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Influence of hydrogen augmentation in inlet air of Single cylinder energised with jatropha biodiesel mixture

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Abstract

Depletion of conventional fuels has promoted research towards alternate fuels. The theory behind this experimental study is that the performance and emission characteristics of water cooled single cylinder compressed ignition engine fuelled by jatropha biodiesel blend with hydrogen addition. Performance and emission characteristics of different blend of biodiesel are studied. The addition of jatropha biodiesel in diesel, the unburned hydrocarbons, carbon monoxide and nitrogen oxides had increased. It is found that B20 shows the maximum brake thermal efficiency and minimum brake specific energy consumption. Emission characteristics also studied and it found that except nitrogen oxide emissions other emissions are significantly reduced. Influence of hydrogen such as 2 lpm, 4 lpm, 6 lpm, 8 lpm and 10 lpm on B20 is studied. The diesel has increased brake specific energy consumption and reduced brake thermal efficiency compared with jatropha biodiesel blended diesel. To overcome this, a B20 biodiesel is used with 8 lpm hydrogen as secondary fuel. This result in the increase of brake thermal efficiency is about 3.26 % and 0.5 % higher than pure diesel and B20+10 lpm hydrogen respectively and correspondingly reduces the brake specific energy consumption is about 5.7MJ/kWh compared to diesel. The emission characteristics of unburned hydrocarbon, carbon monoxide and smoke opacity reduces significantly about 29ppm, 0.16% and 4.5 % respectively. NO_x emissions increase about 140 ppm and 272 ppm when compared to B20 and diesel respectively. It is mainly due to oxygen concentration the peak combustion temperature increased in the combustion chamber.

Keywords: Jatropha Biodiesel, Hydrogen, Performance, Emissions

1. Introduction

In the present situation, biodiesel has been targeted as an alternative fuel as a result of a rise in demand for fossil fuels and global warming. Petroleum and diesel fuels are non-renewable and will decrease in supply in the near future, so demand for petrol and diesel fuel will also rise. Biodiesel is not obtained from fossil fuels, but can be generated from local crops. This decreases greenhouse gas emissions, and a domestic fuel economy is generated by the production and selling of biodiesel. Biodiesel is made from waste vegetable oil obtained from the kitchens, or with our oil seed press, we extract the oil ourselves. Seed pressed oil is chemically modified by trans-esterification process to change the oil viscosity and to adopt in the diesel engine. Biodiesel is renewable, Sustainable and environment friendly in operating modes. With its environmental characteristics, biodiesel is rapidly becoming a commonly known petroleum diesel blending agent. Biodiesel is a substitute fuel for diesel engines manufactured from animal fats or vegetable oil. EPA regulations have significantly lowered the permissible levels of exhaust contaminants for diesel engines since 2007, but the reduced emissions of biodiesel are recorded far less regularly. Based on the experimental results obtained, Jatropha oil has been found to be a promising renewable source for Diesel engine. It's used for blending up to J20 without any thermal efficiency reduction. J5 recorded better thermal efficiency and bsfc compared to diesel. Quite good results can be seen with up to J10 from the study of the optimum proportion of Jatropha blend. (Chalatlon *et al.*, 2011) Jatropha oil's methyl ester results in a significantly higher thermal efficiency than that of petrol. With the jatropha methyl ester, the temperature of the exhaust gas is lowered relative to gasoline. With Jatropha oil's methyl ester, CO2 emissions are poor. Compared to Jatropha oil's methyl ester, CO emissions are low at higher loads. The emission of NOX with Jatropha methyl ester is slightly elevated.(Hanumantha Rao *et al.*, 2008) As an additive, to improve the engine's combustion dimethyl ether is used. The engine was tested with BDE 5, BDE 10 and BDE 15. The results show that the performance of engine increased and the exhaust concentration level decreased due to the addition of diethyl ether with jatropha biodiesel as related to neat jatropha. (Loganathan, Anbarasu and Velmurugan, 2013) Blends containing up to 50 percent jatropha oil volume, sufficient engine thermal efficiencies were obtained. (Pushparaj, Ramabalan and Selvan, 2015) Before the air enters, hydrogen is infused into the burning chamber and the injection of hydrogen speeds up the rate of diesel ignition. By doing this, the loss of energy and pollution would be minimized. It allows the engine to generate high torque and with a small amount of fuel, runs cleaner and cooler. The direct induction of hydrogen with diesel fuel in CI engine produces a higher brake power, with peak pressure being around 14% higher, compared to conventional diesel-fuelled operation. Additions of hydrogen with diesel as duel fuel steer to significant improvements in performance and reductions in emissions. (Gomes Antunes, Mikalsen and Roskilly, 2009) Hydrogen was injected in small quantities into the diesel engine, while the main fuel was an emulsion of karanja bio-oil and methyl ester injected into the cylinder. In this paper on diesel fuel operation, the results were compared to and discussed. (Prakash *et al.*, 2011) In comparison to the engine without any alteration, the HHO system resulted in an average increase of 18.9 percent in engine power output, CO emission 13.5 percent decreased, HC emissions about of 5 percent and SFC is about 14 percent decreased. (Yilmaz, Uludamar and Aydin, 2010) The addition of hydrogen into the combustion process has been shown that the exhaust emission of CO, HC and smoke reduced and the thermal efficiency was increased. Increased NOx emissions and reduced specific fuel consumption have been observed. (Wall, 2010) Supply of hydrogen gas at a flow rate of 4 lpm and induction at a distance of 40 cm from an intake manifold shows better result in thermal efficiency. The engine performance and emission parameters were studied with and without enrichment of hydrogen using used transformer oil (UTO 40) and UTO 100 as the main fuel. (Pullagura *et al.*, 2012) Compared to the other tests, diesel with 5 LPM hydrogen demonstrated higher brake thermal efficiency at all kinds of loads.

2. Materials and Methods

Jatropha Biodiesel

In the current work, we utilized the screw pressing extraction strategy by means of expeller with the jatropha seeds and the jatropha oil is recuperated. Screw press extraction method was used to remove the oil at the extraction temperature of 120 °C and a motor speed of 80 rpm. The conversion of jatropha oil to biodiesel was carried out in two stages, the primary stage was a) acid catalyst esterification process and b) base catalyst esterification process. In the primary stage, the oil was treated in a conical flask with methanol and concentrated sulphuric acid (1% H_2SO_4, in view of the oil volume). The reaction was led at 65 °C and 800 rpm and it is continuously agitated for 2 h. Methanol to oil molar proportion of 9:1 was utilized. After this reaction, the blend was permitted to remain settled for two hours. The subsequent stage was to deliver biodiesel utilizing the sodium hydroxide catalyst by base trans-esterification. The catalyst and alcohol combination were added, and the blend was again heated to 65°C and mixed at 800 rpm for 60 min in a magnetic stirrer then it is allowed to resolve inside the conical funnel. Glycerol and jatropha methyl ester were developed at base layer and top layer respectively in conical flask. Fuel mix was set up by persistently agitated diesel and biodiesel for homogeneous blending. Marking of B10, B20, B30, B40 and B50 depend on 10%, 20%, 30%, 40% and 50% of biodiesel on volume premise with diesel.

