THERMAL ANALYSIS ON FOUR STROKE C.I ENGINE USING BIODIESEL (COTTON SEED AND MAHUA)

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ABSTRACT

The diesel engine is the most efficient power plant among all known types of internal combustion engines. Heavy trucks, urban buses, and industrial equipment are powered almost exclusively by diesel engines all over the world and diesel powered passenger cars are increasingly popular. Increase in petroleum prices, threat of global warming has generated an interest in developing alternative fuels for engine. Technologies now focusing on development of plant based fuels, plant oils, plant fats as an alternative fuel. In diesel-Cotton seed oil, Mahua oil blend, the specific fuel consumption of blends is more than that of diesel, this is due to lower calorific value of the fuel, and engine consumes more amount of the fuel in order to produce the same out-put power as in the case of pure diesel and the brake thermal efficiency of all the blends are lower than that of pure diesel [2]. This project Thermal Analysis of Four Stroke C.I Engine Using Biodiesel (Cotton Seed and Mahua oil with diesel blend under different load conditions. This project will give the perfect combination of diesel- Cotton seed oil, diesel-Mahua oil blend, so that problem of lower calorific value as well as more fuel consumption will be avoided. In rural area Mahua oil is mostly mixed with diesel, It causes some effects on environment as well as engine performance and life of the engine. As Mahua oil is easily available, it will be use with diesel and Mahua oil especially in rural areas. In this project the properties of the different blended fuel will be test in the laboratories. Several engine parameters like brake specific fuel consumption, brake power, brake thermal efficiency, etc. will be determine for all blended fuel.

Keyword: - *Alternative fuel, cotton seed oil mahua oil, performance testing, and engine emission*

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1. INTRODUCTION

Energy is one of the most significant inputs for growth of all sectors including agricultural, industrial service and transport sectors. Energy has been at the centre stage of national & global economic development from several decades. The demand for energy, around the world is increasing exponentially; specifically the demand for petroleum-based energy **[2].** India with the high rate of economic growth and increase in the population is the significant consumer of energy resources. India lacks in sufficient energy reserves and dependent on oil imports, but India has an abundant re-source of vegetable oils. The use of vegetable oil in a diesel engine is not a new concept. In fact early engines were demonstrated with straight vegetable oils (SVO). Vegetable oils were proved to be very costlier during those days. However due to limited reserves of fossil fuels, escalation nature of diesel fuel prices and increase in environmental pollution, created a renewed interest of research in vegetable oil as substitute fuel for diesel engines. Vegetable oil is easily available, renewable and environment friendly. Vegetable oils have energy content suitable for use as a fuel in diesel engines. Some of these oils have already been evaluated as substitutes for diesel fuels. However, several operational and durability problems of using straight vegetable oils in diesel, caused by their relatively higher viscosity compared to mineral diesel. This viscosity can be brought into the acceptable range by transesterification, by blending of vegetable oil with diesel, or by preheating the vegetable oil.

In the last few years interest & activity has grown up around the globe to find a substitute of fossil fuel. According to Indian scenario the demand of petroleum product like diesel is increasing day by day hence there is a need to find a solution. The use of edible oil as a bio-fuel in India is not feasible in view of big gap in demand and supply of such oil. Under Indian condition only non-edible oil can be used as bio-fuel which are produced in appreciable quantity and can be grown in large scale on non-cropped marginal lands and waste lands. Non-edible oils like jatropa, cotton, palm, karanja and mahua contain 30% or more oil in their seed, fruit or nut. India has more than 300 species of trees, which produce oil bearing seeds **[1].** Traditionally the collection and selling of tree based oil seeds were generally carried out by poor people for use as fuel for lightning.

2. MATERIALS AND METHODS

2.1 Characterisation of Cottonseed and Mahua seeds oil

Mahua seed is also called as Bassia Latifolia, Madhuca indica. It is also known as Indian Butter Tree. Its oil cake is used as fodder, bio-fertilizer and organic manure. It is widely available in most of the state e.g. Orissa, Chhattisgarh, Jharkhand, Bihar, Madhya Pradesh and Tamil Nadu. It can be successfully grown in waste land and dry land. Its oil is edible and is similar to that of ground nut oil. Mahua oil is obtained from the seeds of madhuca indica, a deciduous tree which can grow in semi-arid, tropical and sub-tropical areas(10).It has an approximate annual production possible of 181 thousand metric tones in India(11). The drying and decortication yield 70% kernel on the weight of seed. The kernel of seed contains about 50 % oil. The oil yield in an expeller is nearly 34 - 37%(13,14). When mahua oil is directly used as fuel in engine it causes problems like poor fuel atomization, incomplete combustion and carbon deposition formation, engine fouling and lubrication oil contamination, which is due to higher viscosity. To reduce the viscosity of mahua oil we may go for several conversion methods such as blending of oils, micro emulsification, cracking / pyrolysis and transesterification. Among this transesterification is widely used for industrial biodiesel production. Mahua oil gives better yield than other transesterified non edible oil(3). Therefore, this study is mainly focused on production of mahua methyl ester using hybrid technology transesterification unit and measure the performance and

Figure: 2.1 Cotton and Mahua tree with fruits

2.2 Collection of seeds

The leaves are eaten by cattle and readily consumed by goats. However, in many areas it is not commonly eaten by farm animals. Its fodder value is greatest in arid regions. The oil cake, remaining when oil is extracted from the seeds, is used as poultry feed.

(a) (b)

Figure 1.2.1: (a) cotton fruit (c) cotton Seed oil

(a) (b)

Figure 1.2.2: (a) Mahua fruit (b) Mahua Seed oil

2.3 Extraction of Cotton oil and Mahua oil

For extraction of Kusum oil from Kernel, two methods have been identified. They are the chemical extraction with n-hexane and mechanical extraction method in two stages using screw type of expellers. In the present study, the Mechanical extraction process is used and it gave the oil content about 23 to 33% from the kernel. In the two stages expellers the oil extracted were 30 to 38%.[3,19]

Fig: 2.3 Mechanical Type Expeller

2.4 Method of trans-esterification

This process has two separate starting points. If vegetable oils can be obtained that are below 2.5% FFA, the esterification step is not necessary.

