INVESTIGATION ON PERFORMANCE CHARACTERISTICS OF DIESEL ENGINES USING PALM OIL BIODIESEL AND ITS BLENDS

Abstract

Internal combustion engine alternative fuels were discovered as a result of rising energy demand, stricter emission regulations, and the depletion of oil reserves. Many alternative fuels, have already achieved widespread commercialization in the transportation industry. Palm oil is combined with diesel in the current work and utilised as an alternative fuel for CI engines. Using a chemical procedure known as trans-esterification, palm oil can be transformed into bio diesel. Blending has resulted in the creation of fuel blends with various ratios. Each mix is evaluated for its fuel qualities. When employing diesel and palm oil blends in 4-stroke diesel engines, load test analysis is completed. The engine's performance metrics are estimated based on experimental observations of the engine and are then contrasted for various mixes. This investigation has highlighted the viability of employing alternative fuels in diesel engines, particularly the potential usage of palm oil as biodiesel.

Keywords: Alternative fuels, Biodiesels, Trans-esterification, and Efficiencies.

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I. INTRODUCTION

The manufacture of biodiesel on the international market is thought to be more diverse by using palm oil as a substitute and promising feedstock. A mixture of monoalkyl esters of biodegradable long chain fatty acids is what is known as biodiesel. It is harmless, renewable, and contains only trace quantities of sulphur[1]. Oil palm plantations have recently come under fire for their alleged role in a number of significant environmental problems. Luckily, numerous studies and scientific conclusions revealed that all the claims are without merit. It can produce a lot of oil with a small amount of land. In essence, fossil fuels are the storage spaces for energy that has been gathered over millions of years and transformed into a concentrated form. Petroleum, often known as crude oil, coal, and natural gas are the three basic types of fossil fuels [2]. Despite having numerous uses, each has a single primary objective. Around 82 percent of the primary energy used in the world in 2011 came from fossil fuels; however, by 2040, this percentage is predicted to drop to 78 percent due to the usage of alternative fuels[3]. The sector of transportation, unavoidably, contributes the most to the increase in petroleum use, which is closely tied to negative environmental effects. 60% of all fossil fuel usage worldwide is accounted for by the transportation sector, which subsequently fuels the environment's severe pollution problems[4,5].Any materials that can be used as fuels along with traditional fuels are considered alternative fuels, also referred to as advanced fuels or non-conventional fuels. Biodiesel, bioethanol (butanol, ethanol, and methanol), hydrogen, propane, oil made from used tyres and plastic, and other sources of biomass are a few well-known alternative fuels. The use of biodiesel as an alternative fuel for diesel engines has enormous potential. However, the use of biodiesel in engines is constrained by its poor low-temperature flow characteristics and high viscosity. As a result, experts view alcohol as a suitable ingredient for diesel-biodiesel (DB) mixtures[6,7].Compared to diesel, these fuels are cost-effective. Therefore, these are most suited for autos and can accommodate the future increase in fuel demand. For use in current internal combustion engines, bioethanol (for Otto engines) and biodiesel have been determined to be the biofuels that are best suited for utilisation (for diesel engines).Planting energy crops with high yield and photosynthetic efficiency on a big scale is necessary to supply these fuels[8].

Biodiesel is a domestically produced, clean-burning alternative fuel. The popular oils used to make biodiesel are palm, soybean, and rapeseed oils, which account for the majority of the fuel's production globally. Other sources of feedstock include used vegetable oil, sunflower, Jatropha, flax, Canola, mustard, palm, neem, and hemp oils[9,10,11]. Even though the supply of animal fats, such as tallow, chicken fat, lard, yellow grease, fish oil by-products, is constrained and inefficient, they may one day make up a small portion of the biodiesel produced today[12]. Fatty acid alkyl esters from vegetable oils, animal fats, or recycled greases are combined to create the fuel. Typically, a homogeneous alkaline catalyst is used in a transesterification reaction to make biodiesel. This method has a number of benefits, including a quick reaction time, high conversion, and minimal catalyst use[13]. Traditional catalysts used in natural oil transesterification procedures include alkaline or alkoxides. However, process can also be done using catalysts, such as magnesium, titanium alcoholates, zinc or oxides of tin, or utilising acid catalysts, such as hydrochloric, sulfuric, and sulfonic acid. After the methanolysis step, all of these catalysts must be eliminated from the products because they all function as homogenous catalysts.

