"Improvement of Performance Characteristics of Calophyllum Bio-diesel Blends with Fossil Diesel Fuel & DEE as an Additive."

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Abstract

The world faces the crises of energy demand, rising petroleum prices & depletion of fossil fuel resources. Bio-diesel is mono-alkyl-ester of a long chain of fatty acids derived from renewable feedstock such as vegetable oils, animal fats by trans-esterification process. This review paper is related to the diesel engine performance & emission characteristics fueled with palm oil, jatropha oil, moringa oil, hone oil, palm fatty acid distillate(PFAD), Pongamia pinnata, tamanu, mustard oil, sunflower oil, olive oil, corn oil. From the comparison of properties such brake thermal efficiency, brake specific fuel consumption, unburned hydrocarbons, smoke &NOx, it is inferred that the bio-diesel prepared can be used as alternative fuel for CI engine. The study reveals that the effect of bio-diesel on CI engine when compared to diesel & evolves conclusions with respect to performance & emissions.

Keywords: Palm oil, jatropha oil, moringa oil, hone oil, palm fatty acid distillate(PFAD), Pongamia pinnata, tamanu oil, mustard oil, sunflower oil, olive oil, corn oil, NO_X, CI engine.

1. Introduction

Calophyllum inophyllum Linn. [Guttifereae (Clusiaceae)], commonly known as ‘Indian laurel' or ‘Alexandrian laurel' is a broad-leaved evergreen tree occurring as a littoral species along the beach crests, although sometimes occurring inland. It is known to have cancer chemopreventive agents, coumarins, and xanthones with antimicrobial activity.

It is well known that Calophyllum bio-diesel is non-toxic, contains no aromatics, has higher biodegradability than fossil fuel, is less pollutant to water & soil. It offers safer handling in the neat form & shows reduced oral & dermal toxicity, mutagenic & carcinogenic compounds. It is the most suitable fuel in environmental conditions & worker protection must meet high standards. Researchers recognized different complications related to the use of oil in the diesel engine, due to their high viscosity and low volatility so they form deposits in the fuel injector of the engine. These problems can be solved by dilution, micro-emulsion, pyrolysis, and transesterification. Trans-esterification is the reaction of oil with an alcohol in presence of a catalyst to form ester and glycerol (the saturated fatty acids get converted into unsaturated fatty acids) The methyl esters produced by transesterification are called biodiesel, which has a low viscosity and high cetane number.

In this project work, emission & fuel consumption measurements from a stationary diesel engine are described. The engine was fueled with fuel blends containing six different blends of biodiesel, at proportion up to 36 percent. In general, according to our results, the substitution of mineral diesel with biodiesels leads to a combination of positive & negative outcomes.

There are several key properties, which need to be characterized before using oil/biodiesel–diesel fuel blends in a diesel engine. These properties are kinematic viscosity, density, and flash point of the blend. It is important to figure out if the properties of the blended fuel meet the standard properties of diesel fuel requirements. To better predict fuel properties, mixing rules are developed as a function of oil/biodiesel volume fraction in the blend.

2. Experimental Work

The Calophyllum tree is valued for its hardiness and beauty as an ornamental tree. Oil from the nuts has been traditionally used for medicine and cosmetics and is today being produced commercially in the South Pacific. The tree grows best in direct sunlight but grows slowly. The annual yield of 20-100 kg/tree of whole fruits has been reported. Trees begin to bear significantly after 4-5 years. The nut kernel contains 50-70% oil and the mature tree may produce 1-10 kg of oil per year depending upon the productivity of the tree and the efficiency of the extraction process.

2.1 Pre-treatment

Every oil has to go through a set of processes before being put through a set of processes before it is finally put into the reactor for esterification process.The seeds are De-shelled and dried at a higher temperature at 100-105 for 30min in the oven. Then seeds are preceded for oil extraction through mechanical expeller at room temperature.

2.2 Filtration

The mixture is fed through filter paper in a filter press. This removes solid impurities from the crude oil.

2.3 Centrifugation

Centrifugation is carried out for removal of solid impurities and gums. The palm fatty acid distillate is fed to a centrifuge. These cause the solid impurities to settle down and are removed from palm fatty acid distillate.

2.4Demoisturing

As the mixture contains water, it is heated in the oven at 900C for 15 min for removal of moisture.

2.5 Esterification

Calophyllum oil contains 19.58% free fatty acids. The methyl ester is produced by chemically reacting Calophyllum oil with an alcohol (methyl), in the presence of a catalyst. A two-stage process is used for the transesterification of Calophyllum oil. The first stage (acid catalyzed) of the process is to reduce the free fatty acids (FFA) content in Calophyllum oil by esterification with methanol (99% pure) and acid catalyst sulfuric acid (98% pure) in one hour time at 57oC in a closed reactor vessel. The Calophyllum oil is first heated to 50oC then 0.7% (by wt. of oil) sulfuric acid is to be added to oil and methyl alcohol about 1:6 molar ratio (by the molar mass of oil) is added. Methyl alcohol is added in an excess amount to speed up the reaction. This reaction was proceeding with stirring at 650 rpm and the temperature was controlled at 55-57oC for 90 min with regular analysis of FFA every after 25-30 min. When the FFA is reduced up to 1%, the reaction is stopped. The major obstacle to acid catalyzed esterification for FFA is the water formation. Water can prevent the conversion reaction of FFA to esters from going to completion24. To achieve an acceptable percentage of FFA, we performed this stage two times.