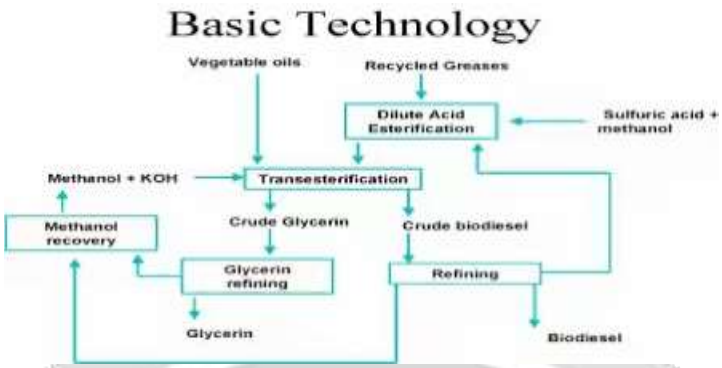


Figure: 2.4 Trans-esterification Process [5]

2.5 Blend Preparation

The blending of Cotton seed oil (COME) and Mahua oil (MOME) is prepared with diesel in different proportion such as

- B25 (Cotton seed 25% & Diesel 75%),
- B50 (Cotton seed 50% & Diesel 50%),
- B75 (Cotton seed 75% & Diesel 25%),
- B100 (Cotton seed 100% & Diesel 00%),
- Raw oil

Figure: 2.5 Blended fuel samples

2.6 Properties of Cotton seed oil and its blends

Table: 5 Properties of Cotton seed oil, COME and its blend

Blends of COME	Density@ 40^{0}C	Calorific Value (KJ/kg)	Kinematic Viscosity@ 40(^{0}C) (cSt)	Flash Point (^{0}C)	Fire Point (^{0}C)
B25(COME25-D75)	862	43663	3.38	81	88
B50(COME50-D50)	879	43010	5.60	97	105
B75(COME25-D75)	889	42895	8.90	134	126
B100(COME100-D00)	905	42209	12.13	167	190
Raw oil	909	40610	52	207	230
Diesel	835	44680	3.07	56	63

Table : 3 Properties of Mahua oil, MOME and its blends With Diesel

Blends of MOME	Density @ 40^{0}C	Calorific Value (KJ/kg)	Kinematic Viscosity@ 40(^{0}C) (cSt)	Flash Point (^{0}C)	Fire Point (^{0}C)
B25(M25-D75)	830	42690	3.49	71	79
B50(M50-D50)	845	41650	6.09	78	88
B75(M25-D75)	869	40950	9.10	112	120
B100(M100-00D)	882	40,120	11.02	170	183
Raw oil	895	39600	36.14	136	235
Diesel	835	44680	3.07	56	63
Reference :- Anacon Lab					

3. EXPERIMENTAL SETUP & EXPERIMENTATION

A 3.75 KW diesel engine AV1 Single Cylinder water cooled, Kirloskar Make was used to test blends of diesel with Cottonseed and mahua oil biodiesel. Engine test setup was developed to carry the trials using these blends. This paper presents a study report on the performance of IC engine using blends of Cottonseed and mahua oil with diesel with various blending ratio. The engine performance studies were conducted with eddy current dynamometer setup. Parameters like speed of engine, fuel consumption and torque were measured at different loads for pure diesel and various combination of dual fuel. Break Power, BSFC, BTE and heat balance were calculated. Paper represents the test results for blends B25% to B100%.

Figure: 2.6 Diesel Engine Test Rig with AVL DiTEST (Exhaust gas analyzer)

Table: 2.2 Specification of Diesel Engine Test rig

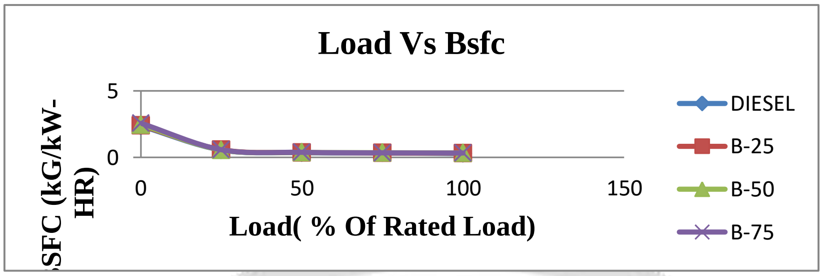
Sr. No.	Constraints	Value / Characteristics
1	Engine	Four stroke single cylinder
2	Make	Kirloskar
3	Brake Power	5 HP
4	RPM	1500
5	Fuel	Diesel
6	No of Cylinder	Single
7	Bore	87.5 mm
8	Stroke Length	110 mm
9	Starting	Cranking
10	Working Cycle	Four Stroke
11	Method of Cooling	Water cooled
12	Method of ignition	Compression Ignition
13	Dynamometer	Eddy Current type
14	Dynamometer Arm Length	145 mm
15	Rated Speed	200-1500 Rpm
16	Rated Power	3.5 KW (max)
17	Torque	3.62 kg-m

4.RESULT AND DISCUSSION

1. Sample :- Mahua + Diesel

4.5.1 Brake specific fuel consumption (BSFC-Kg/KW-hr):-

The variation of brake specific fuel consumption with brake power is shown in table 4.17. The plot it is reveals that as the brake power increases brake specific fuel consumption decreases



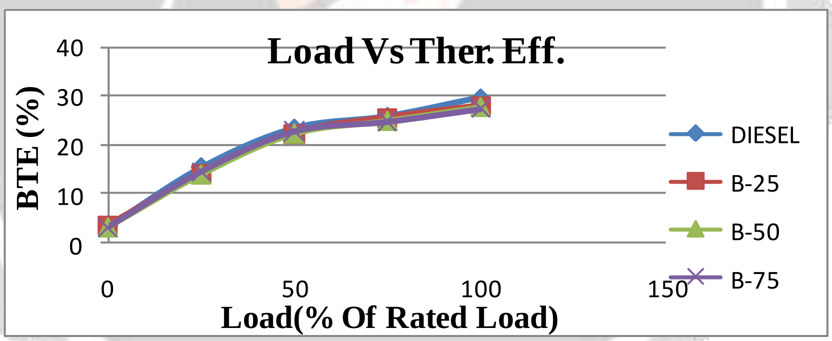
Graph: 4.1 Comparison of BSFC of Mahua -diesel blends with load

Figure shows the comparison of brake specific fuel consumption (kg/Kw-hr) of mahua-diesel and blends with load. Graph indicates that BSFC reduces with increase in load in all cases. This may due to higher viscosity and lower calorific value.

