and converted to work in the DEE injection mode. DEE was injected into the intake port throughout suction stroke, whereas rubber seed oil was injected directly within the cylinder at finish of compression stroke. Their results indicated that the brake thermal efficiency of the engine was improved from 26.5% with neat RSO to a most of 28.5% with DEE injection rate of 200 g/h. Smoke was reduced from 6.1 to 4 BSU with DEE injection at the maximum efficiency flow rate. Hydrocarbon and carbon monoxide gas emissions were also less with DEE injection. There was a rise in the NOx emission from 6.9 g/kWh to 9.3 g/kWh at the optimum DEE flow rate. DEE injection with RSO showed higher peak pressure and rate of pressure rise compared to neat RSO. Heat release rate indicated a rise in the combustion rate due to the reduced ignition delay and combustion duration with DEE injection. In this experimental work, RSO was taken as the main fuel and DEE as the ignition improver in a diesel engine. India is the fourth largest producer of natural rubber. Apart from supplying natural rubber, tree also provides a variety of ancillary product, prominent being rubber seeds from that the oil can be extracted. Except for some application in soap and lubricating oil industries, use of rubber seed oil is limited. Its availability of 150 kg/ hectare is lower compared to many prominent bio-diesel sources like jatropha curcas. This is often mainly due to its high demand for rain, humidity and bright sun light. Rubber seed oils were reported to have 17–20% saturated fatty acids and 77–82% unsaturated fatty acids.

Sivalakshmi and Balusamy [2] carried out an experimental investigation to judge the impact of using diethyl ether as additive to biodiesel on the combustion, performance and emission characteristics in an unmodified diesel engine at different loads and constant engine speed. Their results indicated during this investigation that the addition of diethyl ether into biodiesel improved the physicochemical properties of biodiesel. The peak cylinder pressure and peak heat release rate was higher for BD5 than alternative fuel blends and neat biodiesel. With the addition of diethyl ether into biodiesel, the brake thermal efficiency and brake specific fuel consumption was improved with the use of BD5. The CO and smoke emissions were found lower for BD5 compared to those of other fuel blends and biodiesel. The NOx emission was higher for BD5 compared to that of neat biodiesel. The HC emissions were higher for all the biodiesel–diethyl ether blends compared to those of biodiesel at all loads. Hence, they observed that addition of diethyl ether up to 5% (by vol.) would be a promising technique for using biodiesel efficiently in diesel engines with none modifications in the engine.

Sezer [3] investigated the use of dimethyl ether and diethyl ether in diesel engines as alternative fuels. A direct injection diesel engine was simulated via a thermodynamic cycle model for investigation. Thermodynamic and performance parameters besides emissions were determined and compared for diesel, dimethyl ether and diethyl ether fuels at two different states. The results showed that dimethyl ether and diethyl ether presented a lower cylinder temperature and pressure, and thus a lower engine performance than diesel fuel for the equal injection conditions. The brake power was declined about 32.1% and 19.4% at 4200 rpm while brake specific fuel consumption was increased about 47.1% and 24.7% at 2200 rpm for dimethylether and diethylether, respectively. Engine performance for dimethyl ether and diethyl ether was extensively improved for the same equivalence ratio condition, but a more amount of fuel was needed about 64% for dimethyl ether and 32% for diethyl ether. The gains in the brake power by dimethyl ether and diethyl were about 13.6% and 6% at 4200 rpm compared to diesel fuel. The brake specific fuel consumption was also higher about 43.5% for dimethyl ether and 23.6% for diethyl ether than diesel fuel. The brake thermal efficiency for dimethyl ether and diethyl was generally found better than diesel fuel. The lower carbon dioxides were obtained by dimethyl and diethyl ethers at all conditions, while carbon monoxide and nitrogen oxide were slightly higher for dimethyl and diethyl ethers at equal equivalence ratio condition.

Ashok and Saravanan [4] carried out investigations to review the performance and emission characteristics of adding diethyl ether as an oxygenated additive with the chosen ratio of 70D:30E. For this experiment, a single-cylinder, four-stroke, water-cooled diesel engine was used. Along with the emulsified fuel 70D:30E , the oxygenated additive diethyl ether was added on a 10th by volume basis.

Conclusions were made are followings:

- Use of emulsified fuel increases the brake thermal efficiency and reduces the specific fuel consumption, smoke density, and particulate matter. However, there's much rising of NOx.
- Addition of diethyl ether to the emulsified fuel improves the performance and reduces the emissions. It additionally reduces the NOx and ignition delay.
- Higher brake thermal efficiency is achieved by the diethyl ether added emulsified fuel. Brake thermal efficiency increases from 365 days (emulsified fuel) to 38th (diethyl ether added emulsified fuel).
- Lower specific fuel consumption is achieved by the diethyl ether added emulsified fuel. There's a difference in the specific fuel consumption of 0.068 kg/kW h between the diethyl ether added blended fuel and the emulsified fuel.
- The best decrease within the smoke density value is obtained for the diethyl ether added emulsified fuel than the other two fuels. The value for the diethyl ether added emulsified fuel and the emulsified fuels are 9 and 13.4 HSU, respectively.
- Particulate matter emission is low at lower outputs and equal to the emulsified fuel values at higher outputs for the diethyl ether added emulsified fuel.
- The NOx value is drastically reduced because of the diethyl ether additive. it is usually higher for the emulsified fuel. It is reduced from 653 to 240 ppm (parts per million) for 70D:30E emulsified fuel and the diethyl ether accessorial emulsified fuel, respectively.

Phan and Phan [5] carried out alkali-catalysed trans-esterification of waste cooking oils, collected within Ho Chi Minh City, Vietnam, with methyl alcohol in a laboratory scale reactor. The result of methanol/waste cooking oils proportion, potassium hydroxide concentration and temperature on the biodiesel change were examined. Their results revealed that the biodiesel experienced a higher but much narrower boiling range than conventional diesel.

Although being collected from dissimilar sources, there was little variation in properties among the WCO samples in terms of chemical and physical properties. This could then help the implementation of biodiesel production procedure from waste cooking oils. In this study, biodiesel production from the WCO was conducted out in the laboratory scale reactor. The results disclose that the highest yield of biodiesel was possess at the proportion of methyl alcohol/WCO of 7:1– 8:1 during 80–90 minute at temperatures ranging 30–50 ^oC in the presence of 0.75 wt% KOH. Although most of the physical properties of the biodiesel were within standards for diesel fuel and for bio-auto fuels (EN14214), the carbon residue was much higher in the biodiesel than in diesel. The carbon remains was 4.0 wt% for the biodiesel but only 0.05 wt% for diesel. Furthermore, the volatility characteristics of the biodiesel were much different to that of diesel as clearly projected in the distillation curve. There was a very narrow order of boiling temperature for biodiesel. The boiling temperature remained nearly 330 ^oC from 20 vol% to 70 vol% fractionate.

Mixing the biodiesel with diesel improved significantly the volatility and decreased the carbon deposits at a percentage of biodiesel in the mix below 50 vol%. The effect obtained revealed that the blend of 20 vol% the biodiesel and 80 vol% diesel (B20) could be applied in engines without greater modification.

In view of improving the combustion, reducing the pollutants and to improve the performance of diesel engines, **Banapurmath et al. [6]** conducted experimental investigations on a single cylinder four stroke direct injection water cooled diesel engine using ethyl alcohol and diethyl ether blended fuels in distinct volume ratios with diesel fuel. The experimental study was executed with four different mix of ethyl alcohol (E0 -pure diesel, E5, E10, E15 and E20) and diethyl ether (DEE0 - pure diesel, DEE5, DEE10, DEE15 and DEE20) to assess the impact of using ethanol and diethyl ether-diesel mix on diesel engine performance, combustion and emissions. For the same rated speed and compression proportion, distinct blended fuels as well as pure diesel, different engine parameters like brake thermal efficiency, fuel consumption, combustion parameters such as peak cylinder pressure, exhaust emissions like smoke opacity, hydrocarbon, CO, and NOx, were measured. The results shown that

- For diesel and alcohol fuelled mix in diesel engine, the BTE tell increasing trend with increased mix ratio of alcohol in diesel up to 20% in usual and with DEE-diesel in specific. Compared to pure diesel both alcohol-diesel blended fuels showed improved performance in terms of increased BTE.

- HC, CO and smoke emissions were diminished with increased alcohol concentration in diesel fuel while they increased with increased loading conditions. DEE-diesel blends showed lower emissions compared to ethyl alcohol-diesel blends. However NOx emissions were increased with increased alcohol.
- Ignition delay, combustion duration, decreased with increased alcohol content in the diesel fuel, while peak pressure and heat release rates increased.

Ashraful et al. [7] introduced some variety of non-eatable vegetables whose oils are potential sources of biodiesel. These species are Pongamia pinnata (karanja), Calophyllum inophyllum (Polanga), Maduca indica (mahua), Hevea brasiliensis (rubber seed), Cotton seed, Simmondsia chinesnsis (Jojoba), Nicotianna tabacum (tobacco), Azadirachta indica (Neem), Linum usitatissimum (Linseed) and Jatropha curcas (Jatropha). They concluded the following results:

Most reviewed biodiesel fuels have superior kinematic viscosity, except jojoba, neem, and linseed biodiesel. However, the viscosity ranges of jatropha, tobacco, and mohua biodiesels are close to that of diesel fuel. Rubber seed, jojoba, tobacco, and jatropha biodiesels are better than others in terms of density. Except for jojoba, neem, and linseed oil biodiesels, other biodiesels meet the specified flash point limit. Karanja, polanga, cotton seed, jojoba, and jatropha oil biodiesels are superior in terms of CN. Jojoba and jatropha biodiesel have better calorific value than other biodiesels. Palmitic acid, stearic acid, oleic acid, linoleic acid, and linolenic acid are the usual fatty acids in vegetable oils.

In most cases, cotton seed and jatropha biodiesels gave higher BSFC but had better thermal efficiency than other biodiesels because of complete combustion. Based on several experimental results, the use of karanja, mohua, rubber seed, and tobacco biodiesel in CI engine can reduce CO, HC, and smoke emission with an increase in NOx emission. More-over, higher oxygen content and higher CN, are favoured to lower emissions. However, some authors found a significant reduction of NOx emission. Based on the review of the emission characteristics, cotton seed, rubber seed, and karanja biodiesels are concluded to give better emission characteristics than other biodiesels. Therefore, non-edible vegetable oil resources have good potential to replace edible oil-based biodiesels in the near future.

Ali et al. [8] blended an oxygenated additive diethyl ether (DEE) with palm oil biodiesel (POME) in the ratios of 2%, 4%, 6% and 8% and tested for their properties improvement to characterize how the key fuel properties changed when diethyl ether were blended with palm oil methyl esters. These blends were tested for energy content and various fuel properties according to ASTM standards. According to the experimental results; the density of the POME-DEE blend decreased with the increase of DEE concentration in the blended fuel and displayed satisfactory fuel properties for all blending ranges. Similarly, the acid value of POME-DEE blends slightly improved with increasing DEE content. However, adding 8% DEE to the POME results in fuel viscosity lower that the limit of EN14213 standard. Increasing DEE content in POME resulted in a statistically significant difference in low temperature performance, with a maximum decrease in pour point by 7°C at 8% DEE compare to POME. On the other hand, there was no significant difference in the cloud point of the biodiesel with DEE. In general, the heating value decreases slightly with increasing DEE portion in the blends. B-DE8 has the minimum heating value which is 4.7% less than POME and still satisfies the limits of the EN 14213.

Iranmanesh et al. [9] conducted tests on a single cylinder DI diesel engine fuelled with neat diesel and biodiesel as baseline fuel with addition of 5 to 20% DEE on a volume basis in steps of 5 vol.% as supplementary oxygenated fuel to analyse the simultaneous reduction of smoke and oxides of nitrogen. The results obtained from the engine tests showed a significant reduction in NOx emissions especially for biodiesel and a little decrease in smoke of DEE blends compared with baseline fuels. They showed that the 5% DEE-Diesel fuel and 15% DEE-Biodiesel blend were the optimal blend based on performance and emission characteristics.

Addition of DEE improved the physicochemical properties of diesel fuel and biodiesel with respect to viscosity, density, boiling point and distillation profile. The heating value of the blends was decreased with addition of DEE. Front-end volatility of the blends was improved by addition of DEE, which in turn improved the cold starting property. From the various DEE-Biodiesel blends tested, the 15 vol% DEE-biodiesel and 5% DEE-Diesel blends was found to be the optimum blend on the basis of emission and performance characteristics. BTE was increased 5.5% and 9.2% with 15% DEE-KOME and DEE-Diesel blends respectively. Smoke opacity got reduced with addition of DEE to the blends. NOx emission of DEE blends was decreased drastically. The effect of DEE on NOx reduction was more effective than the other emissions. HC and CO produced by DEE blends were more than baseline fuels (diesel fuel and biodiesel).

