# EXPERIMENTAL INVESTIGATION ON DIESEL ENGINE FUELED WITH TYRE PYROLYSIS OIL AND DIESEL BLENDS

*A Project report submitted in partial fulfillment of the requirements for*

*the Award of the Degree of*

**BACHELOR OF ENGINEERING**

**IN**

**MECHANICAL ENGINEERING**

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# CERTIFICATE

This is to certify that this project report entitled **"EXPERIMENTAL INVESTIGATION ON DIESEL ENGINE FUELED WITH TYRE PYROLYSIS OIL AND DIESEL BLENDS"** has been submitted by **T.Samrat(315126520217), T. G. Manikanta Eswar (315126520243), J.Soma Sekhar (315126520250), V.Vineesha (315126520229) and A.Varun (315126520287)** in partial fulfillment of the requirements for the award of **"Bachelor of Engineering"**in **Mechanical Engineering** of Andhra University is a record of bonafide work carried out under my guidance and supervision.

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# ABSTRACT

In everyday life consumption of commercial fuels has been increased such a way that there will be no more conventional fuels in future and which is also increasing the environmental pollution by the usage of crude oils. So, there is a need for the search of alternative fuel sources for the automobile applications and the development of alternative-fuel technologies are to be investigated to deliver the replacement of fossil fuel. To meet the growing fuel requirements many governments are entering into bio-diesel sector. The focused technologies are bio-ethanol, bio-diesel lipid derived bio-fuel, waste oil recycling, pyrolysis, gasification bio-ethanol, bio-diesel lipid de dim-ethyl ether, and biogas. On the other hand, appropriate waste management strategy is another important aspect of sustainable development since waste problem is concerned in every city. Therefore, in the present investigation the oil taken is the Tyre pyrolysis oil which was obtained by the pyrolysis of the waste automobile tyres.

In the initial stage the tests were conducted on four stroke single cylinder diesel engine by using diesel and base line data was generated. Further in the second stage experimental investigations were carried out on the same engine with same operating parameters by using the Tyre pyrolysis oil blended with diesel in different proportions such as D700, D800, T600 and T700 to find out the performance parameters. This work presents the experimental investigation carried on four stroke single cylinder diesel engine with Methanol as additive to the diesel-bio-diesel blends. Methanol was added as 5% ,Bio-diesel from coconut was as added as 10% by volume to the diesel-bio-diesel blends. Various parameters such as Thermal Efficiency, Fuel Consumption, Specific Fuel Consumption, Brake Power etc., were recorded. The performance analysis of all these blended oils are compared with standard diesel.

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# NOMENCLATURE

B.P - Brake Power

I.P - Indicated Power

M.E - Mechanical efficiency

B.T.E - Brake thermal efficiency

I.T.E - Indicated thermal efficiency

I.M.E.P - Indicated mean effective pressure

B.M.E.P - Brake mean effective pressure

I.S.F.C - Indicated specific fuel consumption

B.S.F.C - Brake specific fuel consumption

TPO - Tyre Pyrolysis Oil

# TABLES

# CHAPTER-1

# INTRODUCTION

## 1.1 Fossil Fuels

A fossil fuel is a fuel formed by natural processes, such as anaerobic decomposition of buried dead organisms, plants, containing energy originating in ancient photosynthesis. The age of the organisms and their resulting fossil fuels is typically millions of years, and sometimes exceeds 650 million years. Fossil fuels contain high percentages of carbon and include petroleum, coal, and natural gas.

The fossil fuels are formed from the fossilized remains of dead plants by exposure to heat and pressure in the Earth's crust over millions of years.This theory of formation of fossil fuels was first introduced by Andreas Libavius in his 1597 Alchemia and later by Mikhail Lomonosov. These fossil fuels are mainly used for energy production across the world such that in 2017 the world's primary energy sources consisted of petroleum (34%), coal (28%), natural gas (23%), amounting to an 85% share for fossil fuels in total primary energy consumption in the world. Although fossil fuels are continually being formed via natural processes, they are generally considered to be non-renewable resources because they take millions of years to form and the known viable reserves are being depleted much faster than new ones are being made. Also the world’s energy consumption was growing at about 2.3% per year. So there is a dire need of alternate fuels which can replace fossil fuels atleast upto some extent.

## 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, 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.

## 1.3 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 Tyre Pyrolysis Oil

Pyrolysis oil is the end-product of waste tyre and plastic pyrolysis, the oil is wide used as industrial fuel to substitute furnace oil or industrial diesel. Typical industrial applications of pyrolysis oil as a fuel, the fuel oil is mainly used in Machine do not require high quality fuel oil.

The pyrolysis oil is extracted from waste tyre or waste plastic by our pyrolysis plant, the pyrolysis plant is a machine converts waste tyre to oil. During the process of converting waste tyre/plastic to fuel oil there will be no pollution and solid waste. The end-product of pyrolysis plant is fuel oil, carbon black, and oil gas. The raw material such as waste plastic/tyre will be heated in reactor, then the waste tyre/plastic will vaporize, the vaporize oil gas will go into condenser and condensed into liquid fuel oil as shown in fig 1.1. The fuel oil is a good energy. The deducting system will deal with the waste perfectly, just little energy is required to heat the energy, the oil gas which cannot be condensed will be recycled back to heat reactor. Thus, will save much energy. The pyrolysis oil is mainly fuel oil used in heavy industry such as construction heating, steel factory, cement factory, boiler factory; hotel heating etc., the oil is closed to NO.2 diesel. By direct combustion in a boiler or furnace pyrolysis oil can be used to produce heat. This is the most simple and straight forward application combustion of pyrolysis oil in heavy industry is available. This application offers some companies the possibility to partly from natural gas, or heating oil to a renewable alternative fuel. pyrolysis oil is completive with the price of heating oil, more and more countries are using pyrolysis oil to replace natural gas.

Pyrolysis oil has the potential to be available in large amounts and competitively priced. Once the plastic/ tyre oil refined it can be used many ways. Such as truck, tractor, ship, diesel power generation and so on. The pyrolysis oil is mainly used in heavy industries for heating purpose as fuel, usually used in industry or machine which doesn’t require high stand oil like steel factory, cement factory, brick factory and glass factory etc. Most of our customers sold their oil to steel factories. In some places like Egypt, they have many cement factories. So, the oil is usually used in cement factory.

**Fig 1.1 Tyre Pyrolysis Oil**

## 1.5 Properties of Tyre Pyrolysis Oil

Tyre oil produced by the pyrolysis process was tested in the laboratory as per IS 1448 for determination of its physiochemical properties as compared to diesel as shown in the table 3. The liquids obtained are dark brown colored products, resembling petroleum fractions. The carbon residue result for the tyre oil is 0.85%. The carbon residue test is a measure of the tendency of the oil to form carbon, particularly when the oil is combusted in the absence of a large excess of air or when the fuel is subject to evaporation and pyrolysis. A high carbon residue result may lead to coking of fuel injector nozzles in a diesel engine or spray combustion orifices. The typical diesel fuel shown in Table 3 has a carbon residue of approximately 0.08% however, fuel oils used in very large diesel engines may have carbon residues up to 12%. Cetane number or CN is a measurement of the combustion quality of diesel during compression ignition. CN is actually a measure of a fuel's ignition delay; the time period between the start of injection and the first identifiable pressure increase during combustion of the fuel. In a diesel engine, higher Cetane fuels will have shorter ignition delay periods than lower Cetane fuels. Cetane number of tyre oil is 42 which is less than normal Cetane requirement. Bi-fueling or blending is the simplest technique for admitting fuels with low Cetane number in high compression engines. Generally, diesel engines run well with a CN from 40 to 55. The Kinematic viscosity of the tyre oil is 6.3 cast at $40^{o}$C which is slightly higher than the limits specified for Euro IV diesel fuel. Viscosity affects injector lubrication and fuel atomization. Fuels with low viscosity may not provide sufficient lubrication for the precision fit of fuel injection pumps or injector plungers resulting in leakage or increased wear. Fuels which do not meet viscosity requirements can lead to performance complaints. Fuel atomization is also affected by fuel viscosity. Diesel fuels with high viscosity tend to form larger droplets on injection which can cause poor combustion and increased exhaust smoke and emissions. The flash point of a liquid fuel is the temperature at which the oil begins to evolve vapors in sufficient quantity to form a flammable mixture with air. The temperature is an indirect measure of volatility and serves as an indication of the fire hazards associated with storage and application of the fuel. The flash point of the tyre-derived oil 32°C. The flash point is low when compared to petroleum refined fuel. But in general, slightly lower than the limit specified for euro IV diesel. The low flash points of the tyre oil were not surprising since the oil represents un-refined oil with a mixture of components having a wide distillation range. The carbon and hydrogen contents of the tyre oil are comparable with that of diesel fuel. The Sulphur content of the tyre oil is 0.88% which is less than found by other researchers. The

Sulphur content is found less than that of a light to medium fuel oil. Nitrogen content is found similar to that of diesel fuel but quite less than that of a light fuel oil and a heavy fuel oil. Higher nitrogen content of the fuel may contribute to the formation of NOx on combustion. Water and sediment can and will cause shortened filter life or plugged fuel filters which can in turn lead to fuel starvation in the engine. In addition, water can have negative impact on fuel corrosion and on microbial growth which is found to be nil for the tyre oil. The copper strip corrosion test indicates potential compatibility problems with fuel system components made of copper, brass or bronze. The limit requires that the fuel not darken these parts under the test conditions. The calorific value of the tyre oil is 10200 kcal/ kg. The calorific value is high and comparable with that of a diesel fuel oil, indicating the potential for the use of tyre derived oils as fuel. Polycyclic Aromatic Hydrocarbons (PAHs) are a group of chemicals that occur naturally in coal, crude oil and gasoline. PAHs also are present in products made from fossil fuels. Some of the PAH have been shown to be carcinogenic and/or mutagenic. PAHs also can be released into the air during the incomplete burning of fossil fuels. The less efficient the burning process, the more PAHs is given off but studies have shown that combustion of tyre oil with excess air results in negligible emissions of PAH. Since diesel engine always operate lean with combustion efficiency of 98% there may be less emission of PAH.

# CHAPTER 2

# LITERATURE REVIEW

Tyre Pyrolysis Oil is one of the product of pyrolysis of tyres. For the past 20 years, it is being used as a fuel. Researchers have successfully blended TPO with diesel to run CI engines. Researchers have also characterized the fuel to understand the constituents present in it. Their research and findings are listed below.

**Bhatt et al** [1] have studied the suitability of TPO as a fuel to be used in IC engines. According to their research about 190 million tons of tyres are produced each year in India alone. They analyzed the properties of TPO and concluded that it can be used as fuel for industrial furnaces and boilers in power plants due to their high calorific value, low ash and Sulphur content. But TPO has higher density, kinematic viscosity and lower cetane value compared to that of diesel. This limits its use as a fuel in IC engines. They proposed to use TPO blended with diesel fuel in various proportions by volume keeping the blend quality under permissible limits. During early years of work,

**Murena et al** [2] did a study on the product produced by hydrogenative pyrolysis of waste tyres. They investigated the temperature ranges between which solid phase and liquid phase products are formed. To maximize gaseous products, the temperature of the plant was proposed to be kept at 4000C. They studied the compounds present in both phases and the residual char left after pyrolysis.

GC-MS analysis of TPO was extensively done by **Islam et al** [3]. Their report revealed that fixed bed fire-tube heating pyrolysis is a viable option for producing the fuel. The TPO yields from such a plant has fuel properties like diesel, viscosity and hydrogen content similar to that of diesel. For the present work TPO produced from such a setup was taken and the properties were verified.

One of the major problems of TPO is its Sulphur content. Before it can be used as a fuel the Sulphur content has to be minimized. **Cumali et al** [4] reported different methods of desulphurization. They found that pyrolysis done at $500^0$C yielded low Sulphur TPO. Their research revealed, treating TPO with CaO, $Ca(OH)_2$ derivatives, formic acid - $H_2O_2$ or acetic acid – $H_2O_2$ was effective for desulphurization of TPO. In the present report, slow distillation of TPO was found effective in desulphurization of TPO.

**Williams et al** [5] studied the compounds present in TPO along with its combustion in a ceramic lined furnace. Their investigation revealed that TPO has PAH in high concentrations. They found high $SO_2$ and $NO_x$ emissions. To avoid PAH, they proposed combustion under excess oxygen conditions.

**Sharma and Murugan** [6] created an oxygen rich environment by blending TPO with an oxygenated fuel i.e. Jatropha Methyl Ester. They reported $NO_x$ and $SO_2$ emissions comparable to that of diesel when used in an IC engine.

