

Experimental Investigation of Diesel Fuel Blended with Emulsified Biodiesel Produced from Orange Peel & Bran Oil on Diesel Engine Performance and Emissions Characteristics

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ABSTRACT

This project aims to compare performance, emission, and combustion of orange and bran oil when blended with diesel in a single-cylinder four-stroke water-cooled direct injection diesel engine. Because of modernizations and the increase in the number of automobiles worldwide, diesel consumption has massively increased. As petroleum is a non-renewable major source of energy and its reserves are scarce nowadays, there is a need for research in finding alternative fuels for automobiles. And also, biodiesels are renewable, non-toxic, and eco-friendly fuels that can play an important role in automobile industries. Based on the above facts, various studies and investigations are carried out with different vegetable oils to prepare cost-effective and reduced NO_x with improved efficient biodiesel. After the intensive study, the identified was orange peel & bran oil. The intensive focus of alternative fuels for the compression ignition engines has been extracted from orange peel & bran oil is found to be potential Fuel for CI engines. The properties of orange peel & bran oil are determined by using standard techniques, and properties are compared with diesel.

The mixed orange peel & bran oil have a lesser cetane number than diesel, which prevented the 100% replacement of diesel with the mixed orange peel & bran oil in the diesel engines.

The mixing proportions are B25%, B50%, B75%, with varying percentage of exhaust gas recirculation. The analysis focuses on all regulated exhaust pollutants, i.e., Opacity, Nitrogen Oxides (NO_x), Carbon Monoxide (CO), Carbon-Di-Oxide (CO₂), and Unburned Hydrocarbons (UHC). Performance analyses such as Brake Power (BP), Brake Specific Fuel Consumption (BSFC), and Brake Thermal Efficiency (BTE) are considered for experimental investigation.

I. INTRODUCTION

The large increase in industrialization and motorization in recent years has resulted in great demand for petroleum products. Petroleum-based fuels are obtained from limited reserves. The price of conventional fossil fuel is too high and has added a burden on the economy of the importing nations. With crude oil reserves estimated to last only for few decades, there has been an active search for alternate fuels.

Experimental investigations revealed that local fuels such as coconut, palm, and rubber seed oils are found to be alternative fuels to diesel in the compression ignition engine. These oils can be used directly without any major modifications in the compression ignition engines. The aim of this paper is to study the suitability of locally available vegetable oil-based biofuels in Kerala rubber seed oils as substitutes for conventional diesel fuel in diesel engines.

A. BENEFITS OF AN BIO-FUELS

- Renewable and alternative energy sources.
- Easy to develop and use.
- Low-cost and not a-very-high-tech route.
- Biodiesel provides more lubrication than petroleum diesel.
- Biodegradable, non-toxic, and free of sulfur and aromatic compounds, therefore, no SO_x emissions.
- Bio-fuel is an ideal synergistic partner for oxidation catalytic converter and reduces CO₂ emissions by 78 % when compared to conventional diesel fuel.
- Bio-diesel is an oxygenated fuel with O₂ content of about 10 % and therefore gives better emission characteristics in terms of CO, Hydrocarbons, and Particulate matter.



- Also, Bio-diesel has a higher Cetane number, ensuring low noise and smooth running during engine combustion.
- In addition, the by-product resulting after extracting biofuel is an excellent source of nitrogen-rich organic fertilizer.

B. ECONOMICS OF BIODIESEL

The major economic factor to consider for input costs of biodiesel production is the feedstock (the price of seed, seed collection and oil extraction, transport of seed, and oil), which is about 75–80% of the total operating cost. Other important cost-related factors are labor, methanol, and catalyst for biodiesel conversion for straight vegetable oil, which must be added to the feedstock. Cost recovery will be through the sale of oil cake and of glycerol (Mulugetta,2009). The volatile oil prices due to increased demand have necessitated continuous research and development into the biodiesel sector to increase biodiesel production of suitable quality and at a reasonable price so that it can compete with diesel fuel.

LITERATURE SURVEY

Prasad C.M.V et al. (1992) have investigated a biodiesel fuel, jatropha curcas oil methyl ester, in a diesel engine. The influence of oil on BSFC, exhaust gas temperature, NO_x, and smoke has been reported. The use of biodiesel fuel showed reasonably good performance and the use of 100 % esterified jatropha oil gave a reduction in NO_x levels and an increase in smoke while maintaining almost the same BSFC in comparison with 100 % diesel fuel operation.

Magesh et al. (1999) used a continuous transesterification process for biodiesel production from vegetable oil and animal fats. They found that the recovery of high-quality glycerol should lower biodiesel's cost. The transesterification reaction is affected by glycerides' molar ratio to alcohol, catalysts, reaction temperature, reaction time, and free fatty acids and water content of oils or fats. The mechanism and kinetics of the Transesterification show how the reaction occurs and progresses as per their observations.

Kumar et al. (2001) has used Orange peel oil as induced Fuel and Jatropha oil methyl ester, jatropha oil, and diesel as pilot fuels. With the admission of Orange peel oil in the dual-fuel operation, there is an appreciable increase in thermal brake efficiency. Orange peel oil induction drastically reduced smoke to 3BSU with Jatropha oil and 2.8BSU with methyl ester of Jatropha oil as pilot fuels

Yasufumi Yoshimoto et al. (2001) conducted a performance and emission test with biodiesel (methyl ester from used frying oil) and

biodiesel-emulsion as well as with gas oil and gas oil-emulsions at rated output. The gas oil-emulsions were prepared by mixing gas oil and water with 1 % (by mass of gas oil) surfactant, Ionet S-2, and biodiesel emulsions were prepared by mixing biodiesel and water with 1 % (by mass of biodiesel) surfactant, polyglycerol fatty acid ester. The engine performance was examined with different water addition rates in a 4-S, water-cooled single-cylinder DI diesel engine with a rated 7.35 kW at 1200 rpm. The BSEC with biodiesel-emulsion is nearly equal to gas oil operation at early injection timings, while it is significantly lower at retarded timings.

The biodiesel-emulsion showed a lower BSEC than a gas oil-emulsion when the water addition rate is small but higher BSEC at higher water addition rate, 40 % (by volume). There is an optimum water addition rate of 40 % for gas oil-emulsion and 30 % for biodiesel-emulsion. Compared with water-free gas oil, both emulsions with 30 % water achieve a 30 % reduction in NO_x. For the water-free gas oil, the NO_x emission decreases from 1020 ppm to 300 ppm with 21 % EGR, while the BSEC and smoke emissions increase to 3 % and 47 %, respectively.

Christopher A. Sharp et al. (2001) have investigated the unregulated emissions from three engines viz, 1997 Cummins N14 (276 kW), 1997 DDC series 50 (205 kW) and 1995 Cummins B5.9 (119 kW) using neat biodiesel (from methyl ester of soybean oil), B100, a blend of 20 % biodiesel by volume in diesel fuel, B20 and neat diesel fuel with and without catalytic converter. Generally, aldehyde emissions were lower with biodiesel. With B100, aldehydes were reduced by about 30 % on the N14 and series 50 engines and nearly 50 % on the B5.9 engine, which had a higher level of aldehydes on diesel than the other two engines. The entire polycyclic aromatic hydrocarbon (PAH) and nitrated-polycyclic aromatic hydrocarbon (NPAH) were present in the exhaust of all three engines when operated on diesel fuel. The use of B100 resulted in dramatic reductions in both engine-out and catalyst-out PAH emissions. In N14 and series 50 engines, the PAH emissions were reduced as much as 85 % for some compounds and at least 50 % for all the compounds measured. The PAH that is present with B100 fuel may represent the contribution from the PAH compounds in the lubricating oil, although this is not certain. The engine-out NAPH compounds showed an even larger reduction with biodiesel than the PAH compounds. 2-nitrofluorene and 1-nitropyrene were reduced between 50 % and 90 % with B100 fuel. The Cummins N14 engine seemed to show a better response to B100 fuel in terms of NAPH emissions than the other two engines, but all three showed larger NAPH reductions in the engine-out exhaust.

