PERFORMANCE CHARACTERISTICS AND SMOKE ANALYSIS OF FOUR STROKE DIESEL ENGINE USING PALM KERNAL OIL.

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

BACHELOR OF TECHNOLOGY

in

MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that this project report entitled **"PERFORMANCE CHARACTERISTICS AND SMOKE ANALYSIS OF FOUR STROKE DIESEL ENGINE USING PALM KERNAL OIL"** has been carried out by **CH.SRI SADGURU PRIYA (315126520030) , B.MADHURI KRISHNA (315126520016) , A.SAI ROHIT REDDY (315126520011) , G.SRINIVAS REDDY (315126520055), V.JASWANTH NAIDU (315126520069)** under the esteemed guidance of Mr.B.B.Ashok Kumar, in partial fulfillment 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 oil resources led to the discovery of alternative fuels for IC Engines. In view of this, there is an urgent need to explore new alternatives, which are likely to reduce our dependency on oil imports as well as can help in protecting the environment for sustainable development. Many alternative fuels are being recently explored as potential alternatives like CNG, LPG etc for the present high-pollutant diesel fuel derived from diminishing commercial resources.

Biodiesel is a renewable diesel substitute that can be obtained by combining chemically any natural oil or fat with alcohol. Experimental investigation was carried out using palm kernel oil to study its properties and to check its suitability as a fuel alternative. In this work, the biodiesel was prepared by the process of Trans-esterification. The various fuel properties of biodiesel produced from kernel oil are determined with the different blends of oils and diesel are tested on 4-Stroke diesel engine to evaluate its performance characteristics and smoke analysis. Hence the problem formulated can be named as "Study of performance characteristics and smoke analysis of 4-Stroke compression ignition automotive engine powered by various blends of bio-diesel extracted from palm kernel oil ".

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1 INTRODUCTION

World energy demand continues to rise. The scarcity of conventional fossil fuels, growing emissions of combustion generated pollutants, and their increasing costs will make biomass sources more attractive. The most feasible way to meet this rising energy demand and replace reducing petroleum reserves, fuels such as biodiesel and bioethanol are in the forefront of alternative technologies. Accordingly, the viable alternative for compression-ignition engines is biodiesel.

1.1 FOSSIL FUELS

Fossil fuels are energy resources derived from the altered remains of living organisms that were buried by sediments and exposed to elevated pressures and temperatures for millions of years. Fossil fuels can be: solids, as in the case of coal which is derived primarily from land plants; liquids, such as crude oil or tar sands; or gas, such as methane. Oil and gas hydrocarbons are derived primarily from the remains of marine plants. They can be turned into other fuels, raw materials, and can be used in many things.

1.2 ALTERNATE FUELS

Alternative fuels are defined as any material or substance that can be used as a fuel other than convention fuels. The lure of alternative fuel is in finding a source of energy with minimal environmental impacts, provides low cost to the end-user and increases energy security. Many alternative fuels exist, but few are as bountiful, easily produced and cost effective as traditional fossil 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.

1.3 NEED FOR ALTERNATIVE FUELS

Alternative fuels have the important benefit of showing that there is a pragmatic path out of the climate crisis. The pragmatic approach involves using existing infrastructure and vehicles. For rapid air travel to continue in a carbon constrained world, biofuels will be a necessity, as there is nothing else on the horizon that comes close. For further, long haul rail and shipping, migrating the diesel engines over to a clean burning bio-fuel will create better economic alignment - among large companies - not beholden to the oil companies.

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.

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:

- Base catalyzed trans-esterification of the oil
- Direct acid catalyzed trans-esterification of the oil
- Conversion of the oil to its fatty acids and then to biodiesel.

There are a 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, palm kernel . 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.

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.

1.5 ADVANTAGES OF BIODIESEL

- Biodiesel is a renewable energy source. Since it is made from animal and vegetable fat, it can be produced on demand and also causes less pollution than petroleum diesel.
- One of the main advantage of using biodiesel is that can be used in existing diesel engines with little or no modifications at all and can replace fossil fuels to become the most preferred primary transport energy source. Biodiesel can be used in 100% (B100) or in blends with petroleum diesel.
- Fossil fuels when burnt release greenhouse gases like carbon dioxide in the atmosphere that raises the temperature and causes global warming. To protect the environment from further heating up, many people have adopted the use of biofuels.
- Vehicles that run on biodiesel achieve 30% fuel economy than petroleum based diesel engines which means it makes fewer trips to gas stations and run more miles per gallon.
- The lubricating property of the biodiesel may lengthen the lifetime of engines.

2 LITERATURE REVIEW

In this literature review we have studied different research papers, theses and international journals. For better understanding, these papers are divided into **four parts** as

PART 1

BIODIESEL PRODUCTION PROCESS REVIEW

Chatpalliwarl et al. [1] described the brief overview of the Biodiesel production plant. Various issues- sources, opportunities, challenges, plant design, and evaluation etc. are discussed related to the Biodiesel production. It discusses the important issues concerned with the Biodiesel production plant design, formulation of Biodiesel plant design problem, mathematical model to evaluate the Biodiesel plant design.

Gulab N. Jham et al. [2] research on wild mustard (Brassica juncea L.) oil is evaluated as a feedstock for biodiesel production. Biodiesel was obtained in 94 wt.% yield by a standard trans-esterification procedure with methanol and sodium methoxide catalyst. The cetane number, kinematic viscosity, cloud, pour and cold filter plugging points, Acid value, lubricity, free, total glycerol content, iodine value, Gardner color, specific gravity, sulfur and phosphorous contents were also determined.

S.L.Sinha et al. [3] investigated, the bio-diesel produced from the jatropha seeds have been considered as a potential alternative for running the compression ignition engines. The different blends of bio-diesel and conventional diesel have been tested on the engine. Acceptable thermal efficiencies of the engine have been obtained with different blends of bio-diesel and diesel. It has been observed that 20% of jatropha oil can be substituted for diesel without any engine modification and preheating of the blends. The level of hydrocarbon emission and noise level have been found to be reduced with the use of more bio-diesel content.

PART 2

BIODIESEL STABILITY REVIEW

P Shinoj et al. [4] analyzed the economic viability and long-term sustainability of bioethanol production from sugarcane molasses and commercial feasibility of biodiesel produced from tree-borne oilseeds like jatropha. The commercial feasibility of jatropha based biodiesel largely depends on development of a proper supply chain by augmenting marketing of jatropha seeds, upgrading processing infrastructure and up-scaling biodiesel distribution.

Y.C. Sharma et al. [5] described the four ways viz. direct use and blending, micro-emulsions, thermal cracking and transesterification, most commonly used method is transesterification of vegetable oils, fats, waste oils, etc. Latest aspects of development of biodiesel have been discussed in this work. Yield of biodiesel is affected by molar ratio, moisture and water content, reaction temperature, stirring, specific gravity, etc. Biodegradability, kinetics involved in the process of biodiesel production, and its stability have been critically reviewed. Emissions and performance of biodiesel has also been reported.

PART 3

EXPERIMENTAL SETUP OUTPUT REVIEW

Avinash Kumar Agarwal et al. [6] reported the technical feasibility of using straight vegetable oils (Jatropha oil ,which is highly viscous) into a constant speed direct injection compression ignition engine. 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 of SVO fuelled engine vis-à-vis mineral diesel fuelled engine was executed and the results are compared.

Jomir Hossain et al. [7] investigated on mustard oil properties are determined in the fuel testing laboratory with standard procedure. An set-up using different blends of bio-diesel converted from mustard oil is used. Initially different blends of bio-diesel (*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 en- gine performance for different blends of bio-diesel has been carried out to determine the optimum blend for different operating conditions.

Ruslans Smigins et al. [8] was to find out the impact of biodiesel and its blends on engine dynamical and economical parameters. A model for in-cylinder thermodynamics is implemented for easy simulation of internal combustion engine performance. The model is verified with the experimental data from an engine fuelled with biodiesel (RME). The matching between the experimental and predicted results is not higher than 3 %, with exception of some parameters at different engine speeds. Another situation is according to the fuel consumption, which is more affected by biodiesel addition, especially, when the addition exceeds 10 %.

PART 4

GASEOUS EMISSION ANALYSIS REVIEW

P.K. Sahoo et. al.[9] results on non-edible filtered high viscous and high acid value polanga oil based mono esters 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. Tests were carried out over entire range of engine operation at varying conditions of speed and load. 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. 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.

N.R. Banapurmatha A et al. [10] described the best way to use vegetable oils as fuel in compression ignition (CI) engines is to convert it into biodiesel. Biodiesel is a methyl or ethyl ester of fatty acids made from vegetable oils (both edible and non- edible) and animal fat. It can be used in CI engines with very little or no engine modifications. Comparative measures of brake thermal efficiency, smoke opacity, HC, CO, NOX, ignition delay, combustion duration and heat release rates have been presented and discussed. Engine performance in terms of higher brake thermal efficiency and lower emissions (HC, CO, NOX) with sesame oil methyl ester operation was observed compared to methyl esters of Honge and Jatropha oil operation.

V P Sethi et al. [11] research on a 4-stroke 5 hp diesel engine was tested with two different fuel blends. In the first case, diesel kerosene blends and in the second case, air-liquefied petroleum gas (LPG) mixture. Different engine exhaust emissions, namely, CO2, CO, unburnt hc, (SO2), (NOx) and (O2) were compared using pure diesel, diesel-kerosene. With diesel-kerosene blends minimum exhaust emissions were observed at 30% kerosene blend. Exhaust gas emissions, namely, CO, UHC, and SO2 reduced by 40%, 18% and 19%, respectively, when compared with pure diesel emissions. Slight increase in the NOx exhaust emission (2.4%) was observed. Engine performance improved and specific fuel consumption (SFC) was observed to be minimal at 30% kerosene blending and decreased by 3.7% as compared to pure diesel value at the same brake power output. The fuel operating cost also reduced by 3.6% at 30% kerosene blend.

Problem Statement

The problem is to determine how the performance characteristics of four stroke diesel engine and smoke analysis of blends varies where palm kernel is used as raw material in production of biodiesel.

Objective of study

The objective of this research is to examine the performance parameters and smoke analysis of four stroke diesel using palm kernel oil blends.

3 SYNTHESIS OF BIODIESEL

Biodiesel production is the process of producing the biofuel, biodiesel, through the chemical reactions transesterification and esterification. This involves vegetable oils or animal fats and waste cooking oils (typically methanol or ethanol). In the transesterification process a glyceride reacts with an alcohol (typically methanol or ethanol) in the presence of a catalyst forming fatty acid alkyl esters and an alcohol.

