PERFORMANCE CHARACTERISTICS OF A FOUR STROKE DIESEL ENGINE USING BIODIESEL OBTAINED FROM RUBBER SEED OIL

A Project report submitted in partial fulfilment of the requirements for the Award of the Degree of

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

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Autonomous status accorded by UGC & Andhra University - 2019

(Approved by AICTE, Permanently affiliated to Andhra University, Accredited by NBA and approved by NAAC with ‘A’ grade)

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CERTIFICATE

This is to certify that this report entitled **"PERFORMANCE CHARACTERISTICS OF A FOUR STROKE DIESEL ENGINE USING BIODIESEL OBTAINED FROM RUBBER SEED OIL"** has been carried out by **G. Radhikesh (315126520052), G. Praveen (315126520048), G. Janardhan (315126520050), G. Chaitanya (315126520057), G. Dileep (315126520056)** under the esteemed guidance of **Mr. G. Naresh, asst prof,** in partial fulfilment of the requirements of Degree of Bachelor of Mechanical Engineering of Andhra University, Visakhapatnam.

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ABSTRACT

Increase in energy demand, stringent emission norms and depletion of resources led to the discovery of alternative fuels for internal combustion engines. Many alternative fuels like alcohols, bio-diesel, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), etc. have been already commercialized in the transport sector. In the present work, Rubber seed oil is blended with diesel and used as an alternate fuel for CI engines. The Rubber seeds can be converted into bio-diesel using a chemical process called trans-etherification.

Different proportions of fuel blends have been produced by the process of blending. The fuel properties of each blend are determined. The load test of Four Stroke Diesel engine using the blends of rubber seed with diesel done. The performance parameters such as Power, Specific Fuel Consumption, Thermal Efficiencies, Mechanical Efficiency and Mean Effective Pressures are calculated based on the experimental observations of the engine and compared for different blends. The comparative graphs are drawn at different loads. The sustainability of using alternate fuels in Diesel engines, especially the potential use of Rubber seed oil as bio-diesel have been brought to the fore through this work.

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CHAPTER - I

1. INTRODUCTION

1.1 Fossil Fuels:

The term fossil is used to describe the broad setoff fuels “formed in the Earth from plant or in the earth from plant or animal remains” that have been transformed into raw energy sources over the course of many years as a result of geological processes. In effect, fossil fuels are the repositories of millions of years of energy that has been accumulated and shaped into a concentrated form.

Fossil fuels come in three main forms: petroleum or crude oil, coal and natural gas. All have many uses, but each serves one main purpose. In 2011, fossil fuels accounted for approximately 82 percent of world’s primary energy use but this is expected to fall to 78 percent by 2040, meaning that the use of fossil fuels is expected to be on a decline due to use of alternative fuels. Yet fossil fuels are finite resources and they can also irreparably harm the environment. According to Environmental Protection Agency, the burning of fossil fuels was responsible for 79 percent of U.S. greenhouse gas emissions in 2010. Oil is the world’s primary fuel source for transportation. Most oil is pumped out of underground reservoirs, but it can also be found imbedded in shale and tar sands. Once extracted, crude oil is processed in oil refineries to create fuel oil, gasoline, liquefied petroleum gas, and other non-fuel products such as pesticides, fertilizers, pharmaceuticals and plastics.

1.2 Alternative fuels:

Alternative fuels, known as non- conventional or advance fuels, are any materials or substances that can be used as fuels, other than conventional fuels. Some well-known alternative fuels include biodiesel, bio alcohol (methanol, ethanol, and butanol), chemically stored electricity (batteries and fuel cells), hydrogen, non-fossil methane, non-fossil natural gas, vegetable oil, propane, oil from waste tyres and plastic, and other biomass sources. These alternative fuels are economical when compared to diesel. So, these are most suitable for automobiles and they can meet the growing demand for fuels in the future [1].

1.3 Need for Shifting Towards Alternative Fuels:

Probably in this century, it is believed that crude oil and petroleum products will become very scarce and costly to find and produce. Although fuel economy of engines is greatly improved, increase in the number of automobiles alone dictates that there will be a great demand for fuel in the near future. Alternative fuel technology, availability, and use must and will become more common in the coming decades. Another reason motivating the development of alternative fuels for the IC-engine is concerned over the emission problems of gasoline engines. Combined with air polluting systems, the large number of automobiles is a major contributor to the air quality problem of the world. A third reason for alternative fuel development is the fact that a large percentage of crude oil must be imported from other countries which control the larger oil fields.

1.4 Biodiesel:

Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources. The fuel is a mixture of fatty acid alkyl esters made from vegetable oils, animal fats or recycled greases. Where available, biodiesel can be used in compression-ignition (diesel) engines in its pure form with little or no modifications.

Biodiesel is simple to use, biodegradable, nontoxic and essentially free of sulphur and aromatics. It is usually used as a petroleum diesel additive to reduce levels of particulates, carbon monoxide, hydrocarbons and toxics from diesel-powered vehicles. When used as an additive, the resulting diesel fuel may be called B5, B10 or B20, representing the percentage of the biodiesel that is blended with petroleum diesel.

Biodiesel is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel). Biodiesel can be made from any vegetable oil, animal fats, waste vegetable oils, or microalgae oils. There are three basic routes to biodiesel production from oils and fats:

1) Base catalysed trans-esterification of the oil.
2) Direct acid catalysed trans-esterification of the oil.
3) Conversion of the oil to its fatty acids and then to biodiesel.

There are variety of oils that are used to produce biodiesel, the most common ones being soybean, rapeseed, and palm oil which make up the majority of worldwide biodiesel production. Other feedstock can come from waste vegetable oil, Jatropha, mustard, flax, sunflower, palm oil or hemp. Animal fats including tallow, lard, yellow grease, chicken fat and fish oil by-products may contribute a small percentage to biodiesel production in the future, but it is limited in supply and inefficient to raise animals for their fat. Jatropha is a small pest and drought resistant shrub that is capable of being grown on marginal/degraded land and produces seeds that yield several times more oil per acre than soybeans.

Biodiesel can be blended in any proportion with mineral diesel to create a biodiesel blend or can be used in its pure form. Just like petroleum diesel, biodiesel operates in the compression ignition (diesel) engine, and essentially requires very little or no engine modifications because the biodiesel has properties similar to mineral diesel. It can be stored just like mineral diesel and hence does not require separate infrastructure. The use of biodiesel in conventional diesel engines results in substantial reduction in the emission of unburned hydrocarbons, carbon monoxide, and particulates. There are currently a large number of existing biodiesel production plants globally, and a large number under construction or planned to supply the growing global demand.

1.5 Advantages of Biodiesel:

- Biodiesel fuel is a renewable energy source unlike petroleum based diesel.
- An excessive production of soybeans in the world makes it an economic way to utilize this surplus for manufacturing the biodiesel fuel.
- One of the main biodiesel fuel advantages is that it is less polluting than petroleum diesel.
- The lack of sulphur in 100% biodiesel extends the life of catalytic convertors.

- Another of the advantages of biodiesel fuel is that it can also be blended with other energy resources and oil.
- Biodiesel fuel can also be used in existing oil heating systems and diesel engines without making any alterations.
- It can also be distributed through existing diesel fuel pumps, which is another biodiesel fuel advantages over other alternative fuels.
- The lubricating property of the biodiesel may lengthen the life time of engine

CHAPTER - II

2. LITERATURE REVIEW

Before going with the project, a brief study on papers related to Performance Analysis of Compression Ignition Engine using Biodiesel was done. Many authors portrayed different ideas related to their works on Biodiesel. The different papers reviewed are listed below:

- **Chatpalliwarl et al.** [1] described the brief overview of the Bio-diesel production plant. Various issues- sources, opportunities, challenges, plant design, and evaluation etc. are discussed related to the Biodiesel production. The contribution of the work is that it discusses the important issues concerned with the Biodiesel production plant design, the fundamental details required for the formulation of Biodiesel plant and also it presents possible approach for the mathematical model to evaluate the Biodiesel plant design.

- **Hamed M. El-Mashad et al.**[2] investigated on Salmon oil, a by-product of salmon processing, was used as a feedstock for biodiesel production via transesterification in a two-step process. It was found that due to the high acid value of salmon oil, alkaline catalysed transesterification was not an effective method for producing biodiesel from the salmon oil. Therefore, a two-step process was applied, in which a sulphuric acid-catalysed pre-treatment was used in the first step to reduce the acid value from 12.0 to 3mg and then, in the second step, KOH-catalysed transesterification was applied. Based on the total weight of salmon oil used, the maximum biodiesel yield of 99% was achieved using a total methanol/molar ratio of 9.2% and 0.5% (w/w) KOH. A preliminary economic analysis showed that the cost of biodiesel production from salmon oil was almost twice that produced from soybean oil.

- **Md. Imran Kais et al.** [3] research focused on algae cultivation. A lab scale production of Chlorella and Botroyococcus braunii was executed in open pond and bioreactor system. Then diesel was produced by transesterification from collected algae oil. Later data was collected from this experiment. Cost analysis was prepared to get a clear concept of the actual scenario of algae fuel probability. This study indicates high potentiality of algae based fuel replacing diesel for energy production. It can be a model for any third world country to mitigate the energy crisis with a greener solution.

- **Piyanuch Nakpong et al.** [4] investigated the production of biodiesel from three mixtures of vegetable oil and used cooking oil by alkali catalysed transesterification. Three kinds of vegetable oils, including jatropha, roselle and coconut oils were tested. The effect of used cooking oil content in oil feedstock (used cooking oil/vegetable oil ratios of 0.03-0.2 v/v) on methyl ester formation was investigated and optimized. The methyl ester content from each reaction condition was determined by gas chromatography (GC). The optimum used cooking oil/vegetable oil ratio was 0.03 v/v for all three kinds of oil feedstock.

- **S.L.Sinha and R.K.Yadav** [5] investigated, the biodiesel produced from the Jatropha seeds. It has been considered as a potential alternative for running the compression ignition engines. The different blends of biodiesel and conventional diesel have been tested on the engine. The experimental data obtained for various concentrations of biodiesel blends have been compared with base line data of conventional diesel. Significant improvement in engine performance has been observed due to the use of biodiesel and diesel. It has been observed that 20% of Jatropha oil can be substituted for diesel without any engine modification and preheating of blends. The level of hydrocarbon emission and noise level have been found to be reduced with the use of more biodiesel content.

- **Avinash Kumar Agarwal** [6] reported the technical feasibility of using straight vegetable oils (Jatropha oil), into a constant speed direct injection compression ignition engine. Vegetable oils have very high viscosity, which make their direct usability in engines questionable. In this investigation, SVO's were preheated by using waste heat from engine exhaust, in order to reduce their viscosity. The effect of using these oils on typical engine problems such as injector coking, piston ring sticking, lube oil dilution etc. was investigated in detail. Long-term endurance test (For a duration of 512 hours) of SVO fuelled engine vis-a-vis mineral diesel fuelled engine was executed and the results are compared.