Senthilkumar .M et al. (2001) have investigated the performance and emission characteristics of a naturally aspirated engine with diesel-methanol blend and Jatropa-methanol dual-fuel engine. The result shows an increase in thermal brake efficiency from 25.9 % to 30.6 % in the case of Jatropa oil and from 30 % to 32.8 % in diesel fuel. This is attributed mainly due to the higher heat release rate of the methanol by flame propagation. Volumetric efficiency is lower for Jatropa when compared with diesel because of the higher exhaust temperature. With methanol admission, volumetric efficiency increases because of the cooling of intake charge by methanol's vaporization. Smoke was drastically reduced from 4.4 BSU with neat Jatropa to 1.6 BSU at the maximum quantity of methanol in Jatropa. This is mainly due to the lesser burning rate of Jatropa, which leads to lower peak temperatures. In dual fuel mode, NO is reduced from 30 g / kWh to 25 g / kWh. However, at a relatively high level of methanol admission, NO is increased to 36 g / kWh. A similar trend is also noticed with diesel. HC emission was increased from 120 ppm with neat Jatropa to 240 ppm at the maximum quantity of methanol supply. The reason was poor mixing and flame quenching. CO emission level was increased from 0.18 % at 0 % methanol supply to 0.32 % at the maximum quantity of methanol supply in the case of Jatropa. Diesel also exhibited a similar trend. The combustion started slightly later with MSO due to the retarded injection timing since the ignition delay was slightly longer. The NO_x emission varied between 7 and 28 g / kWh in the entire load range with diesel. With MSO, the NO_x ranged from 6 to 26 g / kWh. Generally, the brake specific hydrocarbon emissions (BSHC) were also lower with MSO than diesel.

With diesel, the BSHC emission varied from 0.3 to 3.4 g / kW h in the tested load range, whereas with MSO, the BSHC emission ranges from 0.1 g / kW h to 2.6 g / kW h. At low loads, the engine was found to emit more CO when operated with MSO than diesel. The exhaust smoke was lower at medium and high loads when the engine was fueled with MSO instead of diesel. Pre-heating of MSO did not strongly affect the engine performance, nor gaseous exhaust emission. The particulate matter emissions did decrease, but not to a level achieved with diesel.

Nagarajan.G et al. (2002) studied the use of neat ethanol in the DI diesel engine. The experimental work involves using ethanol with the introduction of diethyl ether (DEE) in the intake manifold just before the port in the form of droplets drawn into the engine cylinder and the intake of air. The DEE present inside the engine cylinder gets combusted during the compression stroke itself, thereby creating a hotter environment, making the subsequently injected ethanol ignite very easily. The

maximum brake thermal efficiency obtained was 36.3 % at 75 % load for ethanol-DEE, while that for diesel, it is 30 %. The improvement in efficiency has been attributed to better combustion of ethanol in the hotter environment created by DEE's early combustion.

Ignition delay for ethanol-DEE is longer by about 8° crank angles than diesel at rated load) due to the higher latent heat of ethanol's vaporization. The CO emissions are more in ethanol-DEE (0.8-1.4 %) than diesel (0.1-0.28 %). The HC emissions are higher in ethanol-DEE (434 ppm) than in diesel (266 ppm) due to the increased amount of HC present in the quench and crevice zones. NO_x emissions are less by about 133 ppm for ethanol-DEE than diesel due to increased vaporization of ethanol and the resulting temperature drop of the cylinder charge. Smoke is less in ethanol-DEE (0.2 BSU) than diesel (1.6 BSU) due to soot-free combustion.

Seppo A. Niemi et al. (2002) determined the exhaust emissions of particulate matter of a direct injection turbocharged, intercooler tractor diesel engine while fueling the engine with mustard seed oil (MSO). No modifications were made to the engine except to the injectors, which were set for high power. The standard injectors have 5 orifices with a bore of 0.245 mm, while the injector adapted for their test program has 5 holes with a diameter of 0.275 mm. A strategic injection timing of 19 ° BTDC was adopted for MSO instead of the 21 ° BTDC used for diesel fuel oil. The thermal break efficiency (BTE) of the test engine was very similar to both fuels at 1800 rpm. However, at 2400 rpm, the efficiencies measured with MSO were slightly lower than those obtained with diesel fuel in the load range of 50 %. The retarded injection adopted for MSO operation did not, thus, deteriorate the BTE at medium speed. One reason was thought to be the more rapid burning of MSO relative to diesel fuel oil. The combustion started slightly later with MSO due to the retarded injection timing since the ignition delay was slightly longer. The NO_x emission varied between 7 and 28 g / kWh in the entire load range with diesel. With MSO, the NO_x ranged from 6 to 26 g / kWh. Generally, the brake specific hydrocarbon emissions (BSHC) were also lower with MSO than diesel.

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Bari et al. (2004) have studied the effect of fuel injection timing with waste cooking oil as a fuel in a direct injection diesel engine. The aspects taken into consideration were the effects of injection timing on combustion, performance, and emission. The results reveal that waste cooking oil and diesel responded identically to injection timing changes. To reduce NO emission, one of the methods is to retard the injection timing from MBT timing. The engine used in this research followed this technique and had its original injection timing set at 15° before the top dead Centre (BTDC). With injection timing advanced by 4°, the engine gave a better efficiency by 1.6% for waste cooking oil and by 1.1% for diesel, reduced CO emission, on an average of 9.9% for waste cooking oil and 44.9%, but suffered increased NO emission of 76.6% for waste cooking oil and 91.4% for diesel.

Huang.Z.H et al. (2004) have conducted a study on the diesel-methanol performance and emissions blend in a compression ignition engine. The study showed that the engine thermal efficiency increases with an increase in the oxygen mass fraction (or methanol mass fraction) of the diesel-methanol blends due to an increased fraction of the premixed combustion phase, oxygen enrichment, and improvement in the diffusive combustion phase. When oxygen mass fraction is less than 8 wt %, the NO_x concentration increases with an increase in the methanol mass. More fuel burns in the premixed combustion phase, the combustion temperature is high and more oxygen is available. A marked reduction in the exhaust CO and smoke can be achieved when operating with the diesel-methanol blend.

Ramadhas et al. (2004) investigated the use of raw banana oil-diesel blend in the compression ignition engine. The experiment was conducted using banana peel oil-diesel blend in proportion of 80% / 20%, 60% / 40%, 40% / 60%, 20% / 80% by volume with preheating. For all fuels, the specific fuel consumption decrease with increasing loads. The blend containing 20-40% of banana peel oil gave the performance closely matching that of diesel oil. In the case of 80:20 blend, the highest thermal efficiency was observed. An increase in exhaust temperature with an increase in brake power irrespective of the blend ratio occurred. Blends in the range of 60-80% of banana peel oil resulted in a

slightly lower exhaust gas temperature than diesel. The highest value of smoke observed was 52%, with diesel, whereas the corresponding value with rubber seed oil was found to be 46% only. Smoke obtained with 60:40 blends was found to match that of diesel closely.

Yanowitz et al. (2009) found that the use of a common biodiesel blend (B20) consistently reduces emissions of particulate matter, hydrocarbons, and carbon monoxide by 10-20%, and B20 show varying effects on oxides of nitrogen (NO_x). The emissions effect of B20 on heavy-duty diesel truck emissions did not show any correlation with model year or type of fuel injection equipment as per their study

Anand et al. (2011) investigated Karanja biodiesel's combustion, performance, and emission characteristics and its methanol blend in the diesel engine. Experiments had been carried out on a turbocharged, direct injection, multi-cylinder truck diesel engine fitted with a mechanical distributor type fuel injection pump using biodiesel- methanol blend and neat Karanja oil derived biodiesel under constant speed and varying load conditions without altering injection timings. Delayed start of combustion and lower combustion duration were observed for biodiesel-methanol blends as compared to neat biodiesel fuel

Hoekmanet. al. (2012) has studied the "biodiesel NO_x effect and theories to explain this effect. The biodiesel NO_x effect can be mitigated by modifying engine control settings - particularly by retarding injection timing and increasing exhaust gas recirculation (EGR). The absolute magnitude of the biodiesel NO_x effect appears to be reduced with modern engines. However, there are cases where the percentage change is still substantial has found that differences in chemical and physical properties among biodiesel fuels can be explained largely by the fuels' FA profiles. Two especially influential features are the size distribution and the degree of unsaturation within the FA structures. For the 12 biodiesel types reviewed, it was found that several fuel properties - including viscosity, specific gravity, cetane number, iodine value, and low-temperature performance metrics - are highly correlated with the average unsaturation