3.1 Feedstock

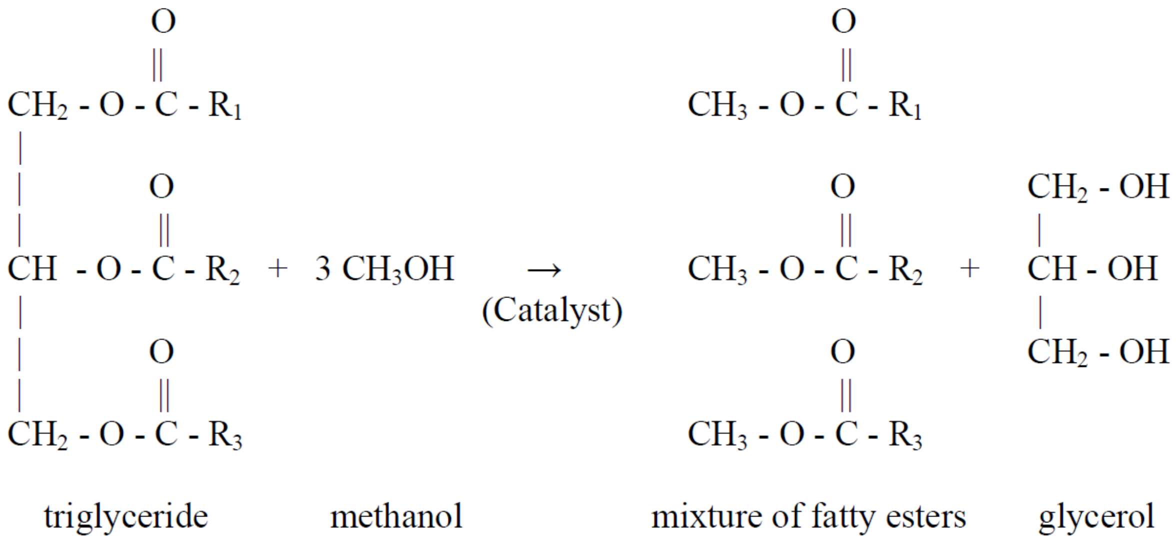
The feedstock for transesterification can be any fatty acids from vegetable or animal origin, or used cooking oils (UCO). Typically used vegetable oils originate from rapeseed, sunflower, soy and oil palms.

Depending on the origin of the oils and fats some pretreatment is necessary before processing.

- In any case water is removed as it causes the triglycerides to hydrolyze during base-catalyzed transesterification, producing soapstock instead of biodiesel.
- Virgin oils are refined, but not to food grade level.
- In some cases, the removal of phospholipids and other plant matter is done by degumming.
- Recycled oils as UCO are purged from impurities such as dirt or charred Food.

3.2 Transesterification process

The transesterification process is a reversible reaction and carried out by mixing the reactants – fatty acids, alcohol and catalyst. A strong base or a strong acid can be used as a catalyst. At the industrial scale, mostly sodium or potassium methanolate is used. The end products of the transesterification process are raw biodiesel and raw glycerol. In a further process these raw products undergo a cleaning step. In case of using methanol as alcohol FAME (fatty acid methyl ester) biodiesel is produced. The purified glycerol can be used in the food and cosmetic industries, as well as in the oleochemical industry. The glycerol can also be used as a substrate for anaerobic digestion.



$$\begin{array}{l} CH_2-O-\overset{\overset{O}{\|}}{C}-R_1 \\ | \\ CH-O-\overset{\overset{O}{\|}}{C}-R_2 \\ | \\ CH_2-O-\overset{\overset{O}{\|}}{C}-R_3 \end{array} + 3\,CH_3OH \xrightarrow[\text{(Catalyst)}]{} \begin{array}{l} CH_3-O-\overset{\overset{O}{\|}}{C}-R_1 \\ CH_3-O-\overset{\overset{O}{\|}}{C}-R_2 \\ CH_3-O-\overset{\overset{O}{\|}}{C}-R_3 \end{array} + \begin{array}{l} CH_2-OH \\ | \\ CH-OH \\ | \\ CH_2-OH \end{array}$$

Fig 3.2.1 REACTION OF TRANSESTERIFICATION

3.3 METHODOLOGY OF TRANS-ESTERIFICATION OF PALM KERNAL OIL

PALM KERNAL OIL which was extracted from the kernel seeds was first pre heated and then filtered with surgical cotton to remove the dust and unwanted suspended particles. To reduce the high viscosity of the palm oil a widely used transesterification process was followed. In this transesterification process the exchange of organic group of esters with organic group of alcohol (CH_3OH), which are catalyzed by addition of base catalyst (NaOH) to form as a methyl ester. Sodium hydroxide pellets of 4 grams was mixed with 90ml of methanol to form a methoxide solution and it was added in 500ml of esterified kernel oil and the solution was maintaining at desired reaction temperatures. After a period of time there will be a clear separation of glycerin and methyl ester, the heavy density glycerin settled in the bottom was removed and the methyl esters was washed continuously with distill water until a clear separation of oil and water appears.

3.4 PROCESS

3.4.1 PRE HEATING OF OIL

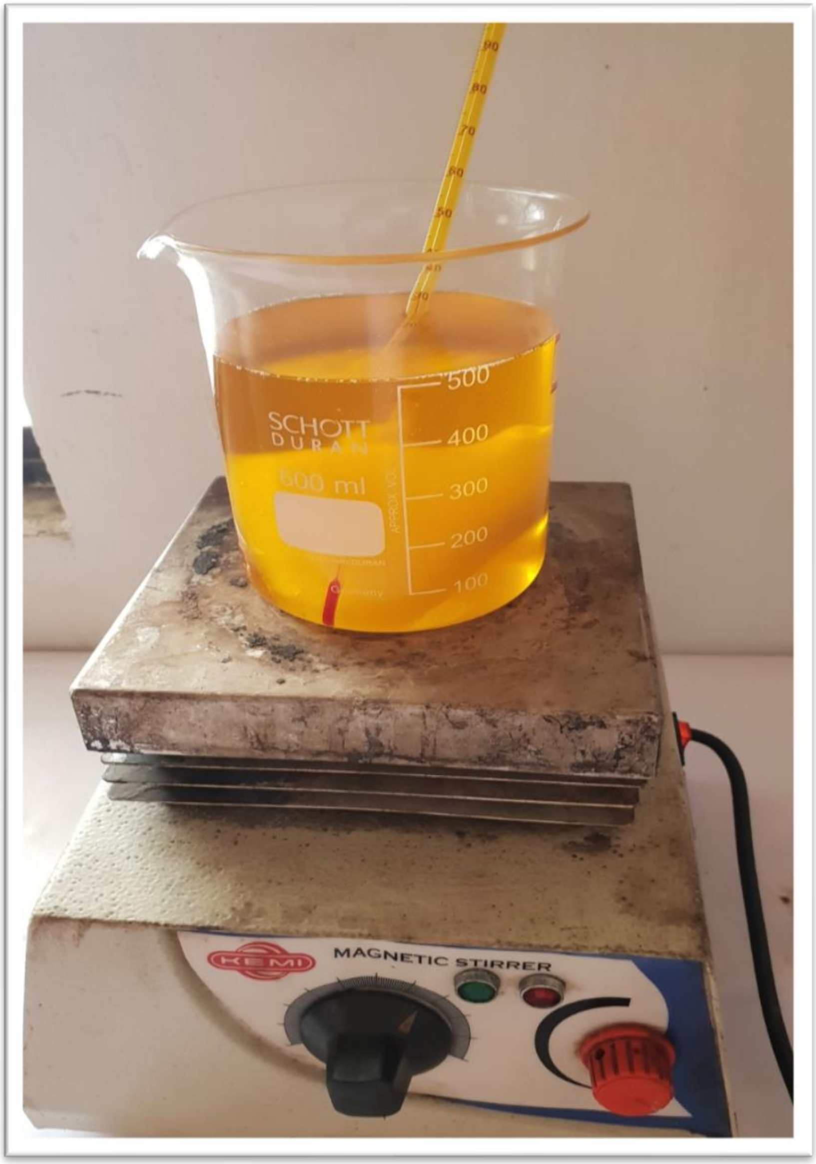


Fig 3.4.1 HEATING OF OIL

3.4.2 TRANS-ESTERIFICATION PROCESS

Fig 3.4.2 TRANS-ESTERIFICATION

3.4.3 DRAINING OF GLYCEROL

Fig 3.4.3 GLYCEROL DRAINING

After the trans-esterification reaction, the glycerol has to be settle to the bottom of the container when kept in a separating funnel. This happens because Glycerol is heavier then biodiesel. 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.

3.4.4 SEPARATION OF BIODIESEL

Fig 3.4.4 REMOVAL OF EXCESS SOAP

The process is done until the separation of biodiesel and distilled water appears to be crystal clear in order to remove the soap solution left after draining glycerol.

3.4.5 PRODUCTION OF BIODIESEL

Final stage after removing of soap solution is the pure biodiesel production.

Fig 3.4.5 FINAL PRODUCT AS BIODIESEL

4 EXPERIMENTAL SETUP

4.1 DIESEL ENGINE

The **Diesel engine** (also known as a **compression-ignition** or **CI engine**), named after Rudolf Diesel, is an internal combustion engine in which ignition of the fuel, which is injected into the combustion chamber, is caused by the elevated temperature of the air in the cylinder due to the mechanical compression (adiabatic compression).

Diesel engines work by compressing only the air. This increases the air temperature inside the cylinder to such a high degree that atomised Diesel fuel injected into the combustion chamber ignites spontaneously. With the fuel being injected into the air just before combustion, the dispersion of the fuel is uneven; this is called a heterogenous air-fuel mixture. The process of mixing air and fuel happens almost entirely during combustion, the oxygen diffuses into the flame, which means that the Diesel engine operates with a diffusion flame. The torque a Diesel engine produces is controlled by manipulating the air ratio; this means, that instead of throttling the intake air, the Diesel engine relies on altering the amount of fuel that is injected, and the air ratio is usually high.

The **Diesel cycle** is a combustion process of a reciprocating internal combustion engine. In it, fuel is ignited by heat generated during the compression of air in the combustion chamber, into which fuel is then injected. This is in contrast to igniting the fuel-air mixture with a spark plug as in the Otto cycle (four-stroke/petrol) engine. Diesel engines are used in aircraft, automobiles, power generation, diesel-electric locomotives, and both surface ships and submarines.

The image on the left shows a P-V diagram for the ideal Diesel cycle; where P is pressure and V the volume or the specific volume if process is placed on a unit mass basis. The ideal Diesel cycle follows the following four distinct processes:

- Process 1 to 2 is isentropic compression of the fluid (blue)
- Process 2 to 3 is reversible constant pressure heating (red)
- Process 3 to 4 is isentropic expansion (yellow)
- Process 4 to 1 is reversible constant volume cooling (green)

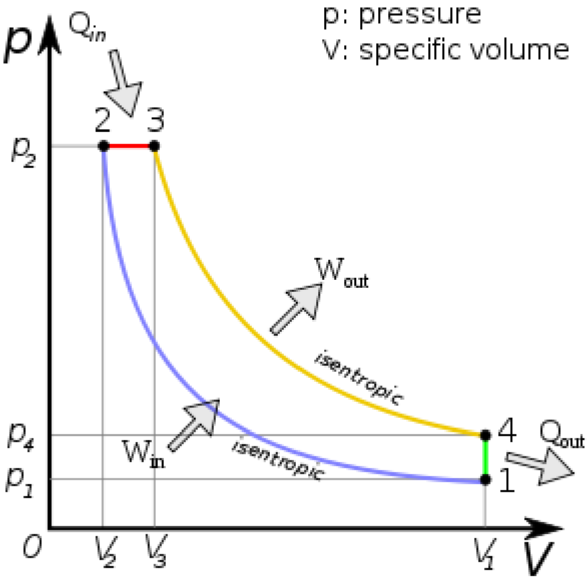


Fig 4.1.1 DIESEL CYCLE

4.2 ENGINE DESCRIPTION

The prepared fuel blends are tested in a Kirloskar make four stroke, single cylinder, constant speed, water-cooled diesel engine- test rig in the laboratory. This engine is provided with a crank handle for starting. The engine is mounted with an absorption dynamometer of brake drum type. The engine set up is also provided with burette, graduations duly marked and a three way valve is used to measure the fuel flow rate. A load test and a smoke analysis test are conducted with additional attachment of muffler to the exhaust smoke pipe.