- **K. Anbumani and Ajit Pal Singh** [7] observed the feasibility of using two edible plant oils mustard and neem as diesel substitute a comparative study on their combustion characteristics on a C.I. engine were made. Oils were esterified (butyl esters) before blending with pure diesel in the ratio of 10:90, 15:85, 20:80 and 25:75 by volume. Pure diesel was used as control. Studies have revealed that on blending vegetable oils with diesel a remarkable improvement in their physical and chemical properties were observed. Cetane number came to be very close to pure diesel. Results have indicated that engine run at 20% blend of oils showed a closer performance to pure diesel. However, mustard oil at 20% blend with diesel gave best performance as compared to neem oil blends in terms of low smoke intensity, emission of HC and NOx. All the parameters tested viz., total fuel consumption, specific energy consumption, specific fuel consumption, brake thermal efficiency and cylindrical peak pressure were improved. These studies have revealed that both the oils at 20% blend with diesel can be used as a diesel substitute.

- **Jomir Hossain et al.** [8] investigated on mustard oil. Properties are determined in the fuel testing laboratory with standard procedure. An experimental set-up is then made to study the performance of a small diesel engine in the heat engine laboratory using different blends of biodiesel converted from mustard oil. It is also observed that with biodiesel, the engine is capable of running without difficulty but with a deviation from its optimum performance. Initially different blends of biodiesel (i.e. B20, B30, B50 etc,) have been used to avoid complicated modification of the engine or the fuel supply system. Finally, a comparison of engine performance for different blends of biodiesel has been carried out to determine the optimum blend for different operating conditions.

- **P.K. Sahoo** [9] results on non-edible filtered high viscous and high acid value (44mg KOH/gm) Polanga oil based mono esters (biodiesel) produced by triple stage transesterification process and blended with high speed diesel (HSD) were tested for their use as a substitute fuel of diesel in a single cylinder diesel engine. The brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were calculated from the recorded data. The engine performance parameters such as fuel consumption, thermal efficiency, exhaust gas temperature and exhaust emissions (CO, CO2, HC, NOx, and O2) were recorded. The optimum engine operating condition based on lower brake specific fuel consumption and higher brake thermal efficiency was observed at 100% load for neat biodiesel. From emission point of view the neat POME was found to be the best fuel as it showed lesser exhaust emission as compared to HSD.

- **G Lakshmi Narayana Rao et al.** [10] Trans esterified vegetable oils (biodiesel) are promising alternative fuel for diesel engines. Used vegetable oils are disposed from restaurants in large quantities. But higher viscosity restricts their direct use in diesel engines. In this study, used cooking oil was dehydrated and then Trans esterified using an alkaline catalyst. The combustion, performance and emission characteristics of Used Cooking oil Methyl Ester (UCME) and its blends with diesel oil are analysed in a direct injection C.I. engine. The fuel properties and the combustion characteristics of UCME are found to be similar to those of diesel. A minor decrease in thermal efficiency with significant improvement in reduction of particulates, carbon monoxide and unburnt hydrocarbons is observed compared to diesel. The use of Trans esterified used cooking oil and its blends as fuel for diesel engines will reduce dependence on fossil fuels and also decrease considerably the environmental pollution.

From the above literature survey, the authors have identified some of the gaps in the areas of Biodiesel. Hence the authors have embarked to study the influence of Alternative Fuels. In this work, the Performance of Compression Ignition Engine using Rubber seed oil as Biodiesel is carried out by following the experimental procedure.

CHAPTER - III

3. SYNTHESIS OF BIODIESEL

Biodiesel is produced through a process known as Trans-Esterification of triglycerides to methyl esters with methanol, a balanced and catalysed reaction. An excess of Methanol is required to obtain a higher degree of conversion. Jatropha and Rubber seed oils are among the some of the best for biodiesel uses.

The conventional catalyst in natural oil transesterification processes are selected among basis such as alkaline or alkaline earth hydroxides or alkoxides. However, transesterification could also be performed using acid catalysts such as hydrochloric, sulphuric and sulfonic acid, or using metallic base catalysts such as titanium alcoholates or oxides of tin, magnesium or zinc. All these catalysts act as homogeneous catalysts and need to be removed from the products after methanolysis step.

Edible vegetable oils such as canola, soybean, and corn have been used for biodiesel production and are proven diesel substitutes. Reducing the cost of the feedstock is necessary for biodiesel's long-term commercial viability. One way to reduce the cost of this fuel is to use less expensive feedstocks including waste cooking oils and vegetable oils that are non-edible and/or require low harvesting costs. Rubber seed oil (RSO), which is much less expensive than edible vegetable oil, is a promising alternative to edible vegetable oil. Rubber seed oil, which gets hold of minimum industrial applications, was chosen as raw material for the production of biodiesel. However, it is well known that some concentration of poisons will always be found in the seeds of all types of plants, including the seeds of the rubber plant. Rubber seeds known to contain linamarin (Duke and Ducellier, 1993). A linamarin is a cyanogenic glucoside. This environmentally threatening problem could be turned into both economic and environmental benefit by proper utilization and management of Rubber seed oil as a fuel substitute. Rubber seed oil, as an alternative feedstock for biodiesel, was studied with different aspects such as optimization using supercritical methanol (SCM) trans-esterification, process design and technological assessment, fuel property analysis and cost estimation approaches. Since biodiesel is made up of esters derived from oils and fats from renewable biological sources, it has been reported to emit far less regulated pollutants than petroleum diesel fuel.

3.1 Rubber Seed Oil as a Biodiesel:

As in the present scenario need for a high yield productive oil for the production of bio-diesel with less wastage in the form of glycerine in the trans-esterification process of bio-diesel though it was a by-product of the bio-diesel making which is used in soap making industry because our primary concern was the bio-diesel making. Some of the oils with high biodiesel productivity are soybeans, rapeseed and canola, mustard, camelina and sunflower. Out of which soybeans produce approximately 1.5 gallons of oil per bushel. U.S farmers produced a record breaking yield in 2009 of 44 bushels per acre whereas Rapeseed and canola75 to 240 gallons of oil per acre it has other advantage of good rotation crop. So, by taking all the above considerations the rubber seed oil has been selected for the project.

Rubber seed oil is oil extracted from the seeds of rubber trees. In latex manufacturing process, rubber seeds are not historically collected and commercialized. Recent analysis shows that rubber seed oil contained the following fatty acids

- Palmitic (C16:0) - 0.2%
- Stearic (C18:0) - 8.7%
- Oleic (C18:1) - 24.6%
- Linoleic (C18:2) - 39.6%
- Linolenic (C18:3) - 16.3%

Although rubber seed is rich in nutrients, it also contains cyanogenic glycosides which will release prussic acid in the presence of enzymes or in slightly acidic conditions. Rubber seed oil also could be used for the paint industry as a semidrying oil, in the manufacture of soap, for the production of linoleum and alkyd resin in medicine as antimalaria oil, and in engineering as core binder for factice preparation, and the cake left after oil extraction is used in fertilizer preparation and as feed for cattle and poultry. The useful properties of the rubber seed oil make it similar to well-known linseed and soybean oil.

3.2 Experimental Work on Rubber Seed Oil:

For production of bio-diesel from rubber seed oil different researchers has found different methods for increasing biodiesel yield such as pyrolysis, micro-emulsification, dilution, and transesterification. Out of these transesterfication process is the most common procedure used widely throughout the world. In transesterfication process there are different types like conventional transesterification (homogeneous catalyst), heterogeneous catalyst, supercritical method (SCM), in-situ process, ultrasound assisted process, and enzymatic process. Each process has its own advantages.

3.3 Methodology of Trans-Esterification Process of RSO:

1. Conventional transesterfication (homogeneous catalyst):

An effective way to produce biodiesel from raw materials of non-edible oil is through two stages. The first step is esterification to reduce the FFA content of the oil. The second step is converting the triglyceride portion of the oils to mono-alkyl ester and glycerol by transesterification. FFA is able to react with the base catalyst to produce soap. It certainly leads to a loss of catalyst, while the soap produced deactivates the catalyst. Therefore, the FFA content has to be removed or converted to alkyl esters via acid esterification. Conventionally, sulfuric acid catalyst is used in acid esterification and alkali metal hydroxides and alkoxides used as catalyst for transesterification reaction.

2. Heterogeneous catalyst:

Homogeneous base-catalysts are reactive on free fatty acids to form unwanted soap as by-products that need expensive separation cost. Thus, the biodiesel production using solid catalysts is preferred. Moreover, the main advantages of heterogeneous reaction come from compatibility with the environment and reduction of manufacturing cost by elimination of the expensive process steps such as separation and purification of biodiesel. Clinker loaded with solid methoxide is used as a catalyst which is reusable and can be carried at low temperatures in single stage only.

3. Supercritical method (SCM):

When the non-catalysed supercritical methanol treatment is applied, the yield of biodiesel has no less significant. By this process, the transesterification of feedstock oil with methanol is done under temperature and pressure, which exceeding the critical properties of methanol. The consequence of transesterification reactions that use supercritical conditions is an expensive investment in process equipment.

4. In-situ process:

In this the oil–bearing material contacts with acidified or alkalized alcohol directly. A catalyst is needed to activate the reaction. Acid or alkali catalyst also helps to hit the cell wall of the seed and improve the ability of the solvent to access the oil. The problem arising from this in-situ method is relatively similar to that of a homogeneous catalyst process; difficult to recycle and impact of serious corrosion and environmental problems.

5. Ultrasound assisted process:

The interactions between alcohols and vegetable oils are weak because of their difficult mixed properties and different reactant densities lead to low reaction rates and increased reaction time. One of the most effective and interesting procedures to overcome this problem is by using ultrasonication (ultrasound) that produces sound waves. The chemical effect comes from radicals such as H+ and OH- produced during a transient implosive collapse of bubbles (in a liquid irradiated with ultrasound), accelerate chemical reaction in the bulk medium. Meanwhile, the physical effect comes from emulsification, in which the microturbulence generated due to radial motion of bubbles leads to intimate mixing (homogenize the mixture) of the immiscible reactants. This both effects speed up the reaction rates of the process.

Out of these all processes heterogeneous catalyst has advantages like reuse of catalyst, elimination of carrion problems etc.

3.4 Trans-esterification Reaction:

The transesterification process was widely used in bio-diesel production from different biomass materials. The process consists of two steps namely, acid esterification and alkali transesterification:

Step 1: Acid esterification: Acid esterification reduces the FFA value of un-refined oil using an acid catalyst.

Step 2: Alkali trans-esterification: After removing the impurities of the product from the step 1, it is trans-esterified to monoesters of fatty acids using an alkali catalyst.

Fig 3.1: Trans-Esterification Process

3.5 Draining of Glycerol Rubber seed oil as a bio-diesel:

After the transesterification reaction, we must wait for the glycerol to settle to the bottom of the container when kept in a separating funnel. This happens because Glycerol is heavier than biodiesel. The settling will begin immediately, but the mixture should be left a minimum of eight hours to make sure all of the Glycerol has settled out. The Glycerol volume should be approximately 20% of the original oil volume. The objective is to remove only the Glycerol and stop when the biodiesel is reached. Glycerol looks very dark compared to the biodiesel as shown in Fig 3.2. The viscosity difference is large enough between the two liquids that the difference in flow from the drain can be seen.

Fig 3.2: Separation of Glycerol and Esters

The Methyl esters thus obtained from trans-esterification of rubber seed oil is referred as Biodiesel in this work. The Biodiesel is mixed with Petroleum Diesel by the process of Blending with varying proportions to obtain various fuel blends.