III. PROPOSED METHODOLOGY

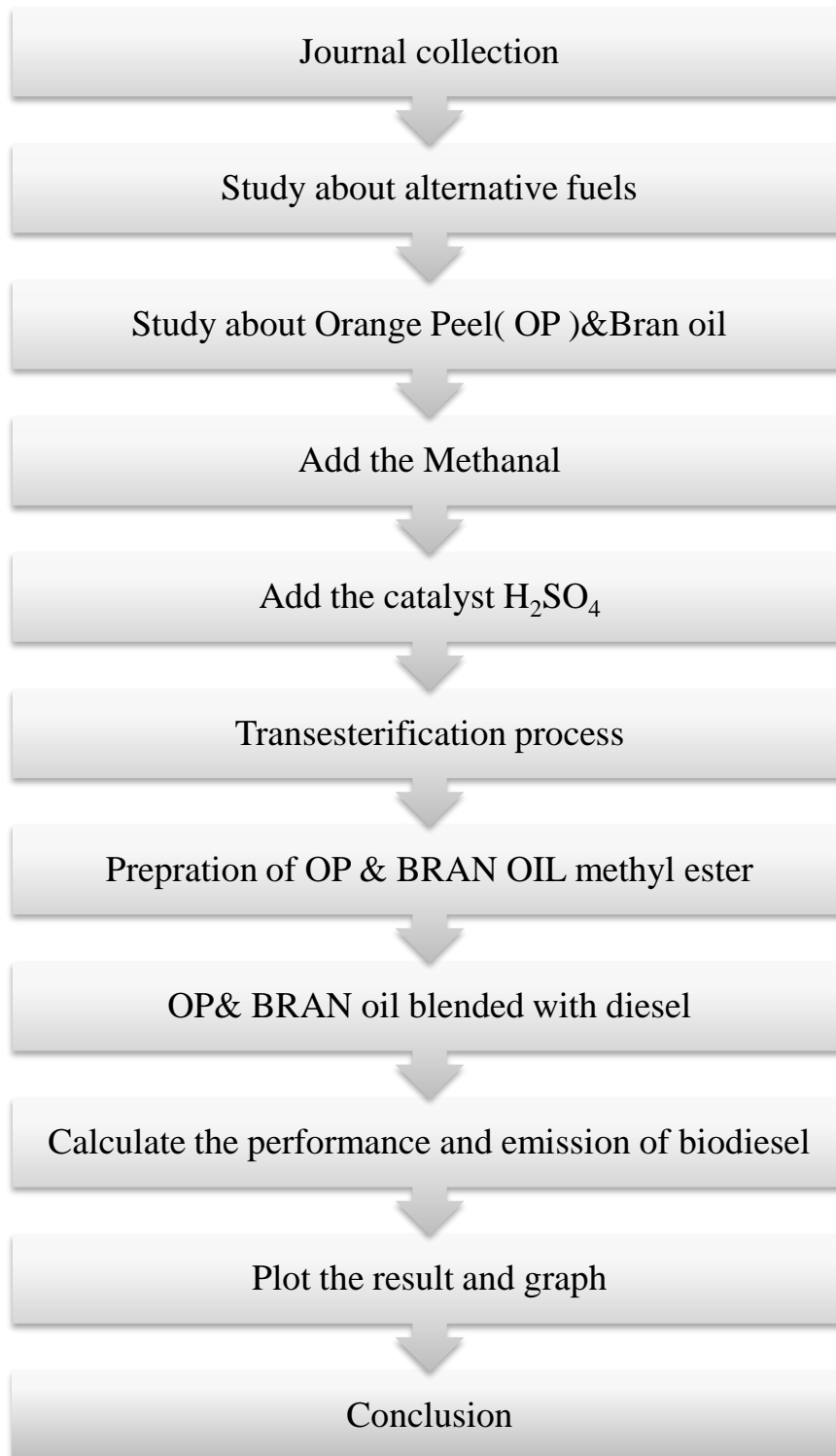
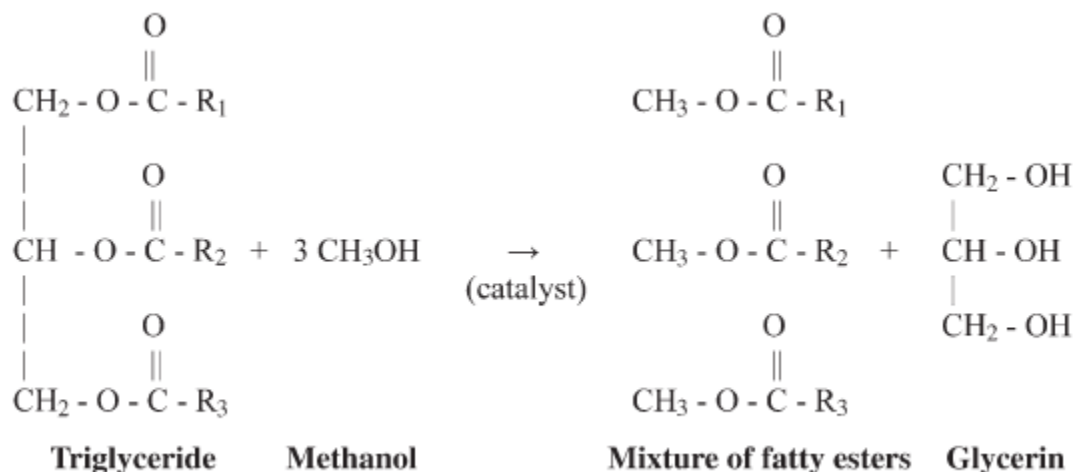


Fig.3.1. Flow Chart of Methodology

IV. A. PRODUCTION OF BIODIESEL FROM HIGH FFA MIXED ORANGE PEEL & BRAN OIL

The process of making biodiesel from vegetable oil is called Transesterification (trans-esterification). Transesterification is the transformation of one type of ester into another type of ester. An ester is a hydrocarbon chain that will bond with another molecule.

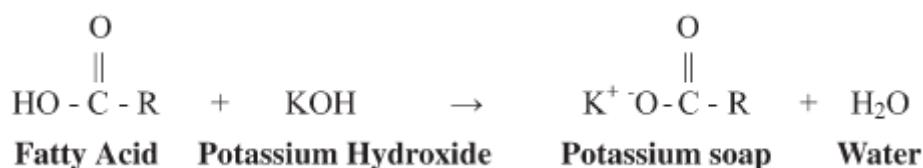
A vegetable oil molecule is made up of three esters attached to a molecule of glycerin. About 20 % of vegetable oil molecule is glycerin. During Trans-esterification, the vegetable's glycerin component is replaced with alcohol to make the oil thinner reduce its viscosity. Biodiesel is produced through a process known as Transesterification, as shown in the equation below.



Where

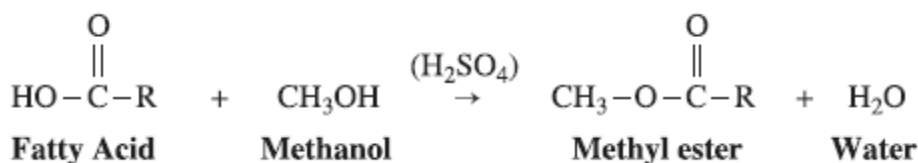
R₁, R₂, and R₃ are long hydrocarbon chains. They are sometimes called fatty acid chains. Special processes are required if the oil or fat contains significant amounts of Free Fatty Acids (FFAs). Used cooking oils typically contain 2–7 % FFAs, and animal fats contain 5 % to 30 % FFAs.

Some very low-quality feedstocks, such as trap grease, can approach 100 % FFAs. When an alkali catalyst is added to these feedstocks, the free fatty acids react with the catalyst to form soap and water, as shown in the reaction below:



Up to about 5 % FFAs, the reaction can still be catalyzed with an alkali catalyst, but an additional catalyst must be added to compensate for the catalyst lost to soap. The soap created during the reaction is either removed with the glycerol or is washed out during the water wash. When the FFA level is above 5 %, the soap inhibits separation of

the methyl esters and glycerol and contributes to emulsion formation during the water wash. The rubber seed oil contains 12.8 % free fatty acid. For these cases, an acid catalyst, such as sulphuric acid, can be used to esterify the free fatty acids to methyl esters, as shown in the following reaction:



This process can be used as a pretreatment to convert the FFAs in high FFA feedstocks to methyl esters and reduce the FFA level. The low FFA pretreated oil can be Trans esterified with an alkali catalyst to convert the triglycerides to methyl esters.