Through the load test and smoke analysis, the performance characteristics and 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.

Fig 4.2.1 FOUR STROKE -SINGLE CYLINDER- VERTICAL DIESEL ENGINE

Table 4.2.1 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

4.3 SMOKE METER

Smoke meters are instruments measuring the optical properties of diesel exhaust. These instruments have been designed to quantify the visible black smoke emission utilizing such physical phenomena as the extinction of a light beam by scattering and absorption. In general, smoke and meters are much simpler (some of them very simple) and less costly in comparison to most other instruments used for PM measurement. They are often used to evaluate smoke emissions in locations outside the laboratory, such as in maintenance shops or in the field. In fact, the smoke opacity measurement is the only relatively low-cost and widely available method to measure a PM-related emission parameter in the field. For this reason, opacity limits are used in most inspection and maintenance (I&M) or periodic technical inspection (PTI) programs for diesel engines. Smoke opacity limits may be also included as auxiliary limits in new engine emission standards.

All modern Diesel Exhaust Smoke Meters should measure diesel emissions characteristics (dark smoke) in Opacity (HSU- Hartridge Smoke Units) and/or Smoke Density (K).

Fig 4.3.1 SMOKE METER

5 EXPERIMENTAL PROCEDURE

The experimental procedure includes further blending process of biodiesel which helps in calculating the performance characteristics using four stroke vertical diesel engine.

5.1 BLENDING

It is a process of mixing diesel and biodiesel in proportions called blends.

This process involves:

- Taking proportions of blend to be prepared.
- Mixing Biodiesel with Petroleum Diesel in the mixer.

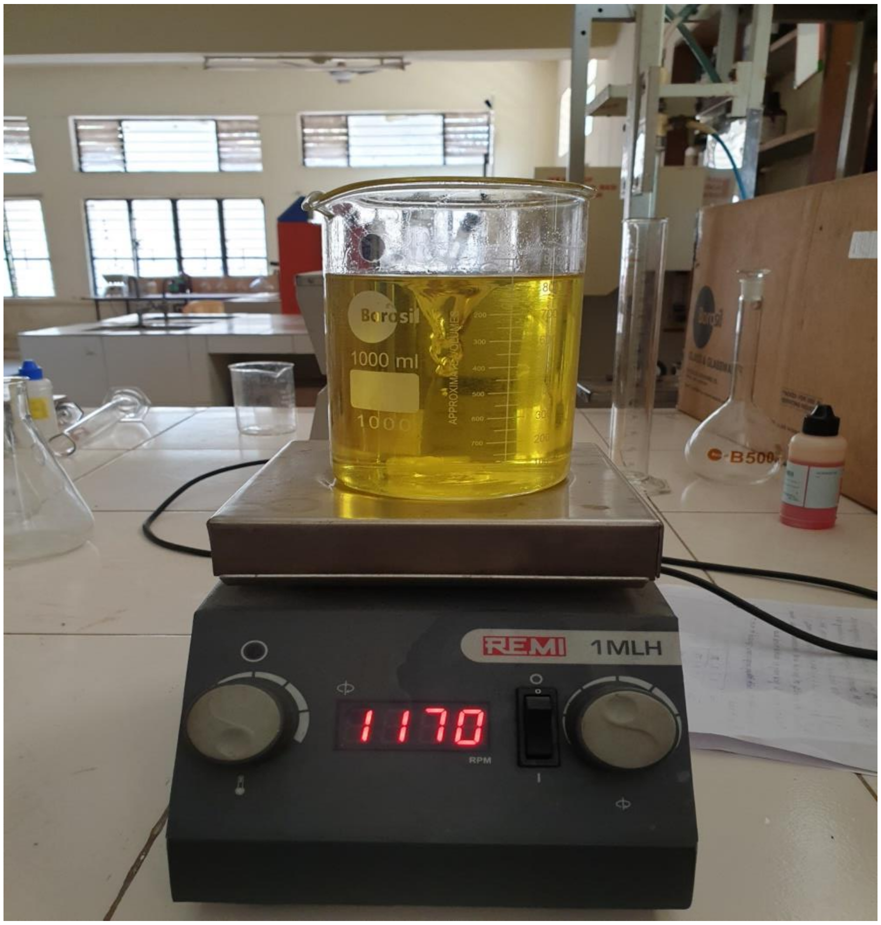


Fig 5.1.1 PROCESS OF BLENDING

5.2 BLENDING OF OILS

In the general terminology the composition of Biodiesel is indicated as B5, B10, B15 etc., where “B” represents the fuel as Biodiesel and the digit represents the percentage of blend.

10% biodiesel, 90% petro diesel is labeled as B10.

20% biodiesel, 80% petro diesel is labeled as B20.

In this work, the following fuel blends with their respective proportions of its constituents were used of 800 ml each as shown in table.

BLEND	DIESEL(ml)	PALM KERNAL OIL (ml)
B5	760	40
B10	720	80
B15	680	120
B20	640	160
B25	600	200

Table 5.2.1 OIL PROPORTIONS IN FUEL BLENDS

5.3 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 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 rated speed.
5. Allow the engine to run for some time in idle condition.
6. Put the 3 way cock in 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.

6 EXPERIMENTAL RESULTS

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 analyzed and the conclusions have been derived.

6.1 Basic notations for calculations

W =Load
S =spring balance reading
F.C =Fuel consumption
B.P. =Brake power
H.S.U= Hartridge smoke unit

I.P. =Indicated power
S.F.C =Specific fuel consumption
IMEP =Indicated mean effective pressure
BMEP =Brake mean effective pressure
FMEP =Friction mean effective pressure

η_{ith} =Indicated thermal efficiency
η_{bth} = Brake thermal efficiency
η_{mech}= Mechanical efficiency

6.2 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

6.3 Basic formulae for calculations

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

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

$$=11.27 \text{ kg}$$

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

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

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 as Willian’s Line Method.

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

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

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

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

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

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

6.4 Model Calculations

Considering B15 blend at 5.6 kgf load

Specific gravity is 0.83 gm/cc

Calorific value is 44746 KJ/kg

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

$$= \frac{2\pi\times 1500\times 5.6\times 9.81\times 0.213}{60000}$$

$$= 1.83\ \text{KW}$$

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

$$= \frac{10}{50.65}\times\frac{0.83\times 3600}{1000}\ \text{kg/hr}$$

$$= 0.589\ \text{kg/hr}$$

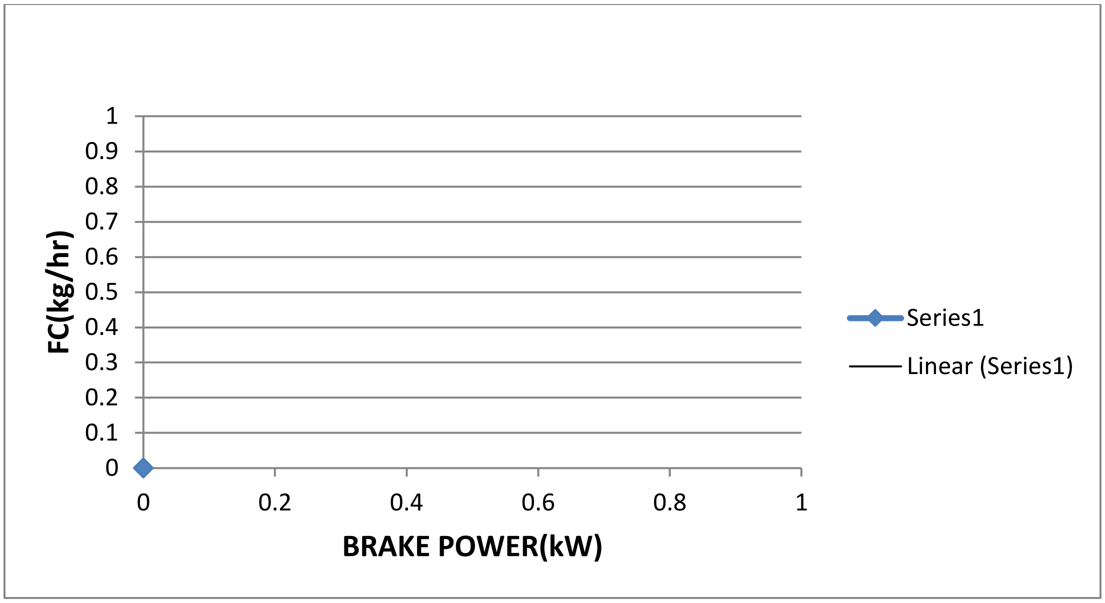


Fig 6.4.1 Brake Power vs Fuel Consumption for B15 blend

Frictional Power from graph (F.P) =1.85 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.

Indicated power (I.P) = B.P +F.P =1.83+1.85

=3.68 KW

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

$= \frac{0.589}{1.83}$

= 0.32 kg/KW hr

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

$= \frac{1.83\times 3600}{0.589\times 44746}$

= 25%

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

$=\frac{3.68\times3600}{0.589\times44746}$

=0.5029

=50.29%

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

$= \frac{1.83}{3.68}$

=0.498

=49.8%

Indicated mean effective pressure (IMEP) $=\frac{I.P\times60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{3.68\times60000}{110\times10^{-3}\times\frac{\pi}{4}(80\times10^{-3})^2\times\frac{1500}{2}}$

=533000 N/m^2

=5.33bar

Brake mean effective pressure (BMEP) $= \frac{B.P\times60000}{L\times\frac{\pi}{4}D^2\times\frac{N}{2}}$ N/m^2

$=\frac{1.83\times60000}{110\times10^{-3}\times\frac{\pi}{4}(80\times10^{-3})^2\times\frac{1500}{2}}$

=265000 N/m^2

=2.65 bar

Table 6.4.1 OBSERVATIONS FOR PURE DIESEL

W-S (kgf)	**Time** (sec)	**F.C** (kg/hr)	**B.P** (KW)	**I.P** (KW)	**S.F.C** (kg/kwhr)	η_{bth} (%)	η_{ith} (%)	η_{mech} (%)	**IMEP** (kn/m^2)	**BMEP** (kn/m^2)	**FMEP** (kn/m^2)	**HSU**
0	82.31	0.359	0	2	0	0	43.95	0	2.89	0	2.89	0.43
2	65.43	0.45	0.65	2.65	0.69	4.43	46.2	24.7	3.85	0.95	2.89	0.86
3.8	55.4	0.53	1.24	3.24	0.43	18.38	47.86	38.4	4.69	1.8	2.89	1.28
5.6	47.19	0.628	1.84	3.84	0.341	23.15	48.34	47.89	5.53	2.659	2.89	2.97
7.4	41.56	0.71	2.42	4.42	0.292	27.05	49.33	54.8	6.4	3.514	2.89	6.65
9.2	38.04	0.77	3.01	5.01	0.259	30.75	51.1	60.15	7.26	4.36	2.89	9.81

Frictional power: 2kW

Table 6.4.2 OBSERVATIONS FOR B5 BLEND

W-S (kgf)	**Time** (sec)	**F.C** (kg/hr)	**B.P** (KW)	**I.P** (KW)	**S.F.C** (kg/kwhr)	η_{bth} (%)	η_{ith} (%)	η_{mech} (%)	**IMEP** (kn/m^2)	**BMEP** (kn/m^2)	**FMEP** (kn/m^2)	**HSU**
0	80.05	0.368	0	2.1	0	0	45.2	0	3.03	0	3.03	0.43
1.9	65.48	0.45	0.62	2.72	0.722	10.98	47.95	22.8	3.94	0.902	3.03	0.85
3.8	54.32	0.543	1.24	3.34	0.43	18.21	48.49	37.2	4.84	1.8	3.03	1.71
5.6	48.10	0.613	1.83	3.93	0.33	23.77	50.9	46.6	5.69	2.65	3.03	2.55
7.4	42.12	0.702	2.432	4.52	0.289	27.43	51.1	53.6	6.554	3.51	3.03	6.95
9.2	38.3	0.77	3.01	5.11	0.255	31.09	52.7	58.9	7.44	4.36	3.03	10.04

