EXPERIMENTAL INVESTIGATION ON DIESEL ENGINE USING FISH OIL METHYL ESTER AS ALTERNATIVE FUEL

RaviKiran[1] Ravi Prakash[2]
[1]Student,Dept of Mechanical Engineering,NMIT,Bengaluru ravikirannmit@yahoo.com
[2]Assistant Professor, Dept of Mechanical Engineering,NMIT,Bengaluru

Abstract— The depletion of world petroleum reserves results in two crisis that are rising prices of fuel and global warming problems. The energy security can be maintained by improving the efficiency of energy producing components. Efforts are being made to find the alternatives. Bio-fuels are those whose energy is derived from carbon fixation. Biodiesel is made from vegetable oil, animal fats, and non edible seeds. These resources are available and also can be grown in plenty. Bio-fuels can be used blended with diesel and can be used to run engines which reduces the dependence on the non renewable resources.

There are different types of bio-fuels like Karanja, Jatropha, Mahua etc. These fuels can be blended with ordinary diesel and can be used. Karanja, Jatropha are already being used in engines along with diesel. Bio-fuels can be blended alone with a diesel or two bio-fuels blended separately can be mixed with ordinary diesel. Bio-fuels are still a new entry and a lot of research is being carried to find more effective bio-fuels so that it adds to the overall performance wherever it is used.

Our project concentrates mainly on preparing biodiesel from fish oil and then comparing the properties of these with ordinary diesel and also experiments were conducted on Injection pressures of 200 and 225bars and compression ratio's 17.5:1 and 14:1 as constant to study the performance and emission characteristics of a TV1, Kirloskar make, direct injection, Four Stroke single cylinder diesel engine using blends of Fish oil methyl esters with diesel. The performance related parameters like BSFC and BTE were studied at different mixing proportions of bio-diesel and diesel. The emission tests also show that Carbon dioxide, Carbon monoxide and Hydro carbon are less for almost all of our blends when compared with diesel.

Keywords— Biofuels,Karanja,Jathropa,BSFC,BTE,Hydrocarbon.

I. 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.

There are limited reserves of the fossil fuels and the world has already faced the energy crisis of seventies concerning uncertainties in their supply. Fossil fuels are currently the dominant global source of CO2 emissions and their combustion is stronger threat to clean environment. Increasing industrialization, growing energy demand, limited reserves of fossil fuels and increasing environmental pollution have jointly necessitating the exploring of some alternative to the conventional liquid fuels, vegetable oils (edible and non edible oil) have been considered as appropriate alternatives to the conventional liquid fuels, vegetable oils have been considered as appropriate alternative due to their prevalent fuel properties. It was thought of as feasible option quite earlier. However despite the technical feasibility, vegetable oils as fuel could not get acceptance, as they were more expensive than petroleum fuels. This led to the retardation in scientific efforts to investigate the further acceptability of vegetable oils as alternate fuels. Later, due to numerous factors as stated above created resumed interest of researchers in vegetable oils as substitute fuel for diesel engines. 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.

II. OVER VIEW ON BIODIESEL

Bio-Diesel is not the regular vegetable oil and is not safe to swallow. However, biodiesel is considered biodegradable, so it is considered to be much less harmful to the environment if spilled. Biodiesel also has been shown to produce lower exhaust emissions than regular fuel. The best thing about biodiesel is that it is made from plants and animals, which are renewable resources. Bio-diesel is defined as the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Bio-diesel, as defined, is widely recognized in the alternative fuels industry as well as by the Department of Energy (DOE), the Environmental Protection Agency (EPA) and the American Society of Testing and Materials (ASTM).

Bio-diesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerin and methyl esters. The reaction is depicted in below. Virtually all of the bio-diesel used and produced in the U.S. to date has been made by this process, however, one additional process of importance is the direct reaction of a fatty acid with methanol, also in the presence of a catalyst, to produce a methyl ester in water.

The greatest driving force for the use of bio-diesel and bio-diesel blends is the need to have a fuel that fulfils all of the environmental and energy security needs previously mentioned which does not sacrifice operating performance. One of thelargest roadblocks to the use of alternative fuels is the change of performance noticed by users. There are several advantages of biodiesel as compared to conventional diesel.

Advantages of biodiesel are:
It helps to reduce carbon dioxide and other pollutants emission from engines.
Engine modification is not needed as it has similar properties to diesel fuel.
It comes from renewable sources whereby people can grow their own fuel.
Diesel engine performs better on biodiesel due to a high cetane number.
High purity of biodiesel would eliminate the use of lubricant.
Biodiesel production is more efficient as compared to fossil fuels as there will be no underwater plantation, drilling and refinery.
Biodiesel would make an area become independent of its need for energy as it can be produced locally.

III. PREVIOUS WORK

Sharanappa Godiganur et al. This paper reviews that Combustion tests for methyl ester of fish oil and its blends with diesel fuel were performed in a kirloskar H394 DI diesel engine, to evaluate fish biodiesel as an alternative fuel for diesel engine, at constant speed of 1500 rpm under variable load conditions. The tests showed no major deviations in diesel engine's combustion as well as no significant changes in the engine performance and reduction of main noxious emissions with the exception on NOx. Overall fish biodiesel showed good combustion properties and environmental benefits. [1]

F.Halek et al. This paper evaluated the method of transesterification of biodiesels and properties of biodiesels are compared with diesel also studied the emission characteristic like carbon monoxide, unburned hydrocarbons and particulate matter. From this work, it can be concluded that use of biodiesel in diesel engine results in substantial reductions of unburned hydrocarbons, carbon monoxide, and particulate matter. [2]

Cherung-Yuan Lin et al. In this study, the discarded part of mixed marine fish species were used as raw material to produce biodiesel using NaOH as a alkali catalyst which was used thereafter as engine fuel to investigate. The experimental results shows that, compared with commercial biodiesel and diesel fish biodiesel can be used as a alternate fuel. [3]

Rasim Behçet This paper deals with fish oils transesterification with the purpose of achieving the conditions for biodiesel usage in a single cylinder, direct injection compression ignition. Biodiesel produced from anchovy fish oil, biodiesel–diesel fuel blends of 25%:75%, 50%:50%, 75%:25% and diesel fuels were used in the engine to specify how the engine performance and exhaust emission parameters changed. Tests were performed at full load engine operation with variable speeds of 1000, 1500, 2000 and 2500 rpm engine speeds. As results of investigations on comparison of fuels with each other, there has been a decrease with 4.14% in fish oil methyl ester and its blends' engine torque, averagely 5.16% reduction in engine power, while 4.96% increase in specific fuel consumption have been observed. On one hand there has been average reduction as 4.576%, 21.3%, and 33.42% in CO2, CO, HC, respectively. [4]10

GVNSR Ratnakara Rao et al. Experimental investigations were carried out on a single cylinder variable compression ratio C.I engine using neat mahua oil as the fuel. Both the performance and exhaust analysis were carried out to find the best suited compression ratio. Tests have been carried out at 7 different compression ratios. All the experiments were carried out at standard test conditions like 70˚c cooling water temperature and at constant speed of 1500rpm. The result shows that 15.7 is the best compression ratio with mahua oil. [5]