**S. Murugan et al** [7] found that TPO when blended with diesel showed anomalous combustion and performance characteristics. They reported that TPO when blended with diesel in ratio of 30 - 40 % by volume, gives better combustion and performance than all other blends.

**Ramaswamy et al** [8], in their research work tested that CI engines can run up to 90% distilled TPO blend, above which the engine fails becomes dysfunctional.

**Aydin and Ilkiliç** [9] carried out optimizing the fuel production from waste vehicle tires by pyrolysis and resembling diesel fuel by various desulfurization methods. On that study, in order to reduce the high sulfur content of the fuel, CaO, $Ca(OH)_2$, and NaOH catalysts were used. In addition, effects of variables such as temperature, the catalyst ratio, and the $N_2$ flow rate on yield were investigated. The sulfur content of the product was found to be 34.25% lower with the utilization of 5% $Ca(OH)_2$ in the reaction. In order to make the sulfur content of the product closer diesel fuel, the acetic acid—$H_2O_2$, formic acid—$H_2O_2$, and $H_2SO_4$ were used in different proportions. It was found that the density and sulfur content of low sulfur tire fuel were slightly higher than that of diesel fuel, but other features and distillation curves were very close to diesel fuel.

A work on the fuel properties of pyrolysis liquid derived from urban solid wastes in Bangladesh was carried out by **Conesa et al.** [10]. Through the experimental investigation it is found that the optimum reaction condition for scrap tire pyrolysis was at reactor bed temperature of 450°C, for feedstock size of 2-3cm with a running time of 75min. At this condition, the liquid yield was 64wt% of the solid scrap tire feed.

A work on the pyrolysis of sugarcane bagasse for liquid fuel production was carried out by **Islam et al**. [11]. Through the experiment investigation it is found that at a reactor bed temperature of 450°C for a feed particle size of (300–600)µm and at a gas flow rate of 4 liter/minute, an oil yield of 49wt% of dry feed was obtained.

**Murgan et al.** [12] carried out evaluating the performance and emission characteristics of a single cylinder direct injection diesel engine fueled by 10, 30, and 50 percent blends of tire pyrolysis oil (TPO) with diesel fuel (DF). Results showed that the brake thermal efficiency of the engine fueled by TPO-DF blends increased with increase in blend concentration and higher than diesel. , HC, CO, and smoke emissions were found to be higher at higher loads due to high aromatic content and longer ignition delay.

**de Marco Rodriguez et al**. [13] studied the behavior and chemical analysis of tire pyrolysis oil. In this work, it is reported that tire oil is a complex mixture of organic compounds of 5–20 carbons with a higher proportion of aromatics. The percentage of aromatics, aliphatic, nitrogenated compounds, and benzothiazole were also determined in the tire pyrolysis oil at various operating temperatures of the pyrolysis process. Aromatics were found to be about 34.7% to 75.6% when the operating temperature was varied between 300°C and 700°C, while aliphatics were about 19.8% to 59.2%.

**Al-Lal et al**. [14] carried out their research on desulfurization of pyrolysis fuels obtained from waste. In this work, they used two affordable desulfurization techniques without hydrogen to reduce the sulfur content of these three pyrolysis fuels with moderate success that could make them useful as heating fuels. These desulfurization methods are based on the oxidation of the sulfur compounds present in these fuels with hydrogen peroxide to more polar sulfur compounds like sulfoxides and sulfones that can be later eliminated by methanol extraction or silica gel adsorption. The desulfurization rate was 64%.

**R. Senthil Kumar. [15]** carried out tests to evaluate the performance analysis of a single cylinder direct injection diesel engine fueled with 5%,15%, 25%, 50%,75%and 85% of tyre pyrolysis oil (TPO) blended with Diesel fuel and concluded that Best suitable blend is pyrolysis oil added in concentration of 50%,75%, with diesel.

**Mitesh D. Parmar.[16]** performed Experiments five engine loads i.e. 1,3,5,7 and 9 kg using pure diesel and Tyre pyrolysis oil-diesel blends i.e.T5, T15, T25, pure Tyre pyrolysis oil with constant speed of diesel engine and studied emissions of HC, CO, CO2,NOx and concluded that the belnd D75T25 give better results in both performance and emission wise.

**Naima et al.[17]** conducted tests on S.I and C.I engines and concluded that Engine fuelled with waste plastic pyrolysis oil exhibits higher thermal efficiency up to 50% of the rated power for petrol engine. Engine fuelled with waste plastic pyrolysis oil exhibits higher thermal efficiency up to 75% of the rated power for diesel engine. The exhaust gas temperature for waste plastic pyrolysis oil is higher than diesel and petrol for engine performance. Unburned hydrocarbon emission of waste plastic pyrolysis oil is less than that of diesel and petrol; for the different load. The NOx emission in waste plastic oil varies from 55 ppm to 91 ppm for petrol grade fuel of plastic oil, and for diesel grade fuel of plastic oil varies from 192 ppm to 1268 ppm. CO emission increased by 5% in waste plastic oil compared to diesel operation. The CO2 concentration increases with increase in load, due to incomplete combustion.

# CHAPTER 3

# SYNTHESIS OF TYRE PYROLYSIS OIL

Pyrolysis is a thermo-chemical conversion process in which an irreversible chemical change caused by the action of heat in absence of oxygen. Tyre is composed of 85% Carbon, 10 – 15% fabric material and 0.9-1.25% Sulphur, Pyrolysis of tyres yields products like:

1. Fuel Oil – (40 – 45 %)
2. Carbon Black – (30 – 35%)
3. Steel Wire – (3 – 5%)
4. Non-Condensable Gases – (8 – 10%)
5. Moisture – (3 - 5%)

The Tyre Pyrolysis Oil obtained is a blackish liquid with pungent odour. In an unrefined state, it contains small particulate carbon suspended in the liquid medium.

## 3.1 Production of Tyre Pyrolysis Oil

Tyre Pyrolysis Oil used for this research work was obtained from a pilot plant located in the city of Rourkela. The plant is a rotary type, pyrolysis reactor as shown in fig 3.2. The dimensions of the reactor is approximately 6.6 m in length, diameter is 2.8 m and has a capacity of 10 tons per batch. The reactor is rotated with the help of electrical motors. Initially it is fired up with waste wood and then coal is used to keep it burning. In the plant, shredded tyres are fed into the reactor. The front end of the reactor has a door with fasteners and can be opened or closed by unlocking or locking the fasteners respectively as shown in fig 3.4. The other end of the reactor is connected to a sealing element and a flexible connection. The volatile vapour which is formed during pyrolysis pass through the oil separator where heavy oil is separated by gravity and collected in an oil tank. A damper is provided at the outlet of the oil separator that connects to a series of water cooled pipes. The volatile gases pass through these condenser pipes where the light fractions are converted into liquid. A cooling tower is used to bring the temperature of coolant near atmospheric temperature. The whole setup and its accessories are operated by motor and pumps with the help of a control panel. The initial temperature at which volatile vapour evolve is 1600C. During the process, carbon black and steel wires are also generated as shown in fig 3.1.

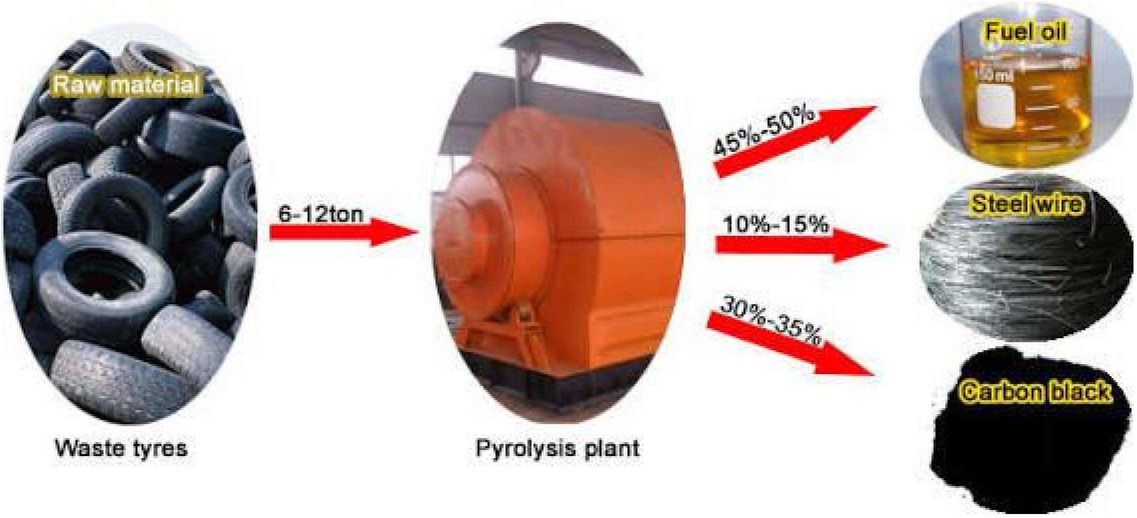


**Fig 3.1 Conversion of Waste Tyres into Useful Products**

**Fig 3.2 Pyrolysis Reactor**

Fig3.3 Pyrolysis Plant

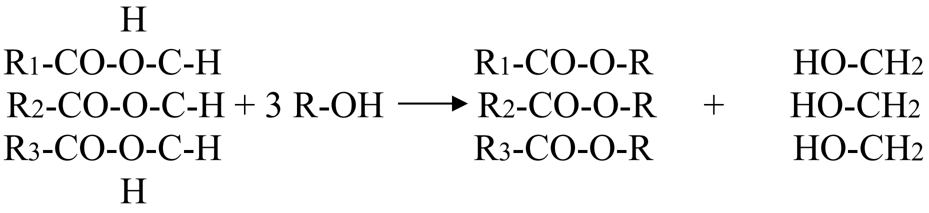
Fig3.4 Feeding of Tyres into Reactor

## 3.2 Production of Bio diesel from the coconut oil

Biodiesel is produced from vegetable oils. The main components of vegetable oil are triglycerides. Triglycerides are esters of glycerol with long chain fatty acids, commonly called fatty acids. Bio-diesel is defined as mono alkyl esters of long chain fatty acids from renewable feed stock such as vegetable oil or, animal fats, for use in compression ignition (CI) engines.

**Fig3.5 Coconut oil**

Coconut oil like any other vegetable oils and animal fats are triglycerides, inherently containing glycerin. The biodiesel process (transesterification) turns the oils into esters, separating out the glycerin from the main product (biodiesel).The glycerin sinks to the bottom and the biodiesel floats on top and can be decanted off. The process is called transesterification, which substitute's alcohol for the glycerin in a chemical reaction, using a catalyst.



$$\begin{array}{lclcl} \text{H} & & & & \\ R_1\text{-CO-O-C-H} & & R_1\text{-CO-O-R} & & \text{HO-CH}_2 \\ R_2\text{-CO-O-C-H} & + 3\ \text{R-OH} \longrightarrow & R_2\text{-CO-O-R} & + & \text{HO-CH}_2 \\ R_3\text{-CO-O-C-H} & & R_3\text{-CO-O-R} & & \text{HO-CH}_2 \\ \text{H} & & & & \end{array}$$

Oil of fats Alcohol Biodiesel Glycerin

## Materials required for production of Bio diesel

In the Laboratory scale, production of biodiesel from coconut oil, the following materials were used; 1 liter of coconut oil, 200 ml of methanol, sodium hydroxide (NaOH) scales accurate to 0.1 grams. The major feedstock source used in this work is coconut oil, locally produced in Bangladesh. By the stoichiometric equation of the process, 1 mol of coconut oil is required to react with 3 moles of methanol to produce 3 moles of the biodiesel and 1 mole of glycerol. 100g coconut oil was used for the transesterification process. A reaction temperature of 65°C was selected as reaction temperature for the process must be below the boiling point of alcohol (methanol, 78°C) used.

Different researchers have reported different reaction times for transesterification process as well as the entire biodiesel production process. The reported reaction time ranges from less than 15 minutes to more than 60 minutes. Reaction time of 30 minutes was therefore selected.

Most researchers have used 0.1 to 1.2 % (by weight of oil) of catalyst for biodiesel production. 0.8% NaOH (by weight of coconut oil) concentration was therefore selected while 20% methanol was used.