Frictional power:2.1kW

Table 6.4.3 OBSERVATIONS FOR B10 BLEND

W-S (kgf)	**Time** (sec)	**F.C** (kg/hr)	**B.P** (KW)	**I.P** (KW)	**S.F.C** (kg/kwhr)	**η_{bth}** (%)	**η_{ith}** (%)	**η_{mech}** (%)	**IMEP** (kn/m^2)	**BMEP** (kn/m^2)	**FMEP** (kn/m^2)	**HSU**
0	67.9	0.43	0	2	0	0	45	0	2.89	0	2.89	0.43
1.9	66.5	0.449	0.623	2.62	0.719	11.11	46.7	23.7	3.79	0.9	2.89	0.87
3.8	56.56	0.528	1.24	3.24	0.42	18.9	49.3	38.4	4.69	1.8	2.89	1.71
5.6	50.7	0.58	1.83	3.83	0.32	24.9	52.1	47.8	5.54	2.65	2.89	2.55
7.4	45.47	0.65	2.42	4.42	0.27	29.6	53.8	54.8	6.40	3.51	2.89	2.97
9.2	40.16	0.744	3.01	5.01	0.246	32.5	52.03	60.17	7.26	4.36	2.89	12.1

Frictional power:2kW

Table 6.4.4 OBSERVATIONS FOR B15 BLEND

W-S (kgf)	Time (sec)	F.C (kg/hr)	B.P (KW)	I.P (KW)	S.F.C (kg/kwhr)	η_{bth} (%)	η_{ith} (%)	η_{mech} (%)	IMEP (kn/m^2)	BMEP (kn/m^2)	FMEP (kn/m^2)	HSU
0	86.47	0.345	0	1.85	0	0	43.07	0	2.67	0	2.67	0.43
1.9	70.36	0.42	0.62	2.47	0.68	11.8	46.8	25.2	3.57	0.902	2.67	1.28
3.8	57.95	0.51	1.24	3.09	0.41	19.45	48.31	40.26	4.48	1.804	2.67	1.71
5.6	50.65	0.58	1.83	3.68	0.32	25	50.29	49.8	5.33	2.65	2.67	2.13
7.4	46.15	0.64	2.42	4.27	0.266	30.18	53.16	56.78	6.19	3.51	2.67	6.65
9.2	42.05	0.71	3.01	4.86	0.23	34.1	55.1	62.0	7.04	4.36	2.67	10.96

Friction power:1.85kW

Table 6.4.5 OBSERVATIONS FOR B20 BLEND

W-S (kgf)	**Time** (sec)	**F.C** (kg/hr)	**B.P** (KW)	**I.P** (KW)	**S.F.C** (kg/kwhr)	η_{bth} (%)	η_{ith} (%)	η_{mech} (%)	**IMEP** (kn/m^2)	**BMEP** (kn/m^2)	**FMEP** (kn/m^2)	**HSU**
0	72	0.42	0	1.9	0	0	36.84	0	2.74	0	2.74	0.43
1.9	67.44	0.44	0.62	2.52	0.71	11.34	45.8	24.7	3.65	0.902	2.74	0.86
3.8	56.32	0.53	1.24	3.14	0.43	18.92	47.74	39.62	4.55	1.80	2.74	1.71
5.6	47.89	0.631	1.83	3.73	0.34	23.7	48.27	49.17	5.40	2.65	2.74	2.97
7.4	42	0.72	2.42	4.32	0.29	27.5	49.02	56.1	6.26	3.51	2.74	3.38
9.2	38.74	0.78	3.01	4.91	0.25	31.5	51.3	61.1	7.11	4.36	2.74	9.03

Frictional power=1.9kW

Table 6.4.6 OBSERVATION FOR B25 BLEND

W-S (kgf)	**Time** (sec)	**F.C** (kg/hr)	**B.P** (KW)	**I.P** (KW)	**S.F.C** (kg/kwhr)	η_{bth} (%)	η_{ith} (%)	η_{mech} (%)	**IMEP** (kn/m^2)	**BMEP** (kn/m^2)	**FMEP** (kn/m^2)	**HSU**
0	70.88	0.42	0	2.1	0	0	40.4	0	3.039	0	3.039	0.13
1.9	63.47	0.47	0.62	2.72	0.76	10.7	46.9	22.8	3.94	0.90	3.039	1.71
3.8	53.69	0.56	1.24	3.34	0.45	18.2	48.8	37.2	4.84	1.80	3.039	2.55
5.6	46.04	0.65	1.83	3.93	0.357	23	49.2	46.67	5.69	2.659	3.039	3.38
7.4	41.06	0.73	2.42	4.52	0.30	27.1	50.5	53.63	6.55	3.514	3.039	8.63
9.2	37.16	0.81	3.01	5.11	0.269	30.4	51.7	58.9	7.4	4.36	3.039	22.74

Frictional power:2.1KW

The frictional power is determined from Willian's line method by plotting graph between brake power and fuel consumption. The Willian's line for each blend (B5, B10, B15, B20, and B25) is plotted on graph at different loads.