Due to palm oil's lower price compared to other vegetable oils, palm biodiesel is particularly competitive. It has a greater flash point than diesel. It is non-toxic, renewable, biodegradable[14,15,16].According to numerous studies, using palm ethyl ester blends reduces NOx emissions and researchers found this by taking selected blends in a four-cylinder CRDI engine at speeds of 1200, 1500, and 1800 rpm under various loads[17]. These blends performance, emission, and combustion properties were then compared to regular diesel fuel. The experiments show that when alcohol percentage in the blends grew, NOx emissions were dramatically reduced, but there was a rise in smoke, carbon monoxide, and hydrocarbon emissions. Engine speeds raised from 1200 to 1800 rpm, increasing brake thermal efficiency while dramatically increasing NOx emissions and decreasing carbon monoxide, hydrocarbon, and smoke emissions. Engine knocking was seen at rpms higher than 1800[18,19]. According to the majority of study findings, a biodiesel-diesel blend, when compared to diesel also offers a shorter ignition delay, a slower rate of heat release, and a slightly higher efficiency by sacrificing a tiny amount of fuel[20].In comparison to petroleum diesel, biodiesel has a cetane number higher, which enhances performance of an engine and produces emissions much more cleaner.

The objective of the paper is to prepare biodiesel from palm oil and carryout performance tests on a single cylinder four stoke diesel engine.

II. EXPERIMENTAL WORK ON PALM OIL AS BIODIESEL

Triglycerides, such as palm oil, are transformed into biodiesel or fatty acid methyl esters, by a process called Transesterification shown in below Figure 1. To create the biodiesel, this conversion reaction needs an alcohol and an alkali-catalyst. The combustion of biodiesel produces only biogenic carbon, which is a renewable, biodegradable, and environmentally advantageous biofuel.

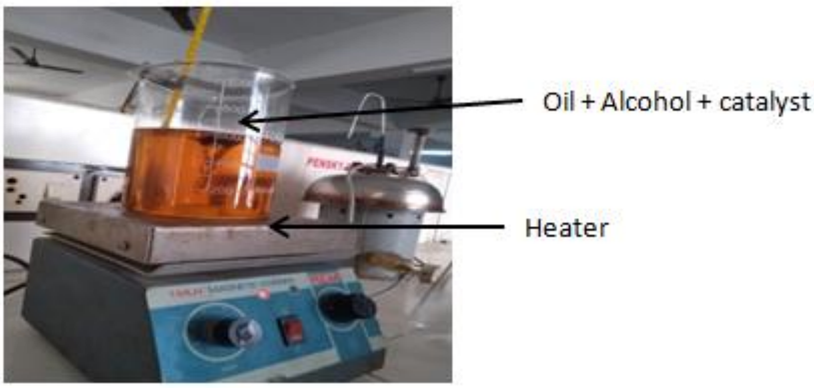


Figure 1: Trans-Esterification

1. **Methodology of Trans-Etherification Process of Palm Oil:** The methanol (AR Grade), diethyl ether, and potassium hydroxide flakes were stirred at 300 revolutions per minute. A 1000 mL round-bottom flask was used for all transesterification reaction studies. As seen in Figure 1, a magnetic pallet setup that was equipped with a temperature reader was utilized to heat the mixture in the flask.

2. **Transesterification:** Many different biomass materials were employed in the transesterification process to produce biodiesel. Alkali transesterification and acid esterification are the two phases that make up the procedure.

Acid esterification is the first step, which uses an acid catalyst to lower the Free fatty acids(FFA) value of crude oil.

Alkali transesterification in Step 2 is used to transesterify the product into monoesters of fatty acids after the contaminants from Step 1 are removed.

3. **Draining of Glycerol:** Glycerol occurs when it has greater mass than biodiesel. Even though the settling will start right away, you should give the mixture at least eight hours to settle completely. 20% of the initial oil volume should be made up of glycerol. The goal is to only extract Glycerol, stopping when biodiesel is obtained. Glycerol seems extremely black in comparison to the biodiesel in Figure 2. The two liquids have different viscosities, are sufficiently different for the difference in drain flow to be observed.