CHAPTER - IV

4. EXPERIMENTAL SETUP:

4.1 Basic Theory:

Engine: Engine is a device or a machine used to convert one form of energy to mechanical energy.

Heat Engine: It converts chemical energy of the fuel into heat energy which is used to do work. They are classified into two categories:

1. Internal Combustion engine (ICE): ICE is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber.

2. External Combustion engine (ECE): ECE is heat engine where a working fluid, contained internally, is heated by combustion in an external source, through the engine wall or a heat exchanger.

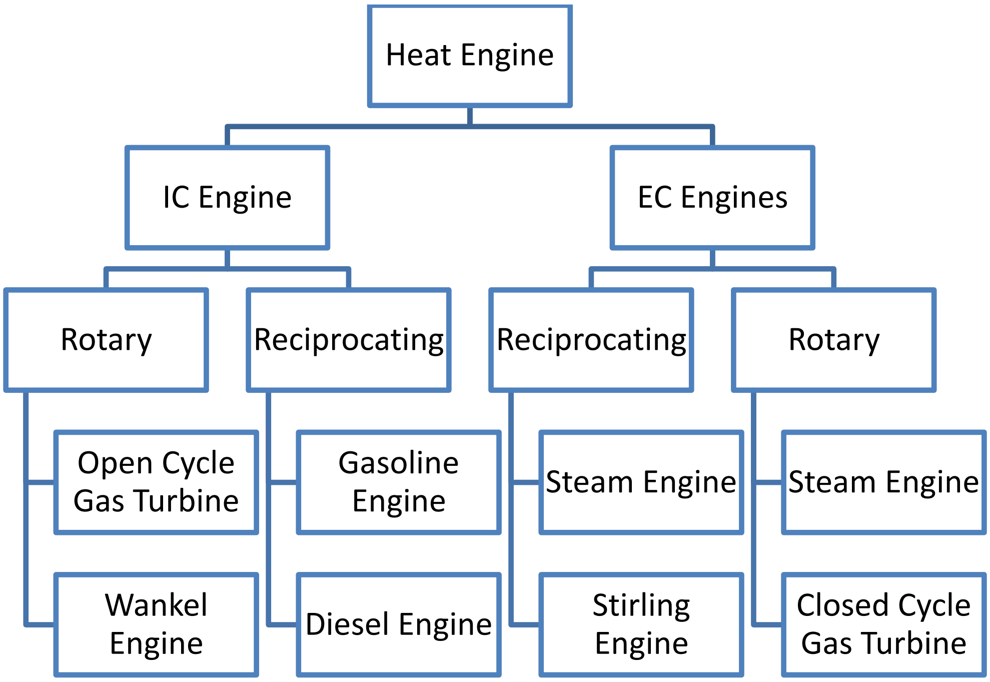

Fig 4.1: Classification of Heat Engine

4.2 IC Engines Classification:

There are several possible ways of to classify IC engines

Reciprocating:

- By number of strokes
  1. Two stroke engines
  2. Four stroke engines
  3. Six stroke engines
- By type of ignition
  1. Compression-Ignition Engine
  2. Spark-Ignition Engine

Rotary:

- Gas turbines
  1. Turbojet
  2. Turbofan
  3. Turboprop
- Ramjet
- Rocket engine

Reasons for Selection of Diesel Engine Over Petrol Engine:

1. Diesel Engines are More Efficient: As of now diesel engines convert 45-50% of the energy whereas gasoline engines convert only 30% of energy.
2. More Reliable: Because it doesn’t require high voltage ignition system so they don’t emit RF (radio frequency) issues with vehicle electronic system. As long as good maintenance is done, vehicles life would be around 5,00,000 miles with advancements in turbo technology some drawbacks are minimized.
3. Fuel Cost is Significantly Lower: Overall cost for kilowatt for diesel fuel runs between 30 to 50% lower than gasoline powered engines. Moreover, diesel require work to refine than gasoline.
4. Diesel is Much Safer: Higher flash and fire point makes diesel much safer than gasoline and vaporization loses are less compared to petrol engines.

4.3 Diesel Engine:

Diesel engine (also known as compression ignition engine) named after **Rudolf Diesel**, is an internal combustion engine in which fuel ignition is caused by elevated temperature of air due to adiabatic compression in the cylinder. In this fuel injectors are used to inject the fuel into the cylinder in the form of small droplets which atomizes the fuel with compressed air.

Fig 4.2: Four Stroke, Single Cylinder, Vertical Diesel Engine

4.4 Diesel Cycle:

Unlike Otto cycle, here the heat addition process takes place at constant pressure because the fuel is injected after the compressed air reaches the temperature higher than the self-ignition temperature of the fuel. So, this is also known as Constant Pressure Cycle but is better to avoid this term as it creates confusion with Joules cycle.

The following process takes place during the cycle

- Suction: Here, air enters through inlet valve opening due to creation of low pressure inside the cylinder till the crank angle reaches 180 degrees in four stroke engine and 90 degrees in two stroke engine.
- Isentropic compression: In this process, air in the cylinder gets compressed through the movement of piston from bottom dead center (BDC) to top dead center (TDC). Since this process takes place in the short period of interval it can be assumed as adiabatic compression process. The compression ratios are higher in order for the air in the cylinder to achieve self-ignition temperature of the fuel.
- Constant pressure heat addition: At the end of the compression process, when the piston is nearer to TDC the fuel injection starts injecting fuel into cylinder in the form of small droplets due to high temperature and pressure present in the cylinder the fuel vaporizes instantaneously and combustion starts taking place. The fuel is added till the initial part of the power stroke so the air-fuel mixture is allowed to expand during the heat addition.
- Isentropic expansion: After the heat addition is done the power stroke takes place till the BDC and work is transferred to the crank shaft through connecting rod. Since the heat addition done at constant pressure the amount of torque generated can be controlled with the change in fuel addition.
- Constant volume heat rejection: When the piston reaches BDC this process starts with the opening of exhaust valve. Here all the burnt and un-burnt gases escapes due to the pressure difference inside the cylinder and exhaust manifold.

- Exhaust: The remaining exhaust gases are pushed out with the movement of piston from BDC and the exhaust valve closes simultaneously when the piston reaches TDC. Thus finishes one ideal diesel cycle process.

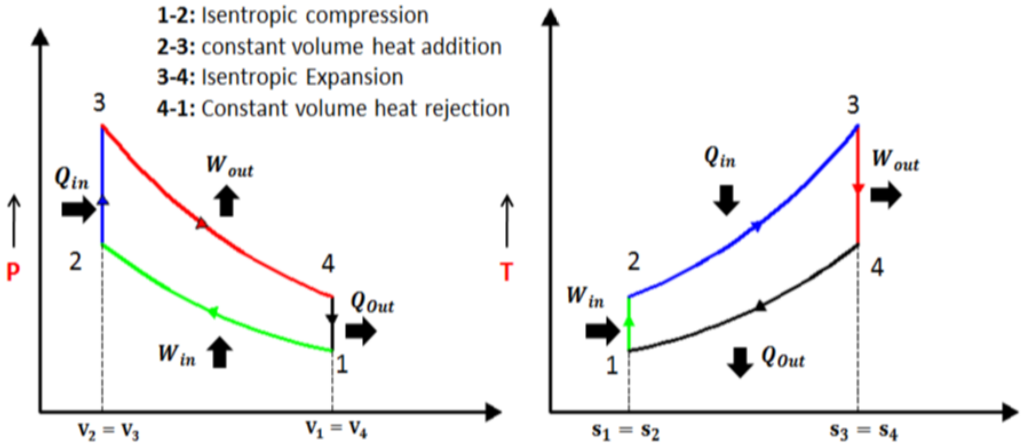

Fig 4.3: P-V and T-S Diagram of Otto Cycle

4.5 Types of Diesel Engine:

1. **Two stroke diesel engine:** In this the cycle is completed in one revolution of the crankshaft. The major difference is method of filling the fresh charge and removing the burnt gases from the cylinder. During the expansion stroke, the charge from the inlet uncovers the exhaust port, due to the decrease of pressure to atmospheric value exhaust products leave the cylinder. Further movement uncovers the transfer ports, permitting slightly compressed charge into the cylinder. To eliminate mixing of charges provisions are made on the cylinder which pushes the fresh charge to top portion and allows the burnt gases to leave from cylinder. Now, during the compression stroke charge in cylinder is compressed and fresh charge is introduced using spring loaded valve into the crankcase. This is the basic working process of the two stroke engine.

2. **Four stroke diesel engine:** The working of this cycle is similar as explained in the above diesel cycle

Advantages of Four Stroke Engine Over Two Stroke Engine:

1. Less noise: 4 stroke engines make less noise and mixture remains only in the combustion chamber.
2. More torque: In general, 4 stroke engines always make extra torque than 2 stroke engines at low RPM. Although 2 stroked ones give higher torque at higher RPM but it has a lot to do with fuel efficiency.
3. More fuel efficiency: 4 stroke engines have greater fuel efficiency than 2 stroke ones because fuel is consumed once every 4 strokes.
4. Less pollution: As power is generated once every 4 strokes and as no oil or lubricant is added to the fuel so 4 stroke engine produces less pollution.
5. More durability: We all know that more the engine runs, quicker it wears out. 2 stroke engines are designed for high RPM. If a 4-stroke engine with 100 rpm will run for 100 minutes than the other 2 stroke engine which has a higher rpm of 500 and will run for only 20 minutes.
6. No extra addition of oil: Only the moving parts need lubrication intermediately. No extra oil or lubricant is added to fuel.

Limitations of Four Stroke Engine:

1. Complicated design: A 4 stroke engine has complex valve mechanisms operated & controlled by gears & chain. Also there are many parts to worry about which makes it harder to troubleshoot.
2. Less powerful: As power gets delivered once every 2 rotations of crankshaft (4 strokes), hence 4 stroke is less powerful.
3. Expensive: A four stroke engine has much more parts than 2 stroke engine. So, they often require repairs which lead to greater expense.

Combustion Processes in Diesel Cycle:

- Unlike in SI engines, combustion process mainly happens with high compression ratios and heterogeneous mixture combustion takes places due to fuel injection.

Stages of Combustion in CI Engines:

- **Ignition Delay Period:** At the instant of injection of fuel droplets the mixture doesn't ignite immediately so some time is taken up by the cycle to build up pressure inside the chamber which has huge effect on combustion rate, knocking, engine start ability and presence of smoke in exhaust. This period is known as ignition delay period.
  It mainly divided into two parts
  1. Physical delay: It is the time between the injection and attainment of chemical reaction conditions. During this the fuel gets atomized, vaporized, mixed with air and reaches self-ignition temperature. It mainly depends on type of fuel used.
  2. Chemical delay: In this the reactions starts slowly and accelerate until ignition takes place. Generally it takes lager time but it depends on temperature of surroundings and at high temperatures it takes shorter time than physical delay.
- **Period of Rapid Combustion:** After the delay period, most of the fuel admitted would have evaporated and forms a combustible mixture with air. The period of rapid combustion starts from end of delay period to the point of attainment of maximum pressure in the cylinder. The rate of heat release is also maximum and it depends on duration of delay period.
- **Period of Controlled Combustion**
- **Period of After-Burning**

4.6 Engine Description:

After the diesel preparation and blending has been done proper type of diesel engine is to be selected which is a crucial step in determining the main conclusions in the project. By conducting survey on the available engines in our locality, based on merits Kirloskar make, four stroke, single speed, water cooled vertical diesel engine test-rig in ANITS college laboratory. The engine is provided with burette, graduations duly marked and three way valve for fuel flow measurement. Along with it provisions are made for applying load with the help of spring balance on the brake drum. So, from the above experimental set we can conduct load test on the four stroke diesel engine and performance characteristics for different blends of bio-diesel can be determined.