Table 1.1.1 Properties of Jatropha Diesel Blend

S. No	Blends	Viscosity at 40°C (mm2/s)	Flash Point (°C)	Specific Gravity	Calorific Value (MJ/kW.hr)
1	Diesel	4.5	86.4	0.852	44.755
2	B10	4.8	88.1	0.865	43.647
3	B20	5.2	90.3	0.868	44.156
4	B30	5.4	91.6	0.872	42.207
5	B100	5.9	94.9	0.882	40.877

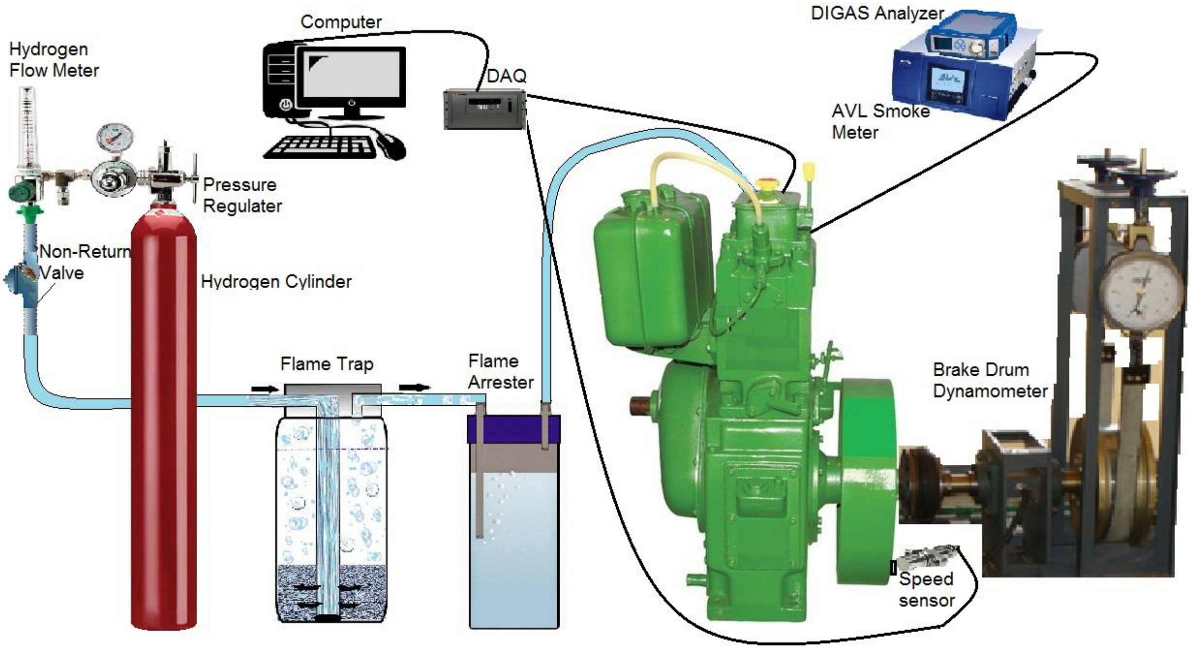
Experimental setup

For steady state condition, the engine initially operated with jatropha biodiesel for about 10 minutes at various loads. The U tube manometers were used to take time for 10cc fuel consumption of biodiesel**.** The investigation is carried with various loading conditions from 0%, 20%, 40%, 60% and 80% respectively. The same experiment is repeated to various blends such as B10, B20 and B30. The information acquired with the assistance of PC based data acquisition system called as Engine Soft. To measure speed of the engine a rotary encoder had used. During combustion the pressure oscillation in the combustion chamber is measured by using pressure transducer based on the voltage produced by piezoelectric material. The pressure range is about 0 to 200 bars. The exhaust tail pipe emission is measured by an AVL analyzer. Exhaust gases from the engine's tail pipe is connected to an AVL testing bench through headline filters. The emissions are measured using AVL digas 4000 light analyzer. The level of smoke is measured by AVL 437 smoke meter.

Figure 3.1 Kirloskar Engine

Table 3.1 Engine specification

S No	Description	Specification
1	Manufacturer	Kirloskar
2	No of Cylinder and Stroke	Single Cylinder and 4 strokes
3	Speed and power	1500 rpm and 5.2kw
4	Bore and Stroke length	87.5mm and 110mm
5	Compression Ratio	17.5
6	Dynamometer	Eddy current dynamometer



Results and Discussion

Performance Characteristics

Figure 4.1 and 4.7 shows the brake thermal efficiency of diesel, biodiesel blends and induction of hydrogen with biodiesel blends respectively. It was found that the brake thermal efficiencies of biodiesel, diesel and mixtures of both were initially increased with load increases and maximum thermal efficiencies of 80% of the load were obtained. When pure Jatropha biodiesel is used as fuel compared to diesel, the brake thermal efficiency is lower. This is due to improper mixture formation as a result of the high viscosity. B20 shows higher thermal efficiency when compared to B10, B20, B100 and neat diesel. The brake thermal efficiency for Jatropha biodiesel is about 30.2% at 80% diesel admission whereas it is about 29.1 % with pure diesel. Compare to performance and emission characteristics of all biodiesel blends and diesel the B20 blend give increased brake thermal efficiency, reduced energy consumption, and reduced HC, CO and excluding NOx emission as shown in figure 4.1. From on above results it found that the B20 blend is the optimum blend to use with hydrogen at various lpm. When hydrogen is injected gradually, the efficiency increases. Proper mixing of hydrogen and air increases the brake thermal efficiency because of combustion and higher burning velocity. The BTE of B20+8 LPM hydrogen has about 3.26 % and 0.5 % higher efficiency than pure diesel and B20+10 LPM hydrogen respectively as shown in figure 4.7.