The Methyl esters thus produced by the trans-esterification of Palm oil must be rinsed in warm distilled water using a 1:1 oil to water ratio.

Following water cleaning process as shown in Figure 3 the resulting oil should be heated to 110°C and left to sit for about 20 minutes to allow the water to evaporate. Finally have pure biodiesel.

Figure 2: Separation of Glycerol and Esters

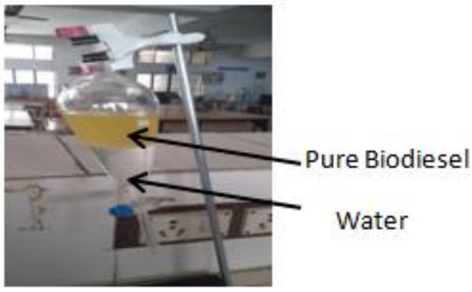


Figure 3: Water Washing

III. SPECIFICATION OF THE ENGINE

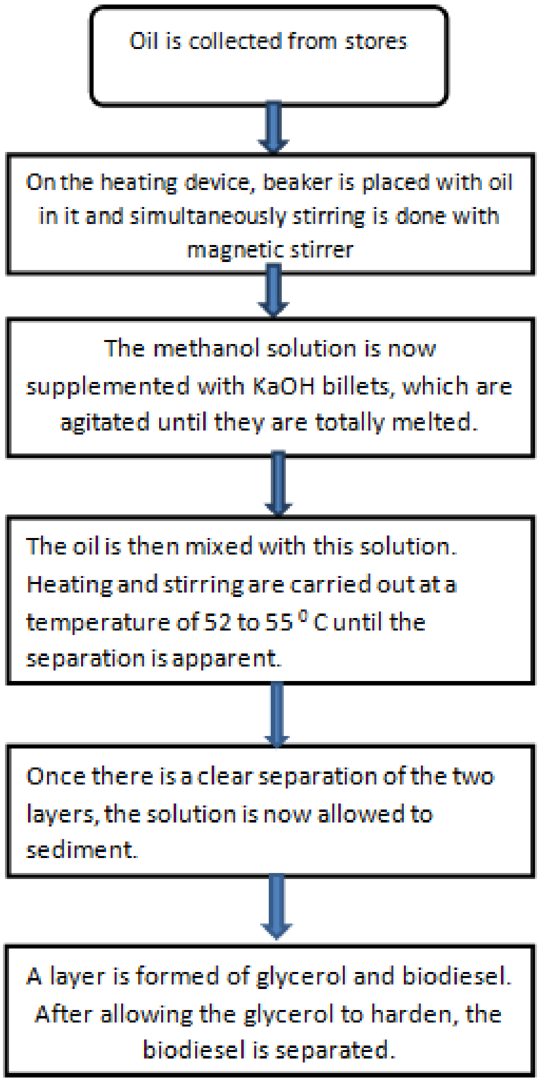
The experiments are performed on Kirloskar four-stroke, one-cylinder, constant speed, water-cooled diesel engine shown in Figure 4, the prepared fuel blends are put to the test. A thermocouple installed at key locations. For starting, this engine comes with a crank handle. A brake drum-style absorption dynamometer is fitted to the engine. Additionally, the engine setup includes a burette, graduations that are clearly defined, and a 3way valve that is used to measure the fuel flow rate.

The performance parameters and combustion analysis of the fuel are discovered through the load test analysis.

Figure 4: Four Stroke, Single Cylinder, Vertical Diesel Engine

IV. FLOW CHART OF BIODIESEL PREPARATION

The steps involved in the preparation of Biodiesel is presented in a flow chart as shown in Figure 5



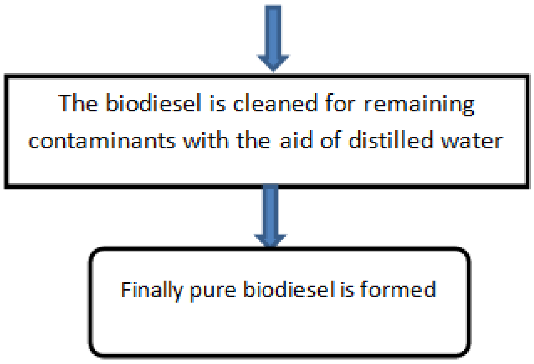


Figure 5: Biodiesel Preparation

1. **Blending:** The use of a magnetic stirrer, as seen in Figure 6, is the primary procedure involved in the synthesis of biodiesels. To get the desired qualities, oil is simply mixed in a specified ratio.