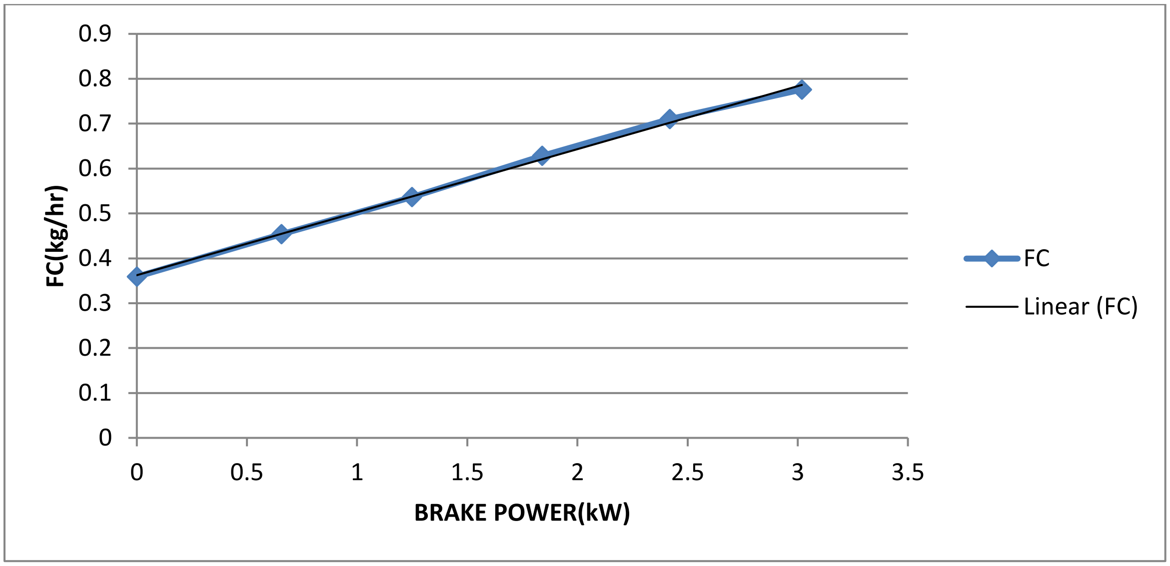


Fig 6.4.2 Variation of Brake power vs. Fuel consumption for diesel

Frictional power=2 kW

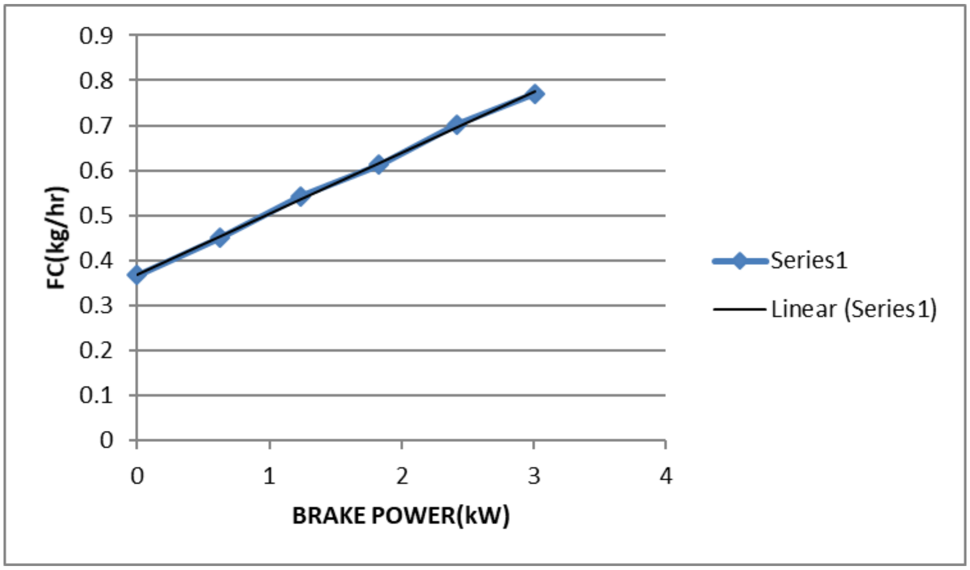


Fig 6.4.3 Variation of Brake power vs. fuel consumption for B5

Frictional power = 2.1 kW

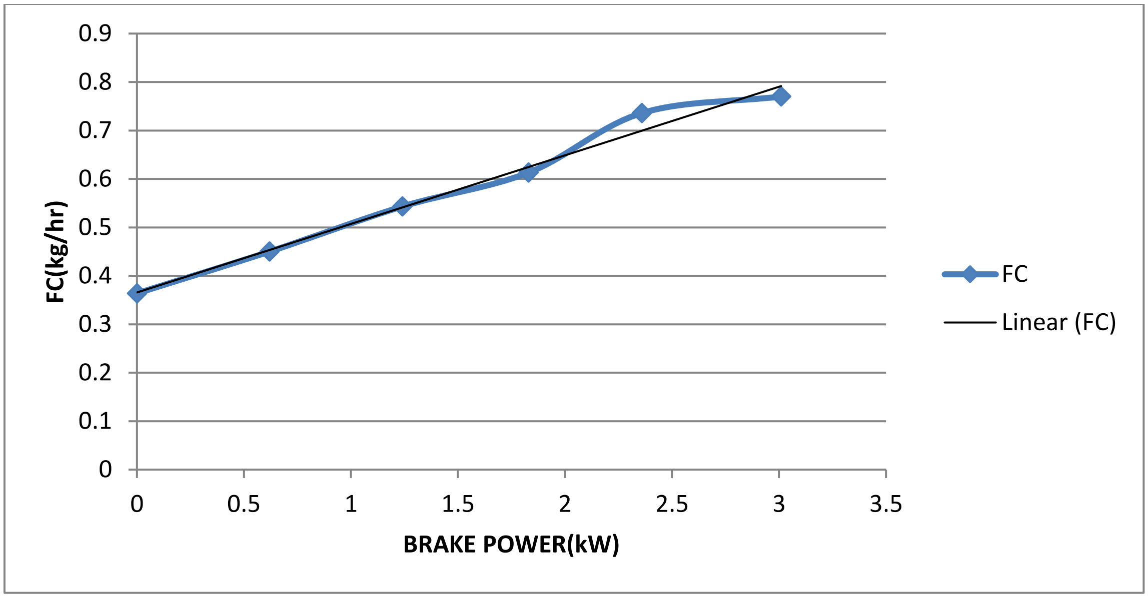


Fig 6.4.4 Variation of Brake power vs. fuel consumption for B10

Frictional power=2 kW

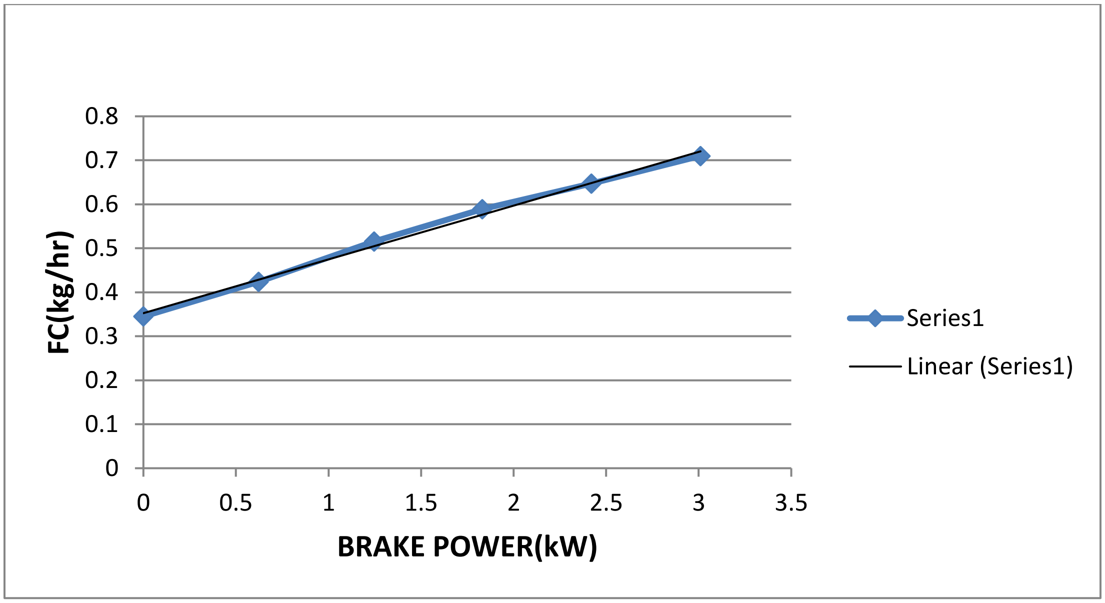


Fig 6.4.5 Variation of Brake power vs. fuel consumption for B15

Frictional power=1.85 kW

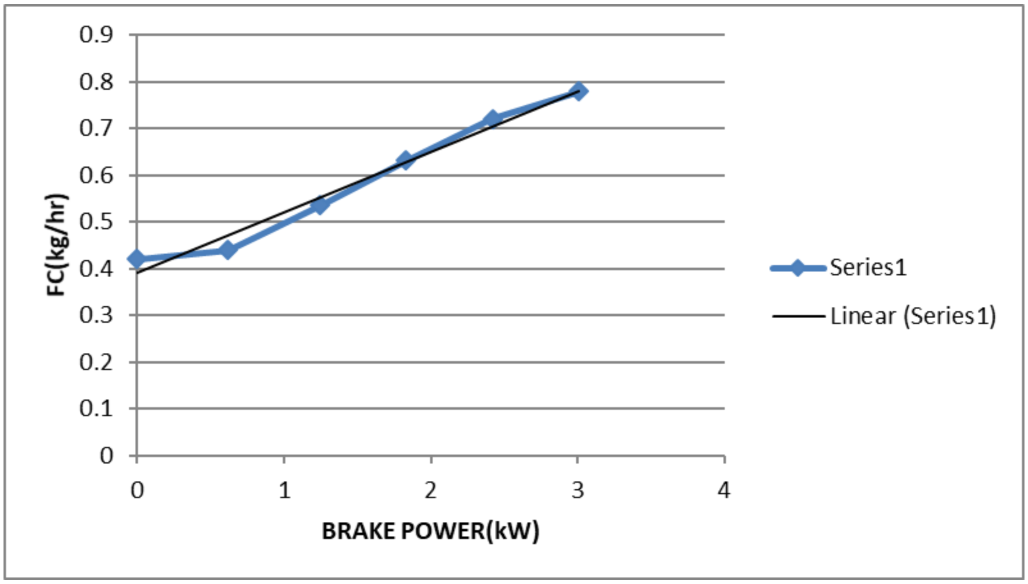


Fig 6.4.6 Variation of Brake power vs. Fuel consumption for B20

Frictional power=1.9 kW

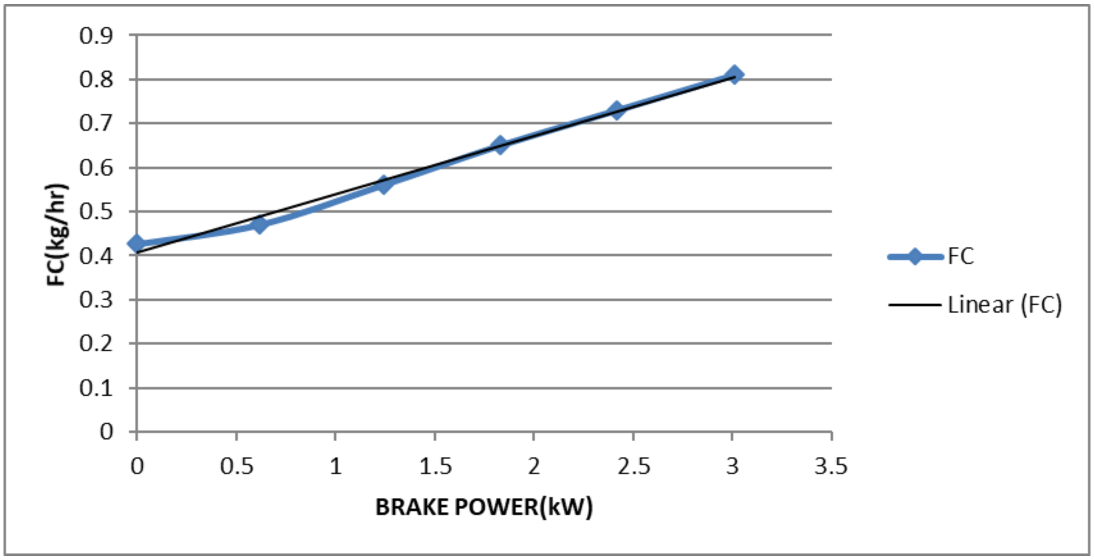


Fig 6.4.7 Variation of Brake power vs. Fuel consumption for B25

Frictional power= 2.1 kW

6.5 Performance Characteristics

The performance characteristics are brake power, mechanical efficiency, specific fuel consumptions, indicated thermal efficiency, brake thermal efficiency.

Engine performance is an indication of 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

6.5.1 Comparison of Mechanical Efficiency

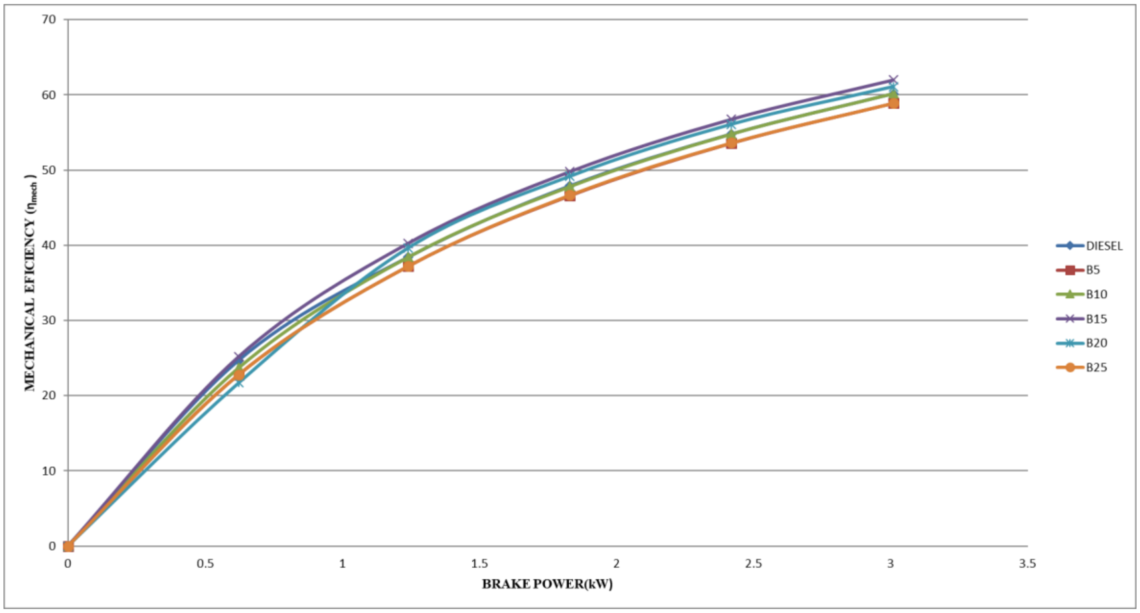


Fig 6.5.1 COMPARISON OF BRAKE POWER VS MECHANICAL EFFICIENCY

Mechanical efficiency measures the effectiveness of a machine in transforming the energy and power that is input to the device into output force and movement i.e., converting the indicated power to brake power. The values of mechanical efficiency at different brake powers are plotted. B15 offers the best mechanical efficiency of all the mixtures and therefore seems to be the best mixture with minimum frictional power.B25 and B5 offers the least mechanical efficiency.