Sharanappa Godiganur et al. A Cummins 6BTA 5.9 G2-1, 158HP rated power, turbocharged, DI, Water cooled diesel engine was run on diesel, methyl ester of mahua oil and its blends at constant speed of 1500rpm under variable load conditions. The volumetric blending ratios of biodiesel with conventional diesel fuel were set at 0,20,40,60 and 100. The results indicate that with the increase of biodiesel in blends CO, HC reduces significantly, fuel consumption and NOx emissions of biodiesel increases slightly compared with the diesel. Brake specific energy consumption decreases and thermal efficiency of engine slightly increases when operating on 20% biodiesel than that operating on diesel. [6]

Cherng-Yuan Lin et al. Biodiesel, which is manufactured from vegetables oils, animal fats, or algae can be an excellent alternative fuel to petroleum diesel due to its superior fuel properties and lower pollutant emissions. In contrast, fishing-boat fuel generally has much poorer fuel properties and a high sulfur content that can reach \ several hundred times that of the premium diesel used in land-based vehicles. Pollutant emissions from fishing boats are known to be a significant source of air pollution in the global environment. This study examines the use of biodiesel to replace fishing-boat fuel A to reduce pollutant emissions from fishing boats. The incremental cost, reduction in emissions, and cost–benefit corresponding to various weight proportions of biodiesel to replace fishing-boat fuel A are evaluated. This study also finds that a replacing 20 wt% of fishing-boat fuel A with biodiesel has the highest cost–benefit ratio, which implies a larger reduction in emissions with a lower fuel cost increase, and is the most suitable option for fishing boats in Taiwan. [7]

Metin Gumus et al. In this study, the effects of fuel injection pressure on the exhaust emissions and brake specific fuel consumption of a direct injection diesel engine have been discussed. The engine was fueled with biodiesel–diesel blends when running the 11 engine at four different fuel injection pressures (18, 20, 22, and 24 MPa) and four different engine loads in terms of mean effective pressure (12.5, 25, 37.5, and 50 kPa). The results confirmed that the BSFC, carbon dioxide, nitrogen oxides and oxygen and carbon monoxide emissions decreased due to the fuel properties and combustion characteristics of biodiesel. On the other hand, the increased injection pressure caused to decrease in BSFC of high percentage biodiesel–diesel blends (such as B20, B50, and B100), smoke opacity, the emissions of CO, UHC and increased the emissions of CO2, O2 and NOx. The increased or decreased injection pressure caused to increase in BSFC values compared to original injection pressure for diesel fuel and low percentage biodiesel–diesel blends (B5). [8]

Sukumar Puhan. N et al. In this study, mahua oil was transesterified with methanol using sodium hydroxide as catalyst to obtain mahua oil methyl ester. This biodiesel was tested in a single cylinder, four stroke, direct injection, constant speed, compression ignition diesel engine to evaluate the performance and emissions. [9]

Rosca Radu et al. The paper presents the results of a research concerning the use of a biodiesel type of fuel in D.I. Diesel engine, the fuel injection system and the engine were tested. The results indicated that the injection characteristics are affected when a blend containing 50% methyl ester and 50% petrodiesel is used as fuel. As a result, the engine characteristics are also affected, the use of biodiesel blend leading to lower output power and torque; the lower autoignation delay and pressure wave propagation time led to changes of the cylinder pressure and heat release traces and to lower peak combustion pressures. [10]

IV. PROPOSED METHODOLOGY

To prepare a biodiesel firstly its FFA(Free Fatty Acid) is checked and based on the value of FFA number of process needed to prepare a biodiesel is determined.

4.1 Determination of Free Fatty Acid Content in the Oil

It involves following steps:

- Prepare 0.1N Sodium Hydroxide solution by mixing 4grams of NaOH crystals with 1 liter of water.
- Take 25 ml of 0.1N NaOH solution in a clean and dry burette.
- Take 50 ml of Isopropyl alcohol in a clean and dry 250 ml conical flask.
- Add few drops of NaOH solution and shake well.
- Measure 10 grams of oil to the flask and shake it well.
- Heat the mixture above 60º c.
- 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.

FFA Content = $$\frac{28.2 * (\text{Normality of NaOH}) * (\text{Titration value})}{\text{Weight of oil}}$$

When the FFA value is more than four both esterification and transesterification are done to prepare a biodiesel.

4.2 Esterification

Esterification is the chemical process for making esters, which are compounds of the chemical structure R-COOR', where R and R' are either alkyl or aryl groups. The most common method for preparing esters is to heat a carboxylic acid R-CO-OH, with an alcohol R'-OH, while removing the water that is formed. A mineral acid catalyst is usually needed to make the reaction occur at a useful rate.

Esters can also be formed by various other reactions. These include the reaction of an alcohol with an acid chloride (R-CO-Cl) or an anhydride (R-CO-O-COR'). Early studies into the chemical mechanism of esterification, concluded that the ester product (R-CO-OR') is the union of the alkyl group (R-C=O-) from the acid, RCO-OH, with the alkoxide group from the alcohol rather than other possible combinations.

4.3 Transesterification

Transesterification is a chemical reaction used for the conversion of vegetable oil/Seed oil to biodiesel. In this process vegetable oil is chemically reacted with an alcohol like methanol in presence of a catalyst like sodium hydroxide. After the chemical reaction, various components of vegetable oil break down to form new compounds.

The triglycerides are converted into alkyl esters, which is the chemical name of biodiesel. If methanol is used in the chemical reaction, methyl esters are formed, but if ethanol is used, then ethyl esters are formed. Both these compounds are Bio-Diesel fuels with different chemical combinations. In the chemical reaction alcohol replaces glycerin.

Glycerin that has been separated during the transesterification process is released as a byproduct of the chemical reaction. Glycerin will either sink to the bottom of the reaction vessel or come to the surface depending on its phase. It can be easily separated by centrifuges, and this entire process is known as transesterification.

The biodiesel produced by the process of transesterification has much lower viscosity, which makes it capable of replacing petroleum diesel in diesel engines. In earlier years when the process of transesterification was not known, the viscosity of vegetable oil was the major hindrance for its use as a fuel for motor engines. The transesterification process has been able to remove this problem. The byproduct of the transesterification chemical reaction is the glycerin that originally formed the bond between the chains of fatty acids. Glycerin can be used for various purposes. Thus during transesterification process nothing goes to waste. All the products and byproducts are utilized for various purposes.