4.5.3 <u>Brake thermal efficiency(BTE)</u> :-

The variation of brake thermal efficiency with brake power for different fuels is presented in Fig.In all cases it increased with increase with brake power. This was due to reduction in heat loss and increase in power with increase in load. The maximum thermal efficiency for Mahua oil blend B-25 blend was nearer to diesel

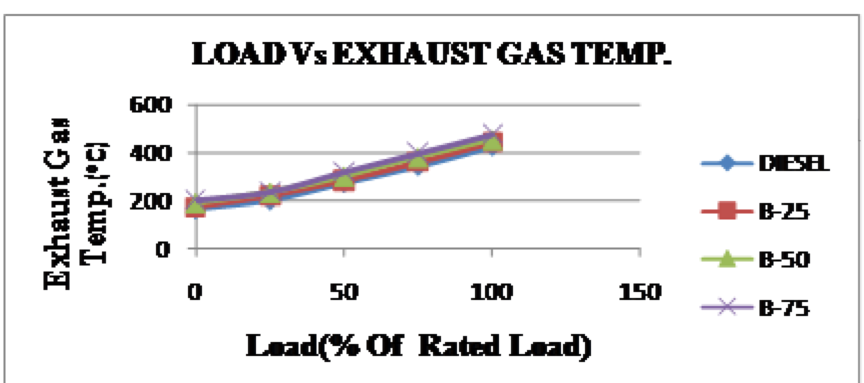
The result after the calculation are summarized compared it with pure diesel in following tables,



Graph: 4.3 Comparison ofBTE of Mahua -diesel blends with load

Graph4.3shows the brake thermal efficiency of mahua-diesel blend with diesel. Graph indicates that brake thermal efficiency increases with increasing load in all cases. B-25 blend gives result slightly less than the pure diesel.

4.5.5 <u>Exhaust Gas Temparature (EGT)</u> :- The variation of exhaust gas temp with the load are shown in the table. As the load on engine increases the exhaust gas temp also increase

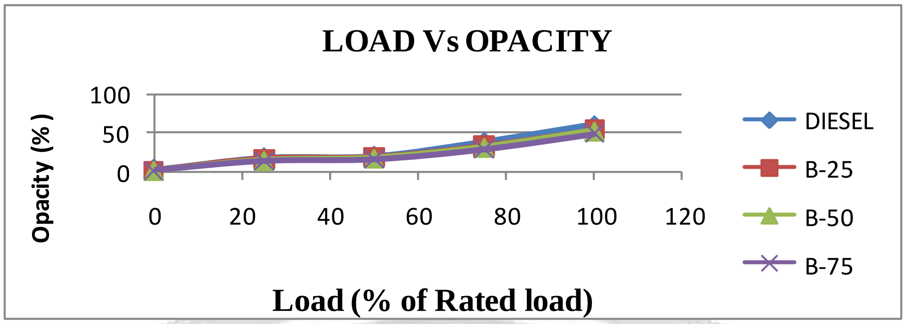


with diesel. Graph indicates that

4.5 Comparison of Exhaust gas Temp. of Mahua -diesel blends with load

4.5.7 Opacity :-

From the test results, it was found that smoke opacity of neat diesel fuel is higher to that of biodiesel blend.

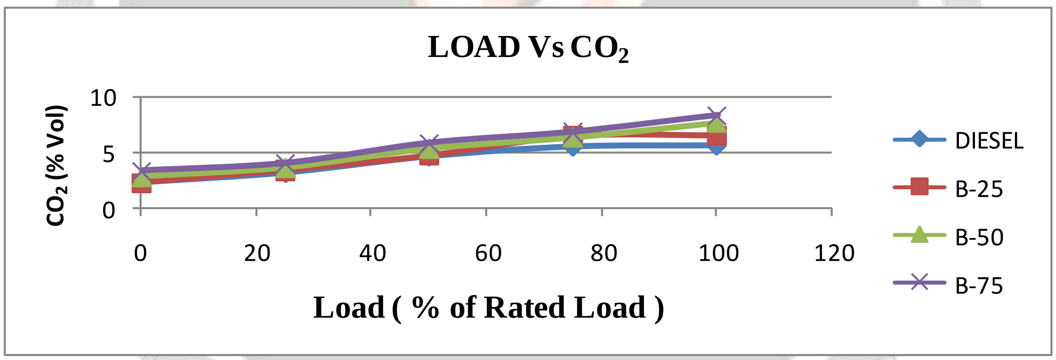


Graph 4.7 Comparison of opacity of Mahua-diesel blends with load

Graph 4.7 shows the comparison of opacity of mahua -diesel blend with diesel. Graph indicates that opacity increases with increasing load in all cases.

4.5. 9 Carbon Dioxide (CO_2) Emission :-

Carbon Dioxide concentration of the exhaust in percent of the total sample. It shows completely burned fuel, represents how well the air/fuel mixture is burned in the engine (efficiency). This gas gives a direct indication of combustion efficiency. This is due to improved gas flow resulting in better combustion efficiency. At night the trees convert CO_2 in to Oxygen.



Graph 4.9Comparison of CO_2 of Mahua -diesel blends with load

Figure 4.9 shows the comparison of CO_2 emission of mahua -diesel blend with diesel. Graph indicates that CO_2 increases with increasing load in all cases.