B. PREPARATION OF MIXED ORANGE PEEL & BRAN OIL METHYESTER

It is difficult to Trans esterify the high FFA vegetable oils using the commercially available alkaline catalyst process. The process consists of two steps, namely, acid esterification and alkaline esterification. The schematic diagram of biodiesel production is shown in Fig. 4.1

C. ACID ESTERIFICATION

The first step reduces the FFA value of raw rubber seed oil to about 2 % using an acid catalyst. One liter crude rubber seed oil requires 200 ml of methanol for the acid esterification process. The rubber seed oil is poured into the flask and heated to about 60°C. Then methanol is added with the pre-heated rubber seed oil and stirred for a few minutes. 6ml of sulphuric acid is also added to the mixture. Heating and stirring are continued for 60 minutes at atmospheric pressure. Upon completing this reaction, the product is poured into a separating funnel for separating the excess alcohol. The excess alcohol, with sulphuric acid and impurities, moves to the Lower surface and is removed. The Top layer is separated for further processing.

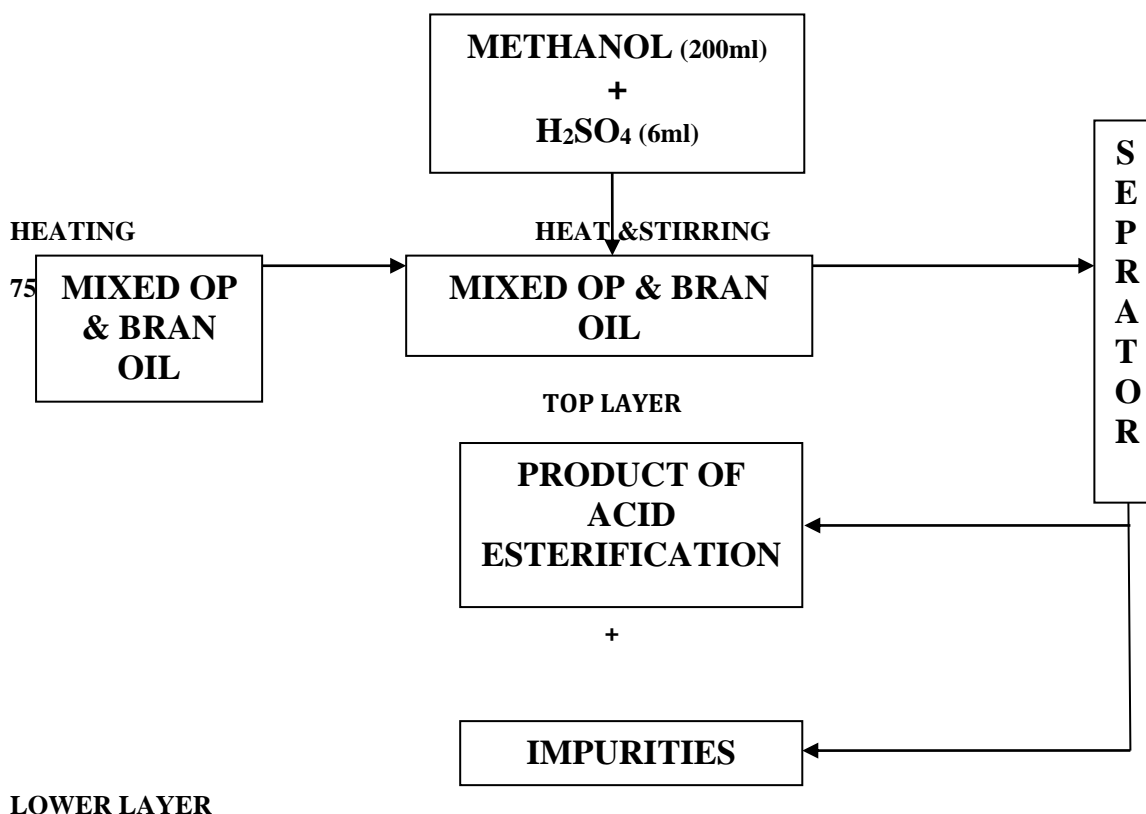


Fig.4.2. The Schematic Diagram of Biodiesel Production Using Acid Esterification

D. ALKALINE ESTERIFICATION

The products of acid-catalyzed esterification are pre-heated to the required reaction temperature of 60°C in the flask. Meanwhile 6gm. KOH is dissolved in 200 ml methanol and is poured into the flask. The mixture is heated and stirred for 60 min. The reaction is stopped, and the products are allowed to separate into two layers. The lower layer, which contained

impurities and glycerol, is drawn off. The ester remains in the upper layer. Methyl esters are washed to remove the entrained impurities and glycerol. Hot distilled water (10 % by volume/75°C) is sprayed over the ester's surface and stirred gently. The lower layer is discarded, and the upper layer is separated.

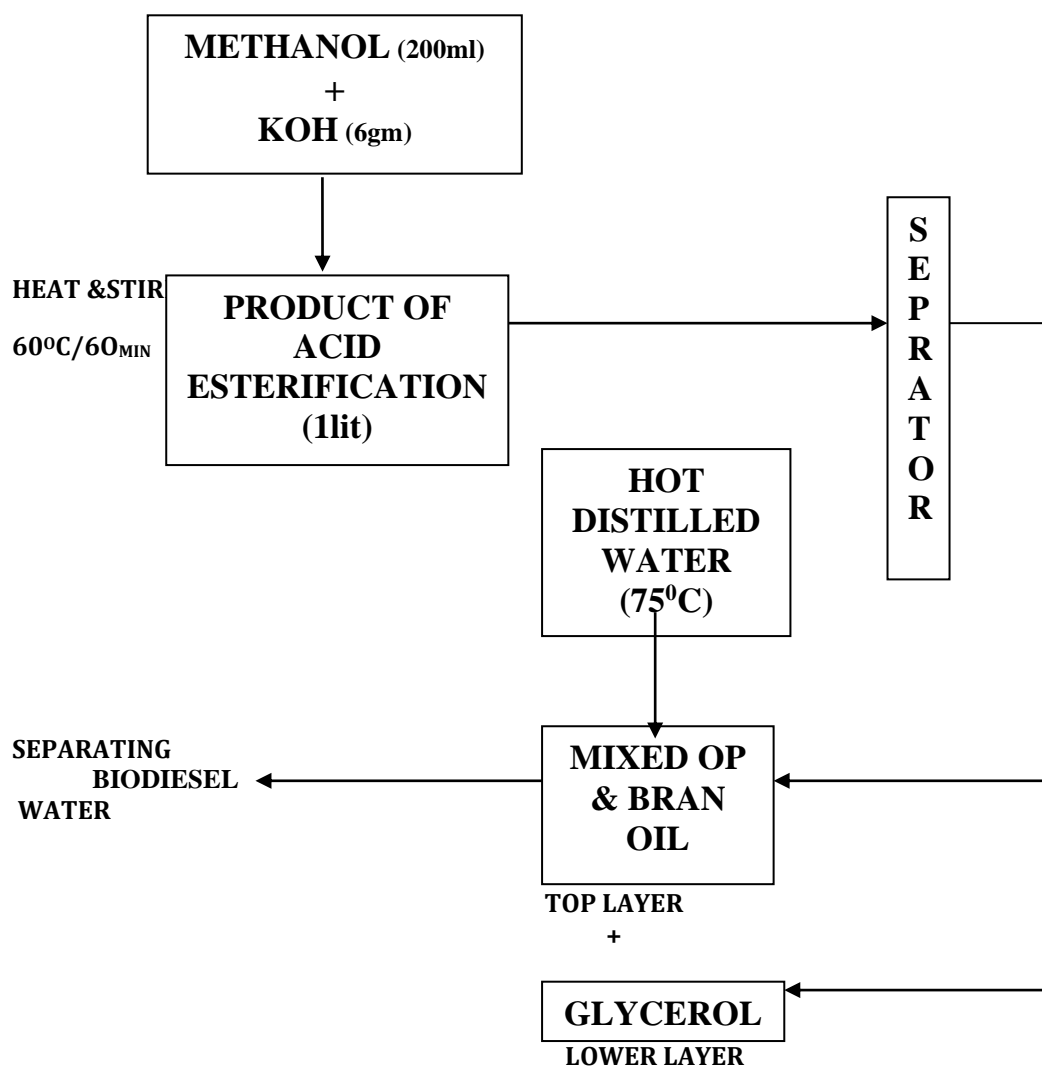


Fig.4.3. The Schematic Diagram of Biodiesel Production Using Alkaline Esterification

E. PURIFICATION OF PRODUCT

After Transesterification, the ester layer may contain an unreacted catalyst, methanol, and residual glycerol. These impurities were removed by hot water treatment. The water washing method was continued (4-6 times) until the water layer becomes clear. For this process, an equal amount of hot distilled water was used to remove the impurities.

