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Experimental Investigation on Injection Parameters by varying Compression Ratio Using Fish Oil Biodiesel in Diesel Engine

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ABSTRACT

Biodiesel synthesized from various vegetable and animal fat oils has proven as a potential resource and shown neutral effect on environmental pollution. The feedstock fish oil has been explored for the synthesis of Biodiesel through Transesterification from sodium hydroxide catalyst. Investigations carried out with bio-diesel operation in a single cylinder diesel engine. The performance and emission characteristics of fish oil bio-diesel compared with ordinary diesel in a diesel engine under varying load and results for various combinations of diesel and Fish oil bio-diesel with blends B-20, and B-30, parameters like total fuel consumption, brake specific fuel consumption, brake thermal efficiency are calculated and tabulated.

Based on the results obtained graphs are plotted to compare Performance parameters. Speed conditions of engine operations are fish oil bio-diesel shows higher fuel consumption rate, kinematic viscosity, brake fuel consumption. Most of the major exhaust pollutants such as CO, CO2 and HC are reduced with the use of bio-diesel and the blend as compared to neat diesel. The exhaust gas temperature increases by increasing the blends as compared to neat diesel. Among the blends, B30 shows the better performance and emission characteristics. Results obtained at compression ratio 17.5 and injection pressure 200bar showed better performance characteristics when compared with others. In terms of fuel properties and exhaust emission characteristics, fish oil bio-diesel can be regarded as an alternative to diesel fuel.

***KEYWORDS**: Biodiesel; Transesterification; Emission; compression ratio.*

1. INTRODUCTION

Energy is considered as a critical factor for economic growth, social development and human welfare. Since their exploration, the fossil fuels continued as the major conventional energy source with increasing trend of modernization and industrialization, the world energy demand is also growing at faster rate. To cope up the increasing energy demand, majority of the developing countries import crude oil apart from their indigenous production. This puts extra burden on their home economy. Hence, it is utmost important that the options for substitution of petroleum fuels be explored to control the burden of import bill. [1]. In view of the potential properties, large number of investigation has been carried out internationally in the area of vegetable oils as alternate fuels. Some of the vegetable oils from farm and forest origin have been identified. The most predominantly sunflower, soybean, cottonseed, canola, jatropha, corn, peanut oil etc. have been report as appropriate substitute of petroleum based fuels. The vegetables oils can be used in diesel engines by various techniques such as fuel modification by esterification, diesel-vegetable blends, vegetable oil heating etc. [5]

2. MATERIALS AND METHOD

To prepare a bio-diesel firstly its FFA(Free Fatty Acid) is checked and based on the value of FFA number of process needed to prepare a bio-diesel is determined involving following steps

Prepare 0.1N Sodium Hydroxide solution by mixing 4grams of NaOH crystals with 1lt of water. Take 25ml of 0.1N NaOH solution in a clean and dry burette. Take 50ml of Isopropyl alcohol in a clean and dry 250ml conical flask. Add few drops of NaOH solution and shake well. Measure 10gm of oil to the flask and shake it well. Heat the mixture above 60^0c. Allow the mixture to cool a little. Add few drops of phenolphthalein indicator. Titrate against 0.1N NaOH from burette. Titrate till colour persists for at least one minute. Note down the burette reading. Free fatty acid content is obtained by using the below formula. When the FFA value is more than four both esterification and transesterification are done to prepare a bio-diesel.

2.1 Production of Biodiesel (Transesterification)

In this process vegetable oil is chemically reacted with an alcohol like methanol in presence of a catalyst like sodium hydroxide. In the chemical reaction alcohol replaces glycerine. Glycerine that has been separated during the transesterification process is released as a by-product of the chemical reaction. Glycerine will either sink to the bottom of the reaction vessel or come to the surface depending on its phase.

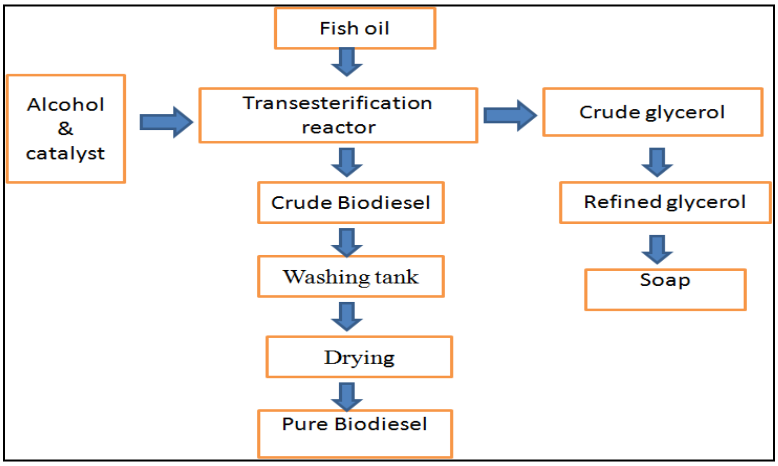


Fig 2.1: Transesterification Process Flow Char.