Lapuerta et al. [10] obtained experimental results by testing two different alcohol-derived biodiesel fuels: methyl ester and ethyl ester, both obtained from waste cooking oil. These biodiesel fuels were tested pure and blended (30% and 70% biodiesel content, volume basis) with a diesel reference fuel, which was tested too, in a common-rail injection diesel engine. The type of alcohol used in the production process was found to have a significant effect on the total hydrocarbon emissions and on the particulate matter composition. As the alcohol used was more volatile, both the hydrocarbon emissions and volatile organic fraction of the particulate matter were observed to increase.

A good correlation with the molecular oxygen concentration was obtained. In case of the emissions affected by other physical/chemical processes, different sensitivity to the oxygen content was found with the two types of esters. Base-catalyzed trans-esterification reaction requires water free and low acid value (< 1) raw materials for biodiesel production. If the oil samples have high FFA content (more than 1%) then the reaction requires more alkali catalyst to neutralize the FFA. Presence of water gave greater negative effect than that of FFAs because water can cause soap formation and frothing which can cause increase in viscosity.

ZHANG et al. [11] investigated the combustion and emission characteristics of a turbo-charged, common rail diesel engine fuelled with diesel-biodiesel-DEE blends.

The primary conclusions are as follows:

1) Brake-specific fuel consumption of biodiesel-diesel-DEE blends increases with the increase of oxygenated-fuel fraction in these blends. Brake thermal efficiency exhibits minimal variation when operating on different biodiesel-diesel-DEE blends.

2) At low load, NOx emission of diesel-biodiesel-DEE blends demonstrates slight variation when compared with the biodiesel fraction. NOx emission slightly increases with increasing biodiesel fraction in the diesel-biodiesel-DEE blends fraction at medium load. NOx emission increases remarkably with the increase of biodiesel fraction in the diesel-biodiesel-DEE blends at high load.

3) Particle mass and number concentration decreases significantly with the increase of oxygenated fuel fraction in the diesel-biodiesel-DEE blends at all engine speeds and loads.

4) HC and CO emissions decrease with the increase of oxygenated fuel fraction in the blends.

Zhang et al. [12] developed four different continuous process flow-sheets for biodiesel production from virgin vegetable oil or waste cooking oil under alkaline or acidic conditions on a commercial scale. Detailed operating conditions and equipment designs for each process were obtained. A technological assessment of these four processes was carried out to evaluate their technical benefits and limitations. Analysis showed that

The alkali-catalyzed process using virgin vegetable oil as the raw material required the fewest and smallest process equipment units but at a higher raw material cost than the other processes. The use of waste cooking oil to produce biodiesel reduced the raw material cost. **The acid-catalyzed process** using waste cooking oil proved to be technically feasible with less complexity than the alkali-catalyzed process using waste cooking oil, thereby making it a competitive alternative to commercial biodiesel production by the alkali-catalyzed process.

For a biodiesel production rate of 8000 tonnes/yr, four flowsheets for continuous alkali- and acid-catalyzed processes (I–IV) using virgin vegetable oil or waste cooking oil as the raw material were designed and simulated. From the technical assessment, all of these processes proved to be feasible for producing a high quality biodiesel product and a top-grade glycerine by-product under reasonable operating conditions. However, each process had its limitations. The alkali-catalyzed process using virgin oil (process I) was the simplest with the least amount of process equipment but had a higher raw material cost than other processes. Despite the reduced raw material cost in using waste cooking oil (process II), it was the most complex process with the greatest number of equipment pieces because of the addition of a pre-treatment unit for free fatty acids removal. The acid-catalyzed process III using waste cooking oil had less equipment pieces than process II, but the large methanol requirement resulted in more and larger trans-esterification reactors, as well as a larger methanol distillation column. Methanol distillation was carried out immediately following trans-esterification to reduce the load in downstream units in process III but more pieces of equipment made from stainless steel material were necessary than in processes I and II. Acid-catalyzed process IV had the same merits and limitations as process III. However, the addition of hexane and methanol/water solvents increased the number of process equipment pieces and sizes of some separation units in process IV. In brief, for process simplicity, the alkali-catalyzed process using virgin vegetable oil (process I) is recommended. However, if raw material cost is of concern, the acid-catalyzed process using waste cooking oil (process III) is a relatively simple process and proved to be a competitive alternative to processes I and II.

Sivalakshmi and Balusamy [13] observed effects of diethyl ether and ethanol as additives to biodiesel (neem oil methyl ester NOME) on the performance and emission characteristics of a diesel engine at different loads and constant engine speed. Compared with biodiesel, slightly lower brake specific energy consumption for diethyl ether and ethanol blended biodiesel fuels was observed. At higher engine loads, CO and smoke emissions were found significantly lower with all blends [BD-1 (5% diethyl ether (D), 95% biodiesel), BD-2 (10% diethyl ether, 90% biodiesel), BE-1 (5% ethanol (E), 95% biodiesel) and BE-2 (10% ethanol, 90% biodiesel)] compared to biodiesel, but HC and NOx emissions were found higher. Biodiesel (NOME) increased BSEC by 5% and decreased BTE by 4.8% relative to diesel.

Addition of D & E to biodiesel has shown an improvement in BTE almost at all loads. Smoke intensity and CO emissions are found lower with addition of D & E to NOME at almost all loads, especially more reduction at full load. HC and NOx emissions are slightly higher with addition of D & E to NOME at all loads. Addition of higher oxygen content and high volatility fuels (D & E) can be a promising technique for using biodiesel efficiently in diesel engines without any modifications in engine.

Patil and Thipse [14] carried out an experimental investigation to evaluate the effects of oxygenated cetane improver diethyl ether (DEE) blends with kerosene and diesel on the combustion, performance and emission characteristics of a direct injection diesel engine. Initially, 2%, 5%, 8%, 10%, 15%, 20% and 25% DEE (by volume) were blended into diesel. The DEE–diesel blends have reduced the trade-off between PM and NOx of diesel engine and the optimum performance blend has been found as DE15D. Similarly, 5%, 10% and 15% kerosene (by volume) were blended into diesel to investigate the adulteration effect. In addition, a study was carried out to evaluate the effects of kerosene adulteration on DE15D by blending with 5%, 10% and 15% kerosene (by volume). The engine tests were carried out at 10%, 25%, 50%, 75% and 100% of full load for all test fuels. Laboratory fuel tests showed that the DEE is completely miscible with diesel and kerosene in any proportion. It was observed that the density, kinematic viscosity and calorific value of the blends decreases, while the oxygen content and cetane number of the blends increases with the concentration of DEE addition. The experimental test results showed that the DEE–kerosene–diesel blends have low brake thermal efficiency, high brake specific fuel consumption, high smoke at full load, low smoke at part load, overall low NO, almost similar CO, high HC at full load and low HC at part load as compared to DE15D blend.

The experimental results indicated that the blends of DEE with diesel up to 25% and kerosene with diesel up to 15% by volume were possible. The laboratory tests showed that DEE can be mixed in any proportion in diesel and kerosene as it is completely miscible with diesel fuel. The density, kinematic viscosity and calorific value of the blends decreases while the oxygen content and cetane number of the blends increases with the concentration of DEE in the blends.

Lapuerta et al. [15] tested two different biodiesel fuels, obtained from waste cooking oils with different previous uses, in a DI diesel commercial engine either pure or in 30% and 70% v/v blends with a reference diesel fuel. Although the engine efficiency was not significantly affected, an increase in fuel consumption with the biodiesel concentration was observed. This increase was proportional to the decrease in the heating value. A sharp decrease was observed in both smoke and particulate matter emissions and mean particle size as the biodiesel concentration was increased. No important differences in emissions were found between the two tested biodiesel fuels. So it can be concluded that biodiesel from used cooking oil is at least not inferior to that from unused cooking oil as a PM-reducing fuel.

Also the bsfc was increased due to the lower heating value of the biodiesel. This increase is only partly reduced when fuel consumption is expressed in volumetric units instead of mass units due to the higher density of the biodiesel.

- The soot and particulate matter emissions, as well as the particle number concentration, decreased sharply, mainly due to the oxygen content of the biodiesel, which improve the oxygen availability in rich-zone flames in the combustion chamber.
- The mean diameter of the emitted particles tends to decrease, which could be considered a harmful effect of using biodiesel. However, the measured particle size distributions show that no significant increases in small particle emissions can be detected in any case.

Rashedul et al. [16] investigated the characteristics of performance and emission of compression ignition engine fuelled with different biodiesel blended with different additives and compared them with those fuelled with diesel fuel and neat biodiesel. It was observed that the use of biodiesel led to loss in engine power due to low temperature properties and lower heating value of biodiesel compared to diesel. Blending with additives like ethanol, methanol and cold flow improver additives improves the cold flow performance. The addition of metal based additives improves the flash point, reduces the pour point and viscosity of biodiesel fuel more as compared to other additives. The addition of oxygenated additives reduces the density and viscosity as well as increases the oxygen content of biodiesel fuel as compared to other additives. The addition of antioxidant increases flash point, cetane number and oxidation stability but reduces calorific value of biodiesel fuels. Oxygenated additives would not be useful for increasing brake power but some antioxidant and metal based additives are more helpful for increasing brake power of the engine. Metal based additives and antioxidants are more efficient to reduce fuel consumption of biodiesel fuel. On the other hand oxygenated additives have less efficiency to reduce fuel consumption compared to other additives. Antioxidants are quite effective in controlling NOX emission. But metal based additives and oxygenated additives are also useful to reduce NOX emission from biodiesel fuel. CO and HC emission of biodiesel fuel reduced with the addition of metal based additives as well as ethanol and methanol also further reduce CO and HC emission.

Metal based additives are more useful to reduce smoke opacity of biodiesel fuel due to their catalyst effect. Diethyl ether and ethanol are also useful to reduce smoke opacity. So additives are must for biodiesel production, their storage, and transportation in different climatic regions and usage in a compression ignition engine to have a comparable fossil diesel performance and to realize the dream of using biodiesels to extend the fossil fuel availability.

Sachuthananthan and Jeyachandran [17] carried out investigations out here to study the combustion, performance and emission characteristics on a single cylinder diesel engine by adding diethyl ether(DEE) as an additive with the constant ratio of Water-Biodiesel emulsion(WBE) as fuel. Literature review indicates that significant work is not carried out with respect to its performance analysis and in regard to pollution level. A four-stroke 5HP single cylinder DI diesel engine was used for the experiment with 5%, 10% and 15% blends of DEE with a constant 30% Water-Biodiesel emulsion as fuel. It was found that DEE when added to water-biodiesel emulsion can significantly lower NOx and smoke levels without adverse effect on brake thermal efficiency. High HC and high CO, which are problems with the water-biodiesel emulsions, can be significantly lowered with the addition of DEE particularly at high outputs. Even at part loads the addition of DEE can improve the performance as compared to neat water biodiesel emulsion without any adverse effect on NOx emission. Test results indicate that 15% DEE blend gives better performance and lower emissions compared to other blends of DEE and Water-Biodiesel emulsion. Hence 15% DEE can be blended with emulsified fuel to improve the performance and to reduce emissions like smoke density, particulate matter and oxides of nitrogen. Use of neat Water-Biodiesel emulsion significantly lowers NO emissions and smoke levels. It also increased the brake thermal efficiency at higher percentage of DEE with the considerable reduction in HC and CO emissions.

Kannan and marappan [18] made two fuels combinations i.e. emulsified biodiesel and DEE mingled biodiesel to find the suitable coalition of fuel in reducing the emissions and improving the performance of the diesel engine. Experiments have been conducted in a single cylinder diesel engine with biodiesel blended with DEE/water in proportion of 5%, 10%, 15% and 20% by volume. The effect depicts that 15% emulsified biodiesel tell the highest brake thermal efficiency of 31.6% among all other fuel combinations at full load. Reduction of nitrogen oxide is observed as 41% for 20% emulsified biodiesel that that of biodiesel at full load whereas only 26% of nitrogen oxides decrease is observed for 20% DEE blended biodiesel . However, the decrease of smoke emission is less for emulsified biodiesel when compare with DEE mix. Reduction in Hydro Carbons is observed as 3.05% for 20% emulsified biodiesel than in biodiesel at full load whereas 7.7% increment in HC emissions is observed for 20% DEE mix. So it was found that emulsified biodiesel and DEE blended biodiesel both showed better performance and less emissions than those of biodiesel. Among these two fuel combinations, 20% emulsified fuel reveal the highest decrease of nitrogen oxide of 41% and HC emissions decrease of 3.05% than those of biodiesel at full load. The maximum brake thermal efficiency of 31.6%was observed for 15% emulsified biodiesel among all other fuel combinations at full load. So it has been determined that emulsified biodiesel effect in improved performance and less emissions than those of DEE blended biodiesel.