2.6 Separation

Once esterification is complete we get two products glycerine and esterified oil. Each has a substantial amount of ethanol. The reacted mixture is neutralized if necessary. Glycerine is dense and gets separated from the bottom of settling tank. Centrifuge could also be used to separate material faster.

2.7 Demoisturisation

The esterified oil is heated in an oven at1000C for 15 min to remove moisture.

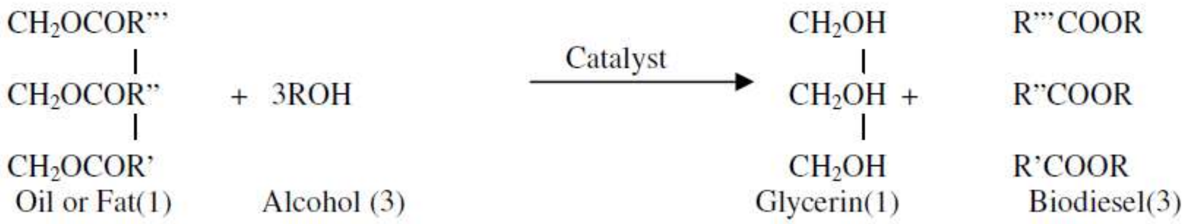
2.8 Transesterification

Transesterification is a base catalyzed reaction involving triglycerides and ethanol which yields mono-alkyl esters and glycerine. Transesterification or alcoholysis is the displacement of alcohol from an ester by another in a process similar to hydrolysis, except an alcohol is used instead of water. This process has been widely used to reduce the high viscosity of triglycerides. The transesterification reaction is represented by the general equation as below

RCOOR' + R"OH_RCOOR" + R'OH

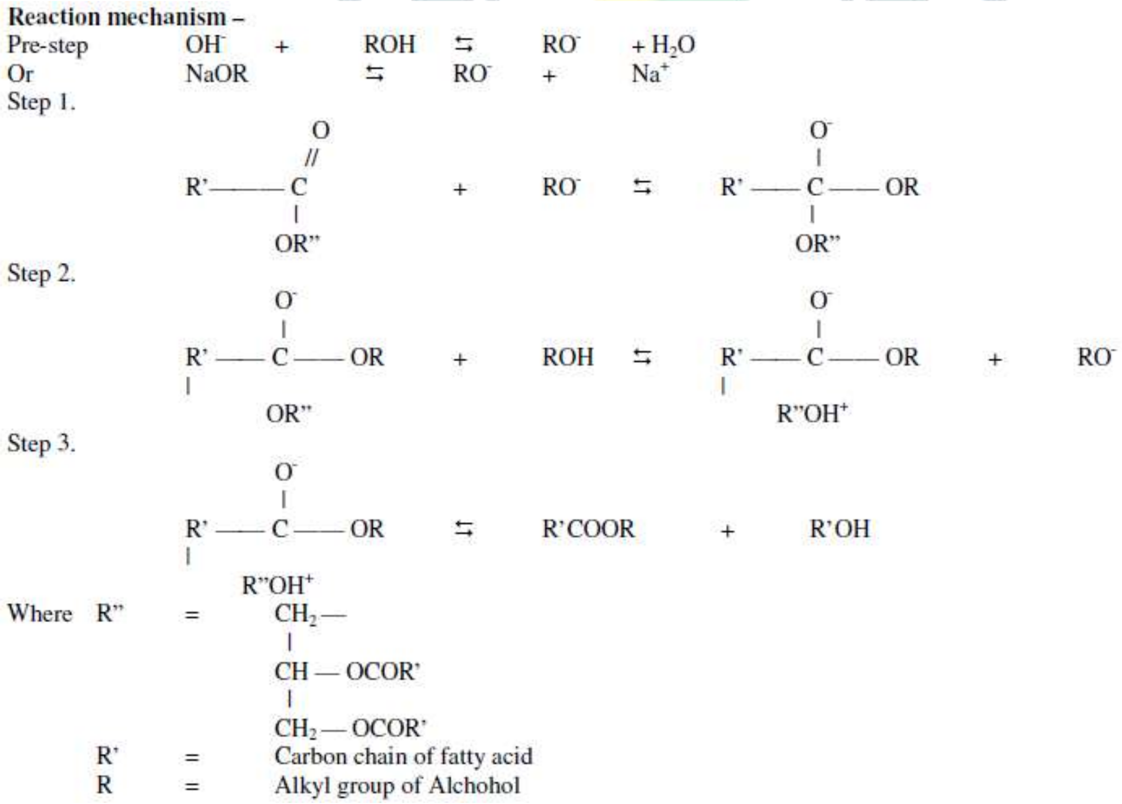
General equation of transesterification

Some feedstock must be pre-treated before they can go through the transesterification process. Feedstock with less than 5 % Free Fatty Acid, may not require pre-treatment. When an alkali catalyst is added to the feedstock's (With FFA > 5 %), the Free Fatty Acid reacts with the catalyst to form soap and water as shown in the reaction.



