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Evaluation of performance, emission and combustion characteristics of waste cooking oil biodiesel using additives

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Abstract:

Transport is a heavily reliant industry on petroleum and subsequent pollution. The development of a new era of biofuels is being considered, although existing biofuels should be used less. Cooking oil may be an intriguing diesel engine alternative fuel in certain rare circumstances. A bio-diesel diesel engine's output and emissions are heavily influenced by the engine's ignition and combustion processes. A mixture of additive solvents are used to study performance evaluation, emission characteristics and combustion characteristics while the engine was running in two distinct dimensions (B20+1, B20+2) (i.e. n-Butanol). Because of the high viscosity of pure cooking oil, the engine had trouble starting, so the team decided to utilise diesel instead. Biodiesel was produced and utilised in diesel engine performance testing as biodiesel.

Keywords: n-Butanol, combustion, transesterification, viscosity.

1. Introduction:

A large number of industries employ compression ignition and diesel-powered engines due to their superior fuel energy conversion and simplicity of operation. When it comes to environmental issues and the impending decline of fossil fuels, the world is searching for sustainable alternatives like bioethanol and biodiesel to take their place. Food oils like soyabean, palm and rapeseed may be used, as can other types of oils including Jatropha, Pongamia, and Mahua. A possible diesel replacement has gained interest due to the immediate use of such oils in engines, however problems have emerged during engine operation, requiring ongoing maintenance and repair. Because the fuel properties of biodiesel and petro diesel are so similar, the latter is a great substitute for the latter. As an oxygenated fuel with the a 5-12 percent lower energy level than diesel, it may be used as a stand-alone fuel or combined with diesel without altering the engine in any way. It is also environmentally friendly. In recent years, efforts were made to utilise a broad variety of different kinds of fuel in contemporary diesel engines, with mixed results. The usage of SVOs is highly restricted because to their high viscosity and the possibility that they may induce engine fouling as a consequence of bad fuel atomization, delaying combustion, as well as carbon deposition at injector and valve seats. The usage of SVOs for the purpose of feeding fuel injection engines results in fast clogging of injectors leading to inadequate atomization, poor combustion, as well as lubricating oil diversion caused by partially burnt vegetable oil. One method of making the oil thick like diesel is to mix SVOs with diesel or transesterify SVOs from biodiesel, both of which are effective.

According to research, changing the injection and ignition time in diesel engines may change the air/fuel ratio. It is evident from the graph that changes in injection time have a substantial effect on brake specific fuel consumption, brake thermal efficiency, and nitrogen oxide emissions (NOx).Proper air-fuel mixture, injection pressure, and timing are all critical for efficient diesel combustion. A higher cetane number results in less smoke, but a higher CO2 output since it shortens the ignition time and raises the injection pressure. When utilising biodiesel as a fuel for engines, problems may arise due to a variety of reasons. This article explores these issues as well as potential solutions. To make biodiesel and biodiesel blends work, existing engines must be updated, which isn't the situation right now.

1.1. FEEDSTOCK'S FOR BIODIESEL PRODUCTION

Biodiesel is indeed a monoalkyl ester containing fatty acids that is created from edible & non-edible oils, but also animal fats. It is a fuel that may be produced from a variety of sources. As a result of high costs and competition with food, there are only so many edible vegetable oils that can be produced. Biodiesel may be made from non-edible oils like Jatropha, Pongam, Linseed, Mahua, & Neem, because they serve no other function than as a fuel. India has enormous potential for these oils. Neem and Mahua, for example, have higher yearly output than other oils, even when accounting for additional applications, such as in pharmaceuticals and cosmetics. Large plantations in India's wastelands, such as Pongamia Pinnatta and Jatropha curcas, are anticipated to begin producing seeds for oil extraction in the next years, and this won't be followed by any agricultural crops.

2. Literature Review:

Surakasi Raviteja, (2021) [1] in their paper titled Combustion Characteristics Of Waste Cooking Oil Bio Diesel On Four Stroke Diesel Engine Using Additives in which this study looked at combustion characteristics utilising variety of additional solvents. Due to the high viscosity of pure cooking oil, the engine struggles to start. Biodiesel for diesel engine performance testing was produced.

Benard A Udeh (2017) [2] in their paper" "Produced biodiesel from waste sunflower oil for improved cost and energy efficiency from fried chicken and plantains" covers the method of "Biodiesel from waste sunflower oil manufacturing".

PremKumar and Indraj Singh (2015) [3] in their article, Biodiesel from cooking food waste oil generation and output were discussed. 97.15 percent of biodiesel may be made by simply transesterifying used cooking oil.. Additionally, the experimental research demonstrates that biodiesel has the same characteristics as diesel fuel derived from used cooking oil.

Krunalkhiraiya, Nityam oza " (2013) [5] in their paper" A Review of Recent Research on Sunflower oil Biodiesel as Fuel for Diesel fired Boiler" in which includes the process is "Performance of CI engine using neat vegetable oil, blending oil with diesel, methyl ester of oil, blending sunflower bio-diesel with diesel is measured and compared to diesel ".

Zhang.Y et.al (2019) [6] in his research, he looked into how different biodiesel blends and diesel fuel droplets affected the burning of fuel droplets in a combustion chamber. In addition to clean diesel and biodiesel, various volumetric percentages of biodiesel blends to replace diesel oil were tested. In order to keep track of the burning of droplets, scientists have used speed schlieren and imaging techniques.

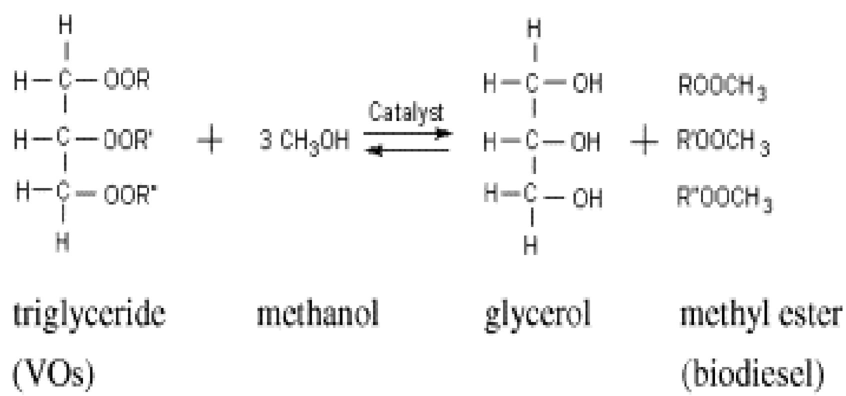
Lu H et.al (2007) [7] the author of the article explains in his paper that the combustion characteristics of Qilianta coal and rice straw were studied using a Pyris l TGA ThermogravimetricAnalyzer (PE/US). The findings indicate that when biomass is added to charcoal, the igniting temperature and time are reduced. When multiple samples are combined in the same volume, the heating rate increases.

3. PRODUCTION OF BIODIESEL

Biodiesel can be made out of edible or non-edible oils, animal fats, or waste cooking oil by utilising transesterification or alcoholysis, or by supercritical methanol transesterification. A strong acid or alkali as a catalyst either methyl nor ethyl alcohol or other solvent may be used, transesterification is the most common technique of producing industrial biodiesel from waste oil. In comparison to using a strong acid catalyst, using a strong alkali catalyst lowers both catalyst need and reaction time, making it a popular choice for transesterification in the production of biodiesel

3.1. Transesterification

The typical biodiesel production method uses transesterification to turn vegetable oils, animal fats, or waste cooking oils into fuel. Fatty acid alkyl esters are formed in the transesterification process by the reaction of glycerides with alcohols (usually methanol or ethanol) with in presence of a catalyst.



