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The Effect of Injection Parameters on CI Engines Performance and Emissions Using Sesame and Pongamia Pinnata Methyl Ester as Fuels

Purushotham Nayaka D S[1], Sreekantha A[2]

1PG student, Dept. of Mechanical Engineering , BTLIT, Bangalore

2Asst.professor Dept. of Mechanical Engineering, BTLIT, Bangalore

ABSTRACT

Biodiesel are derived from vegetable and animal fats. In this present work, transesterification of sesame (Gingelly) oil and pongamia pinnata (Honge) oil is done to reduce the viscosity of the vegetable oil. The processed oil is used to operate four strokes, single cylinder diesel engine with blends of methyl ester of sesame and pongamia pinnata. The influence of different injection parameters like injection timing and injection pressure on the performance of diesel fuel blends is studied with an aim to obtain comparative measures of brake power, brake specific fuel consumption brake thermal efficiency and emission like smoke opacity, unburnt hydro carbons, carbon mono oxide, carbon di oxide, and oxides of nitrogen with petroleum diesel. At 200 Bar injection pressure and 30°C injection timing the engine performance is found to be better, while sesame is found to be superior than pongammia pinnata.

Keywords: biodiesel, injection pressure, injection pressure, injection parameters.

1. INTRODUCTION

The history of alternative energy sources is worthy of study from many points of view. Diesel engines have been widely used for automobiles engineering, machinery, shipping equipment's and power generation because of their excellent drivability and thermal efficiency. At the same time diesel engines are the major consumers of the fossil fuels and contribute to various types of air pollutant emissions such as carbon monoxide (co), oxides of nitrogen (NOx), particulate matters. The excessive use of the fossil fuels has led to global environmental degradation and health hazards. The increasing concern of environmental protection and more stringent regulation on exhaust emissions, reduction in engine emissions becomes a major task in engine development. Also lot of effort is needed to reduce the dependence on the petroleum fuels as these are obtained from the limited reserves.All these points have led to research on alternative renewable fuels in the last decade.Biodiesel is one such alternative.Bio-diesel is essentially sulfur free and engines fueled with biodiesel emit significantly less particulates, hydrocarbons, and less carbon monoxide than those operating on conventional diesel fuel. Biodiesel is defined as the mono alkyl esters of long chain fatty acids derived from renewable lipid sources. Biodiesel can be produced from vegetable oil like neem, jatropha, soya, peanut, honge, cotton seed and many more.[1],[2],[3]. This oil can be used in diesel engine by reducing its viscosity, flash point and fire point by transesterification process. Jinlin Xue **[**10] studies the Effect of biodiesel on engine performances and emissions and concluded that the effect of biodiesel on engine power, economy, durability and emissions including regulated and non-regulated emissions, and the corresponding effect factors are surveyed and analyzed in detail. The use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engines with no or fewer modification. In this paper, the performance and emission characteristics of a single cylinder diesel engine is studied using sesame oil methyl ester (SOME) and pongamia pinnata methyl ester (POME) as fuels at different injection pressure [IP] and injection timing [IT]

2. Transesterification

The raw vegetable oil was extracted by mechanical expeller in which small traces of organic matter, water and other impurities were present. The basic composition of vegetable oils is triglycerides which are esters of three acids and one glycerol.Transesterification is a most common and well established chemical reaction in which alcohol reacts with triglycerides of fatty acids (vegetable oil) in presence of catalyst to form glycerol and esters. The vegetable oil is heated up to 60°c when 1%wt of catalyst KOH is mixed well in required amount of alcohol and then added to the heated oil which is continuous stirred. For complete reaction 3:1 alcohol: oil molar ratio is needed. 90% of the reaction takes place in first 2 minutes; for better biodiesel yield mixture is stirred for 60 minutes [10].The produced biodiesel is separated from glycerol and dried.

3. EXPERIMENTAL SETUP

The Figure1[18] shows the experimental setup and its components necessary to carry out engine test for performance characteristics at different injection pressure (IP) and injection timings (IT) using sesame and honge oil biodiesel blend with diesel (20% SOME and POME with 80% diesel separately) as fuel. The engine used for this test is Kirloskar, Single cylinder, 4 strokes, water cooled diesel engine having a rated output of 5.2 kW at 1500 rpm for a compression ratio of 17.5:1 and the engine is coupled with eddy current dynamometer for different load measurements. The water flow measurement is carried out with rotometer and exhaust emission measurement with INFRAYT model *ELD* gas analyser. The diesel engine performance and emission results at 180Bar and 27° bTDC are taken as standard and it is compared with performance and emission results for different fuels at different injection pressure and injection timing.