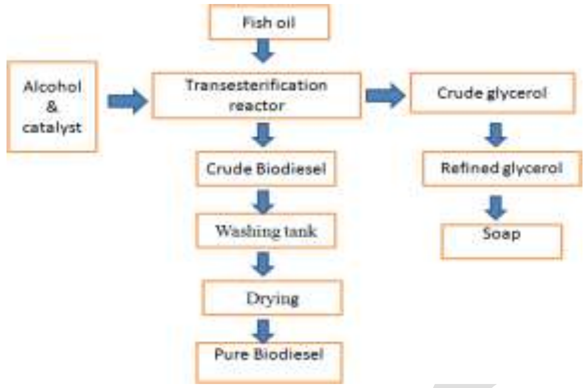


Figure 4.1: Transesterification Process flow chart

4.5 Steps Involved in Transesterification:

- Measuring the Free fatty acid content in the oil.
- Heating the oil up to 65ºC.
- Adding required amount of Sodium Hydroxide and methanol.
- Heating the solution using a magnetic stirrer for two hours.
- Keeping the oil for settling process in a settling funnel for five hours.
- After settling methanol is recovered from the solution through distillation

4.5.1 FFA-NAOH CHART

F.F.A(of oil)	NaOH(in gm)
0	3.5
1	4.5
2	5.5
3	6.5

Table 5.1: FFA-NaOH

4.5.2 FFA-H2SO4 CHART

F.F.A(of oil)	H2SO4(in gm)
1	0.25
2	0.5
3	0.75
4	1
5	1.25
6	1.5
7	1.75
8	2
9	2.25
10	2.5
11	2.75
12	3
13	3.25
14	3.5
15	3.75
16	4

Table 5.2: FFA-H2SO4

Fig 4.2: Magnetic stirrer used for transesterification

5.5.3 METHANOL RECOVERY FROM BIO-DIESEL

- Transfer the Bio-diesel into the reaction vessel (3 neck flask).
- Make the necessary arrangement for the distillation set up, like heating and fixing the double wall condenser along with the recovery flask.
- Maintain the temperature at 343K.
- Methanol stars evaporating.
- Collect the methanol in a conical flask.
- Switch off the system when the methanol condensation stops.

Fig 4.3: Methanol recovery through distillation

4.5.4 WASHING OF BIO-DIESEL

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

Fig 4.4: Biodiesel washing

4.5.5 HEATING OF BIO-DIESEL

- Transfer the washed Bio-Diesel from the washing funnel to the 1 liter beaker.
- 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.
- Store it in a clean and dry container.

Fig 4.5: Biodiesel heating

5. PROPERTIES OF FISH OIL BIO-DIESEL 6.1 BIO-DIESEL DENSITY

A hydrometer is the instrument used to measure the specific gravity (relative density) of Bio Diesel that is the ratio of density of Bio-Diesel to the density of water. The Hydrometer is made of glass and consists of cylindrical stem and a bulb weighed with mercury or lead shot to make it float up right. The hydrometer contains a paper scale inside the stem, so that specific gravity can be read directly.

5.2 KINEMATIC VISCOSITY TEST AT 40 **°c** 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.

5.3 COPPER TEST CORROSION TEST Copper Corrosion 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.

Result: No Copper corrosion

5.4 PENSKY-MARTENS CLOSED CUP TEST 6.4.1 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 ignition is removed.

5.4.2 FIRE POINT The fire point of a fuel is the temperature at which it will continue to burn for at least 5 seconds after ignition by an open flame. At the flash point a lower temperature, a substance will ignite briefly, but vapor might not be produced at a rate to sustain the fire. Most tables of material properties will only list material flash points, but in general the fire points can be assumed to be about 10 °C higher than the flash points. However, this is no substitute for testing if the fire point is safety critical. This is a point on which oxidation of a lubricating oil starts.

5.4.3 MEASUREMENT: There are two basic types of flash point measurement: open cup and closed cup. In open cup devices the sample is contained in an open cup which is heated, and at intervals a flame is brought over the surface. The measured flash point will actually vary with the height of the flame above the liquid surface, and at sufficient height the measured flash point temperature will coincide with the fire point The best known example is Cleveland open cup (COC).

VI. EXPERIMENTAL SET UP AND PROCEDURE

6.1 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. Fish oil methyl ester blends and pure Diesel were used to test a TV1, Kirloskar, single cylinder, 4-stroke, water-cooled diesel engine having a rated output of 5.2 kW at 1500 rpm and a compression ratio of 17.5:1. The engine was coupled with an eddy current dynamometer to apply different engine loads. The emissions from the engine were studied at different engine loads. 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 analyzer. The experimental set-up and photographic views of engine are as shown. in fig 6.1, 6.2, 6.3, 6.4& 6.5 and table 6.1 provides the engine specification.

Fig 6.1: Photographic view of TV1, Kirloskar made, 4 stroke single cylinder Engine

Fig 6.2: Photographic View across Load cell

Fig 6.3: Photographic View across the Control Panel

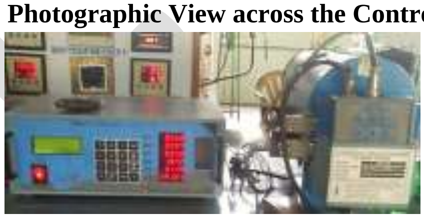


Fig 6.4: Photographic view of Exhaust gas analyzer

6.3 METHODOLOGY & EXPERIMENTAL PROCEDURE:

1. Switch on the mains of the control panel and set the supply voltage from servo stabilizer to 220volts. 2. The main gate valve is opened, the pump is switched ON and the water flow to the engine cylinder jacket (300 liters/hour), calorimeter (50 liters/hour), dynamometer and sensors are set. 3. Engine is started by hand cranking and allowed to run for a 20 minutes to reach steady state condition. 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 and 225bar are used for the study of best performance as specified by the manufacturer. The engine is first run with neat diesel at loading conditions such as 6.5, 13, 19.5 and 26 N-m. Between two load trials the engine is allowed to become stable by running it for 3 minutes before taking the readings. At each loading condition performance parameters namely speed, exhaust gas temperature, brake powers etc are measured under steady state conditions and diesel is drained out from the engine. The engine is next run with the fish oil biodiesel blend (B10) 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 various combinations of fish oil biodiesel blends. With the experimental results, the parameters such as total fuel consumption, brake specific fuel consumption, brake mean effective pressure, brake thermal efficiency are calculated. 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.

VII. EXPERIMENTAL RESULTS

This chapter contains the results of the experiments and analysis concerning the engine investigations carried out with biodiesel operation in a single cylinder diesel engine. With the observed experiments results for various combinations of diesel and Fish oil biodiesel 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. 7.1 PERFORMANCE RESULT

CR17.5	IP200 bar	DIESEL					
Load Nm	Speed rpm	Time For 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %
6.5	1441	110	0.98098	0.5432	0.5538	23252.07	15.1880
13	1402	86	1.9088	0.6948	0.3640	29741.02	23.1059
19.5	1392	67	2.8428	0.8919	0.3137	38175.04	26.8090
26	1389	54	3.7823	1.1066	0.2925	47365.33	28.7465

Table 7.1: Engine performance for Diesel, CR 17.5, IP 200 bar

CR17.5	IP200 bar	B10						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1442	110	0.9816	0.5465	0.5567	23149.48	15.2659	189
13	1401	84	1.9075	0.7157	0.3752	30314.79	22.6524	228
19.5	1386	63	2.8306	0.9542	0.3371	40419.73	25.2111	304
26	1390	51	3.7850	1.1788	0.3114	49930.25	27.2905	382