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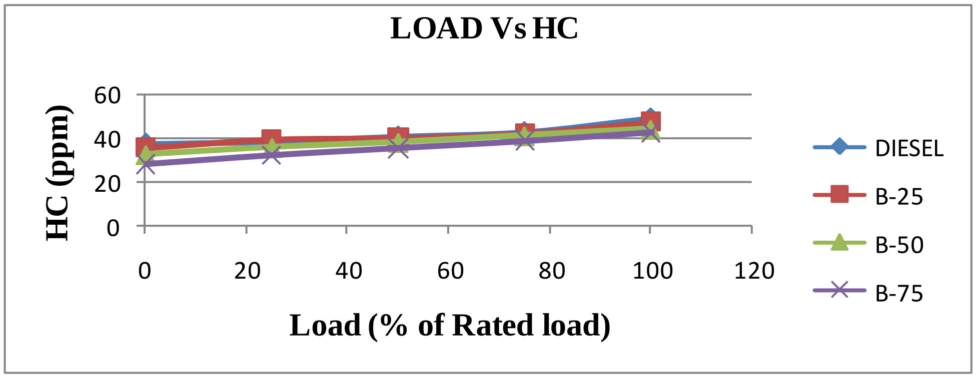
4.5.11 Hydrocarbons (HC) Emission :-

Hydrocarbons, concentration of the exhaust in parts per million (ppm).It represents the amount of unburned fuel due to incomplete combustion exiting through the exhaust. This is a necessary evil. We don't want it so try to keep it as low as possible. An approximate relationship between the percentage of wasted fuel through incomplete combustion and the ppm of HC is about 1/200 (1.0% partially burned fuel produces 200 ppm HC, 10%=2000 ppm HC, 0.1%=20 ppm HC)

There are some unburned or partially burned hydrocarbons in the exhaust. The amount is insignificant from an energy standpoint, but it is objectionable from the view point of its odour, its photochemical smog, and from the standpoint of its having a carcinogenic effect. The product of photochemical smog cause watering and burning of the eyes, and affect the respiratory system, especially when the respiratory system is marginal for other reasons.



Graph 4.11 Comparison of HC of Mahua -diesel blends with load

Graph 4.11 shows the comparison of HC emission of mahua -diesel blend with diesel. Graph indicates that HC emission increases with increasing load in all cases.

4.5.13 Carbon Monoxide(CO) Emission :-

Carbon Monoxide,concentration of the exhaust is in percent of total sample. This is the fuel that has combusted, but not completely.

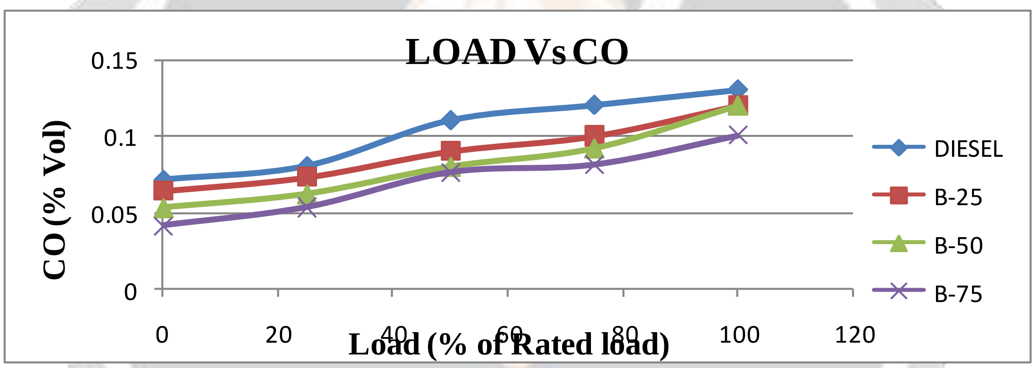


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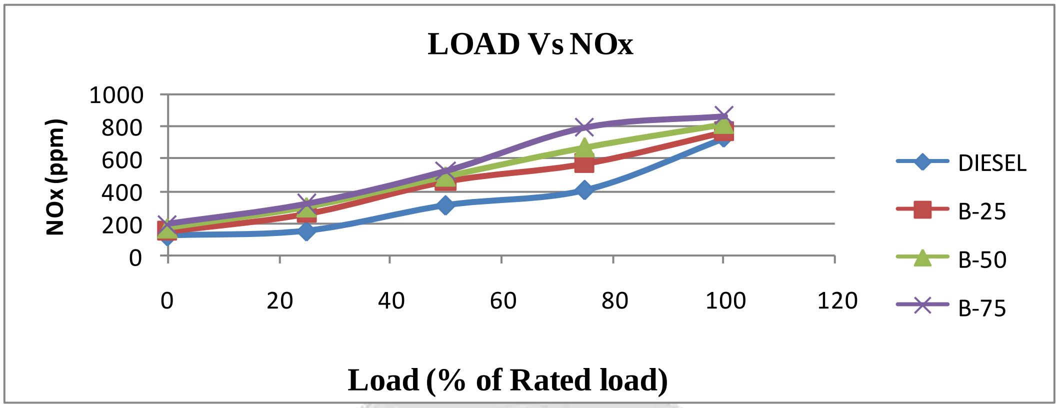
Figure 4.13 Comparison of CO of Mahua -diesel blends with load

This gas is formed in the cylinders when there is incomplete combustion and an excess of fuel. Therefore excessive CO contents are always a sign of an overly rich mixture preparation. (The CO should have become CO2 but did not have the time or enough O2 to become real CO2 so it is exhausted as CO instead.)Carbon monoxide is toxic. The hemoglobin in the blood, which carries oxygen to the different parts of the body, has a higher affinity for carbon monoxide than for oxygen. The percent carboxy hemoglobin gradually increases with time to an equilibrium value which depends upon the carbon monoxide concentrations.