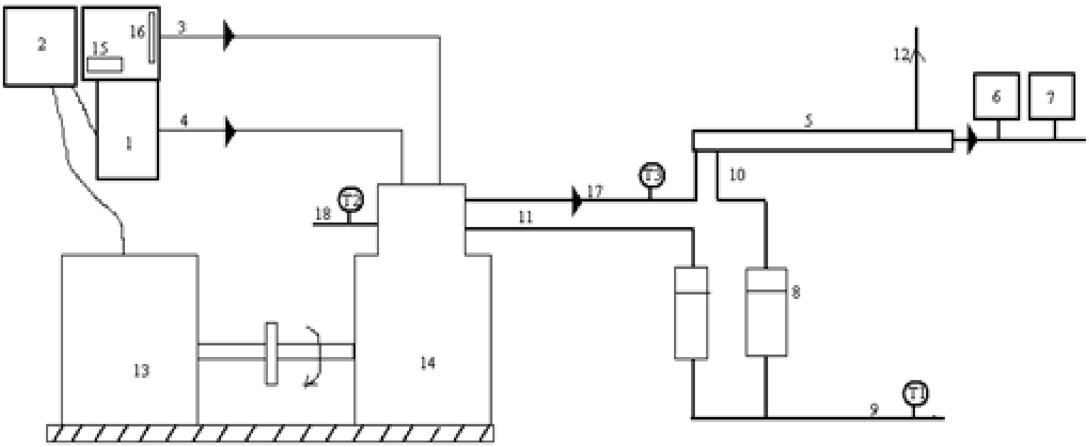

Figure 1: Schematic Diagram of the Experimental Set-up.

1 = Control Panel, 2 = Computer system, 3 = Diesel flow line, 4 = Air flow line, 5= Calorimeter, 6 = Exhaust gas analyser, 7 = Smoke meter, 8 = Rota meter, 9= Inlet water temperature, 10= Calorimeter inlet water temp., 11= Inlet water to engine jacket, 12 =Calorimeter outlet water temp., 13 = Dynamometer, 14 = CI Engine, 15 = Speed measurement, 16 = Burette for fuel measurement, 17 = Exhaust gas outlet, 18 = Outlet water from engine jacket, T1= Inlet water temperature, T2 = Outlet water temperature, T3 = Exhaust gas temperature.

Table 1: properties of fuel. [19]

PROPERTIES	DIESEL	SESAME OIL	SOME	PPO	POME
Density (kg/m^3)	826.44	920	870	0.924	0.860
Specific gravity	0.826	0.920	0.870	0.967	0.892
Viscosity (mm²/sec)at 0°c	3.22	32.5	4.28	48	6.27
Acid value (mg KoH/grm	0.0	0.0567	0.0312	5.40	0.46
Flash point (°c)	50	260	162	225	120
Calorific value(kj/kg)	42227	39349	40210	8742	3700

4. FUEL PROPERTIES

The properties of fuel used in this test i.e. diesel, sesame oil, sesame oil methyl ester, pongammia pinnata oil, pongammia pinnata methyl ester are as shown in Table 1

5. RESULTS AND DISCUSSION:

Effect of injection pressure on engine performance and emission

Brake specific fuel consumption

Variation of brake specific fuel consumption (BSFC) with brake power (BP) at injection pressure of 180 bar 200 bar and 220 bar for methyl esters of sesame seed and pongamia pinnate oils is shown in figure 2 and 3. The figure 2 shows that the BSFC for all fuels is higher than diesel fuel, which was observed due to lower calorific value of bio diesel, high density and lower energy content. Higher the density more will be the discharge of fuel for the same

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displacement of the plunger of the fuel injection pump. It is found that the BSFC is decreased with increase in injection pressure to 200 bars. This may be due to that, as injection pressure increases the penetration length and spray cone angle increases, so that at optimum pressure, fuel air mixing and spray atomization will be improved[6],[11]. BSFC for methyl esters sesame seed and pongamia pinnate oil fuels are 0.332and 0.34kg/kW-hr at 200 bars, whereas diesel fuel is l 0.301 kg/kW-hr.