General equation for methanol of triglycerides

Transesterification is one of the reversible reactions. However, the presence of a catalyst (a strong acid or base) accelerates the conversion. In the present work, the reaction is conducted in the presence of base catalyst. The mechanism of alkali-catalyzed transesterification is described below. The first step involves the attack of the alkoxide ion to the carbonyl carbon of the triglyceride molecule, which results in the formation of tetrahedral intermediate. The reaction of this intermediate with an alcohol produces the alkoxide ion in the second step. In the last step, the rearrangement of the tetrahedral intermediate gives rise to an ester and a diglyceride. The same mechanism is applied to diglyceride and monoglyceride. The reaction mechanism of transesterification is shown below.



Mechanism of base-catalyzed transesterification

2.9Settling of fluids & Separation

Once transesterification is complete there exist two products biodiesel and glycerine. Settling process happens due to the gravity experienced by the mixture. The esterified oil is kept for 8-10 hours in a settling tank. After biodiesel and glycerine had settled the heavier content i.e, Glycerine settles down due to its high density at the bottom and can be separated out. This gives Calophyllum oil.

2.10Washing of oil

The biodiesel was washed for 12 hours with hot pure distilled water to remove alcohol and catalyst residue. After washing process is completed it must wait until biodiesel and water were separated into two different phases and later water is drained out.

2.11Drying of oil

To eliminate the water in the biodiesel which remains from washing, it is dried by heating it up to 100^{o}C for half an hour. The water in the biodiesel is evaporated during the drying process.

2.12Product Quality

Prior to use as a commercial fuel, biodiesel must be analyzed using sophisticated types of equipment to meet ASTM6751 standards. The most important aspect of biodiesel production to ensure trouble-free operation in a diesel engine are complete reaction, removal of glycerine, removal of the catalyst, removal of alcohol and absence of FFA.

2.13Blending of oils

The end product of the reaction is the pure bio-oil that is then converted into different blends such as B6, B12, B18, B24, B30, B36 etc by splash blending at room temperature. At first, the diesel is heated in the water bath and bio oil to 40^{o}C and then the two components are simultaneously poured into a new jar mixing both components creating biodiesel blends.