Table 7.2: Engine performance for B10, CR 17.5, IP 200 bar

CR17.5	IP200 bar	B20						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1444	108	0.9830	0.5600	0.5696	23473.52	15.0761	200
13	1407	83	1.9156	0.7286	0.3803	30543.86	22.5788	245
19.5	1393	64	2.8449	0.9450	0.3321	39611.57	25.8553	318
26	1384	52	3.7687	1.1630	0.3086	48752.7	27.8290	392

Table 7.3: Engine performance for B20, CR 17.5, IP 200 bar

CR17.5	IP200 bar	B30						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1441	107	0.9809	0.5685	0.5796	23587.72	14.9719	216
13	1405	81	1.9129	0.75111	0.3926	31159.09	22.1015	268

19.5	1392	62	2.8428	0.9812	0.3451	40707.85	25.1410	335
26	1390	52	3.7850	1.1700	0.3091	48356.28	28.0743	398

Table 7.4: Engine performance for B20, CR 17.5, IP 200 bar

CR17.5	IP225 bar	DIESEL						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1426	112	0.9707	0.5335	0.5496	22836.86	15.3032	191
13	1385	86	1.8857	0.6948	0.3684	29741.02	22.8257	248
19.5	1374	68	2.8061	0.8788	0.3131	37613.65	26.8573	335
26	1355	51	3.6895	1.1717	0.3175	50151.53	26.4859	424

Table 7.5: Engine performance for Diesel, CR 17.5, IP 225 bar

CR17.5	IP225 bar	B10						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1425	103	0.9701	0.5636	0.6016	24722.74	14.1259	196
13	1384	79	1.8843	0.7610	0.4038	40419.73	25.0110	245
19.5	1375	63	2.8081	0.9542	0.3398	40419.73	25.011	343
26	1348	50	3.6706	1.2024	0.3275	50928.85	25.946	431

Table 7.6: Engine performance for B10, CR 17.5, IP 225 bar

CR17.5	IP225 bar	B20						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1426	105	0.97077	0.5760	0.5933	24144.19	14.4746	208
13	1379	76	1.8775	0.7957	0.4238	33357.11	20.2631	257
19.5	1368	64	2.7938	0.9450	0.3382	39611.57	25.3913	359
26	1349	48	3.6734	1.2600	0.3430	52815.42	25.0387	452

Table 7.7: Engine performance for B20, CR 17.5, IP 225 bar

CR17.5	IP225 bar	B30						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1417	101	0.9646	0.6023	0.6244	24988.98	13.8970	220
13	1379	80	1.8775	0.7605	0.4050	31548.58	21.4247	271
19.5	1375	64	2.8081	0.9506	0.3385	39435.73	25.6350	386
26	1352	50	3.6815	1.2168	0.3305	50477.73	26.2565	459

Table 7.8: Engine performance for B30, CR 17.5, IP 225 bar

CR14	IP200 bar	DIESEL						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1445	106	0.9830	0.5640	0.5730	24129.50	14.6720	178

13	1406	81	1.9140	0.7380	0.3860	31576.88	21.8180	234
19.5	1390	66	2.8380	0.9050	0.3190	38753.45	26.3630	327
26	1363	50	3.7100	1.1950	0.3220	51154.56	26.1120	438

Table 7.9: Engine performance for Diesel, CR 14, IP 200 bar

CR14	IP200 bar	B10						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1444	103	0.9827	0.5836	0.5938	24722.74	14.3095	202
13	1398	80	1.9031	0.7515	0.3948	3183053	21.5210	240
19.5	1377	63	2.8118	0.9542	0.3393	40419.72	25.0391	332
26	1362	46	3.7083	1.3069	0.3542	55357.45	24.1112	450

Table 7.10: Engine performance for B10, CR 14, IP 200 bar

CR14	IP200 bar	B20						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1442	101	0.9815	0.5981	0.6071	25100.39	14.0770	208
13	1407	78	1.9150	0.7753	0.4048	32501.79	21.2120	259
19.5	1386	62	2.8302	0.9751	0.3445	40889.35	24.9141	349
26	1364	48	3.7137	1.2600	0.3392	52815.42	25.3092	458

Table 7.11: Engine performance for B20, CR 14, IP 200 bar

CR14	IP200 bar	B30						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1448	100	0.9856	0.6084	0.6172	25238.86	14.0583	215
13	1402	78	1.9086	0.7800	0.4086	32357.52	21.2312	265
19.5	1390	62	2.8384	0.9806	0.3454	40707.84	25.0971	368
26	1378	49	3.7518	1.2416	0.3309	51507.88	26.2180	478

Table 7.12: Engine performance for B30, CR 14, IP 200 bar

CR14	IP225 bar	DIESEL						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1436	98	0.9774	0.6097	0.6237	26099.26	0.13481	248
13	1394	77	1.8977	0.7761	0.4089	33217.24	20.5702	324
19.5	1374	57	2.8061	1.0301	0.3672	44098.75	22.9075	427
26	1360	44	3.7362	1.3283	0.3556	56838.40	23.6641	530

Table 7.13: Engine performance for Diesel, CR 14, IP 225 bar

CR14	IP225 bar	B10						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1435	95	0.9767	0.6328	0.6478	26804.66	13.1175	265
13	1394	76	1.8977	0.7863	0.4196	33505.82	20.3829	335
19.5	1377	57	2.8118	1.0547	0.3750	44672.87	22.6591	430

26	1360	44	3.7028	1.3663	0.3689	57871.00	23.0341	532

Table 7.14: Engine performance for B10, CR 14, IP 225 bar

CR14	IP225 bar	B20						
LOAD Nm	SPEED rpm	TIME FOR 20cc(sec)	BP KW	TFC kg/hr	BSFC kg/kw-hr	TEC kJ/hr	BTE %	EGT (°C)
6.5	1430	96	0.9733	0.6300	0.6472	26407.71	12.7190	267
13	1391	75	1.8936	0.8064	0.4258	33801.86	20.1674	343
19.5	1370	57	2.7975	1.0610	0.3792	44473.93	22.6447	448
26	1365	43	3.7165	1.4065	0.3784	58956.26	22.6937	543

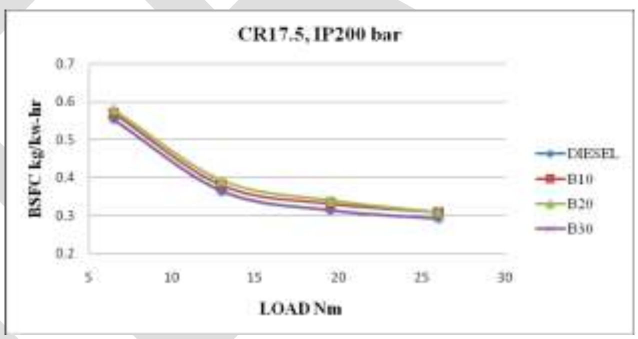
Table 7.15: Engine performance for B20, CR 14, IP 225 bar