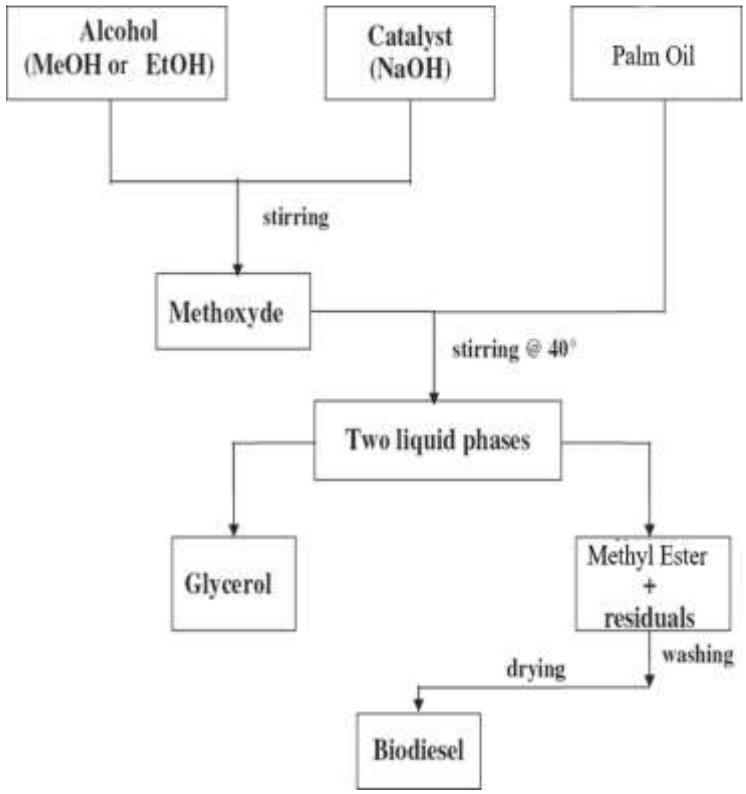


Fig. 3.1 Transesterification process schematic diagram

3.2. Biodiesel Preparation Process:-

1. Take a 500 ml or larger beaker. Heat 400ml oil in magnetic stirrer. Maintain a speed of less than 500 RPM while using the magnetic pellet. Regularly check the oil temperature using a thermometer. When the oil reaches 40oC, pour in the methanol already prepared. Heat the solution.
2. Dissolve 12 pellets of sodium hydroxide (NaOH) or 3.5 gramme in 125ml Methanol. Reduce the heat when the oil reaches 56°-58°C. Give it an hour to settle.
3. We can make out the methyl ester as well as glycerol layers that need to be separated
4. Fill the separator funnel with the gathered oil. Pour the glycerine into a separator and allow the oils to do the rest of the work of evaporation. Now take the glycerin and oil and separate them.
5. Refill the funnel with water and add the oil back in. Combine oil and hot water in a separating funnel to get rid of soap odours. This process should be repeated two or three times until the water is clear.
6. Remove the beaker from the stove and discard the used oil. The remaining water may be evaporated by heating the oil to 90°C. Bio Diesel requires the leftover oil.

3.3. Composition of a Bio-Diesel Blend

Isobutyl alcohol and diesel are the two main constituents of the blends we've created. We're uploading two examples of the mixes, each with a distinct persentage composition.

B-20

1) In which 20 percent of the fuel is bio diesel and 80 percent is regular diesel (Additive Isobutyl Alcohol With 2 percent of overall solution)
   In a beaker, combine 400 ml of diesel with 100 ml of biodiesel and 10 ml of isobutyl alcohol. Stir thoroughly (taken 2 percent of 500ml).
2) Biodiesel accounts for 20% of total fuel; diesel accounts for 80% (Additives Isobutyl Alcohol with 1 percent of overall solution)
   Isobutyl alcohol (5ml) is added while the mixture is being stirred thoroughly. Then we pour in the rest of the diesel and swirl it again (taken 1 percent of 500ml).

3.4. **Procedure for Biodiesel Engine Testing with a Diesel Engine:**

1. Fill the diesel tank just on panel frame.

2. The monitoring power input connector requires 230V single phase electricity. Now the RPM and temperature digital metres show the readings.

3. Disconnect the water line from the engine jacket.

4. Inspect the oil sump for lubricant.

5. Loosen the fuel valve then check the fuel line for air.

6. Start the engine as well as note the engine speed with the loads applied, keeping it under 1500RPM.

7. Then load the engine 6kg, 12kg at a time, letting it steady between each load and record

   - Engine speed using digital RPM indicator
   - Load the spring scale.
   - Burette fuel consumption
   - Manometer airflow quantity
   - Temperature indicator varies.

8. Slowly load the engine.

9. Record all relevant parameters.

10 Turn off the gasoline valve on the panel after the test is over.

Fig. 3.11 Engine test rig.

3.5. Five gas Analyzer

Fig. 3.12 Five gas analyser

This is mostly used for the purpose of inspecting the engine's emissions. As no air may enter the catalytic convertor's exhaust, the five gas analyzer gets precise emissions values by measuring the concentrations of each of the five gases present in the exhaust. Analyzer measures carbon monoxide, hydrogen carbide, carbon dioxide, oxygen, and nitrous oxide in five different ways (nitrogen dioxide).

4. Results and discussions:

4.1 Emission Parameters:

Table 1: Emission parameters of biodiesel B20 with additives

ALCOHOL	BLENDS	LOAD	CO	CO2	HC	O2	Nox
Isobutyl	B20+1	6	0.06	10.08	0.023	12.5	0.24
		12	0.065	12.5	0.031	13.01	0.245
	B20+2	6	0.058	10.1	0.019	11.92	0.242
		12	0.062	12.6	0.011	12.87	0.25