   The first step in this method is to measure out the biodiesel. The Second one is using the mixer to combine diesel and biodiesel.

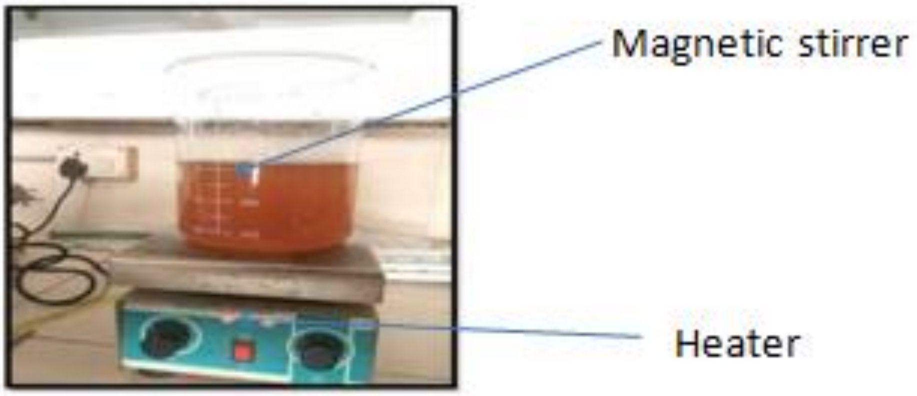


Figure 6: Blending of Oils using Magnetic Stirrer

2. **Blending of Oils:** The usual terminology used to describe biodiesel's composition is B5, B10, B15, etc., where "B" stands for the fuel type, biodiesel, and the number denotes the blend's percentage.

   B10 is a designation for 10% biodiesel and 90% petroleum diesel.
   B20 fuel contains 80% petroleum diesel and 20% biodiesel, oil proportions are shown in below Table 1

Table 1: Oil Proportion in Fuel Blends

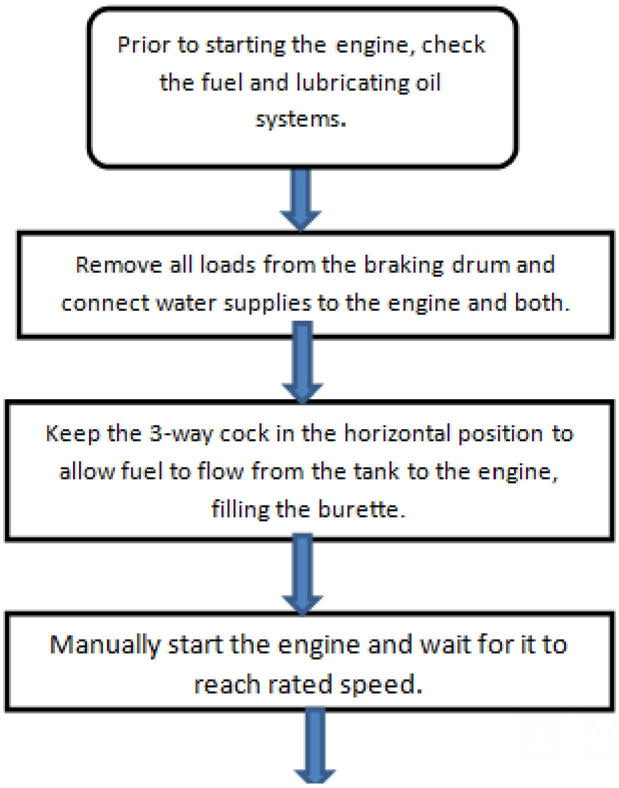
Blends	Diesel(ml)	Bio Diesel(ml)
B5	950	50
B10	900	100
B15	850	150
B20	800	200

3. **Oil Blends Properties:** The properties of oil blends are shown in below Table 2

Table 2: Properties of Oil Blends

	Diesel	B5	B10	B15	B20
Flash point (°C)	49	50	50	53	55
Fire point (°C)	53	56	59	59	61
Specific Gravity (gm/cc)	0.853	0.832	0.836	0.837	0.839
Calorific value (kJ/kg)	44500	42275	40050	37825	35600

4. **Flowchart for Engine Testing:** The performance of an engine was tested by following the procedure specified in the flowchart as shown in the Figure 7.



