PERFORMANCE CHARACTERISTICS AND EXHAUST ANALYSIS OF FOUR STROKE DIESEL ENGINE USING SUNFLOWER OIL AND PALM OIL AS BIODIESEL

A Project report submitted in partial fulfilment of the requirements for the
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CERTIFICATE

This is to certify that this project report entitled **"PERFORMANCE CHARARCTERISTICS AND EXHAUST ANALYSIS OF FOUR STROKE DIESEL ENGINE USING SUNFLOWER OIL AND PALM OIL AS BIODIESEL"** has been carried out by B.Y. Narayana (314126520026), B. Akshay (314126520011), B. SreeKavya (314126520024), D.Sarath (314126520039), A. Suraj (314126520007) under the esteemed guidance of Ms.M.Amareswari Reddy, in partial fulfillment of the requirements of Degree of Bachelor of Mechnaical 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 internal combustion engines. Many alternative fuels like alcohols, bio-diesel, Liquid Petroleum Gas (LPG), Compressed Natural Gas (CNG), etc. have been already commercialized in the transport sector. In the present work, Waste cooking oil and Soya bean oils are blended with diesel and used as an alternate fuel for CI engines. The Waste cooking oil can be converted into bio diesel using a chemical process called trans-esterification.

Different proportions of fuel blends have been produced by the process of blending. The fuel properties of each blend are determined. The load test along with smoke analysis of 4- Stroke Diesel engine using the blends of waste cooking oil and soya bean oil with diesel are done. The performance parameters such as Power, Specific Fuel Consumption, Thermal Efficiencies, Mechanical Efficiency and Mean Effective Pressures are calculated based on the experimental observations of the engine and compared for different blends. The smoke analysis is simultaneously conducted for different types of blended oils using Hartridge Smoke Meter and the comparative graphs are drawn for Smoke Intensity at different loads. The sustainability of using alternate fuels in Diesel engines, especially the potential use of waste cooking oil and soya bean oil as biodiesel have been brought to the fore through this work.

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1. INTRODUCTION

1.1 Fossil Fuels:

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

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

1.2 Alternative fuels:

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

1.3 Need for Shifting Towards Alternative Fuels:

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

1.4 Biodiesel:

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

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

Biodiesel is produced through a process in which organically derived oils are combined with alcohol (ethanol or methanol) in the presence of a catalyst to form ethyl or methyl ester. The biomass-derived ethyl or methyl esters can be blended with conventional diesel fuel or used as a neat fuel (100% biodiesel). Biodiesel can be made from any vegetable oil, animal fats, waste vegetable oils, or microalgae oils. There are three basic routes to biodiesel production from oils and fats [2]:

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

There are 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. Animal fats including tallow, lard, yellow grease, chicken fat and fish oil by-products may contribute a small percentage to biodiesel production in the future, but it is limited in supply and inefficient to raise animals for their fat. Jatropha is a small pest- and drought resistant shrub that is capable of being grown on marginal/degraded land and produces seeds that yield several times more oil per acre than soybeans.

Biodiesel can be blended in any proportion with mineral diesel to create a biodiesel blend or can be used in its pure form. Just like petroleum diesel, biodiesel operates in the compression ignition (diesel) engine, and essentially requires very little or no engine modifications because the biodiesel has properties similar to mineral diesel. It can be stored just like mineral diesel and hence does not require separate infrastructure.

The use of biodiesel in conventional diesel engines results in substantial reduction in the emission of unburned hydrocarbons, carbon monoxide, and particulates. There are currently a large number of existing biodiesel production plants globally, and a large number under construction or planned to supply the growing global demand.

1.5 Advantages of Biodiesel:

Biodiesel fuel is a renewable energy source unlike petroleum-based diesel. An excessive production of soybeans in the world makes it an economic way to utilize this surplus for manufacturing the Biodiesel fuel.

One of the main biodiesel fuel advantages is that it is less polluting than petroleum diesel.

The lack of sulphur in 100% biodiesel extends the life of catalytic converters.

Another of the advantages of biodiesel fuel is that it can also be blended with other energy resources and oil.

Biodiesel fuel can also be used in existing oil heating systems and diesel engines without making any alterations.

It can also be distributed through existing diesel fuel pumps, which is another biodiesel fuel advantage over other alternative fuels.

The lubricating property of the biodiesel may lengthen the lifetime of engines.

2. LITERATURE REVIEW

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

Chatpalliwarl et al. [3] 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. The contribution of the work is that it discusses the important issues concerned with the Biodiesel production plant design, the fundamental details required for the formulation of Biodiesel plant and also it presents possible approach for the mathematical model to evaluate the Biodiesel plant design.

Hamed M. El-Mashad et al. [4] investigated on Salmon oil, a by-product of salmon processing, was used as a feedstock for biodiesel production via transesterification in a two-step process. It was found that due to the high acid value of salmon oil, alkaline catalysed transesterification was not an effective method for producing biodiesel from the salmon oil. Therefore a two-step process was applied, in which a sulphuric acid-catalysed pre-treatment was used in the first step to reduce the acid value from 12.0 to 3mg and then, in the second step, KOH-catalysed transesterification was applied. Based on the total weight of salmon oil used, the maximum biodiesel yield of 99% was achieved using a total methanol/molar ratio of 9.2% and 0.5% (w/w) KOH. A preliminary economic analysis showed that the cost of biodiesel production from salmon oil was almost twice that produced from soybean oil.

Md. Imran Kais et al. [5] research focused on algae cultivation. A lab scale production of Chlorella and Botroyococcusbraunii was executed in open pond and bioreactor system. Then diesel was produced by transesterification from collectedalgae oil. Later data was collected from this experiment. Cost analysis was prepared to get a clear concept of the actual scenario of algae fuel probability. This study indicates high potentiality of algae based fuel replacing diesel for energy production. It can be a model for any third world country to mitigate the energy crisis with a greener solution.