F. DRYING OF PRODUCT

MIXED OIL
&
BRAN OIL

After completing the purification process, the ester layer may contain some amount of water and methanol. This should be removed before the commercialization of Fuel. Because methanol reduces the flashpoint of Fuel, and it has corrosive nature to fuel hoses. Water content is responsible for the growth of biological organisms, and it also increases the acid value of Fuel. Hence the ester layer was heated in a hot plate with a stirrer at 100°C for 15 to 30 min to remove the water and methanol content present in the product (biodiesel). Finally, the dried biodiesel fuel was saved.

S.NO	PROPERTIES	ORANGE PEEL & BRAN OIL	DIESEL
1	Density (kg/m ³)	880	850
2	Calorific value	39786.12	42000
3	Kinematic viscosity @ 40 c	5.149	3.05
4	Cetane number	51	55
5	Flash point ^o C	48	50
6	Fire point ^o C	60	56
7	Pour point ^o C	-4	15
8	Carbon residue %	0.01	0.2
9	Sulphur content %	<0.002	<0.035
10	chemical structure	C _n H _{2n-1}	C ₁₂ H ₂₆

Table 4.4 Properties of Mixed OP & Bran oil and diesel

EXPERIMENTAL SETUP

A. TEST ENGINE

The test engine used in the experiments is a single-cylinder four-stroke, naturally aspirated, constant speed compression ignition engine. The engine was tested at a rated speed of 1500rpm. The exhaust gas was sent to the smoke meter and gas analyzer to measure smoke intensity, CO, CO₂, etc.

The engine was coupled to a generator set and loaded by electrical resistance to apply different engine loads. The specification of the engine and generator is demonstrated in the table. The voltage, current, and power developed by the engine were directly displayed on the control. The readings taken during each set of experiments were used to calculate brake specific consumption, thermal efficiency, and other engine characteristics.

B. TEST ENGINE SETUP



Fig. 5.1 Photo View Of Test Engine Setup

C. ENGINE SCHEMATIC DIAGRAM

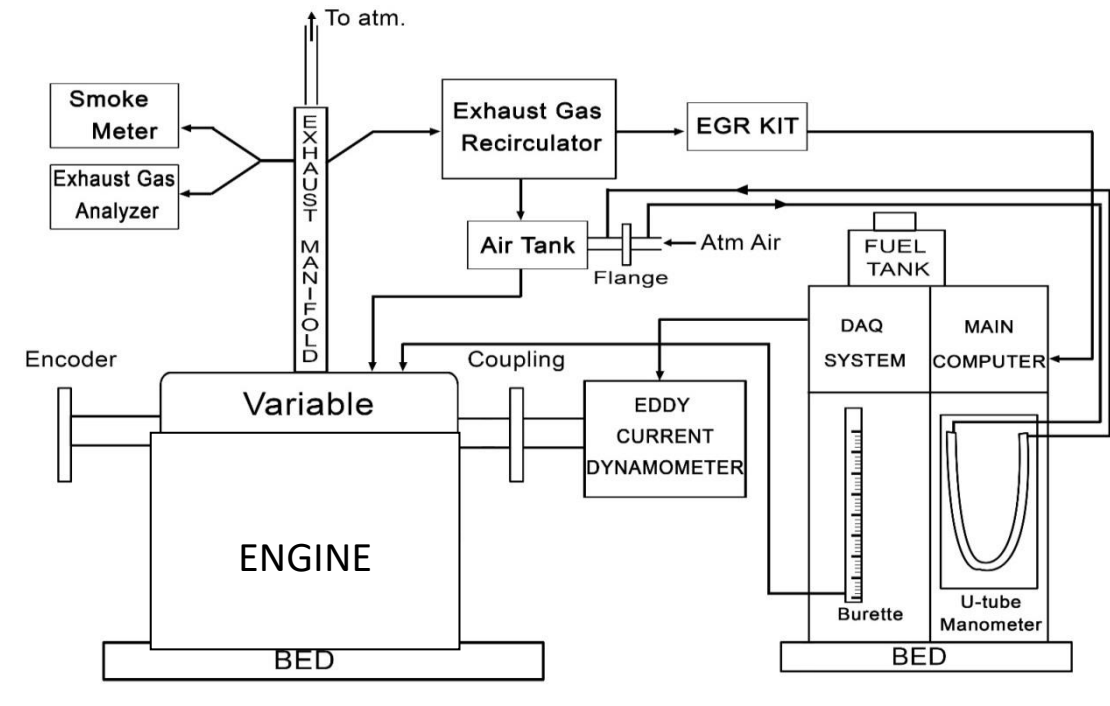


Fig. 5.2 Schematic view of Engine Setup

The pressures versus crank angle diagrams were directly displayed on the Digital Storage Oscilloscope (DSO). A tachometer checked the

engine speed. AVL Exhaust Gas Analyzer measured the Unburnt Hydrocarbon (UHC), Carbon Monoxide (CO), and Nitrogen Oxide (NOx) emission.

D. TEST ENGINE SPECIFICATION

Engine make	Kirloskar model AV1
Fuel	H.S. Diesel Oil
No. of cylinders	1
No. of Strokes	4
Cylinder Diameter	0.0875m
Stroke length	0.11m
Engine power	5.2 kW (7hp)
Compression ratio	17.5:1
RPM	1500 rpm
Type of starting	Crank starting
Air Measurement Orifice Diameter	0.02m
Eddy current dynamometer Dynamometer arm length	0.195m
Cooling technique	Water-cooled

Table 5.3 Parameters of IC research engine

RESULT AND DISCUSSION

From the observations, the data for conventional diesel and biodiesel were obtained and compared. With the help of these data, the characteristic curves were plotted and compared. Brake thermal efficiency shows a tendency to increase with an increase in load. This is due to the reduction in heat loss and leads to an increase in output power—the mixing of biodiesel with diesel oil yields high thermal efficiency curves.

The thermal efficiency of the engine is improved with increasing concentration of the biodiesel in the blend. The reason may be the additional lubricating effect shown by the orange peel and bran oil, and biodiesel. Also, biodiesel molecules (i.e., methyl esters of the oil) contain some amount of oxygen, which takes part in the combustion process.

A. BRAKE THERMAL EFFICIENCY

Brake thermal efficiency is the ratio of brake power output to power input. Differences in thermal efficiency were small at low load values but became more obvious at higher load. The variation of thermal brake efficiency with brake power is shown in Figure 7.1. It can be observed from the figure that the thermal efficiency is 28.67% at 5.19kw brake power for diesel. The maximum BTE obtained for diesel, B25, B50, B75, and B100 is 28.99%, 26.69%, 27.08%, and 23.79%, respectively, and with diesel, it is 29.92% with respectively at 5.19kw brake power full load. It is observed that the orange peel and bran oil diesel blends showed poor thermal efficiency compared to diesel because of high viscosity and low volatility and leads to poor atomization and vaporization of the orange peel and bran oil fuel. The BTE of B25 is higher compared with all orange peel and bran oil diesel blends.

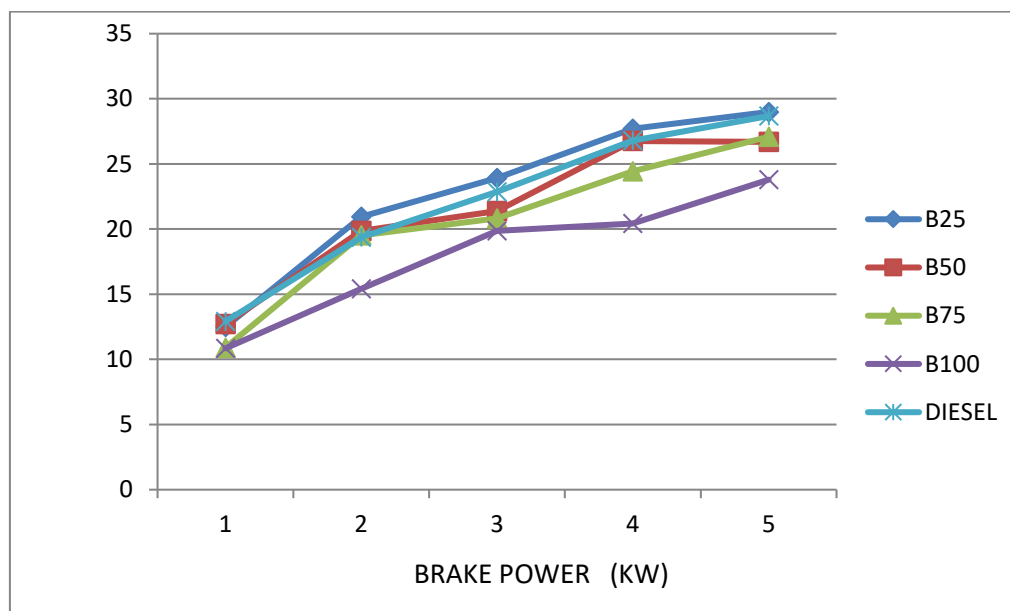


Figure 7.1 Brake thermal efficiency against load

B. INDICATED THERMAL EFFICIENCY

The ratio between the indicated power output of an engine and the rate of supply of energy in the steam or Fuel, the amount of power developed in the cylinder, can also be considered as the power exerted on the piston. Fuel power is converted into indicated power, but there are various losses like heat loss from cylinder walls, cooling water, and heat loss in the exhaust gas. Hence this IP is lower than FP. The variation of indicated thermal efficiency with load is shown in Figure 7.2. It can be observed from