4.1.1 Graphical representation of Load Vs CO

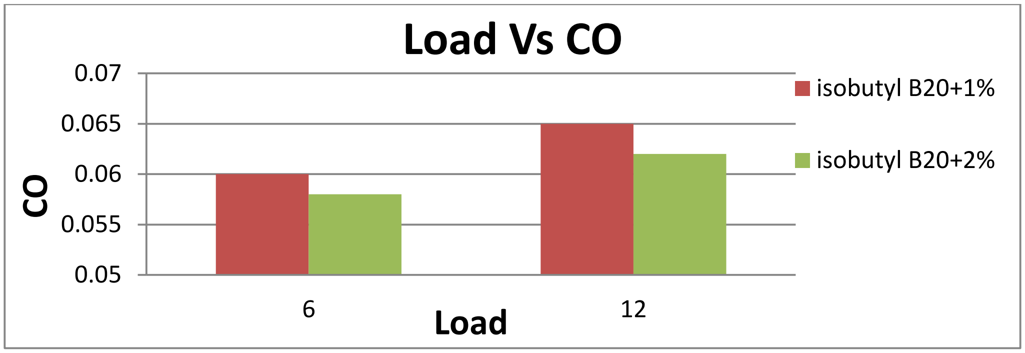


Fig.4. 1 Plot between load and CO

4.1.2 Graphical representation of Load Vs CO_2

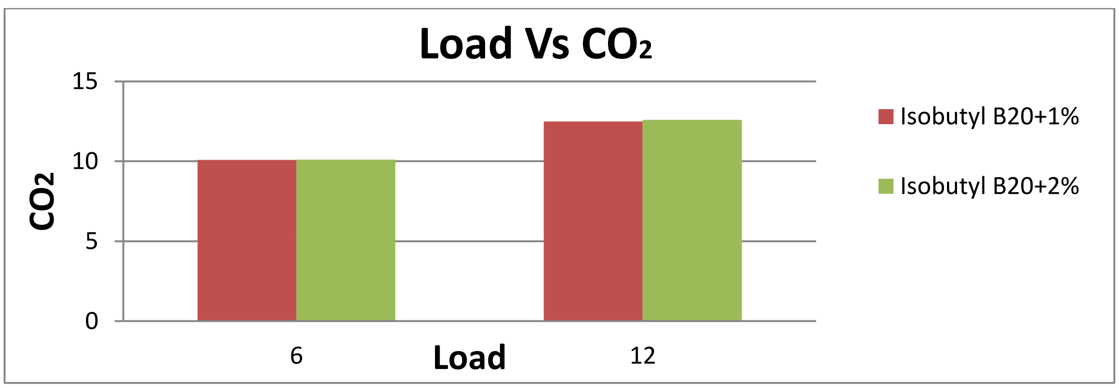


Fig. 4.2 Plot between Load Vs CO_2

4.1.3 Graphical representation of Load Vs HC

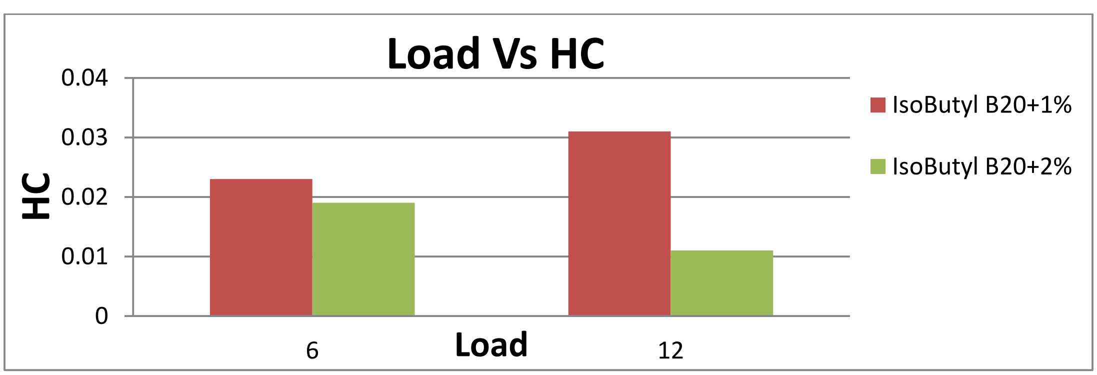


Fig. 4.3 Plot between Load Vs HC

4.1.4 Graphical representation of Load Vs O_2

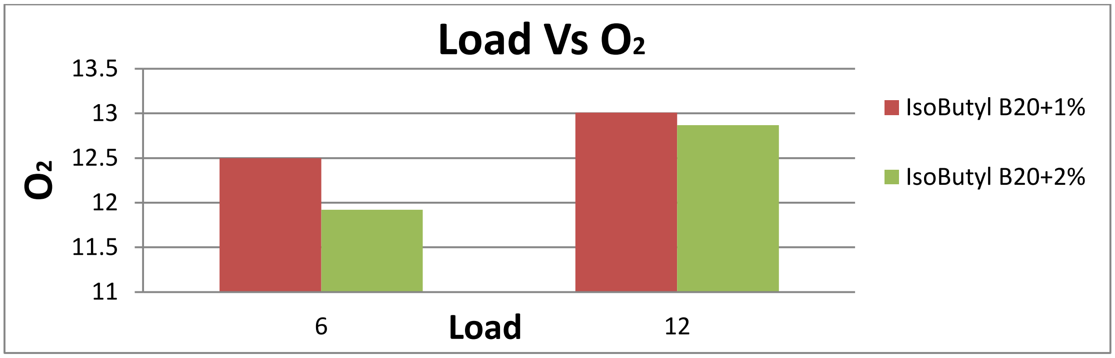


Fig. 4.4 Plot between Load Vs O_2

4.1.5 Graphical representation of Load Vs NO_X

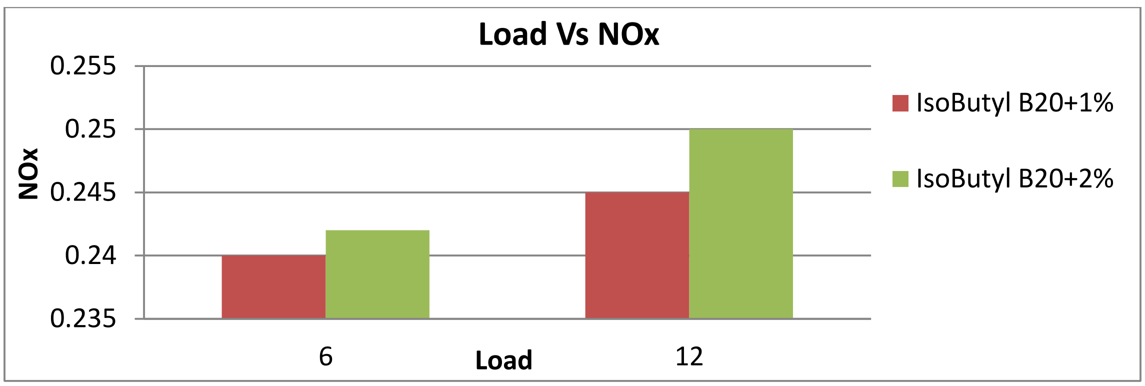


Fig. 4.5 Plot between Load Vs NO_x

Fig.4.1. explains the relation between load and CO for both 6kgs and 12 kgs of pure diesel, isobutyl B20+1% and isobutyl B20+2% and it can be observed that the value of CO is less for isobutyl B20+2% at 6kg load

Fig.4.2. provides context on the relationship between load and CO_2 for both 6kgs and 12 kgs of pure diesel, isobutyl B20+1% and isobutyl B20+2% and it can be observed that the value of CO_2 is less for isobutyl B20+1% at 6kg load

Fig.4.3. provides context on the relationship between load as well as HC with both 6kgs and 12 kgs of pure diesel, isobutyl B20+1% and isobutyl B20+2% and it can be observed that the value of HC is less for isobutyl B20+2% at 12kg load

Fig.4.4. provides context on the relationship between load as well as O_2 with both 6kgs and 12 kgs of pure diesel, isobutyl B20+1% and isobutyl B20+2% and it can be observed that the value of O_2 is less for isobutyl B20+1% at 6kg load

Fig.4.5. provides context on the relationship between load as well as NO_x with both 6kgs and 12 kgs of isobutyl B20+1% and isobutyl B20+2% and it can be observed that the value of NO_x is less for isobutyl B20+1% at 6kg load

4.2 Combustion characteristics:

4.2.1. B20+1% at 6Kg load

Figure4.6 shows the relationship between crank angle and cylinder pressure (CP) for B20+1 percent n-Butanol when the engine is loaded with 6 kg of weight. At a crank angle of 150 degrees, the maximum pressure was measured to be 58 Pa.