PiyanuchNakpong et al. [6] investigated the production of biodiesel from three mixtures of vegetable oil and used cooking oil by alkali catalysed transesterification. Three kinds of vegetable oils, including jatropha, roselle and coconut oils were tested. The effect of used cooking oil content in oil feedstock (used cooking oil/vegetable oil ratios of 0.03-0.2 v/v) on methyl ester formation was investigated and optimized. The methyl ester content from each reaction condition was determined by gas chromatography (GC). The optimum used cooking oil/vegetable oil ratio was 0.03 v/v for all three kinds of oil feedstock.

S.L.Sinha and R.K.Yadav [7] investigated, the bio-diesel produced from the Jatropha seeds. It has 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. The experimental data obtained for various concentrations of bio-diesel blends have been compared with base line data of conventional diesel. Significant improvement in engine performance has been observed due to the use of bio-diesel. 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.

Avinash Kumar Agarwal [8] reported the technical feasibility of using straight vegetable oils (Jatropha oil), into a constant speed direct injection compression ignition engine. Vegetable oils have very high viscosity, which make their direct usability in engines questionable. In this investigation, SVO's were preheated by using waste heat from engine exhaust, in order to reduce their viscosity. The effectof using these oils on typical engine problems such as injector coking, piston ring sticking, lube oil dilution etc. was investigated in detail. Long-term endurance test (For a duration of 512 hours) of SVO fuelled engine vis-à-vis mineral diesel fuelled engine was executed and the results are compared.

K. Anbumani and Ajit Pal Singh [9] observed the feasibility of using two edible plant oils mustard and neem as diesel substitute a comparative study on their combustion characteristics on a C.I. engine were made. Oils were esterified (butyl esters) before blending with pure diesel in the ratio of 10:90, 15:85, 20:80, and 25:75 by volume. Pure diesel was used as control. Studies have revealed that on blending vegetable oils with diesel a remarkable improvement in their physical and chemical properties was observed. Cetane number came to be very close to pure diesel. Results have indicated that engine run at 20% blend of oils showed a closer performance to pure diesel. However, mustard oil at 20% blend with diesel gave best performance as compared to neem oil blends in terms of low smoke intensity, emission of HC and NO x. All the parameters tested viz., total fuel consumption, specific energy consumption; specific fuel consumption, brake thermal efficiency and cylindrical peak pressure were improved. These studies have revealed that both the oils at 20% blend with diesel can be used as a diesel substitute.

Jomir Hossain et al. [10] investigated on mustard oil. Properties are determined in the fuel testing laboratory with standard procedure. An experimental set-up is then made to study the performance of a small diesel engine in the heat engine laboratory using different blends of bio-diesel converted from mustard oil. It is also observed that with bio-diesel, the engine is capable of running without difficulty but with a deviation from its optimum performance. 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 engine performance for different blends of bio-diesel has been carried out to determine the optimum blend for different operating conditions.

P.K. Sahoo [11] results on non-edible filtered high viscous and high acid value (44 mg KOH/gm) Polanga oil based mono esters (biodiesel) produced by triple stage transesterification process and blended with high speed diesel (HSD) were tested for their use as a substitute fuel of diesel in a single cylinder diesel engine. The brake specific fuel consumption (BSFC) and brake thermal efficiency (BTE) were calculated from the recorded data. The engine performance parameters such as fuel consumption, thermal efficiency, exhaust gas temperature and exhaust emissions (CO, CO2, HC, NOx, and O2) were recorded. The optimum engine operating condition based on lower brake specific fuel consumption and higher brake thermal efficiency was observed at 100% load for neat biodiesel. From emission point of view the neat POME was found to be the best fuel as it showed lesser exhaust emission as compared to HSD.

G Lakshmi Narayana Rao et al. [12] Trans esterified vegetable oils (biodiesel) are promising alternative fuel for diesel engines. Used vegetable oils are disposed from restaurants in large quantities. But higher viscosity restricts their direct use in diesel engines. In this study, used cooking oil was dehydrated and then Trans esterified using an alkaline catalyst. The combustion, performance and emission characteristics of Used Cooking oil Methyl Ester (UCME) and its blends with diesel oil are analysed in a direct injection C.I. engine. The fuel properties and the combustion characteristics of UCME are found to be similar to those of diesel. A minor decrease in thermal efficiency with significant improvement in reduction of particulates, carbon monoxide and unburnt hydrocarbons is observed compared to diesel. The use of Trans esterified used cooking oil and its blends as fuel for diesel engines will reduce dependence on fossil fuels and also decrease considerably the environmental pollution.

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

2. SYNTHESIS OF BIODIESEL

Biodiesel is the mono-alkyl esters of long-chain fatty acids derived from vegetable oils (palm oil, rapeseed, soybean, etc.) as well as animal fats. Biodiesel synthesized from the triglycerides in vegetable oils by transesterification reaction with alcohol. In this reaction, the oil reacts with an alcohol in a number of consecutive, reversible steps to form esters and glycerol.

The CPO stock (10 L divided into two containers) was preheated using hot-bath with a fixed temperature (between 60-80°C) until the CPO contents were in a semi-transparent, dark brown, viscosed liquid form, the contents after that was mixed homogonously. After that, the oil was distributed into smaller containers with suitable size (500 mL conical flask. The CPO was stored at 4°C. The alkali catalyst-methanol solution was prepared with the certain concentrations required by the specific run and then the fixed amount of heated CPO was added to the contents. The solution then was mixed with the desired temperature and agitation speed to start the transesterification reaction inside the incubator shaker (Infors HT, Ecotron). After the specific duration of the reaction finished, heating and agitation were stopped and the reaction's product was allow to settle over night (for ensuring result it can be left for 2 days). The reaction's result was two distinct liquid phases; the first was the Palm Oil Methyl Ester (POME) or the biodiesel on the top and the second was the denser phase of glycerol. Methyl ester phase was apply to a separation process (for better results the methyl ester was pipette from the top) and showered by cold or warm deionized water several times until becomes clean. Excess methanol and water in methyl ester was removed by an evaporation process under atmospheric pressure conditions. Finally, the dried biodiesel was weighted for yield calculations and the ester contents were analyzed for evaluation of product purity.