Table 4.1: Specifications of Diesel Engine

Single Cylinder Four Stroke Diesel Engine Test Rig:	
Engine Make	M/S Kirloskar
Cylinder Position	Vertical
Brake Power	5 HP
Speed	1500 RPM
Bore	80 mm
Stroke	110 mm
Compression ratio	17.5:1
Air Box Orifice Diameter	20 mm
Cooling	Water Cooled
Starting	Hand Cranking
Dynamometer	Rope Brake

4.7 Viscometer:

Viscosity is the measure of resistance offered by the fluid in the form of layers due to gradual deformation by shear stress or tensile stress. In general, it corresponds to the informal concept of “thickness”. For example, oil takes more time to fill than water.

A viscometer (also called viscosimeter) is a device used to measure the viscosity of a fluid which is an important property for determining the characteristics of the bio-diesel. For liquids viscosities which vary with flow conditions, an instrument called rheometer is used. Viscometers only measure under one flow condition. There are different types of viscometers such as Ostwald viscometers or glass capillary viscometers, Falling-sphere viscometers, vibrational viscometers based on different principle of operations.

At 20.00 degrees celsius the viscosity of water is 1.002mPa and its kinematic viscosity (ratio of viscosity to density) is 1.0038 mm2/s. These values are used for calibrating certain types of viscometer. Redwood viscometer determines the viscosity in terms of seconds. Here, initially time for collection of 50 cc fluid through a small orifice which is uniformly heated in terms of seconds is noted from this value by calculations viscosity can be determined.

Redwood viscometers are of two types:

1. Redwood viscometer No.1 (for fluids having viscosity corresponds to redwood seconds less than 2000)
2. Redwood viscometer No.2 (for fluids having viscosity corresponds to redwood seconds greater than 2000)

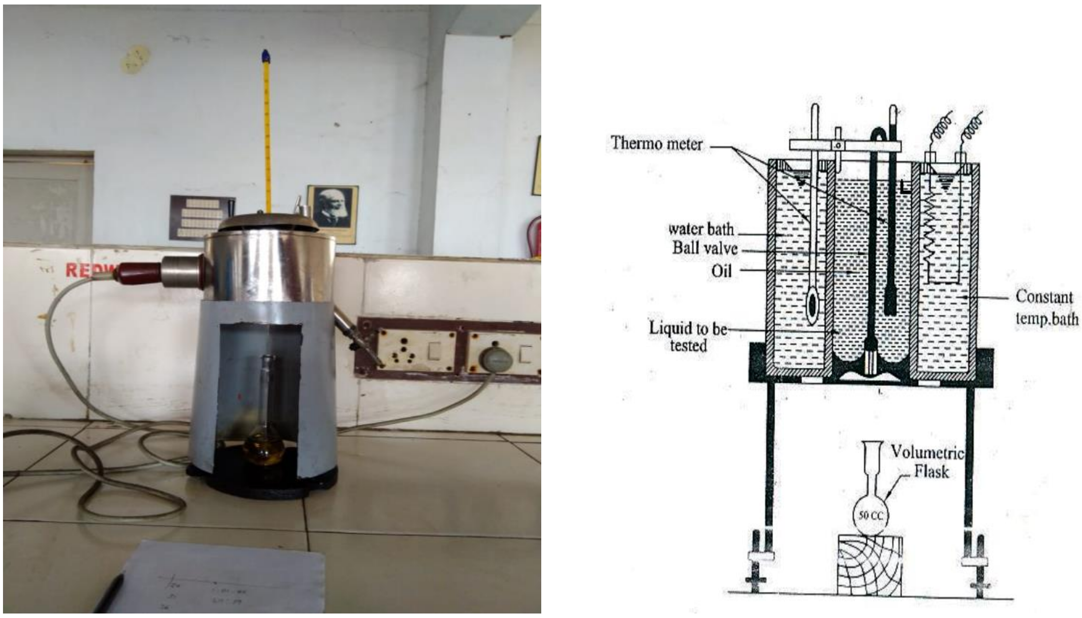

Fig 4.4: Viscometer Apparatus

CHAPTER - V

5. EXPERIMENTAL PROCEDURE:

5.1 Biodiesel preparation:

1. First the oil is manufactured from the rubber seeds.
2. Removal of impurities and particulate matter from the oil through filter.
3. Removal of water particles by heating the oil upto 100 degrees centigrade.
4. Now allow the oil to cool then methanol and sulfuric acid is added in required quantities.
5. Place the mixture on the heating machine and with the help magnetic stirrer heating and stirring is done simultaneously around 2 hours.
6. In the second stage NaoH billets are added to methanol solution and stirred until the billets gets melted completely. Then this solution is added to the main mixture.
7. Again the process of heating and stirring is done around 52-55 degrees centigrade until the separation is visible.
8. Now the solution is allowed for sedimentation until clear separation of two layers.
9. One layer contains biodiesel and other glycerol. Glycerol is allowed to solidify and the biodiesel is separated.
10. With the help of distilled water any further impurities are removed from the biodiesel.

- **Precautions:**

1. Make sure that the apparatus is free from impurities and water particles.
2. The oil should not contain any other proportions of chemicals.

5.2 Blending:

It is the main process involved for preparation of biodiesels by using a magnetic stirrer mixing is done with different oils to obtain the required properties.

This process involves:

a. Taking proportions of biodiesel.
b. Mixing biodiesel with petroleum diesel in the mixer.

Fig 5.1: Blending of Oils using Magnetic Stirrer

5.3 Blending of oils:

In general terminology to indicate the composition of biodiesel is as B5, B10, B15 etc., where "B" represents the percentage of blend.

For example: 10% biodiesel, 90% diesel is represented as B10.

Table 5.1: Oil Proportion in Fuel Blends

Blends	Diesel (ml)	Rubber Seed Oil (ml)
B 10	720	80
B 15	680	120
B 20	640	160
B 25	600	200
B 30	560	240

5.4 Properties of Oil Blends:

The properties of the above prepared oil blends were determined using the experimental setup described earlier and tabulated as follows in table 5.2

Table 5.2: Properties of Oil Blends

	B10	**B15**	**B20**	**B25**	**B30**
Flash point (^{O}C)	58	60	61	63	64
Fire point (^{O}C)	60	61	62	62	64
Viscosity (centi poise)	0.0343	0.0408	0.0413	0.0443	0.0465
Specific Gravity (gm/cc)	0.812	0.812	0.812	0.812	0.812
Calorific Value (kJ/kg)	43790.6	43368.7	42964.4	42477.3	41931.4

5.5 Testing procedure:

1. Check the fuel and lubricating oil systems before staring the engine.
2. Connect the water supply to the engine and brake drum and remove all load on the brake drum.
3. Keep 3-way cock in horizontal position so that fuel flows from the tank to the engine filling the burette.
4. Start the engine by hand cranking and allow the engine to pick up the rated speed.
5. Allow the engine to run for some time in idle condition.
6. Pull the 3-way cock in vertical position and measure the fuel consumption rate by noting the time for 10cc of fuel flow.
7. Experiment repeated at different loads.
8. Engine is stopped after detaching load from the engine.

CHAPTER - VI

6. RESULTS AND DISCUSSION:

In this chapter, the observations are evaluated from the basic formulae to obtain the required results and graphs. The observations and results are tabulated which are also mentioned in this chapter. The results were analysed and the conclusions have been derived.

6.1 Basic Data for Calculations:

1. Rated brake power of the engine B.P = 5 H.P =3.77KW
2. Speed of the engine N = 1500RPM
3. Effective radius of the brake drum R=0.213 m.
4. Stroke length L =110×10^{-3} m
5. Diameter of cylinder bore D = 80×10^{-3} m
6. Time taken for 10cc fuel consumption is ‘t’ sec

6.2 Basic Formulae for Calculations:

$$\text{Maximum load} = \frac{Rated\ B.P\times60000}{2\pi NR\times9.81}$$

$$= \frac{3.7\times60000}{2\pi\times1500\times0.213\times9.81}$$

=11.27 kg

$$\text{Brake Power (B.P)} = \frac{2\pi N(W-S)\times9.81\times R}{60000}$$

$$\text{Fuel Consumption (F.C)} = \frac{10}{t}\times\frac{specific\ gravity\times3600}{1000}\ \text{kg/hr}$$

Indicated Power (I.P) = B.P + F.P

Where F.P is the Frictional Power obtained from the graph drawn between Brake Power and Fuel Consumption. The linear portion of the graph is extended to cut the negative of the x-axis on which B.P. is taken. The length of intercept point from zero gives Frictional Power. This method of determining F.P. is known is known as Willian line Method.

Specific fuel consumption (SFC) = $\frac{F.C}{B.P}$ kg/KW.hr

Brake Thermal efficiency $\eta_{Bth} = \frac{B.P \times 3600}{FC \times CV}$

Indicated thermal efficiency $\eta_{Ith} = \frac{I.P \times 3600}{FC \times CV}$

Mechanical efficiency $\eta_{mech} = \frac{B.P}{I.P}$

Indicated mean effective pressure (IMEP) = $\frac{I.P \times 60000}{L \times \frac{\pi}{4} D^2 \times \frac{N}{2}}$ N/m^2

Brake mean effective pressure (BMEP) = $\frac{B.P \times 60000}{L \times \frac{\pi}{4} D^2 \times \frac{N}{2}}$ N/m^2

6.3 Model Calculations:

Considering B0 blend at 1.8 kgf load:

Specific gravity is 0.833 gm/cc

Calorific value is 45000 KJ/kg

$$\text{Brake Power (B.P)} = \frac{2\pi N(W-S)\times 9.81\times R}{60000}$$

$$=\frac{2\pi\times 1500\times 1.8\times 9.81\times 0.213}{60000}$$

$$=0.5908 \text{ KW}$$

$$\text{Fuel Consumption (F.C)} = \frac{10}{t}\times\frac{specific\ gravity\times 3600}{1000}\ \text{kg/hr}$$

$$=\frac{10}{64}\times\frac{0.833\times 3600}{1000}\ \text{kg/hr}$$

$$=0.4685 \text{ kg/hr}$$

Frictional Power from graph (F.P) =2.45 KW

Indicated power (I.P) = B.P +F.P =0.5908+2.45

=3.0408 KW

Where F.P is the frictional power obtained from the graph drawn between Brake Power and Fuel Consumption as shown in Fig 6.1. The linear portion of the graph is extended to cut the negative of the x-axis on which B.P is taken as shown in fig 6.1. The length of intercept point from zero gives frictional power. This method of determining F.P. is known as Willian’s Line Method.