Figure 4.7 provides context on the relationship between crank angle as well as the total amount of net heat released (NHRR) when working with B20+1 percent n-Butanol at a 6 kg load. At an 80-degree crank angle, the neat heat release rate drops by 1000J, and at a 100-degree crank angle, the total amount of net heat released rises to 2100J.

Fig. 4.8 shows the connection between crank angle as well as pressure increase rate (RPR) for 6 kg of B20+1 percent n-Butanol, where the pressure rise rate first decreases by -12 Pa at an 80-degree crank angle before reaching a maximum of 21 Pa at a 100-degree crank angle.

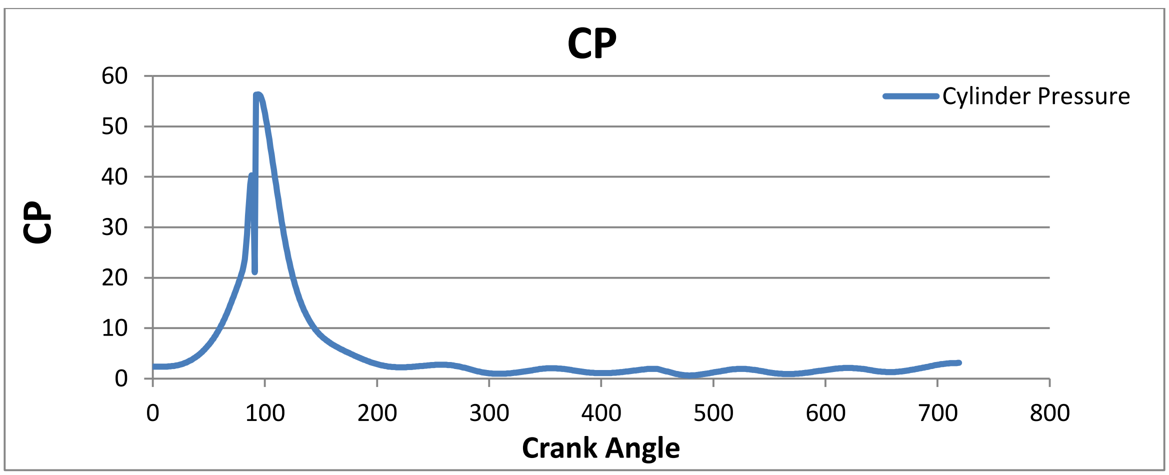


Fig.4.6 Crank angle vs. CP plot for a 6kg load at B20+1 percent

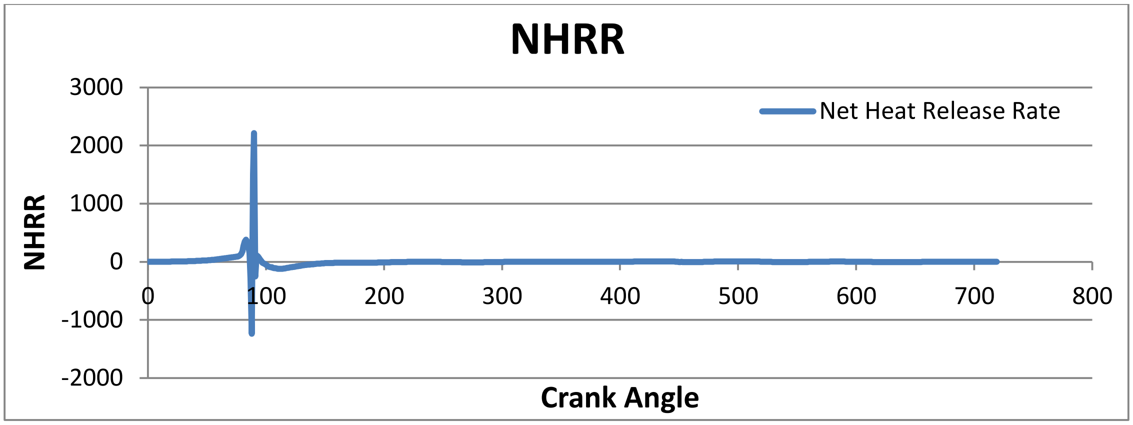


Fig. 4.7 Graph showing the relationship between the crank angle and the NHRR while using a 6kg load at B20+1 percent

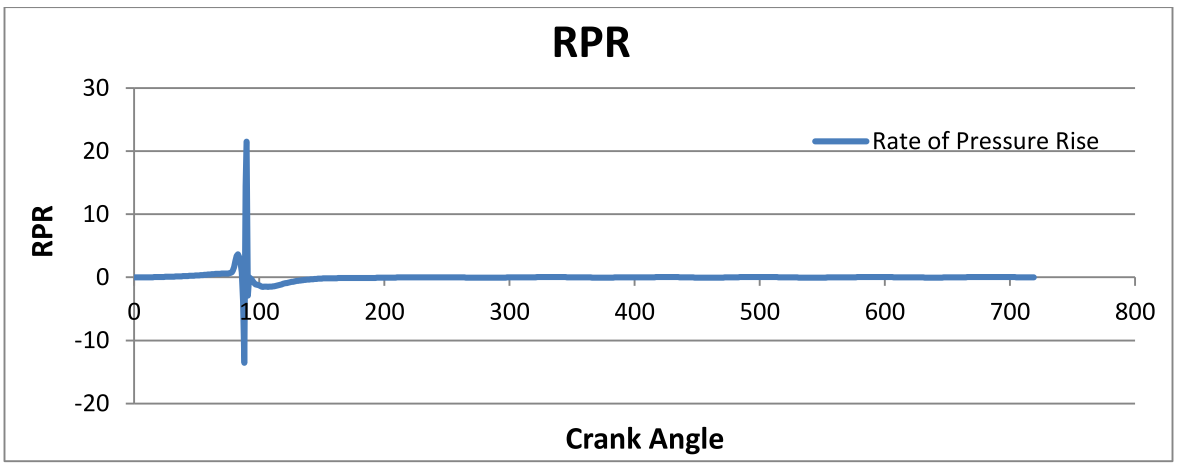


Fig. 4.8 The relationship between the crank angle and RPR for a B20+1 percent 6kg load is shown.

4.2.2 B20+1% at 12Kg Load

Crank angle versus CP using B20+1 percent n-Butanol at 12 kg weight are shown in Fig 4.9, as well as the maximum pressure were determined to be 60 Pa at a crank angle of approximately 410 degrees

Crank angle as well as NHRR of B20+1 percent n-Butanol @ 12 kg load are shown in Figure 4.10, with the highest net heat release rate occurring at around 400 degrees Celsius. The 200J crank angle was discovered.

When using B20+1 percent n-Butanol at 12 kg weight, the relationship of crank angle and RPR is shown in Figure 4.11. At a 390 degree crank angle, the maximum pressure is determined to be 6 Pa.