CR14	IP225 bar	B30						
6.5	1405	98	0.9563	0.6208	0.6491	25753.94	13.3675	284
13	1389	76	1.8909	0.8005	0.4233	32209.03	21.1345	362
19.5	1374	56	2.8057	1.0862	0.3871	45059.92	22.4157	461
26	1363	45	3.7110	1.3520	0.3643	56086.36	23.8196	556
6.5	1405	98	0.9563	0.6208	0.6491	25753.94	13.3675	284

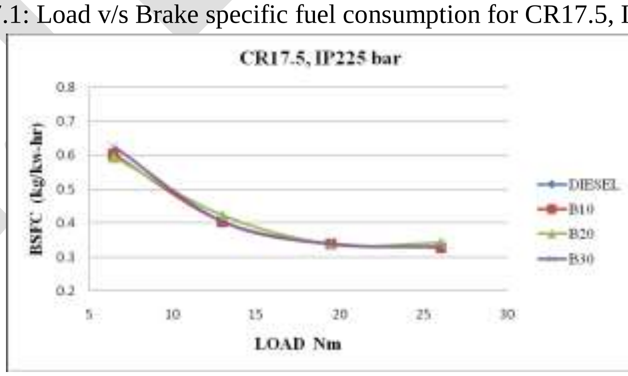
Table 7.16: Engine performance for B30, CR 14, IP 225 bar

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

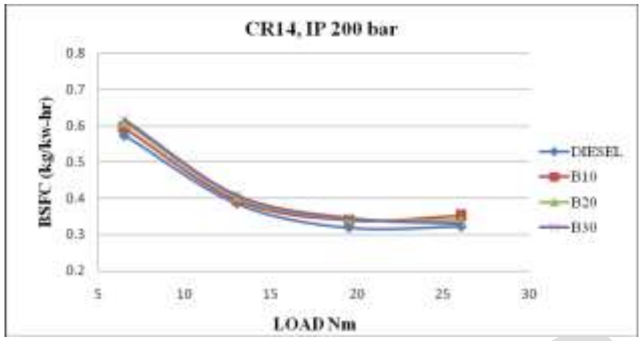
7.1.1 Brake Specific Fuel Consumption (BSFC): The brake specific fuel consumption is the mass rate of fuel consumption per unit brake power.



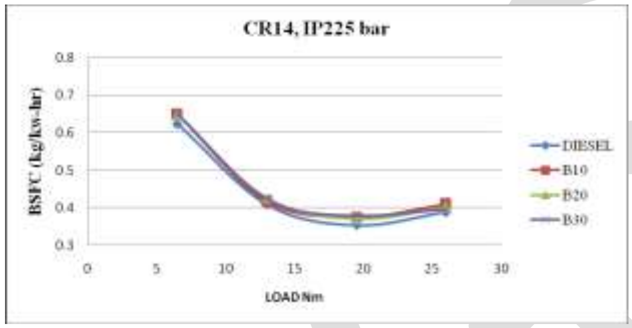
Graph 7.1: Load v/s Brake specific fuel consumption for CR17.5, IP200 bar



Graph 7.2: Load v/s Brake specific fuel consumption for CR17.5, IP225 bar



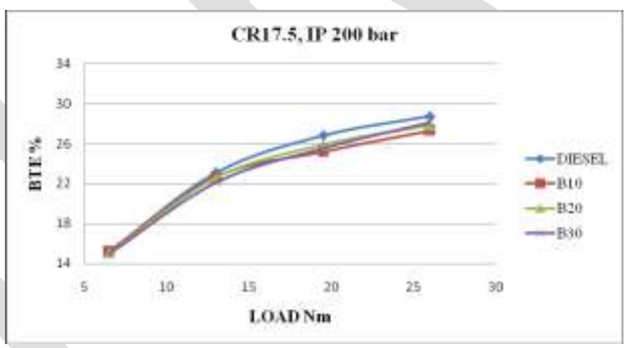
Graph 7.3: Load v/s Brake specific fuel consumption for CR14, IP200 bar



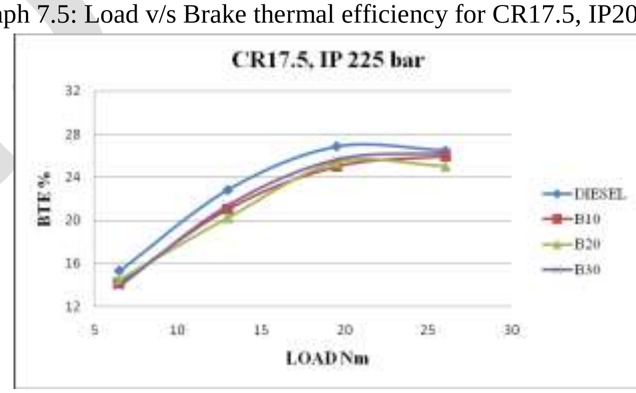
Graph 7.4: Load v/s Brake specific fuel consumption for CR14, IP225 bar

Graph 7.1, 7.2, 7.3 & 7.4 shows the variation of brake specific fuel consumption (BSFC) with load for different diesel–biodiesel blends & neat diesel at compression ratio of 17.5:1 and14:1 and injection pressure of 200 bar and 225 bar. 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 due to the fact that engine consumes more fuel with diesel-biodiesel blend fuels than with neat diesel fuel to develop the same power output due to the lower calorific value of diesel–biodiesel blend fuel.

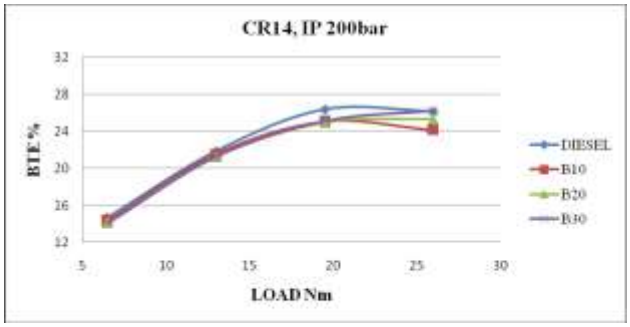
7.1.2 Brake Thermal Efficiency (BTE): This is defined as the ratio between the brake power output and the energy of the oil/fuel combustion.



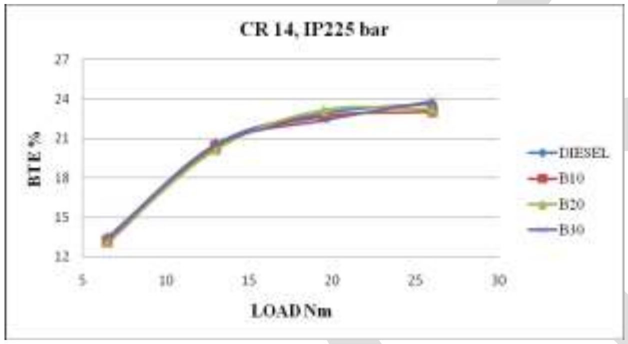
Graph 7.5: Load v/s Brake thermal efficiency for CR17.5, IP200 bar