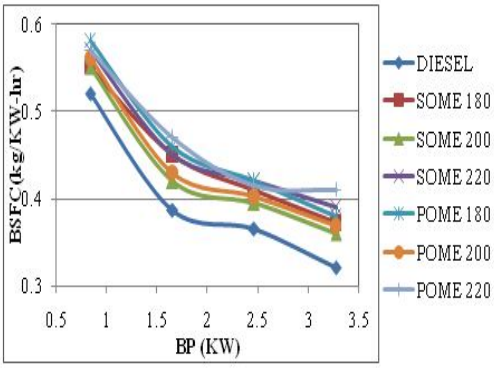

Figure 2: Variation of BSFC with BP for Different IP at 27 0C IT

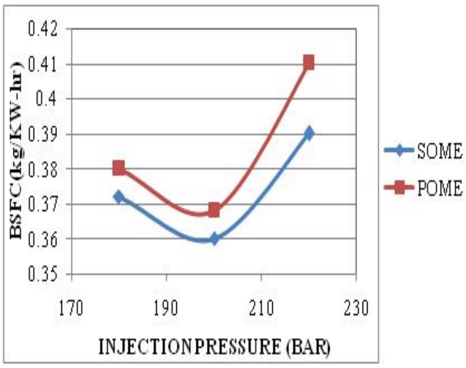

Figure 3: Variation of BSFC with Injection Pressure at 200 Bar IP

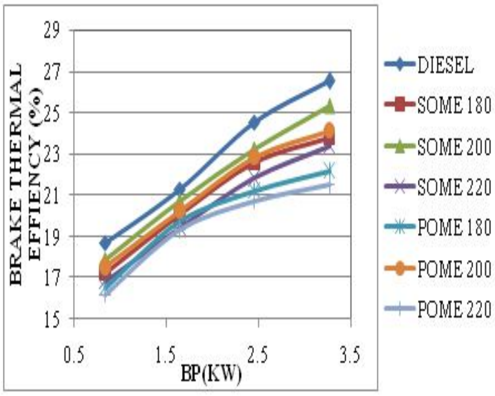

Figure 4: Variation of BTE with BP for Different IP at 27 0C IT

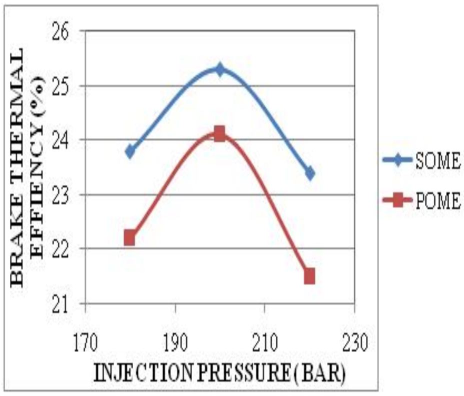

Figure 5: Variation of Injection Pressure with BTE

Brake Thermal Efficiency (BTE)

Variation of brake thermal efficiency with BP at injection pressure of 180 bar 200 bars and 220 bars for methyl esters of sesame seed and pongamia pinnate oils is shown in figure 4 and 5 respectively. Brake thermal efficiency is increased with increase in BP due to reduced heat loss with increase in power and increase in load. From figures 4 and 5 efficiency of all fuels is low at lower injection pressure; this is due to poor atomization and mixture formation of vegetable oils during injection. With increase in injection pressure, the brake thermal efficiency (BTE) is increased due to the reduction in the viscosity, improved atomization and better combustion. The maximum efficiency for all fuels tested is obtained at 200 bar injection pressure, this is due to fine spry formed during injection and improved atomization, which reduces the physical delay period resulting in better combustion and also observed that, the efficiency is again decreased at 220 bar, this may be due to that at higher injection pressure the size of fuel droplets decreases and very high fine fuel spray will be injected, because of this, penetration of fuel spray reduces and momentum of fuel droplets will be reduced[6],[11],[13]. With increase in injection pressure from 180 bars to 200 bars, the efficiency is increased, indicating efficiency is improved in case of methyl esters and 1 to 2% is decrease by the increase to 220 bar injection pressure.

Effect of Injection pressure on emission

Smoke Opacity

The Figure 6 represents variation of smoke opacity with brake power for different injection pressures of diesel and biodiesel blends and from the figure 6 it is seen that smoke opacity variation is higher for diesel compared to biodiesel at different injection pressures, this is because of oxygen content in the biodiesel i.e., nearly 11% by weight. The presence of oxygen in the fuel increases combustion rate of the fuel thereby reducing the smoke opacity. It is also seen from Figure 7, that by increase of injection pressure smoke opacity reduces and smoke opacity increases with the increase of brake power [19],[6]. The Figure 7 shows the minimum smoke opacity of 61.2% for SOME at IP 220 Bar