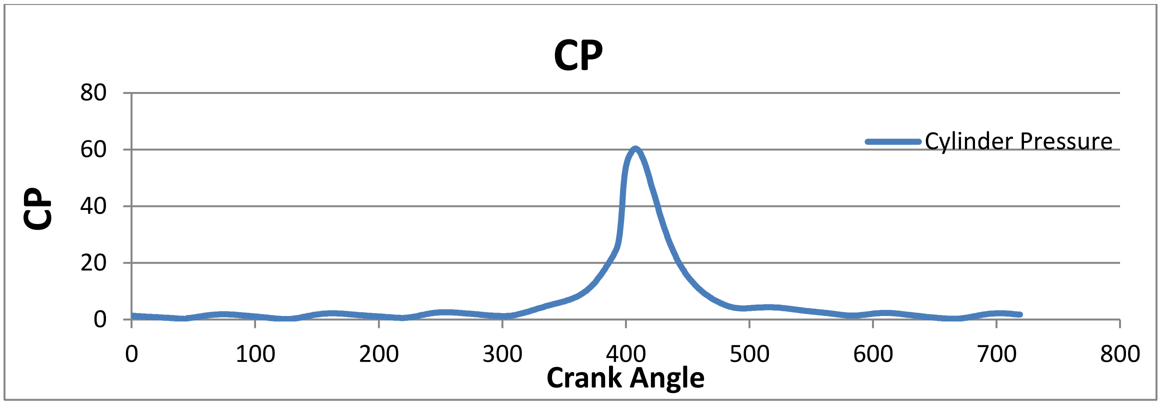


Fig. 4.9 Crank angle vs CP plot for a 12kg load at B20+1 percent

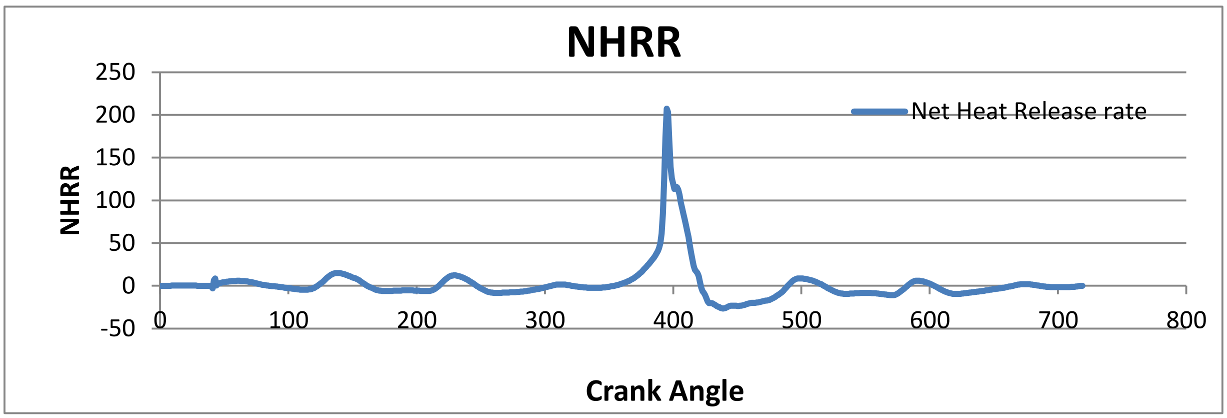


Fig.4.10 graph showing the relationship between the crank angle and the NHRR while using a 12kg load at B20+1 percent

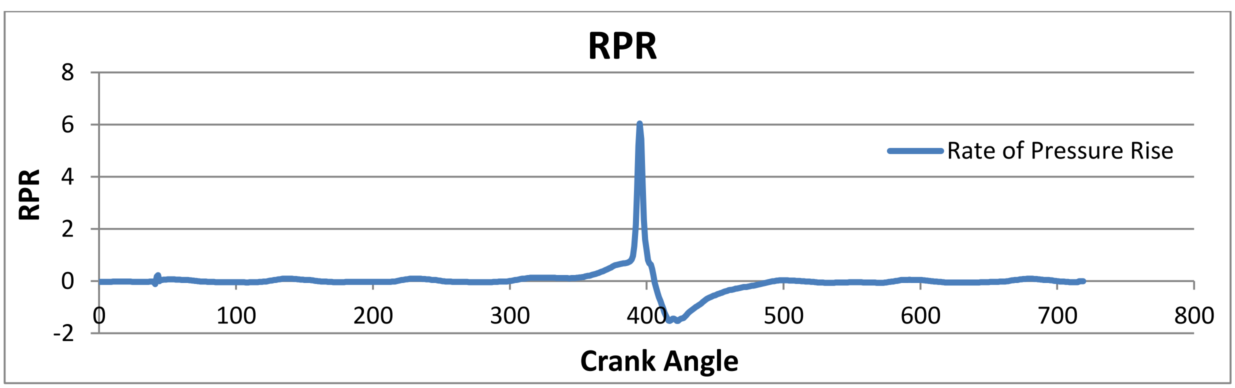


Fig. 4.11 The relationship between the crank angle and the RPR for a B20+1 percent 12kg load is shown.

4.2.3 B20+2% at 6Kg load

Crank angle & CP are shown in Figure 4.12 for B20+2% n-Butanol with a 6 kg load, and the maximum pressure is determined to be 52 Pa at a 380-degree Crank angle According to Figure 4.13, the relationship involving crank angle as well as NHRR is shown for B20+2% n-Butanol at 6 kg load, and the highest net heat release rate is determined to be 50 J at a crank angle of about 385 degrees.For B20+2% isopropyl alcohol at a 6 kg load, Figure 4.14 shows the relationship between crank angle and RPR; the maximum pressure was determined to be 4.5 Pa for about 364 degrees crank angle.