Graph 4.13 shows the comparison of CO emission of mahua-diesel blend with diesel. Graph indicates that CO emission increases with increasing load in all cases

4.5.15 Oxides Of Nitrogen (NO_x) Emission:-

NOx emissions rise and fall in a reverse pattern to HC emissions. As the mixture becomes leaner more of the HC's are burnt, but at high temperatures and pressures (under load) in the combustion chamber there will be excess O2 molecules which combine with the nitrogen to create NOx. NOx increases in proportion to the ignition timing advance, irrespective of variations in A/F ratio. This gas is related to the exhaust gas detoxification systems (in conjunction with Co and HC), exhaust gas recirculation systems. Those systems bring some of the inert (processed) exhaust gas back in to the engine to be burned again. This time around this gas has no O2 extra molecules and prevents high combustion temperatures and further increase in NOx formation. NOx is very dangerous lethal gas and air pollutant.



Graph 4.15 Comparison of NOx of Mahua-diesel blends with load

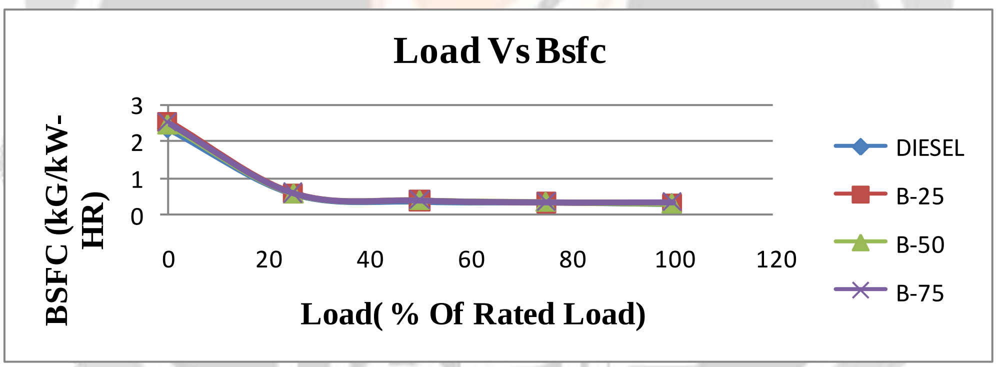
Graph 4.15 shows the comparison of NOx emission of mahua-diesel blend with diesel. Graph indicates that NOx emission increases with increasing load in all cases.

4.6 Experimental Result:-

2. Sample: - Cotton seed oil + Diesel

4.6.1 Brake specific fuel consumption (BSFC-Kg/KW-hr) :-

The variation of brake specific fuel consumption with brake power is shown in table 4.14. The plot it is reveals that as the brake power increases brake specific fuel consumption decreases.



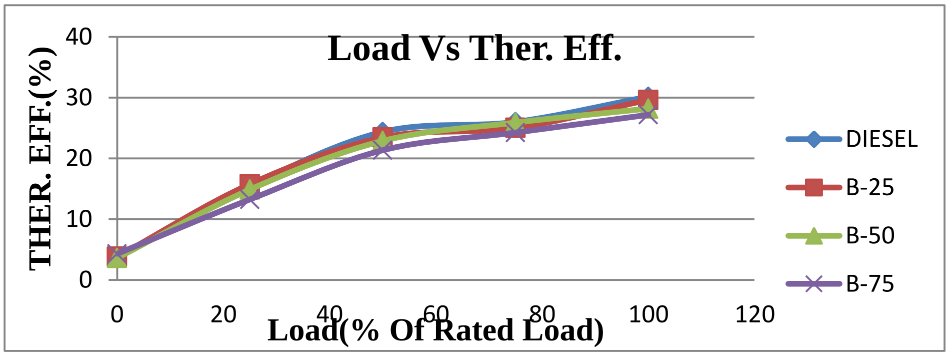
Graph: 4.6.1 Comparison of BSFC of Cotton seed oil - diesel blends with load

Figure shows the comparison of brake specific fuel consumption (kg/Kw-hr) of cotton seed oil -diesel and blends with load. Graph indicates that BSFC reduces with increase in load in all cases. This may due to higher viscosity and lower calorific value.

As the blending ratio increases from diesel to B25, B50 and B75 the BSFC also increases.

4.6.3 Brake thermal efficiency(BTE) :-

The result after the calculation are summarized compared it with pure diesel in following tables,

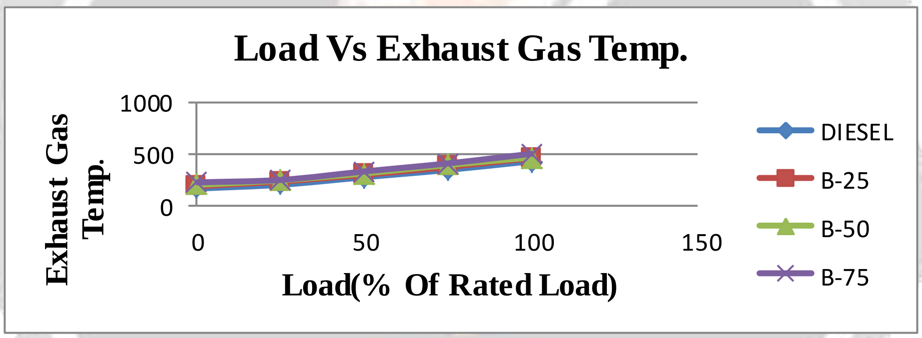


Graph: 4.6.3 Comparison of BTE of Cotton seed oil -diesel blends with load

Graph 4.6 shows the brake thermal efficiency of cotton seed oil -diesel blend with . diesel. Graph indicates that brake thermal efficiency increases with increasing load in . all cases. B-25 blend gives result slightly less than the pure diesel.

4.6.5 Exhaust Gas Temperature (EGT) :-

The variation of exhaust gas temp with the load are shown in the table. As the load on engine increases the exhaust gas temp also increases.