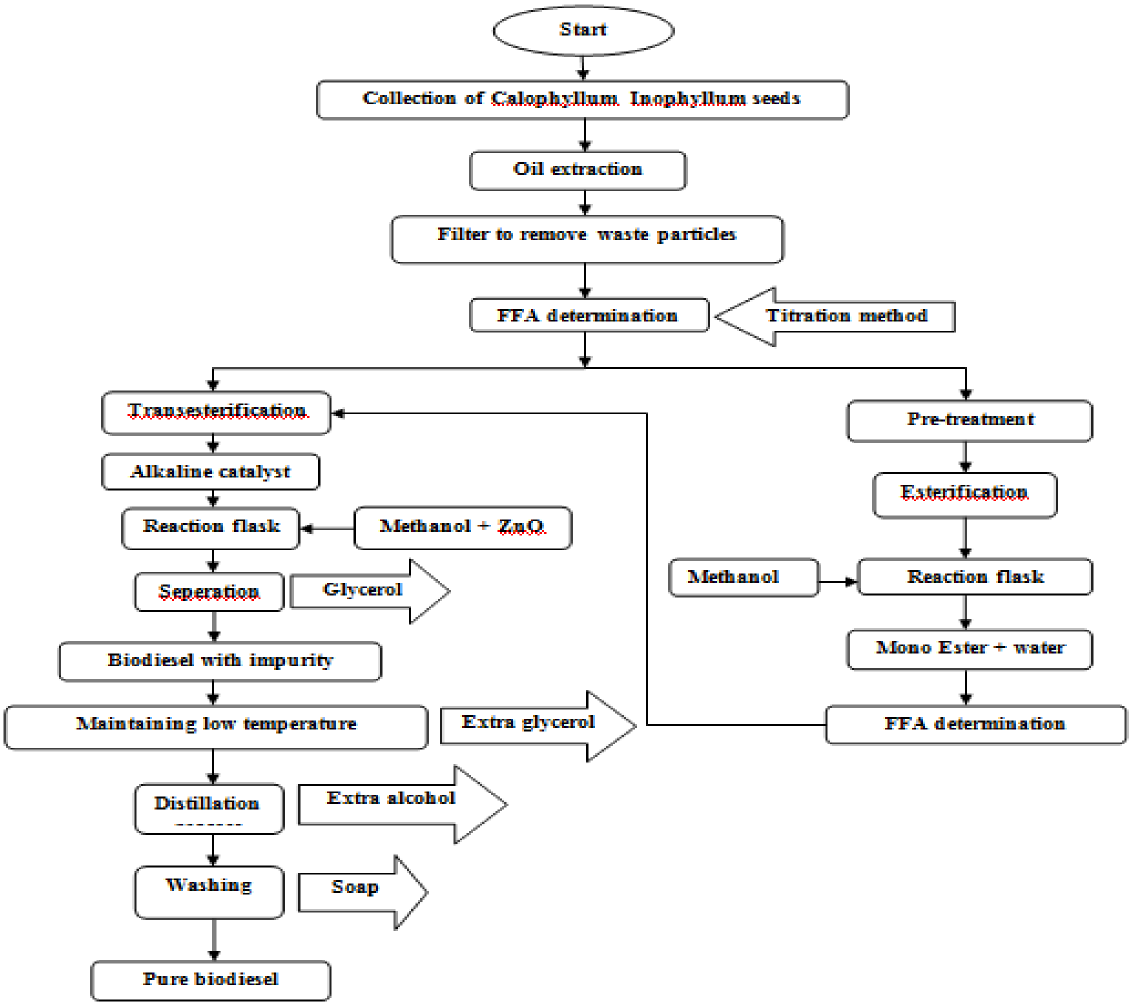


Fig.1 Methodology

2.14 Properties of Biodiesel:-

SR.NO.	TEST DESCRIPTION	REF.STD. ASTM 6751	REFERENCE	DIESEL	CALOPHYLLUM BIODIESEL AND BLENDS					
			UNIT	B0	B6	B12	B18	B24	B30	B36
1	DENSITY	D1448	gm/cc	0.830	0.831	0.833	0.834	0.836	0.837	0.839
2	CALORIFIC VALUE	D6751	MJ/Kg	42.50	42.39	42.28	42.11	41.90	41.78	41.55
3	VISCOSITY	D445	mm^2/sec	2.7	-	-	-	2.96	-	-
4	MOISTURE	D2709	%	NA	NA	NA	NA	NA	NA94	NA
5	FLASHPOINT	D93	◦c	64	68	72	79	85	-	105
6	FIRE POINT	D93	◦c	71	-	-	-	96	-	-
7	CLOUD POINT	D2500	◦c	-4	-	-	-	2.5	-	-
8	POUR POINT	D2500	◦c	-9	-	-	-	-1	-	-
9	ASH	D	%	0.05	-	-	-	0.1	-	-

Table 1:-Properties of Bio-diesel and It's Blends According to Standard ASTM6751

2.15 Experimental Test Setup &Procedure:-

The CALOPHYLLUM(Calophyllum) biodiesel and diesel were used as alternative fuel to operate diesel engine in the IC Engine Lab of Department of Mechanical Engineering in SIES GST, Nerul.The performance test is conducted on a single cylinder, four stroke, direct injection, water cooled diesel engine test rig. The engine is coupled to rope brake dynamometer for variable loading.The engine specification is shown in Table2 and schematic diagram of the experimental test setup is as shown in Fig.2

The engine has been run using biodiesel & required data are collected to calculate the engine performance parameters. The performance of CALOPHYLLUM biodiesel-diesel blends at different loading conditions such as 0kg, 0.5kg, 1.5 kg, 2.5 kg was evaluated.

Specifications	Values
Manufacturer	Rocket Manufacturer
Bore	76 mm
Stroke	76 mm
RPM	1500
BHP	5 H.P.
Compressor Ratio	16.7:1
Coefficient of Discharge	0.65