6.5.2 Comparison of Brake Thermal Efficiency

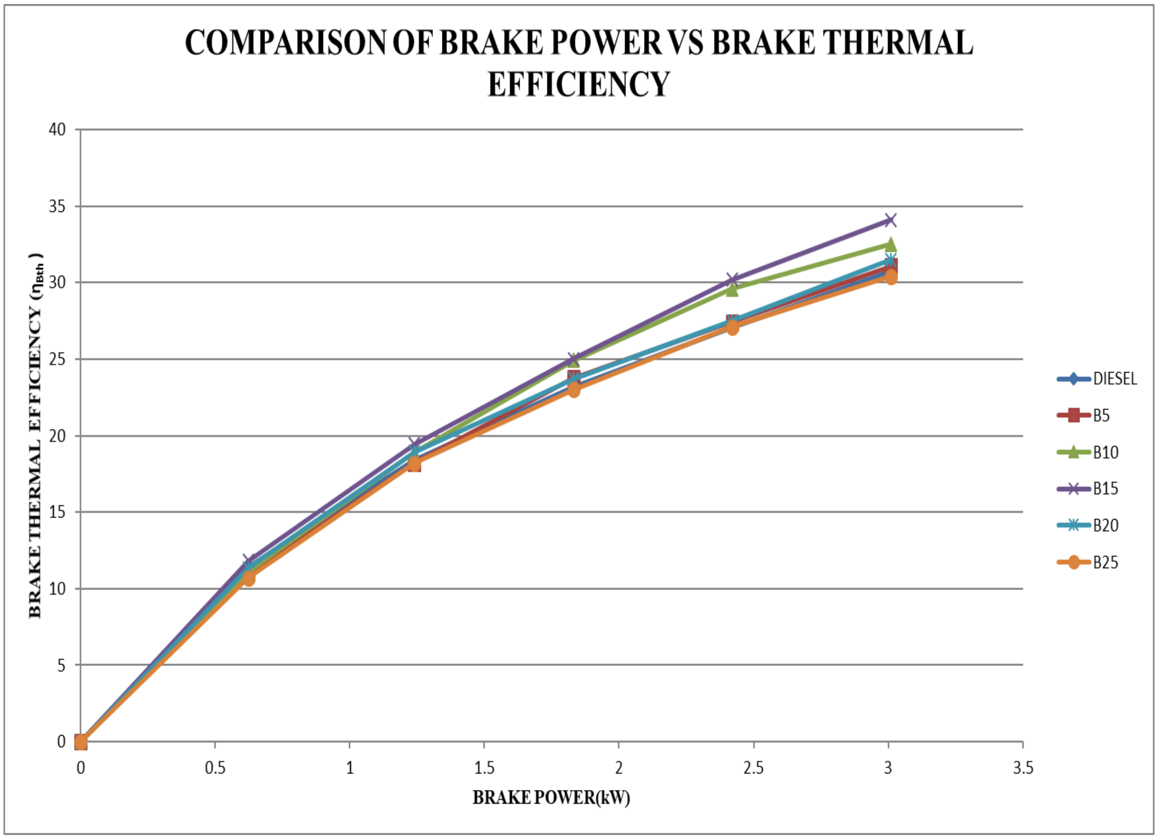


Fig 6.5.2 COMPARISON OF BRAKE POWER vs BRAKE THERMAL EFFICIENCY

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 are plotted in the figure. B15 blend offers the highest brake thermal efficiency when comparable with other blends. B25 offers the least brake thermal efficiency.

6.5.3 Comparison of Indicated Thermal Efficiency

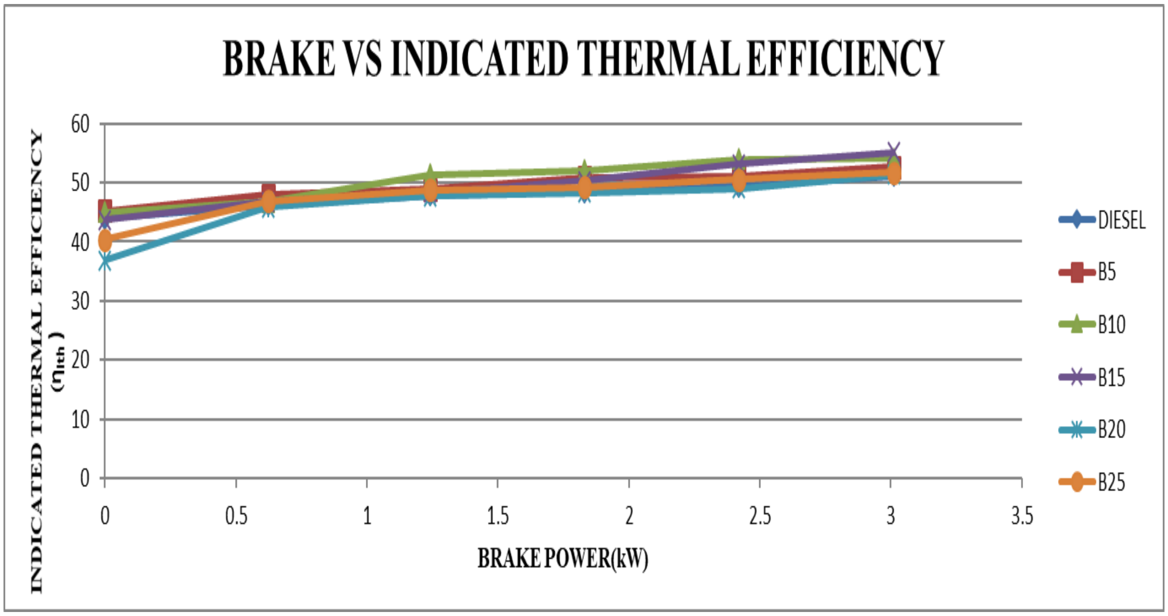


Fig 6.5.3 COMPARISON OF BRAKE POWER vs INDICATED THERMAL EFFICIENCY

Thermal efficiency is sometimes called the fuel conversion efficiency, defined as the ratio of the work produced per cycle to the amount of fuel energy supplied per cycle that can be released in the combustion process. The values of indicated thermal efficiency at different brake powers are plotted in graph. B5 offers maximum indicated thermal efficiency upto 0.75 kW. Above 0.75 kW, B10 offers maximum indicated thermal efficiency up to 2.5 kW and above 2.5 kW, B15 offers the best efficiency. B25 offers the least indicated thermal efficiency.

6.5.4 Comparison of Specific Fuel Consumption

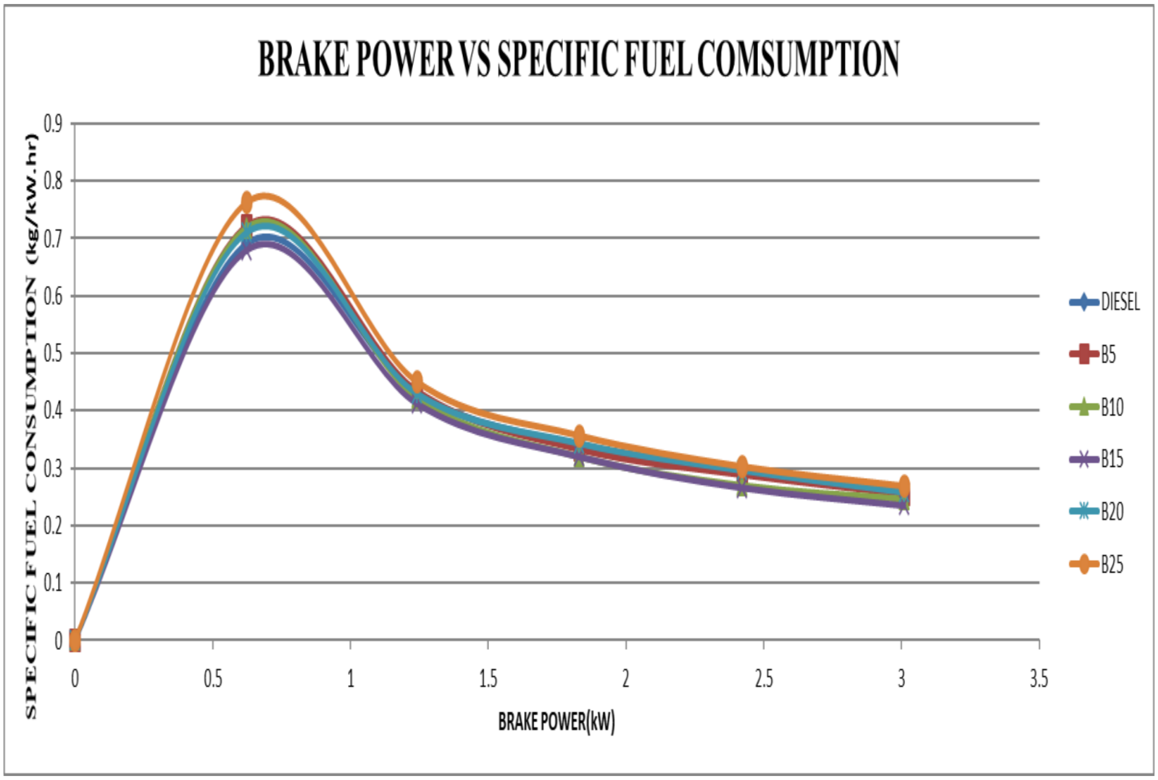


Fig 6.5.4 COMPARISON OF BRAKE POWER VS SPECIFIC FUEL CONSUMPTION

Specific fuel consumption is ratio of fuel consumption per unit time (in Kg/hr) to power produced by engine (in kWh). It is a measure of fuel efficiency i.e., how much amount of fuel is consumed to produce unit power output. The values of specific fuel consumption at different brake powers are plotted in graph. B15 offers the least specific fuel consumption when compared with other blends. And B25 has maximum specific fuel consumption rate.

6.5.5 Comparison of Indicated Power

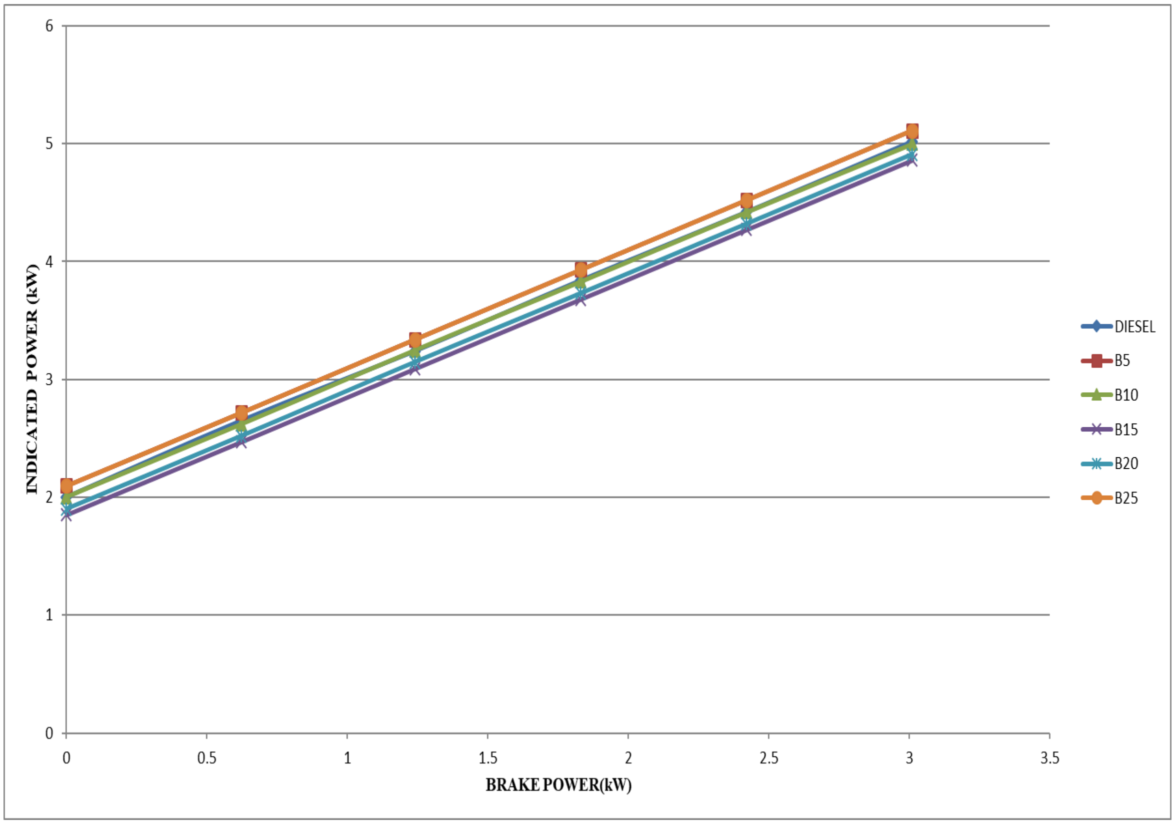


Fig 6.5.5 COMPARISON OF BRAKE POWER vs INDICATED POWER

Indicated power is the theoretical maximum output power of engine. The indicated power is the total power available from the expansion of the gases in the cylinders without taking into account any friction loss, heat loss or entropy within the system. The values of indicated power at different brake powers are plotted in the graph. B25 offers the maximum indicated power. B15 offers the minimum power.