Rakopoulos et al. [19] saw the effects of using blends of diesel fuel with two (direct) vegetable oils, namely sunflower and cottonseed, and their corresponding methyl ester biodiesels in ratio of 10% and 20% (by volume), on the performance and emissions of a completely instrumented, six-cylinder, turbocharged and after-cooled, heavy-duty direct injection (HDDI), Mercedes-Benz, bus diesel engine. Results are as follows:

- Reduction (often significant) of smoke opacity with all biofuel merges against the corresponding pure diesel fuel case.
- Reduction of smoke opacity with increasing percentage of biofuels in the merge.
- Higher reduction of smoke opacity with the vegetable oils against the corresponding biodiesel cases.
- In terms of discharge soot, improve performance of cottonseed oil or its biodiesel against their sunflower counterparts.
- Slight increase of emitted nitrogen oxides with all biofuel blends against the corresponding pure diesel fuel case.
- Increase of nitrogen oxides with increasing percentage of biofuels in the merge.
- No observable trend of emitted nitrogen oxides between vegetable oils and corresponding biodiesel cases.
- Increase of CO emissions with the vegetable oil mix and lowering with biodiesel blends against the corresponding pure diesel fuel case.
- Increase of unburned HC emissions with all biofuel mix against the corresponding pure diesel fuel case, with higher increases for the vegetable oils against the corresponding biodiesel cases.

Chapter - 3

BIODIESEL PRODUCTION

3.1 INTRODUCTION

Waste cooking oil (WCO) is harmful to human health on its reuse as it is not recommendable to use after deep frying, but further the advantage is that it helps to preserve environment with conversion of waste to useful energy. It can be easily converted to Biodiesel. The main components of vegetable oils and animal fats are triglycerides or also known as ester of fatty acid attached to glycerol. The term WCO arises from many different sources, including domestic, commercial and industrial ones. Today, we should use alternative fuels because of energy security, socioeconomic reasons and environmental concerns. Therefore, we need better alternatives of energy than fossil fuels. With the rise in pollution caused by fossil fuels such as coal, petroleum, and natural gas and their depletion; renewable sources of energy such as biodiesel are coming. The side effect of petroleum based fuels is over the years we see that there has been a continuous increase in the amount of pollution produced by these fuels. The use of these sources over many years has resulted to the rise in global temperature levels; also known as global warming. For the last few years, biodiesel has gain importance as an alternative fuel for diesel engines. The biodiesel production also has the advantage of low price and can be made of used vegetable oil. Even it does not emit any extra carbon-dioxide to the atmosphere as compared to other fuels. The most common way of its production is by the process of trans-esterification in which a chemical reaction is catalysed involving vegetable oil and an alcohol to yield fatty acid that is further explained in this chapter.

3.2 PRODUCTION PROCESSES OF BIODIESEL USING WASTE COOKING OIL BY TRANS-ESTERIFICATION:

Step 1. Mixing of Alcohol and Catalyst: This typical process is mainly done by mixing alkali hydroxide (commonly potassium hydroxide and sodium hydroxide) with common alcohols (methanol and ethanol) in the mixer with standard agitator to facilitate the mixing. Alkali hydroxide is dissolved in the alcohol to produce alkoxide solution.

Step 2. Chemical Reaction: The alcohol and catalyst mixture is then charged into a closed reaction vessel and the oil is added. The reaction system is totally closed to the atmosphere to prevent the loss of alcohol, since it easily vaporizable.

Fig. 3.1 Solution of catalyst, alcohol in WCO

The reaction mixture is kept just near the boiling point of the alcohol to speed up the reaction. Excess alcohol is normally used to ensure total conversion of the oil to its esters as there is no problem of recovering of the alcohol for later use after recycling.

Step 3. Separation: After the reaction is completed, there exists glycerol and biodiesel formation. Both have a significant amount of the excess alcohol that was used in the reaction which is in need of being recovered. The reacted mixture is sometimes neutralized at this step if the basic media that is caused by alkali hydroxide is occurred.

Fig. 3.2 Separation process WCO

The glycerol phase is much denser than biodiesel phase, making biodiesel to be floated. The two products can be separated by gravity using settling vessel. The glycerol is drawn off at the bottom of the settling vessel and biodiesel is drawn off at the top. In some cases, a centrifuge is used to separate the two materials faster by screening both phases.

Step 4. Removal of alcohol: After the glycerol and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation commonly. But currently extractive distillation can instead be used to fasten the process and to be more economical. On the other hand, the alcohol is removed and the mixture neutralized before the glycerol and esters have been separated to prevent the effect of basic media inside the reactor. After the alcohol is being recovered it is used as main raw material.

Step 5. Biodiesel Washing: After trans-esterification the upper ester layer may contain traces of NaOH, methanol and glycerol. Since the remaining unreacted methanol in the biodiesel has safety risks and can corrode engine components, the residual catalyst (NaOH) can damage engine components, and glycerol in the biodiesel can reduce fuel lubricity and cause injector coking and other deposits. This being water soluble is removed by washing (4-6 times) the biodiesel with water maintained at 40-50ºC. Washing is carried out by spraying hot water over the biodiesel; precautions were taken to avoid soap formation.

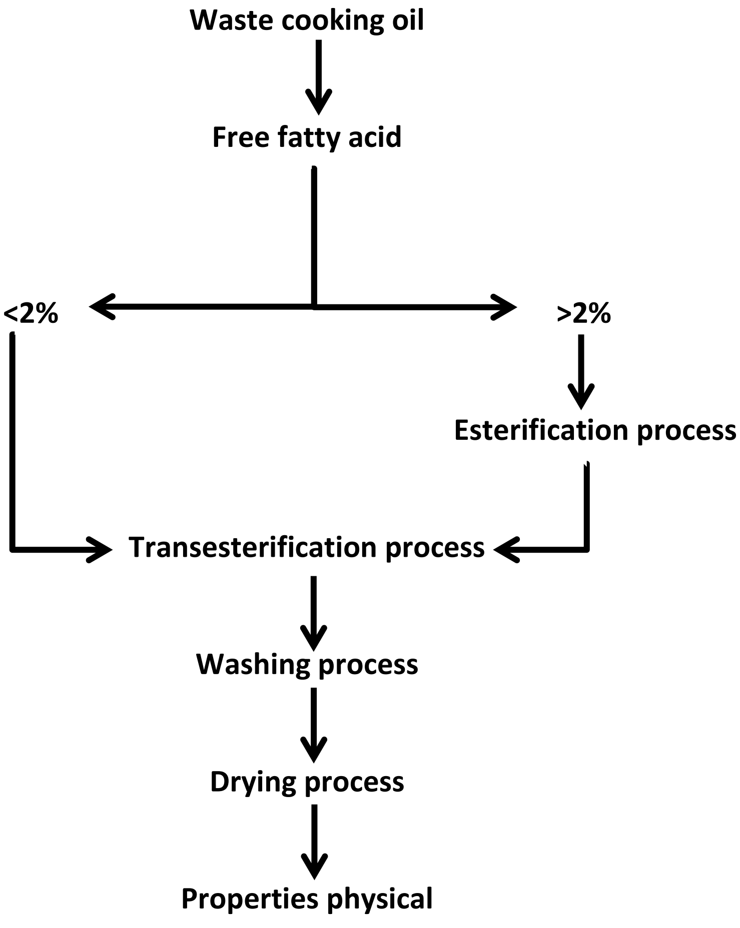


Fig. 3.3 Production process of WCO

The washed biodiesel needs drying in order to remove trace impurities. After the completion of washing process the biodiesel may contain some traces of water. Biodiesel is heated to 110 ^{o}C to remove the trapped traces of water (for drying).

3.3 WASTE COOKING OIL

Waste cooking oil is easy to collect from other industries such as domestic usage and restaurant and also cheaper than other oils (refine oils). Hence, by using these oils as the raw material, we can reduce the cost in biodiesel production. The advantages of using waste cooking oils to produce biodiesel are the low cost and prevention of environment pollution. These oils need to be treating before dispose to the environment to prevent pollution. Due to the high cost of disposal, many individuals dispose waste cooking oils directly to the environment especially in rural area. So that, the use of waste cooking oils is an effective way to reduce the cost of biodiesel production. Used cooking oil has sufficient potential to fuel the compression ignition engines. The kinematic viscosity of used cooking oil (UCO) is about 10 times greater, and its density is about 10% higher than that of mineral diesel. These properties play vital role in the combustion; therefore these must be modified prior to the use of UCO in the engine. Many techniques have been developed to reduce the kinematic viscosity and specific gravity of vegetable oils, which include pyrolysis, emulsification, leaning and trans-esterification. Among these techniques, trans-esterification is the best one. This is because of the fact that this method is relatively easy, carried out at normal conditions, and gives the best conversion efficiency and quality of the converted fuel.

3.3.1 Determination of FFA contents in WCO

- Make solution by adding 1gm of NaOH in 100ml of distilled water & dilute the same by adding another 900 ml of distilled water.
- Pour 10 ml of Methanol in a glass beaker.
- Add 1 ml of vegetable oil to Methanol and mix.
- Add two–three drop of Phenolphthalein in mixture.
- Start adding 0.1% lye to the mixture in small measured quantities till the mixture turns pink.
- Find the FFA contents from table.

Table 3.1 Free fatty acid with NaOH titration

Titration of 0.1% NaOH (ml)	% FFA	Titration of 0.1% NaOH (ml)	% FFA
0	0	3.5	2.5
0.5	0.36	4	2.86
1	0.72	4.5	3.22
1.5	1.07	5	3.58
2	1.43	5.5	3.94
2.5	1.79	6	4.29
3	2.15	6.5	4.65

3.3.2 Waste cooking oil biodiesel production experimental Procedure

- WCO oil (400 g) is taken in a beaker & filtered it to remove impurities. Then it is heated through a heating device up to 110 ^{o}C in order to remove water contents in oil.
- This solution of Methyl alcohol and KOH is now mixed with WCO oil. Initially the Methanol is immiscible with the oil.
- Now Methyl alcohol is taken with a molar ratio of (1:4.5 & 1:6) and catalyst (KOH) is taken as 0.5%, 0.75% & 1% by weight of oil.
- The mixture of oil Methanol & catalyst KOH is kept inside the ultrasonic processor transducer.
- When reaction is completed the beaker is kept for the separation of Glycerol and biodiesel.
- After complete separation bio-diesel (Methyl Ester) is visible in the upper layer & Glycerol at the bottom.
- Bio-diesel is separated & collected for purification.
- To remove the catalyst water should be 33% wt. of biodiesel at around 50 ^{o}C is mixed with the Methyl ester & left for setting down will takes 2-4 hour.
- Excess Methanol present in biodiesel can be removed by distillation process.
- Finally separated biodiesel is water washed and heated to remove moisture.