the figure that the indicated thermal efficiency is 34.30 % at 5.19kw brake power for diesel. When the engine is fueled with orange peel and bran oil diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and 100% orange peel and bran oil, it gives the thermal efficiency of 34.67%, 31.93%, 32.39%, and 28.46 % respectively at 5.19kw brake power. It is also observed that indicated thermal efficiency is also higher for 25% blends, and it is slightly lower for 50%, 75%, and 100% orange peel and bran oil Diesel blend compared to pure diesel.

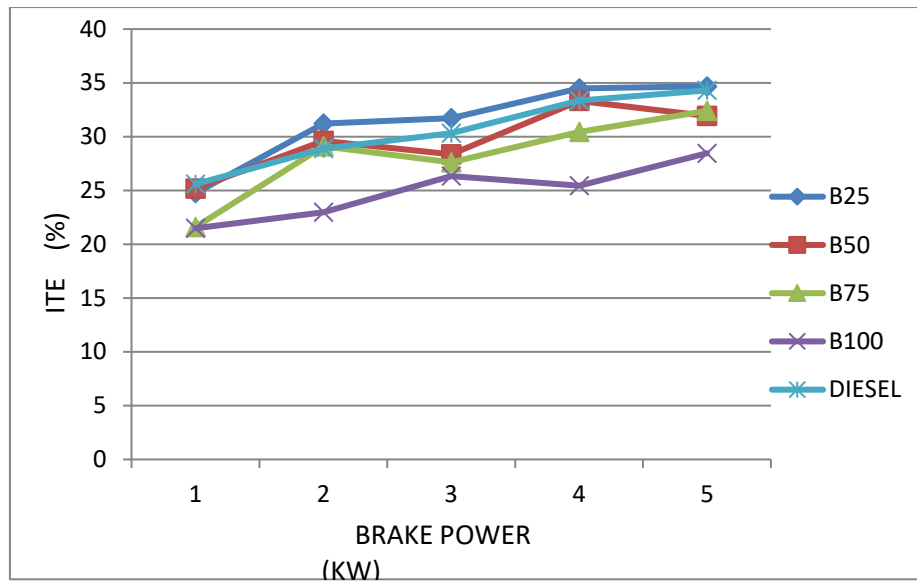


Figure 7.2 Indicated thermal efficiency against load

C. BRAKE SPECIFIC FUEL CONSUMPTION

Brake specific fuel consumption is the rate of fuel consumption divided by the rate of power production. Brake specific fuel consumptions descend from lower to higher load level. It is related to brake thermal efficiency. The variation of brake specific fuel consumption with load is shown in Figure 7.3. It can be observed from the figure that the brake specific fuel consumption is 0.282 kg/kWh at 5.19kw brake power for diesel. When the engine is

fueled with RSO diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and 100% orange peel and bran oil, its brake specific fuel consumption are 0.2791 kg/kWh, 0.3032 kg/kWh, 0.2988 kg/kWh and 0.3401 kg/kWh respectively at 5.19kw break power. It is also noted that the brake-specific fuel consumption is decreased for 25 % orange peel and bran oil Diesel blends, and it slightly increases for 50%, 75%, and 100% orange peel and bran oil Diesel blend when compared to pure diesel.

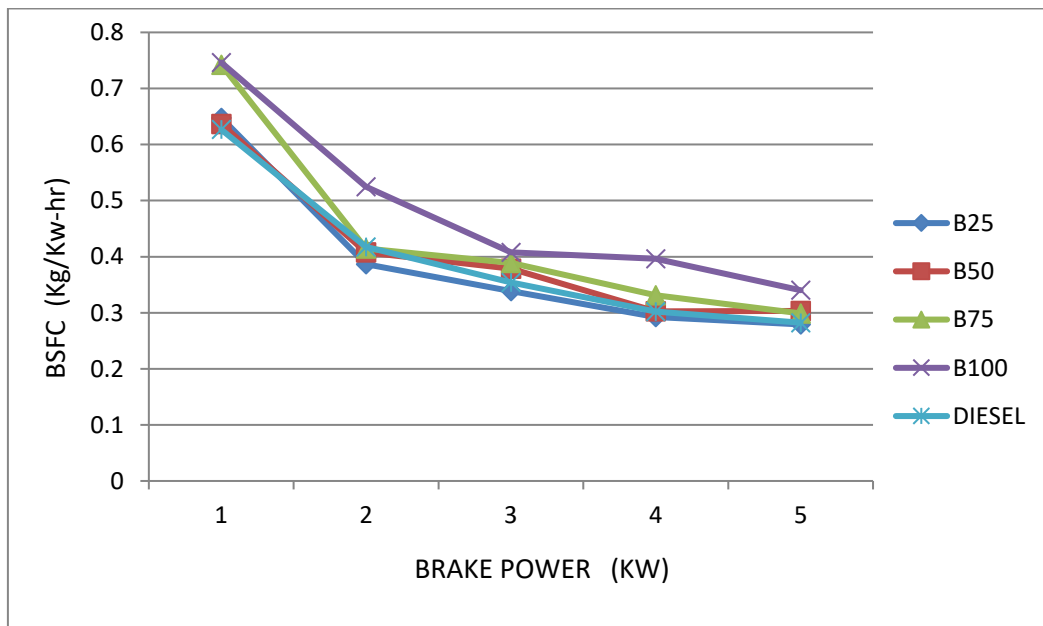


Figure 7.3 Brake specific fuel consumption against brake power

D. INDICATED SPECIFIC FUEL CONSUMPTION

Specific fuel consumption is the ratio that compares the Fuel used by the engine to the amount of power the engine produces. The variation of indicated specific fuel consumption with load is shown in Figure7.4. It can be observed from the figure that the indicated specific fuel consumption is 0.236 kg/kWh at 5.19kw brake power for diesel. When the engine is fueled with orange peel and bran

oil diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and 100% orange peel and bran oil, its indicated specific fuel consumption are 0.2334 kg/kWh, 0.2534 kg/kWh, 0.2498 kg/kWh and 0.2844 kg/kWh respectively at 5.19kw break power. It is also noted that the indicated specific fuel consumption is decreased for 25 % orange peel and bran oil Diesel blends, and it is slightly increasefor50%, 75%, and 100% orange peel and bran oil Diesel blend when compared to pure diesel.