For the transesterification of coconut oil, the following steps were being followed in this work First 200 ml methanol was mixed with 150 ml (1 N) NaOH. As this is an exothermic reaction, so the mixture would get hot. This solution is known as sodium methoxide, which is a powerful corrosive base and harmful for human skin. So, safety precautions should be taken to avoid skin contamination during methoxide producing. Next, sodium methoxide was added with 1 liter of coconut oil, which was preheated about 65°C. Then the mixture was shaken for 5 minutes in a glass container. After that the mixture was left for 24 hours (the longer is better). For the separation of glycerol and ester this mixture then gradually settles down in two distinctive layers. The uppermost transparent layer is 100% biodiesel and the lower concentrated

**Fig3.6 transesterification of coconut oil**

layer is glycerol. The heavier layer is then removed either by gravity separation or with a centrifuge. In some cases if the coconut oil contains impurities, then a thin white layer is formed in between the two layers. This thin layer composes soap and other impurities. Then the biodiesel has been washed with distilled water in order to remove waste and a dry wash has been done by air-stone.

Biodiesel produced in the above process contains moisture (vaporization temperature 100°C), methanol (vaporization temperature 60°C) and usually some soap. If the soap level is low enough (300-500 ppm), the methanol can be removed by vaporization and the methanol will usually be dry enough to directly recycle back to the reaction. Methanol tend to act as a co-solvent for soap in biodiesel, so at higher soap levels the soap will precipitate as a viscous sludge when the methanol is removed. Anyway, heating the biodiesel at temperature above 100 °C would cause the removal of both the moisture and methanol as well.

In the first step of washing process, the collected biodiesel after transesterfication reaction was taken into a beaker. Hot water (40°C) was poured into the biodiesel slowly. Then the mixtures were shaken slowly and the solution was kept 4 hours in stable position. Then a layer of soap has formed in the bottom of beaker. Then the biodiesel was collected by a pipe followed by siphoning method. the process had been repeated 4 times and gradually soap formation was reduced. The pH of the solution was also measured after each wash .This process is known as wet wash process. At last we get the pure Bio diesel of coconut oil.

### 3.3 Blending with Fossil fuels

In this method, tyre pyrolysis oil and coconut biodiesel is blended with fossil fuels (diesel is commonly used) with magnetic stirrer and preheated. Because of this blending the reduction in viscosity accompanied by decrease in its density, its volatility is also improved. Thus, desired fuel characteristics are obtained.

# CHAPTER-4

# EXPERIMENTAL SETUP

## 4.1 Diesel Engine:

A diesel engine also known as a compression-ignition engine. It is an internal combustion engine that uses the heat of compression to initiate ignition to burn the fuel that has been injected into the combustion chamber. This is in contrast to spark-ignition engines such as a petrol engine, gasoline engine or gas engine using a gaseous fuel as opposed to gasoline, which uses a spark plug to ignite an air-fuel mixture. The engine was developed by German inventor Rudolf Diesel in 1893.

The diesel engine has the highest thermal efficiency of any regular internal or external combustion engine due to its very high compression ratio. Low-speed diesel engines are used in ships and for other applications where overall engine weight is relatively unimportant, can have a thermal efficiency that exceeds 50%.

Diesel engines are manufactured in two-stroke and four-stroke versions. They were originally used as a more efficient replacement for stationary steam engines. Since the 1910s they have been used in submarines and ships. Its use in locomotives, trucks, heavy equipment and electric generating plants followed later. In the 1930s, they slowly began to be used in a few automobiles. Since the 1970s, the use of diesel engines in larger on-road and off-road vehicles in the USA increased. As of 2007, about 50% of all new car sales in Europe are diesel.

The world's largest diesel engine is currently a Wartsila-Sulzer RTA96-C Common Rail marine diesel of about 84,420 kW (113,210 HP) @ 102 rpm output. According to the British Society of Motor Manufacturing and Traders, the EU average for diesel cars account for 50% of the total sold, including in France 70%, and in the UK - 38%.

### 4.1.1 Size groups:

There are three size groups of Diesel engines.

- Small -Under 188 kW (252 HP) output
- Medium
- Large

### 4.1.2 Engine speeds:

Within the diesel engine industry, engines are often categorized by their rotational speeds into three groups:

- High-speed engines (>1,000 rpm),
- Medium-speed engines (300 - 1,000 rpm), and
- Slow-speed engines (<300 rpm).

High-speed and Medium-speed engines are predominantly four-stroke engines; except for the Detroit Diesel two-stroke range. Medium-speed engines are physically larger than high-speed engines and can burn lower-grade (slower-burning) fuel than high-speed engines.

Slow-speed engines are predominantly large two-stroke crosshead engines, hence very different from high- and medium-speed engines. Due to the lower rotational speed of slow-speed and medium-speed engines, there is more time for combustion during the power stroke of the cycle.

### 4.1.3 Major advantages:

Diesel engines have several advantages over other internal combustion engines:

- They burn less fuel than a petrol engine performing the same work, due to the engine's higher temperature of combustion and greater expansion ratio. Gasoline engines are typically 30% efficient while diesel engines can convert over 45% of the fuel energy into mechanical energy.

- They have no high voltage electrical ignition system, resulting in high reliability and easy adaptation to damp environments. The absence of coils, spark plug wires, etc., also eliminates a source of radio frequency emissions which can interfere with navigation and communication equipment, which is especially important in marine and aircraft applications.

- The life of a diesel engine is generally about twice as long as that of petrol engine due to the increased strength of parts used. Diesel fuel has better lubrication properties than petrol as well.

- Diesel fuel is distilled directly from petroleum. Distillation yields some gasoline, but the yield would be inadequate without catalytic reforming, which is a more costly process. Diesel fuel is considered safer than petrol in many applications. Although diesel fuel will burn in open air using a wick, it will not explode and does not release a large amount of flammable vapour. The low vapour pressure of diesel is especially advantageous in marine applications, where the accumulation of explosive fuel-air mixtures is a particular hazard. For the same reason, diesel engines are immune to vapour lock.

- For any given partial load, the fuel efficiency (mass burned per energy produced) of a diesel engine remains nearly constant, as opposed to petrol and turbine engines which use proportionally more fuel with partial power outputs. They generate less waste heat in cooling and exhaust.

- Diesel engines can accept super- or turbo-charging pressure without any natural limit, constrained only by the strength of engine components. This is unlike petrol engines, which inevitably suffer detonation at higher pressure.

- The carbon monoxide content of the exhaust is minimum; therefore diesel engines are used in underground mines.

- Biodiesel is easily synthesized, non-petroleum-based fuel (through transesterification) which can run directly in many diesel engines, while gasoline engines either need adaptation to run synthetic fuels or else use them as an additive to gasoline (e.g., ethanol added to gasohol).

### 4.1.4 Engine description:

The prepared fuel blends are used in Kirloskar made Four stroke, single cylinder diesel engine- test rig in the laboratory and load test is held with additional attachment of muffler to the exhaust smoke pipe as shown in fig 4.1 and fig 4.2. By the load test, the performance characteristics and from smoke analysis, combustion analysis of fuel is obtained.

The given I.C engine is a vertical, single cylinder, 4-stroke, and water-cooled constant speed diesel engine. It is fitted with a flywheel sufficient enough to give momentum to absorb energy when in power stroke and release during the other three strokes to get a uniform speed. Provision is made to measure the exhaust heat with the help of a calorimeter and thermocouples fixed at salient points. This engine is provided with a crank handle for starting. The engine is mounted with an absorption thermometer of brake drum type. The engine set up is also provided with burette, graduations duly marked and a three way to measure the fuel flow rate.

## TABLE 1SPECIFICATIONS OF VERTICAL 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 |
| Orifice Diameter | 20 mm |
| Cooling | Water Cooled |
| Starting | Hand Cranking |
| Dynamometer | Rope Brake |

### 4.1.5 Combustion in diesel engine:

Combustion in diesel engines takes place in three distinct phases as shown in fig 4.5.

### First Phase of Combustion:

Ignition delay period is the time span between commencement of fuel injection and the start of fuel ignition. The fuel emerges into the cylinder as small liquid particles, which are surrounded by hot compressed air. They receive heat from the air and more volatile constituents of the fuel vaporize. During the ignition delay period a large part of the fuel charge is prepared for combustion. During the ignition delay, the injector continued to inject the fuel and, if this has built up a sufficient quantity, the rapid combustion and pressure rise will be quite violent, causing detonation and shock loading creating a noise termed diesel knock. After ignition commences flame propagation proceeds very quickly in the fuel vapor or air mixture, accompanied by rapid temperature and pressure rise. Towards the end of the rapid pressure rise a point is reached where the rate of pressure rise falls away quickly, and the curve flattens out towards the maximum pressure point. The point where the rate of pressure rise changes near and approaching the maximum pressure point is the end of the second phase of combustion. This shows only a small pressure rise, as the rate is decreased due to downward movement of the piston. The end of injection occurs approximately at or slightly beyond the maximum pressure point. Combustion in diesel engines can be termed as a 'controlled explosion'.

**Second Phase of Combustion:**

Rapid or uncontrolled combustion usually occur just after the ignition of the fuel vapors.

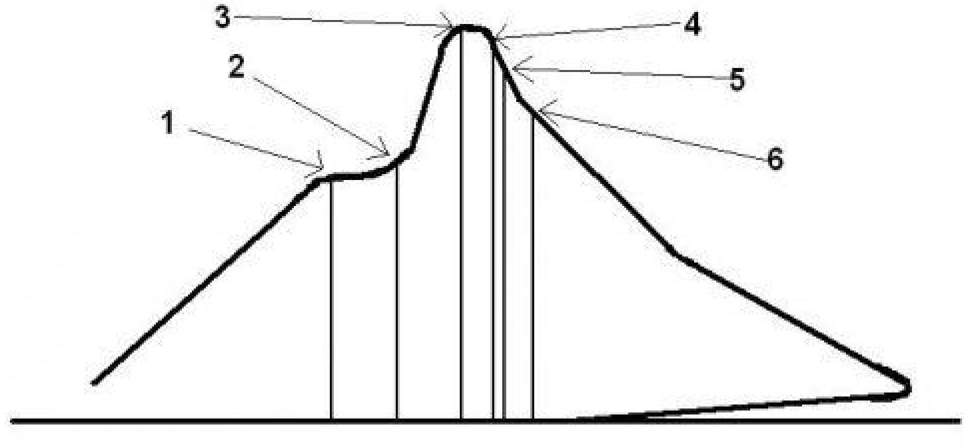
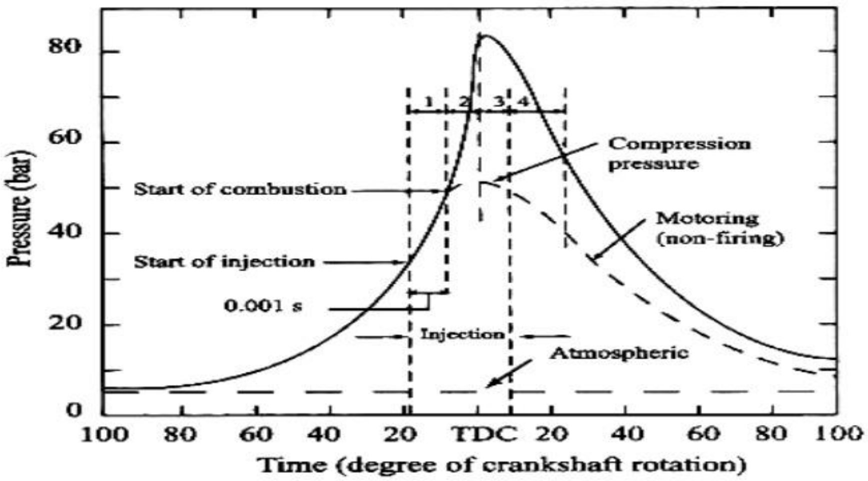


**Fig 4.5 Different Stages of Combustion**



1. Start of Injection
2. Beginning of Ignition

3. Maximum Pressure
4. End of Injection
5. End of Ignition
6. End of After Burning

**Different stages in combustion:**

1-2 : Ignition Delay Period
2-3 : Rapid / Uncontolled combustion
2-4 : Ignition Period
3-4 : Controlled Combustion
5-6 : After Burning

**Third Phase of Combustion:**

Controlled combustion is regulated by the rate at which fuel continues to be delivered.

**After Burning:**

After burning is said to occur when the third phase of combustion extends over a long period. It may be caused by incorrect fuel grade, bad atomization, poor or excess penetration, incorrect fuel temperature, incorrect injection timing, insufficient air supply, or any combination of these. Slow burning, high viscosity, high density, high carbon content fuels may also cause after burning of a serious nature leading to engine damage.

**Effect of After Burning:**

After burning creates high exhaust temperatures and may cause overheating of the engine in severe cases. Some drop in the maximum firing pressure usually accompanies this. There is a loss of thermal efficiency when after burning occurs, due to greater loss of heat to exhaust gases and the transfer of large amount of heat to the cooling water. There is a risk of damage to exhaust valves and scavenge fires.