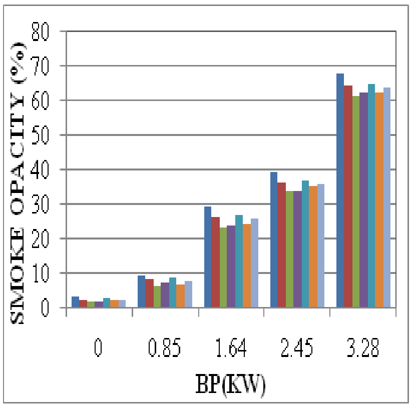

Figure 6: Variation of BP with Smoke Opacity for Different IP at 27 °C IT

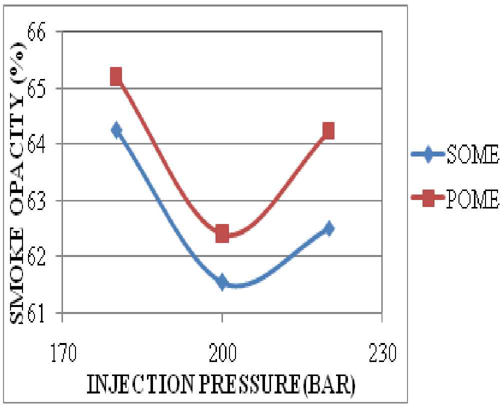

Figure 7: Variation of IP with Smoke Opacity

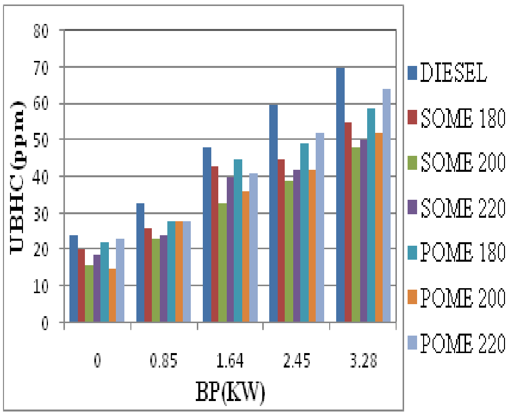

Figure 8: Variation of UBHC with BP for Different IP at 27 oC IT

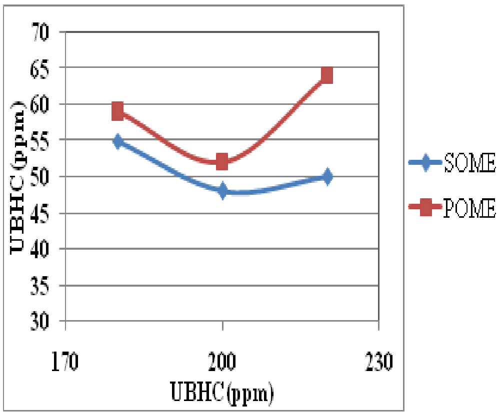

Figure 9: Variation of UBHC with IP

Unburnt Hydro Carbons:

It is observed from figures 8 and 9 that the UBHC emissions for all bio diesels are lower than the diesel fuel, indicating that the heavier hydrocarbon particles that are present in the diesel fuel increase UBHC emissions. The UBHC emission of methyl esters at full load is approximately 31 to 34% lower than the diesel value. Hydrocarbon chains of original vegetable oil that have been chemically split off from the naturally occurring triglycerides and its one end of the hydrocarbon chains are oxygenated. The presence of oxygen in the fuel was thought to promote complete combustion that leads to lowering the HC emissions. These reductions indicate more complete combustion of the fuel. At 200 Bars injection pressure there was minimum UBHC emissions. At 220 bar it seems to an increase in UBHC which may be because of finer spry which reduces momentum of the droplets resulting in less complete combustion [11].

Carbon Monoxide (CO):

Variation of carbon monoxide (CO) with BP is shown in figure 10 and 11. Carbon monoxide emission from a diesel engine mainly depends upon the physical and a chemical property of the fuel. The bio diesel itself contains 11% of oxygen which helps for complete combustion From the figures 10 it is found that the amount of CO is decreased at part loads and again increased at full load condition for all fuels. This is common in all internal combustion engines since air-fuel ratio decreases with increase in load. The carbon monoxide emissions increase as the fuel air ratio becomes greater [13],[19]. The CO emission for fuels at full load is approximately 42 to 49% lower than the corresponding value for diesel.

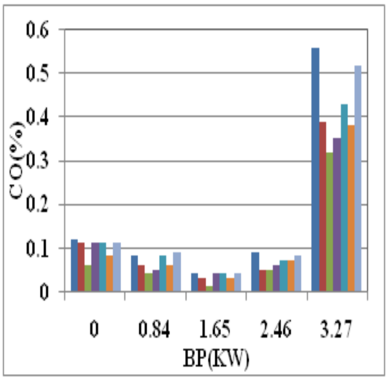

Figure 10: Variation of CO with BP at Different IP and 27 °C IT.