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

Edible vegetable oils such as canola, soybean, sunflower, palm and corn have been used for biodiesel production and are proven diesel substitutes. Reducing the cost of the feedstock is necessary for biodiesel's long- term commercial viability. One way to reduce the cost of this fuel is to use less expensive feedstocks including waste cooking oils and vegetable oils that are non-edible and/or require low harvesting costs. Crude sunflower Oil and Palm oil, which is much less expensive than edible vegetable oil, is a promising alternative to edible vegetable oil. Waste cooking oil and fats set forth significant disposal problems in many parts of the world. This environmentally threatening problem could be turned into both economic and environmental benefit by proper utilization and management of waste cooking oil as a fuel substitute. Waste cooking oil, as an alternative feedstock for biodiesel, was studied with different aspects such as optimization using supercritical methanol (SCM) transesterification, process design and technological assessment, fuel property analysis and cost estimation approaches. Since biodiesel is made up of esters derived from oils and fats from renewable biological sources, it has been reported to emit far less regulated pollutants than petroleum diesel fuel [13].

3.1 Palm And Sunflower Oil as a Biodiesel:

Biodiesel is an alternative diesel fuel derived from vegetable oils or animal fats. The main components of vegetable oils and animal fats are triglycerides or also known as ester of fatty acid attached to glycerol. One of the main driving force for biodiesel widespread is the greenhouse gas emission (CO2 being the major one).

The term Sunflower Oil refers to vegetable oil has been in food production. Any fatty acid sources may be used to produce biodiesel. Therefore, any animal or plant lipid should be ready substrate for the production of biodiesel. The use of edible vegetable oils and animal fats for biodiesel production has recently been of great concern because they compete with food material the food versus fuel dispute. There is a concern that biodiesel feedstock may compete with food supply in the long term.

From an economic point of view the production of biodiesel is very feedstock sensitive. The cost of feedstock accounted for 88% of total estimated production cost. In all cases, more than 80% of the production cost is associated with the feedstock, such as recycled cooking oils. Reusing of these waste greases not only reduce the burden of the government in disposing the waste, maintaining public sewers, and treating the oily wastewater, but also lower the production cost of biodiesel significantly.

The primary feedstock is a vegetable oil or animal fat, biodiesel is generally considered to be renewable. Since the carbon in the oil or fat originated mostly from carbon dioxide in the air, biodiesel is considered to contribute much less to global warming than fossil fuels. Diesel engines operated on biodiesel have lower emissions of carbon monoxide, unburned hydrocarbons, particulate matter, and air toxics than when operated on petroleum-based diesel fuel. Sunflower oil is one of the alternatives for biodiesel process.

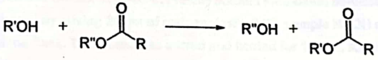
Biodiesel from Sunflower Oil can reduce the cost of biodiesel production since the feedstock costs constitutes approximately 70-95% of the overall cost of biodiesel production.

Although biodiesel cannot entirely replace petroleum-based diesel fuel, there are at least five reasons that justify its development.

- It provides a market for excess production of vegetable oils and animal fats.
- It decreases, although will not eliminate, the country's dependence on imported petroleum.
- Biodiesel is renewable and does not contribute to global warming due to its closed carbon cycle. A life cycle analysis of biodiesel showed that overall CO2 emissions were reduced by 78% compared with petroleum-based diesel fuel.

3.2 Transesterification Reaction:

Transesterification is the process of exchanging the organic group R" of an ester with the organic group R' of an alcohol. These reactions are often catalyzed by the addition of an acid or base catalyst.[1] The reaction can also be accomplished with the help of enzymes (biocatalysts) particularly lipases.



Transesterification: alcohol + ester → different alcohol + different ester

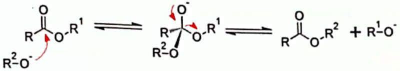
Strong acids catalyse the reaction by donating a proton to the carbonyl group, thus making it a more potent electrophile, whereas bases catalyse the reaction by removing a proton from the alcohol, thus making it more nucleophilic. Esters with larger alkoxy groups can be made from methyl or ethyl esters in high purity by heating the mixture of ester, acid/base, and large alcohol and evaporating the small alcohol to drive equilibrium.Thetransesterification process was widely used in bio-diesel production from different biomass materials. The process consists of two steps namely, acid esterification and alkali transesterification.

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

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

Mechanism

In the transesterification mechanism, the carbonyl carbon of the starting ester ($RCOOR^1$) undergoes nucleophilic attack by the incoming alkoxide (R^2O^-) to give a tetrahedral intermediate, which either reverts to the starting material, or proceeds to the transesterified product ($RCOOR^2$). The various species exist in equilibrium, and the product distribution depends on the relative energies of the reactant and product.



A 100gm of a sample oil is weighted and place on a hot plate in around bottom flash equipped with a magnetic stirrer and thermometer. The oil was stirred and heated at 60-65 C. Freshly sodium methoxide solution was prepared by mixing 25 gm of methanol with 0.5% sample NAOH and added into the flask. The mixed was stirred and heated for 1 hour. After the time the flask was removed from hot plate and the products of reaction were allowed to settle for a several hours to produce a distinct liquid phase.

The top phase that is crued ester was separated from bottom phase glycerol by decantation then washed for 3 times by warm water and heated 80 c

To remove the excess catalyst until the wash water become clear. The final product bio diesel was obtained as a clear light yellow liquid .