## 4.2 Magnetic Stirrer:

A magnetic stirrer or magnetic mixer is a laboratory device that employs a rotating magnetic field to cause astir bar (also called “flea”) immersed in a liquid to spin very quickly, thus stirring it as shown in fig 4.6. The rotating field may be created either by a rotating magnet or a set of stationary electro magnets, placed beneath the vessel with the liquid. Since glass does not effect a magnetic field appreciably (it is transparent to magnetism) and most chemical reactions take place in glass vessels (i.e. see beaker (glassware) or laboratory flasks), magnetic stir bars work well in glass vessels. On the other hand, the limited size of bar means that magnetic stirrers can only be used for relatively small (under 4 litres) experiments. They also have difficulty dealing with viscous liquids or thick suspensions. For larger volumes or more viscous liquids, some sort of mechanical stirring is typically needed.

Magnetic stirrers are often used in chemistry and biology. They are preferred over gear-driven motorized stirrers because they are quieter, more efficient, and have no moving external parts to brake or wear out (other than the simple bar magnet itself).Because of its small size, a stirring bar is more easily cleaned and sterilized than other stirring devices. They do not require lubricants which could contaminate the reaction vessel and the product. They can be used inside hermetically closed vessels or systems, without the need for complicated rotary seals. Magnetic stirrers may also include a hotplate or some other means for heating the liquid.

**Fig 4.6 Magnetic Stirrer**

## 4.3 Cleveland’s Apparatus:

The Cleveland open-cup method is one of the three main methods in chemistry for determining the flashpoint of a petroleum product using a Cleveland open-cup apparatus, also known as a Cleveland open-cup tester as shown in fig 4.7. First, the test cup of the apparatus (usually brass) is filled to a certain level with a portion of the product. Then, the temperature of the chemical is increased rapidly and then at a slow constant rate as it approaches the theoretical flash point. The increase in temperature will cause the chemical to begin to produce flammable vapour in increasing quantities and density.

The lowest temperature at which a small test flame passing over the surface of the liquid causes the vapour to ignite is considered the chemical's flash point. This apparatus may also be used to determine the chemical's fire point which is considered to have been reached when the application of the test flame produces at least five continuous seconds of ignition.

**Fig 4.7 Cleveland's Apparatus**

# CHAPTER 5

# EXPERIMENTAL PROCEDURE

### 5.1 Blending

It is the main process involved for making biodiesels. It is nothing but mixing of transesterified oil in certain proportions to obtain the required properties. This process involves:

Taking proportions of the oil

Mixing of oil in the mixture up to the foam arises

### 5.1.1 Blending of oil

In this process, the conventional diesel fuel is mixed with Tyre pyrolysis oil ,bio diesel from coconut and methanol in required proportions to obtain the required blends .

Following are the blends obtained in this process:

D100 –DIESEL 100%
D700 - TYRE PYROLYSIS OIL 25%, METHANOL 5%, DIESEL 70%
D800 - TYRE PYROLYSIS OIL 15%, METHANOL 5%, DIESEL 80%
T600 - TYRE PYROLYSIS OIL 20%, BIO DIESEL 20% DIESEL 60%
T700 - TYRE PYROLYSIS OIL 10%, BIO DIESEL 20%,DIESEL 70%

### 5.2 Performance Characteristics of the Diesel Engine

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

**Indicated Thermal Efficiency:** Indicated thermal efficiency is the ratio of energy in the indicated power(IP) to the Input fuel energy.

**Brake Thermal Efficiency:** Brake thermal efficiency is the ratio of energy in the brake power (BP), to the input fuel energy. Brake thermal efficiency is the true indication of the efficiency with which the thermodynamic input is converted into mechanical work. It also accounts for Combustion efficiency.

**Mechanical Efficiency:** Mechanical efficiency is defined as the ratio brake power to the indicated power.

**Mean effective pressure:** Mean effective pressure is the average pressure inside the cylinders of an internal combustion engine based on the calculated or measured power output Mean effective Pressure, gives an indication of engine displacement utilization higher the mean effective pressure higher will be power developed by the engine for a given displacement.

**Specific fuel consumption:** Specific fuel consumption is an important parameter that reflects how good the engine performance is. It is the reciprocal of thermal efficiency. Specific fuel consumption is widely used to compare the performance of different engine.

### 5.2.1 Procedure

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

### 5.2.2 Basic data

1. Rated brake power of engine - 3.7 KW
2. Speed of the engine - 1500 rpm

3. Effective radius of break drum "R" - 0.12 meter.
4. Stroke length - 110 x$10^{-3}$ meter
5. Diameter of cylinder bore - 0.08 meter

### 5.2.3 Variables to be considered

1. Specific Gravity of fuel
2. Dead load applied on break drum "W "(Kg)
3. Spring balance reading "S”. (Kg)
4. Calorific value of fuel
5. Time taken for 10 cc fuel consumption

### 5.2.4 Calculations

Fuel consumption (F.C) = $\frac{10 \times sp.gravity \times 3600}{t \times 1000}$

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

Friction power (F.P)**:** It is obtained from the graph drawn between Brake power vs Fuel consumption

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

Specific fuel consumption (S.F, C) = $\frac{F.C}{B.P}$

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 ($\eta_{mech}$) = $\frac{B.P}{I.P}$

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

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

# CHAPTER 6

# CALCULATION AND ANALSYIS

## 6.1 PURE DIESEL

**Basic data**

4-Stroke single cylinder vertical diesel engine

| | |
|---|---|
| Rated brake power of engine B.P | = 3.7KW |
| Speed of engine N | = 1500 rpm |
| Effective radius of the brake drum R | = 0.213 m |
| Specific gravity of fuel | = 0.82 gm/cc |
| Load on brake drum (W-S) | = 1.9 kg |
| Stroke length L | $=110\times10^{-3}$ m |
| Diameter of cylinder bore D | $= 80\times10^{-3}$ m |
| Calorific Value of fuel CV | = 45000 kJ/kg |
| Time taken for 10cc consumption of fuel is‘ | = 62 sec |

**Calculation**

**1. Pure Diesel**

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

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

$$= 11.27 \text{ kg}$$

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

$$= \frac{2\pi\times1500\times1.9\times9.81\times0.213}{60000}$$

$$= 0.6233 \text{ KW}$$

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

$= (10/62) \times \frac{0.82 \times 3600}{1000}$ kg/hr

$= 0.476129$ kg/hr

Frictional power from graph (F.P) = 2.051 KW

Indicated power (I.P) = B.P + F.P = 0.6233+2.051

= 2.6743 KW

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

$= \frac{0.476129}{0.6233}$

= 0.7638 kg/KW- hr

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

$= \frac{0.6233 \times 3600}{0.476129 \times 45000}$

= 10.4729%

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

$= \frac{2.6743 \times 3600}{0.476129 \times 45000}$

= 44.9341%

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

$$= \frac{0.6233}{2.6743}$$

$$= 23.3072\%$$

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

$$= \frac{2.6743 \times 60000}{110 \times 10^{-3} \times \frac{\pi}{4}(80 \times 10^{-3})^2 \times \frac{1500}{2}}$$

$$= 3.8676 \text{ bar}$$

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

$$= \frac{0.6233 \times 60000}{110 \times 10^{-3} \times \frac{\pi}{4}(80 \times 10^{-3})^2 \times \frac{1500}{2}}$$