2.2 Purity of Reactants

The reactants used in the preparation of bio-diesel should be highly pure; any impurity present will adversely affect the quality of bio-diesel prepared. Wax like impurities should be completely absent.

3. STEPS INVOLVED IN TRANSESTERIFICATION

3.1 Magnetic Stirring

Fig 3.1: Magnetic Stirrer Used for Transesterification.

Oil is heated up to 65^{0}C. Adding required amount of Sodium Hydroxide and methanol. Solution is heated using the magnetic stirrer for two hours. Keeping the oil for settling process in a settling funnel for five hours

3.2 Methanol Recovery from Bio-Diesel

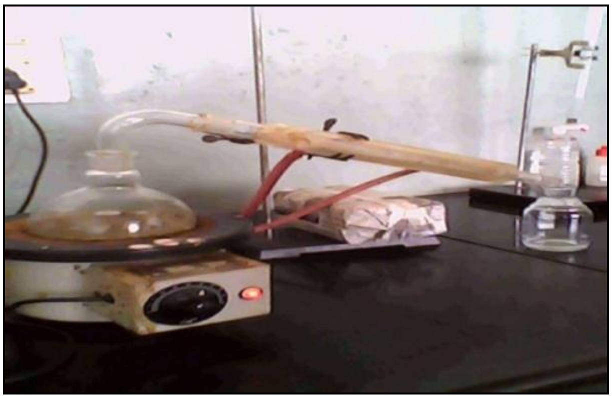


Fig 3.2: Methanol Recovery through Distillation.

Transfer the Bio-diesel into the round bottom flask. Maintain the temperature at 70^{0}C. Methanol stars evaporating. Collect the methanol in a conical flask. Switch off the system when the methanol condensation stops.

3.3 Washing Of Bio-Diesel

Fig 3.3: Bio-Diesel Washing.

Transfer the Bio-Diesel after methanol recovery into the plastic washing funnel. Spray 300ml of warm water slowly into Bio-Diesel. Water gets collected in the bottom of funnel. Keep 15min for settling for each trail. Remove the water and check the pH value. Repeat the process till pH of water reaches 7.

3.4 Heating Of Bio-Diesel

Fig 3.4: Bio-Diesel Heating

Add the magnetic pellet and adjust rpm to suitable speed. Heat the bio-diesel to the temperature of 393K (moisture evaporates). Allow the bio-diesel to cool gradually. Measure the quantity of final finished bio-diesel.

4. PROPERTIES OF FISH OIL BIO-DIESEL

4.1 Bio-Diesel Density

Measure 500ml of bio-diesel in a clean dry measuring cylinder. Bring down the temperature to the nearest reference temperature (15^0C). Allow the bio-diesel to settle. Gently lower the hydrometer into the bio-diesel in the cylinder until it floats freely.

The **density value obtained = 875 kg/m^3**.

a) Kinematic Viscosity Test At 40^0C

Viscosity is the fluid’s resistance to flow (shear stress) at a given temperature. Kinematic Viscosity takes into account the fluid density and centistokes is the engineering unit used to express kinematic viscosity. The time taken for the bio-diesel to flow through the capillary tube can be converted directly to kinematic viscosity.

Fig 4.1 : Kinematic Viscometer

Fill the bio-diesel in the cannon-Fenske viscometer tube NO: 100(direct type) at bulb marked at the top of tube. Heat to 40^0C and maintain the temperature for a period of 20-30min. The above process is done so that the oil will obtain the

prescribed temperature during testing. After 30min open the tube and simultaneously start the stop watch. Note the seconds in the stopwatch.
Kinematic viscosity = (Number of seconds) x (Standard factor of bulb of the viscometer).
The kinematic viscosity obtained = 4.3 mm2/sec.