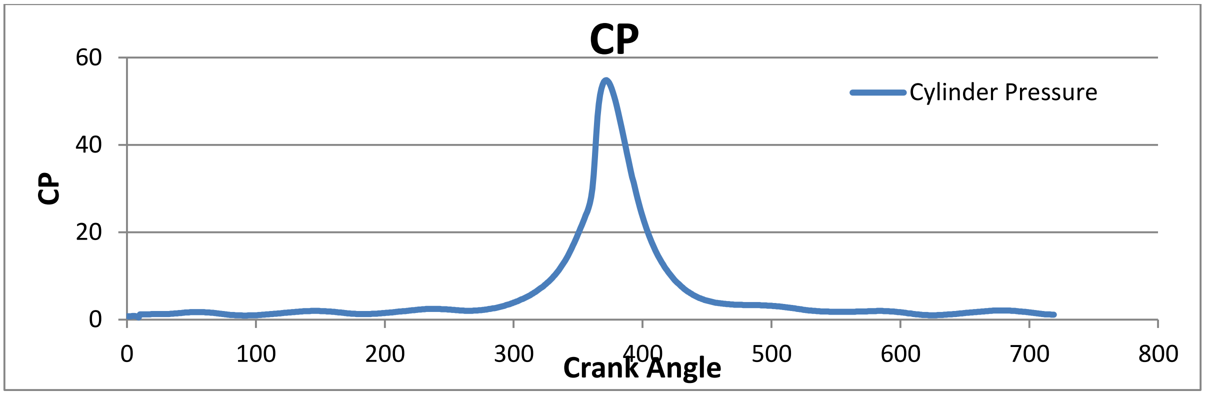


Fig. 4.12 Crank angle vs. CP plot for a 6kg load at B20+2 percent

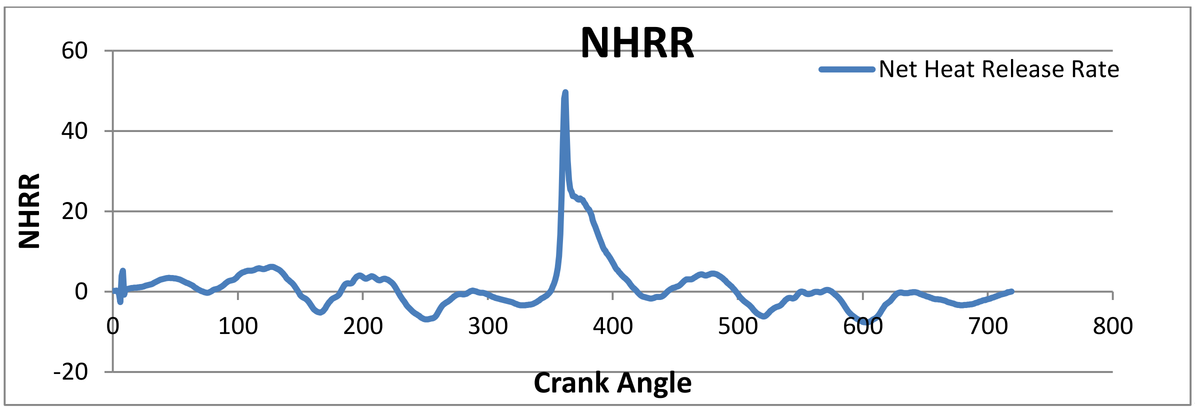


Fig.4.13 . graph showing the relationship between the crank angle and the NHRR while using a 6kg load at B20+2 percent

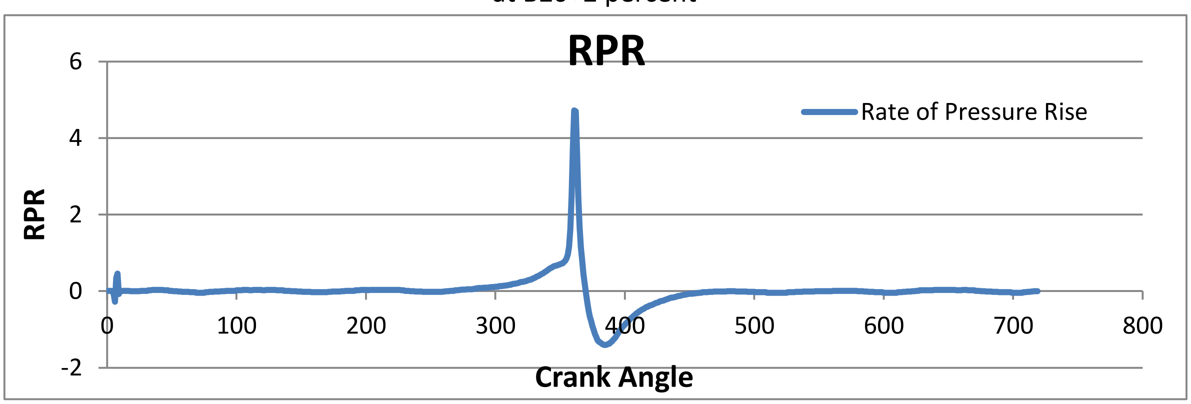


Fig. 4.14 The relationship between the crank angle and the RPR for a B20+2 percent 6kg load is shown.

4.2.4 B20+2% at 12Kg Load

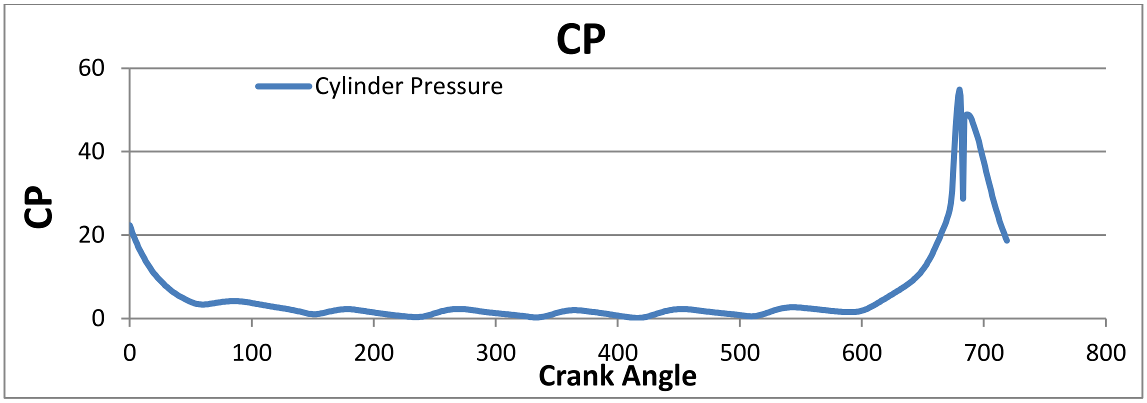


Fig. 4.15 Crank angle vs. CP plot for a 12kg load at B20+2 percent

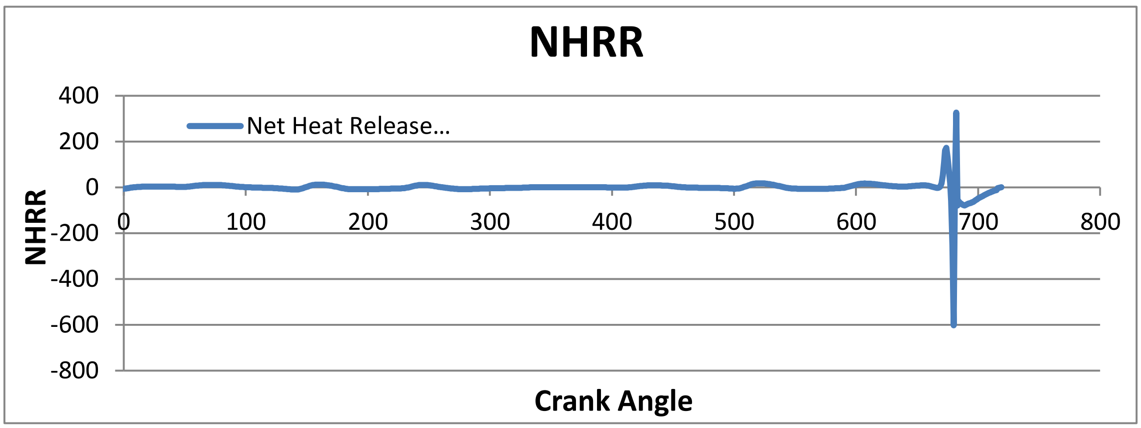


Fig. 4.16 graph showing the relationship between the crank angle and NHRR while using a 12kg load at B20+2 percent

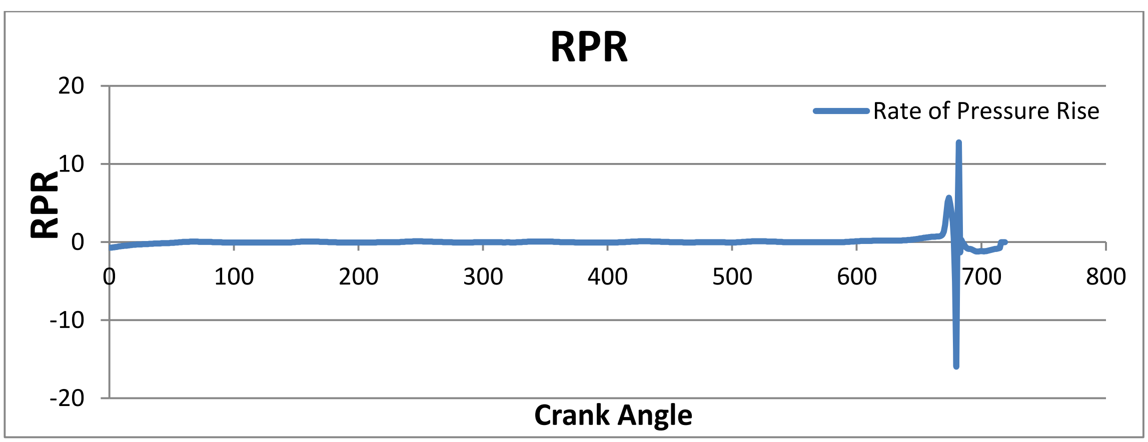


Fig. 4.17 The relationship between the crank angle and the RPR for a B20+2 percent 12kg load is shown.