$$= 0.9014 \text{ bar}$$

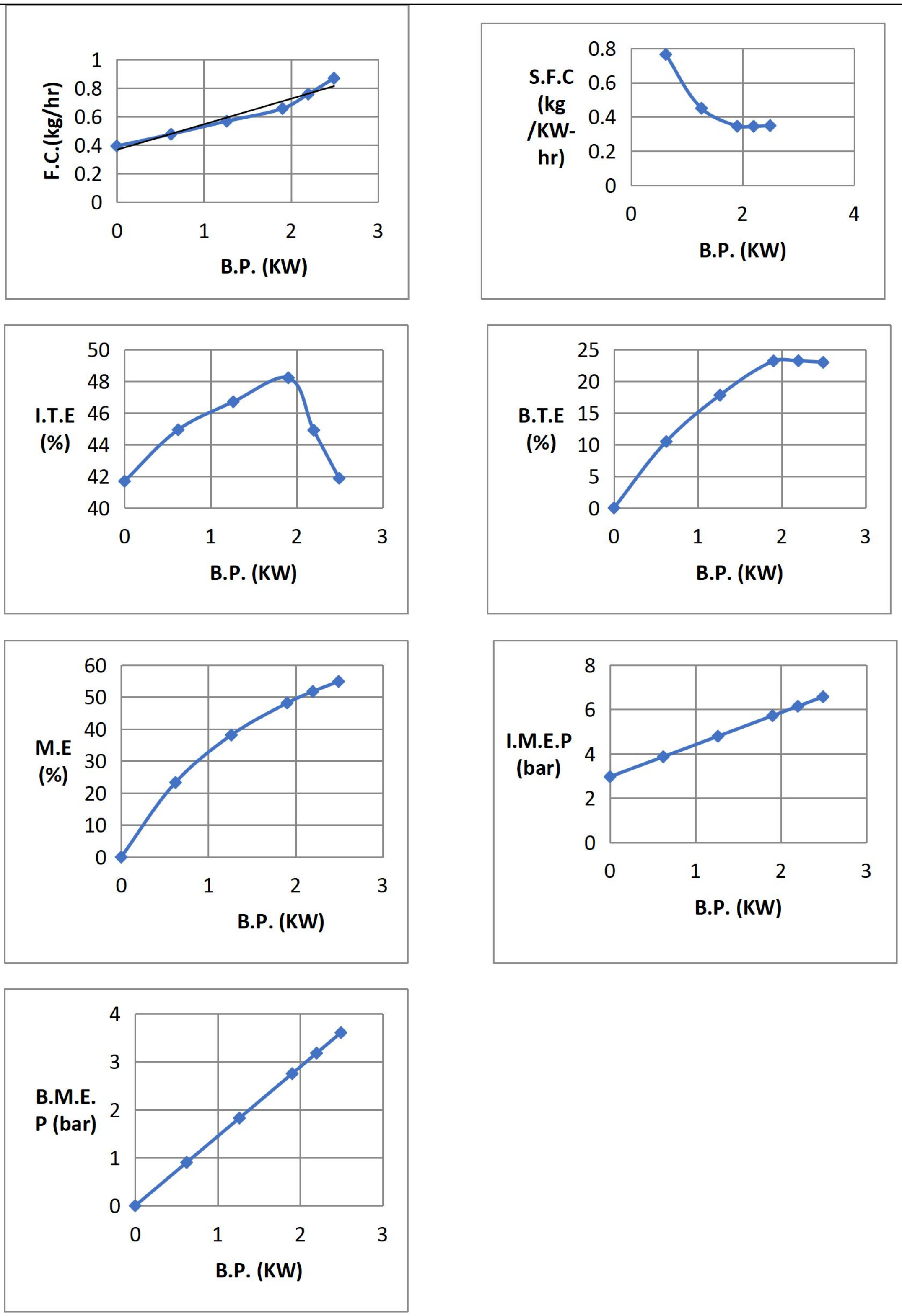


**Fig 6.1 Performance Characteristics of Pure Diesel**

### 6.2. D-800

**Basic data**

4-Stroke single cylinder vertical diesel engine

Rated brake power of engine B.P = 3.7 KW

Speed of engine N = 1500 rpm

Effective radius of the brake drum R = 0.213 m

Specific gravity of fuel = 0.856gm/cc

Load on brake drum (W-S) = 7.2 kg

Stroke length L $=110\times10^{-3}$ m

Diameter of cylinder bore D $= 80\times10^{-3}$ m

Calorific Value of fuel CV = 43700 kJ/kg

Time taken for 10cc consumption of fuel is = 38.56 sec

**Calculation**

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

$$=\frac{2\pi\times1500\times7.2\times9.81\times0.213}{60000}$$

=2.363 KW

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

$$=(10/38.56)\times\frac{0.856\times3600}{1000}\text{kg/hr}$$

=0.8kg/hr

Frictional power from graph (F.P) = 2.1 KW

Indicated power (I.P) = B.P + F.P $=2.363+2.1$

$=4.463$ KW

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

$$=\frac{0.8}{2.363}$$

$=0.338$ kg/KW -hr

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

$$=\frac{2.363\times 3600}{0.8 \times 43700}$$

$= 24.33\%$

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

$$=\frac{4.463\times 3600}{0.8\times 43700}$$

$= 45.95\%$

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

$$=\frac{2.363}{4.463}$$

$=52.94\%$

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

$$=\frac{4.463\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$$

=6.457 bar

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

$$=\frac{2.363\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$$

=3.418 bar

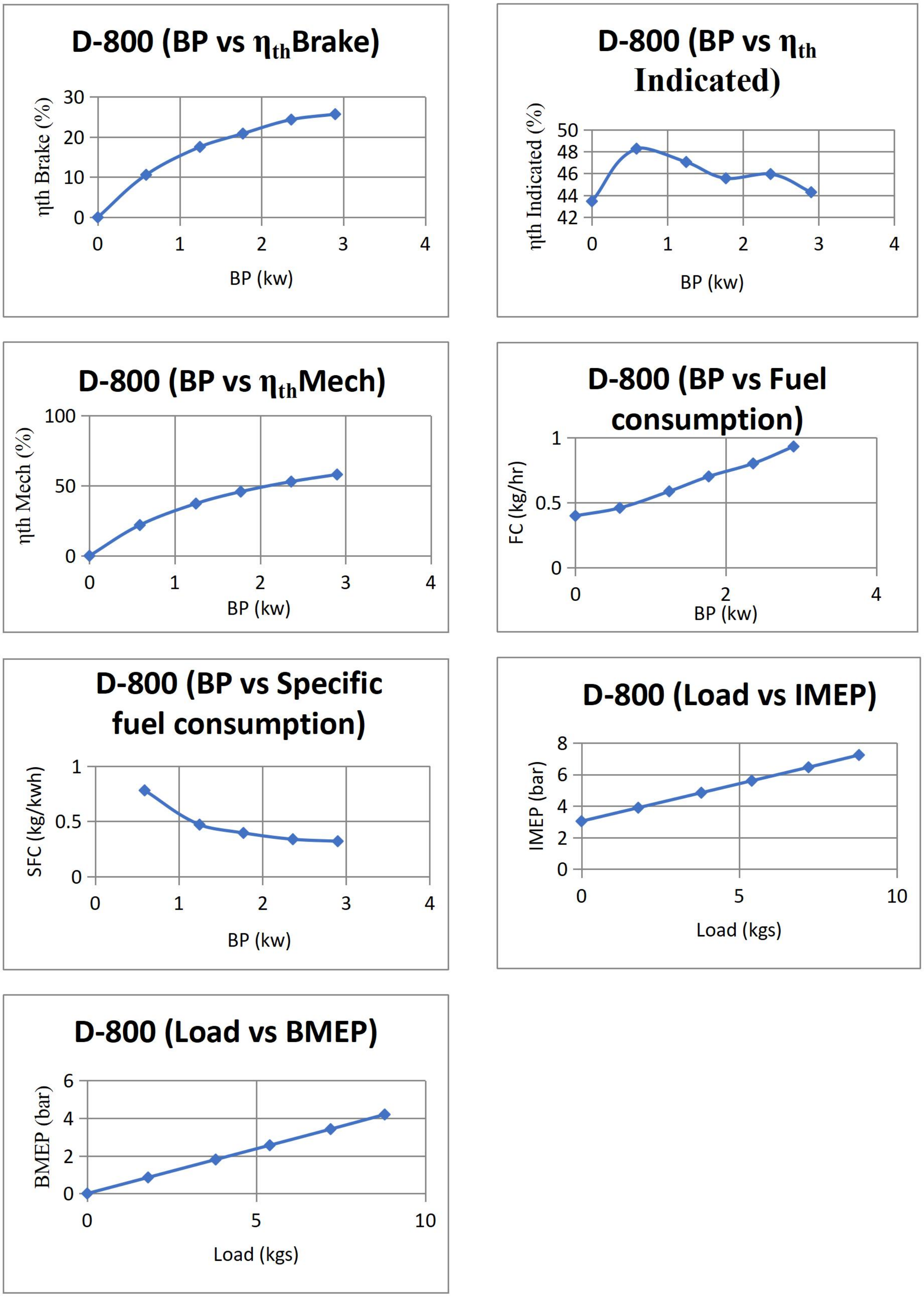


**Fig 6.2 Performance Characteristics of D800**

### 6.3. D-700

**Basic data**

4-Stroke single cylinder vertical diesel engine

| | |
|---|---|
| Rated brake power of engine B.P | = 3.7 KW |
| Speed of engine N | = 1500 rpm |
| Effective radius of the brake drum R | = 0.213 m |
| Specific gravity of fuel | = 0.8616 gm/cc |
| Load on brake drum(W-S) | = 7.2 kg |
| Stroke length L | =$110\times10^{-3}$ m |
| Diameter of cylinder bore D | = $80\times10^{-3}$ m |
| Calorific Value of fuel CV | = 43250 kJ/kg |
| Time taken for 10cc consumption of fuel is | = 37.8 sec |

**Calculation**

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

$$=\frac{2\pi\times1500\times7.2\times9.81\times0.213}{60000}$$

=2.363 KW

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

$$=(10/37.8)\times\frac{0.8616\times3600}{1000}\text{ kg/hr}$$

= 0.82 kg/hr

Frictional power from graph (F.P) =2.32 KW

Indicated power (I.P) = B.P + F.P = 2.363+2.32

= 4.683 KW

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

$= \frac{0.82}{2.363}$

=0.347 kg/KW- hr

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

$= \frac{2.363 \times 3600}{0.82 \times 43250}$

= 23.98 %

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

$= \frac{4.683 \times 3600}{0.6198 \times 39780.65}$

=47.53 %

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

$= \frac{2.363}{4.683}$

=50.94 %

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

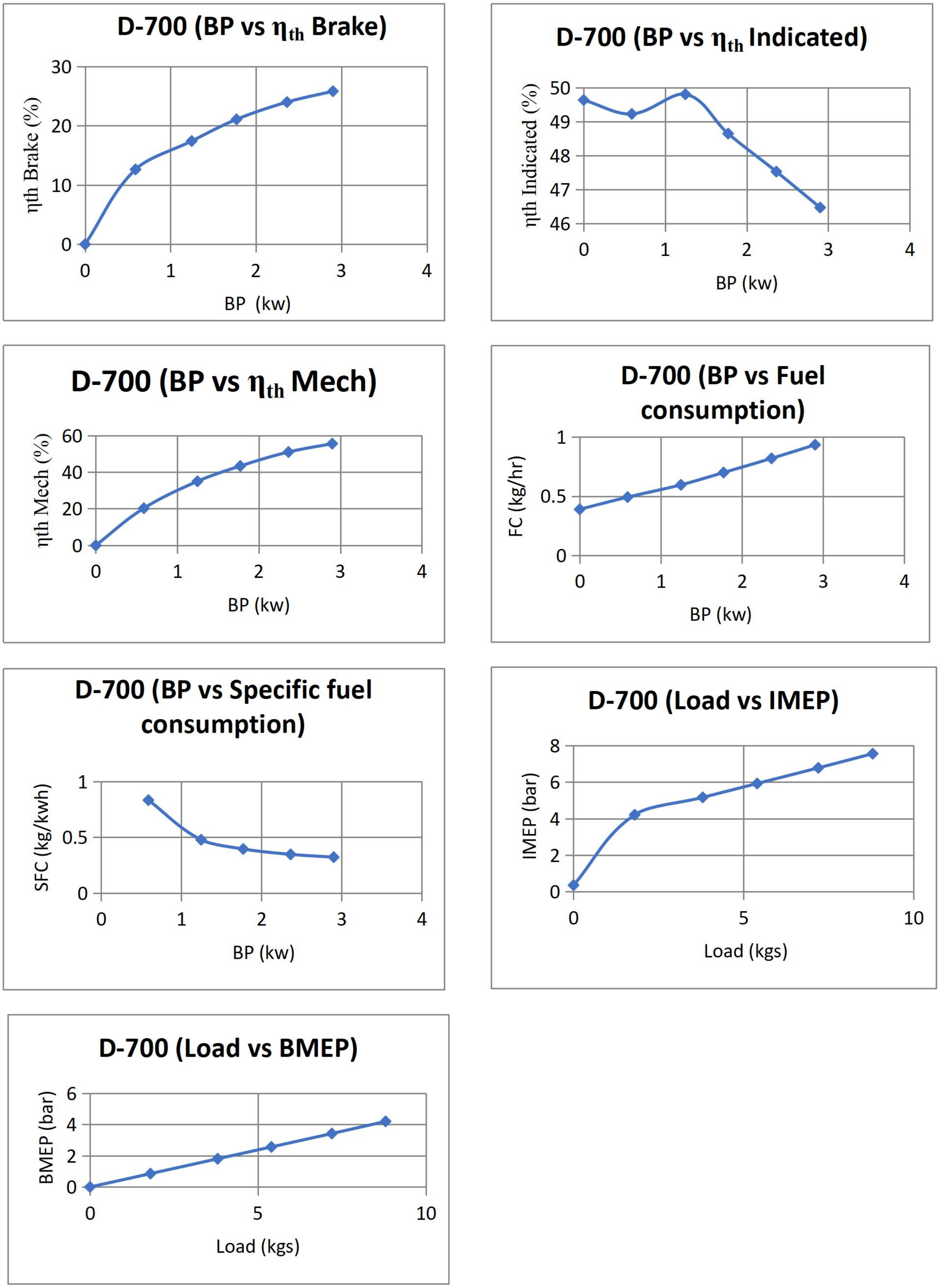
$=\frac{6.683\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=6.775 bar

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

$=\frac{2.363\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$

=3.418 bar



D-700 (BP vs $\eta_{th}$ Brake)

D-700 (BP vs $\eta_{th}$ Indicated)

D-700 (BP vs $\eta_{th}$ Mech)

D-700 (BP vs Fuel consumption)

D-700 (BP vs Specific fuel consumption)

D-700 (Load vs IMEP)

D-700 (Load vs BMEP)

**Fig 6.3 Performance Characteristics of D700**

## 6.4. T-700

**Basic data**

4-Stroke single cylinder vertical diesel engine

Rated brake power of engine B.P = 3.7 KW

Speed of engine N = 1500 rpm

Effective radius of the brake drum R = 0.213 m

Specific gravity of fuel = 0.8872 gm/cc

Load on brake drum(W-S) = 7.2 kg

Stroke length L $=110\times10^{-3}$ m

Diameter of cylinder bore D $= 80\times10^{-3}$ m

Calorific Value of fuel CV = 44370 kJ/kg

Time taken for 10cc consumption of fuel is‘ = 38.8 sec

**Calculation**

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

$$=\frac{2\pi\times1500\times7.2\times9.81\times0.213}{60000}$$

= 2.3632 KW

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

$$=(10/38.8)\times\frac{0.8872\times3600}{1000}\text{kg/hr}$$

=0.82317 kg/hr

Frictional power from graph (F.P) =1.6 KW

Indicated power (I.P) = B.P + F.P =2.2632+1.6

=3.3682 KW

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

$=\frac{0.82317}{2.2632}$

=0.3483 kg/KW- hr

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

$=\frac{2.3632\times 3600}{0.8232\times 44370}$

=23.29%

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

$=\frac{3.8632\times 3600}{0.8232\times 44370}$

= 39.26%

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

$=\frac{2.3632}{3.8632}$

= 59.32 %

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

$$=\frac{3.8632\times 60000}{110\times 10^{-3}\times \frac{\pi}{4}(80\times 10^{-3})^2\times \frac{1500}{2}}$$

=5.763 bar

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

$$=\frac{2.3632\times 60000}{110\times 10^{-3}\times \frac{\pi}{4}(80\times 10^{-3})^2\times \frac{1500}{2}}$$