Table 2. Engine Specifications

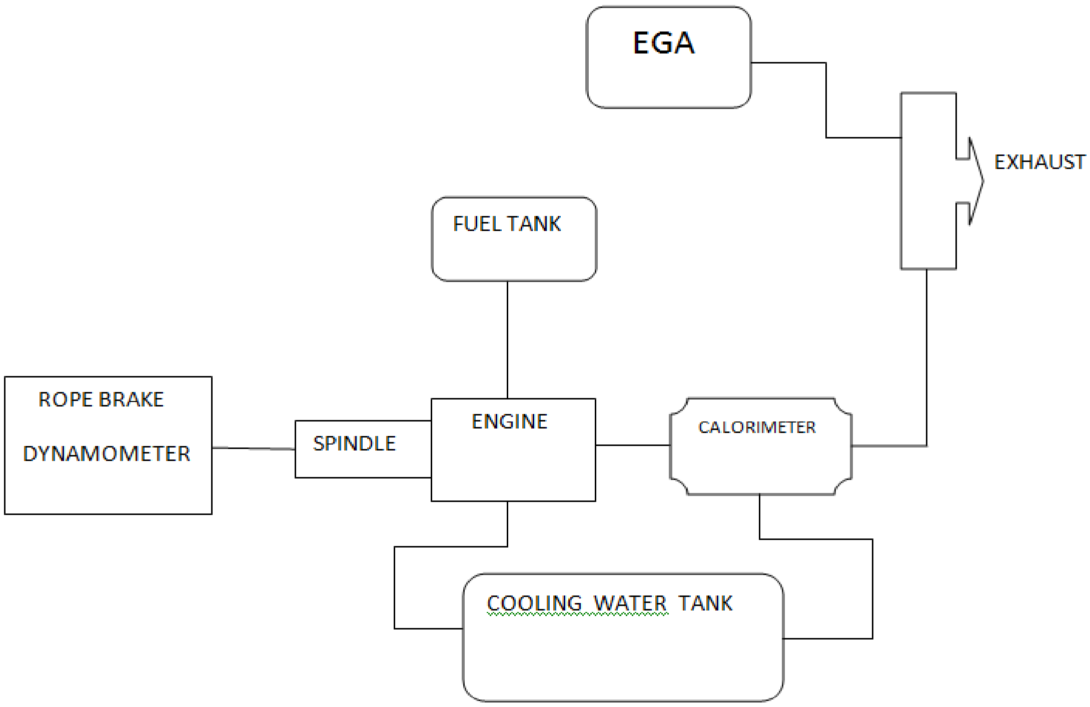


Fig.2 Schematic Diagram for diesel engine test rig

3. Observations

Different engine performance characteristics were observed at various loads and this is tabulated as follows:-

Performance Characteristics	Diesel	B6	B12	B18	B24	B30	B36
Brake Power(KW)	0	0	0	0	0	0	0

Brake Specific Fuel Consumption (KJ/KW.hr)	-	-	-	-	-	-	-
Torque(N.m)	0	0	0	0	0	0	0
Brake Thermal Efficiency(%)	0	0	0	0	0	0	0
Volumetric Efficiency(%)	91.54	92.53	92.88	94.3	94.4	95.87	95.9

Table 3:-The observed engine performance using Calophyllum biodiesel and diesel (load=0kg)

Performance Characteristics	Diesel	B6	B12	B18	B24	B30	B36
Brake Power(KW)	0.131	0.131	0.131	0.131	0.131	0.131	0.131
Brake Specific Fuel Consumption (KJ/KW.hr)	4.31	4.58	4.938	5.076	5.53	6.27	7.70
Torque(N.m)	1.79	1.79	1.79	1.79	1.79	1.79	1.79
Brake Thermal Efficiency(%)	1.86	2.23	1.7	1.66	1.5	1.36	1.12
Volumetric Efficiency(%)	93.54	92.53	92.88	9437	94.4	95.87	95.9

Table 4:-The observed engine performance using Calophyllum biodiesel and diesel (load=0.5kg)

Performance Characteristics	Diesel	B6	B12	B18	B24	B30	B36
Brake Power(KW)	0.392	0.392	0.392	0.392	0.392	0.392	0.392
Brake Specific Fuel Consumption (KJ/KW.hr)	1.4	1.48	1.58	1.641	1.76	2.08	2.409
Torque(N.m)	5.35	5.35	5.35	5.35	5.35	5.35	5.35
Brake Thermal Efficiency(%)	6.08	6.905	5.3	5.1	4.85	4.11	3.57
Volumetric Efficiency(%)	91.54	92.53	92.88	94.37	94.4	95.87	95.9

Table 5:-The observed engine performance using Calophyllum biodiesel and diesel (load=1.5kg)

Performance Characteristics	Diesel	B6	B12	B18	B24	B30	B36
Brake Power(KW)	0.653	0.653	0.653	0.653	0.653	0.653	0.653
Brake Specific Fuel Consumption (KJ/KW.hr)	0.836	0.889	0.9202	0.984	1.058	1.15	1.38
Torque(N.m)	8.91	8.91	8.91	8.91	8.91	8.91	8.91

Brake Thermal Efficiency(%)	10.12	11.5	9.2	8.6	8.1	7.49	6.27
Volumetric Efficiency(%)	93.03	92.53	92.88	94.37	94.4	95.87	95.9

Table 6:-The observed engine performance using Calophyllum biodiesel and diesel (load=2.5kg)

EMISSIONS OF CALOPHYLLUM BIODIESEL				
LOAD (Kg)	CO_2 (%)	O_2 (%)	CO (%)	HC (%)
B00				
0	0.50	20.08	0.019	3
0.5	0.60	21.49	0.025	9
1.5	0.80	21.42	0.043	11
2.5	0.80	21.39	0.040	12
B06				
0	0.70	20.12	0.036	3
0.5	0.60	20.88	0.027	5
1.5	0.50	21.23	0.021	6
2.5	0.50	21.23	0.032	10
B12				
0	0.60	21.29	0.026	5
0.5	0.90	21.33	0.033	8
1.5	0.70	21.35	0.021	7
2.5	0.78	21.22	0.021	7
B18				
0	0.60	20.77	0.018	5
0.5	0.60	21.12	0.023	7
1.5	1.10	21.20	0.036	11
2.5	0.90	21.93	0.036	9
B24				
0	0.47	21.97	0.028	4