Temperature is not above the boiling point of methanol or else a violent eruption can take place when we mix the reaction

$$\text{100gm palm oil+25gm methanol} \xrightarrow{\text{0.5\%NAOH}} \text{100gm biodiesel+25gm glycerol}$$

MASS BALANCE:

$$\text{100gm palm oil+25gm methanol} \xrightarrow{\text{0.5\%NAOH}} \text{92.2gm bio diesel +15.3gm glycerol}$$

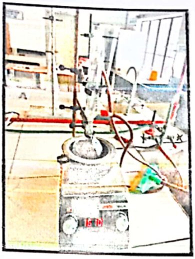


Fig 3.1: Trans-Esterification Process

3.3 Draining of Glycerol:

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

Fig 3.2: Separation of Glycerol and Esters

The Methyl esters thus obtained from the trans-esterification of waste cooking oil are mixed with Soya Bean which is referred as Biodiesel in this work. This Biodiesel is mixed with petroleum Diesel by the process of Blending with varying proportions to obtain various fuel blends.

4. EXPERIMENTAL SETUP

In this chapter, the experimental setup used to carry on the Performance Analysis and Smoke Analysis are briefly described as follows:

4.1 Diesel Engine:

A diesel engine, also known as a compression-ignition engine, is an internal combustion engine that uses the heat of compression to initiate ignition of 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 a German inventor Rudolf Diesel in 1893 [15].

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. 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%.

The diesel internal combustion engine differs from the gasoline powered Otto cycle by using highly compressed hot air to ignite the fuel rather than using a spark plug (compression ignition rather than spark ignition).

In the true diesel engine, only air is initially introduced into the combustion chamber. The air is then compressed with a compression ratio typically between 15:1 and 23:1. This high compression causes the temperature of the air to rise. At about the top of the compression stroke, fuel is injected directly into the compressed air in the combustion chamber. This may be into a (typically toroidal) void in the top of the piston or a pre-chamber depending upon the design of the engine. The fuel injector ensures that the fuel is broken down into small droplets, and that the fuel is distributed evenly. The heat of the compressed air vaporizes fuel from the surface of the droplets. The vapour is then ignited by the heat from the compressed air in the combustion chamber, the droplets continue to vaporize from their surfaces and burn, getting smaller, until all the fuel in the droplets has been burnt. Combustion occurs at a substantially constant pressure during the initial part of the power stroke. The start of vaporization causes a delay before ignition and the characteristic diesel knocking sound as the vapor reaches ignition temperature and causes an abrupt increase in pressure above the piston (not shown on the P-V indicator diagram). When combustion is complete the combustion gases expand as the piston descends further; the high pressure in the cylinder drives the piston downward, supplying power to the crankshaft.

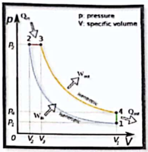


Fig 4.1: Diesel cycle

The p–V diagram shown in Fig 4.1 is a simplified and idealized representation of the events involved in a Diesel engine cycle, arranged to illustrate the similarity with a Carnot cycle. Starting at 1, the piston is at bottom dead center and both valves are closed at the start of the compression stroke; the cylinder contains air at atmospheric pressure. Between 1 and 2 the air is compressed adiabatically that is without heat transfer to or from the environment by the rising piston. During this compression, the volume is reduced, the pressure and temperature both rise. At or slightly before 2 fuel is injected and burns in the compressedhot air. Chemical energy is released and this constitutes an injection of thermal energy (heat) into the compressed gas. Combustion and heating occur between 2 and 3.

In this interval the pressure remains constant since the piston descends, and the volume increases; the temperature rises as a consequence of the energy of combustion. At 3 fuel injection and combustion are complete, and the cylinder contains gas at a higher temperature than at 2. Between 3 and 4 this hot gas expands, again approximately adiabatically. Work is done on the system to which the engine is connected. During this expansion phase the volume of the gas rises, and its temperature and pressure both fall. At 4 the exhaust valve opens, and the pressure falls abruptly to atmospheric

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. Provision is made to measure the exhaust heat with the help of a exhaust gas calorimeter and thermocouples fixed at salient points. 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 is shown in Fig 4.2.

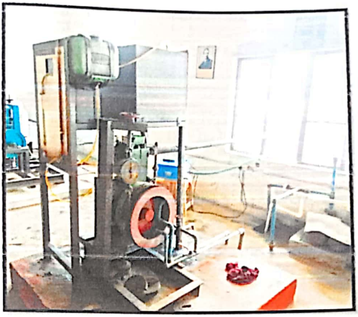


Fig 4.2: Four Stroke, Single Cylinder, Vertical Diesel Engine

Table 4.1: Specifications of Diesel Engine

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

4.3 Viscometer:

A viscometer (also called viscometer) is an instrument used to measure the viscosity of a fluid. For liquids with viscosities which vary with flow conditions, an instrument called a rheometer is used. Viscometers only measure under one flow condition. The Fig 4.3 shows a viscometer and its working principle.

At 20.00 degrees Celsius the viscosity of water is 1.002mPa and its kinematic viscosity (ratio of viscosity to density) is 1.0038 mm2/s. These values are used for calibrating certain types of viscometer. Redwood Viscometer determines the viscosity in terms of seconds that uniformly heated oil passes through a standard orifice and collected in flask of 50 cc capacity.

Redwood Viscometer are of two types:

1. **Redwood Viscometer No. 1 (For fluid having viscosity corresponds to Redwood seconds less than 2000)**
2. **Redwood Viscometer No. 2 (For fluid having viscosity corresponds to Redwood seconds greater than 2000)**

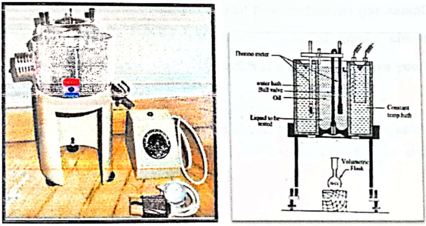


Fig 4.3: Viscometer Apparatus

4.4 Smoke Meter:

Diesel Exhaust Smoke meters, also referred to as opacity meters, detect and measure the amount of light blocked in a sample of smoke emitted by diesel engines from cars, trucks, ships, buses, motorcycles, locomotives and large stacks from industrial operations. The smoke meter readout displays the smoke density giving a measure of the efficiency of combustion. This makes the smoke meter an excellent diagnostic tool to ensure proper maintenance of diesel engines for improved fuel economy and protection of the environment.