Table 3.2 Amount of oil, methanol and catalyst used during the experiment

Molar Ratio (Alcohol/oil)	Quantity of Non-edible oil (grams)	Quantity of methanol (grams)	Percentage catalyst (KOH)		
			@0.5%	@0.75%	@1%
6:1	400	88	2.0g	3.0g	4.0g
4.5:1	400	66.24	2.0g	3.0g	4.0g

Following data is used for the calculations:

Molecular weight of triglycerides of non-edible oil= 870

Molecular weight of methanol = 32

Therefore, 1 gram mole of non-edible oil = 870 g

And, 1 gram mole of methanol = 32 g

For 1:6 molar ratio= 32/870*400*6= 88g

For 4.5:1 molar rario= 32/870*400*4.5= 66.24 g

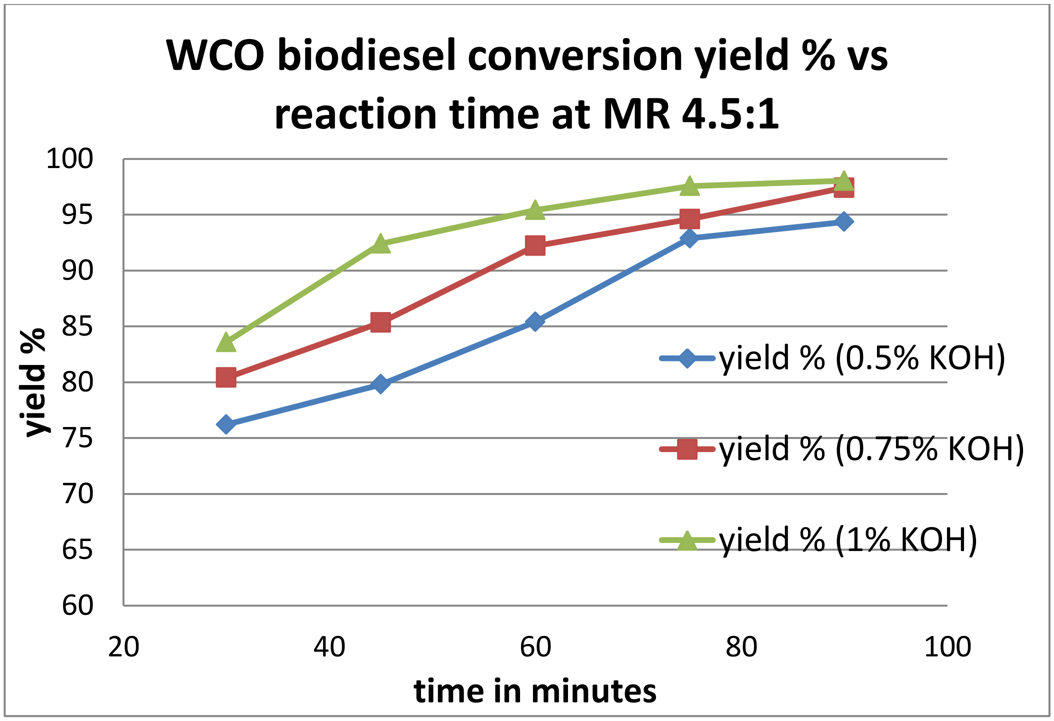


Fig. 3.4 WCO biodiesel conversion yield % vs reaction time at MR 4.5:1

It has been observed that there is higher yield in case of 6:1 molar ratio as compared to 4.5:1 molar ratio. It may be because of alcohol used for 6:1 molar ratio is more than that of 4.5:1

molar ratio. The yield of Biodiesel for 0.5 % KOH is less as compared to 0.75% & 1% KOH in both the cases.

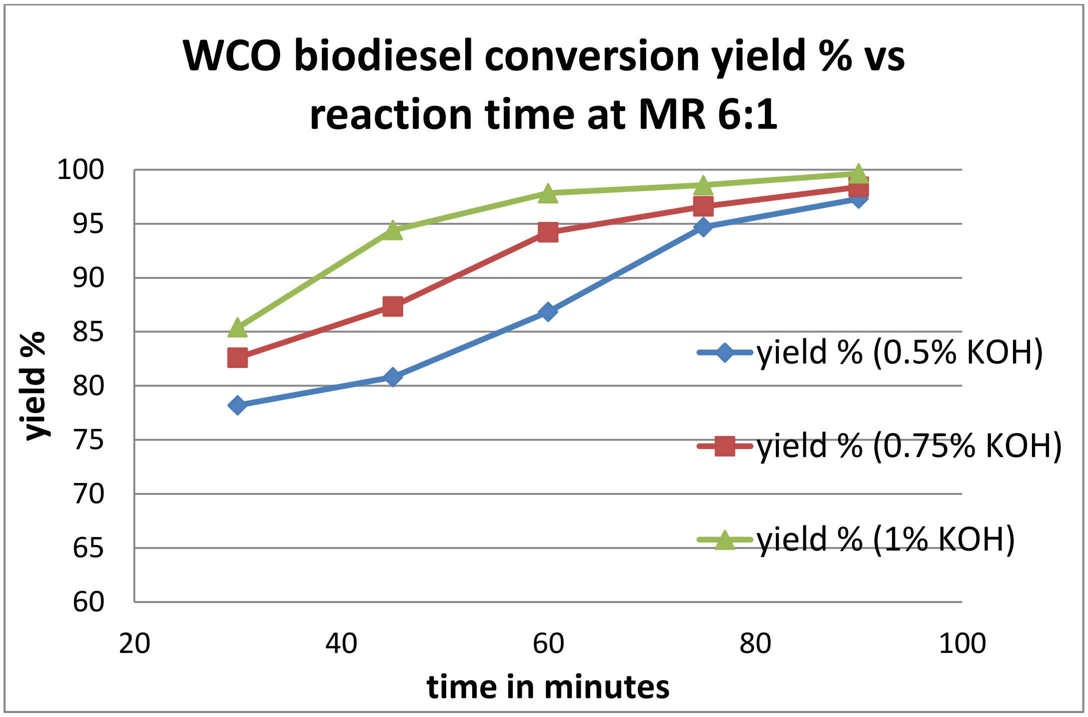


Fig. 3.5 WCO biodiesel conversion yield % vs reaction time at MR 6:1

The reason may be that 0.5% KOH is not sufficient to carry on the reaction giving high yield. Still in case of 6:1 molar ratio, 0.5% KOH is sufficient as we can see that there is no appreciable difference in maximum yield obtained for 0.75% and 1% KOH. Hence , lower KOH must be used in case 6:1 molar ratio.

Chapter - 4

EQUIPMENT USED & METHODOLOGY

4.1 INTRODUCTION

As we all know that to carry out any experimental work we need some equipment that the help of these equipment we can't even think about the experiment. These equipment play a vital role in the accuracy of the work. For this work the following equipment are used:

- Single cylinder diesel engine test set up
- Exhaust Gas analyser
- Smoke meter

Any experiment gains value because of its objective, its methodology and what parameters were taken into account during the experimental work. In this chapter methodology i.e. the phases of the experimental work and parameters which were taken into account during the experimental work are discussed as well as there is a test matrix in chapter, which briefly represent the picture of the experimental work and parameter taken in account.

4.2 TEST EQUIPMENTS

Engine: single cylinder constant compression ratio engine

The setup consists of single cylinder, four strokes, Multi-fuel, research Engine connected to eddy current type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. In both modes, the compression ratio can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The injection point and spark point can be changed for research tests. Setup is provided with necessary instruments for combustion pressure, diesel-line pressure and crank angle measurements. These signals are interfaced with a computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has stand-alone panel box consisting of air box, two fuel tanks for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and hardware interface. Rotameters are provided for cooling water and Calorimeter water flow measurement. A battery, starter and battery charger is provided for engine electric start arrangement. The setup enables study of VCR engine performance for brake Power, torque, BMEP, IMEP, brake thermal efficiency, thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel. Lab view based Engine Performance Analysis software package "Enginesoft" is provided for on line Performance evaluation.

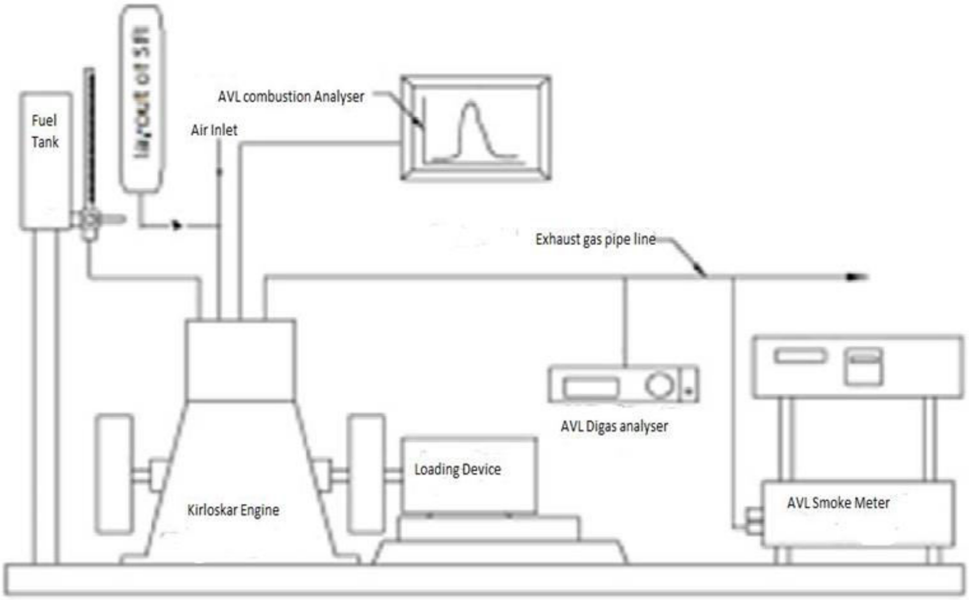


Fig. 4.1 Kirloskar diesel engine test set up

4.3 ENGINE SPECIFICATION

Product : Engine test setup 1 cylinder, 4 stroke, Diesel (Computerized)

Engine: Make Kirloskar, Type 1 cylinder, 4 strokes Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm., CR 17.5

Dynamometer: Type eddy current, water cooled, with loading unit

Fuel tank: Capacity 15 lit with glass fuel metering column

Temperature sensor: Type RTD, PT100 and Thermocouple, Type K

Load indicator: Digital, Range 0-50 Kg, Supply 230VAC

Load sensor: Load cell, type strain gauge, range 0-50 Kg

Software: “EnginesoftLV” Engine performance analysis software

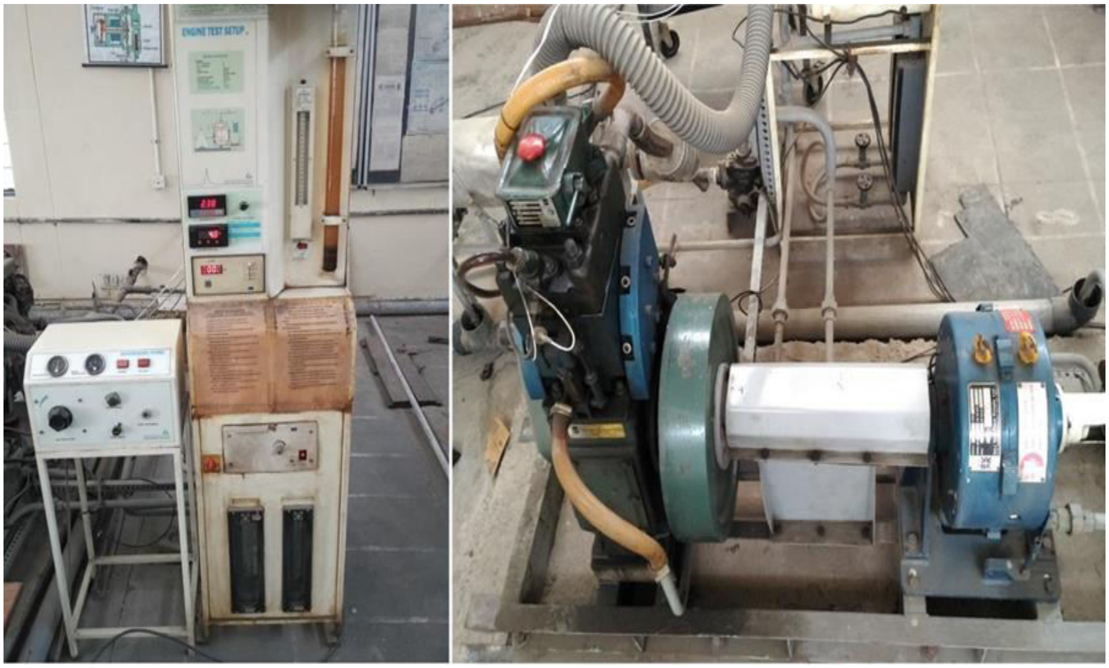


Fig. 4.2 Kirloskar single cylinder diesel engine test setup.

Load sensor:

The load sensor is used to measure the loading value on the engine. Here load cell is used as load sensor. When a force is applied on load cell it generated an electric signal is in direct proportion with the applied load. The load cells are of different kind like hydraulic, pneumatic and strain gauge type. The load cell used here is of strain gauge type. In strain gauge type load cell when load is applied the deformation in strain gauge take place and this deformation then get converted into electric signal which after further computation provided the value of applied load.

Enginesoft:

This is computational software which received and computes the data acquired by all the mounted sensors. The Enginesoft acquired data related to combustion as well as performance characteristics of an IC engine and compile it into useful parameters like mass fraction burn, efficiency, cylinder pressure and brake specific fuel consumption etc.

4.4 GAS ANALYSER

A gas analyser is a device which analysis the exhaust emission and shows the exact amount of different gases. We have AVL digas analyser having the facility to measure the five residual gases i.e. unburned hydrocarbons, oxygen, carbon di-oxide, carbon mono-oxide, nitrogen oxide. To check the emission level of an engine, probe of digas analyser is placed into the exhaust of the engine and the exhaust gases are reached into the sensor through the probe.

The sensors identifies different gases and represents the value in terms of percentage or in terms of ppm (part per million).