0.5	0.55	21.23	0.023	6
1.5	0.40	20.62	0.031	7
2.5	0.60	21.16	0.035	7
B30				
0	0.58	21.08	0.023	7
0.5	0.78	21.22	0.037	8
1.5	0.88	21.12	0.023	11
2.5	0.99	21.15	0.021	4
B36				
0	0.58	20.78	0.033	4
0.5	0.50	20.94	0.031	6
1.5	0.60	21.42	0.028	7
2.5	0.78	21.92	0.028	7

Table 7 Emission Results

4. Results And Discussion:-

4.1 Brake Thermal Efficiency:-

Change in Bth of blends B6, B12, B18, B24, B30, B36 and diesel with respect to change in load is shown in the figure. At low load condition, brake thermal efficiency of B6,B12,B18,B24,B30,B36 and diesel are very close.As the load on the engine increases, brake thermal efficiency increase, because brake thermal efficiency is the function of brake power and brake power, increases as load increases.

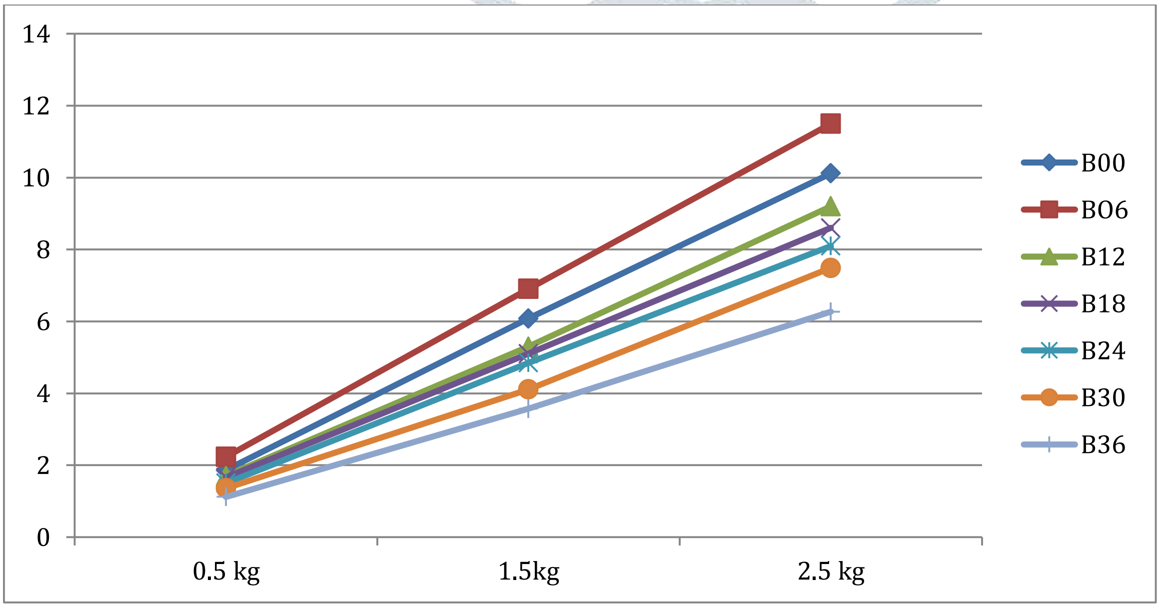


Fig.3 Brake Thermal Efficiency Vs Load

4.2 B.S.F.C.:-

Change in B.S.F.C. of blends B6, B12, B18, B24, B30, B36 and diesel with respect to change in load is shown in the figure. At low load condition, of B6,B12,B18,B24,B30,B36 and diesel are very high. As the load on the engine increases, brake specific fuel consumption decreases because brake specific fuel consumption is the function of brake power and is inversely proportional to brake power and brake power increases as load increases.