=3.4192 bar

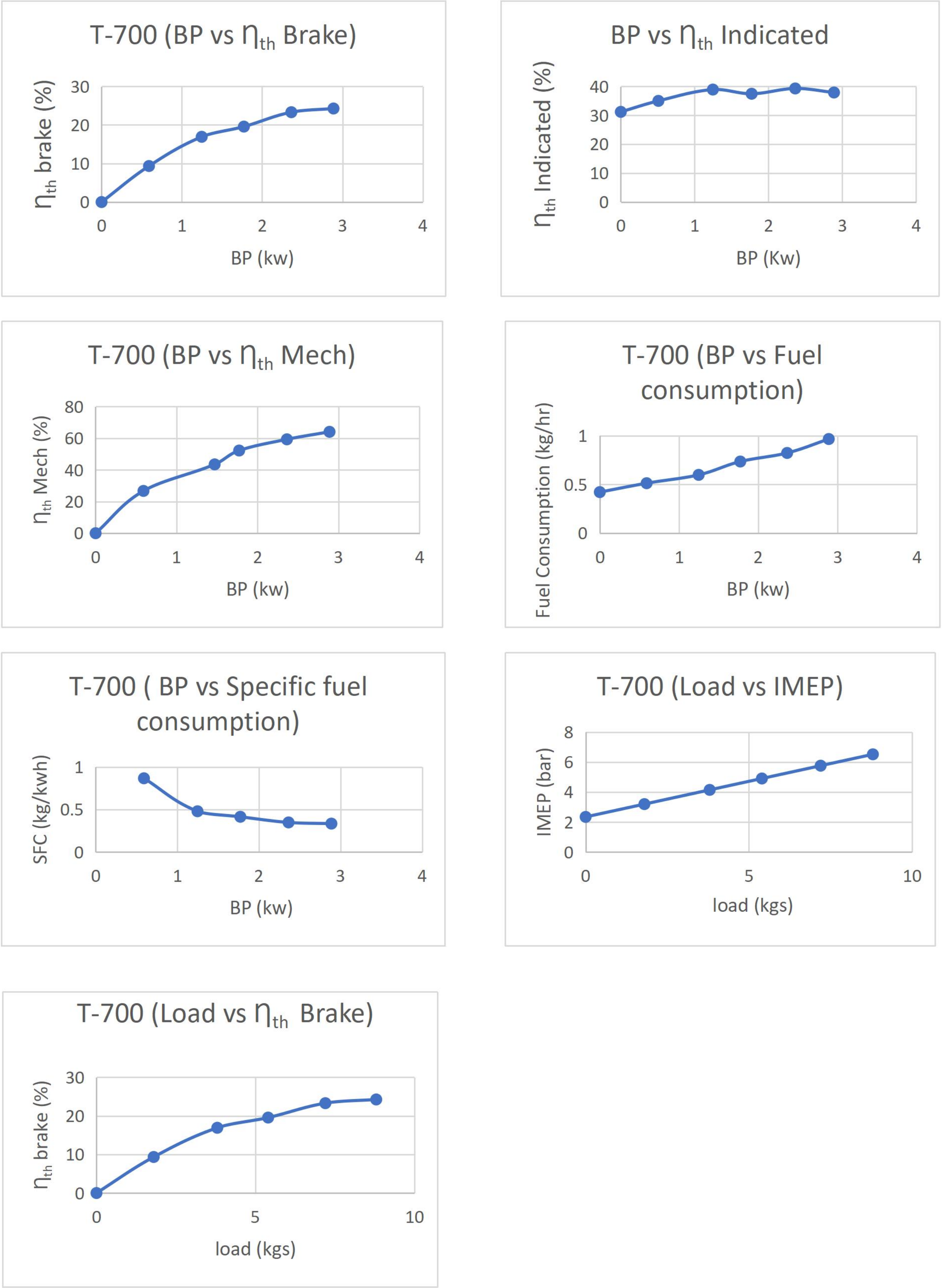


**Fig 6.4 Performance Characteristics of T700 Blend**

### 6.5. T-600

**Basic data**

4-Stroke single cylinder vertical diesel engine

Rated brake power of engine B.P = 3.7 KW

Speed of engine N = 1500 rpm

Effective radius of the brake drum R = 0.213 m

Specific gravity of fuel = 0.9196 gm/cc

Load on brake drum(W-S) = 7.2 kg

Stroke length L $=110\times10^{-3}$ m

Diameter of cylinder bore D $= 80\times10^{-3}$ m

Calorific Value of fuel CV = 44194 kJ/kg

Time taken for 10cc consumption of fuel is‘ = 37.12 sec

**Calculation**

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

$$=\frac{2\pi\times1500\times7.2\times9.81\times0.213}{60000}$$

$$=2.2632 \text{ KW}$$

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

$$=\left(10/37.12\right)\times\frac{0.9196\times3600}{1000}\text{kg/hr}$$

$$= 0..8918 \text{ kg/hr}$$

Frictional power from graph (F.P) $=1.61$ KW

Indicated power (I.P) $= B.P + F.P \quad = 2.2632+1.61$

$= 3.8732$ KW

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

$= \frac{0.8932}{2.2632}$

$=0.394$ kg/KW- hr

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

$= \frac{2.2632 \times 3600}{0.8918 \times 44194}$

$= 20.67\%$

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

$= \frac{3.8732 \times 3600}{0.8918 \times 44194}$

$=35.37\%$

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

$= \frac{2.2632}{3.8732}$

$=58.43\ \%$

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

$$=\frac{3.8732\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$$

$= 5.603$ bar

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

$$=\frac{2.2632\times 60000}{110\times 10^{-3}\times\frac{\pi}{4}(80\times 10^{-3})^2\times\frac{1500}{2}}$$

$=3.274$ bar

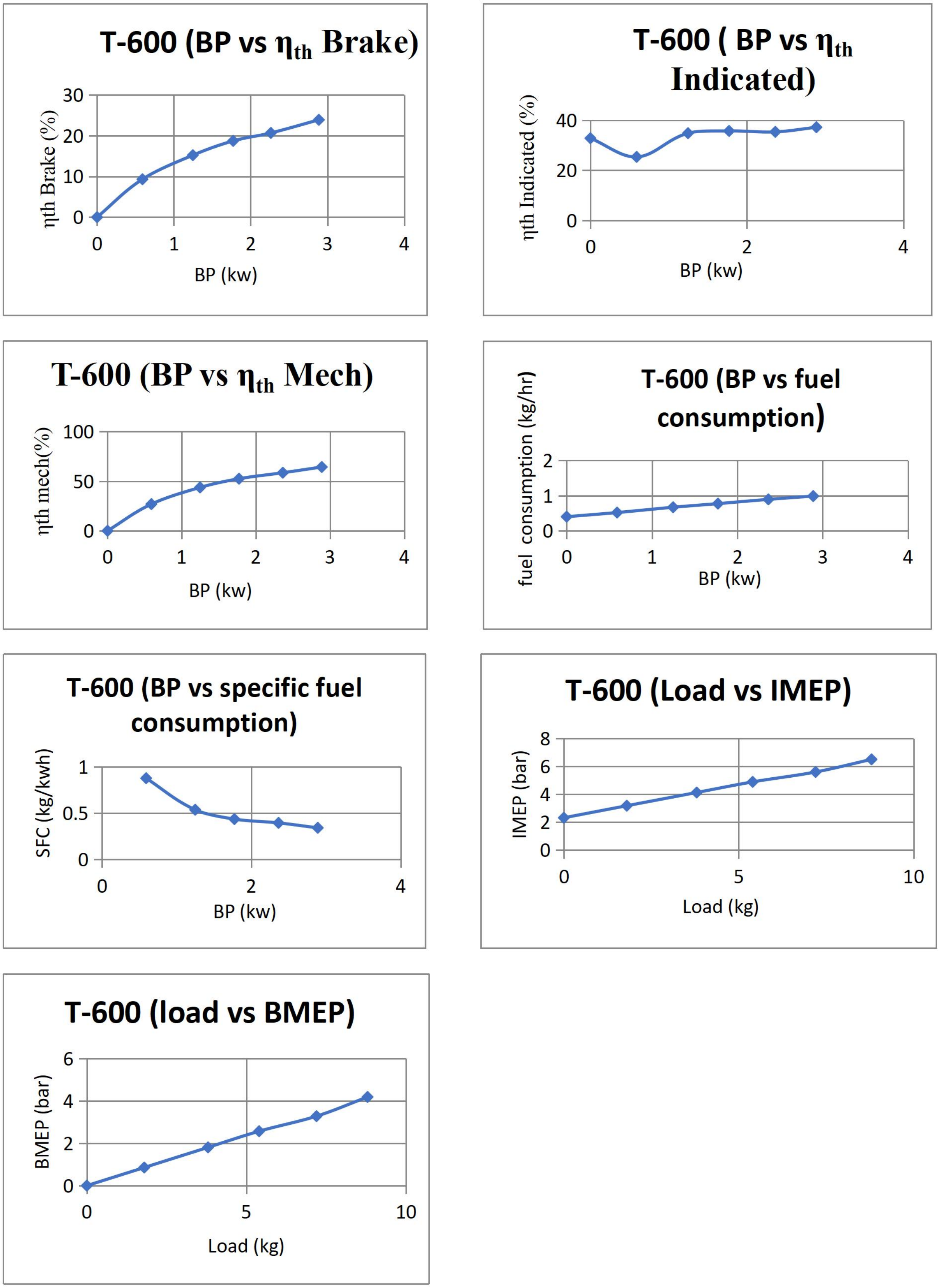


Fig 6.5 Performance Characteristics of T600 Blend

# CHAPTER 7

# PERFORMANCE CHARACTERISTICS

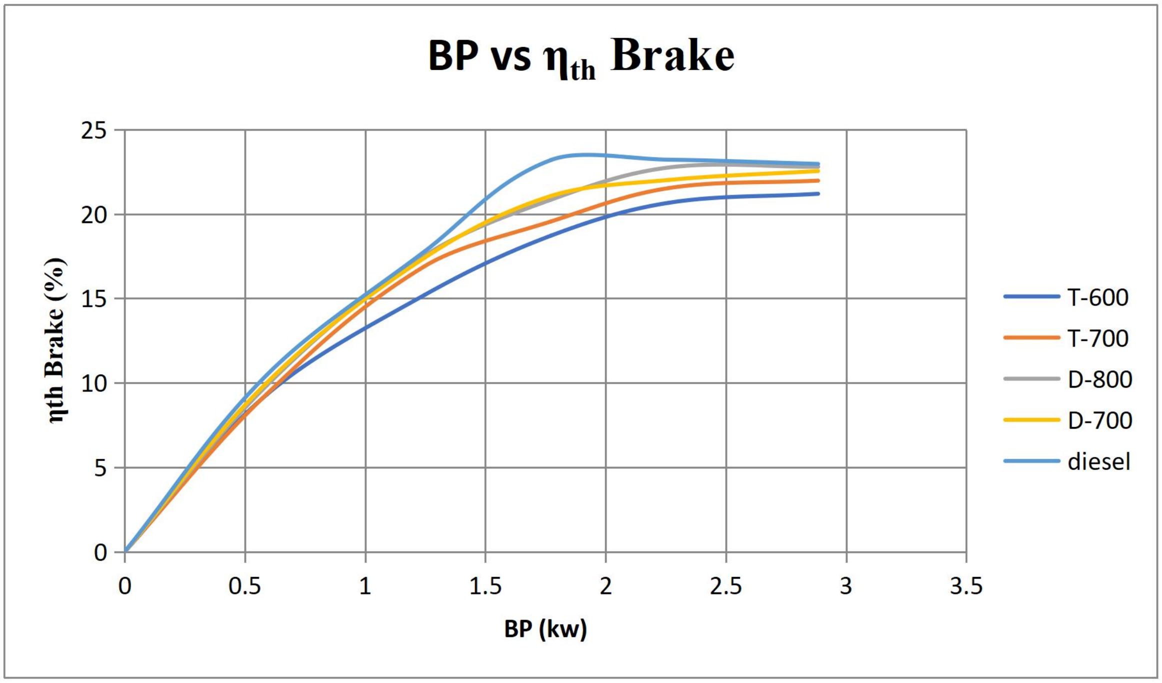


Fig 7.1 Variation of Brake Power Vs Brake Thermal Efficiency

- From the above graph it is inferred that Brake thermal efficiency increases with break power and D-800 has the highest Brake thermal efficiency.

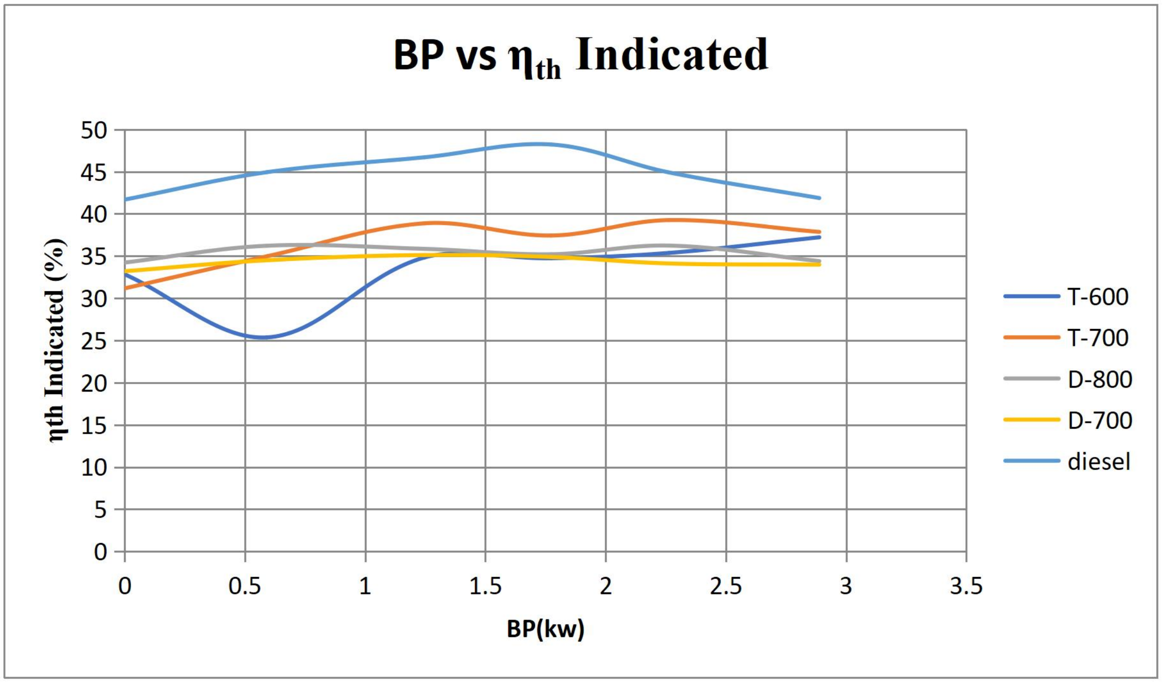


Fig 7.2 Variation of Brake Power Vs Indicated Thermal Efficiency

- From the above graph it is inferred that Indicated thermal efficiency increases with increase in Brake power and it is highest for T-700 blend.