b) Copper Corrosion Test

Copper Corrosion test assesses the relative degree of corrosivity of a petroleum product due to active sulphur compounds. Results are rated by comparing the stains on a copper strip to a colour match scale from 1-4. Pour the measured quantity of bio-diesel in the copper strip corrosion test bomb. Keep the copper strip in the oil in the test bomb apparatus, with bio-diesel in a water bath vertically. Maintain the temperature at $50^0C \pm 1^0C$
Result: No Copper corrosion.

c) Pensky-Martens Closed Cup Test

Fig 4.2: Pensky–Martens closed cup test

4.2 Flash Point

The flash point of a volatile material is the lowest temperature at which it can vaporize to form an ignitable mixture in air. Measuring a flash point requires an ignition source. At the flash point, the vapour may cease to burn when the source of ignitions removed. The flash point of a flammable liquid is the lowest temperature at which there will be enough flammable vapour to ignite when an ignition source is applied.

4.3 Fire point

The fire point of a fuel is the temperature at which it will continue to burn for at least 5s after ignition by an open flame. Most tables of material properties will only list material flash points, but in general the fire points can be assumed to be about 10^0C higher than the flash points. This is a point on which oxidation of a lubricating oil starts.

4.4 Measurement

There are two basic types of flash point measurement: open cup and closed cup. The measured flash point will actually vary with the height of the flame above the liquid surface, In the Pensky-Martens closed-cup flash-point test, a brass test cup is filled with a test specimen and fitted with a cover. The sample is heated and stirred at specified rates depending on what it is that is being tested. Pensky-Martens closed cup is sealed with a lid through which the ignition source can be introduced periodically.

Temperature in ^0C	Observation
100	No Flash
120	No Flash
140	No Flash
150	No Flash
160	No Flash
165	Flash
174	Fire

Table 4.1: Flash & Fire Point

4.5 Calorific value

Pour measured bio-diesel into small cup and close the lid. Combustion of bio-diesel takes place inside the calorimeter; the temperature steadily increases, after 30-40min there will be an indication of stable temperature (final temp of oil) on the digital meter and note down the temperature.

Fig 4.3: Bomb Calorimeter

Formula:

Calorific value, CV = 4.187 x (W + w) x t /m = 44216.71KJ/kg

Result:

Calorific value of pure bio-diesel and different blends of bio-diesel with diesel found out and is given as

Sample	Calorific Value (KJ/Kg)
Diesel	42800
Fish Oil Bio-Diesel	44216.71
20% Blend	43095.5
30% Blend	43240.71

Table 4.2: Calorific Value

5. EXPERIMENTAL SET UP AND PROCEDURE

5.1 Experimental set up

The experimental work carried out for the objectives, requires an engine test set-up adequately instrumented for acquiring necessary performance and emission characteristics. Water-cooled diesel engine has rated output of 5.2 kW at 1500 rpm and a compression ratio of 17.5:1. After the engine reach stabilized working condition, emissions like carbon monoxide (CO), Hydrocarbon (HC), Nitrous oxide (NOx), carbon dioxide (CO2) and exhaust gas temperature (EGT) were measured using a smoke-meter and an exhaust gas analyser. The experimental set-up and photographic views of engine are as shown in fig 5.1(a), 5.1(b), 5.1(c) and 5.1(d)

Fig 5.1(a): Photographic view of TV1, Kirloskar made, 4 Stroke Single Cylinder Engine.

Fig 5.2(b): Photographic View across Load Cell.

Fig 5.3(c): Photographic View across the Control Panel.

Fig 5.4(d): Photographic view of Exhaust Gas Analyser.

The engine has a compression ratio of 17.5:1 and a normal speed of 1500 rpm controlled by the governor. An injection pressure of 200bar, 250bar and 300bar are used for the study of best performance as specified by the manufacturer. The engine is first run with neat diesel with standard injection time crank angle (20.5^0C) at loading conditions such as 6.5, 13, 19.5 and 26Nm. Between two load trials the engine is allowed to become stable by running it for 3 minutes before taking the readings. Now the injection time is varied for advance crank angle (25.5^0C), the parameters are tabulated.

The engine is next run with the fish oil bio-diesel blend (B20) sample is poured into engine fuel tank and engine is started by hand cracking, the engine is allowed to become stable by running it for few minutes and then the engine is loaded using eddy current dynamometer and at each loading condition performance parameters namely speed, exhaust gas temperature, time taken for 20CC fuel consumption, brake powers etc. are measured under steady state conditions and are tabulated. Next the experiments are repeated for fish oil bio-diesel blend (B30). Finally graphs are plotted for brake specific fuel consumption, brake thermal efficiency with respect to loading conditions for diesel and bio-diesel blends. From these plots, performance characteristics of the engine are determined.