Fig. 4.3 AVL gases analyser

4.5 SMOKE MEASUREMENT

The AVL Smoke Meter is a filter-type smoke meter for measuring the soot content in the exhaust of diesel and GDI engines. The variable sampling volume and thermal exhaust conditioning assures a wide applications range, e.g. measurements during engine development or DPF calibration.

Fig. 4.4 AVL smoke meter

It has become an industry standard for developing modern engines. The result of the measurement is displayed as a filter smoke number (FSN) conforming to the standard ISO 10054 or as soot concentration (mg/m³) or Hartridge Smoke Unit (HSU). A defined flow rate is sampled from the exhaust pipe through a clean filter paper in the instrument. The filtered soot causes blackening on the filter paper which is detected by a photoelectric measuring head and evaluated in the microprocessor to calculate the result.

4.6 METHODOLOGY

The methodology for this experimental work is comprises of following stages:

- Basic testing of engine with pure diesel.
- Blend preparation

  (B-Biodiesel, DEE- Diethyl-ether, D-Diesel)
- Testing of blends and pure diesel on IC engine.
- Analysis the **emissions and performance** characteristics of IC engine with blend.
- Comparison the **emission and performance** characteristics of blends with diesel respective characteristics.

Table 4.1 Properties of various blends

Fuel	Density (g/ml)	LCV (kJ/kg)
DIESEL(D)	0.832	43000
BIODIESEL(B)	0.880	37500
Diethyl-Ether(DEE)	0.714	35300
B10DEE10D80	0.825	41680
B20DEE20D60	0.818	40360
B0DEE20D80	0.808	41460

4.7 PARAMETERS

The Parameters can be defined as the standard on the basis of which we observe the engine. For this study followings are the parameters taken:

- Performance parameters
- Emission parameters

Performance parameters:

The performance parameters are the parameters which indicate the effect on the performance of the engine when there is change in the operating conditions of the engine.

For experimental work these parameters plays a very important role because these parameters exactly represent the variations in the system with the varying operating conditions.

1. **Brake specific energy consumption (BSEC):** Brake specific energy consumption can be defined as the energy consumption to obtain per unit of brake power. The brake specific energy consumption is the ratio of the product of fuel burned and heating value of the fuel to per unit of brake power obtained.

   BSEC = Total amount of fuel burn x Heating value of fuel / Obtained Brake power.

2. **Brake thermal efficiency:** The brake thermal efficiency can be define as the ratio of the brake power produced to the energy content released during the combustion of the fuel. The brake thermal efficiency shows that what amount of energy emitted by the fuel is converted into the brake power and what amount of energy is waste. The brake thermal efficiency also told about the heat losses during the combustion or during the operation of the engine. So it can be stated that higher the brake thermal efficiency better the engine performance.

3. **Torque:** The torque can be defined as the tendency of a force to rotate any object about its axis. The increase in the torque represent that the rotating capacity of the force increases. In case of engine rotational distance is fixing and increase in the torque is directly proportional to the force. Torque, moment, or moment of force is the tendency of a force to rotate an object about an axis, fulcrum, or pivot. Just as a force is a push or a pull, a torque can be thought of as a twist to an object. Mathematically, torque is defined which tends to as the cross product of the lever-arm distance vector and the force vector, which leads to produces rotation. The SI unit for torque is the newton meter (N-m).

Emission parameters

Emissions parameters are the emitted gases such as CO_2, CO and nitrogen oxides etc. as per given below:

1. **Unburned hydrocarbons (HC):** Unburned hydrocarbons (UHCs) are the hydrocarbons emitted after diesel is burned in an engine. When unburned fuel is emitted from a

combustor, the emission is caused by fuel "avoiding" the flame zones. For example, in piston engines, some of the fuel-air mixture "hides" from the flame in the crevices provide by the piston ring groove. Further, some regions of the combustion chamber may have very weak flames, that is, they have either very fuel-lean or very fuel-rich conditions and consequently they have a low combustion temperature. These regions will cause intermediate species such as formaldehyde and alkenes to be emitted. Sometimes the term Products of incomplete combustion," or PICs, is used to describe such species.

The unburned hydrocarbons are one of the major polluting elements which are emitted by the internal combustion engine. Due to various reasons like late ignition, lesser air available and improper valve timings a very large amount of fuel exhaust away unburned. And the particles of this unburned fuel are known as the unburned hydrocarbons. These unburned hydrocarbon particles are very harmful for the atmosphere. They work as the burned gas as well as cause a very large number of diseases in living organism. The amount of unburdened hydrocarbons emission testing signifies the quality of combustion and also signifies that combustion is proper or not. The unburned hydrocarbon emission testing is also used to measure the wastage of fuel.

2. **Carbon dioxide (CO_2):** Carbon dioxide (CO_2) is an important trace gas in Earth's atmosphere currently constituting about 0.04% (400 parts per million) of the atmosphere. Despite its relatively small concentration, CO_2 is a potent greenhouse gas and plays a vital role in regulating Earth's surface temperature through radioactive forcing and the greenhouse effect. Carbon dioxide is essential to life on Earth and is an integral part of the carbon cycle, a biogeochemical cycle in which carbon is exchanged between the Earth's oceans, soil, rocks and biosphere. Plants and other photoautotrophs extract carbon from the atmosphere in the form of carbon dioxide by the process of photosynthesis and use it as an energy source and a source of carbon compounds for the construction of their body parts. Therefore, the present biosphere of Earth could not exist without atmospheric CO_2. Carbon dioxide is well mixed in the Earth's atmosphere and study shows that concentrations of CO_2, in the atmosphere have varied, ranging from as high as 7,000 parts per million during the Cambrian period about 500 million years ago to as low as 180 parts per million during the Quaternary glaciations of the last two million years.

   The current episode of global warming has been attributed primarily to increasing industrial CO_2 emissions into Earth's atmosphere. The global annual mean concentration of CO_2 in the atmosphere has increased markedly since the Industrial Revolution, from

280ppm to 400ppm as of 2015. The present concentration is the highest in the past 800,000 years and likely the highest in the past 20 million years. The increase has been caused by anthropogenic sources, particularly the burning of fossil fuels and deforestation. The daily average concentration of atmospheric CO_2, at Mauna Loa first exceeded 400 ppm on 10 May 2013. It is currently rising at a rate of approximately 2 ppm/year and accelerating. An estimated 30-40% of the CO_2 released by humans into the atmosphere dissolves into oceans, rivers and lakes. That's contributes to ocean acidification.

Carbon di-oxide is one of the most responsible gases for the greenhouse effect and global warming. Carbon dioxide is one of the most responsible gases for the greenhouse effect and global warming. Carbon dioxide emitted during the complete combustion of a fuel having carbon element is in the presence of air and by the respiration of the living animals. During the emission testing for an engine the increased carbon die oxide level is good because it is the indicator of complete combustion and also ensures the less wastage of fuel.

3. **Carbon monoxide (CO):** Carbon mono-oxide is one of the very harmful exhaust gases emitted from the internal combustion engine. This gas is toxic in nature and produces when the combustion takes place in the presence of very less amount of Oxygen. The amount of carbon mono oxide in emission testing signifies the uncompleted combustion of the fuel.

   Carbon monoxide poisoning occurs after enough inhalation of carbon (CO). Carbon monoxide is a toxic gas but being colourless, odourless, tasteless and initially non-irritating, it is very difficult for people to detect. Carbon monoxide is a product of incomplete combustion of organic matters due to insufficient oxygen supply to enable complete oxidation to carbon dioxide (CO_2). It is often produced in domestic or industrial settings by motor vehicles that run on diesel, gasoline, diesel, methane, or other carbon based fuel sand tools, heaters, and cooking equipment that are powered by carbon based fuels such as propane and butane. Exposures at 100ppm or greater can be dangerous to human health. Symptoms of mild acute poisoning will include light-headedness, confusion, headaches, vertigo, and flu-like effects; larger exposures can lead to significant toxicity of the central nervous system and heart, and death. Following acute poisoning, long-term squeal often occur. Carbon monoxide can also have severe effects on the foetus of a pregnant woman. Chronic exposure to low levels of carbon monoxide can lead to depression, confusion, and memory loss. Carbon monoxide mainly causes adverse effects in humans by combining with haemoglobin to form carboxy-haemoglobin (HbCo) in the blood. This prevents haemoglobin from carrying oxygen to the tissues, effectively reducing the oxygen-carrying capacity of the blood, leading to hypoxia. Additionally, myoglobin and mitochondrial cytochrome oxidase are thought to be adversely affected. Carboxy-haemoglobin can revert to haemoglobin, but the recovery takes time because the HbCo complex is fairly stable.

Treatment of poisoning largely consists of administering 100% oxygen or providing hyperbaric oxygen therapy, although the optimum treatment remains controversial. Oxygen works as an antidote as it increases the removal of carbon monoxide from hemoglobin, in turn providing the body with normal levels of oxygen.

The prevention of poisoning is a significant public health issue. Domestic carbon monoxide poisoning can be prevented by early detection with the use of household carbon monoxide detectors. Carbon monoxide poisoning is the most common type of fatal poisoning in many countries. Historically, it was also commonly used as a method to commit suicide, usually by deliberately inhaling the exhaust fumes of a running car engine. Modern automobiles, even with electronically controlled combustion and catalytic converters, can still produce levels of carbon monoxide which will kill if enclosed within a garage tailpipe is obstructed (for example, by snow) and exhaust gas cannot escape normally. Carbon monoxide poisoning has also been implicated as the cause of apparent haunted houses; symptoms such as delirium and hallucinations have led people offering poisoning to think they have seen ghosts or to believe their house is haunted.

4. **Oxides of Nitrogen (NO):** Nitric oxide, or nitrogen oxide, also known as nitrogen monoxide, is a molecule with the chemical formula NO. It is a free radical and is an important intermediate in the chemical industry. Nitric oxide is a by-product of combustion of substances as in automobile engines, fossil fuel power plants, and is produced naturally during the electrical discharges of lightning in thunderstorms.

   In mammals including humans, NO is an important cellular signalling molecule involved in many physiological and pathological processes. It is a powerful vasodilator with a short half-life of a few seconds in the blood. Long known Pharmaceuticals such as nitroglycerine and amyl nitrite were found to be precursors to nitric oxide more than a century after their first use in medicine.

Low levels of nitric oxide production are important in protecting organs such as the liver from ischemic damage. Nitric oxide should not be confused with nitrous Oxide (N_2O), an anaesthetic, or with nitrogen dioxide (NO_2), a brown toxic gas and a major air pollutant. Humphrey Davy discovered this to his discomfort, when he inhaled the gas early in his career. Nitric oxide is rapidly oxidized in air to nitrogen dioxide. Despite being a simple molecule, NO is an important biological regulator and is therefore a fundamental component in the fields of neuroscience, physiology, and immunology. It was proclaimed "Molecule of the Year" in l992. Research into its function led to the 1998 Nobel Prize for discovering the role of nitric oxide as a cardiovascular signalling molecule.

The oxides of nitrogen generate at high temperature and in the presence of excess air. At very high temperature the air ionises and formation of NOx takes place. This polluting agent causes acid rain which is very harmful for the all livings and non-living thing.

5. **Smoke opacity:**

Opacity is the degree to which smoke blocks light, and the basis for measuring the amount of smoke coming from a diesel-powered vehicle. Poorly maintained or malfunctioning engines are sometimes the cause of excessive smoke. The percentage (**%**) of light transmitted from a source which is prevented from reaching a light detector is opacity. Diesel Exhaust Smoke meters, also referred to as opacity meters, detect and measure the amount of light blocked in a sample of smoke emitted by diesel engines from cars, trucks, ships, buses, motorcycles, locomotives and large stacks from industrial operations. The measurement may be in terms of HSU, FSN or mg/m^3.