6.5.6 Comparison of Indicated Mean Effective Pressure

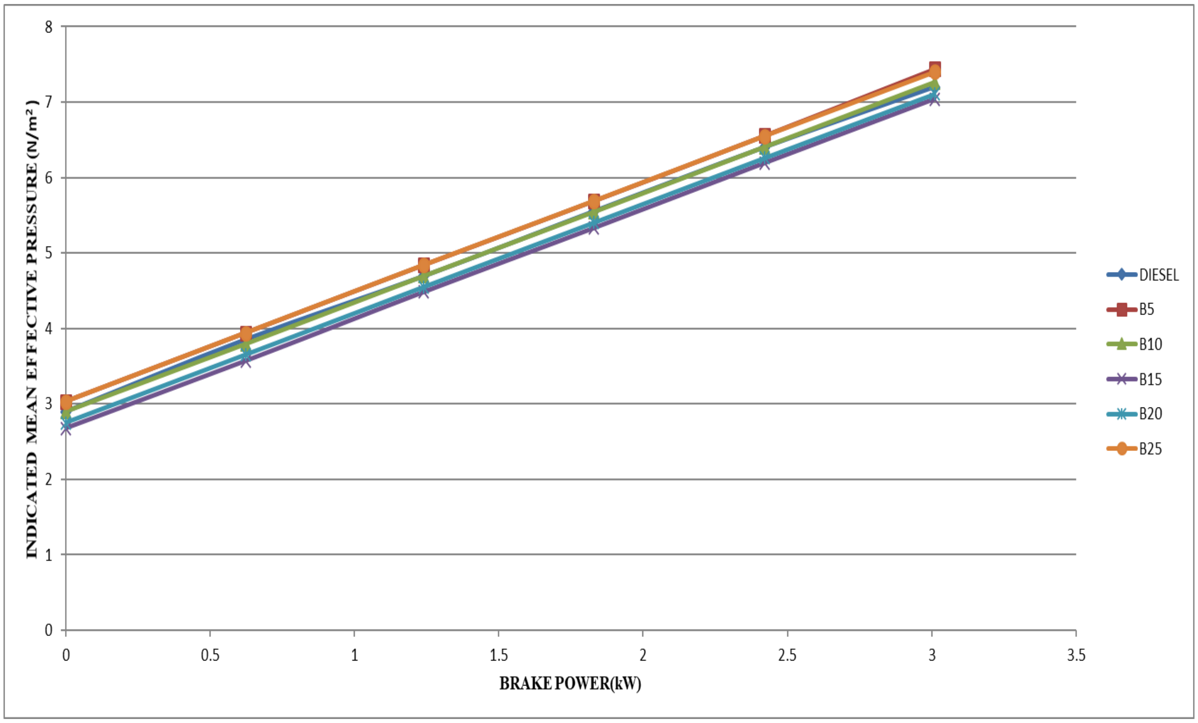


Fig 6.5.6 COMPARISON OF BRAKE POWER vs INDICATED MEAN EFFICIENCY

Indicated mean effective pressure (IMEP) is defined as the average pressure produced in the combustion chamber during the operating cycle. IMEP is equal to the break mean effective pressure plus friction effective pressure. The variations of IMEP with respect to brake power for different blends at different loading conditions are plotted in graph. B15 offers the minimum indicated mean effective pressure of all mixtures and it seems to be the best mixture with regards to minimum frictional power while B25 and B5 offers the maximum indicated mean effective pressure.

6.6 Smoke Intensity analysis

The major pollutants appearing in the exhaust of a diesel engine are smoke and the oxides of nitrogen. For measuring the smoke opacity, Hartridge Exhaust smoke-meter was used. Hartridge smoke meter consists of two identical tubes, a smoke type and a clean air tube. A pressure relieve valve allows a regulated quantity of exhaust through the smoke tube. During smoke density measurements, a light source (45-W bulb) at one end of the smoke tube projects a light beam through smoke, which at the other end falls on a photoelectric cell. Clean air tube is used for initial zero setting. Of the light beam projected across a flowing stream of exhaust gases, a certain portion of light is absorbed or scattered by the suspended soot particles in the exhaust. The remaining portion of the light falls on a photocell, generating a photoelectric current, which is a measure of smoke density. A micro-voltmeter is connected to the photoelectric cell with its scale graduated 0–100, indicating the light absorbed in Hartridge Smoke Meter unit. Zero reading corresponds to no smoke (clean air), whereas 100 reading refers to dense smoke.

6.6.1 Comparison of Smoke Intensity with Blends

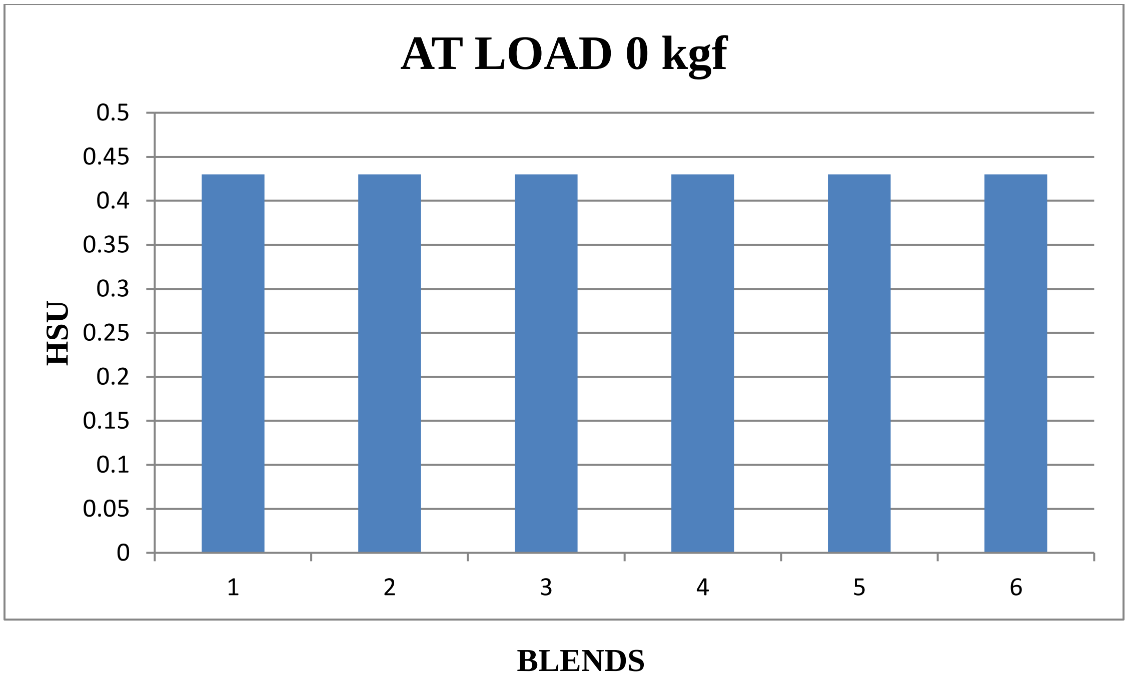
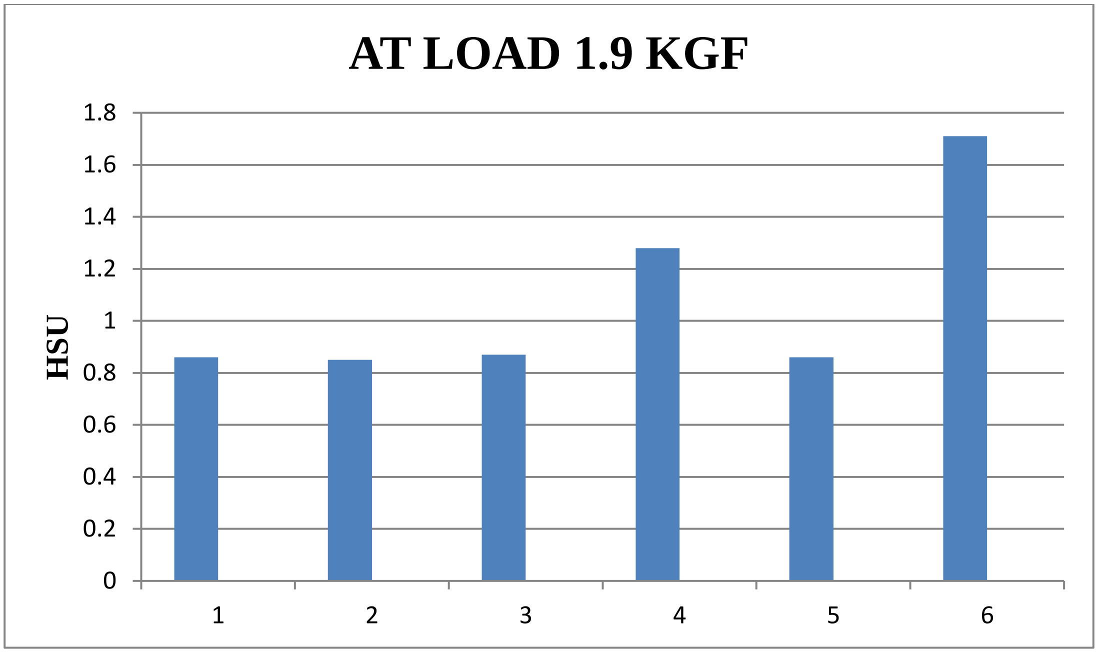
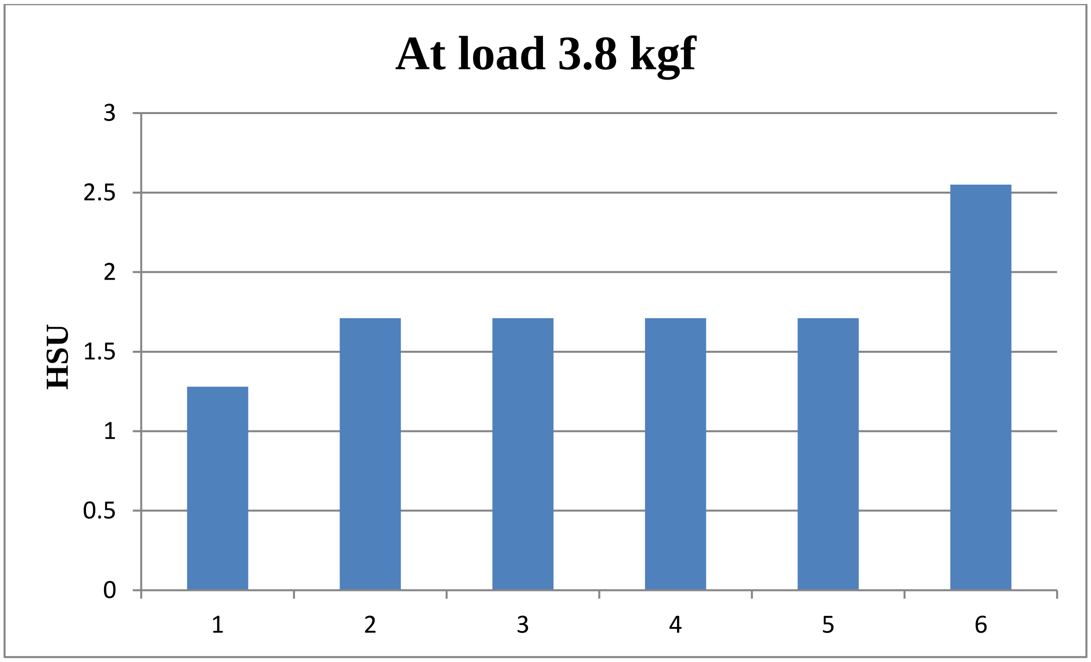