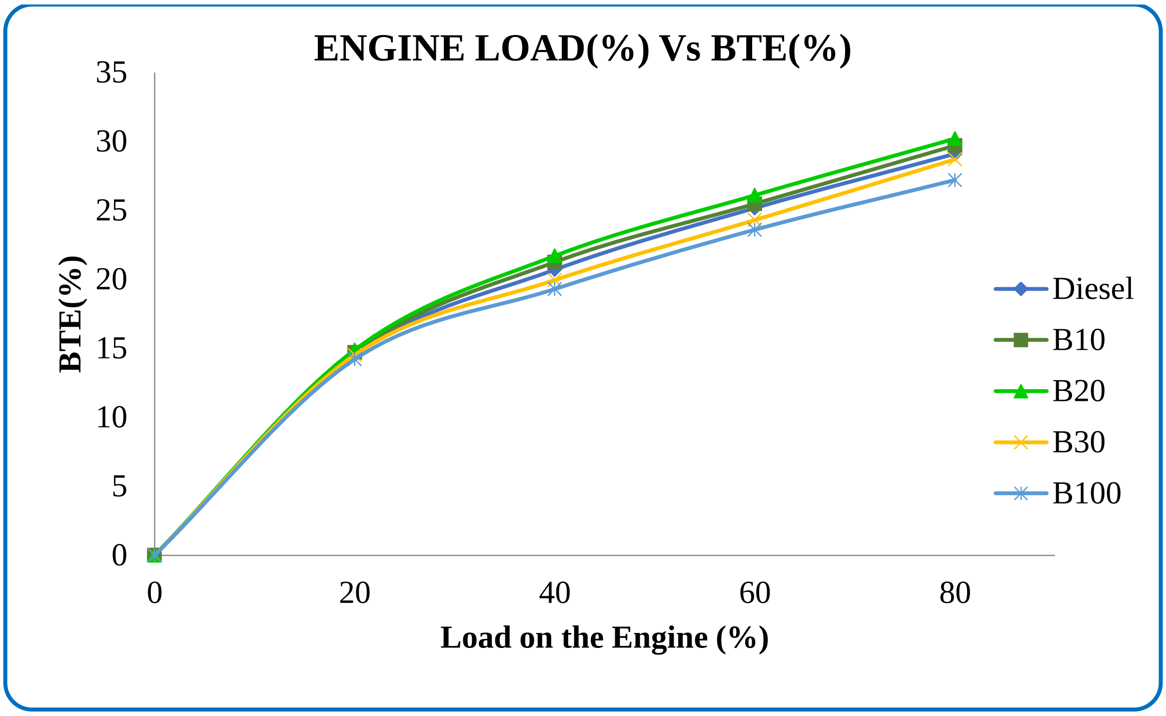


Figure 4.1 Variation of brake thermal efficiency with different engine load

The brake specific energy consumption is the amount of energy consumed in a one kilogram of fuel. The brake specific energy consumption with 20 % jatropha biodiesel is lower when compare with pure diesel as shown in Figure 4.2. This is because of the required amount of oxygen obtained from the jetropha biodiesel and the viscosity also reduced by adding 20% biodiesel with 80% diesel. It was observed that the BSEC for only pure jatropha biodiesel is the highest i.e.33.8 MJ/kWh. When it is replaced by the 30 % blended biodiesel, there is a considerable decrease of BSEC up to 32.4 MJ/kWh in lower load. It was further reduced by 3.5 MJ/kWh as compared to that of 100% biodiesel when blend B20 is used. This could be due to the maximum utilization by more total combustion of the injected fuel. The deviation of the brake specific energy consumption (BSEC) for B20 blend and various hydrogen ratios are displayed in Figure 4.8. The energy consumption decreases for B20+H2@8LPM by about 5.7MJ/kWh when compared to neat diesel. This is owing to suitable mixture formation inside the cylinder and by the energy share between hydrogen and biodiesel.

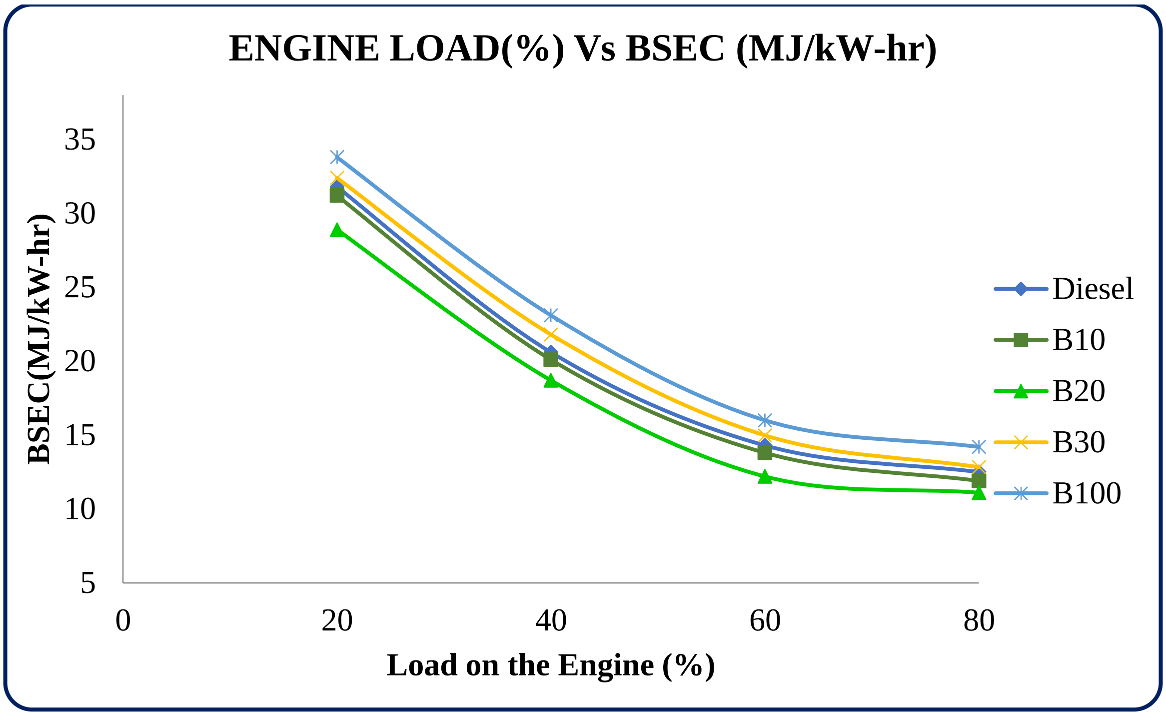


Figure 4.2 Variation of brake specific energy consumption with different engine load