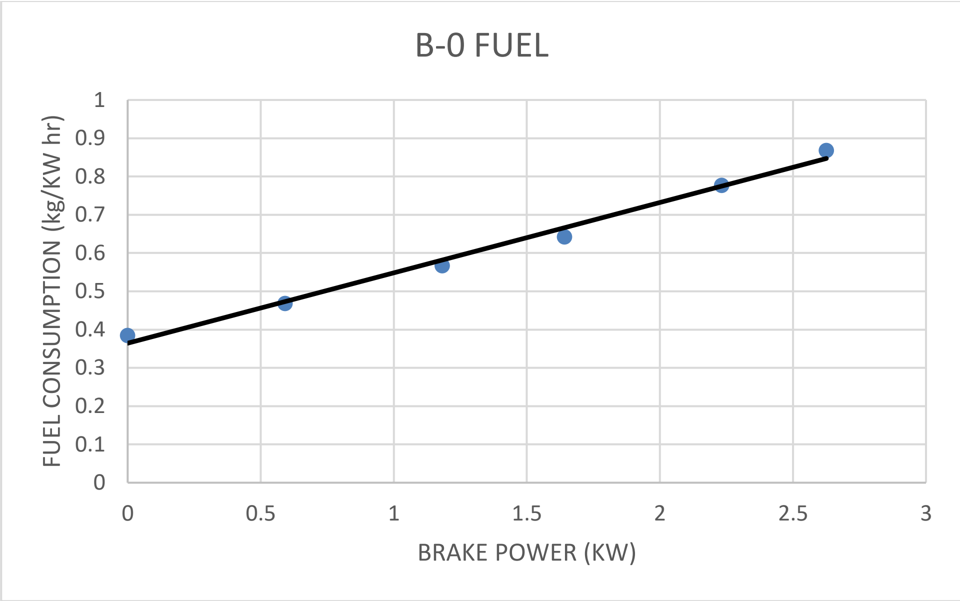

Fig 6.1: Brake Power vs Fuel Consumption for B0 blend

Specific fuel consumption (SFC) $= \frac{F.C}{B.P}$ kg/KW.hr

$=\frac{0.4685}{0.5908}$

=0.7929 kg/KW hr

Brake thermal efficiency η_{Bth} $=\frac{B.P\times 3600}{FC\ \times CV}$

$=\frac{0.5908\times 3600}{0.4685\times 45500}$

=0.0997

=9.97%

Indicated thermal efficiency η_{Ith} $=\frac{I.P\times 3600}{FC\times CV}$

$=\frac{3.0408\times 3600}{0.4685\times 45500}$

=0.5135

=51.35%

Mechanical efficiency η_{mech} $=\frac{B.P}{I.P}$

$=\frac{0.5908}{3.0408}$

=0.1942

=19.42%

Indicated mean effective pressure (IMEP) $=\frac{I.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{3.0408\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=345545.45 N/m^2

=3.45 bar

Brake mean effective pressure (BMEP) $=\frac{B.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{0.5908\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=85480.73 N/m^2

=0.85 bar

6.3.1 Model Calculations for B10 Blend:

Considering B10 blend at 1.8 kgf load:

Specific gravity is 0.812 gm/cc

Calorific value is 43790.6 KJ/kg

Brake Power (B.P) = $\frac{2\pi N(W-S)\times 9.81\times R}{60000}$

$=\frac{2\pi\times 1500\times 1.8\times 9.81\times 0.213}{60000}$

=0.5908 KW

Fuel Consumption (F.C) = $\frac{10}{t}\times\frac{specific\ gravity\times 3600}{1000}$ kg/hr

$=\frac{10}{72}\times\frac{0.833\times 3600}{1000}$ kg/hr

=0.406 kg/hr

Frictional Power from graph (F.P) =2.125 KW

Indicated power (I.P) = B.P +F.P =0.5908+2.125

=2.7158 KW

Where F.P is the frictional power obtained from the graph drawn between Brake Power and Fuel Consumption as shown in Fig 6.2. The linear portion of the graph is extended to cut the negative of the x-axis on which B.P is taken as shown in fig 6.2. The length of intercept point from zero gives frictional power. This method of determining F.P. is known as Willian’s Line Method.

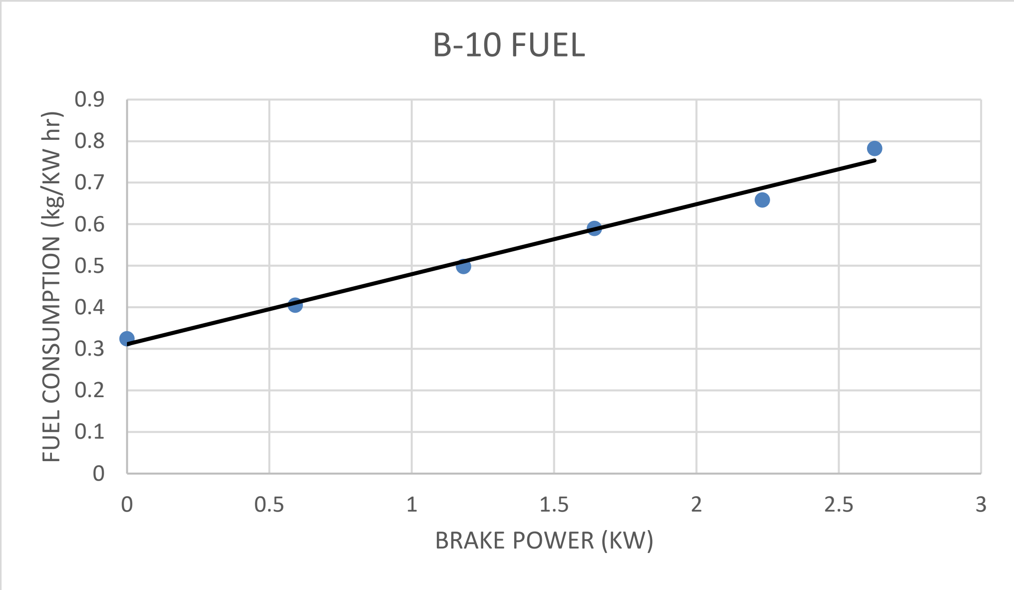

Fig 6.2: Brake Power vs Fuel Consumption for B10 blend

Specific fuel consumption (SFC) $= \frac{F.C}{B.P}$ kg/KW.hr

$=\frac{0.406}{0.5908}$

=0.6872 kg/KW hr

Brake thermal efficiency ηBth $=\frac{B.P\times3600}{FC \times CV}$

$=\frac{0.5908\times3600}{0.406\times43790.6}$

=0.1196

=11.96%

Indicated thermal efficiency ηIth $=\frac{I.P\times3600}{FC \times CV}$

$=\frac{2.7158\times3600}{0.406\times43790.6}$

=0.5499

=54.99%

Mechanical efficiency η_{mech} $=\frac{B.P}{I.P}$

$=\frac{0.5908}{2.7158}$

=0.2175

=21.75%

Indicated mean effective pressure (IMEP) $=\frac{I.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{2.7158\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=392939 N/m^2

=3.929 bar

Brake mean effective pressure (BMEP) $=\frac{B.P\times 60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{0.5908\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=85480.73 N/m^2

=0.85 bar

The observations made from the experimental procedure during the Load test are tabulated in the following tables (Table 6.1 – 6.7).

Table 6.1: Observations for Pure Diesel

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	77.94	0.3847	0	2.45	-	0	0.5038	0	2.78	0	3.5448
2.	1.8	64	0.4685	0.5908	3.0408	0.7929	0.0997	0.5135	0.1942	3.45	0.854	3.5448
3.	3.6	53.88	0.5671	1.1816	3.6316	0.4799	0.1648	0.5066	0.3253	4.12	1.34	3.5448
4.	5	46.7	0.6421	1.6411	4.091	0.3912	0.2022	0.5041	0.4011	4.64	1.86	3.5448
5.	6.8	38.58	0.7772	2.2319	4.6819	0.3482	0.2272	0.4766	0.4767	5.32	2.53	3.5448
6.	8	34.56	0.8677	2.6257	5.075	0.3304	0.2394	0.4628	0.5173	5.73	2.98	3.5448

Table 6.2: Observations for B10 Blend

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	90	0.3248	0	2.125	-	0	0.5378	0	2.4147	0	3.0745
2.	1.8	72	0.406	0.5908	2.7159	0.6872	0.1196	0.5499	0.2175	3.929	0.845	3.0745
3.	3.6	58.6	0.4988	1.1816	3.3066	0.4221	0.1947	0.5449	0.3573	4.784	1.709	3.0745
4.	5	49.5	0.5905	1.6411	3.7661	0.3598	0.2284	0.5243	0.4357	5.449	2.374	3.0745
5.	6.8	44.36	0.6589	2.2319	4.3569	0.2952	0.2784	0.5436	0.5122	6.303	3.229	3.0745
6.	8	37.36	0.7825	2.6257	4.7507	0.2979	0.2758	0.499	0.5526	6.81	3.79	3.0745

Table 6.3: Observations for B15 Blend

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	91	0.3212	0	1.6	-	0	0.4134	0	2.31	0	2.3149
2.	1.8	73.56	0.3973	0.5908	2.19	0.6726	0.123	0.457	0.269	3.16	0.854	2.3149
3.	3.6	60.24	0.4852	1.1816	2.78	0.41	0.202	0.4707	0.42	4.02	1.709	2.3149
4.	5	50.94	0.5738	1.6411	3.2411	0.349	0.237	0.468	0.506	4.68	2.37	2.3149
5.	6.8	43.7	0.6689	2.2319	3.8319	0.299	0.276	0.475	0.58	5.54	3.22	2.3149
6.	8	38.5	0.7592	2.6257	4.22	0.289	0.287	0.461	0.621	6.11	3.79	2.3149

Table 6.4: Observations for B20 Blend

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	94	0.3109	0	1.5	-	0	0.4311	0	2.17	0	2.1702
2.	1.8	73.2	0.3993	0.5908	2.09	0.675	0.123	0.459	0.2825	3.025	0.854	2.1702
3.	3.6	58.76	0.497	1.1816	2.68	0.421	0.199	0.469	0.4404	3.879	1.709	2.1702
4.	5	51.26	0.5702	1.6411	3.1411	0.347	0.2411	0.476	0.5224	4.54	2.37	2.1702
5.	6.8	44.12	0.662	2.2319	3.2819	0.2968	0.2822	0.427	0.68	4.748	3.22	2.1702
6.	8	37.38	0.782	2.6257	4.12	0.2879	0.281	0.452	0.636	5.969	3.79	2.1702

Table 6.5: Observations for B25 Blend

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	94.38	0.3097	0	1.9	-	0	0.5199	0	2.74	0	1.8809
2.	1.8	73.5	0.3977	0.5908	2.4908	0.6731	0.1239	0.5227	0.2371	3.6	0.85	1.8809
3.	3.6	58.2	0.5022	1.1816	3.0816	0.4250	0.1994	0.52	0.3834	4.45	1.70	1.8809
4.	5	50.12	0.5832	1.6411	3.5411	0.3553	0.2384	0.5145	0.4634	5.12	2.37	1.8809
5.	6.8	43.38	0.6738	2.2319	4.1319	0.3018	0.2807	0.5197	0.5401	5.97	3.22	1.8809
6.	8	38.18	0.7656	2.6257	4.5257	0.2915	0.2906	0.5009	0.5801	6.54	3.79	1.8809

