Performance Analysis of Blends of Jatropha Biodiesel

Partha Protim Borthakur, Pranjal Sarmah

Abstract—This paper investigates the performance analysis of blends of Jatropha biodiesel. The experiment was carried out on a single cylinder, four stroke, water cooled compression ignition engine where blends of Jatropha bio-diesel and pure diesel were tested with load variations and its effect on the parameters like brake thermal efficiency, exhaust gas temperature, volumetric efficiency, specific fuel consumption, air-fuel ratio, heat loss in brake power, heat content in Jacket cooling water, radiant heat loss and heat content in exhaust were observed and compared. Eventually, it was found that blends of Jatropha bio-diesel proved to be a better environmental friendly fuel than that of pure diesel.

Index Terms — Biodiesel,Blends, Environmental friendly fuel,Jatropha oil, Non conventional energy,.

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1 INTRODUCTION

Biodiesel are biodegradable. They are non-toxic. They have significantly fewer noxious emissions than petroleum-based diesel, when burned. They are renewable. With a much higher flash point than it is for petro-diesel (biodiesels have a flash point of about 160 °C), biodiesel is classified as a non-flammable liquid by the Occupational Safety and Health Administration. This property makes a vehicle fuelled by pure biodiesel far safer in an accident than one powered by petroleum diesel or the explosively combustible gasoline. Combustion of biodiesel alone provides over 90% reduction in total unburned hydrocarbons, and a 75-90% reduction in aromatic hydrocarbons. When burned in a diesel engine, biodiesel replaces the exhaust odor of petroleum diesel with the pleasant smell of popcorn or French fries. Biodiesel further provides significant reductions in particulates and carbon monoxide than petroleum diesel fuel. Thus, biodiesel provides a 90% reduction in cancer risks. In sum, the use of biodiesel will also reduce the following emissions, Carbon monoxide, Hazardous diesel particulates of solid combustion products, Acid rain-causing sulfur dioxide, arbon dioxide. The use of biodiesel can extend the life of diesel engines because it is more lubricating than petroleum diesel fuel, while fuel consumption, auto ignition, power output, and engine torque are relatively unaffected by biodiesel. Biodiesel is safe to handle and transport because it is as biodegradable as sugar, 10 times less toxic than table salt, and has a high flashpoint of about 300 °F compared to petroleum diesel fuel, which has a flash point of 125 °F, making it one of the safest alternative fuels, in terms of combustibility.

2.1 Blending Processes

The method used to blend the fuel is the most important factor contributing to blend accuracy. The two major blending techniques used are splash blending and in-line (injection) blending. Currently, the most widely implemented technique is splash blending. This blending process involves adding biodiesel or any other constituent to a fuel vehicle that is partially filled with diesel fuel. The blending occurs as the vehicle drives and the fuel splashes around in the tank. Unfortunately, in many cases, the vehicle does not drive far enough for the two fuels to blend uniformly. In addition, environmental factors such as temperature and humidity can affect the speed at which the fuels blend. A second, more accurate blending method is in-line blending. This type of blending occurs at a fuel rack, where dedicated blending equipment delivers a metered amount of fuel into a waiting truck. Ethanol and other fuel additives are commonly blended using this method. With in-line blending, the correct ratio of blending component is metered with automated control valves into the diesel fuel before it is dispensed into a truck. Since the resulting fuel is blended prior to entering the truck, the mixing problem associated with splash blending is eliminated. Although in-line blending offers a more accurate blending method than splash blending, any mechanical system is subject to wear and/or failures. The need to test the diesel blend ratio after final mixing is necessary regardless of the blending method. An accurate method to determine the biodiesel blend is just as important as an accurate blending method

2.2 Impacts of Blending

It has been observed that lower molecular weight blended diesels have higher cloud points. Because fuel that has reached its cloud point will clog fuel filters, high blend percentages made from low molecular weight feed-stocks cannot be used in colder climates. Understanding the climate to which engines will be subjected and the feedstocks available will allow a distributor to determine the optimal blend ratio to deliver to customers. In many cases the optimal blend will change depending on the season.

3 Production of Biodiesel

3.1 Feedstock Treatment

If waste vegetable oil (WVO) is used, it is filtered to remove dirt, charred food, and other non-oil material often found. Water is removed because its presence causes the triglycerides to hydrolyze, giving salts of the fatty acids (soaps) instead of undergoing transesterification to give biodiesel.