Graph 7.6: Load v/s Brake thermal efficiency for CR17.5, IP225 bar



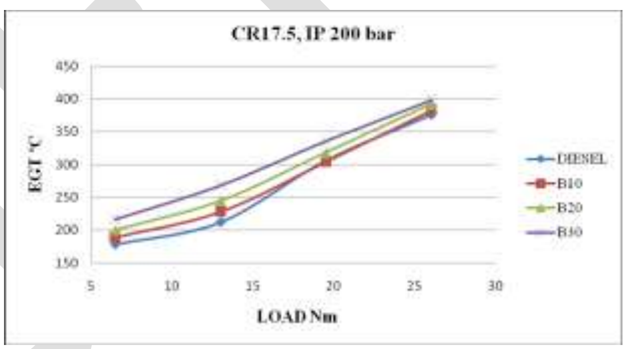
Graph 7.7: Load v/s Brake thermal efficiency for CR14, IP200 bar



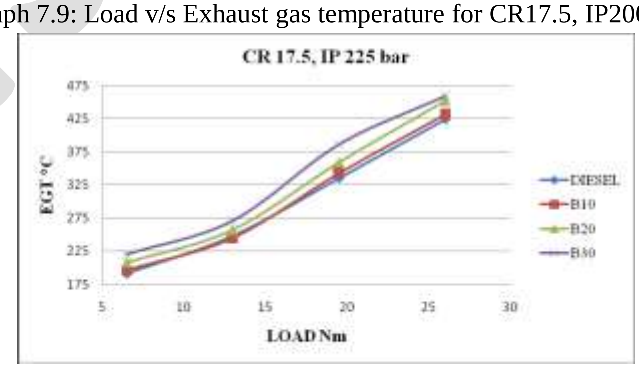
Graph 7.8: Load v/s Brake thermal efficiency for CR14, IP225 bar

Variation of Brake Thermal efficiency for CR 17.5 & 14 and injection pressure of 200bar and 225bar with load for different fuel blends are shown in graphs respectively. Brake thermal efficiency is increased due reduced heat loss with increase in load. From the graphs, it is found that brake thermal efficiency for biodiesel in comparison to diesel engine is a better option for part load on which most engine runs. The maximum thermal efficiency for B30 (28.07 %) was slightly less than that of diesel (28.7465) for the CR17.5 & IP200bar. The lower brake thermal efficiency obtained could be due to reduction in calorific value and increase in fuel consumption as compared to B30.

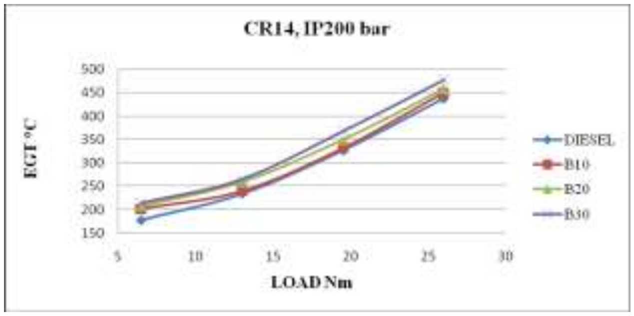
7.1.3 Exhaust gas temperature (EGT):



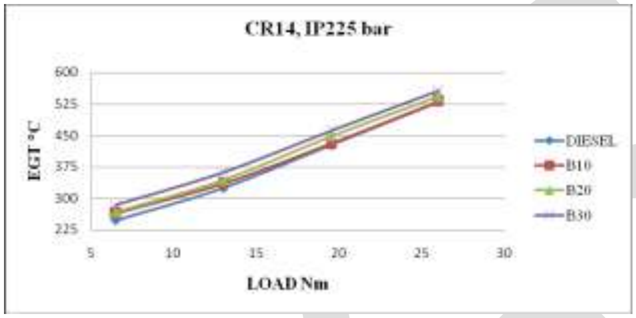
Graph 7.9: Load v/s Exhaust gas temperature for CR17.5, IP200 bar



Graph7.10: Load v/s Exhaust gas temperature for CR17.5, IP225 bar



Graph7.11: Load v/s Exhaust gas temperature for CR14, IP200 bar



Graph 7.12: Load v/s Exhaust gas temperature for CR14, IP225 bar

Graphs show the variation of exhaust gas temperature with load for various blends and diesel. The results show that the exhaust gas temperature increases with increase in load for all blends. At all loads, diesel was found to have the lowest temperature and the temperatures for various blends show an upward trend with increasing concentration of fish oil biodiesel in the blends. The biodiesel contains oxygen which enables the combustion process and hence the exhaust gas temperatures are higher in the engine to generate that extra power needed to take up the additional loading.

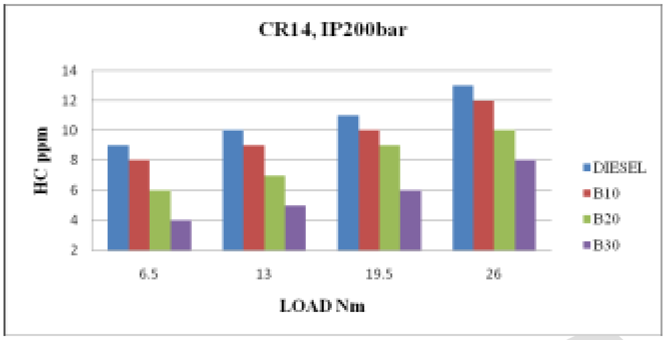
7.2 ENGINE EMISSION TEST RESULT

7.2.1 Hydrocarbon Emission (HC):

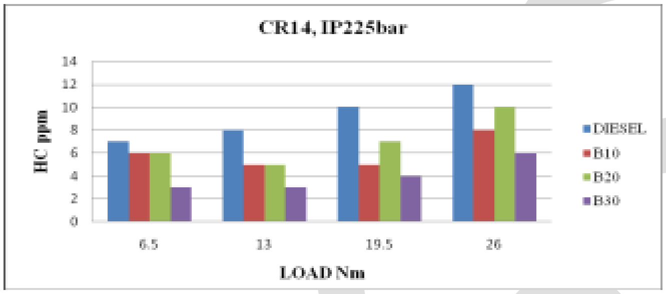
Hydrocarbons (ppm)								
LOAD (Nm	CR=17.5,IP=200bar				CR=17.5,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	4	3	3	2	5	4	3	3
13	5	4	4	3	6	5	5	5
19.5	5	5	4	3	7	6	5	5
26	7	6	6	5	9	8	7	7

Hydrocarbons (ppm)								
LOAD (Nm	CR=14,IP=200bar				CR=14,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	9	8	6	4	7	6	6	3
13	10	9	7	5	8	5	5	3
19.5	11	10	9	6	10	5	7	4
26	13	12	10	8	12	8	10	6

Table 7.17: Hydrocabon emission for different CR & IP



Graph7.15: Load v/s Hydrocarbon for CR14, IP200 bar



Graph 7.16: Load v/s Hydro carbon for CR14, IP225 bar

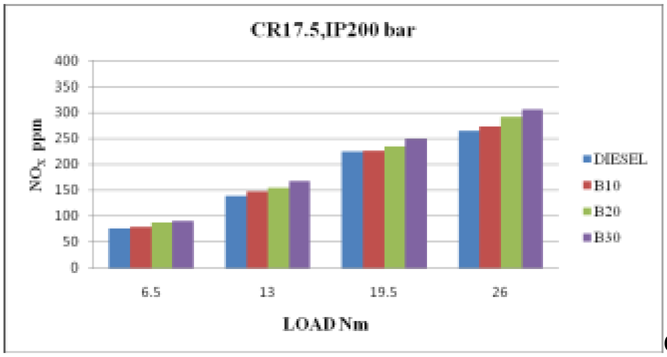
Graph shows the variation of hydro carbon emission with different load for different diesel–biodiesel blends & neat diesel. It is observed that HC emission of the various blends was lower at partial load, but increased at higher engine load. This is due to the availability of less oxygen for the reaction when more fuel is injected into the engine cylinder at higher engine load. It is also observed from the graphs that biodiesel blends give relatively lower HC as compared to the diesel. This is because of better combustion of the biodiesel inside the combustion chamber due to the availability of excess content of oxygen in the biodiesel blends as compared to clean diesel. The HC emissions are almost same for all blends & neat diesel at both injection pressures.