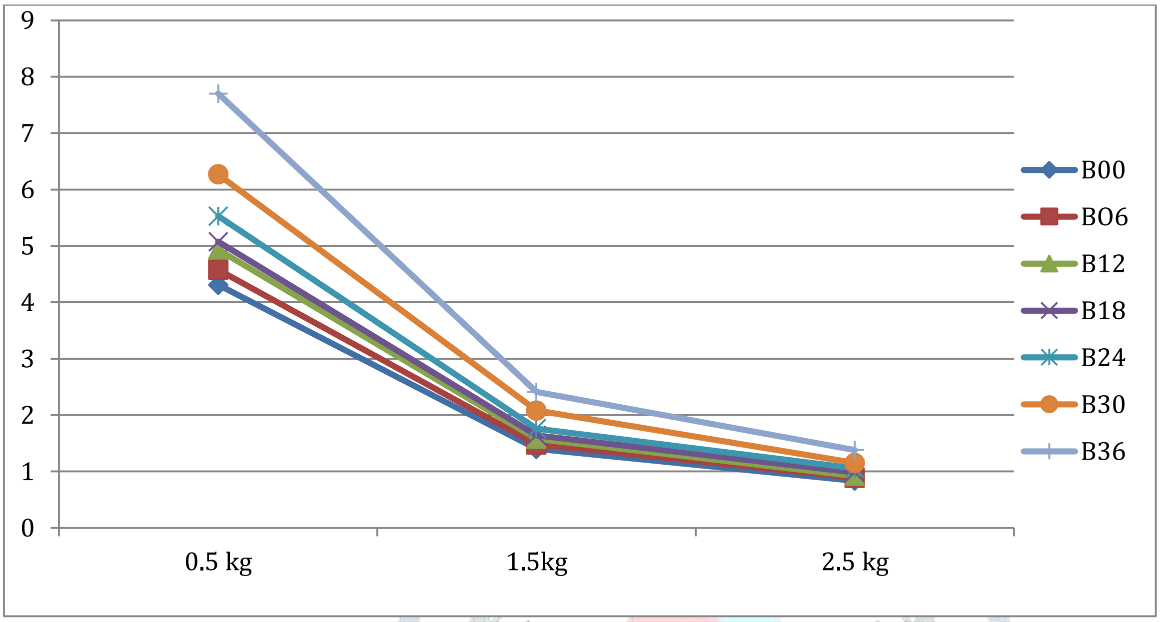


Fig.4 B.S.F.C. Vs Load

4.3CO Emission:-

It is seen from the Fig that as the Load and proportion of bio-diesel are increased, the CO emission reduces for all the fuels. This is due to increase in the amount of Calophyllum in diesel. It can also be observed that CO emissions are less for pure diesel at lower loads and emissions are high at higher loads compared to different blends.CO emissions are 1.2% less for B36 biodiesel as compared to Diesel at load 2.5kg.

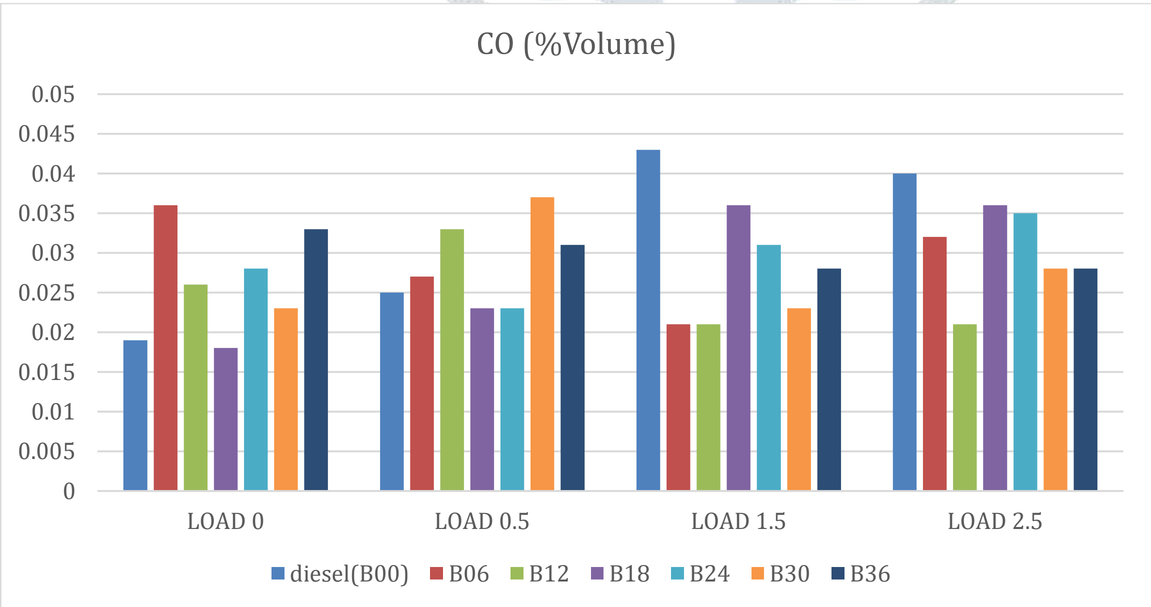


Fig.5 CO Emission Vs Load

4.4 CO_2 Emission:-

It is observed from the Figure that CO2 emission initially increases at lower loads, but subsequently decreases with the increase in load for all the fuels tested. CO2 emission is lower for bio-diesel(B36) compared to Diesel at 2.5kg load. It can be noted that the percentage decrease in CO2 emissions between Diesel and the B36 blend is 2%.