The opacity meter consists of an optical unit mounted inside a measuring head and a separate electronic control unit. The measurement principle is based on light extinction detection. The collimated beam from the light-source (SLED) is absorbed and scattered by the particulate exhaust emissions. A photodiode determines the light intensity of the attenuated beam and the corresponding opacity value is transmitted to a separate remote display as shown in Fig 4.4. Partial flow continuous gas sampling combined with a heated and temperature controlled smoke chamber compensates for changes in pressure and test conditions to give you the most accurate readings possible.

All modern Diesel Exhaust Smoke Meters should measure diesel emissions characteristics (dark smoke) in Opacity (HSU- Hartridge Smoke Units) and/or Smoke Density (K) as shown in Fig4.5[16].

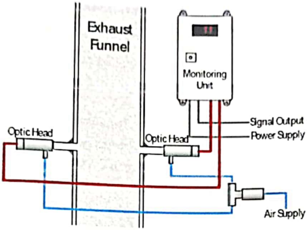


Fig 4.4: Principle of Smoke Meter

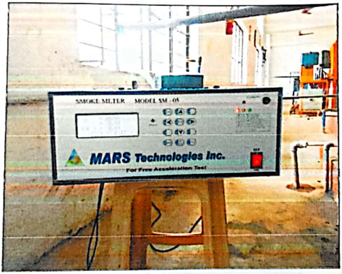


Fig 4.5: Smoke Meter

5. EXPERIMENTAL PROCEDURE

In this chapter, the procedure followed for the preparation of Biodiesel blends, determining the properties of fuel blends, load test and smoke analysis are described as following:

5.1 Blending:

It is the main process involved for preparation of biodiesels by using as a magnetic stirrer as shown in Fig 5.1. It is nothing but mixing of oil in certain proportions to obtain the required properties.

This process involves:

a. Taking proportions of Biodiesel.
b. Mixing Biodiesel with Petroleum Diesel in the mixer.

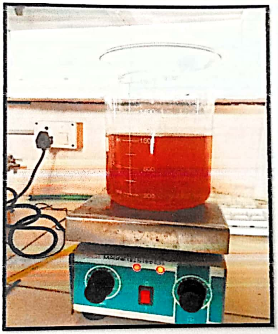


Fig 5.1: Blending of Oils using Magnetic Stirrer

5.2 Blending of Oils:

In the general terminology to indicate the composition of Biodiesel is 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 1000 mL each as shown in table 5.1.

Table 5.1: Oil Proportion in Fuel Blends

Label	Diesel (mL)	WCO (mL)	Soya Bean Oil (mL)
B 10	900	50	50
B 15	850	100	50
B 20	800	150	50
B 25	750	200	50
B 30	700	250	50

5.3 Properties of Oil Blends:

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

Table 5.2: Properties of Oil Blends

	B10	B15	B20	B25	B30
Flash point (°C)	55	57	58	60	61
Fire point (°C)	60	61	62	62	64
Viscosity(centi poise)	0.00185	0.00365	0.01062	0.01676	0.02078
Specific Gravity (gm/cc)	0.82	0.82	0.82	0.82	0.82
Calorific value (kJ/kg)	44090.6	43677.4	43268.7	42864.4	42464.4

5.4 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. RESULTS AND DISCUSSION

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

6.1 Basic Data for Calculations:

1. Rated brake power of engine B.P = 5 H.P = 3.7KW
2. Speed of engine N = 1500rpm
3. Effective radius of the brake drum R = 0.213 m
4. Stroke length L =110×10 m
5. Diameter of cylinder bore D = 80×10 m
6. Time taken for 10cc consumption of fuel is 't' sec

6.2 Basic Formulae for Calculations:

Maximum load = $\frac{Rated\ B.P\times 60000}{2\pi RN\times 9.81}$

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

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

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

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

Break thermal efficiency ηBth = $\frac{B.P\times 3}{FC\times CV}$

Indicated thermal efficiency $\eta_{th} = \frac{I.P \times 3600}{F.C \times C.V}$

Mechanical efficiency $\eta_{mech} = \frac{B.P}{I.P} D^2$

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

Break mean effective pressure (BMEP) = $\frac{B.P \times 600}{L \times \frac{\pi}{4} D^2 \times \frac{N}{2}} N/m^2$

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.

6.3 Model Calculations:

B10 blend at 1.3 kgfload :

Specific gravity is 0.82 gm/cc

Calorific value is 44090.6 kj/kg

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

$= \frac{2\pi\times 1500\times 1.3\times 9.81\times 0.213}{60000}$

= 0.4264 kW

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

$= \frac{10}{64}\times\frac{0.82\times 3600}{1000}\ kg/hr$

= 0.476 kg/hr

Frictional power from graph (F.P) = 2.605 kW

Indicated power (I.P) = B.P + F.P = 0.426 + 2.605

= 3.031 kW

Where F.P is the Frictional power obtained from the graph draw between brake power and fuel consumption

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

$= \frac{0.476}{0.426}$

= 1.116 kg/kW.hr

Brake thermal efficiency $\eta^{Bth} = \frac{B.P \times 360}{F.C \times C.V}$

$= \frac{0.426 \times 3600}{0.476 \times 44090.6}$

= 7.313 %

Indicated thermal efficiency $\eta^{Ith} = \frac{I.P \times 360}{F.C \times C.V}$

$= \frac{3.031 \times 3600}{0.476 \times 44090.6}$

= 51.986 %

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

$= \frac{0.426}{3.031}$

= 14.068 %

Indicated mean efficiency pressure (I.M.E.P) $= \frac{I.P \times 60000}{L \times \frac{\pi}{4} D^2 \times \frac{N}{2}}$ **N/m²**

$= \frac{3.031 \times 60000}{110 \times 10^{-3} \times \frac{\pi}{4} (80 \times 10^{-3})^2 \times \frac{1500}{2}}$

= 438400 N/m²

= 4.384 bar

Break mean effective pressure (B.M.E.P) $= \frac{B.P \times 60000}{L \times \frac{\pi}{4} D^2 \times \frac{N}{2}}$ **N/m²**

$= \frac{0.426 \times 60000}{110 \times 10^{-3} \times \frac{\pi}{4} (80 \times 10^{-3})^2 \times \frac{1500}{2}}$

= 616700 N/m²

= 6.167 bar

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.