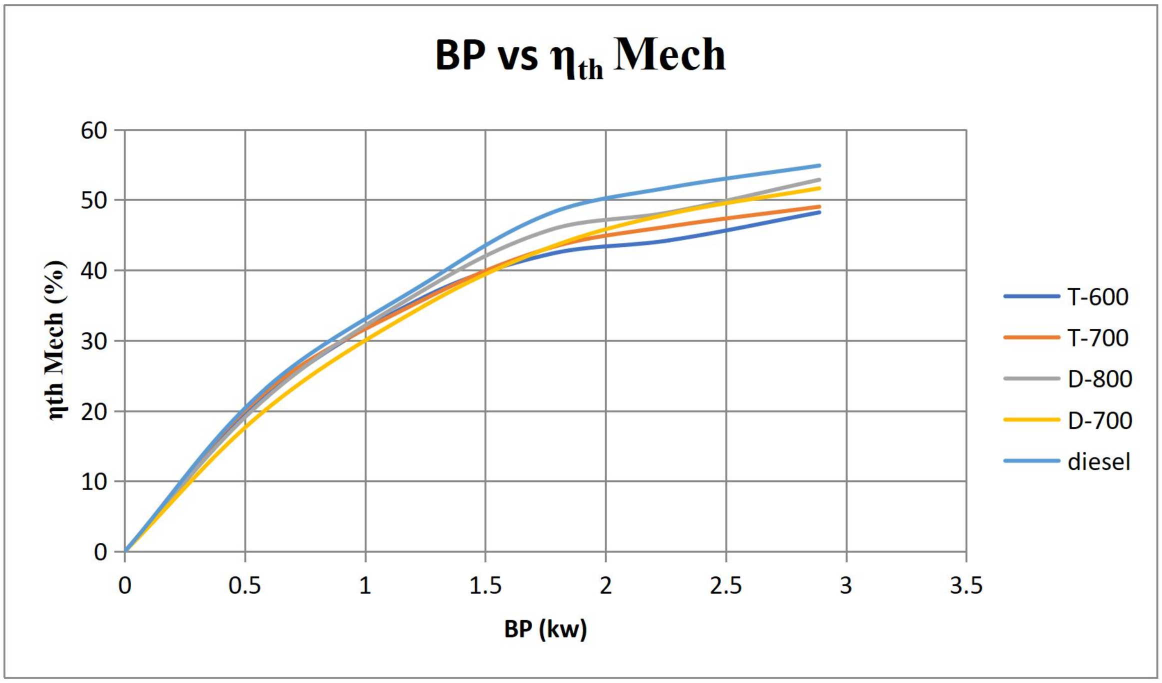


Fig 7.3 Variation of Brake Power Vs Mechanical Efficiency

- From the above graph it is inferred that Mechanical efficiency increases with increase in brake power and it is highest for D-800 blend.

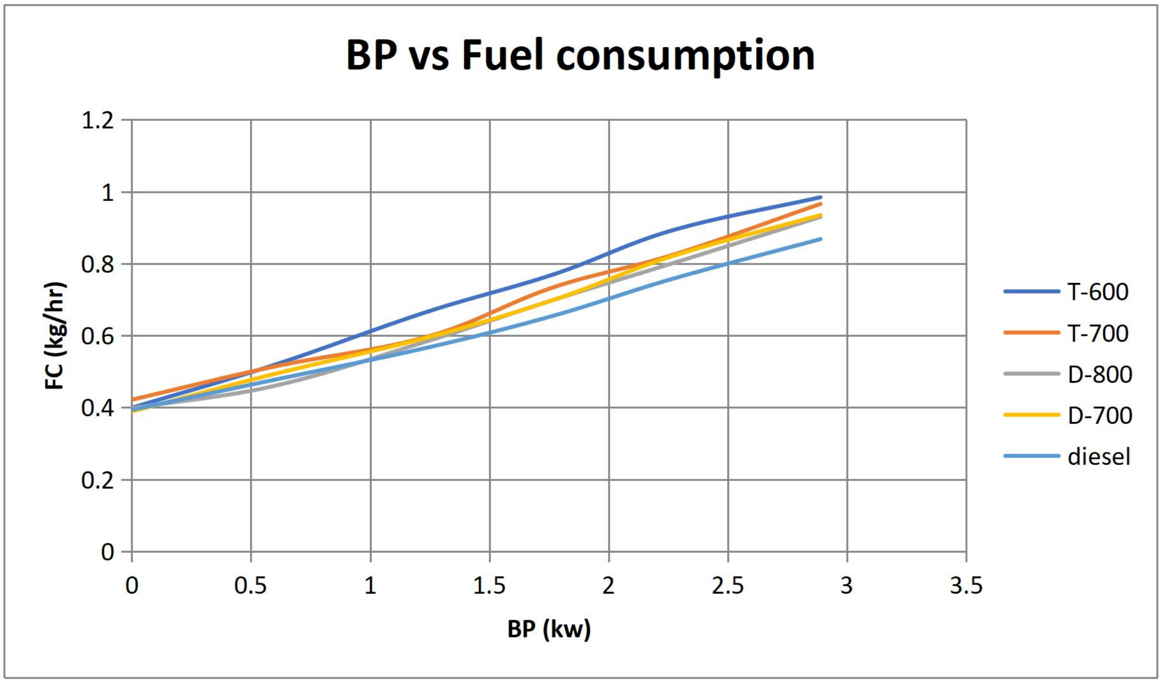


Fig 7.4 Variation of Brake Power Vs Fuel Consumption

- From the above graph it is inferred that Fuel consumption increases with Brake power and D-800 has least Fuel consumption.

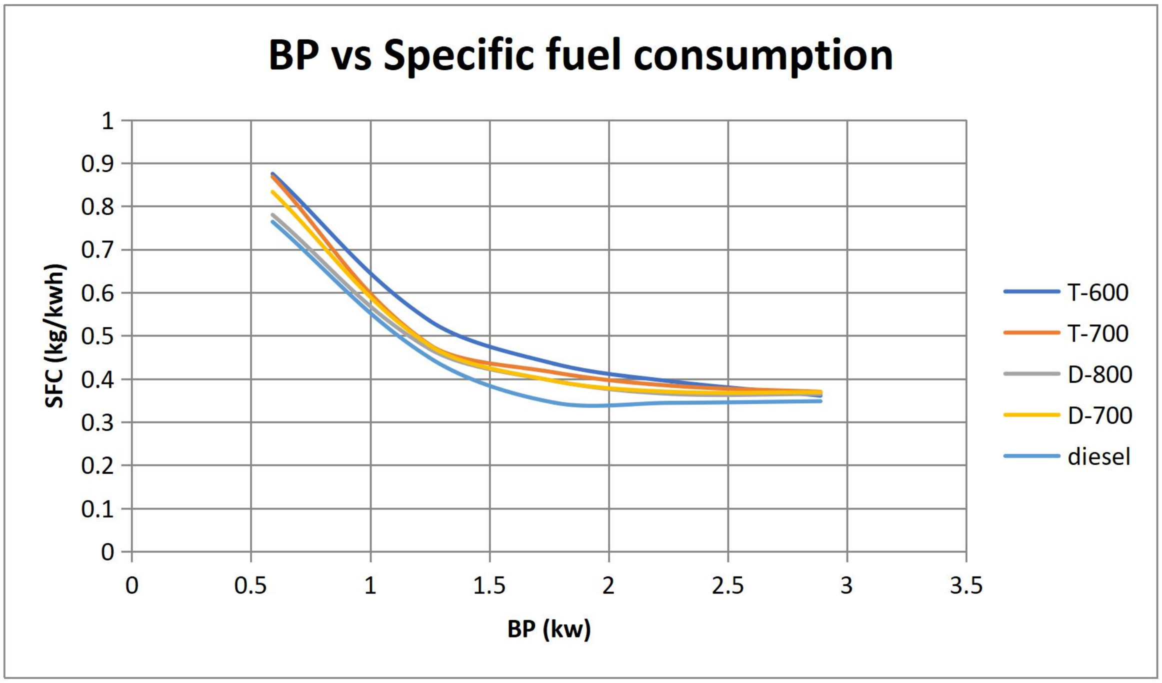


**Fig 7.5 Variation of Brake Power Vs Specific Fuel Consumption**

- From the above graph it is inferred that Specific fuel consumption decreases with increase in Brake power and it is least to D-800 blend.

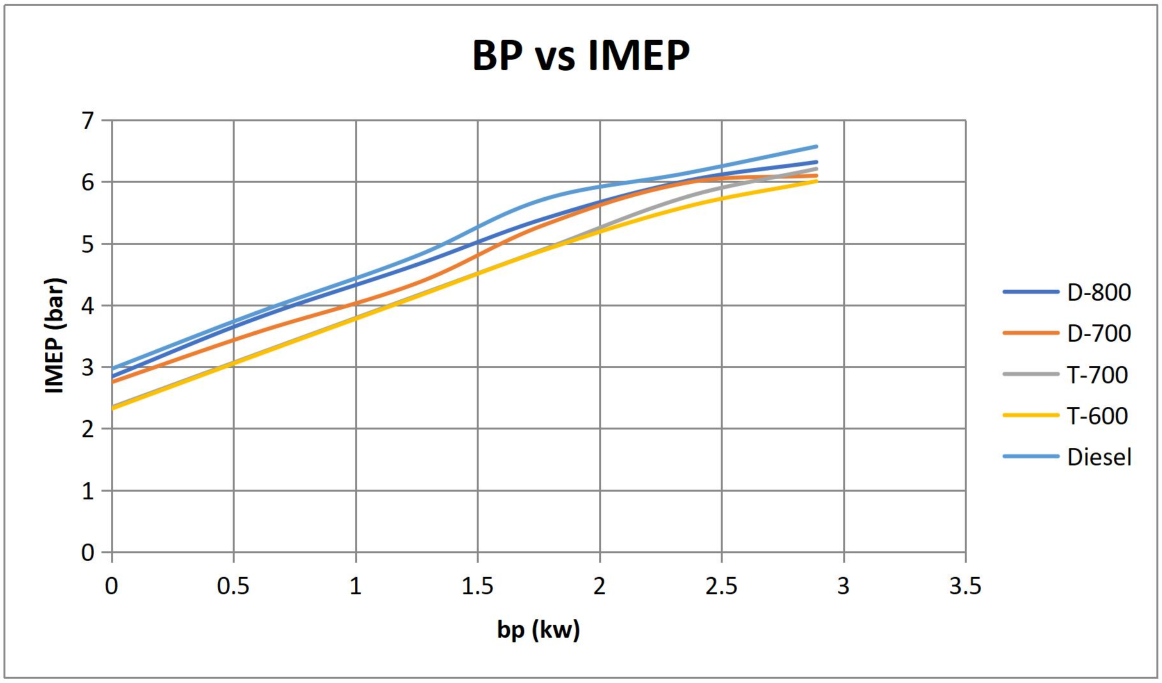


**Fig 7.6 Variation of Brake Power Vs Indicated Mean Effective Pressure**

- From the above graph it is inferred that Indicated mean effective pressure increases with Brake power and it is highest to D-800 blend.