Emission characteristics

According to the experimented data, a graph is being plotted between load and hydrocarbon emissions as shown in figure 4.3. In higher load, the HC emission is increased for all blends of biodiesel and diesel fuel. The fuel mixture is too rich to ignite because there is too much fuel and not enough air. Hydrocarbon emissions are often created when a cold engine is first started due to the rich fuel mixture and slower fuel vaporization rate. HC emissions also increase momentarily when the engine is a higher load, due to less time to get more oxygen through the intake manifold. Hydrocarbon emissions can be minimized by maintaining a balanced air/fuel ratio. Hydrocarbon emission is increased by about 102 ppm while pure biodiesel is used as fuel. B20 gives reduced HC emission is about 4 ppm when compared to diesel. Graph is being plotted between hydrogen ratios with B20 blend and pure diesel as shown in figure 4.9. HC emission was considerably decreased when biodiesel B20 used with hydrogen. The B20+H2@8 LPM reduces the HC emission by about 29 ppm when compared with diesel. The high oxygen concentration of biodiesel and hydrogen create more complete and cleaner combustion of fuel therefore the unburned hydrocarbon emission decreases.

A graph is being plotted between load and carbon monoxide emissions as shown in figure 4.4. The emission of carbon monoxide (CO) for pure diesel is reduced compared with B30 and B100 biodiesel blends as a result of higher viscosity which leads to poor atomization. CO concentration was reduced for B10 and B20 than diesel. This is may be caused by readily available 11% oxygen concentration in the biodiesel. Significant decrease was observed in B20 when compared to all tested fuels. CO emissions also increase momentarily when the engine is a lower and higher load. This is due to insufficient engine temperature in lower load and rich mixture in higher load. When compared B100 biodiesel with pure diesel the co emission is increased by about 0.07%. Adding of 20% biodiesel with 80% diesel, the CO emission is reduced significantly by about 0.06% when compared to diesel. Figure 4.10 represents the carbon monoxide (CO) concentration for various blends of fuels. Generally, the CO concentration should be lesser to avoid the emission of toxic gases. For B20 has higher CO value when compared to pure diesel and B20 blend. Injection of hydrogen decreases the CO concentration. B20+H2@8 LPM reduces 0.16% CO emissions Compared with Diesel. This is due to the nonappearance of carbon content in the hydrogen fuel. This indicates the importance of hydrogen as a secondary fuel.