Fig 6.6.1.1 COMPOSITION VS SMOKE INTENSITY (LOAD 0kgf)



BLENDS

Fig 6.6.1.2 COMPOSTION VS SMOKE INTENSITY(LOAD 1.9 kgf)



BLENDS

Fig 6.6.1.3 COMPOSITION VS SMOKE INTENSITY (LOAD 3.8 kgf)

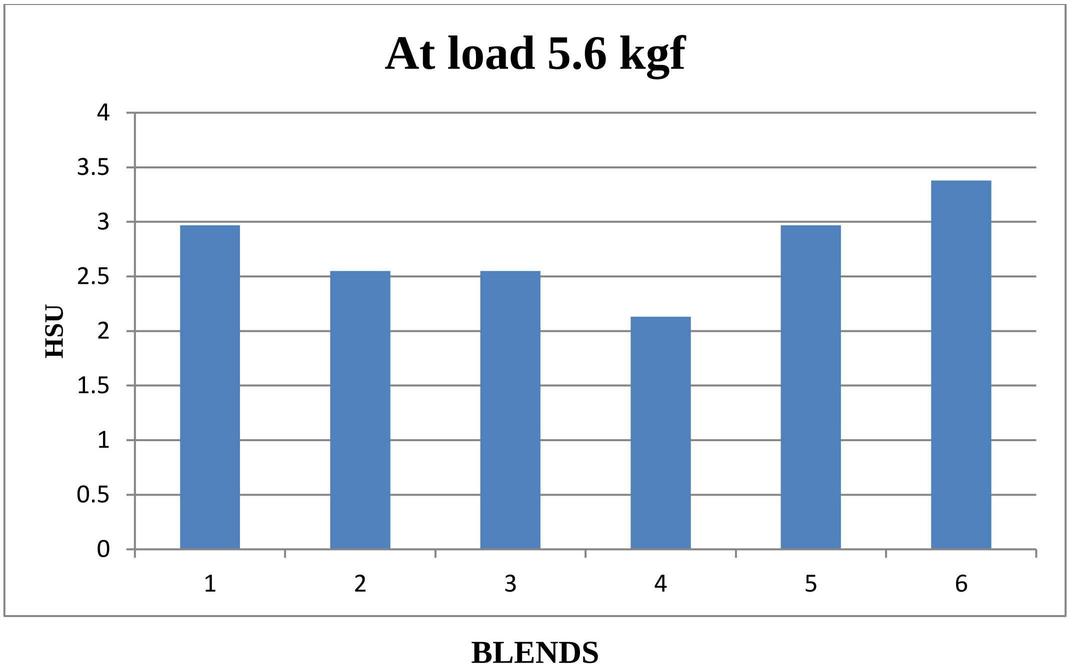


Fig 6.6.1.4 COMPOSITION VS SMOKE INTENSITY (LOAD 5.6 kgf)

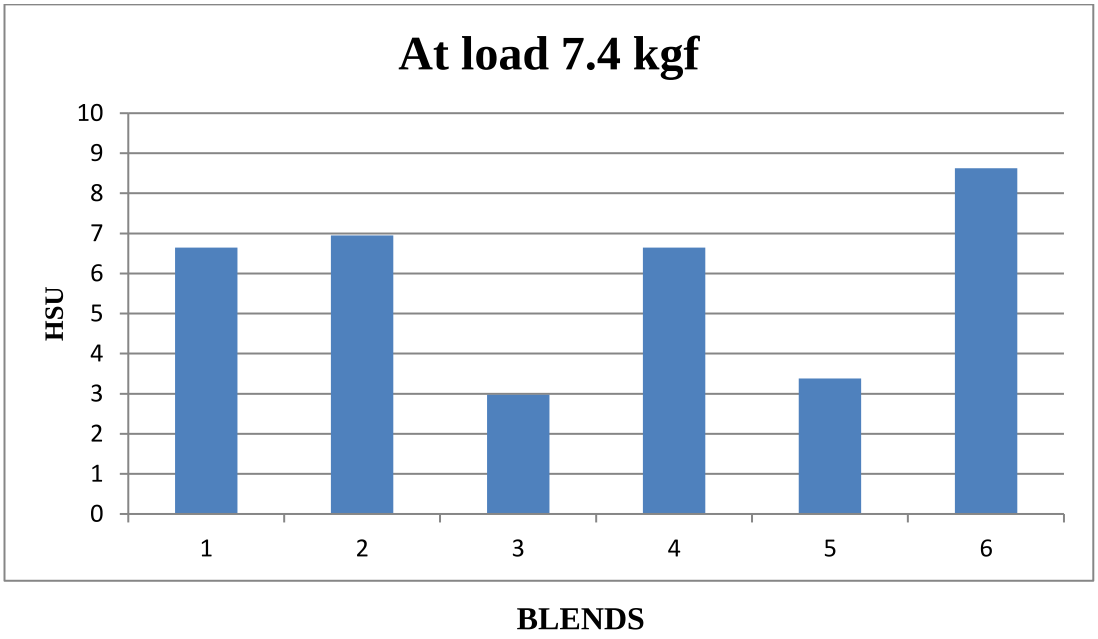


Fig 6.6.1.5 COMPOSITION VS SMOKE INTENSITY (LOAD 7.4 kgf)

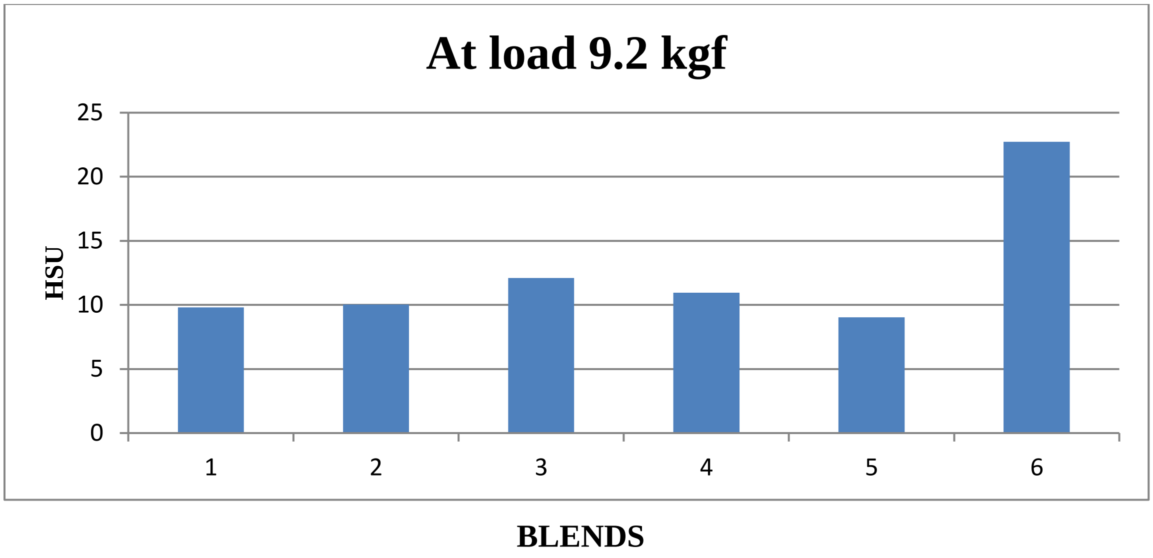


Fig 6.6.1.6 COMPOSTION vs SMOKE INTENSITY (LOAD 9.2 kgf)

Smoke analysis measures the amount of oxygen burnt during combustion process. Higher the H.S.U value, higher the smoke intensity. The graphs are plotted between H.S.U (Hartridge smoke units) and composition (Diesel, B5, B10, B15, B20, and B25). B20 has the least value of H.S.U in each case when compared to other blends.

6.6.2 For different Fuel Blends

The graph showing the variation of Smoke Intensity as a function of Brake power for the different blends is indicated in the following graph.

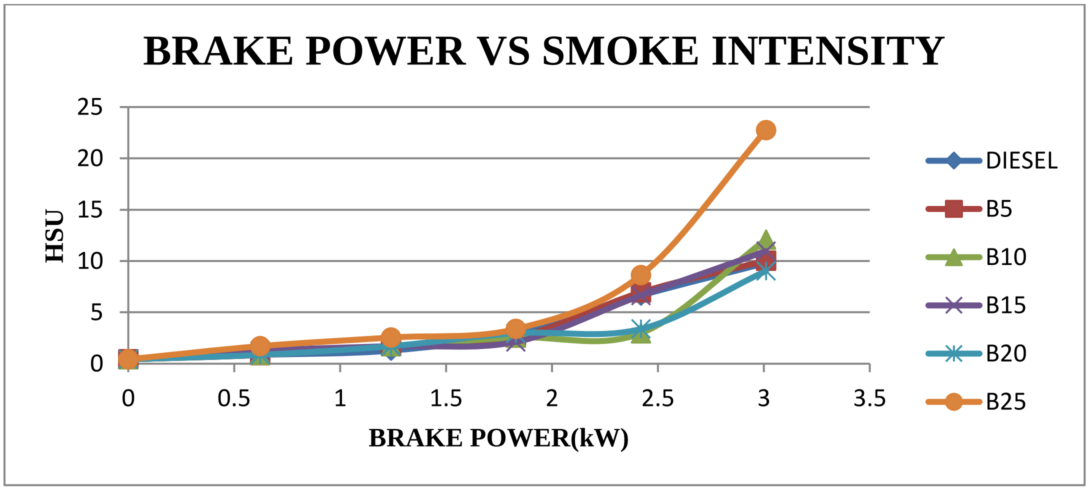


Fig 6.6.2.1 BRAKE POWER vs SMOKE INTENSITY

7 CONCLUSIONS

Biodiesel is produced from palm kernel oil by transesterification process. And an experimental procedure is carried out to evaluate and compare the use of palm kernel oil as a full or partial supplement to conventional diesel fuel in I.C engines.

A four stroke diesel engine under a constant of 1500 r.p.m, running on pure conventional diesel, conventional diesel with certain amounts of biodiesel (5%, 10%, 15%, 20%, 25%) has been tested at different loading conditions. And various performance gauging parameters like mechanical efficiency, thermal efficiencies, specific fuel consumption, mean effective pressure etc. are evaluated. Smoke analysis is carried out to measure smoke intensity values.

Based on the experimental results, the following conclusions are made

- On comparing mechanical efficiencies of different blends at different loads, it was observed that B15 offers the highest mechanical efficiency.
- On comparing the thermal efficiencies at different loads for all blends, it can be deduce that B15 shows the highest thermal efficiency.
- Specific fuel consumption is low for B15 when compared with other blends at different loads.
- B25 and B5 offers maximum indicated power when compared to other blends.
- Based on the values of H.S.U obtained from smoke analysis, B20 is the best among all blends
- Therefore, it can be concluded that B15 blend containing 85% Diesel and 15% palm kernel oil is the best blend.

Scope of Study

The scopes of this research are

1. To study the effect of palm kernel oil as biodiesel in real time application.
2. To study the performance characteristics of palm kernel biodiesel followed by smoke analysis. This idea can be applicable for further research about design modifications in engine and blend proportions of different oils used in different cases.

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