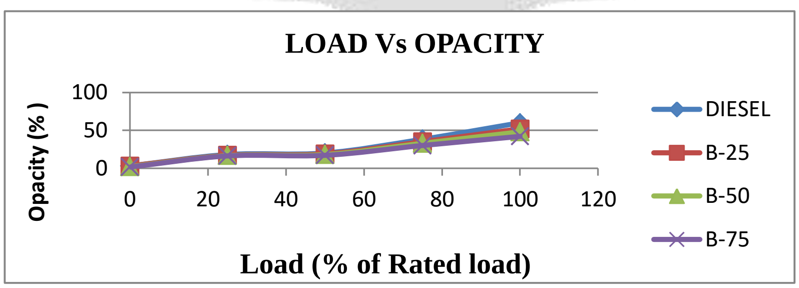


Graph: 4.6.5 Comparison of Exhaust gas Temp. of Cotton seed -diesel blends with load

Graph shows the exhaust gas temp. of cotton seed -diesel blend with diesel. Graph indicates that with increase in load the exhaust gas temp. also increases in all cases. B-25blend gives result slightly similar result than the pure diesel.

4.4.7 Opacity:-

From the test results, it was found that smoke opacity of neat diesel fuel is higher to that of biodiesel blend



Graph 4.6.7 Comparison of opacity of Cotton seed oil -diesel blends with load

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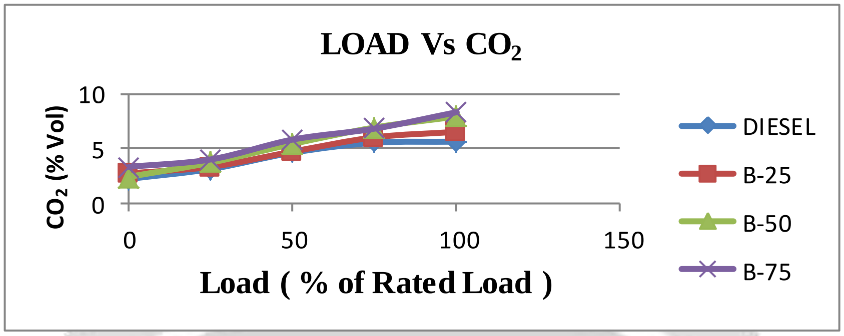

Graph 4.6.9 Comparison of CO_2 of Cotton seed-diesel blends with load

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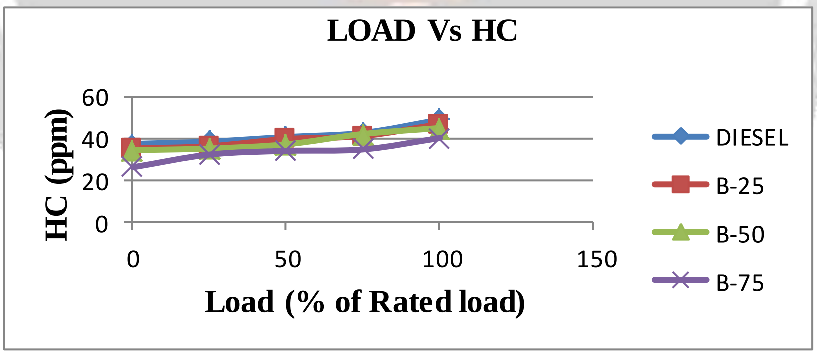

Figure 4.6.11 Comparison of HC of Cotton seed oil -diesel blends with load

Graph4.11 shows the comparison of HC emission of cotton seed oil -diesel blend with diesel. Graph indicates that HC emission increases with increasing load in all cases.

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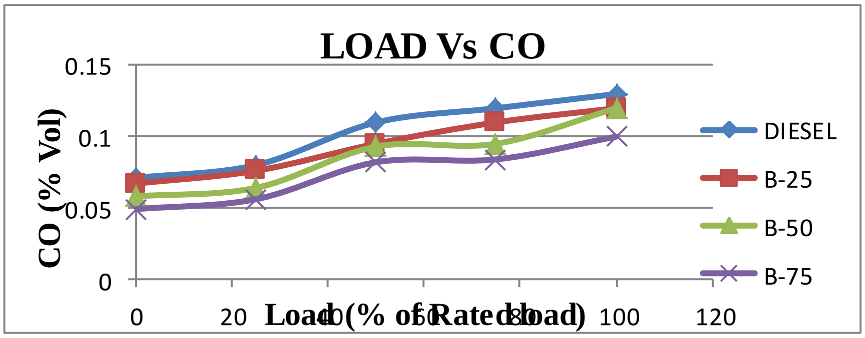

Graph: 4.6.13 Comparison of CO of cotton seed-diesel blends with load

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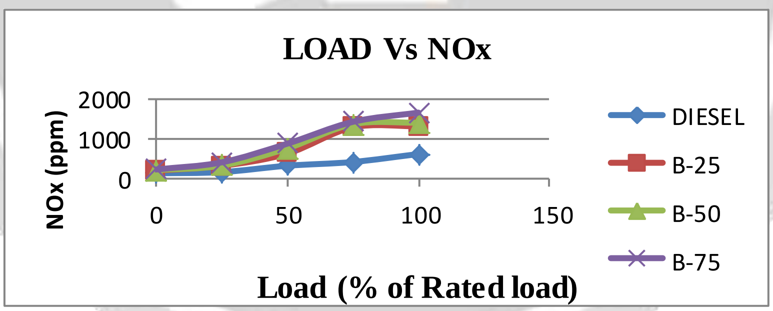

Graph 4.6.15 Comparison of NOx of Cotton Seed Oil-diesel blends with load

Graph 4.6.15 shows the comparison of NOx emission of cotton seed-diesel blend with diesel. Graph indicates that NOx emission increases with increasing load in all cases.