6. RESULTS AND DISCUSSION

This chapter contains the results of the experiments and analysis concerning the engine investigations carried out with bio-diesel operation in a single cylinder diesel engine. With the observed experiments results for various combinations of diesel and Fish oil bio-diesel blends parameters such as total fuel consumption, brake specific fuel consumption, brake thermal efficiency are calculated and tabulated for different Compression Ratio (CR) and different Injection Pressures (IP) as shown below.

PERFORMANCE RESULT FOR CR=17.5

Load (Nm)	**Speed (rpm)**	**Time for 20cc(sec)**	**BP (kW)**	**TFC (Kg/hr)**	**BSFC (kg/kWh)**	**BThE (%)**	**EGT (^{0}C)**
6.5	1442	107.53	0.98167	0.5508	0.559311	15.14469	205
13	1382	85.56	1.88164	0.6912	0.366724	23.098	257
19.5	1365	68.6	2.78774	0.8604	0.308724	27.43744	323
26	1350	56.56	3.67614	1.044	0.283952	29.83106	409

Table 6.1: Engine performance for Diesel, CR - 17.5, IP - 200bar, IT=STD (20.5^0).

Load (Nm)	**Speed (rpm)**	**Time for 20cc(sec)**	**BP (kW)**	**TFC (Kg/hr)**	**BSFC (kg/kWh)**	**BThE (%)**	**EGT (^{0}C)**
6.5	1385	111.41	0.94286	0.5292	0.562049	15.07091	194
13	1358	84.81	1.84896	0.6948	0.376505	22.49792	291
19.5	1344	67.06	2.74485	0.882	0.320748	26.40886	388
26	1330	54.06	3.62168	1.0908	0.301551	28.09009	494

Table 6.2: Engine performance for B-20, CR - 17.5, IP - 200bar, IT=STD (20.5^0).

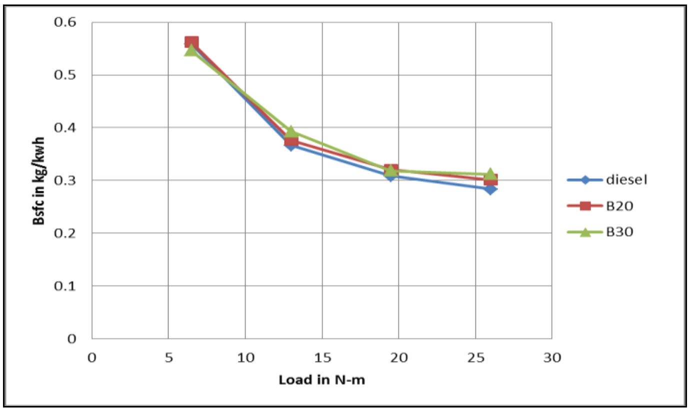
Load (Nm)	**Speed (rpm)**	**Time for 20cc(sec)**	**BP (kW)**	**TFC (Kg/hr)**	**BSFC (kg/kWh)**	**BThE (%)**	**EGT (^{0}C)**
6.5	1474	107.69	1.00345	0.5472	0.546355	15.50381	189
13	1398	78.87	1.90342	0.7488	0.393277	21.53845	200
19.5	1392	65.22	2.84288	0.9036	0.318425	26.60154	387
26	1368	50.78	3.72516	1.1628	0.312111	27.13965	499

Table 6.3: Engine performance for B-30, CR - 17.5, IP - 200bar, IT=STD (20.5^0).

Based on the above results, graphs are plotted to compare Performance parameters such as variation of brake thermal efficiency, brake specific fuel consumption against the varying load.

Brake Specific Fuel Consumption (BSFC):

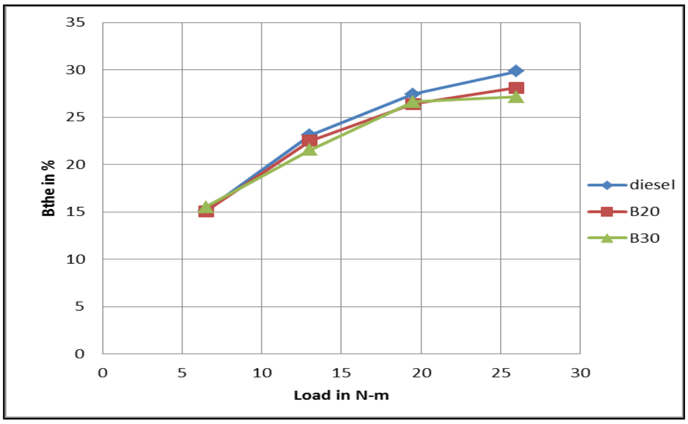
Graph 6.1, shows the variation of brake specific fuel consumption (BSFC) with load for different diesel and bio-diesel blends (B20, B30) & neat diesel at compression ratio of 17.5:1 and injection pressure of 200bar similarly for 250 and 300bar graph is plotted. As the load increases, BSFC decreases for all fuel blends. It is found that the specific fuel consumption for the blend B30 is close to diesel. It can be observed that for IP = 300bar will give better results with less specific fuel consumption even for higher loads.