Table 5.1 Conversion chart for HSU, FSN and mg/m^3 [30]

Hartridge smoke units (HSU)	Filter smoke number (FSN)	mg/m^3
10	1.10	33
11	1.20	38
12	1.30	42
13	1.40	47
14	1.48	52
15	1.57	57
16	1.67	62
17	1.75	66

Chapter - 5
RESULT AND DISCUSSION

5.1 INTRODUCTION

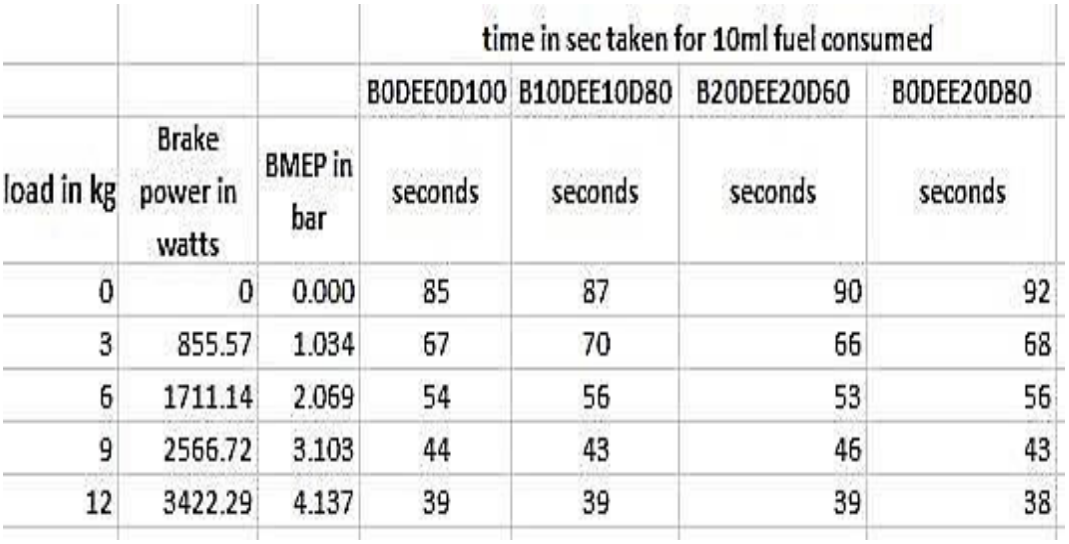
The result obtained from the experimental work can be separated in to the three categories on the basis of the nature of the parameters.

- Optimization of waste cooking oil.
- Result on performance parameter.
- Result on emission parameters.

5.2 RESULT ON PERFORMANCE PARAMETER

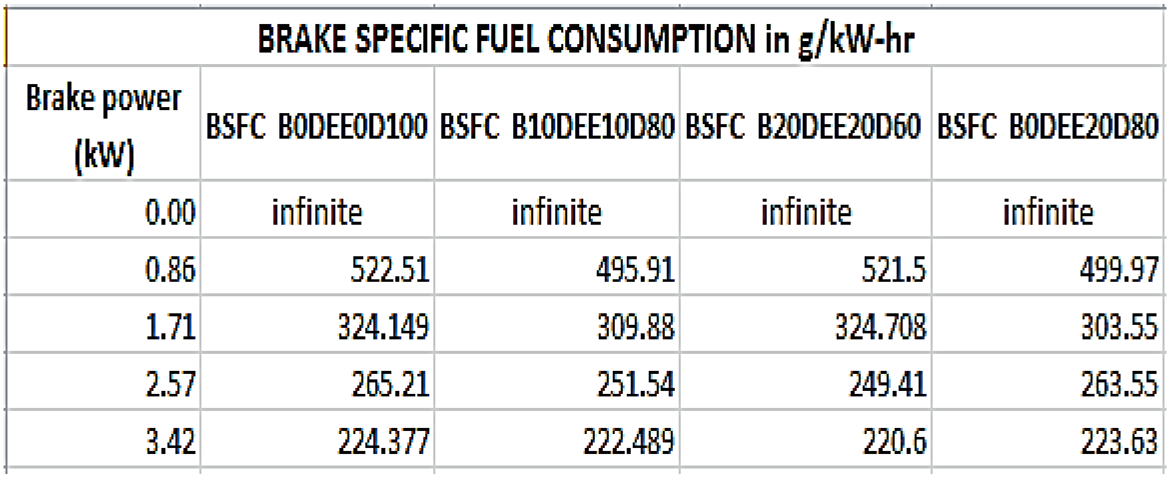
Brake specific fuel consumption:

Figure 5.1 represents the variation of brake specific fuel consumption with brake power for different fuels. The BSFC is high at low load for all the fuels and as we increase the load the BSFC start decreasing this trend follows approximately up to 50% to 70% load and if we further increases the load then the value of BSFC start increase. And here we can see that the value of BSEC at higher load or even at moderate load is very close in case of different fuels. These trends signify that the use of diethyl ether, biodiesel and diesel blends is feasible and helpful in solving energy problems of India.



			time in sec taken for 10ml fuel consumed			
			B0DEE0D100	B10DEE10D80	B20DEE20D60	B0DEE20D80
load in kg	Brake power in watts	BMEP in bar	seconds	seconds	seconds	seconds
0	0	0.000	85	87	90	92
3	855.57	1.034	67	70	66	68
6	1711.14	2.069	54	56	53	56
9	2566.72	3.103	44	43	46	43
12	3422.29	4.137	39	39	39	38

Fig. 5.1 various blends’ 10 ml fuel consumption time



BRAKE SPECIFIC FUEL CONSUMPTION in g/kW-hr				
Brake power (kW)	BSFC B0DEE0D100	BSFC B10DEE10D80	BSFC B20DEE20D60	BSFC B0DEE20D80
0.00	infinite	infinite	infinite	infinite
0.86	522.51	495.91	521.5	499.97
1.71	324.149	309.88	324.708	303.55
2.57	265.21	251.54	249.41	263.55
3.42	224.377	222.489	220.6	223.63

Fig. 5.2 variation of bsfc with load

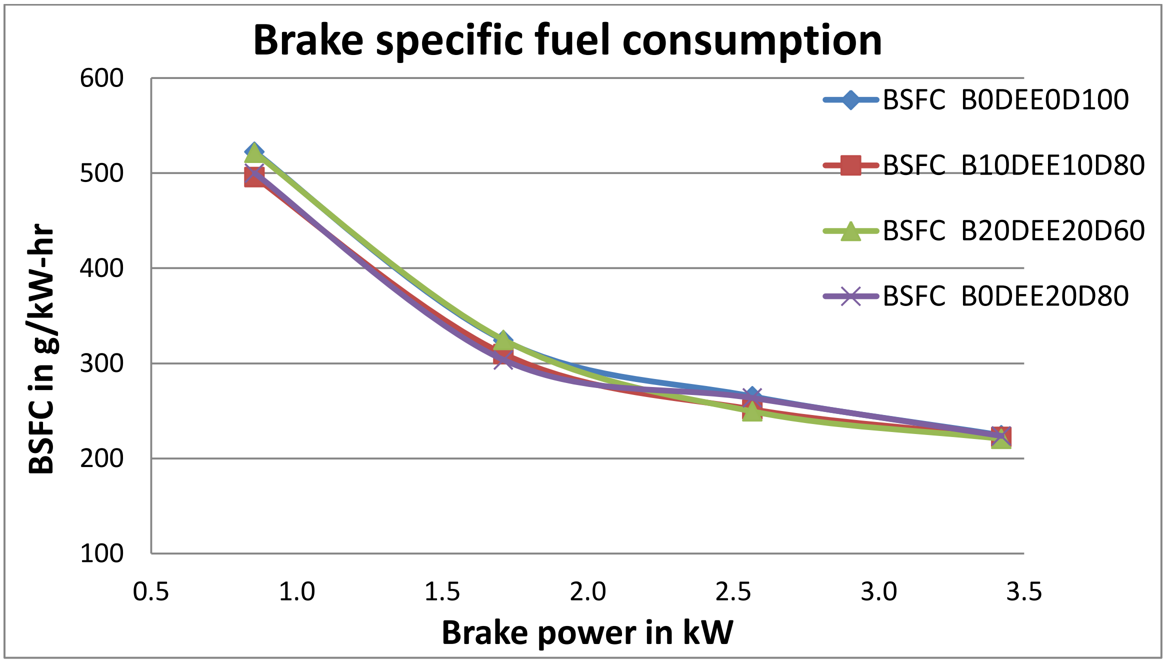


Fig. 5.3 variation of bsfc with brake power

Brake specific energy consumption:

Brake specific energy consumption is the ratio of energy obtained by burning fuel for an hour to the actual energy or Brake power obtained at the wheels. It is dimensionless. It is indicative how effectively the energy obtained from the fuel is reaching the wheels. In the following Figure 5.4, we can easily see that throughout the brake power variation, change in BSEC value with different fuel blends is not that much. Even at full load, it is negligible with B20DEE20D60 having minimum BSEC, that shows fuel burnt per unit brake power is minimum for this blend.

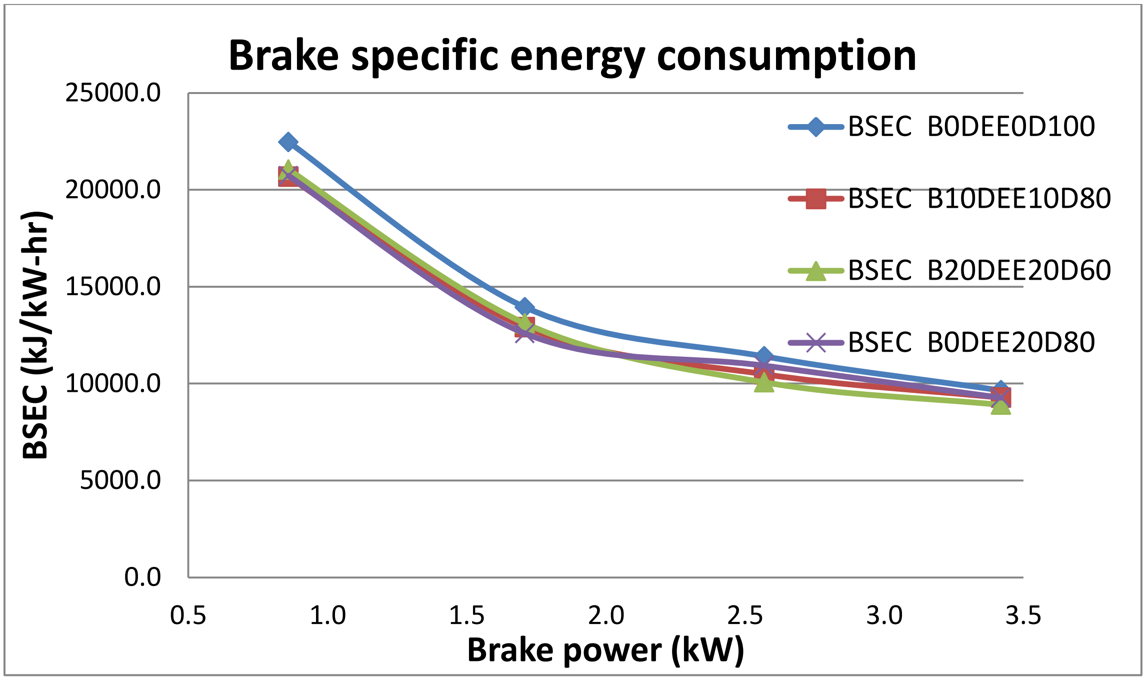


Fig. 5.4 variation of BSEC with brake power

Brake thermal efficiency (BTE):

Here Figure 5.5 represents the variation of brake thermal efficiency with brake power for different fuels. As the load increases the BTE start rising. The value of BTE at any load show small variation from fuel to fuel. Thus diethyl ether, biodiesel and diesel blends can be used to meet energy demand of the future India.

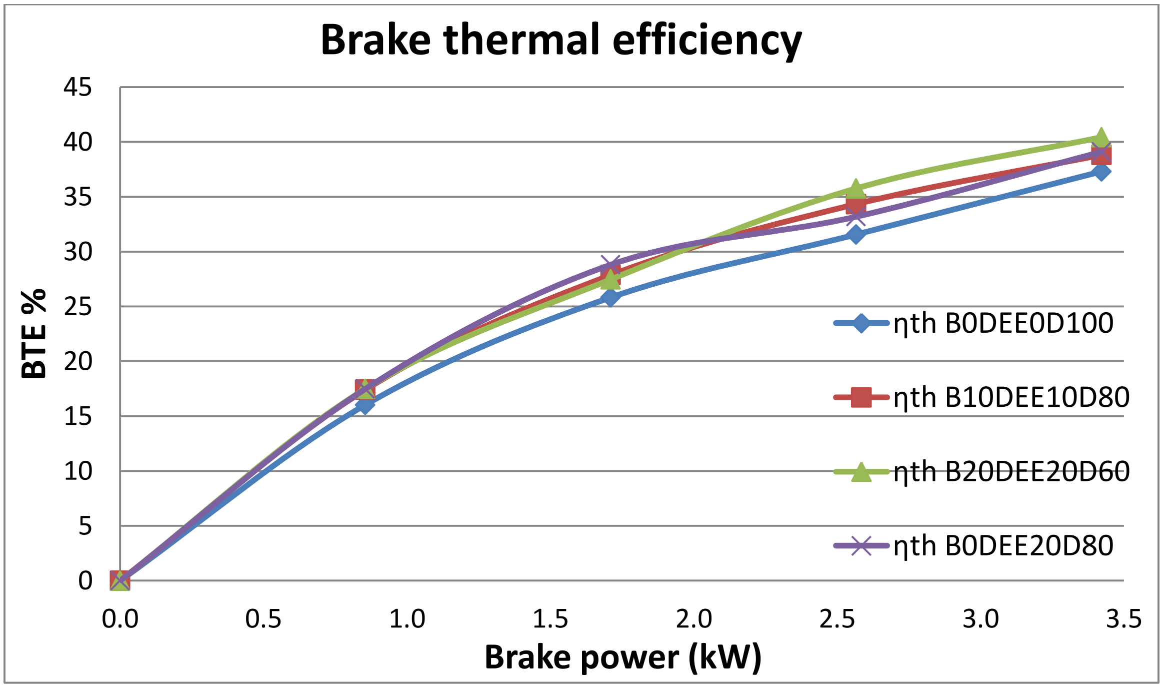


Fig. 5.5 brake thermal efficiency variations

Torque:

The Figure 5.6 represents the variation of torque with the brake power for various types of fuels. As we increases the load the torque increases proportionally with brake power. We always desire higher torque for an engine used for driving an automobile.