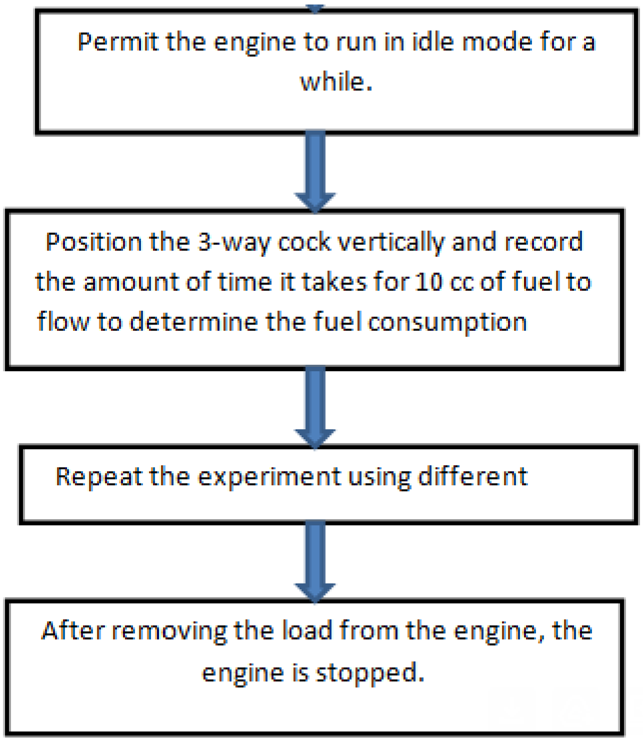


Figure 7: Engine Testing

V. RESULTS AND DISCUSSION

The observations in this paper are assessed using the fundamental equations to get the desired outcomes and graphs.The tabulated observations and outcomes are also mentioned in this paper. The findings were reached after careful analysis of the results and the parameters considered for it are Rated brake power of engine B.P is 5 H.P i.e 3.7KW, Speed of engine N is 1500rpm,Effective radius of the brake drum R is 0.213 m, Stroke length L is 110×10^{-3} m, Diameter of cylinder bore D is 80×10^{-3} m and time taken for 10cc fuel consumption is 't' sec and basic formulae for calculations is

$$\text{Maximum Load} = \frac{\text{Rated B.P} \times 60000}{2\pi\text{NR} \times 9.81}$$

$$= \frac{3.7 \times 60000}{2\pi \times 1500 \times 0.213 \times 9.81}$$

=11.27 Kg

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

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

Indicated Power (I.P) = Brake power(B.P) +Frictional Power(F.P)

When brake power and fuel consumption are compared on a graph, the result is F.P. To cut the negative of the x-axis where B.P. is taken, the linear component of the graph is expanded. Frictional Power is measured as the distance from zero of the intercept point. The Willian's Line Method is the name given to this approach to calculate F.P.

1. Experimental Calculations

- Specific fuel Consumption (SFC) $= \frac{\mathrm{F.C}}{\mathrm{B.P}}$ kg/kw. Hr
- Brake Thermal efficiency $= \frac{\mathrm{B.P} \times 3600}{\mathrm{FC} \times \mathrm{CV}}$
- Indicated Thermal efficiency $= \frac{\mathrm{I.P} \times 3600}{\mathrm{FC} \times \mathrm{CV}}$
- Mechanical efficiency $= \frac{\mathrm{B.P}}{\mathrm{I.P}}$
- Indicated mean effective pressure (I.M.E.P) $= \frac{\mathrm{I.P} \times 60000}{\mathrm{L} \times \frac{\pi}{4} \times \mathrm{D}^2 \times \frac{\mathrm{N}}{2}}$ N/m^2
- Brake mean effective pressure (B.M.E.P) $= \frac{\mathrm{B.P} \times 60000}{\mathrm{L} \times \frac{\pi}{4} \times \mathrm{D}^2 \times \frac{\mathrm{N}}{2}}$ N/m^2

2. Performance Specifications: The engine performance characteristics are specified to be brake power, mechanical efficiency, fuel consumptions, indicated thermal efficiency, and brake thermal efficiency.