		B10	FP	2.2						
W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{ith}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	112	0.2655	0.0000	2.2000	-	0.00%	66.36%	0.00%	318.1818	0.0000
1.9	65	0.4575	0.6239	2.8239	0.7334	10.92%	49.43%	22.09%	408.4115	90.2297
3.8	60	0.4957	1.2477	3.4477	0.3972	20.16%	55.71%	36.19%	498.6412	180.4594
5.6	51	0.5831	1.8388	4.0388	0.3171	25.26%	55.47%	45.53%	584.1220	265.9402
7.4	45	0.6609	2.4298	4.6298	0.2720	29.45%	56.11%	52.48%	669.6028	351.4210
9.2	40	0.7435	3.0209	5.2209	0.2461	32.54%	56.24%	57.86%	755.0835	436.9017

		B15	FP	2.35						
W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{ith}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	87	0.3418	0.0000	2.3500	-	0.00%	55.06%	0.00%	339.8760	0.0000
1.9	71	0.4189	0.6239	2.9739	0.6714	11.93%	56.86%	20.98%	430.1057	90.2297
3.8	63	0.4721	1.2477	3.5977	0.3783	21.17%	61.04%	34.68%	520.3354	180.4594
5.6	51	0.5831	1.8388	4.1888	0.3171	25.26%	57.53%	43.90%	605.8162	265.9402
7.4	43	0.6916	2.4298	4.7798	0.2846	28.14%	55.35%	50.84%	691.2970	351.4210
9.2	38	0.7826	3.0209	5.3709	0.2591	30.92%	54.96%	56.25%	776.7778	436.9017

		B20	FP	0.6						
W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{ith}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	80	0.3717	0.0000	0.6000	-	0.00%	12.93%	0.00%	86.7769	0.0000
1.9	70	0.4249	0.6239	1.2239	0.6810	11.76%	23.07%	50.98%	177.0066	90.2297
3.8	58	0.5128	1.2477	1.8477	0.4109	19.49%	28.86%	67.53%	267.2363	180.4594
5.6	50	0.5948	1.8388	2.4388	0.3235	24.76%	32.84%	75.40%	352.7170	265.9402
7.4	43	0.6916	2.4298	3.0298	0.2846	28.14%	35.09%	80.20%	438.1978	351.4210
9.2	35	0.8497	3.0209	3.6209	0.2813	28.47%	34.13%	83.43%	523.6786	436.9017

		B25	FP	1.5						
W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{lth}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	71	0.4189	0.0000	1.5000	-	0.00%	28.68%	0.00%	216.9421	0.0000
1.9	63	0.4721	0.6239	2.1239	0.7567	10.59%	36.04%	29.37%	307.1719	90.2297
3.8	55	0.5407	1.2477	2.7477	0.4334	18.48%	40.70%	45.41%	397.4016	180.4594
5.6	48	0.6196	1.8388	3.3388	0.3369	23.77%	43.16%	55.07%	482.8823	265.9402
7.4	43	0.6916	2.4298	3.9298	0.2846	28.14%	45.51%	61.83%	568.3631	351.4210
9.2	38	0.7826	3.0209	4.5209	0.2591	30.92%	46.27%	66.82%	653.8439	436.9017

		B30	FP	1.2						
W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{ith}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	88	0.3380	0.0000	1.2000	-	0.00%	28.44%	0.00%	173.5537	0.0000
1.9	69	0.4310	0.6239	1.8239	0.6909	11.59%	33.89%	34.21%	263.7834	90.2297
3.8	57	0.5217	1.2477	2.4477	0.4182	19.15%	37.57%	50.98%	354.0131	180.4594
5.6	53	0.5611	1.8388	3.0388	0.3052	26.25%	43.37%	60.51%	439.4939	265.9402
7.4	43	0.6916	2.4298	3.6298	0.2846	28.14%	42.04%	66.94%	524.9747	351.4210
9.2	38	0.7826	3.0209	4.2209	0.2591	30.92%	43.20%	71.57%	610.4554	436.9017

D100 FP 1.2

W-S (kgf)	t (sec)	FC (kg/hr)	BP (kW)	IP (kW)	SFC (kg/kWhr)	η_{bth}	η_{ith}	η_{mech}	IMEP (kN/m2)	BMEP (kN/m2)
0	76	0.3913	0.0000	1.2000	-	0.00%	24.56%	0.00%	173.5537	0.0000
1.9	64	0.4647	0.6239	1.8239	0.7448	10.75%	31.44%	34.21%	263.7834	90.2297
3.8	56	0.5311	1.2477	2.4477	0.4256	18.82%	36.92%	50.98%	354.0131	180.4594
5.6	48	0.6196	1.8388	3.0388	0.3369	23.77%	39.28%	60.51%	439.4939	265.9402
7.4	42	0.7081	2.4298	3.6298	0.2914	27.48%	41.06%	66.94%	524.9747	351.4210
9.2	37	0.8038	3.0209	4.2209	0.2661	30.10%	42.06%	71.57%	610.4554	436.9017

The Frictional Power in case of each blend is determined through the Willians's Line Method as described earlier. The Willian Line for each blend is obtained from the graphs shown in Figs 6.2, 6.3, 6.4, 6.5 and 6.6 for Diesel, B15, B20, B25 and B30 respectively.