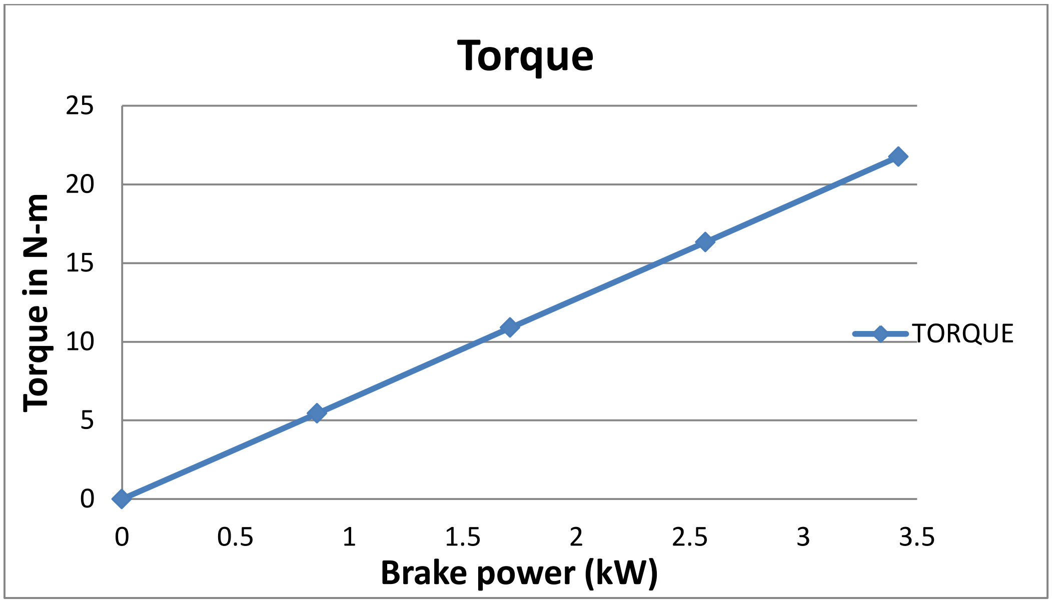


Fig. 5.6 variation of torque with brake power

The result shows that we get higher torque at high load, nearly equal to pure diesel in case of blended fuel. This signifies that these blends are useful as a feedstock for internal combustion engine.

Exhaust gas temperature:

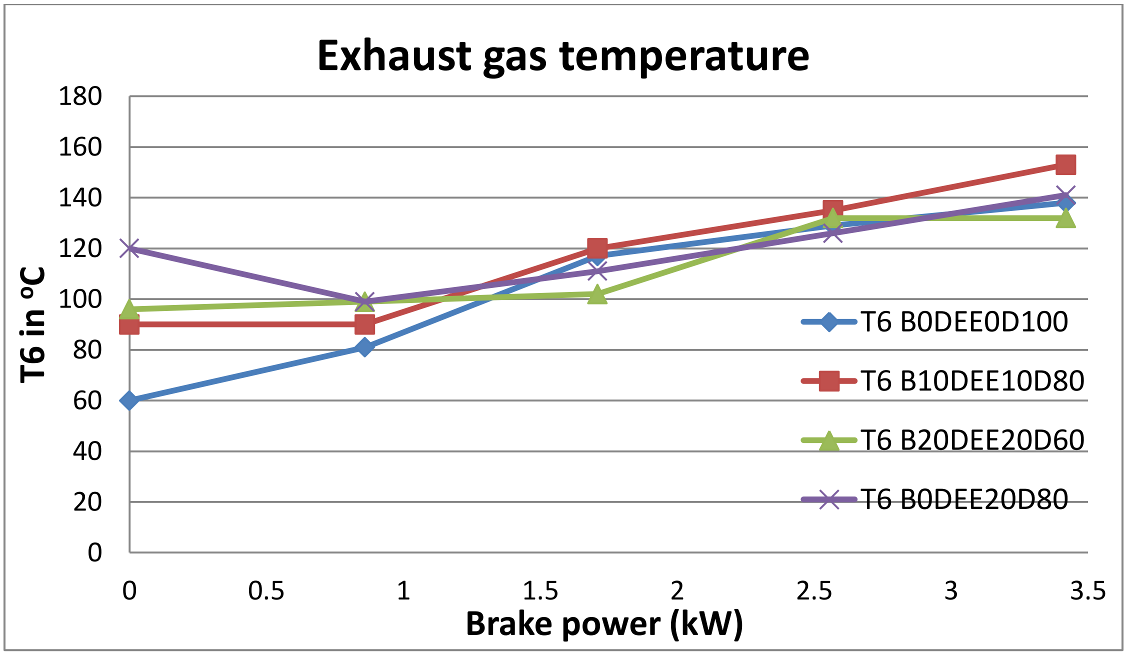


Fig. 5.7 variation in EGT with brake power

It shows the amount of heat taken away with the flue gases, hence showing fuel's inefficient utilization. Therefore its value should be minimum. In Figure 5.7, we could easily see that at 50-100% load, B20DEE20D60 is having minimum or equal value of T6 (exhaust gas temperature) as compared to other fuel blends. So these fuel blends can alternatively be used replacing neat diesel in this engine.

5.3 RESULTS ON EMISSION PARAMETERS

Carbon monoxide (CO):

Figure 5.8 shows the variation of CO with brake power for different percentage of blends. It is formed as a result of incomplete combustion. CO emissions are higher at lower loads. This due to fact that at low load condition, although DEE has higher cetane number, its latent heat of evaporation is slightly higher than that of diesel; as result there is not enough vaporization and hence very less time to burn fuel completely that results in considerable increase in CO emissions.

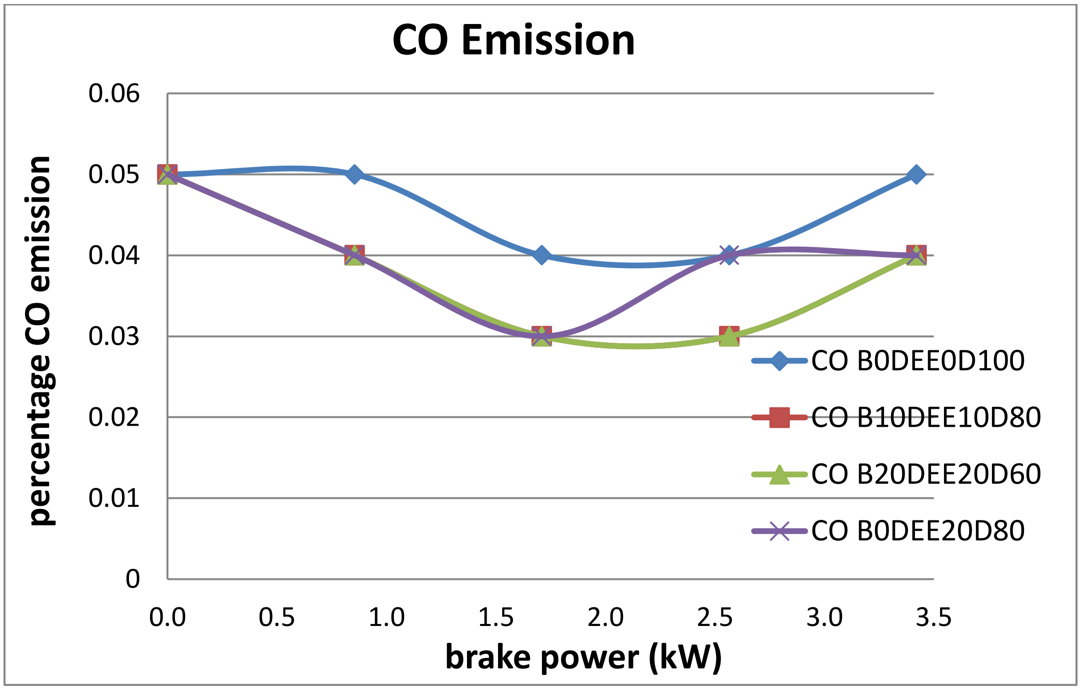


Fig. 5.8 variation in CO with brake power

At higher loads, enough time available for combustion to occur, better mixing and inbuilt fuel oxygen that results in complete combustion and hence slightly reduces the CO emissions, for blends at high load. At full load, there is no significant change between the fuels for CO emissions. The blends of DEE and diesel have lower CO emissions at full load signifying the complete combustion whereas biodiesel addition to this blend relatively increase the CO emission at 75% of full load, though the difference is negligible throughout all load variations.

Therefore we can say. We can replace some amount of diesel with biodiesel and DEE without providing any further harm to environment and without any modification to already manufactured engines.

Unburned hydrocarbon (HC):

In Figure 5.9 represent the emission of unburned hydrocarbons with respect to brake power. As we increases the load the amount of unburned hydrocarbon emission varies without showing any consistent nature. Addition of biodiesel to DEE-diesel blend is making the conditions better by providing better combustion and having minimum HC emissions at full load. The reduction of unburned hydrocarbon signifies the improvement in the combustion properties of fuel.

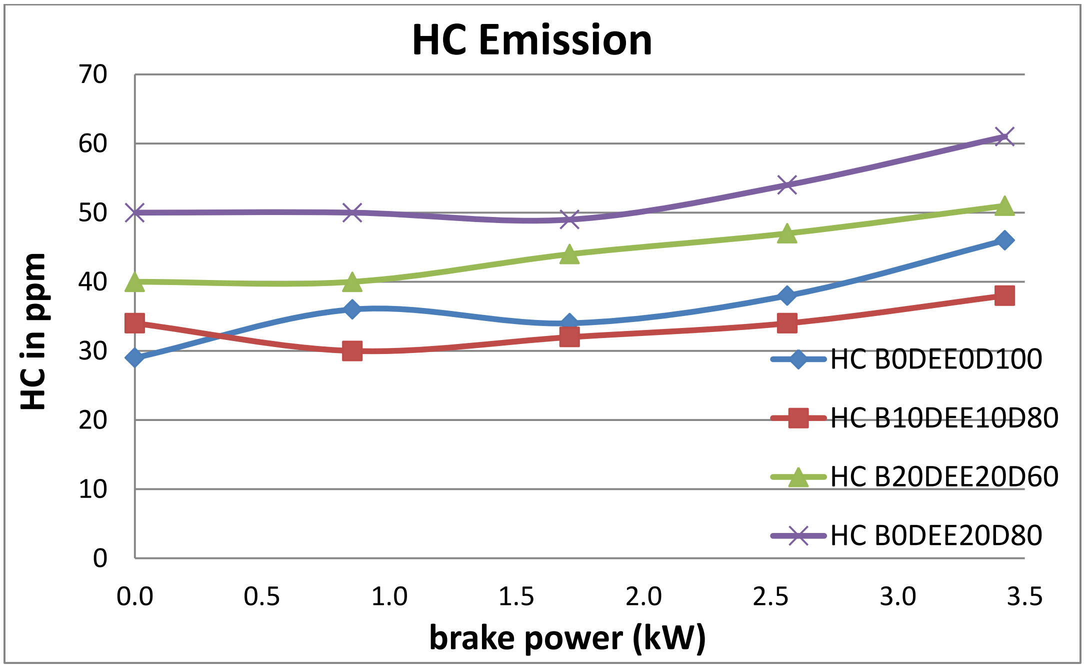


Fig. 5.9 HC emissions vs brake power

10% biodiesel with 10% DEE in diesel is proven to be the best fuel with regards to HC emissions. The HC are one of the major pollutants thus reduction of HC by addition of DEE-biodiesel is a very welcome outcome. It can be seen that the HC emissions for all the fuel blends are higher with the increase being higher in the percentage of diethyl ether in the blend. As known, the formation of unburned HC originates from various sources and varies widely with operating conditions. The increase of HC may be due to the higher latent heat of evaporation of diethyl ether causing lower combustion temperature, especially the temperature near the cylinder walls during the mixture formation. In this case more HC will be produced from the cylinder boundary.