Engine efficiency, or the degree to which the fuel's chemical energy is converted into meaningful mechanical effort, is a measure of how well an engine is performing its assigned task.

The following criteria are used to compare success levels:

- Particular fuel usage
- Mean effective brake pressure
- The efficiency of brakes
- Thermal efficiency as indicated
- Machine effectiveness

3. Comparison of Mechanical Efficiency: How effectively an engine converts the specified power to practical power is measured by its mechanical efficiency. Plotted in Figure 8 are the Mechanical Efficiency values at various Brake Powers. B20 blend appears to be the best mixture in terms of the least amount of frictional power because it delivers the best Mechanical Efficiency of all the blends. The least mechanically efficient fuel is diesel.

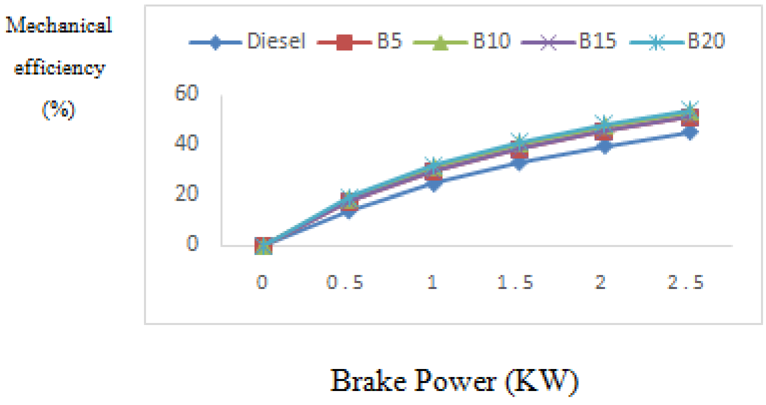


Figure 8: Brake Power Vs Mechanical Efficiency

4. **Comparison of Brake Thermal Efficiency:** The brake power of a heat engine is stated to have a high Brake Thermal efficiency. It is used to determine how well an engine converts thermal energy from a fuel to mechanical energy. Figure 9 displays a curve at various braking powers. Out of all the blends, B20 blend has the Brake Thermal Efficiency very higher, on the other hand diesel has the lower

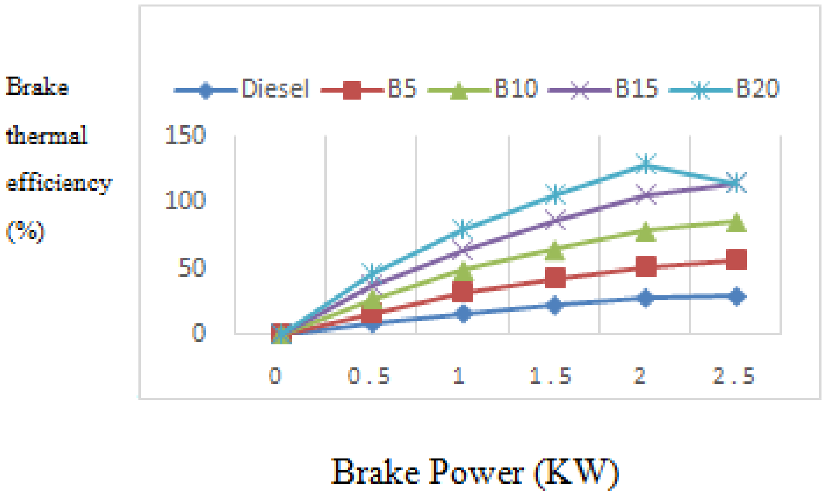


Figure 9: Brake power Vs Brake Thermal efficiency

5. **Comparison of Indicated Thermal Efficiency:** By observation from Figure 10, the indicated thermal efficiency values are plotted at various braking powers. Diesel blend appears to be the ideal mixture because it has the highest indicated thermal efficiency of any of the combinations, whereas pure B20 has the lowest indicated thermal efficiency.