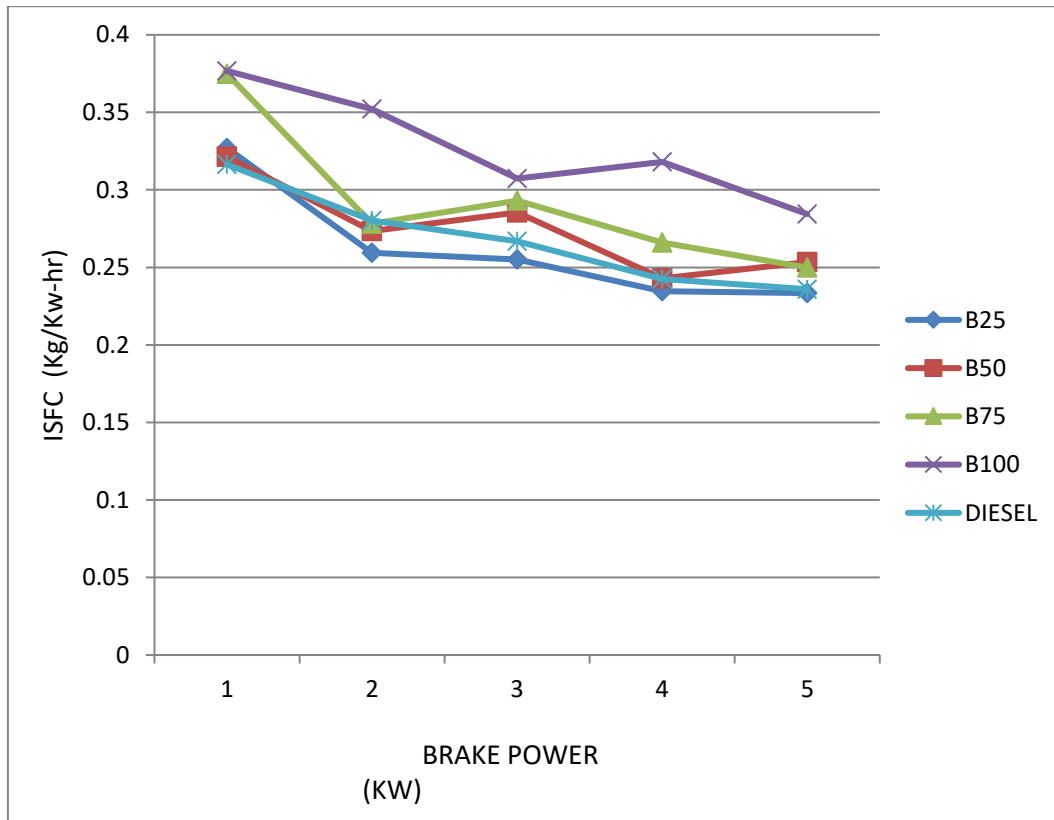


Figure 7.4 Indicated specific fuel consumption against brake power

E. CARBON MONOXIDE (CO)

The variations in carbon monoxide emission with brake power for all the test fuels are presented in Figure7.5. It can be observed from the figure that carbon monoxide (CO) is 0.36% at 5.19kw brake power for diesel. However, when the engine is fuelled with orange peel and bran oil -diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and

100% orange peel and bran oil, it gives the carbon monoxide (CO) of 0.15%, 0.2%, 0.2%, and 0.17% respectively at 5.19kw brake power. The higher viscosity of B100 results in poorer combustion and higher CO emission, especially at higher load levels. It is also observed that carbon monoxide (CO) is lower for 25%, 50%, 75%, and 100% orange peel and bran oil Diesel blends when compared to pure diesel.

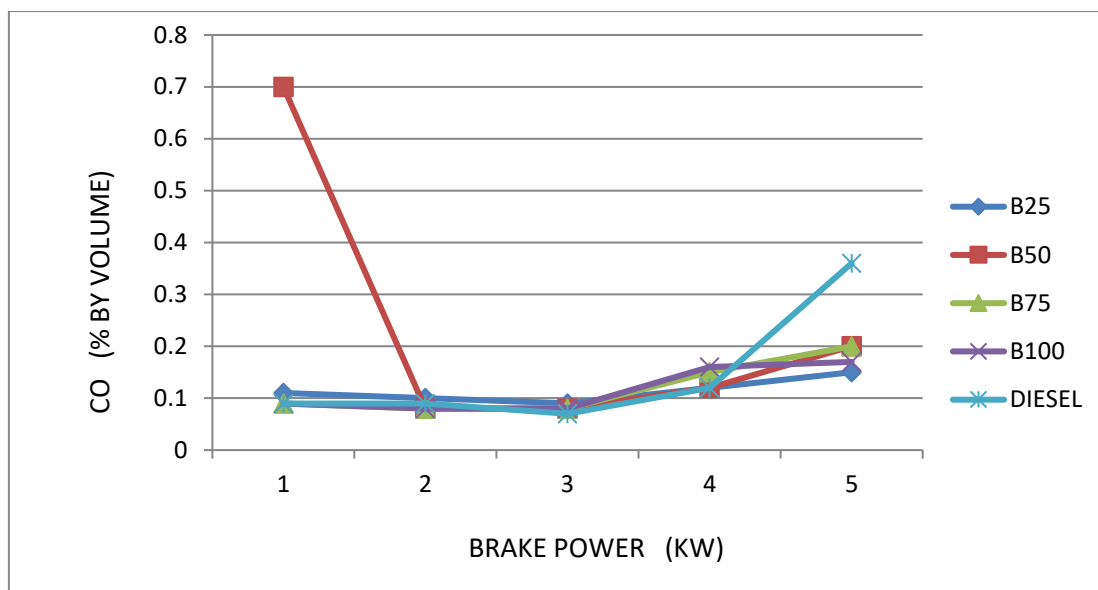


Figure 7.5 Carbon monoxide (CO) against brake power

F. CARBON DIOXIDE (CO₂)

The differences in CO₂ emission of B5 and B100 compared with diesel fuel. The variation of Carbon dioxide (CO₂) with brake power is shown in Figure 7.7. It can be observed from the figure that Carbon dioxide (CO₂) is 7% at 5.19kw brake power for diesel. A higher level of CO₂ emitted indicates better combustion of Fuel. However, when the engine

is fuelled with RSO-diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and 100% orange peel and bran oil, it gives the Carbon dioxide (CO₂) of 7%, 6.8%, 6%, and 6% respectively at 5.19kw brake power. It is also observed that Carbon dioxide (CO₂) is lower for 25%, 50%, 75%, and 100% orange peel and bran oil Diesel blends when compared to pure diesel.

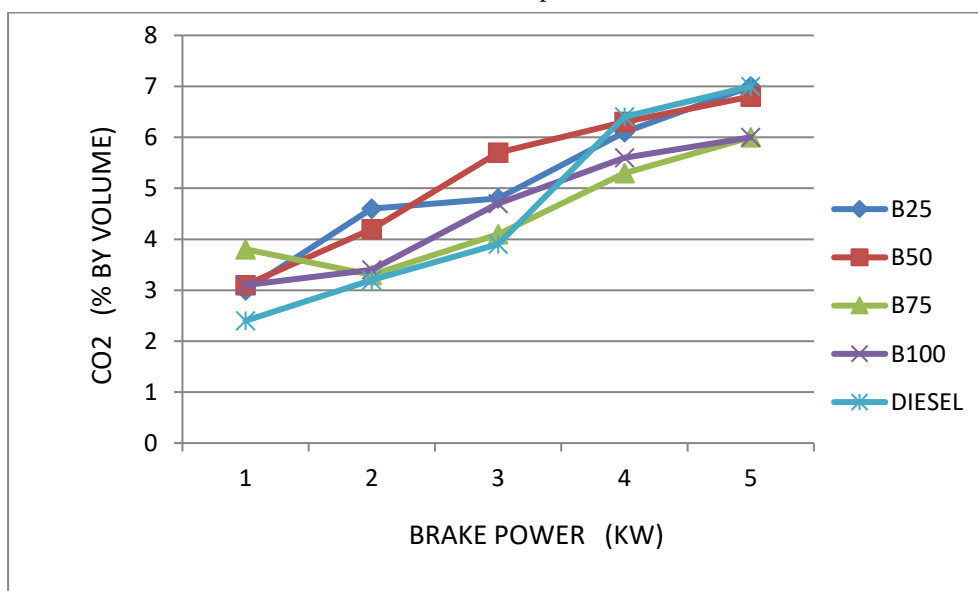


Figure 7.6 Carbon dioxide (CO₂) against brake power

G. HYDROCARBONS (HC)

Total hydrocarbon was measured by emission test for various blends of biodiesel and diesel at the rated engine speed of 1500 rpm under various load conditions. The variation of

hydrocarbons (HC) with brake power is shown in Figure 7.6. The HC emission also increases with the increase in loading and increase in the percentage of orange peel and bran oil in the diesel blend. It is noticed that higher HC emissions are obtained for all orange peel and bran oil -diesel blends compared to

diesel. It can be observed from the figure that a hydrocarbon (HC) is 154ppm at 5.19kw brake power for diesel. However, when the engine is fuelled with orange peel and bran oil -diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran oil, and 100% orange peel and bran oil, it gives the hydrocarbons (HC) of 88 ppm 102 ppm, 67 ppm, and 89 ppm respectively at 5.19kw brake power.

It is also observed that hydrocarbons (HC) are lower for 25%, 50%, 75%, and 100% orange peel and bran oil Diesel blends when compared to pure diesel. The increase of THC was due to insufficient combustion, caused by deposits and injector clogging.