NOx emissions:

Figure 5.10 represents the trends of emission of NOx with respect to brake power. The NO emissions are very harmful and cause acid rain. As we increases the load the NOx emission increases for all types of fuel. The NOx emission reduces sharply as we shift diesel to blended fuel. At no load condition the variation in NOx emission for diesel and B10DEE10D80 are almost same. And at peak load the variation is more for B0DEE20D80 fuel as well as B20DEE20D60 fuel.

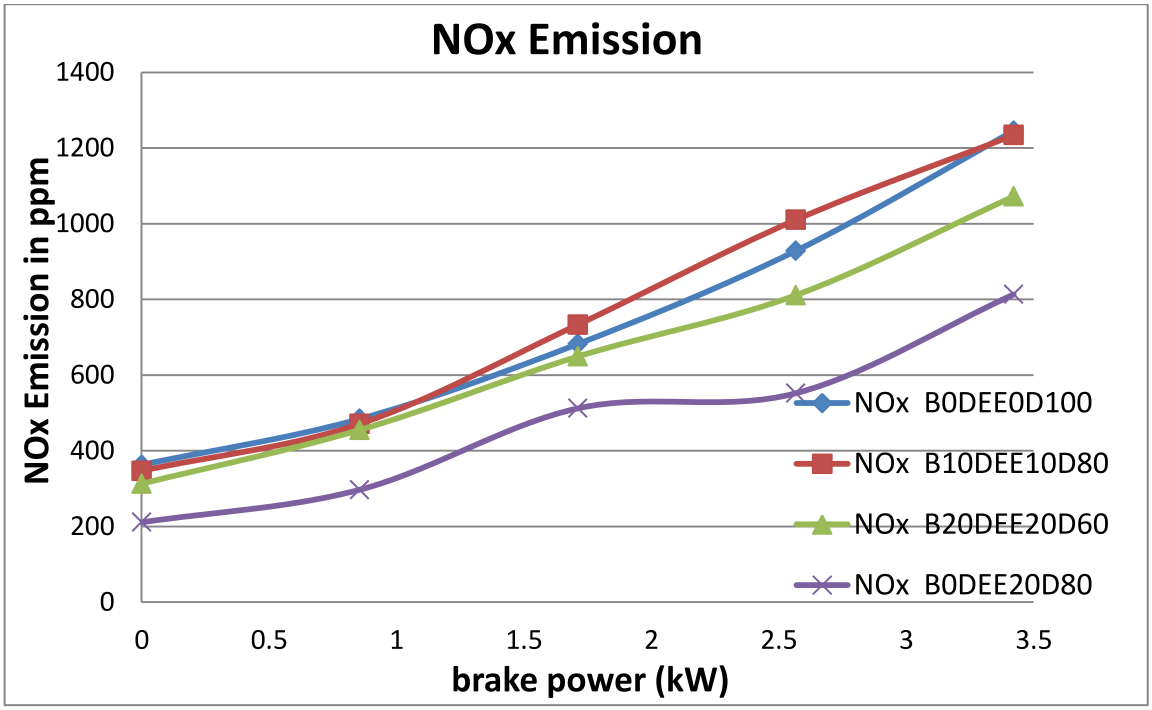


Fig. 5.10 NOx emissions variation with brake power

Carbon dioxide:

The Figure 5.11 represents the variation of emission of CO_2 with respect to brake power. The percentage of CO_2 in total emission increased when we increases the load this is mainly due to incomplete combustion.

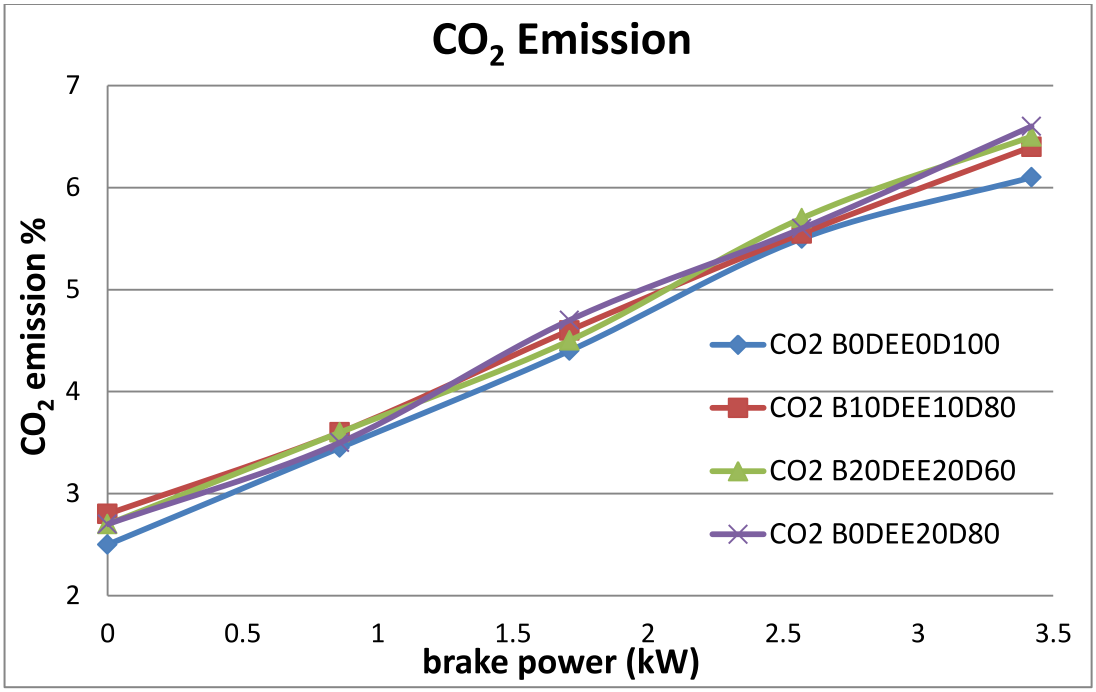


Fig. 5.11 Carbon dioxide (CO_2) variation with brake power

When DEE is blended with biodiesel and diesel there is increase in the percentage of the amount of CO_2 in exhaust gases at full load. Diesel is having minimum CO_2 emissions at full load. The increase of CO_2 is welcome because it signifies complete combustion. And hence blending with DEE is a good option to reduce the demand of diesel.

Smoke opacity:

The smoke meter readout displays the smoke density giving a measure of the efficiency of combustion. The amount of smoke is shown in terms of Hartridge Smoke Units (HSU). From the Figure 5.12, we can easily conclude that smoke opacity i.e. considered as an indicator of dry soot emissions, as well as particulate matter emissions, which have soot as one of their main components, are both noticeably reduced with biodiesel blends. Value is higher in case of combustion with diesel as compared to others.

Since the smoke is mainly produced in the diffusive combustion phase, the addition of oxygenated fuel can overcome poor mixing of the fuel with air and leads to improvement in diffusive combustion .The reason for the fluctuations may explained by the fact that the properties of DEE such as its oxygen content and its latent heat of vaporization (LHV) are in competition. In the other words, its oxygen content leads to smoke reduction and its high LHV decreases the combustion temperature.

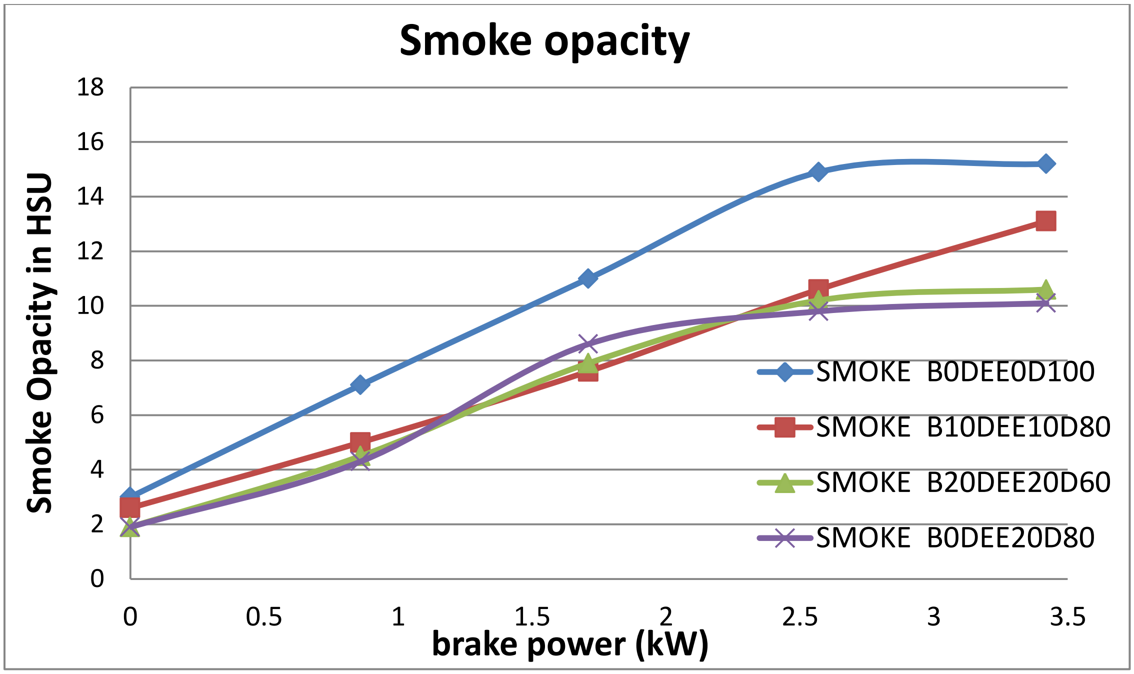


Fig. 5.12 Smoke opacity variation with brake power

Though the smoke opacity is increasing with increase in load, the B20DEE20D60 & B0DEE20D80 are the better fuels at full load showing minimum smoke opacity values.

Chapter - 6

CONCLUSION AND FUTURE SCOPE

After completion of the experiment and thorough analysis of obtained result it can be concluded that the Biodiesel, diethyl ether and diesel blend is very beneficial to use as a feedstock for CI engine. The performance characteristics represent that the using blended fuel does not affect mechanical efficiency, BSEC, brake thermal efficiency and torque negatively i.e. the above parameters are almost similar in case of all fuels. The emission results at peak load signify the reduction of the major polluting agents CO, NO and CO_2 respectively. There is increase in the CO_2 emission at peak load for B0DEE20D80 which indicates the complete combustion i.e. combustion quality is improved when diesel is blended with diethyl ether. Use of DEE addition to diesel fuel and biodiesel increases the BTE in a general trend. BTE rises 8.32% with blend B20DEE20D60 with respect to neat diesel.

Considering the advantages and obstacles of DEE, diesel fuel and biodiesel; and utilization of their combinations in suitable ratio can amplify their advantages and overcome their shortcomings.

The heating value of the blends decreases with addition of DEE. Front-end volatility of the blends improves by addition of DEE, which in turn improves the cold starting property. From the various DEE-Biodiesel blends tested, the 20%vol DEE 20%vol Biodiesel with 60%vol Diesel is found to be the optimum blend on the basis of emission and performance characteristics. Hence, the addition of diethyl ether up to 20% (by vol.) can be a promising technique for using biodiesel efficiently in diesel engines without any modifications in the engine by limiting diesel usage up to 60% only.

There is possibility of addition of some different type of biodiesel with diethyl ether and diesel blend which further enhance the properties of this blend. For satisfying the energy hungriness of our country we should focus on these non-conventional energy sources and we should always have to keep exploring for such energy sources.

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APPENDIXES

Table: specification of variable compression single cylinder diesel engine

Product	Engine test setup 1 cylinder, 4 strokes, Diesel (Computerized).
Engine	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water cooled, power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5,
Dynamometer	Type eddy current, water cooled, with loading unit.
Fuel tank	Capacity 15 lit with glass fuel metering column.
Piezo sensor	Range 5000 PSI, with low noise cable.
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Piezo powering unit Make	Cuadra, Model AX-409.
Digital milivoltmeter	Range 0-200mV, panel mounted .
Temperature sensor	Type RTD, PT100 and Thermocouple, Type.
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, Range 0–1200 Deg C, Output 4–20 mA.
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC.
Load sensor	Load cell, type strain gauge, range 0-50 Kg.
Software	“EnginesoftLV” Engine performance analysis software.
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH.
Overall dimensions	W 2000 x D 2500 x H 1500 mm.