3.2 Determination and treatment of free fatty acids

If waste vegetable oil (WVO) is used, it is filtered to remove dirt, charred food, and other non oil material often found. Water is removed because its presence causes the triglycerides to hydrolyze, giving salts of the fatty acids (soaps) instead of undergoing transesterification to give biodiesel.

3.3 Transesterification

A reaction scheme for transesterification is shown in the figure below. R1, R2, and R3 in this equation represent long carbon chains that are too lengthy to include in the diagram. Animal and plant fats and oils are typically made of triglycerides which are esters of free fatty acids with the trihydric alcohol, glycerol. In the transesterification process, the alcohol is deprotonated with a base to make it a stronger nucleophile. Commonly, ethanol or methanol is used. As can be seen, the reaction has no other inputs than the triglyceride and the alcohol. Normally, this reaction will proceed either exceedingly slowly or not at all. Heat, as well as an acid or base are used to help the reaction proceed more quickly. It is important to note that the acid or base are not consumed by the transesterification reaction, thus they are not reactants but catalysts. Almost all biodiesel is produced from virgin vegetable oils using the base-catalyzed technique as it is the most economical process for treating virgin vegetable oils, requiring only low temperatures and pressures and producing over 98% conversion yield (provided the starting oil is low in moisture and free fatty acids). However, biodiesel produced from other sources or by other methods may require acid catalysis which is much slower. Since it is the predominant method for commercial-scale production, only the base-catalyzed transesterification process will be described below.

During the esterification process, the triglyceride is reacted with alcohol in the presence of a catalyst, usually a strong alkali (NaOH, KOH, or Alkoxides). The main reason for doing a titration to produce biodiesel, is to find out how much alkaline is needed to completely neutralize any free fatty acids present, thus ensuring a complete transesterification. Empirically 6.25 g / L NaOH produces a very usable fuel. One uses about 6 g NaOH when the WVO is light in color and about 7 g NaOH when it is dark in color. The alcohol reacts with the fatty acids to form the mono-alkyl ester (or biodiesel) and crude glycerol. The reaction between the bio-lipid (fat or oil) and the alcohol is a reversible reaction so the alcohol must be added in excess to drive the reaction towards the right and ensure complete conversion.

(A) First stage: The glycerine phase is much denser than biodiesel phase and the two can be gravity separated with glycerine simply drawn off the bottom of the settling vessel. In some cases, a centrifuge is used to separate the two materials faster.

(B) Second stage: Once the glycerine and biodiesel phases have been separated, the excess alcohol in each phase is removed with a flash evaporation process or by distillation. In other systems, the alcohol is removed and the mixture neutralized before the glycerine and esters have been separated. In either case, the alcohol is recovered using distillation equipment and is re-used. Care must be taken to ensure no water accumulates in the recovered alcohol stream.

(C) Third stage: The glycerine by-product contains unused catalyst and soaps that are neutralized with an acid and sent to storage as crude glycerine (water and alcohol are removed later, chiefly using evaporation, to produce 80-88% pure glycerine).

(D) Final stage: Once separated from the glycerin, the biodiesel is sometimes purified by washing gently with warm water to remove residual catalyst, dried and then sent to storage..

4 Experimental Set-ups

The experiment was carried out on a single cylinder, four stroke, water cooled compression ignition engine where blends of Jatropha bio-diesel and pure diesel were tested with load variations and its effect on the parameters like brake thermal efficiency, exhaust gas temperature, volumetric efficiency, specific fuel consumption, air-fuel ratio, heat loss in brake power, heat content in Jacket cooling water, radiant heat loss and heat content in exhaust were observed and compared. 20% blends of jatropha oil and pure diesel were tested separately. We obtained some good comparative results which are discussed bellow

5 Results and Discussion

5.1 Comparisons of Parameters for Different Fuels at Same Loads

Brake power and indicated power:

At loads of 6.02 kg, 9.02 kg and 11.92 kg, we find that the values of BP are approximately same for both blended (20%) and pure diesels. But the IP seems to be quite higher in case of biodiesel than diesel. This is mainly due to the more viscosity of 20% blended fuel. So, it will have a low calorific value as indicated from the set of results. Bio-diesel blends(20%) have a calorific value of 43.20 MJ/Kg. as against 46.97 MJ/Kg.