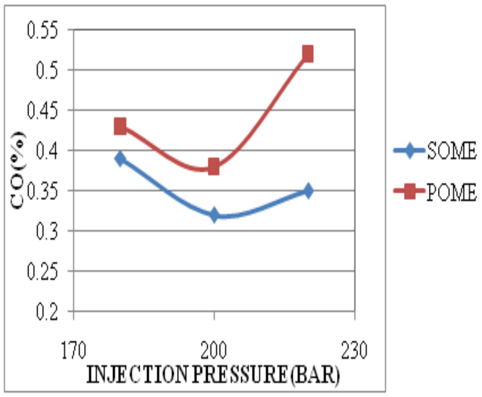

Figure 11: Variation of Injection Pressure with CO

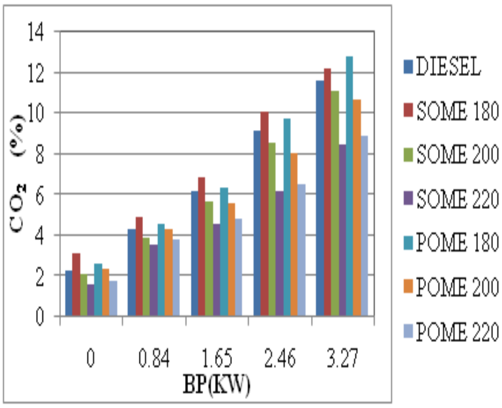

Figure 12: Variation of CO2 BP at IP and at 27 0C IT

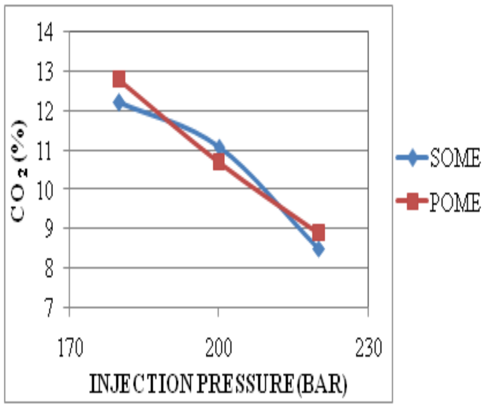

Figure 13: Variation of IP with CO2 Emissions

Carbon di oxide

From the Figure 12 and 13, the variation of carbon dioxide emission is found higher at SOME 180 Bar which is lower than SOME 220 Bar. This is because of low injection pressure combustion rate will be low resulting in high carbon dioxide emission whereas, at high injection pressure the combustion rate will be high resulting in low carbon dioxide emission. The Figure 13 shows low carbon dioxide emission of 8.8% at IP of 220 Bar for sesame oil biodiesel [6], [11], [13].

Oxides of Nitrogen

The nitrogen oxides results from the oxidation of atmospheric nitrogen at high temperature inside the combustion chamber of an engine rather than resulting from a contaminant present in the fuel. From the figures 14, we see that the amount of NO_x is increased with increase in BP for all fuels this is because with increasing load, the temperature of combustion chamber increases and NO_x formation is a strongly temperature dependent phenomenon and the average NOx emission in the case of conditioned bio diesel is 1123ppm which is slightly higher than the diesel fuel (1038ppm) [11,13,19]. At lower temperature oxygen and nitrogen are chemically unreactive, but at above 1500°c oxygen and nitrogen react to form NO_x. NO_x emissions were lower at 200 bar injection pressure indicating that effective combustion was taking place during the early part of expansion stroke it can be observed in figure 15.

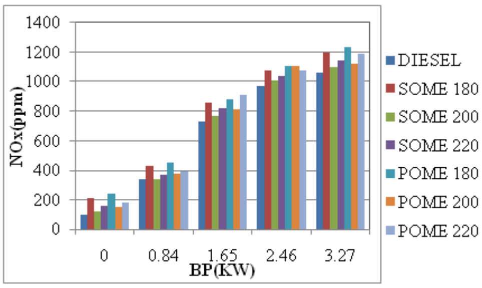

Figure 14: Variation of NOX Emission with BP for Different IP at 270C IT

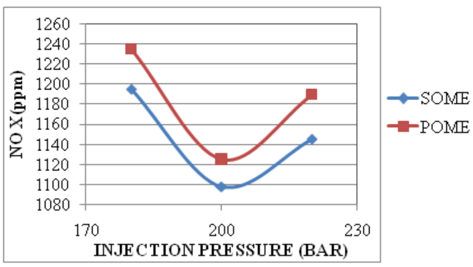

Figure 15: Variation of Oxides of Nitrogen with IP.

Effect of Injection Timing on Engine Performance and Emission

Brake specific fuel consumption (BSFC)

From figures 16 and 17 shows larger amount of conditioned bio diesel is supplied to the engine compared that of standard diesel. The higher brake specific fuel consumption values in the case of vegetable oil esters due to the higher density and lower calorific values. It can also observed from figure 17 that advance of injection timing leads with lower BSFC this is due to optimum delay period and smaller amount of fuel during after burning[14],[4].

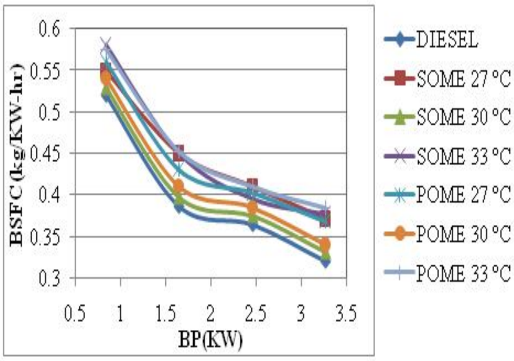

Figure 16: Variation of BSFC with BP at IP 200 Bar for Different IT

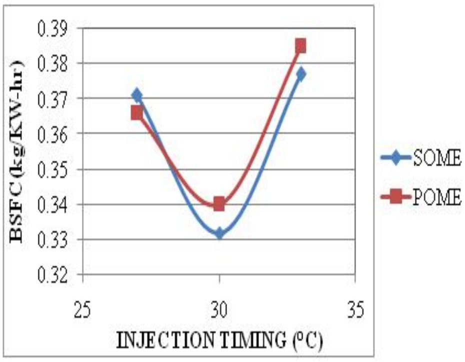

Figure 17: Variation of BSFC with Injection Timing

Brake Thermal Efficiency (BTE)

Brake thermal efficiency as seen in figure 18 increases when the injection timing is advanced. This is because starting the combustion earlier compensates the effect of slow burning [4],[5]. Combustion is slow with conditioned bio diesel on account of its high viscosity which leads to a poor spray and mixture with air. The maximum brake thermal efficiency occurred at the static injection timing of 30°bTDC which is selected as optimal. This is 3° more advanced than that of diesel. Hence changing the injection timing from the one optimum for diesel to the one suitable for conditioned bio diesel increases the brake thermal efficiency at full load from 24 to 25.4 % in case of methyl esters. Injection pressure combustion rate will be low resulting in high carbon dioxide emission whereas, at high injection pressure the combustion rate will be high resulting in low carbon dioxide emission.The Figure 13 shows low carbon dioxide emission of 8.8% at IP of 220 Bar for sesame oil biodiesel [6], [11],[13].