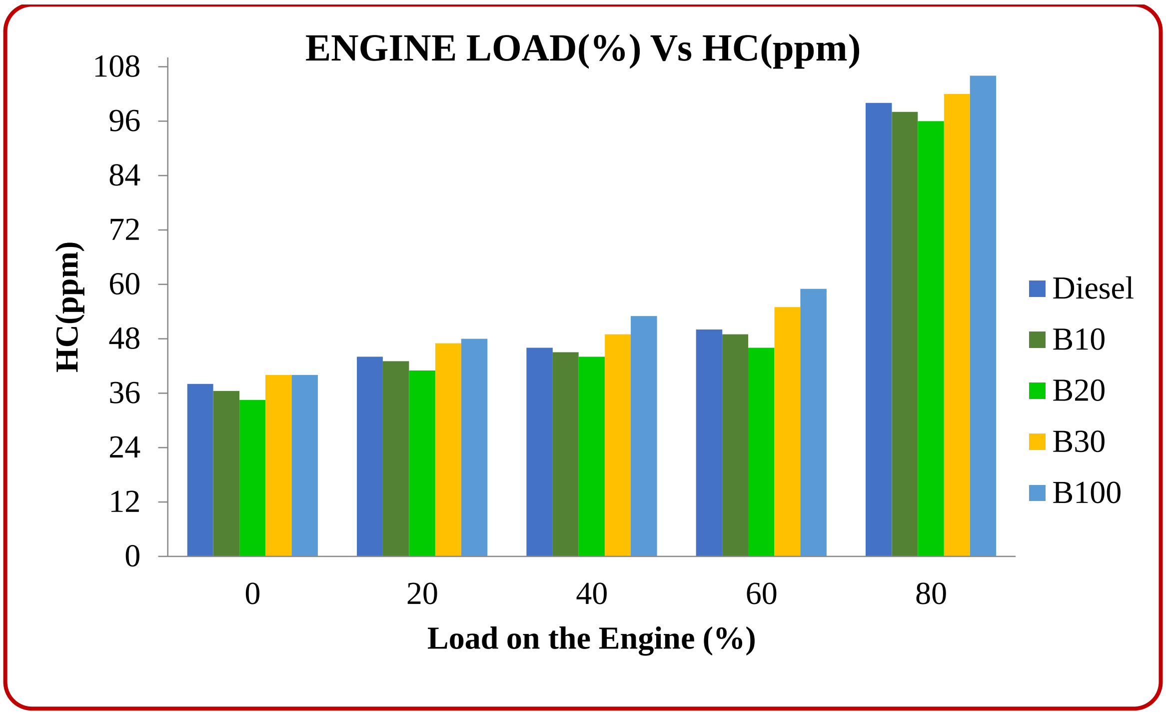


Figure 4.3 Effect of Hydrocarbon with changing engine load

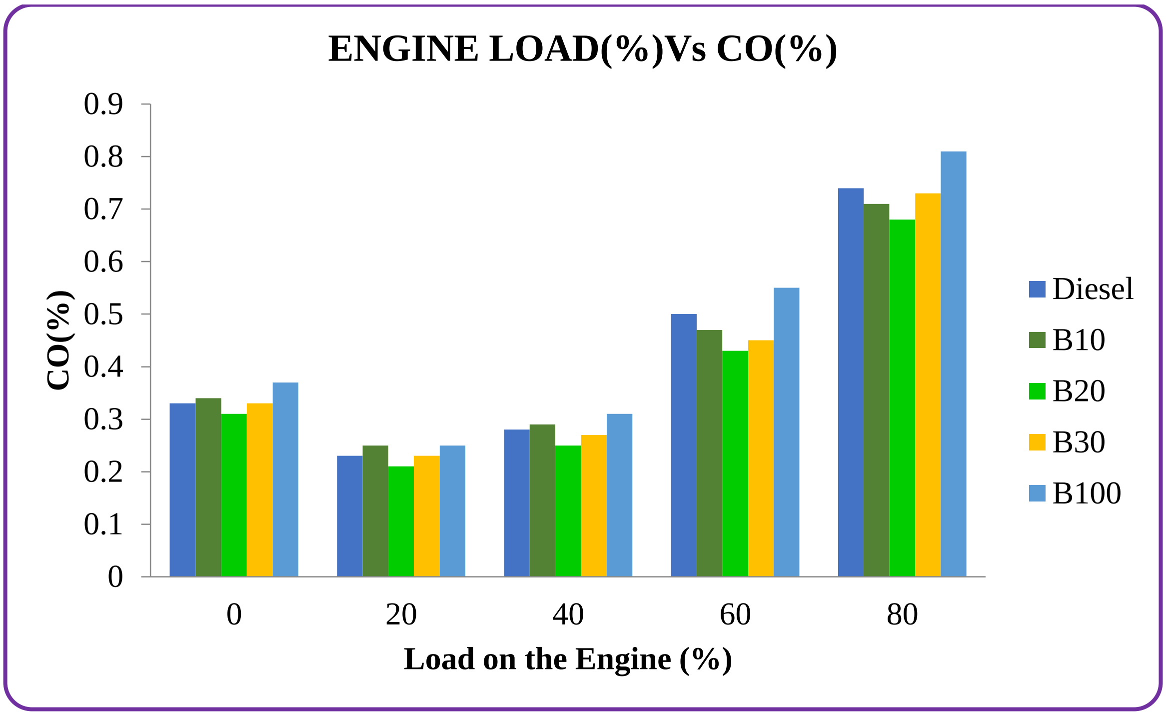


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Figure 4.4 Effect of carbon monoxides with changing engine load

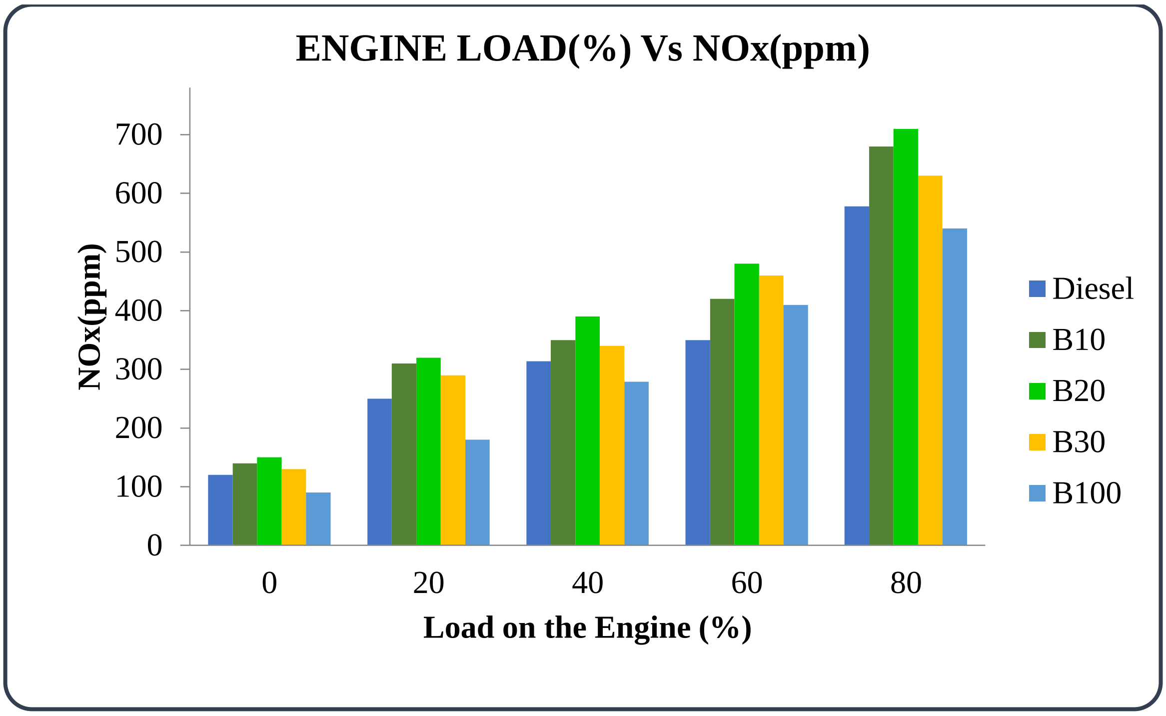

Figure 4.5 Effect of NOx emissions with changing engine load

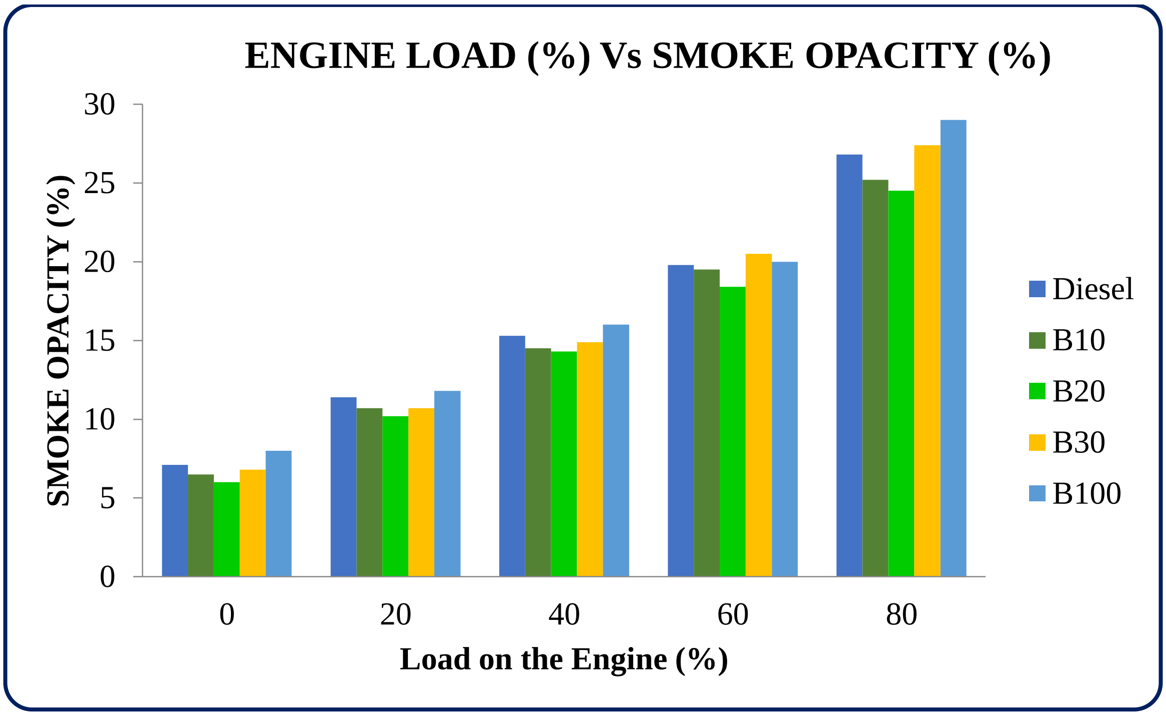

Figure 4.6 Effect of smoke opacity with changing engine load

A rise in after combustion temperature allows the emission of NOx to increase. NOx formation is increased by all variables affecting and accelerate the response among oxygen and nitrogen. Thus, the temperature is the major element in NOx formation. The increase in