5. ANSYS SIMULATION

A. Thermal Stress Distribution in Engine Parts

a. Cylinder

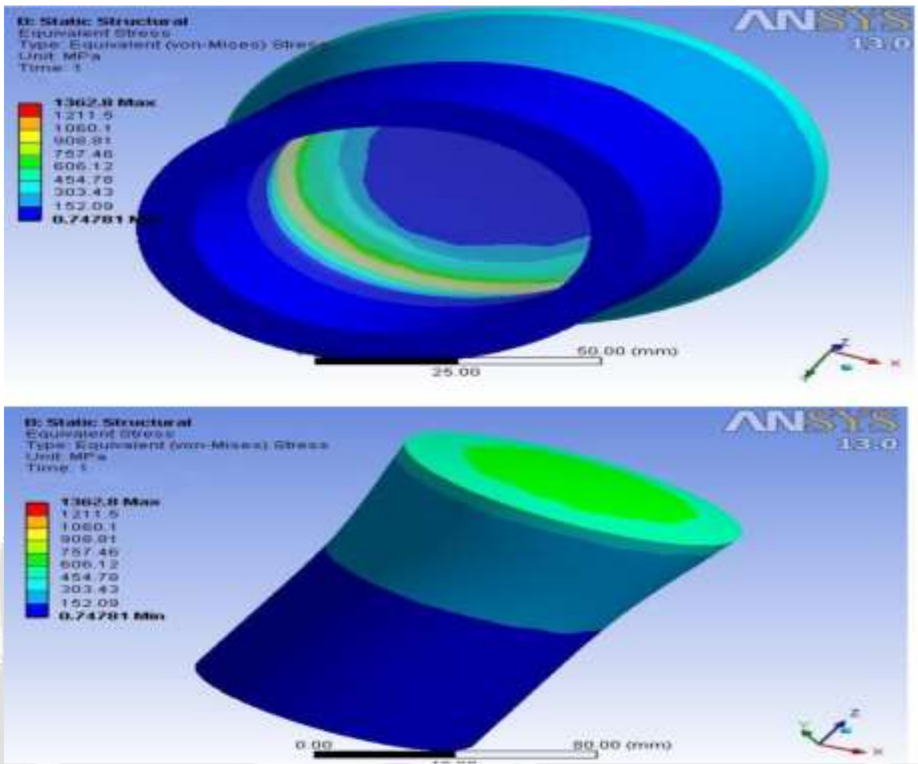

Figure: 5.1 Thermal stresses on cylinder body

b. Piston

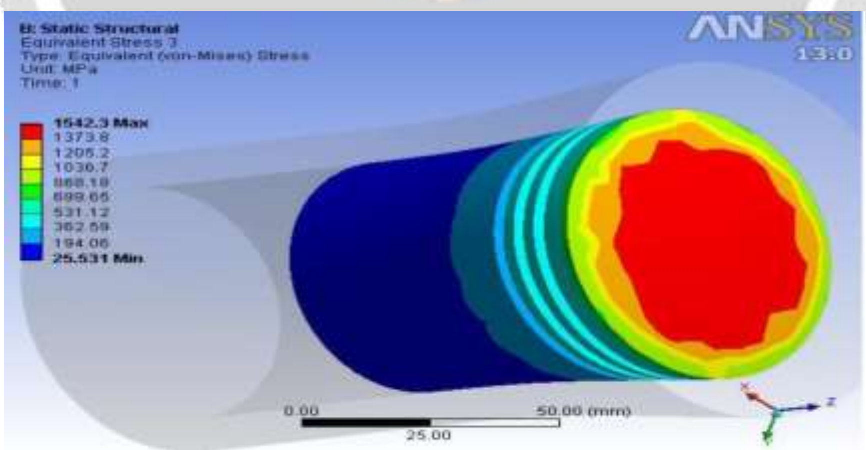

Figure: 5.2 Thermal stresses on piston

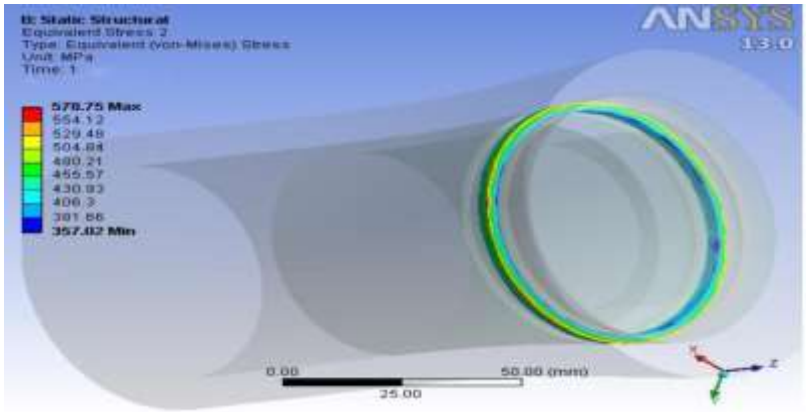

Figure: 5.3 Thermal stresses on piston Ring

6. CONCLUSIONS

Based on the experimental investigation carried with blends of kusum methyl ester and diethyl ether with simultaneous influence of fuel injection pressure following conclusion are drawn.

The optimization of biodiesel production from kusum oil was evaluated using tran-esterification process .The performance and emission parameters for diesel fuel were compared with B25, B50, and B75. The following conclusions can be drawn from the present study:

- The optimum conditions for maximum biodiesel production were obtained at molar ratio of 5:1, reaction time 60 minutes and 0.5% KOH concentration. A maximum yield of 98% was determined.
- The fuel properties of optimized biodiesel were found to be comparable to diesel and were conforming to the latest biodiesel standards.
- The calorific value of optimized mahua biodiesel B-25 was 43,690 KJ/Kg which is 0.044 % lower than diesel fuel.
- The flash and fire point of mahua biodiesel were determined to be 170^{0}C and 183 ^{0}C respectively which are higher than diesel fuel.