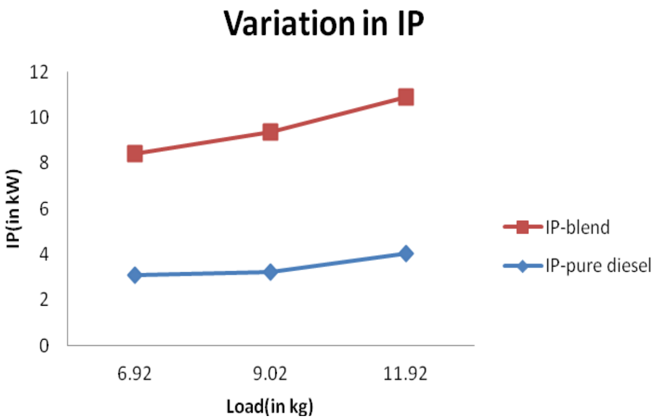

Fig. 1 Varaition in IP:

At loads of 6.09 kg, 9.02 kg and 11.92 kg, results yielded that range of BMEP and IMEP values are slightly higher for biodiesels than pure diesel. Increase in BMEP will increase the pressure on the piston rings, causing greater friction and will cause a greater side force on the piston skirt, causing greater friction. It will probably have an influence on the power expended on oil pump water pump because there will have to be larger for an engine of the same displacement but greater output.

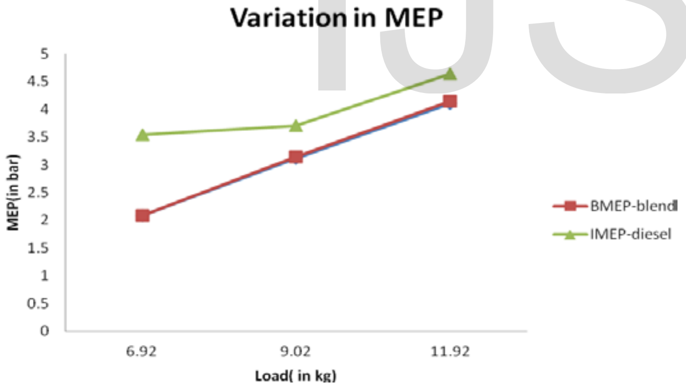

Fig.2 Variation in MEP

At nearly loads of 6.09 kg, 9.02 kg and 11.92 kg, we find that brake thermal efficiency is slightly lower for bio-diesel (20% blend) than diesel. This is due to higher viscosity of bio-diesel. Results are expected due to the lower energy content of the bio-diesel fuel. So at part loads, it will be lower, as a result of which bmep will be lower. Similarly the mechanical efficiencies obtained are 34.19%, 43.82% and 51.26% for 20% blend as against 58.18%, 82.98% and 86.45% at the same corresponding loads, making it undesirable for commercial use in the long r

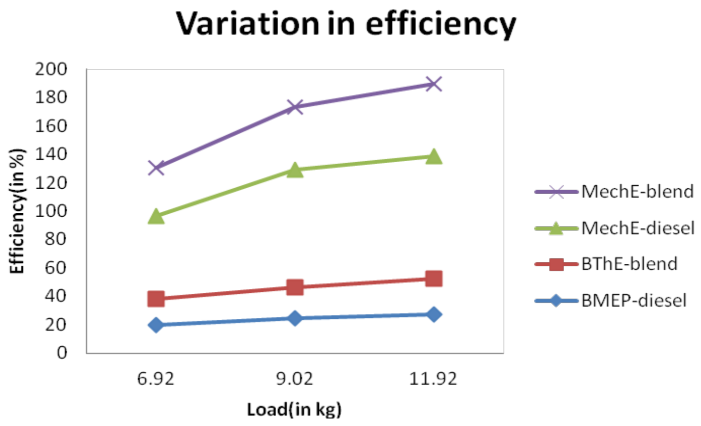

Fig.3 Variation in efficiency

SFC:

At nearly loads of 6.09 kg, 9.02 kg and 11.92 kg, the SFC obtained are 0.47 kg/kW-h, 0.40 kg/kW-h, 0.34 kg/kW-h for 20% blend against 0.43 kg/kW-h, 0.35 kg/kW-h and 0.32 kg/kW-h for pure diesel. Specific fuel consumption is slightly more in the case of blended fuels. This can be attributed to viscous nature, lower calorific value and high torque developed in case of bio-diesel.