Table 6.6: Observations for B30 Blend

S. No	Load on brake drum(W-S) kgf	Time for 10cc fuel consumption (Sec)	F.C. (Kg/hr)	Brake power (kW)	Indicated power (kW)	Specific fuel consumption (Kg/kW-hr)	Brake thermal efficiency	Indicated thermal efficiency	Mechanical efficiency	I.M.E.P (bar)	B.M.E.P (bar)	F.M.E.P (bar)
1.	0	92.38	0.3164	0	1.75	-	0	47.48	0	2.53	0	2.532
2.	1.8	73.7	0.3966	0.5908	2.348	0.67129	12.789	50.67	25.23	3.38	0.85	2.532
3.	3.6	58.18	0.5024	1.1816	2.9316	0.4251	20.19	56.91	40.305	4.24	1.7	2.532
4.	5	50.24	0.5818	1.6411	3.3911	0.3545	24.21	50.04	48.39	4.9	2.3	2.532
5.	6.8	42.82	0.68267	2.2319	3.9819	0.3058	28.06	50.07	56.05	5.76	3.2	2.532
6.	8	38.2	0.7652	2.6257	4.3757	0.2915	29.46	49.09	60.006	6.3	3.79	2.532

The Frictional Power in case of each blend is determined through the Willian's Line Method as described earlier. The Willian Line for each blend is obtained from the graphs shown in Figs 6.3, 6.4, 6.5, 6.6, 6.7 and 6.8 for Diesel, B10, B15, B20, B25, B30 respectively.