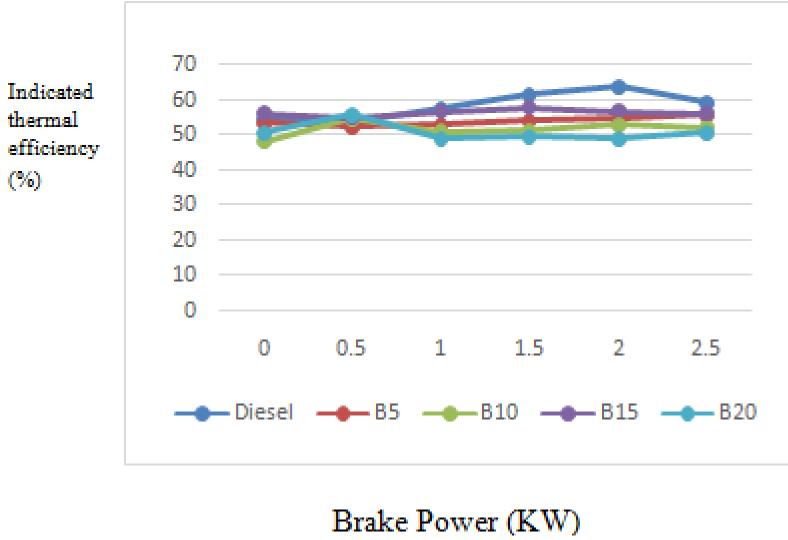


Figure 10: Brake power Vs Indicated Thermal Efficiency

6. **Comparison of Specific Fuel Consumption (SFC):** The SFC of any prime mover that consumes fuel to generate rotational, or shaft, power is a gauge of the fuel efficiency of the device. IC engines with a shaft output are frequently compared for efficiency using this method. It measures the ratio of fuel use to power output. The differences in SFC relative to braking power for various fuel mixtures are depicted in Figure 11. Of all the blends, B15 blend has the lowest Specific Fuel Consumption, whilst Diesel has the most.

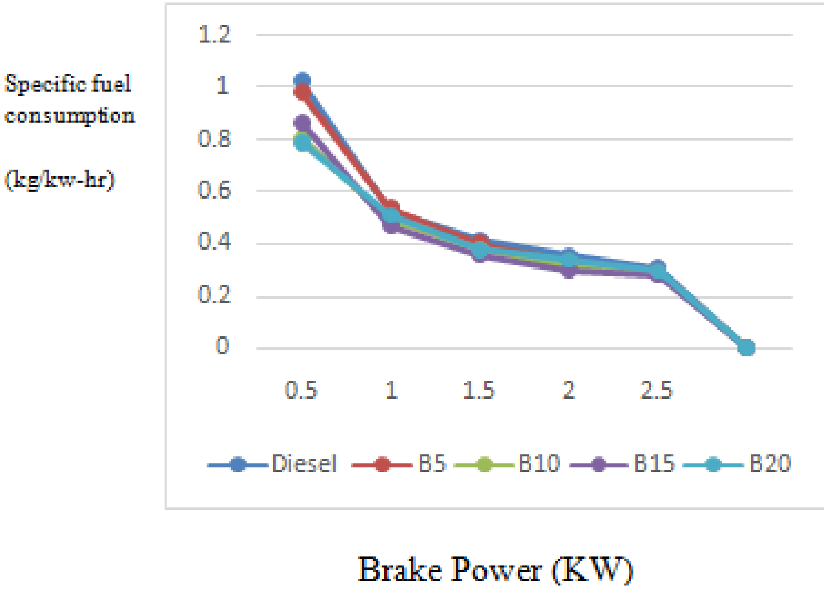


Figure 11: Brake power Vs Specific fuel Consumption

7. **Comparison of Indicated Mean Effective Pressure(IMEP:** The average pressure generated in the combustion chambers throughout the operation cycle is known as the I.M.E.P. Figure 12 illustrates how the I.M.E.P varies in relation to brake power for various fuel blends and diesel. As compared to other blends, B20 blend has the lowest, B5 has the highest Indicated Mean Effective Pressure