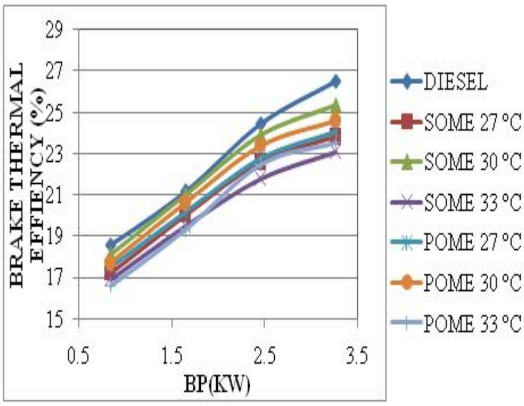

Figure 18: Variation of BTE with BP for Different IT at 200 Bar IP

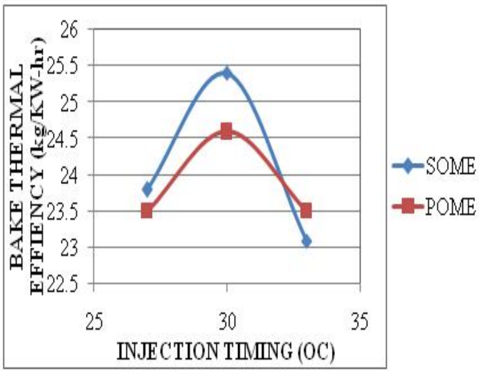

Figure 19: Variation of IT with BTE

Effect of injection timing on emission

Smoke opacity

From the figure 20 and 21 indicates the variation of smoke opacity with BP. The opacity is increased with increase in load. The figure shows that the opacity is significant variation with conditioned bio diesel compared to diesel fuel. The smoke level decreases as the injection timing is advanced because of the dominance of the premixed combustion phase [5], [11].

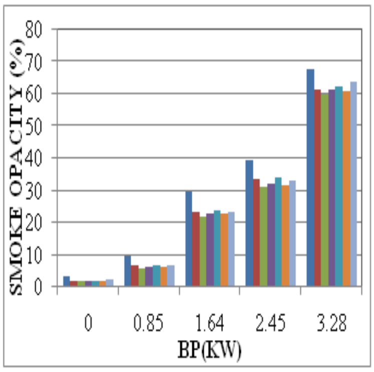

Figure 20: Variation Of Smoke Opacity with BP For Different IT at 200 Bar IP

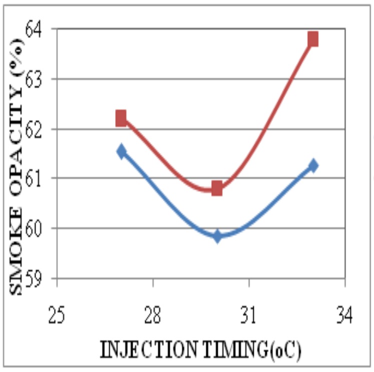

Figure 21: Variation of Smoke Opacity with IT

Unburnt Hydro Carbons

As shown in figure 22 and 23 this injection timing lowers the HC level at all loads due to improved combustion and use of over leaner fuel air mixtures as compared to other timings 27^0bTDC and 33^0bTDC and account to improved brake thermal efficiency as shown in the figure 21 and 22.The HC level at full output falls off from average 68 ppm with the timing of 27^0bTDC to average 46 ppm with the best injection timing of average 30°bTDC[11],[18].

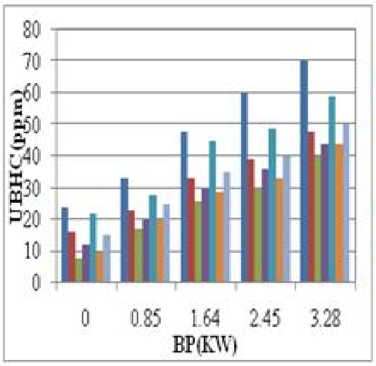

Figure 22 Variation of IT with BP for Different IT at 200 Bar IP

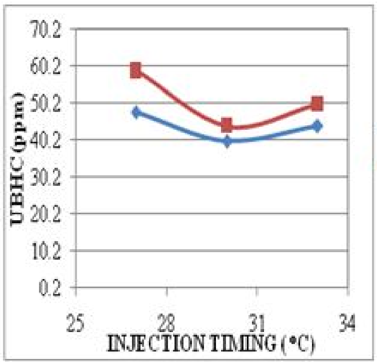

Figure 23:Variation of IT with UBHC

Carbon Mono Oxide

An increase in BP at any conditioned oil and injection timing at low load CO level increases and medium loads CO level decreases slightly as shown in figure 24 and 25. At all loads, at 30°bTDC injection timing condition of CO level is less about 10% volume compared with 27°bTDC and 33^obTDC. This is because of optimum delay period. At 27^obTDC and 33^obTDC injection timing, the timing required for proper mixing of air and conditioned bio diesel may not be sufficient, this will result high fuel consumption and exhaust level[14],[18].