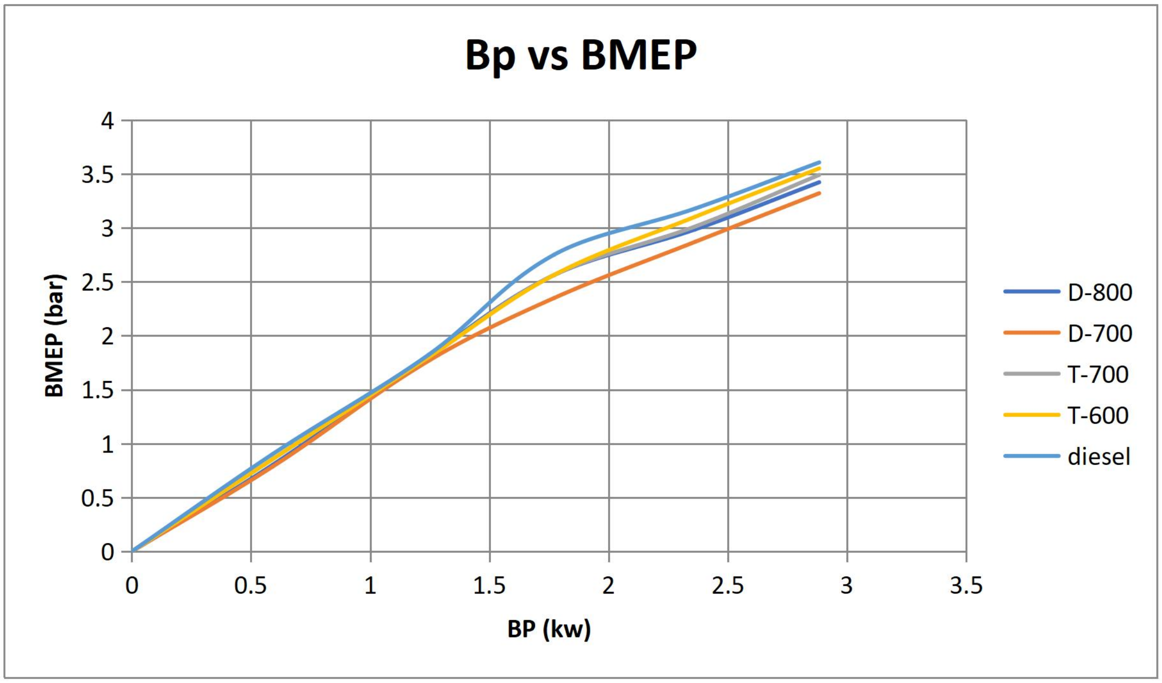


Fig 7.7 Variation of Brake Power Vs Brake Mean Effective Pressure

- From the above graph it is inferred that Break mean effective pressure increases with Break power and it is highest to T-600 blend

# CHAPTER 8

# RESULTS AND DISCUSSIONS

A comparative analysis of diesel with different blends of diesel,tyre pyrolysis oil and bio-diesel from coconut with reference to the performance of the engine and cost of the fuel was taken up for experimental study and analysis. It has been observed that a right blend of two oils not only gives best performance but also economically viable. The following observations were made from graphs plotted.

1. It is found that frictional power which is generally function of speed of engine is also found to be variable which changes with composition. From experimentation, it is inferred that T700 blend has minimum losses in terms of mechanical power and power consumed by auxiliaries, which put together generally known as Frictional Power. Therefore, T700 blend offers the best mechanical efficiency.
2. The specific fuel consumption varies directly with respect to fuel consumption. It is observed that at smaller loads, specific fuel consumption is less for D800 blend whereas at higher loads also D800 is found to be the best.
3. Indicated thermal efficiency of diesel engine varies inversely with fuel consumption rate. The lesser the fuel consumption, higher is the indicated thermal efficiency and vice versa. It is observed that at higher loads D700 offers higher indicated thermal efficiency. Even though its fuel consumption rate is not very small, it offers higher thermal efficiency because of variation of calorific value.
4. All the blended samples are lesser in cost when compared to the cost of conventional diesel fuel.

## COST ANALYSIS: (1000 ML)

Table 2 Costs of different samples

| SAMPLE | PRICE(RUPEEES) |
|---|---|
| PURE DIESEL | 70.55 |
| D800 | 68.44 |
| D700 | 64.88 |
| T600 | 68.66 |
| T700 | 72.72 |

# CHAPTER 9

# CONCLUSION

- Tests have been carried out to evaluate the performanceof a single cylinder direct injection diesel engine fueled with the blends of tyre pyrolysis,Bio-diesel oil and conventional diesel fuel .
- The series of tests are conducted using each of fuels with the engine working at a constant speed of 1500 rpm and at different loads starting from no load. In each test fuel consumption, specific fuel consumption, thermal efficiency, mechanical efficiency and mean effective pressure are computed from measured flow rate and calorific value.
- From the performance characteristics it is observed that when mechanical efficiency values are considered it is better to use T700 blend, price being lesser than conventional diesel. When specific fuel consumption is considered it is found that D800 has low specific fuel consumption than other blends. When indicated thermal efficiency is considered D700 is more preferable than other blends.

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# TABLES

## TABLE 3 : D700

| S.No | Load on Brake Drum (W-S) kgf | Time for 10 cc Fuel Consumption (sec) | F.C. Kg/hr | Brake power (KW) | Indicated power (KW) | Specific Fuel Consumption (SFC) (kg/KW hr) | Brake Thermal Efficiency (%) | Indicated Thermal Efficiency (%) | Mechanical Efficiency (%) | I.M.E.P (bar) | B.M.E.P (bar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 0 | 79.62 | 0.398 | 0 | 1.92 | - | 0 | 33.2 | 0 | 3.356 | 0 |
| 2. | 1.8 | 69.92 | 0.492 | 0.59 | 2.46 | 0.833 | 10.01 | 34.5 | 20.2 | 4.21 | 0.8534 |
| 3. | 3.8 | 52 | 0.596 | 1.247 | 3.124 | 0.478 | 17.41 | 35.12 | 34.96 | 5.16 | 1.804 |
| 4. | 5.4 | 44.24 | 0.7 | 1.772 | 3.752 | 0.395 | 21.07 | 34.89 | 43.3 | 5.92 | 2.563 |
| 5. | 7.2 | 37.8 | 0.82 | 2.363 | 4.189 | 0.37 | 22.02 | 34.12 | 47.98 | 6.775 | 3.418 |
| 6. | 8.8 | 33.12 | 0.935 | 2.9 | 4.324 | 0.369 | 22.55 | 33.98 | 51.64 | 7.552 | 4.195 |

## TABLE 4: D800

| S.No | Load on Brake Drum (W-S) kgf | Time for 10 cc Fuel Consumption (sec) | F.C. Kg/hr | Brake power (KW) | Indicated power (KW) | Specific Fuel Consumption (SFC) (kg/KW hr) | Brake Thermal Efficiency (%) | Indicated Thermal Efficiency (%) | Mechanical Efficiency (%) | I.M.E.P (bar) | B.M.E.P (bar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 0 | 7.38 | 0.398 | 0 | 1.95 | - | 0 | 34.23 | 0 | 3.038 | 0 |
| 2. | 1.8 | 67.06 | 0.459 | 0.59 | 2.45 | 0.78 | 9.85 | 36.22 | 21.93 | 3.892 | 0.8536 |
| 3. | 3.8 | 52.56 | 0.586 | 1.247 | 2.94 | 0.47 | 17.53 | 35.85 | 37.25 | 4.842 | 1.804 |
| 4. | 5.4 | 44.06 | 0.7 | 1.772 | 3.872 | 0.395 | 20.85 | 35.21 | 45.76 | 5.602 | 2.563 |
| 5. | 7.2 | 38.56 | 0.8 | 1.92 | 4.12 | 0.365 | 22.76 | 36.24 | 48.21 | 6.457 | 3.418 |
| 6. | 8.8 | 33.12 | 0.93 | 2.12 | 4.32 | 0.36 | 22.8 | 34.4 | 52.85 | 7.234 | 4.195 |

## Table 5 (T700)

| S.No | Load on Brake Drum (W-S) kgf | Time for 10 cc Fuel Consumption (sec) | F.C. Kg/hr | Brake power (KW) | Indicated power (KW) | Specific Fuel Consumption (SFC) (kg/KW hr) | Brake Thermal Efficiency (%) | Indicated Thermal Efficiency (%) | Mechanical Efficiency (%) | I.M.E.P (bar) | B.M.E.P (bar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0 | 75.74 | 0.4216 | 0 | 1.62 | - | 0 | 31.17 | 0 | 2.343 | 0 |
| 2 | 1.8 | 62.26 | 0.5129 | 0.59 | 2.2107 | 0.8682 | 9.34 | 34.97 | 22.85 | 3.198 | 0.854 |
| 3 | 3.8 | 53.38 | 0.5983 | 1.247 | 2.8672 | 0.4797 | 16.91 | 38.88 | 35.89 | 4.148 | 1.804 |
| 4 | 5.4 | 43.44 | 0.7352 | 1.772 | 3.3923 | 0.4148 | 19.56 | 37.43 | 43.21 | 4.908 | 2.564 |
| 5 | 7.2 | 38.8 | 0.8232 | 1.92 | 3.9832 | 0.384 | 21.54 | 39.26 | 46.21 | 5.763 | 3.4192 |
| 6 | 8.8 | 33.06 | 0.9661 | 2.12 | 4.508 | 0.37 | 21.98 | 37.86 | 49.02 | 6.522 | 4.1789 |

## Table 6(T600)

| S.No | Load on Brake Drum (W-S) kgf | Time for 10 cc Fuel Consumption (sec) | F.C. Kg/hr | Brake power (KW) | Indicated power (KW) | Specific Fuel Consumption (SFC) (kg/KW hr) | Brake Thermal Efficiency (%) | Indicated Thermal Efficiency (%) | Mechanical Efficiency (%) | I.M.E.P (bar) | B.M.E.P (bar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | 82.88 | 0.3994 | 0 | 1.61 | - | 0 | 32.83 | 0 | 2.32 | 0 |
| 2 | 1.8 | 64 | 0.517 | 0.59 | 2.2008 | 0.875 | 9.308 | 25.36 | 22.12 | 3.184 | 0.854 |
| 3 | 3.8 | 49.56 | 0.6679 | 1.247 | 2.857 | 0.5355 | 15.21 | 34.84 | 36.21 | 4.133 | 1.804 |
| 4 | 5.4 | 42.94 | 0.7709 | 1.772 | 3.3824 | 0.4349 | 18.7 | 34.74 | 42.32 | 4.893 | 2.564 |
| 5 | 7.2 | 37.12 | 0.8918 | 1.92 | 3.8732 | 0.394 | 20.67 | 35.37 | 44.23 | 5.603 | 3.274 |
| 6 | 8.8 | 33.62 | 0.9846 | 2.12 | 4.4983 | 0.361 | 21.2 | 37.22 | 48.21 | 6.508 | 4.179 |

**Table 7(DIESEL)**

| S.No | Load on Brake Drum (W-S) kgf | Time for 10 cc Fuel Consumption (sec) | F.C. Kg/hr | Brake power (KW) | Indicated power (KW) | Specific Fuel Consumption (SFC) (kg/KW hr) | Brake Thermal Efficiency (%) | Indicated Thermal Efficiency (%) | Mechanical Efficiency (%) | I.M.E.P (bar) | B.M.E.P (bar) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 0 | 75 | 0.3936 | 0 | 2.0510 | - | 0 | 41.6870 | 0 | 2.9662 | 0 |
| 2. | 1.8 | 62 | 0.4761 | 0.6233 | 2.6743 | 0.7639 | 10.4729 | 44.9342 | 23.372 | 3.8676 | 1.9014 |
| 3. | 3.8 | 52 | 0.5677 | 1.2630 | 3.3140 | 0.4495 | 17.7986 | 46.7016 | 38.1114 | 4.7928 | 1.8266 |
| 4. | 5.4 | 45 | 0.6560 | 1.9027 | 3.9537 | 0.3448 | 23.2040 | 48.2162 | 48.1249 | 5.7179 | 2.7518 |
| 5. | 7.2 | 9 | 0.7569 | 2.1980 | 4.2490 | 0.3444 | 23.2306 | 44.9079 | 51.7296 | 6.1449 | 3.1787 |
| 6. | 8.8 | 34 | 0.8682 | 2.4932 | 4.5442 | 0.3482 | 22.9728 | 41.8709 | 54.8658 | 6.5719 | 3.6057 |

## TABLE 8: FLASH POINT AND FIRE POINT

| **SAMPLE** | **FLASH POINT($^0$C)** | **FIRE POINT($^0$C)** |
|---|---|---|
| Diesel | 45 | 49 |
| D700 | 51 | 53 |
| D800 | 48 | 50 |
| T600 | 61 | 64 |
| T700 | 63 | 67 |