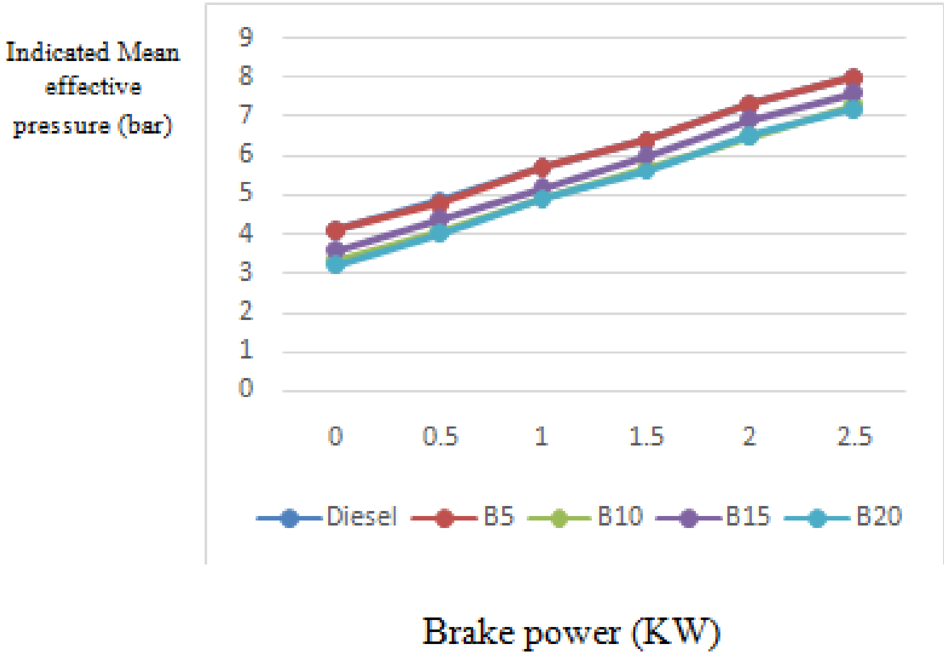


Figure 12: Brake power Vs Indicated Mean Effective Pressure

8. **Comparison of Brake Mean Effective Pressure:** It is a calculation of the engine cylinder pressure that would give the measured brake horsepower and is an indication of engine efficiency regardless of capacity or engine speed. The more efficient it is the higher the average pressure or BMEP. Pressure increases by compression alone can do wonders to a stock engine, it is, by factory choice, usually a low number and it is shown below in Figure 13

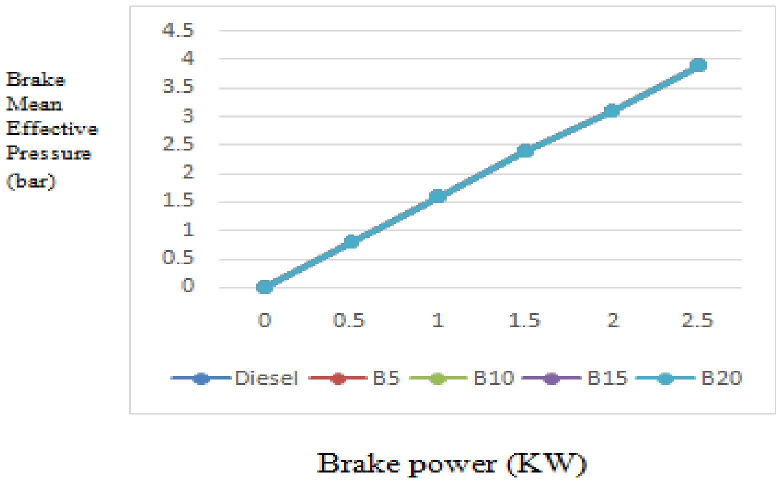


Figure 13: Brake power Vs Brake Mean Effective Pressure

VI. CONCLUSIONS

An experimental investigation is carried out to assess and contrast the usage of palm oil in IC engines as a full or partial replacement for conventional diesel fuel. Several trials were carried out using each of the fuels in various ratios, with the engine running at a constant speed of 1500 rpm and changing loads ranging from no load to full load. The performance measurement metrics, such as fuel consumption, thermal efficiency, mechanical efficiency, mean effective pressures, etc., were computed for each test that was conducted. The following conclusions have been made in light of the experimental findings: Considering the mechanical efficiency for all mixes at various loadsIt is observed that B20 delivers the maximum mechanical efficiency.When analysing the particular fuel consumption for each unique blend, B15 uses the least fuel.The various blends' thermal efficiency were also assessed, and it was found that B20 is the best combination.Therefore, it may be said that the B20 blend, which contains 80% diesel and 20% biodiesel made from palm oil, is the ideal blend.

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