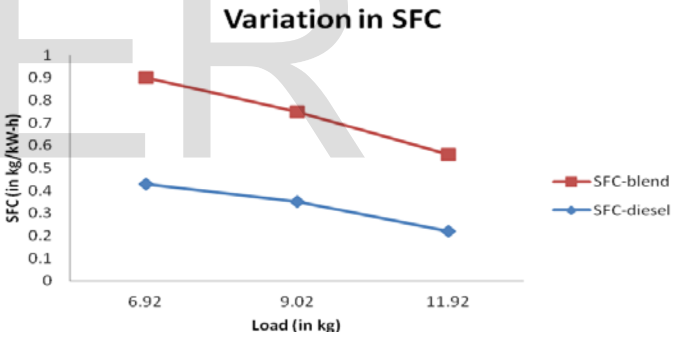

Fig.4 Variation in SFC

Volumetric efficiency:

We observed the volumetric efficiencies are lower for the 20% blend with respect to the pure diesel for the same brake loads. The lower volumetric efficiency ascertains lower volume of fuel charge swept in the cylinder. This may be due to low heating value of the blend supplemented by higher initial temperature by the domination of residual gases. This leads to increase in cylinder pressure in the case of bio-diesels. But the oxygenated nature of bio-diesel improves the combustion process. Similar results are also carried with A/F ratio.

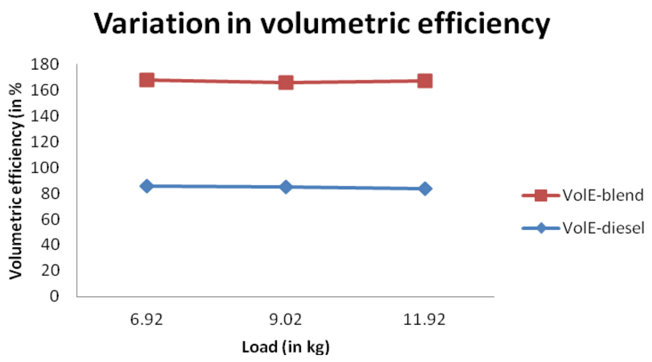

Fig.5 Load(in kg)

HBP:

At nearly loads of 6.09 kg, 9.02 kg and 11.92 kg, the range of values of heat lost in brake power is more for pure diesel than the 20% blend one. It shows 19.76%, 24.47% and 27.01% for pure diesel as against 18.28%, 21.83% and 25.16% for the blend. Percentage indicates the fraction of the total power produced. Consequently, it contributes to increase in BMEP due to relatively less portion of the heat lost at higher torques.

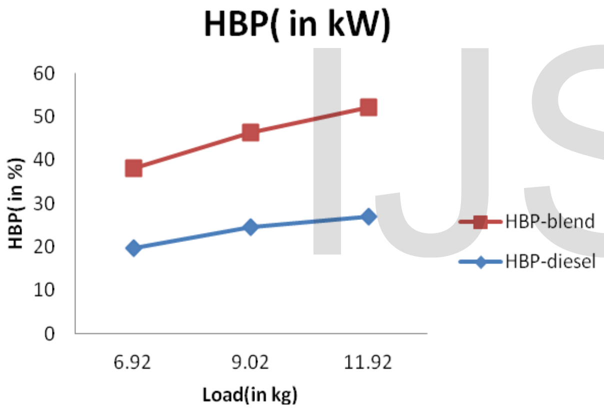

Fig.6 HBP(in kW)

Heat lost

At near loads of 6.09 kg, 9.02 kg and 11.92 kg, the heat lost in exhaust gases are higher for pure diesel than the blend. This indicates low latent heat of vaporization of Jatropha oil in the blends and also more availability of oxygen in the case of blended fuels. This indicates a high exhaust gas temperature for pure diesel than bio-diesel.