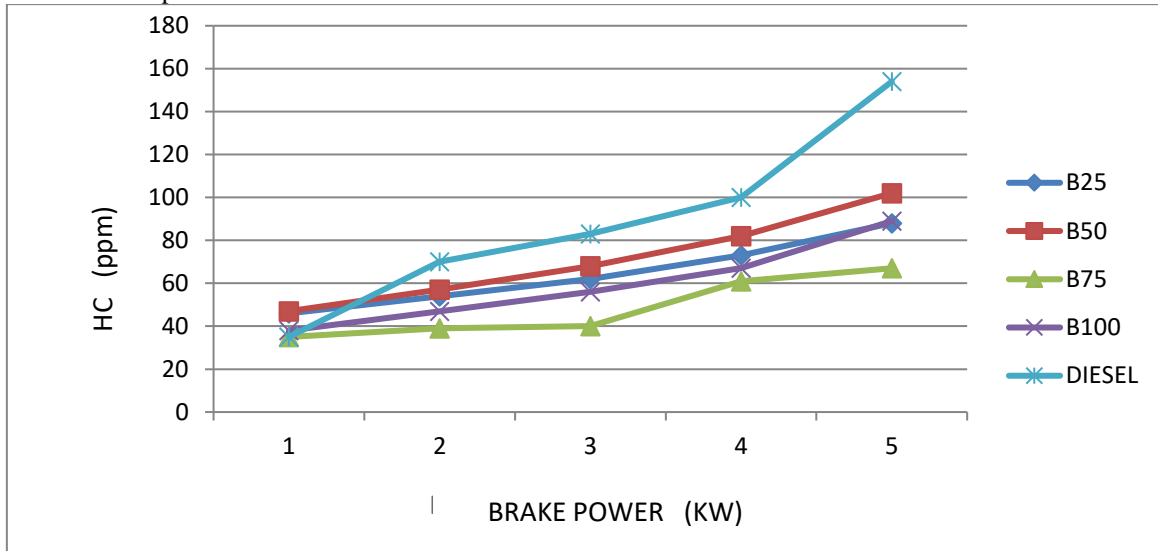


Figure 7.7 Hydrocarbons (HC) against brake power

H. OXYGEN (O₂)

The variation of Oxygen (O₂) with brake power is shown in Figure 7.8. It can be observed from the figure that Oxygen (O₂) is 12.1% at 5.19kw brake power for diesel. However, when the engine is fuelled with orange peel and bran oil -diesel blends such as 25% orange peel and bran oil 50%, orange peel and bran oil 75%, orange peel and bran oil and

100% orange peel and bran oil, it gives the Oxygen (O₂) of 18.8%, 11.1%, 18.32%, and 11.21 % respectively at 5.19kw brake power. It is also observed that Oxygen (O₂) is lower for 50% and 100% orange peel and bran oil Diesel blends, and it is slightly higher for 25% and 75% orange peel and bran oil Diesel blend when compared to pure diesel.

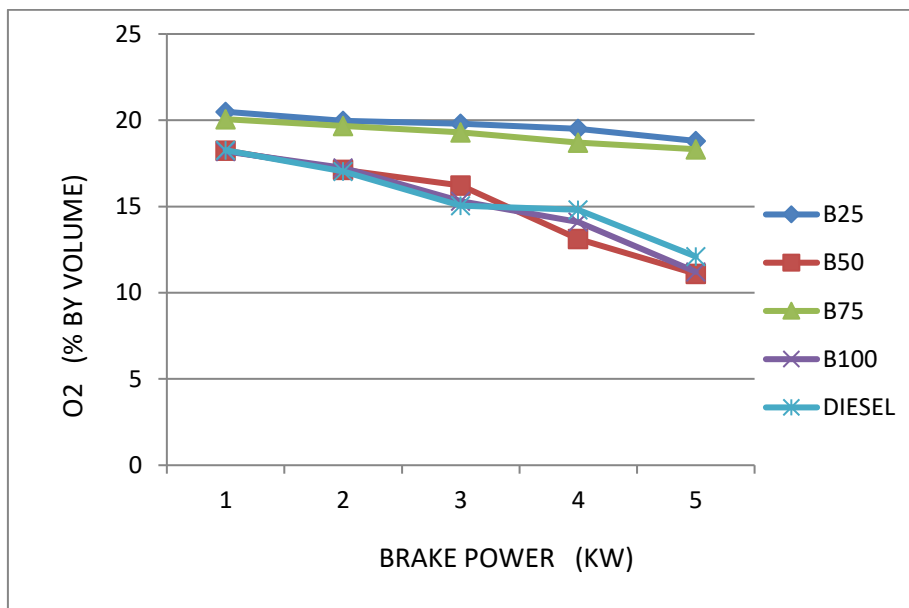


Figure 7.8 Oxygen (O₂) against brake power

I. NITROGEN OXIDE (NO_x)

The NO emission increases with an increase in engine load due to an increase in average gas temperature in the combustion chamber and hence the increase in NO emission for all test fuels. The variation of Nitrogen oxide (NO_x) with brake power is shown in Figure 7.5. It can be observed from the figure that Nitrogen oxide (NO_x) is 1230ppm at 5.19kw brake power for diesel. However, when the engine is fuelled with orange peel and bran oil -diesel blends such as 25% orange peel and bran oil, 50% orange peel and bran oil, 75% orange peel and bran

oil, and 100% orange peel and bran oil, it gives the Nitrogen oxide (NO_x) of 1073ppm, 924ppm, 824ppm, and 740ppm respectively at 5.19kw brake power. It is also observed that Nitrogen oxide (NO_x) is lower for 25%, 50%, 75%, and 100% orange peel and bran oil Diesel blends when compared to pure diesel. This reduction in NO with orange peel and bran oil operation is due to the lower intensity of premixed combustion than diesel. The NO emissions decreases as the amount of orange peel and bran oil increases in the diesel blend.

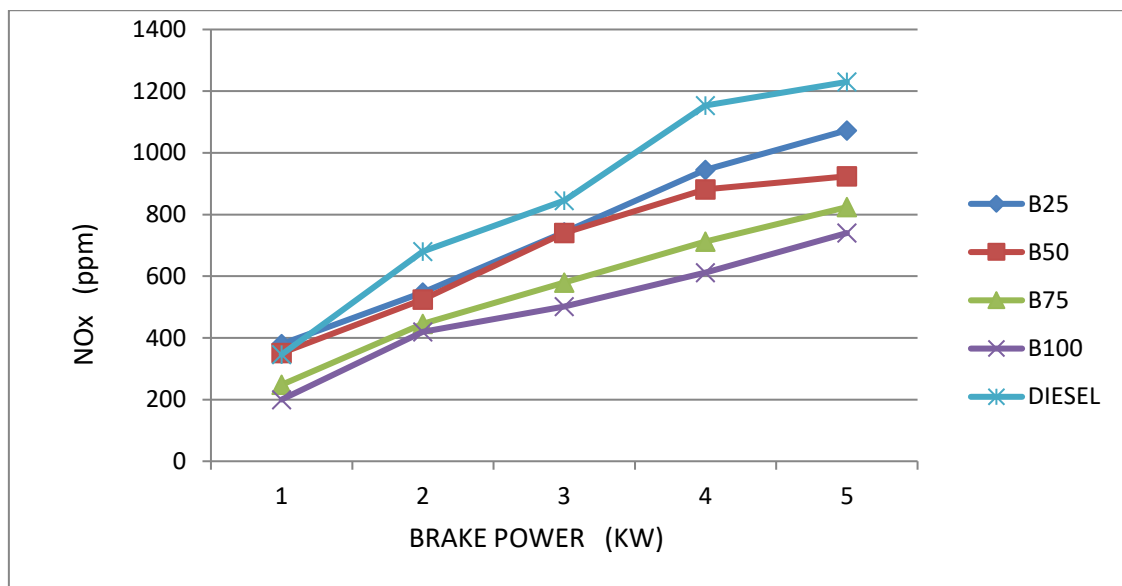


Figure 7.9 Nitrogen oxide (NO_x) against brake power

CONCLUSION

In this Theoretical study, methyl ester production from Mixed orange peel & bran oil has been successfully performed. The acid esterification-alkaline transesterification reaction was adopted. The first step is to reduce FFA content in vegetable oil by esterification with methanol and acid catalyst. The second step is the transesterification process, in which the triglyceride (TG) portion of the oil reacts with methanol and base catalyst to form ester and glycerol.

Various blends of biodiesel, diesel fuel are to test in diesel engines, and its performance emission characteristics are analyzed experimentally in future phase projects.

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