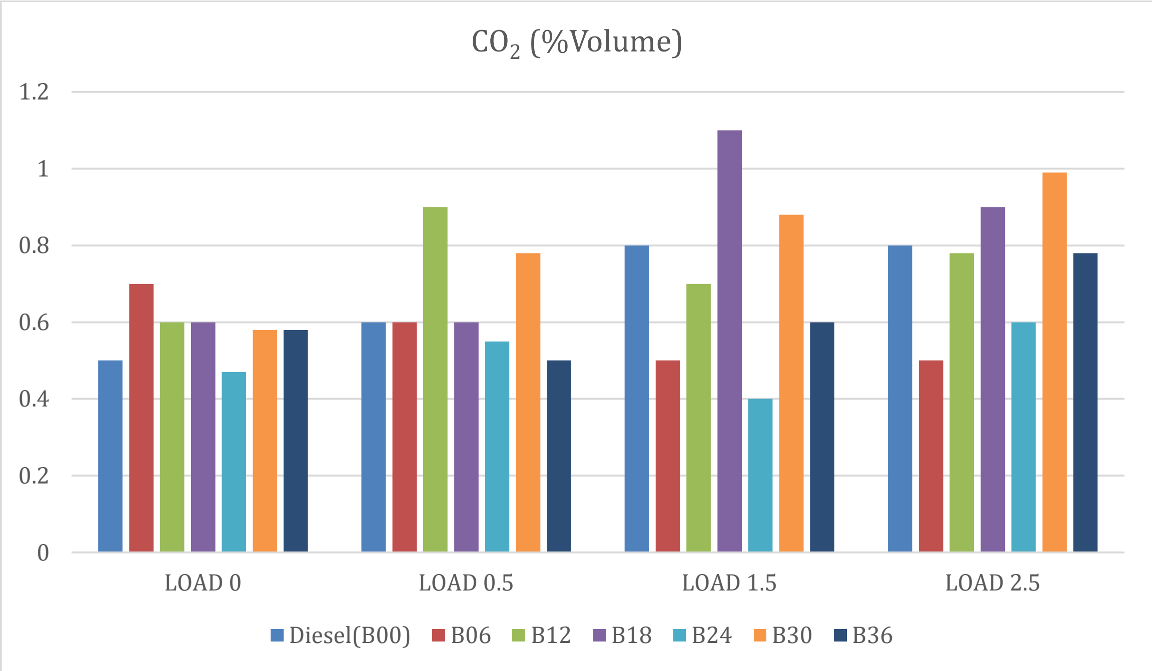


Fig.6 CO_2 Emission Vs Load

4.5 HC Emission:-

It can be observed from the Figure that HC emissions decrease with increase in the load for all the fuels tested. It is also observed that HC decreases with the increase in blend proportion. This is due to better combustion of biodiesel due to its oxygenated nature. The mean percentage decrease in HC emission with biodiesel as compared to Diesel is of the order of 30%.

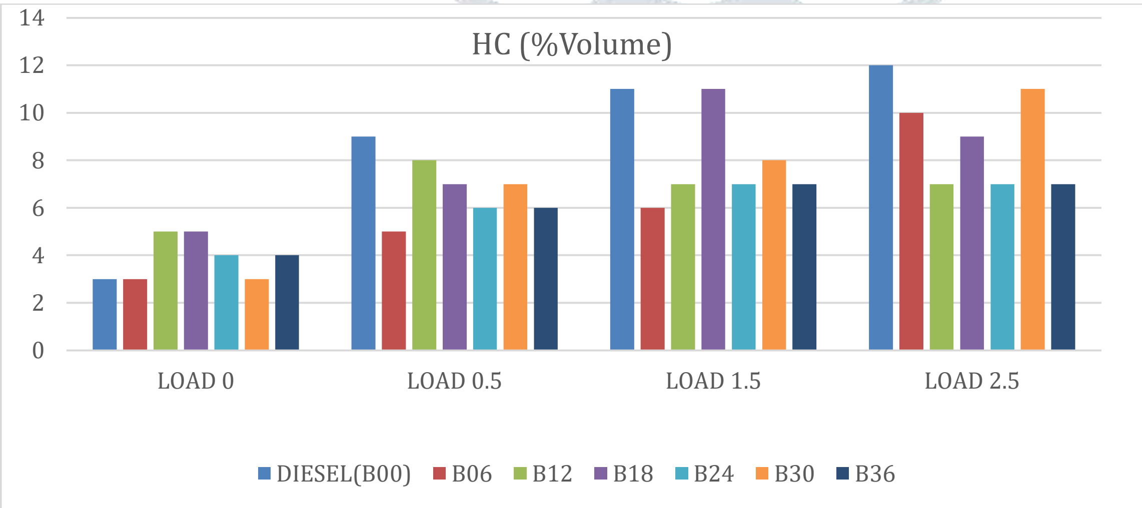


Fig.7 HC Emission Vs Load

5. Conclusion

The experimental investigation leads to the following conclusions.

- From the experimentation and test results, it is clear that as the amount of Bio-oil increases in the diesel blend the brake thermal efficiency of the engine reduces.
- Also, increase in the proportion of bio-oil in the mixture increases the fuel consumption per unit time i.e. BSFC increases with % bio-oil.
- After carefully studying the variation in characteristics of diesel and the bio-diesel blends on specific loads we concluded that B06 blend is the most preferable out of all the six blends that were tested.
- Thus bio-oil mixed with diesel in a proportion of 6% gives a performance chart that is the closest to that of diesel. The B06 blend performs better in brake thermal efficiency when compared to that of diesel as per studying the results obtained after experimentation.
- The B06 blend could prove to be a preferable alternative for diesel in the near future reducing the amount of consumption of fossil fuel alone.

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