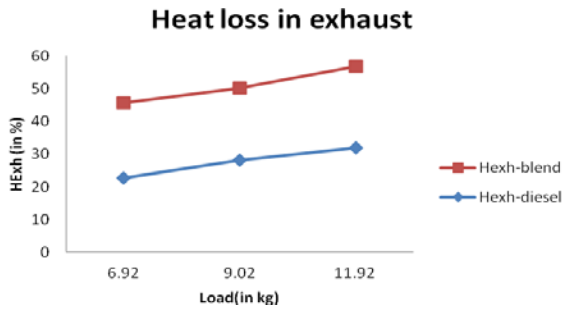

Fig. 7 Heat loss in exhaust

At approximate loads of 6.09 kg, 9.02 kg and 11.92 kg the range of HJW values so obtained are higher for pure diesel as compared to blended fuel. The greater heat content in Jacket Cooling Water is mainly due to poor combustion and poor atomization in the case of pure diesel. But in the case of blended fuels, it induces lubricity. So, frictional losses decreases. So, the heat circulated by the coolant decreases, hence lesser heat content in Jacket cooling water.

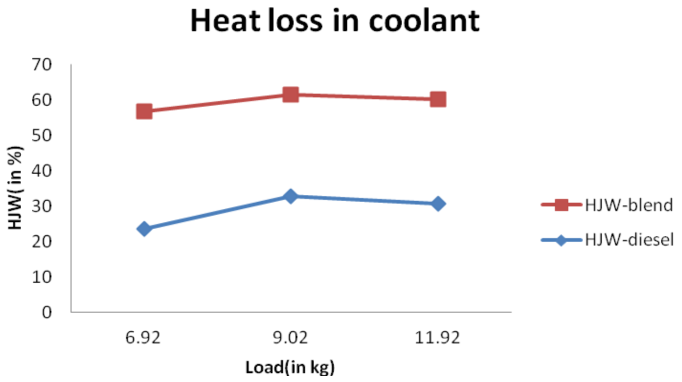

Fig.8 Heat loss in coolant

RAD:

It is the radiated heat loss, expressed in terms of percentage of the total heat loss. At same loads, we observed that heat loss is greater for blended fuels as compared to pure diesel. This reduces the chances of having an abnormal combustion as it prevents overheating of the area around the exhaust valves quickly. Also, it will have cleaner burning due to greater available oxygen content. This increased radiated heat loss makes the bio-diesel a greater value as a home-heating fue

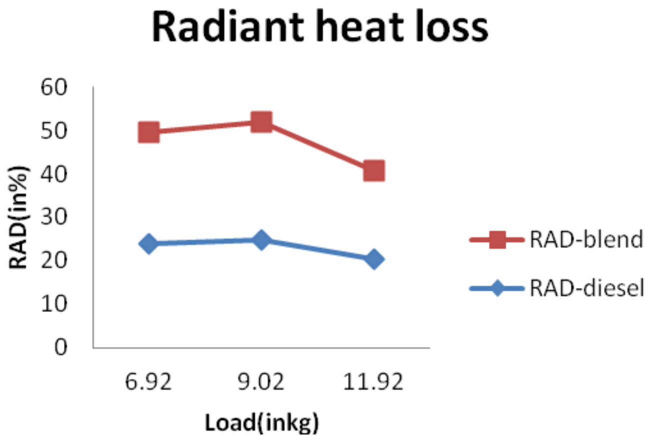

Fig 9 Radiant heat loss

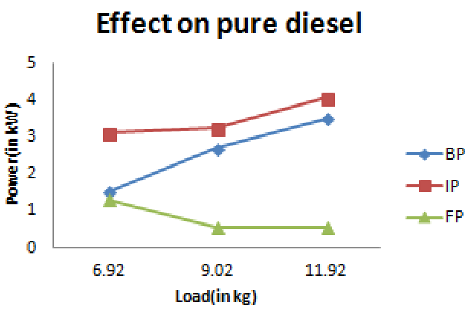

Fig.10 Effect on pure diesel

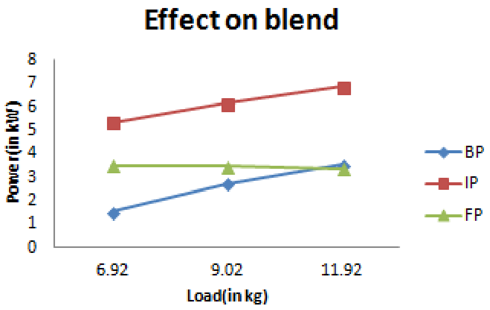

Fig. 11 Effect on blend

IMEP,BMEP,FMEP:

Again in case of indicated mean effective pressure for the load 6.08kg,9.10 kg and for 12.02 kg,we have seen that imep at first increased from 4.5 bar to 6 bar and again there is a sharp increased in imep to 8 bar with increased in load with imep 6.01bar,7.15 bar and 7.91 bar for blend of 20%.And imep for the pure diesel is increases for same load. For the bmep or brake mean effective pressure we have seen that for the load 6.08kg,9.10 kg and 12.02 kg for pure diesel we have the increased in bmep is 2.08bar,3.11 bar and 4.11 bar. For the blend fuel with increased in load 6.08kg,9.10 kg and 12.02 kg the increased in bmep are obtained from 2.06 to 4.01 bar.