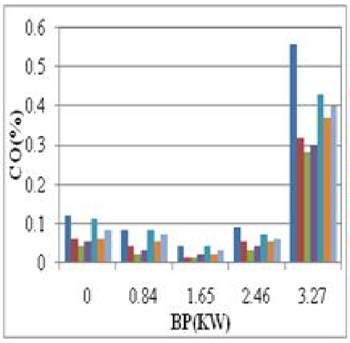

Figure24:Variation of CO with BP for Different IT and at 200 Bars IP

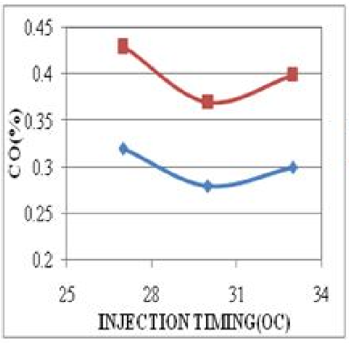

Figure25:Variation of IT with CO

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Carbon Di oxide

The Figure 26 shows carbon dioxide emission variation for different injection timings and it is found that the carbon dioxide emission is lower for 30^0 bTDC and higher for 27^0 bTDC. The minimum carbon dioxide emission value of 10.1% is found in case of SOME at IT of 30^0 bTDC is shown in Figure 27[11],[18].

Oxides of nitrogen

Variation of NO_x with BP is shown in figure 28 to 29. From the figure 28 it can observed that the NO emission level increases with advance the injection timing as expected due to increased cylinder gas temperatures. At full load the average increase of 1100 ppm at the injection timing of 27^0bTDC to 1200 ppm with the optimum timing of 33^0bTDC with conditioned bio diesel[14],[18]. It can observed that the NOX emission level increases with advance the injection timing as expected due to increased cylinder gas temperatures.

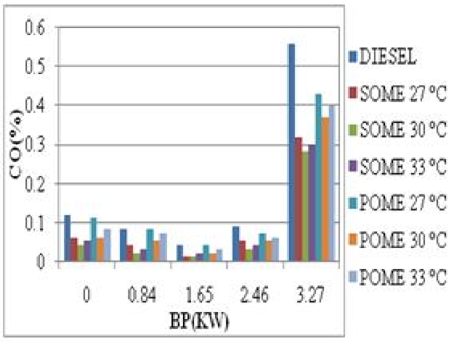

Figure 24: Variation of CO with BP for Different IT and at 200 Bars IP

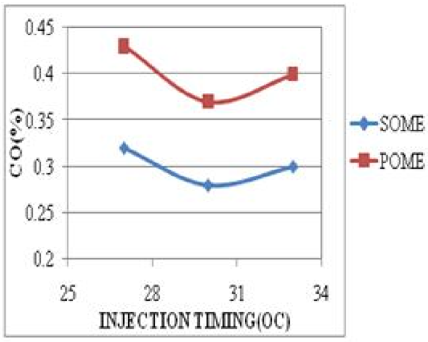

Figure25: Variation of IT with CO

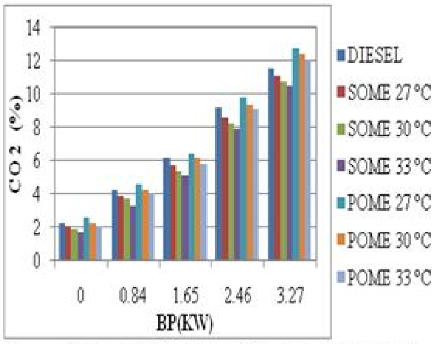

Figure 26: Variation of CO2 with BP at Different IT and at 200 Bar IP

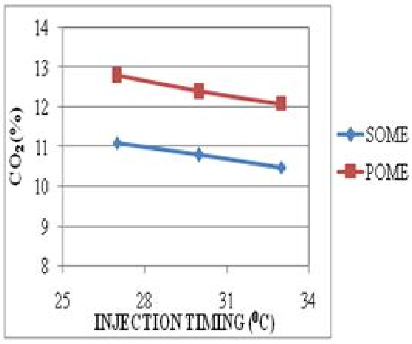

Figure 27: Variation of Injection Timing with CO2

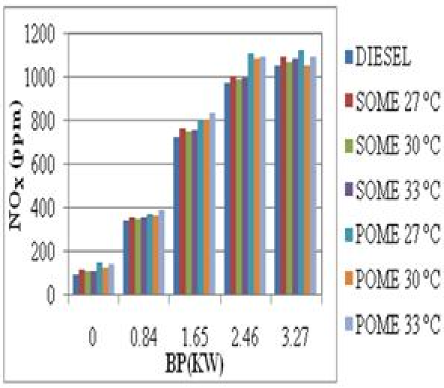

Figure 28: Variation of BP With NOX for Different IP at 200 Bars.