Based on the experimental results the following results are made:-

For Mahua

- **Effect on Brake Specific fuel Consumption:-**
  With increase in the load at constant speed the BSFC of blends gets decreases. The BSFC of diesel is 2.359 Kg/Kw-hr. at the no load condition. As the load increases the BSFC gets decreases from B-75 to B-25. It was found that the Blend B-75 gives the highest value of 0.5732 Kg/Kw-hr at the 25 load condition.
- **Effect on Brake Thermal Efficiency (BTE):-**
  As the load on the engine increases at the constant speed then there is increase in the Brake Thermal Efficiency. The BTE of the diesel is 29.65 % which is the highest value. As the blend ratio of mahua -diesel is minimum then BTE of B-25 is nearly equal to the diesel and as the blend ratio increases then BTE gets decreases. It was found that among the all blends B-25 is having highest value of 28.901 % at 100 % load.
- **Effect on Exhaust gas Temperature(EGT):-**
  During the experiment with the increase in the load at constant speed the EGT gets increases. The EGT of diesel is 426^{0}C at full load. At the Initial blend of mahua-diesel the EGT is low which is 474 ^{0}C and as the blend is increases the EGT gets increases. It was found that among the all blends the B-75 blends gives the 474^{0}C. at full load.
- **Effect on Opacity:-**

From the experiment it is clear that as the load increases at constant speed the opacity gets increases. The highest value of opacity is 60 % for pure diesel at full load. Among the all blends the blend B-25 is the highest value is 54 % at full load.

Effect on Carbon Dioxide:-

As the load on the CI engine with constant speed increases the % of C02 on volume basis increases. Diesel contain 0 % of O_2 hence diesel contain the lowest value of CO_2. Among the all blends the highest value of blend i.e. B-75 is having the highest value which is 8.3 %.

- **Effect on Hydrocarbons (HC):-**

From the experiment it was found that as the load on the engine at full load increases HC also increases. The highest value of diesel is 48.8 ppm at the full load. From the calculation it is clear that the among the all blend of mahua-diesel the B-25 is having the highest value of 47 ppm.

- **Effect on Carbon Monoxide (CO):-**

Carbon Monoxide percentage increases with increase in load at constant speed. The value of the CO is found to be 0.13 % for pure diesel at full load. As the blend of mahua-diesel gets increase then there is decrease in % of CO from B-25 to B-75. The highest value of the blend B-25 is 0.12 % at full load.

- **Effect on Oxides of Nitrogen (NO_x):-**

The % of NO_x is increases from as the load on the engine at constant speed is increases. The highest value of the diesel is found out to be 730 ppm at full load. As the % of blend mahua-diesel increases the value of NO_x also gets increases. The highest value of the blend B-75 is 860ppm at the full load.

- **Effect on Thermal Analysis:-**

From the analysis of ANSYS simulation of B25 blend maximum thermal stresses developed on piston and piston ring is 1542 Mpa and 579 Mpa respectively; stresses developed in cylinder inner surface is 1362 Mpa. at the internal temperature is 1190^0C. As internal temperature of cylinder and piston using pure diesel and biodiesel blend (B25) is nearly equal so that internal stresses and temperature distribution is

The result is tabulated at 100 % load in the following table.

For Cotton Seed :-

- **Effect on Brake Specific fuel Consumption:-**

With increase in the load at constant speed the BSFC of blends gets decreases. The BSFC of diesel is 2.359 Kg/Kw-hr. at the no load condition. As the load increases the BSFC gets decreases from B-75 to B-25. It was found that the Blend B-75 gives the highest value of 0.5828 Kg/Kw-hr at the 25 load condition.

- **Effect on Brake Thermal Efficiency (BTE):-**

As the load on the engine increases at the constant speed then there is increase in the Brake Thermal Efficiency. The BTE of the diesel is 30.16 % which is the highest value. As the blend ratio of mahua -diesel is minimum then BTE of B-25 is nearly equal to the diesel and as the blend ratio increases then BTE gets decreases. It was found that among the all blends B-25 is having highest value of 29.63 % at 100 % load.

- **Effect on Exhaust gas Temperature(EGT):-**

During the experiment with the increase in the load at constant speed the EGT gets increases. The EGT of diesel is 426^0C at full load. At the Initial blend of mahua-diesel the EGT is low which is 183 ^{0}C and as the blend is increases the EGT gets increases. It was found that among the all blends the B-75 blends gives the 498^0C. at full load.

- **Effect on Opacity:-**

From the experiment it is clear that as the load increases at constant speed the opacity gets increases. The highest value of opacity is 60 % for pure diesel at full load. Among the all blends the blend B-25 is the highest value is 52 % at full load.

Effect on Carbon Dioxide:-

As the load on the CI engine with constant speed increases the % of C02 on volume basis increases. Diesel contain 0 % of O_2 hence diesel contain the lowest value of CO_2. Among the all blends the highest value of blend i.e. B-75 is having the highest value which is 8.3 %.

- **Effect on Hydrocarbons (HC):-**

From the experiment it was found that as the load on the engine at full load increases HC also increases. The highest value of diesel is 48.8 ppm at the full load. From the calculation it is clear that the among the all blend of mahua-diesel the B-25 is having the highest value of 47 ppm

- **Effect on Carbon Monoxide (CO):-**

  Carbon Monoxide percentage increases with increase in load at constant speed. The value of the CO is found to be 0.13 % for pure diesel at full load. As the blend of mahua-diesel gets increase then there is decrease in % of CO from B-25 to B-75. The highest value of the blend B-25 is 0.12 % at full load.

- **Effect on Oxides of Nitrogen (NO_x):-**

  The % of NO_x is increases from as the load on the engine at constant speed is increases. The highest value of the diesel is found out to be 605 ppm at full load. As the % of blend mahua-diesel increases the value of NO_x also gets increases. The highest value of the blend B-75 is 1648 ppm at the full load.

- **Effect on Thermal Analysis:-**

  From the analysis of ANSYS simulation of B25 blend maximum thermal stresses developed on piston and piston ring is 1542 Mpa and 579 Mpa respectively; stresses developed in cylinder inner surface is 1362 Mpa. at the internal temperature is 1190^0C. As internal temperature of cylinder and piston using pure diesel and biodiesel blend (B25) is nearly equal so that internal stresses and temperature distribution

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