Graph 6.1: BSFC v/s Load for CR – 17.5, IP = 200 bar, IT = STD (20.5^0)

Brake Thermal Efficiency (BTE):

This is defined as the ratio between the brake power output and the energy of the oil/fuel combustion.



Graph 6.2: BTE v/s load for CR=17.5, IP=200Bar, IT=STD (20.5^0)

Variation of Brake Thermal efficiency for CR-17.5 and injection pressure of 200bar, 250bar and 300bar with load for different fuel blends are shown in graph 6.2. From the graphs, it is found that brake thermal efficiency for bio-diesel in comparison to diesel engine is a better option for part load on which most engine runs. The maximum thermal efficiency for B30 (26.32%) was slightly less than that of diesel (26.48%) for the CR=17.5 & IP=300bar. The reduction in brake thermal efficiency is due to increased fuel consumption in blend (B30). Better results are obtained for IP=300bar.

PERFORMANCE RESULT FOR CR=20.1

Load (Nm)	**Speed (rpm)**	**Time for 20cc(sec)**	**BP (kW)**	**TFC (Kg/hr)**	**BSFC (kg/kWh)**	**BThE (%)**	**EGT (^{0}C)**
6.5	1467	116	0.998685	0.5076	0.509636	16.62086	187
13	1420	87	1.933377	0.6804	0.351003	24.13254	260
19.5	1382	69	2.822459	0.8568	0.303158	27.94113	355
26	1369	55	3.727878	1.0728	0.287953	29.41654	465

Table 6.4: Engine performance for Diesel, CR=20.1, IP= 200 bar, IT=STD (20.5^0)

Load (Nm)	**Speed (rpm)**	**Time for 20cc(sec)**	**BP (kW)**	**TFC (Kg/hr)**	**BSFC (kg/kWh)**	**BThE (%)**	**EGT (^{0}C)**
6.5	1405	106.25	0.95647	0.5544	0.580955	14.58044	188
13	1379	83.53	1.87755	0.7056	0.376453	22.50102	268
19.5	1360	66.11	2.77752	0.8928	0.321529	26.34467	365
26	1346	50.44	3.66524	1.17	0.319351	26.5244	475

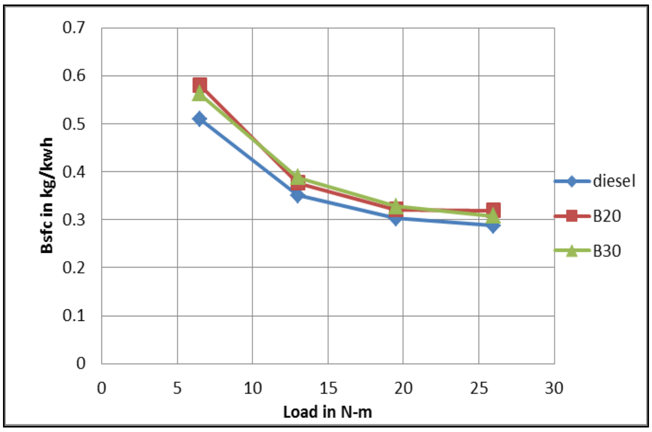
Table 6.5: Engine performance for B20, CR=20.1, IP= 200 bar, IT=STD (20.5^0)

Load (Nm)	Speed (rpm)	Time for 20cc(sec)	BP (kW)	TFC (Kg/hr)	BSFC (kg/kWh)	BThE (%)	EGT (^{0}C)
6.5	1470	104.94	1.00072	0.5616	0.562198	15.0669	189
13	1396	80.03	1.90070	0.738	0.388132	21.82397	276
19.5	1389	63.53	2.83675	0.9288	0.327601	25.85639	379
26	1373	51.34	3.73877	1.1484	0.307583	27.53924	485