NOx for B20 fuel could be the result of an increase in the temperature of the after-combustion and combustion chamber. NOx emission with B20 fuel showed 18.5% increased when compared with diesel fuel as shown in figure 4.5. Compare both B10 and B30 fuel with the diesel fuel NOx emission increased by 15% and 8.5% respectively. NOx concentration decreased at particularly low loads by lower the combustion chamber temperatures. The figure 4.11 indicates the NO_x emission for various combinations of hydrogen with B20 blend. It denotes NO_x emission increases by the injection of hydrogen is about 140 ppm and 272 ppm while compared to B20 and diesel respectively. Due to available of higher oxygen with hydrogen increases the combustion rate which leads to increase the temperature inside the combustion chamber.

Figure 4.6 shows the effect of opacity with variation of engine load for diesel and biodiesel blends. B10 and B20 biodiesel blends gives reduced smoke opacity when compared to neat diesel fuel. In locally rich fuel combustion zones, the oxygen content of fuel may lead to improved fuel oxidation by oxidation, resulting in smoke reduction. Reduced concentration of smoke opacity was found for B20 fuels compared with diesel. When introduce hydrogen with Biodiesel blend (B20) the B20+H2@8 LPM reduces smoke further about 4.5% compared to diesel as shown in figure 4.12.

BTE OF HYDROGEN

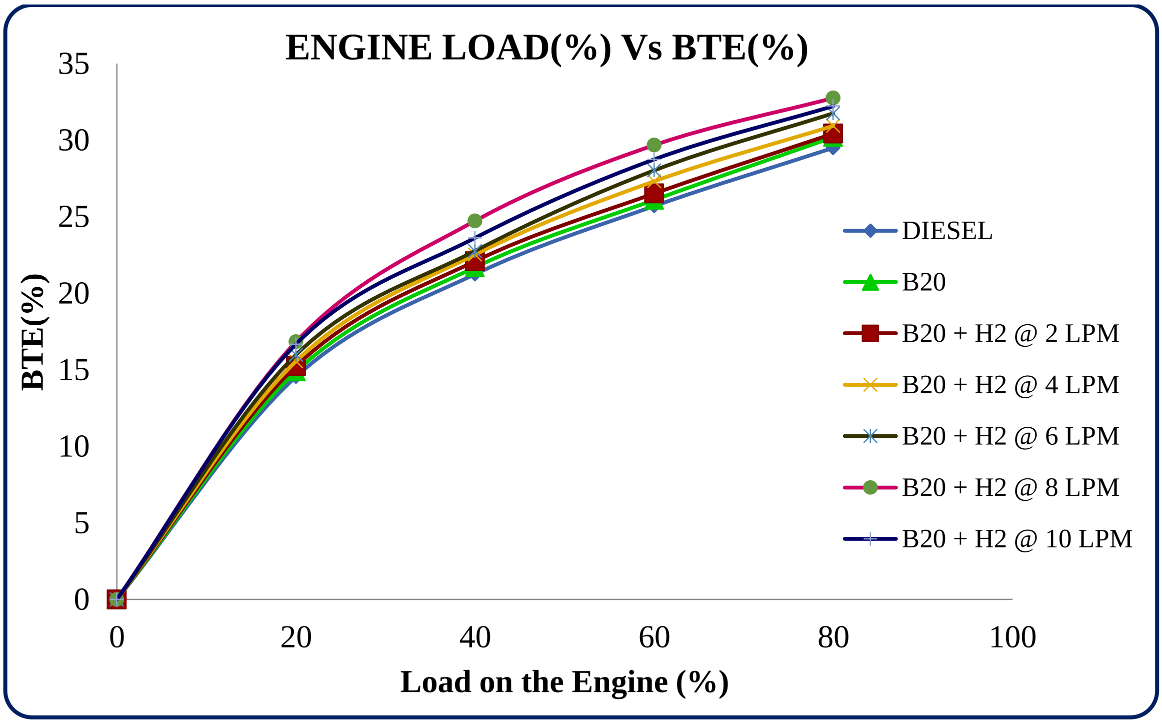

Figure 4.7 Thermal efficiency of brakes as a function of engine load

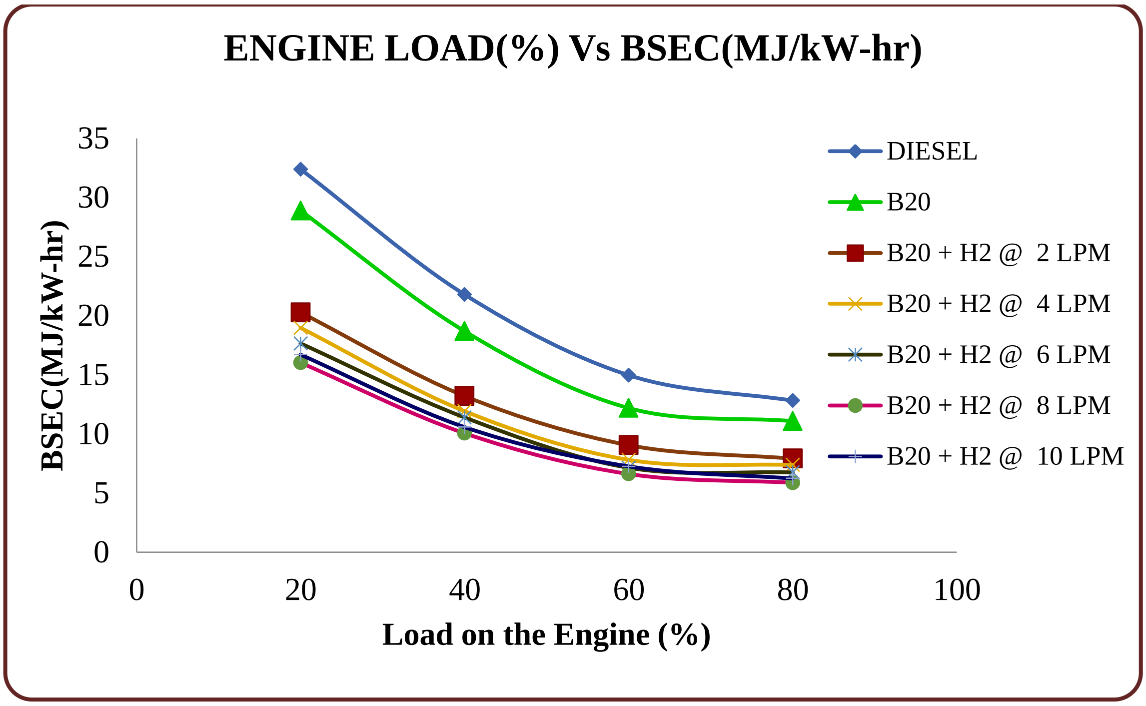

Figure 4.8 Variation of brake specific energy consumption with different engine load