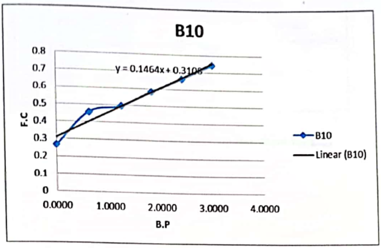


Fig 6.1: Brake Power vs. Fuel Consumption for B10

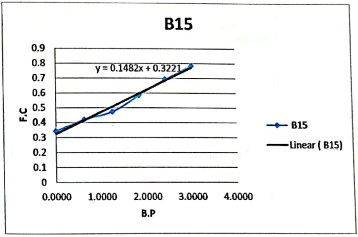


Fig 6.2: Brake Power vs. Fuel Consumption for B15

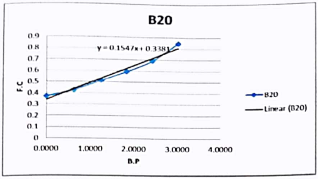


Fig 6.3: Brake Power vs. Fuel Consumption for B20

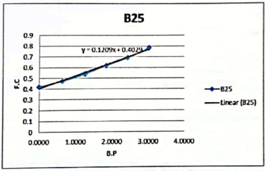


Fig 6.4: Brake Power vs. Fuel Consumption for B25

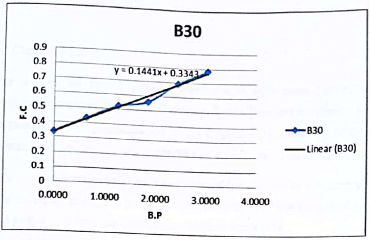


Fig 6.5: Brake Power vs. Fuel Consumption for B30

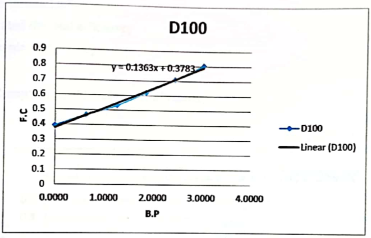


Fig 6.6: Brake Power vs. Fuel Consumption for D100

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

For Diesel, F.P. = 2.596 KW

For B10, F.P. = 2.605 KW

For B15, F.P. = 2.448 KW

For B20, F.P. = 2.984 KW

For B25, F.P. = 2.442 KW

For B30, F.P. = 2.239 KW

6.4 Performance Characteristics:

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

Engine performance is an indication of the degree of success with which it is doing its assigned job, i.e., the conversion of the chemical energy contained in the fuel into the useful mechanical work [17]. The degree of success is compared on the basis of the following

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

6.4.1 Comparison of Mechanical Efficiency:

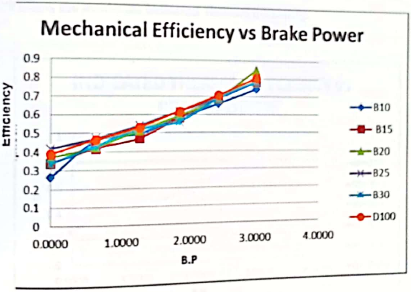


Fig 6.7: Brake power Vs Mechanical efficiency

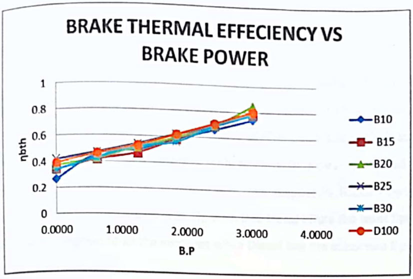


Fig 6.8: Brake power Vs Brake Thermal Efficiency

6.4.3 Comparison of Indicated Thermal Efficiency:

The values of Indicated Thermal Efficiency at different brake powers are plotted as shown in Fig 6.9. B20 blend offers the maximum Indicated Thermal Efficiency of all the mixtures and it seems to be the best mixture, while B20 offers the maximum Indicated Thermal Efficiency.

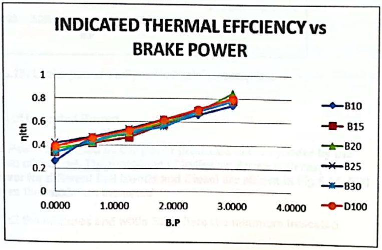


Fig 6.9: Brake power Vs Indicated Thermal Efficiency

6.4.4 Comparison of Specific Fuel Consumption:

Specific Fuel Consumption is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft, power. It is typically used for comparing the efficiency of IC engines with a shaft output. It is a rate of Fuel consumption with respect to power produced. The variations of Specific Fuel consumption with respect to Brake Power for different fuel blends as shown in Fig 6.10. B30 blend offers the least Specific Fuel Consumption of all the mixtures while Diesel has the maximum Specific Fuel Consumption.

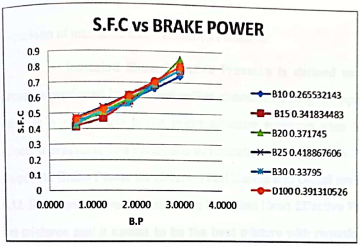


Fig 6.10: Brake power Vs Specific Fuel Consumption

6.4.5 Comparison of Indicated Power:

Indicated Power is defined as the power produced in the cylinder by the combustion of the fuel. The variations of Indicated Power with respect to Brake Power for different fuel blends and Diesel are shown in Fig 6.11. B20 blend offers the maximum Indicated

Power of all the mixtures and while B30 offers the minimum Indicated Power.

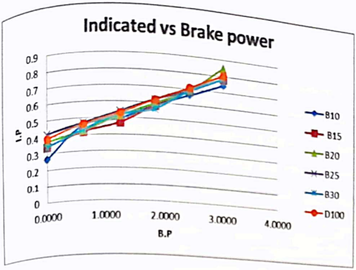


Fig 6.11: Brake power Vs Indicated Power

6.4.6 Comparison of Indicated Mean Effective Pressure:

Indicated Mean Effective Pressure is defined as the average pressure produced in the combustion chambers during the operating cycle. IMEP is equal to the brake mean effective pressure plus friction mean effective pressure. The variations of Indicated Mean Effective Pressure with respect to Brake Power for different fuel blends and Diesel are shown in Fig 6.12. B30 blend offers the minimum Indicated Mean Effective Pressure of all the mixtures and it seems to be the best mixture with regards to minimum Frictional Power while B20 offers the maximum Indicated Mean Effective Pressure.