For B20+2% n-Butanol at a load of 12 kg, Figure 4.15 shows the relationship among crank angle as well as CP, with the highest pressure being obtained at a crank angle of approximately 680 degrees (54 Pa).For B20+2% n-Butanol with a 12 kg load, the relationship with crank angle as well as NHRR is indicated in Figure 4.16. At a crank angle of 660 degrees, the neat heat release rate decreases by 600J, and the largest overall heat release rate is determined to be 300J at a 680 degree crank angle. Figure 4.17 depicts the relationship with crank angle and RPR with B20+2% n-Butanol at a mass of 12 kg. At a crank angle approaching 660 degrees, the rate of pressure rise decreases by -14 Pa, and the maximum pressure is obtained at approximately 680 degrees.

4.3 Performance Parameters

Table 2: Performance parameters of biodiesel B20 with additives

			B.P (kW)	**BSFC (Kg/kw-hr)**	**$\eta_{B.Th}$ (%)**	**I.P (kW)**	**$\eta_{I.Th}$ (%)**	**η_{Mech} (%)**
Isobutyl	B20+1%	6	1.32	0.48	19.1	1.81	26	72
		12	2.62	0.315	29.4	3.43	38	77
	B20+2%	6	1.37	0.45	19.7	1.82	26.7	75
		12	2.71	0.306	30.2	3.44	37	78

Figs 4.18 to 4.23 shows the graphs projected between Load and performance parameters and from all the analysis it can be concluded that biodiesel B20+2% at 12kg load posses good performance characteristics