7.2.2 Nitrogen Oxides (NOx):

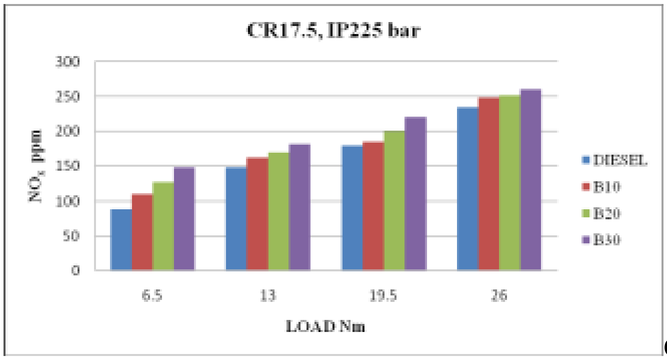
Nitrogen Oxides (ppm)								
LOAD (Nm	CR=17.5,IP=200bar				CR=17.5,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	76	79	87	90	88	110	127	148
13	139	148	155	167	148	162	170	181
19.5	224	226	235	249	179	185	200	220
26	265	274	292	306	235	249	252	260

Nitrogen Oxides (ppm)								
LOAD (Nm	CR=17.5,IP=200bar				CR=17.5,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	54	68	70	74	50	51	56	58
13	127	141	141	151	61	64	71	74
19.5	139	153	155	168	66	68	78	80
26	158	168	179	181	78	81	84	89

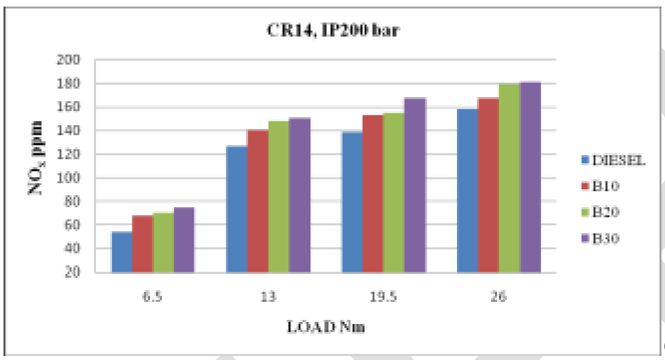
Table 7.18: Nitrogen Oxides emission for different CR & IP



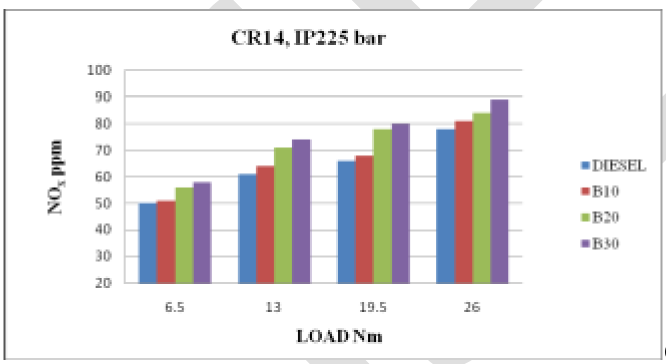
Graph 7.17: Load v/s Nitrogen Oxides for CR17.5, IP200 bar



Graph 7.18: Load v/s Nitrogen Oxides for CR17.5, IP225 bar



Graph7.19: Load v/s Nitrogen Oxides for CR14, IP200 bar



Graph 7.20: Load v/s Nitrogen Oxides for CR14, IP225 bar

Variation of nitrogen oxides for CR 17.5 & 14 and injection pressure of 200bar and 225bar with load for different fuel blends are shown in graphs respectively. Anything which causes combustion temperatures to rise will also cause NOx emissions to rise. Misfire can also cause NOx to rise because of the increase in oxygen that it causes in the catalytic converter feed gas. NOx is more likely to cause respiratory problems such as asthma, coughing, etc.

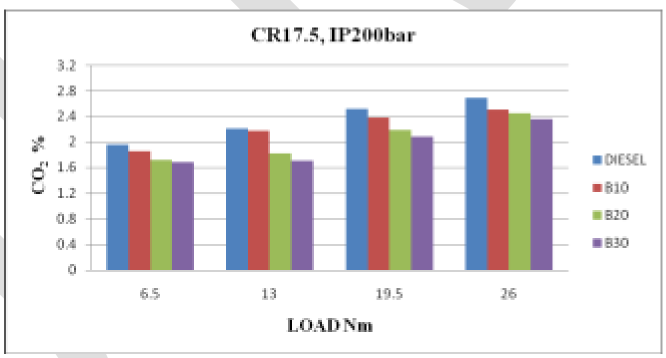
NOx emissions are extremely undesirable. Three conditions which favor NOx formation are higher combustion temperature, more oxygen content and faster reaction rate. The above conditions are attained in biodiesel combustion very rapidly as compared to neat diesel. Hence, NOx formations for biodiesel blends are always greater than neat diesel. It can be observed from graphs that at higher power output conditions, due to higher peak temperatures, the NOx values are likely higher for diesel-biodiesel blends.