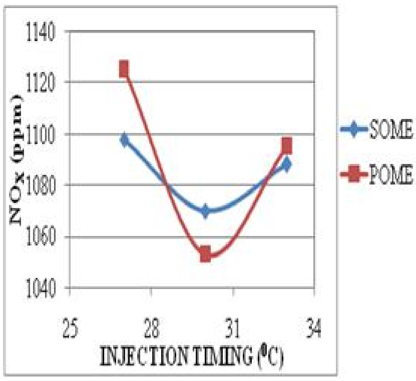

Figure 29: Variation of IP with Nox

6. CONCLUSION

The present investigation evaluates the biodiesel production from KoH catalyst and methanol. Performance and emission characteristics of both sesame and pongamia pinnate oil methyl esters are compared with ordinary diesel in a diesel engine under varying load and speed different injection pressure and injection timing conditions. The following are derived from this investigation.

1. The BTE is improved with increase in BP, this was due to reduction in heat loss and increase in power with increase in load. At 200 bar pressure the maximum efficiency of methyl ester of sesame and pongamia pinnate oil fuel are obtained as 25.4% and 24.6% respectively at full load conditions which are very close to diesel efficiency (26.52%)
2. Brake thermal efficiency increases when the injection timing is advanced. This is because starting the combustion earlier compensates the effect of slow burning. The combustion is slow with conditioned bio fuels on account of its high viscosity which leads to a poor spray and mixture with air.
3. BSFC for all fuels is higher than diesel fuel, which was observed due to lower calorific value of biofuels. BSFC is decreased with increase in injection pressure to 200 Bar for all fuels. This may be due to that, as injection pressure increases the penetration length and spray cone angle increases.
4. It is seen that larger amount of conditioned bio fuel is supplied to the engine compared that of standard diesel. The higher brake specific fuel consumption values in the case of vegetable oil esters can be due to the higher density and lower calorific values. The advancement of injection timing leads with lower BSFC this may due to optimum delay period and smaller amount of fuel during after burning.
5. The UBHC emission of methyl esters at full load is approximately 23% lower than the diesel value. At 200 Bar injection pressure there was minimum UBHC emissions. At 220 Bar it seems to an increase in UBHC which may be because of finer spry which reduces momentum of the droplets resulting in less complete combustion.
6. HC emission is lowest with the best injection timing namely 30°bTDC.This injection timing lowers the HC level at all loads due to improved combustion and use of over leaner fuel air mixtures as compared to other timings and account improved brake thermal efficiency. The HC level at full output falls off from average 56 ppm with the timing of 27°bTDC to average 48 ppm with the best injection timing of average 30° bTDC.
7. It is observed that the CO emissions for methyl ester fuels used are lower than the diesel fuel, approximately 33% lower than the corresponding value for diesel.
8. At 30°bTDC injection timing condition of CO level is less about 15% volume compared with 27°bTDC and 33°bTDC. This is because of optimum delay period, the timing required for proper mixing of air and conditioned biofuels may not be sufficient.
9. It is also observed that the average NOx emission in the case of conditioned bio fuels is 1112 ppm which is slightly higher than the diesel fuel (1063ppm).NOX emissions were lower at 200 Bar injection pressures indicating that effective combustion was taking place during the early part of expansion stroke.
10. It can observed that the NOX emission level increases with advance the injection timing as expected due to increased cylinder gas temperatures.
11. The higher opacity is occurred at lower injection pressure (180 Bar). With the increase in injection pressure from 180 to 200 Bar, the opacity is reduced by average 7 to 8%. It indicates that the injection pressure variation does not much effect on opacity measurement.
12. The smoke level decreases as the injection timing is advanced, as is normal in diesel engines because of the dominance of the premixed combustion phase.
13. Increasing the injector opening pressure from the rated value for diesel (180 Bar) to 200 Bar resulted in a significant improvement in performance and emissions with conditioned oils (methyl esters) due to better spray formation.
14. Advance of ignition timing increases the ignition delay and leads to a more prominent initial phase of combustion, the premixed part. Advancing the injection timing by 3°crank angles (to 30°bTDC) performance and emission characteristics have been improved.
15. Compared to pongamia pinnate, sesame methyl esters have better and superior performance and emission characteristics under same working conditions.

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AUTHOR

purushotham Nayaka D, S is pursuing M.Tech in thermal power engineering from BTLIT Bangalore. Working on biodiesel from past 4 years on different blends and different factors which affect the performance, emission and suitability in CI engines. Published technical paper titled "Effect of Injection Parameters on Engine Performance and Emissions Using Cotton Seed Biodiesel as Fuel in International journal of emerging trends in engineering and development, ISSN NO 2249-6149, issue 4, volume 3, April-May 2014

Sreekantha A , working as Asst. professor in Dept. of mechanical engineering , BTLIT, Bangalore. secured II rank in M.Tech (thermal engineering systems technology) from Davangere university, Davangere. Area of research are computation fluid dynamics and Biodiesel