Table 6.6: Engine performance for B30, CR=20.1, IP= 200bar, IT=STD (20.5^0)

Brake Specific Fuel Consumption (BSFC):

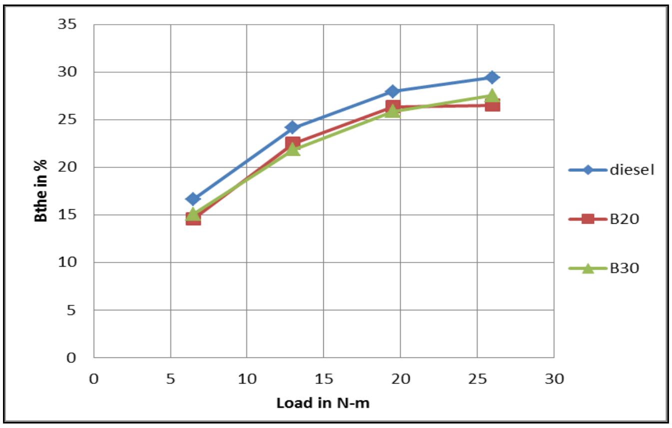
The brake specific fuel consumption is the mass rate of fuel consumption per unit brake power. Graph 6.3, shows the variation of brake specific fuel consumption (BSFC) with load for different diesel and bio-diesel blends (B20, B30) & neat diesel at compression ratio of 20.1:1 and injection pressure of 200bar. Similarly 250 and 250bar graph is plotted. As the load increases, BSFC decreases for all fuel blends. It is found that the specific fuel consumption for the blends B20 (0.31) and B30 (0.31) are close to diesel (0.3). It can be observed that for B30, IP=200bar BSFC=0.308 and for B30, IP=250bar BSFC=0.31 and for B30, IP=300bar BSFC=0.314. Hence we conclude that B30 will give better results with less specific fuel consumption even for higher loads.



Graph 6.3: BSFC v/s Load for CR=20.1, IP=200bar, IT= STD (20.5^0)

Brake Thermal Efficiency (BTE):

This is defined as the ratio between the brake power output and the energy of the oil/fuel combustion.



Graph 6.4: BTE v/s load for CR=20.1, IP=200bar, IT=STD (20.5^0)

Variation of Brake Thermal efficiency for CR 20.1 and injection pressure of 200bar load for different fuel blends are shown in graphs 6.4. Similarly for 250bar and 300bar graphs are plotted Brake thermal efficiency is increased due to reduced heat loss with increase in load. The brake thermal efficiency for diesel IP=200bar (29.42%), for B20 (26.52%), B30 (27.54%), For IP=250bar, diesel (28.44%), for B20 (27.83%), for B30 (27.31%) And for IP=300bar diesel (27.97%), B20 (27.16%) and for B30 (26.96%). The maximum thermal efficiency for B20 (27.16%) was slightly less than that of diesel (27.97%) for the CR=20.1 & IP=300bar. The results obtained are almost equal due to close calorific value for diesel and B30 blend. The reduction in BTE is due to increased fuel consumption in blend (B20). Better results are obtained for IP=300bar.

7. CONCLUSIONS

The present investigation evaluates the production from sodium hydroxide catalyst and performance and emission characteristics of fish oil bio-diesel compared with ordinary diesel in a diesel engine under varying load and speed conditions of engine operations. The following conclusions are drawn from this investigation.

- In comparison with the diesel, fish oil bio-diesel shows higher fuel consumption rate, kinematic viscosity, brake fuel consumption.
- Engine performance with bio-diesel does not differ greatly from that of diesel fuel. The B30 shows good brake thermal efficiency in comparison with diesel. A little increase in fuel consumption is often encountered due to increase in delay period because of high flash point.
- At higher loads engine suffers from nearly 1 to 1.5% brake thermal loss for blends.
- Most of the major exhaust pollutants such as CO, CO2 and HC are reduced with the use of bio-diesel and the blend as compared to neat diesel. But NOx emissions increase when fuelled with diesel and bio-diesel fuel blends as compared to conventional diesel fuel. This is one of the major drawbacks of bio-diesel.
- The exhaust gas temperature increases by increasing the blends as compared to neat diesel due to different characteristics of the diesel and bio-diesel.
- Among the blends, B30 shows the better performance and emission characteristics
- Results obtained at compression ratio 17.5 and injection pressure 200bar showed better performance characteristics when compared with others.
- In terms of fuel properties and exhaust emission characteristics, fish oil bio-diesel can be regarded as an alternative to diesel fuel.

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