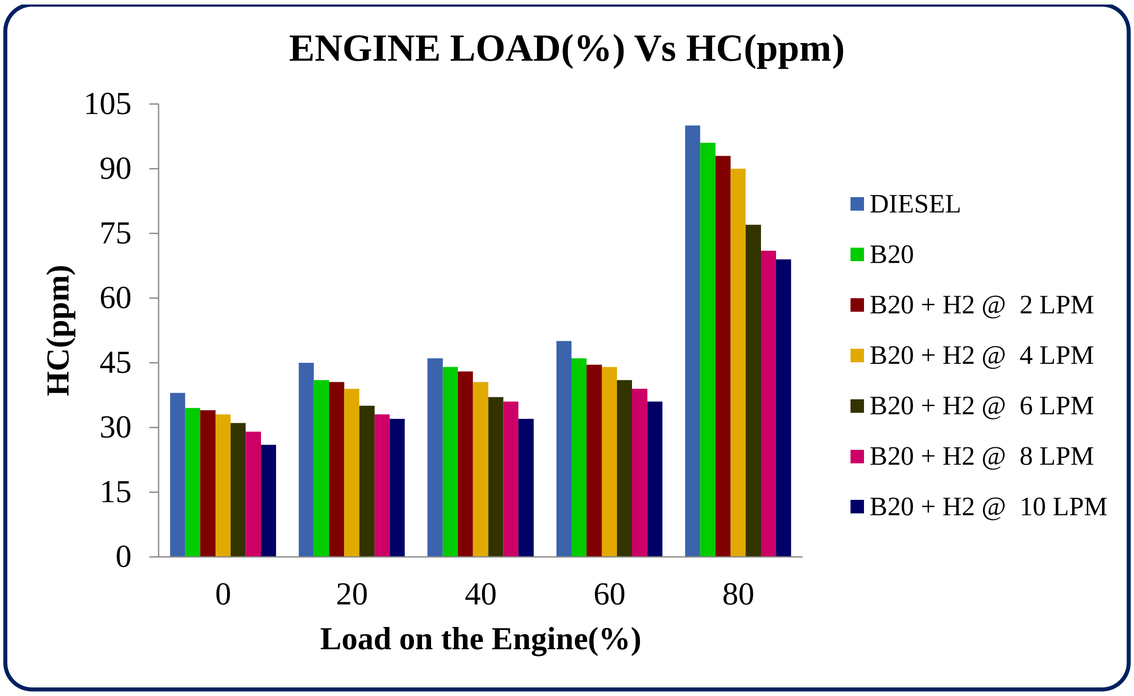

Figure 4.9 Effect of hydrocarbon with changing engine load

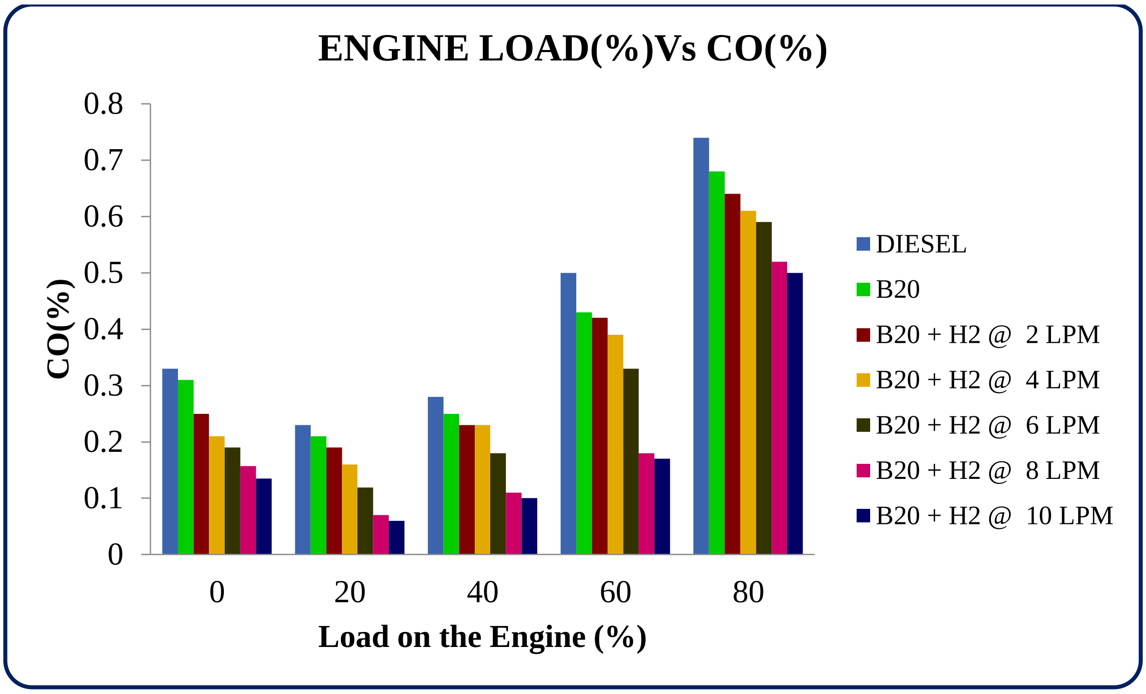

Figure 4.10 Effect of carbon monoxides with changing engine load

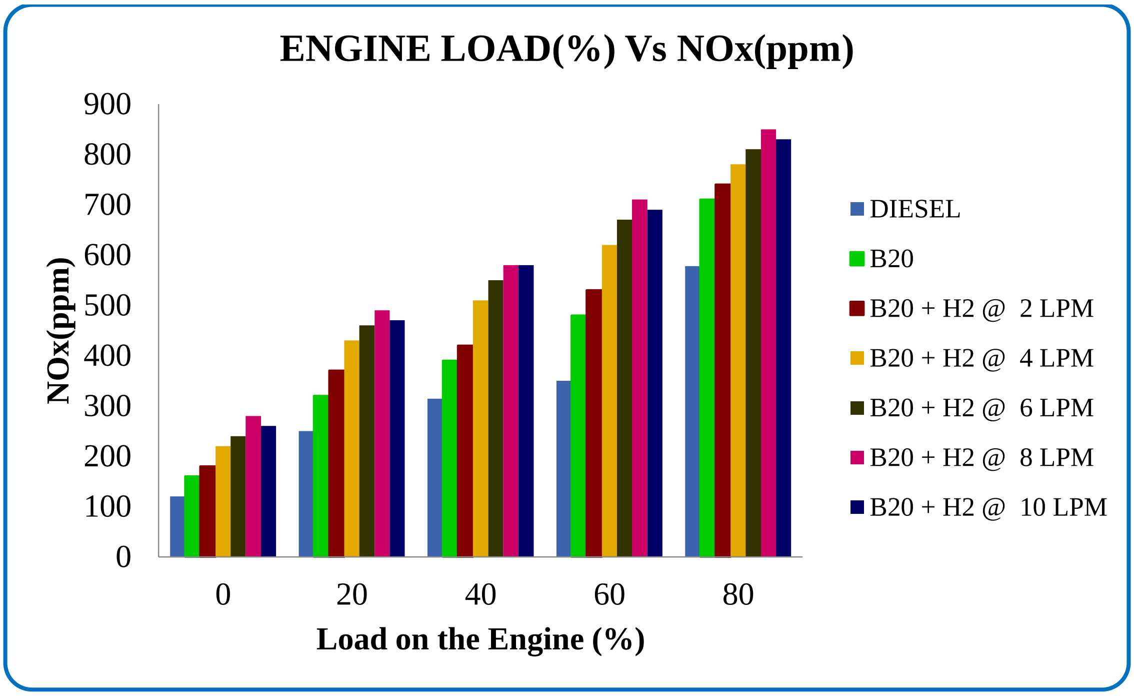

Figure 4.11 Effect of NOx emissions with changing engine load

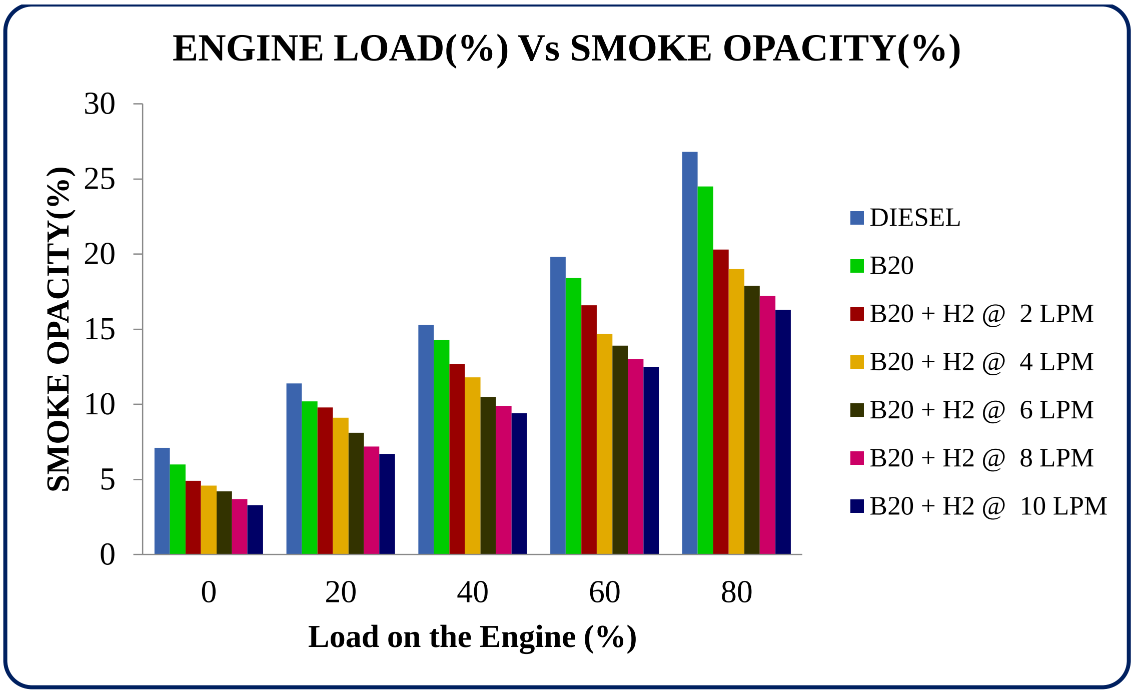

Figure 4.12 Effect of smoke opacity with changing engine load

Conclusion

Jatropha oil has features that are very similar to diesel. The higher viscosity of jatropha oil is reduced by converting to biodiesel with the help of transestrification process. The method of transesterification will significantly decrease the viscosity of the jatropha oil and permit it to be used in the engine. It also decreases the specific gravity. Transesterified Jatropha oil is mixable with any percentage of diesel fuel and can be used as exchangers for diesel fuel. One of the alternative fuels for engine application may be the biodiesel blend diesel fuel.

The use of 8 LPM hydrogen induction with B20 at intake manifold in a diesel engine offered a higher brake thermal efficiency has about 3.26 % higher than the diesel.

Experimental findings indicate that the brake specific energy consumption of different blends is initially higher at lower loads because of increased specific gravity and viscosity.

The BSFC for all the blends is higher initially at lower loads. Due to the rise in cycle temperature at higher loads, the viscosity decreased and the BSEC decreased slightly at a point of about 4 percent. CO and HC emissions from engine exhaust for B20 with hydrogen at 2, 4, 6, 8 and 10 lpm are lower than those produced from engine exhaust for B10, B20, B30, B100 and diesel fuel.

Owing to improved combustion resulting in higher cycle temperatures, NOx concentrations from B20 and B20 with hydrogen are greater than diesel emissions. Since NOx concentration depends on temperature, they are higher at elevated temperatures.

During part loading conditions the 20% and 80% of biodiesel and diesel supplied to the engine intake decreased the amount of smoke opacity, whereas the improvement was reduced at the maximum load condition. During the addition of 8 lpm hydrogen with B20 blend, in part load condition, as much as 45 sharp decreases in smoke concentrations was accomplished whereas the reduction was around 8.2 percent at the maximum rated load when compared to B20 blend. The results showed that the lowest density of smoke occurs when the exhaust gas temperature for a specified engine load and speed was about the minimum value.

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