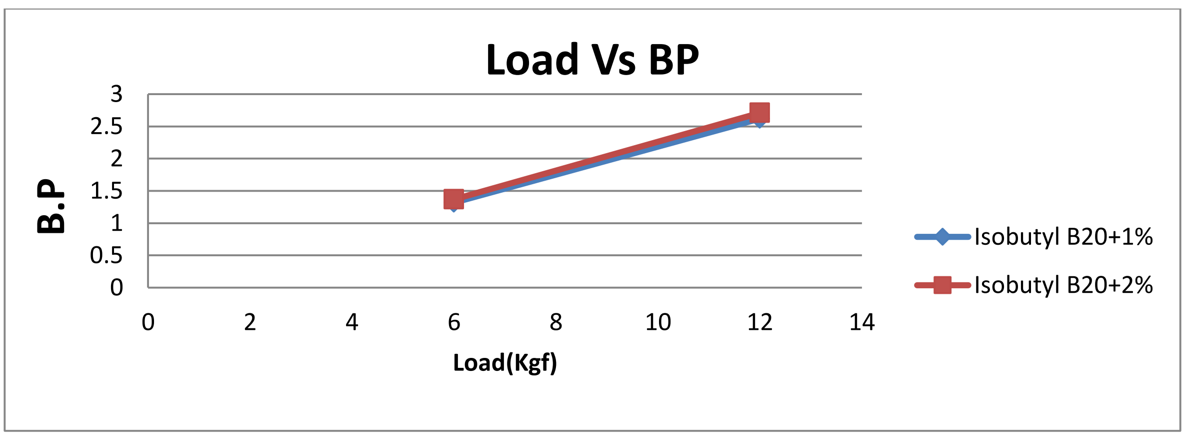


Fig 4.18. Plot for Load Vs BP

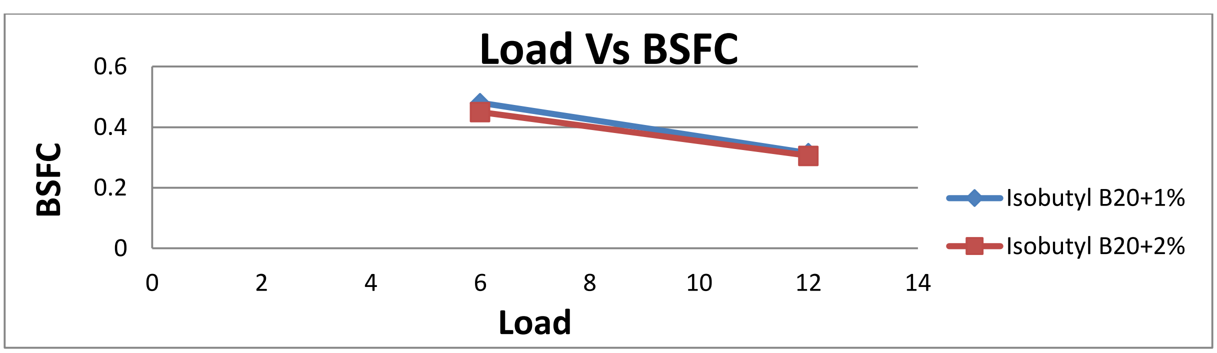


Fig 4.19. Plot for Load Vs BSFC

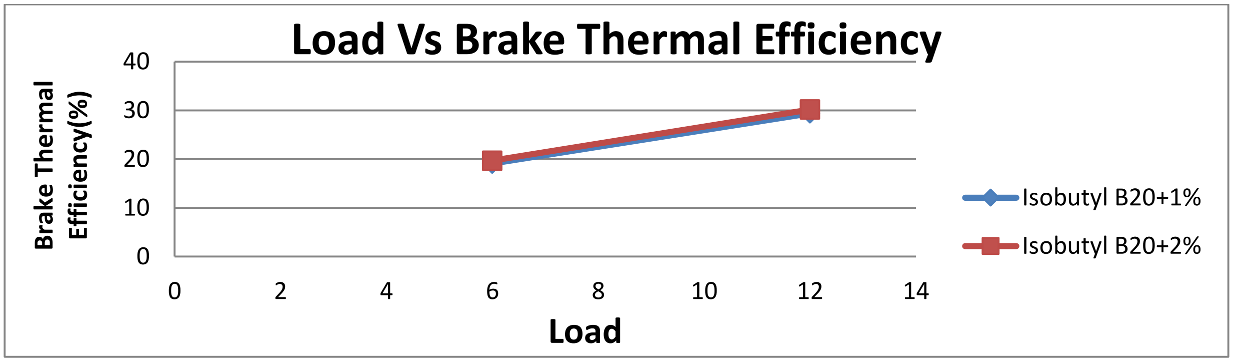


Fig 4.20. Plot for Load Vs Brake thermal efficiency

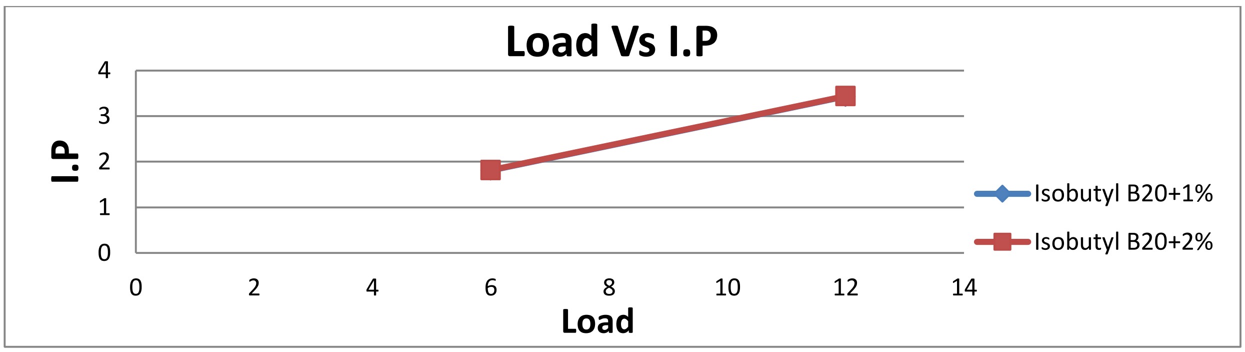


Fig 4.21 Plot for Load Vs IP

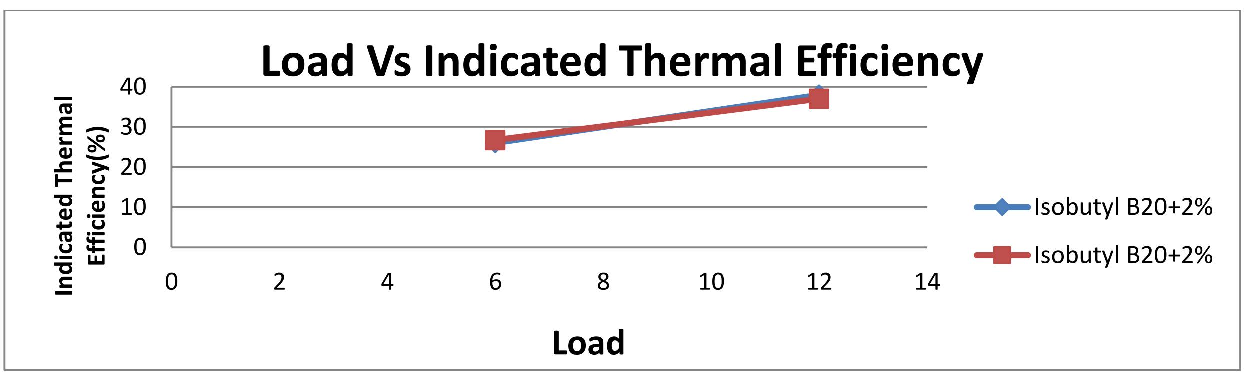


Fig 4.22. Plot for Load Vs Indicated thermal efficiency

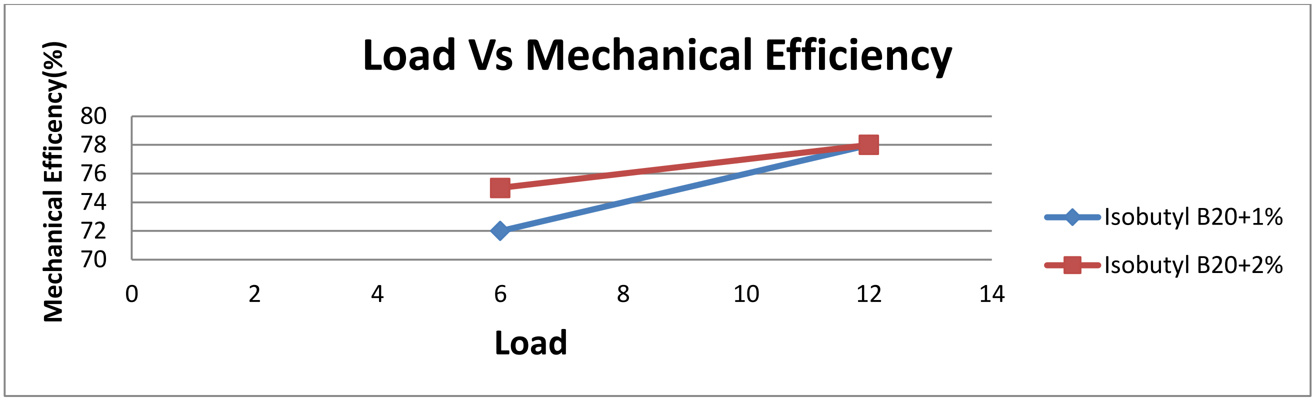


Fig 4.23. Plot for Load Vs Mechanical efficiency

5.Conclusions:

1. From the emission characteristics it can be observed that the value of CO is less for isobutyl B20+2% at 6kg load
2. It is also observed that the value of CO_2 , O_2 and NO_x is less for isobutyl B20+1% at 6kg load
3. It can be observed that the value of HC is less for isobutyl B20+2% at 12kg load
4. It can be indicated that the maximum pressure for B20+1 percent n-Butanol at 6 kg load is 58 Pa at approximately 150 degrees crank angle, 60 Pa at approximately 410 degrees crank angle for B20+1 percent n-Butanol at 12 kg load, and 52 Pa at approximately 380 degrees crank angle for B20+2 percent n-Butanol at 6 kg load and 54 Pa at approximately 680 degrees crank angle for B20+2 percent n-Butanol at 12 kg load
5. If you use B20+1 percent n-Butanol with a 6 kg weight, you'll see an initial fall in NHRR of 1000J at an 80° crank angle, as well as a maximum net heat release rate of 2100J at roughly a 100° crank angle. The greatest NHRR for B20+1 percent n-Butanol at 12 kg load was determined to be 200J at roughly 400° crank angle. Crank angle and NHRR are linked for B20+2% n-Butanol at 6 kg load, with the NHRR found to be 50 J at a crank angle of roughly 385 degrees. According to the results, the connection between crank angle and NHRR for B20+2% n-Butanol with a 12 kg load reduces by 600J at a crank angle of 660 degrees, while the maximum NHRR is found to be 300J at a 680 degree crank angle.
6. With a crank angle of 80 degrees, the rate of pressure increase lowers by 12 Pa and the RPR determined to be 21 Pa around 100 degrees when B20+1 percent n-Butanol is employed initially at 6 kg. If you use B20+1 percent n-Butanol, the RPR will be 6 Pa around 390 degrees when you use a 12 kg weight with it. Maximum pressure was found to be 4.5 Pa for B20+2% isopropyl alcohol at a mass of 6 kg and for B20+2% n-Butanol at a mass of 12 kg at roughly 364 degree crank angle. When the crank is turned to a 660-degree angle, the RPR drops by -14 Pa, and the maximum pressure is reached at a 680-degree angle.
7. It is also analysed from the load and performance parameters it can be concluded that biodiesel B20+2% at 12kg load posses good performance characteristics

6. Future Scope:

1. To improve the performance characteristics of the engine nowadays researchers are implementing new techniques by using additives mixed with various percentage composition to achieve combustion characteristics

2. In our work we have used n-Butanol as an additive taken in volume percentages of 1% and 2% and the combustion characteristics are well achieved For much better progress other additives such as cerium oxide and Fecl3 can be used

7. References:

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