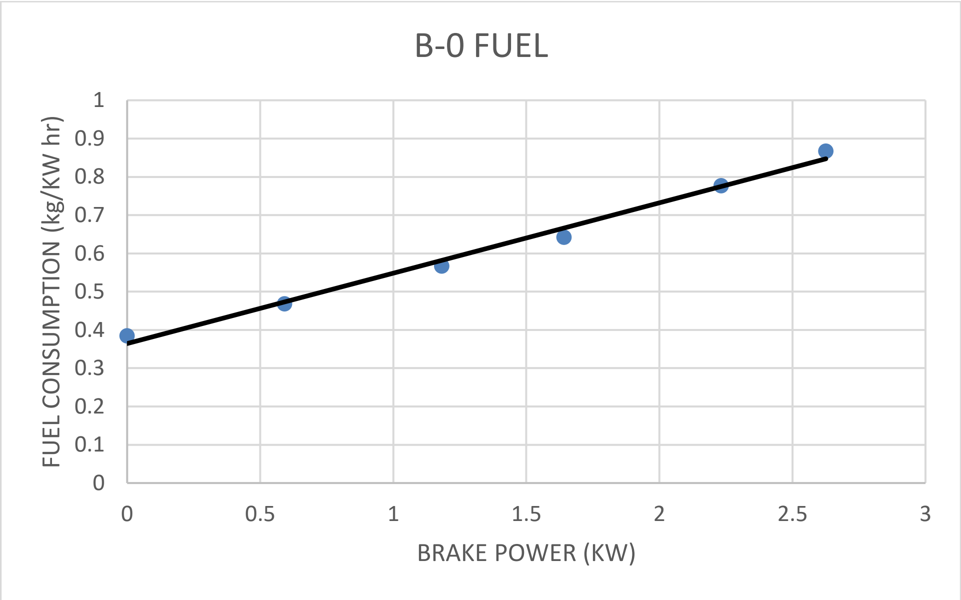

Fig 6.3: Brake Power vs. Fuel Consumption for Diesel

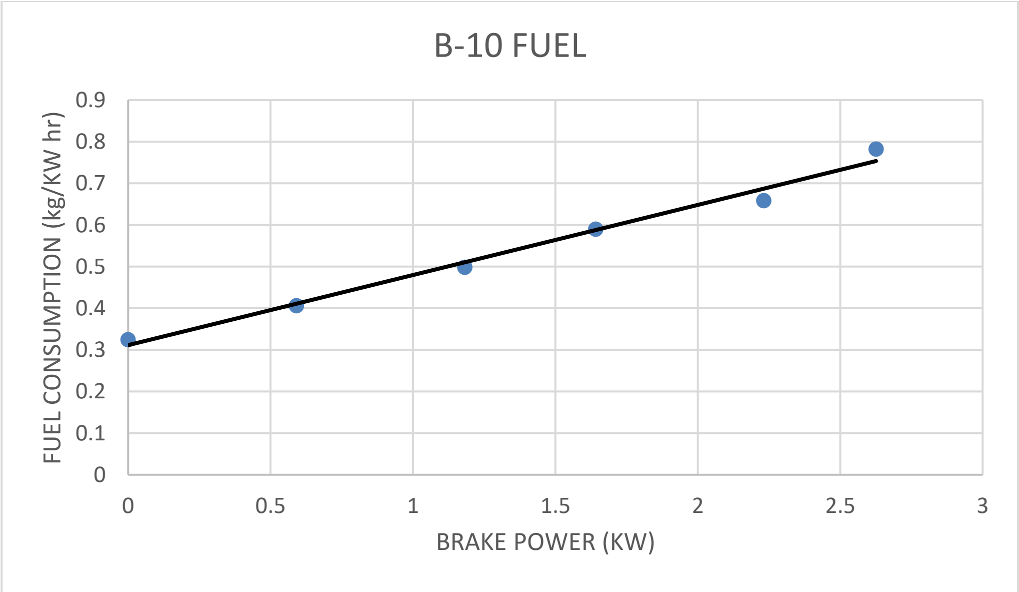

Fig 6.4: Brake Power vs. Fuel Consumption for B10

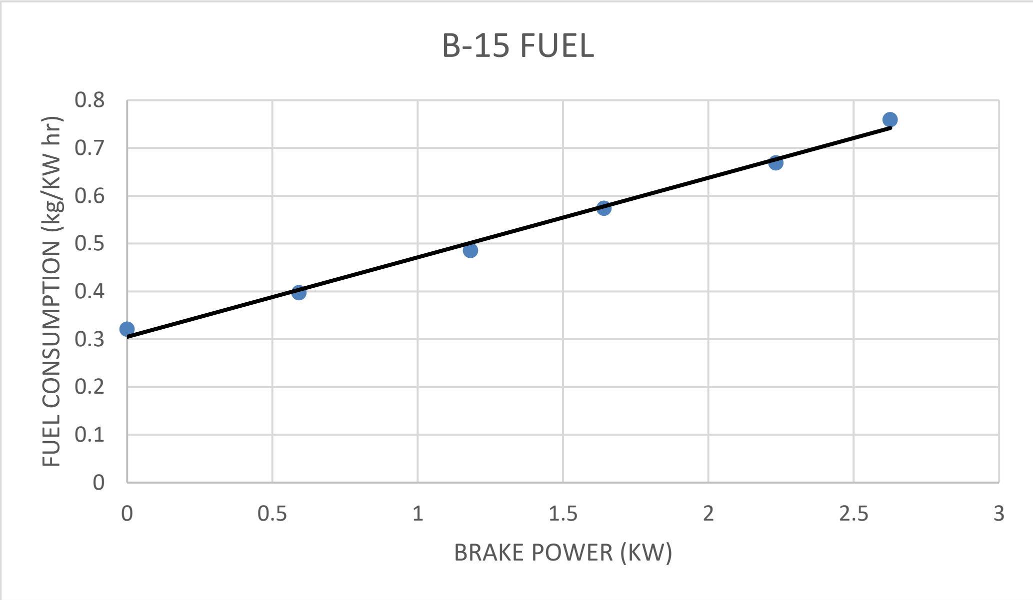

Fig 6.5: Brake Power vs. Fuel Consumption for B15

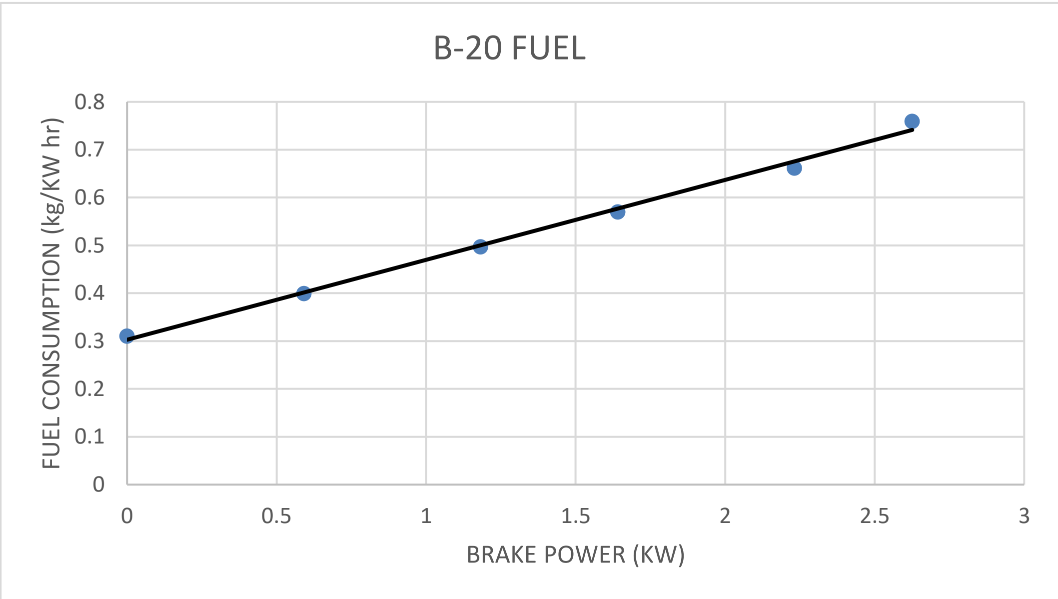

Fig 6.6: Brake Power vs. Fuel Consumption for B20

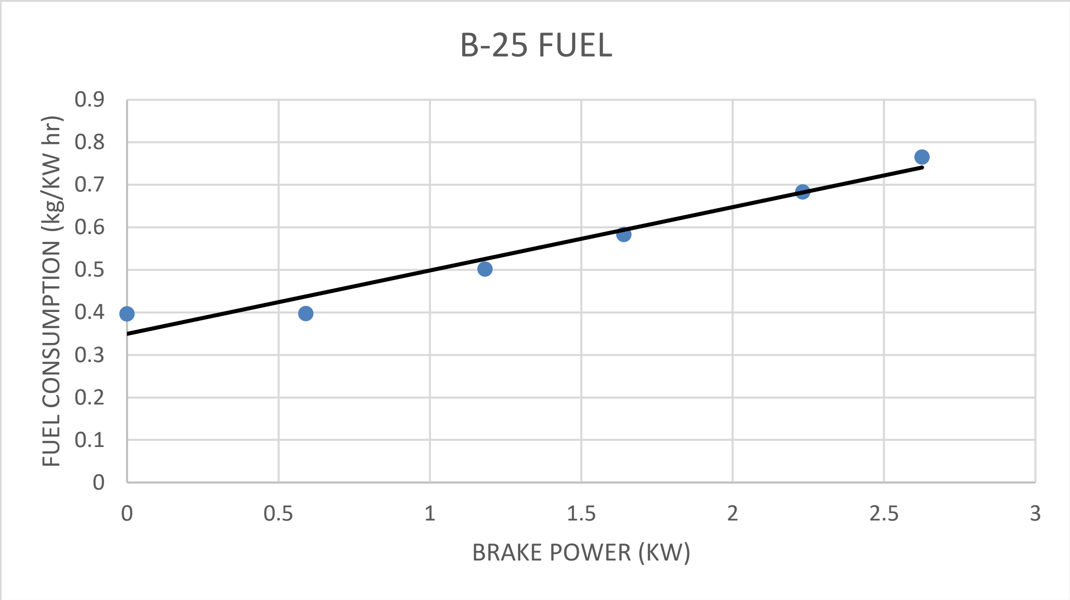

Fig 6.7: Brake Power vs. Fuel Consumption for B25

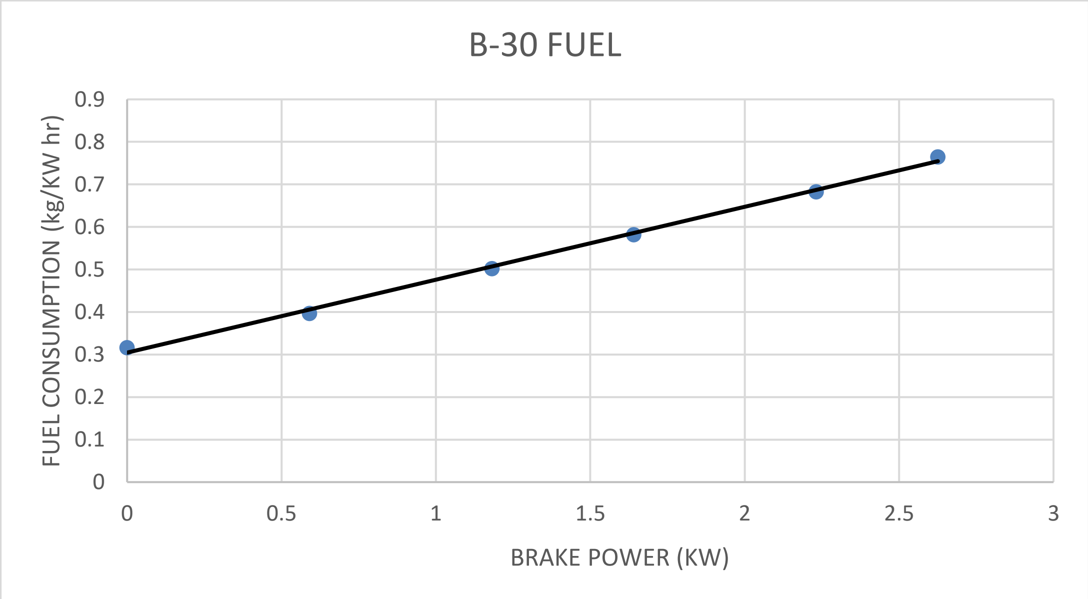

Fig 6.8: Brake Power vs. Fuel Consumption for B30

The Frictional Power obtained from the above graphs for each fuel blend is as follows:

For Diesel, F.P. = 2.45 KW

For B10, F.P. = 2.125 KW

For B15, F.P. = 1.6 KW

For B20, F.P. = 1.5 KW

For B25, F.P. = 1.9 KW

For B30, F.P. = 1.75 KW

6.4 Performance Characteristics:

The values of brake power, mechanical efficiency, specific fuel consumptions, Indicated thermal efficiency, brake thermal efficiency are set to be the parameters of performance of the engine. By comparing of different blend characteristics values are made to all combinations of conditions.

Engine performance is an indication of the degree of success with which it is doing its assigned job, i.e., the conversion of the chemical energy contained in the fuel into the useful mechanical work.

The degree of success is compared on the basis of the following

1. Specific fuel consumption
2. Brake mean effective pressure
3. Brake thermal efficiency
4. Indicated thermal efficiency
5. Mechanical efficiency

6.4.1 Comparison of Mechanical Efficiency:

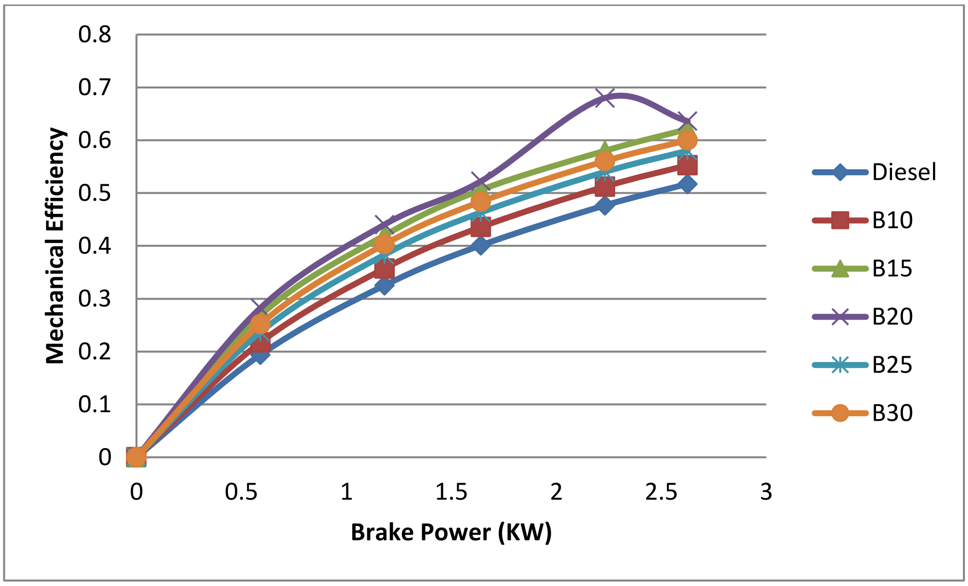

Fig 6.9: Brake Power Vs Mechanical Efficiency

Mechanical efficiency indicates how good an engine is inverting the indicated power to useful power. The values of Mechanical Efficiency at different Brake Powers are plotted as shown in Fig 6.9. B20 blend offers the best Mechanical Efficiency of all the mixtures and therefore seems to be the best mixture with regards to the minimum Frictional Power. Diesel gives the least Mechanical Efficiency.

6.4.2 Comparison of Brake Thermal Efficiency:

Brake Thermal Efficiency is defined as Brake Power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. The values of Brake Thermal Efficiency at different brake powers are plotted as shown in Fig 6.10. Diesel offers least Brake Thermal Efficiency.

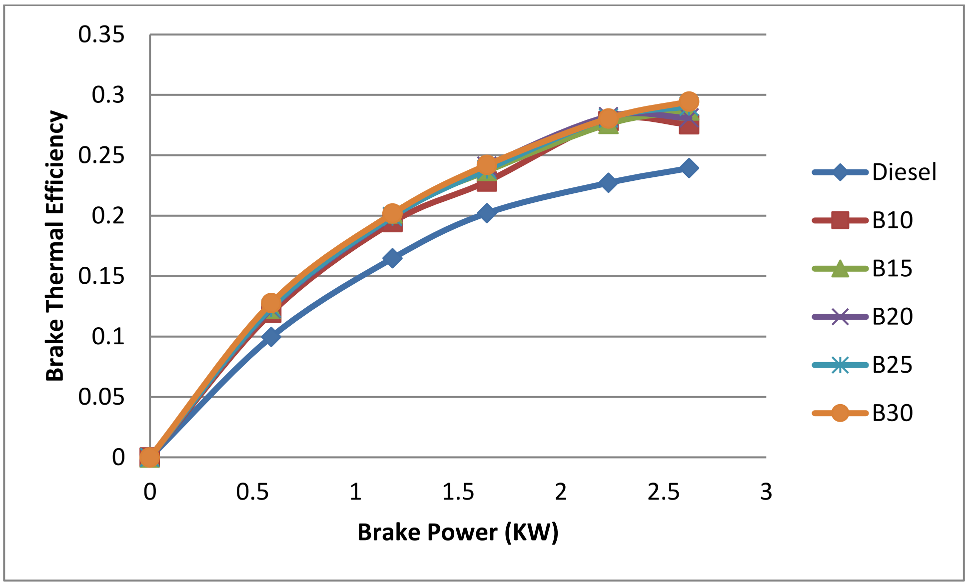

Fig 6.10: Brake Power Vs Brake Thermal Efficiency

6.4.3 Comparison of Indicated Thermal Efficiency:

The values of Indicated Thermal Efficiency at different brake powers are plotted as shown in Fig 6.11. B10 blend offers the maximum Indicated Thermal Efficiency of all the mixtures and it seems to be the best mixture, while B20 offers the maximum Indicated Thermal Efficiency.

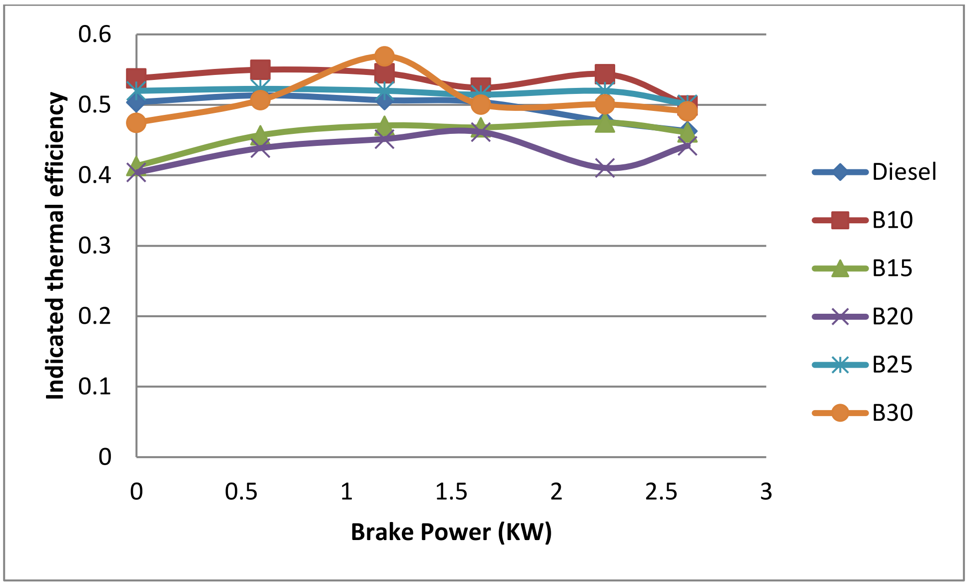

Fig 6.11: Brake Power Vs Indicated Thermal Efficiency

6.4.4 Comparison of Specific Fuel Consumption:

Specific fuel consumption is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. It is typically used for comparing the efficiency of IC engines with a shaft output. It is a rate of Fuel consumption with respect to power produced. The variations of Specific Fuel consumption with respect to Brake Power for different fuel blends as shown in Fig 6.12. B15 blend offers the least Specific Fuel Consumption of all the mixtures while Diesel has the maximum Specific Fuel Consumption.