7.2.3 Carbon dioxide (CO2)

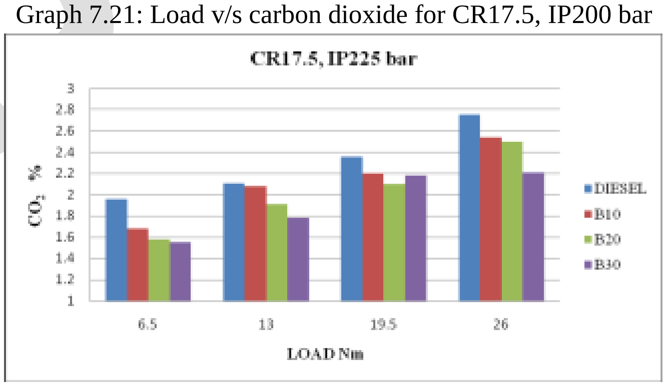
LOAD (Nm	Carbon dioxide %							
	CR=17.5,IP=200bar				CR=17.5,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	1.96	1.85	1.72	1.68	1.96	1.68	1.58	1.55
13	2.21	2.28	1.82	1.71	2.11	2.08	1.91	1.78
19.5	2.52	2.38	2.19	2.08	2.36	2.22	2.1	2.18
26	2.69	2.51	2.45	2.38	2.75	2.54	2.5	2.21

LOAD (Nm	Carbon dioxide %							
	CR=17.5,IP=200bar				CR=17.5,IP=225bar			
	DIESEL	B10	B20	B30	DIESEL	B10	B20	B30
6.5	1.81	1.76	1.74	1.69	1.68	1.42	1.44	1.38
13	1.96	1.87	1.84	1.80	1.65	1.38	1.31	1.29
19.5	2.05	1.94	1.96	1.95	1.81	1.52	1.51	1.32
26	2.48	2.18	18.05	2.11	1.97	1.44	1.48	1.36

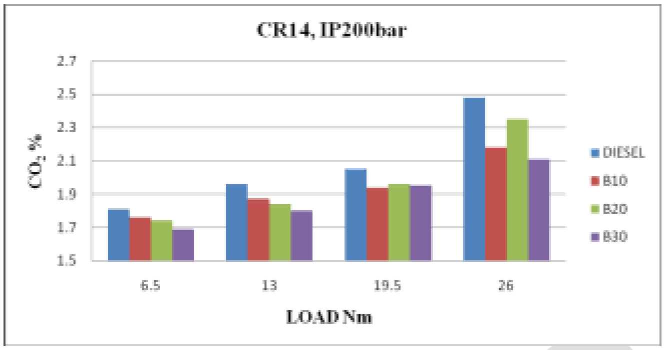
Table 7.19: Carbon dioxide emission for different CR &IP



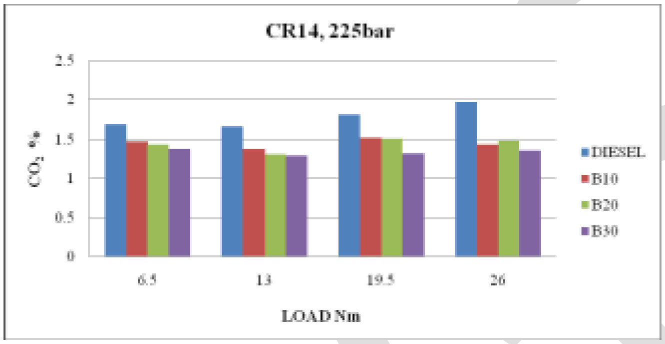
Graph 7.21: Load v/s carbon dioxide for CR17.5, IP200 bar



Graph 7.22: Load v/s carbon dioxide for CR17.5, IP225 bar



Graph 7.23: Load v/s carbon dioxide for CR14, IP200 bar



Graph 7.24: Load v/s carbon dioxide for CR14, IP225 bar

Graph shows the variation of CO2 emissions with load for different diesel–biodiesel blends & neat diesel at compression ratio of 17.5:1 and injection pressure of 200 bars and 225bars and 14:1 and injection pressure of 200 bars and 225bars. Carbon Dioxide is measured by an exhaust analyzer in percent (%) or parts per hundred. Carbon dioxide is a by-product of efficient and complete combustion. Near perfect combustion will result in carbon dioxide levels which approach the theoretical maximum of 15.5%. Carbon dioxide levels are affected by air/fuel ratio, spark timing, and any other factors which effect combustion efficiency.

Graph shows the emission levels of CO2 for various blends and diesel. Test measurements reveals that the CO2 emission for all blends were less as compared to diesel at all loads. The rising trend of CO2 emission with load is due to the higher fuel entry as the load increases. Bio-fuels contain lower carbon content as compared to diesel and hence the CO2 emission is comparatively lower.

7.3 CALCULATIONS

Sample calculation

For 10%Fish oil + 90%diesel (CR 17.5, Injection Pressure 200 bar)

1. Brake power,
   BP = (2πNT) / 60000 = (2π x 1442 x 6.5) / 60000 = 0.9816 KW
2. Total Fuel Consumption,
   TFC = (20 x 3600 x Specific gravity) / (t x 1000) = (20 x 3600 x 0.835) / (110 x 1000) = 0.5465 Kg/ hr
3. Specific fuel consumption
   SFC = TFC / BP = 0.5567 Kg/ KW hr

4. CV of blend
   CV= [density of diesel x % of diesel x CVD] + [density of BD x % diesel x CV of BD] [Density of diesel x % diesel] + [density of BD x % of BD]

CV = [830 x 0.9 x 42800] + [885 x 0.1 x 38604] [830 x 0.9] + [885 x 0.1] = 42356 KJ / kg

5. Brake Thermal Efficiency
   = (BP x 3600 x 100) / (TFC x CV) = (0.9816 x 3600 x 100) / (0.5465 x 42356) = 15.2662 %

7.4 Cost Analysis of Fish Oil Biodiesel

- Cost of the raw fish oil from market

- Cost of the materials required for the processing o NAOH

o Methanol

- Miscellaneous cost includes Transportation, power required for processing

Item	Cost per unit(lit/Kg)
Raw fish oil	32 Rs/lit
NAOH	70 Rs/kg
Methanol	35 Rs/lit

Table no 7.2

To produce 890 ml fish oil biodiesel requires one liter of raw fish oil. So recovery of fish oil biodiesel is 89%

For the processing of 1 lit of fish oil of FFA 2.3, it requires

 300 ml of Methanol

- 6.5 gm of NAOH

So total processing cost = (35*0.3) + (70*0.0065) + 5 = 16 = 16 Rs

The total cost per liter = (32 + 16) Rs = 48 Rs/lit

The by-product glycerin can also be sold and around 30 to 40% of methanol recovered, hence the cost can again be decreased.

So total final cost = (48 - 4) = 44Rs

VIII. FUTURE SCOPES

Need to study on biodiesel from Fish oil using different catalyst like CaO, CaTiO3, MgO.
Need to study the effect of biodiesel derived from Fish oil and its blend with diesel when directly injected at different injection pressures & injection timings in a single cylinder water-cooled compression ignition engine.

Conduct the experiment on multi-cylinder engine fuelled by Fish oil biodiesel and compare with single cylinder engine performance and emissions to know the effect of biodiesel operation in higher rated engines.

Performance of bio-fuelled engines can be improved by adding oxygenated fuel additives.

More blends of fuel can be brought under investigation

Need to study the performance and emission characteristics on modified piston and compare the results with base piston.

CONCLUSION

- In comparison with the diesel, fish oil biodiesel shows higher fuel consumption rate, kinematic viscosity, brake fuel consumption.
- Engine performance with biodiesel 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 the lower calorific value of the biodiesel
- 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 biodiesel and the blend as compared to neat diesel. But NOx emissions increase when fuelled with diesel– biodiesel fuel blends as compared to conventional diesel fuel. This is one of the major drawbacks of biodiesel.
- The exhaust gas temperature increases by increasing the blends as compared to neat diesel due to different characteristics of the diesel and biodiesel.

- 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 biodiesel can be regarded as an alternative to diesel fuel

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