Mechanical efficiency indicates how good an engine is inverting the indicated power to useful power. The values of Mechanical Efficiency at different Brake Powers are plotted as shown in Fig 6.7. B30 blend offers the best Mechanical Efficiency of all the mixtures and therefore seems to be the best mixture with regards to the minimum Frictional Power. B20 blend gives the least Mechanical Efficiency.

6.4.2 Comparison of Brake Thermal Efficiency:

Brake Thermal Efficiency is defined as Brake Power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. The values of Brake Thermal Efficiency at different brake powers are plotted as shown in Fig 6.8. B20 blend offers the maximum Brake Thermal Efficiency of all the mixtures and B10 offers the least Brake Thermal Efficiency.

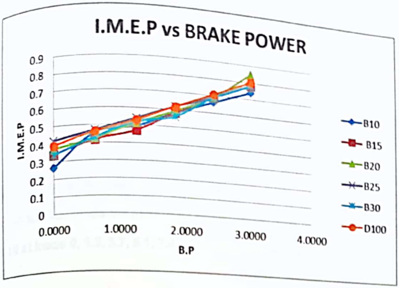


Fig 6.12: Brake power Vs Indicated Mean Effective Pressure

6.5 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, which allows no light to pass through [18].

6.5.1 At constant load:

The graphs indicating the Smoke intensity in terms of Hartridge Smoke Units for each fuel blend including pure diesel at various experimental loads are plotted as shown in Fig 6.14, 6.15 6.16, 6.17, 6.18 and 6.19 at loads 0, 1.3, 3.7, 5.1, 7.4 and 9.2 kgf respectively.

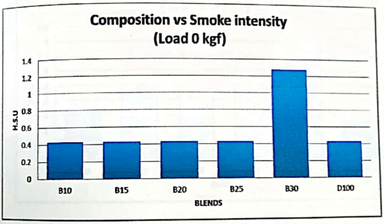


Fig 6.14: Composition vs. Smoke Intensity (Load 0 kgf)

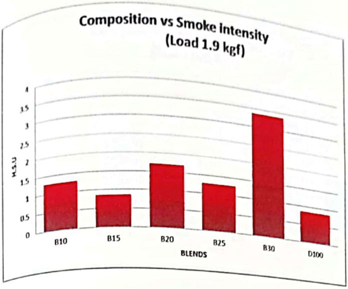


Fig 6.15: Composition vs. Smoke Intensity (Load 1.9 kgf)

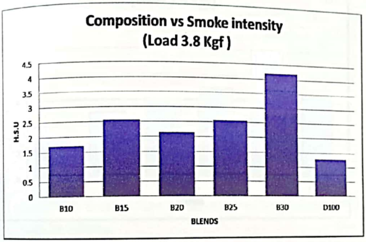


Fig 6.16: Composition vs. Smoke Intensity (Load 3.8 kgf)

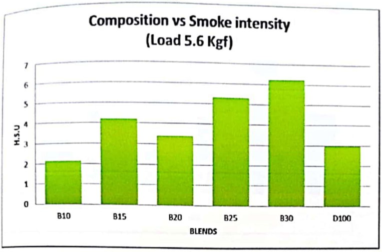


Fig 6.17: Composition vs. Smoke Intensity (Load 5.6 kgf)

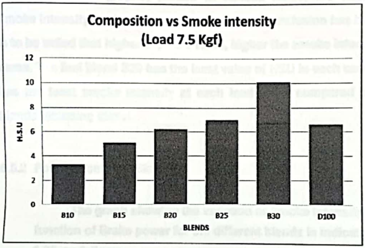


Fig 6.18: Composition vs. Smoke Intensity (Load 7.5 kgf)

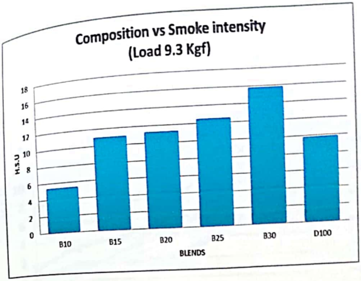


Fig 6.19: Composition vs. Smoke Intensity (Load 9.3 kgf)

From the graphs, plotted at various loads, the variation of the Smoke Intensity is observed and the following conclusion has been drawn. It is to be noted that higher the HSU value, higher the smoke intensity and vice versa. The fuel blend B20 has the least value of HSU in each case. Thus, B20 has the least smoke intensity at each load when compared to other fuel blends including diesel.

6.5.2 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 Fig. 6.20. as follows.

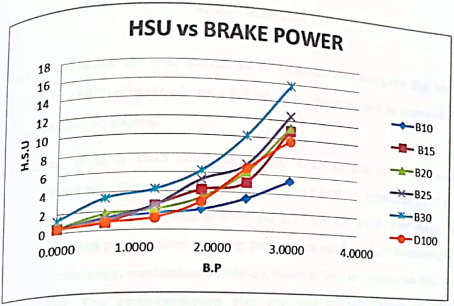


Fig 6.20: Brake Power vs. Smoke Intensity

6. CONCLUSIONS

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

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

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

Comparing the mechanical efficiencies at different loads for all blends, it can be inferred that B30 offers the highest mechanical efficiency.

Comparing the specific fuel consumption for each particular blend, it was observed that B20 has least specific fuel consumption for shaft output greater than 1kW. For output less than 1kW, B15 seems to be the best blend.

The different blends were also evaluated for the thermal efficiencies and it was observed that B20 is best mixture for brake output greater than 1kW and for power less than 1kW, B15 is the best.

B20 composition is the best among all blends in terms of the intensity of smoke. This conclusion is drawn based on the values of HSU obtained from the smoke analysis. It can therefore be concluded that the usage of oxygen in the air and the effectiveness of combustion is best for this blend.

It can therefore be concluded that B20 blend containing 80% diesel, 15% palm oil and 5% sunflower oil is the best blend.

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