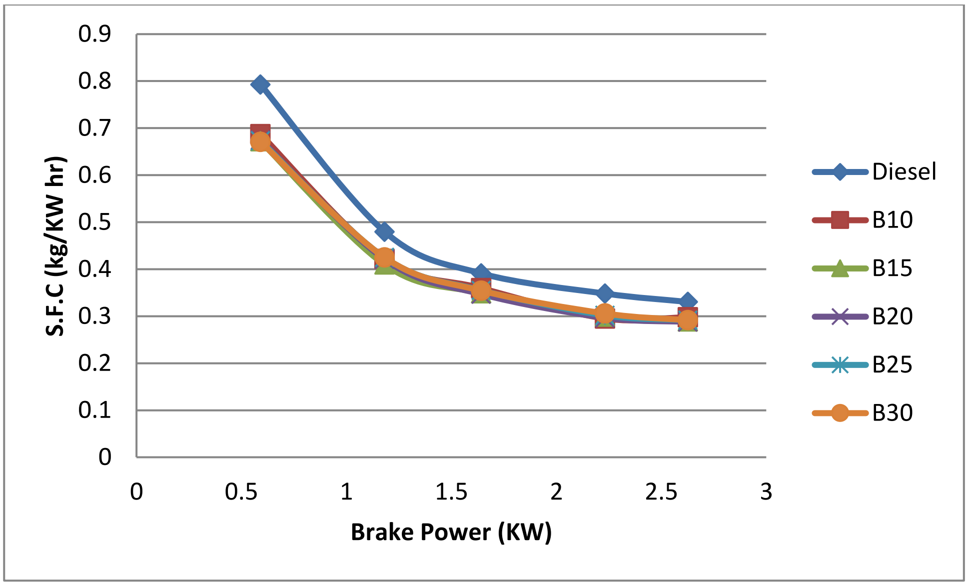

Fig 6.12: Brake Power Vs Specific Fuel Consumption

6.4.5 Comparison of Indicated Power:

Indicated Power is defined as the power produced in the cylinder by the combustion of the fuel. The variations of Indicated Power with respect to Brake Power for different fuel blends and Diesel are shown in Fig 6.13. B10 blend offers the maximum Indicated Power of all the mixtures and while B20 offers the minimum Indicated Power.

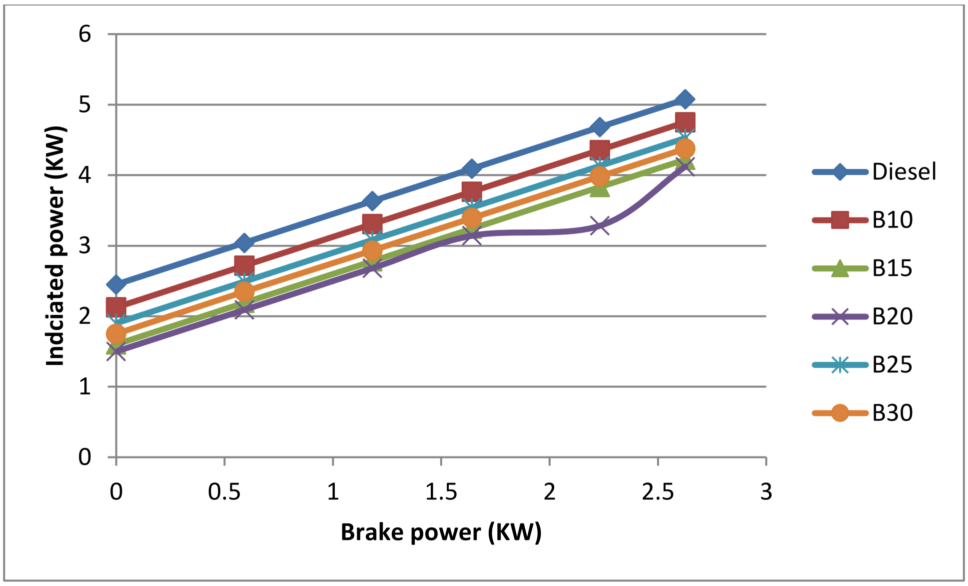

Fig 6.13: Brake power Vs Indicated Power

6.4.6 Comparison of Indicated Mean Effective Pressure:

Indicated Mean Effective Pressure is defined as the average pressure produced in the combustion chambers during the operation cycle. IMEP is equal to the brake mean effective pressure plus friction mean effective pressure. The variations of Indicated Mean Effective Pressure with respect to Brake Power for different fuel blends and Diesel are shown in Fig 6.14. B20 blend offers the minimum Indicated Mean Effective Pressure of all the mixtures and it seems to be the best mixture with regards to minimum Frictional Power while B10 offers the maximum Indicated Mean Effective Pressure.

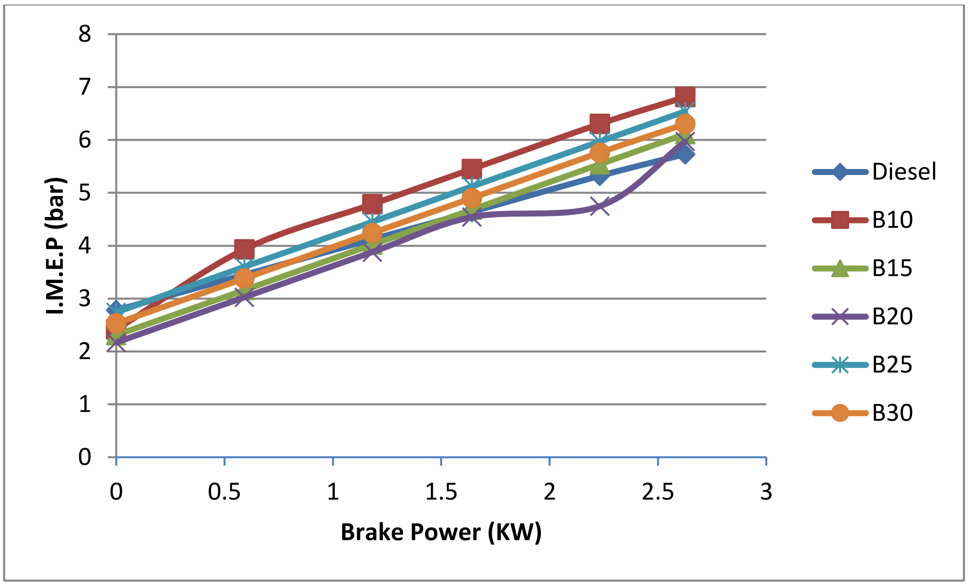

Fig 6.14: Brake Power Vs Indicated Mean Effective Pressure

6.4.7 Comparison of Frictional Mean Effective Pressure:

The Fig 6.15 shows the graph for Frictional Mean Effective Pressure (F.M.E.P) for the various fuel blends and diesel. The maximum FMEP is obtained for the B10 fuel blend while B25 fuel has the minimum FMEP comparatively.

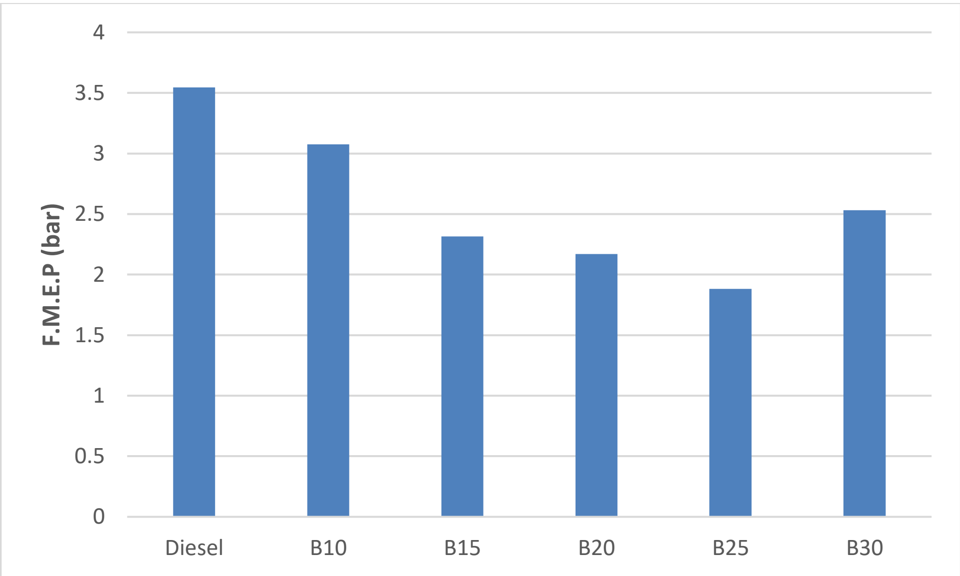

Fig 6.15: Blends Vs F.M.E.P

CHAPTER - VII

7. CONCLUSIONS

An experimental study is conducted to evaluate and compare the use of Rubber Seed Oil as a full or partial supplement to conventional diesel fuel in IC engine.

A series of tests were conducted using each of the fuels in various proportions with the engine working under the constant speed of 1500 rpm, and at different loads ranging from no load to full load. For each test performed, the performance gauging parameters such as fuel consumption, thermal efficiency, mechanical efficiency, mean effective pressure etc. were computed. Further the performance characteristics were also plotted.

Based on the experimental results, the following conclusions have been drawn:

- Comparing the mechanical efficiencies at different loads for all blends, it can be inferred that B20 offers the highest mechanical efficiency.
- Comparing the specific fuel consumption for each particular blend, it was observed that B30 has least specific fuel consumption for shaft output greater than 1kW. For output less than 1kW, B15 seems to be the best blend.
- Comparing the indicated power and indicated mean effective pressure for each blend, we came to know that B10 blend gives the highest indicated power compared to all blends.
- The different blends were also evaluated for the thermal efficiencies and it was observed B10 is the best mixture for indicated output and between 1kW TO 2kW B30 is the best.
- It can therefore be concluded that B10 blend containing 90% diesel and 10% rubber seed oil is the best blend.

Future scope:

The present day demand can't be reached by the existing reserves of fossil fuels and efficiency of conversion of this fuel energy to maximum extent is still in the development stages and lot of interest is being created for the topic of alternatives fuels. This substitute for these fossil fuels should have the following features

- Shouldn't deplete the existing resources at faster rate and make them available for our future generations.
- Usage of this substitute should have less environmental impacts than present fuels.
- The production of these fuels should be on large scale to meet our present needs efficiently.
- The cost of production for these fuels should be minimum.

The alternative should be applied without any major modifications to the existing diesel engine technologies effectively.

World's biofuel development and production status:

To increase the production on a large scale we should cultivate the biodiesel producing crops like palm trees, rubber trees etc. In many developed countries like U.S.A, U.K etc. there is the preference to utilize crops that can be grown domestically and import them when their own production can't meet their demand. U.S.A tops the lists in the usage of bio-ethanol and U.K for bio-diesel. The main reason is the cost of diesel is more than petrol. Other countries like India, Japan, China etc. are expanding their production of jatropha to produce fuel.

Moreover, with the usage of other techniques like turbo charging, super charging etc. may improve the efficiency and there is a large scope for development in this field. So, with enough encouragement for the use of biodiesel like government subsidies, awareness camps etc. this alternative can find a way to a new eco-friendly technologies.

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