From the above we can have the imep for both the cases is large then bmep,this is because the imep is the average pressure over a cycle in the combustion chamber of the engine, that means the average pressure that would have to be present in each cylinder during the power stroke to generate the maximum horsepower. While the bmep is the average pressure that imposed on the piston uniformly from top to the bottom of each power 705ylinder.

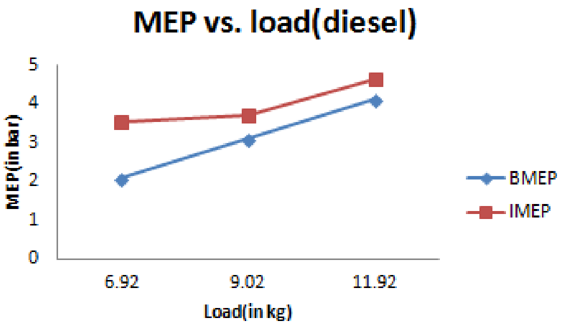

Fig.12 MEP vs load(diesel)

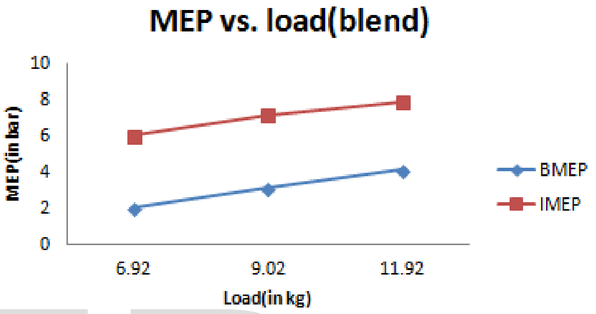

Fig.13 MEP vs. load(blend)

Torque and mechanical efficiency:

We find that for 100% pure diesel, for loads 6.02, 9.02 and 11.92 kg, the torque is 11.03, 16.52 and 21.81 Nm. While for 20% blend the torque is 10.93, 16.37 and 21.63 Nm. Thus we find that as the load increases the torque also increases gradually for both 100% pure diesel and 20% blend.This is significant since torque is directly proportional to load.

The mechanical efficiency of the engine for loads 6.02, 9.02 and 11.92 kg are 34.19, 43.82 and 51.26%, while for 20% blend, it is 58.18, 82.98 and 86.45% for the same loads. This is because mechanical efficiency is directly proportional to brake power, brake power directly depends on load. Thus as the load increases the mechanical efficiency increases.

Air and fuel flow:

For 100% pure diesel for loads 6.02, 9.02 and 11.92 kg, the air flow rate is 31.63, 31.15 and 30.40 kg/hr respectively. While for 20% blend the air flow rate is 29.78, 29.00 and 29.39 kg/hr for the same loads. We observed that for 100% pure diesel the air flow rate gradually decreases. But in case of 20% blend we noticed that the air flow rate first of all decreases from 29.78 to 29.00 kg/hr for loads 6.02 and 9.02 kg, but for load of 11.92 kg it again increases to 29.39 kg/hr. This indicates that there is slight reduction in volumetric efficiency, since A/F ratio goes on decreasing with increase in load as the intake temperature Increases. But one advantage is of the fact that the delay period will decrease since increasein intake temperature at suction will increase the temperature of compressed air inside the cylinder, thus reducing the tendency to knock.

Also for fuel flow rate, we find that for 100% pure diesel for loads 6.02, 9.02 and 11.92 kg, the fuel flow rate is 0.78, 0.94 and 1.11 kg/hr. While for 20% blend the fuel flow rate is0.86, 1.06 and 1.20 kg/hr. In this case we observe that the fuel flow rate gradually increases with an increase in load. Similarly for 10% blend also the fuel flow rate increases gradually.This is significant since A/F ratio decreases, thus enriching the desired mixture to be introduced per stroke. Flame speed becomes low and the timing losses increases.

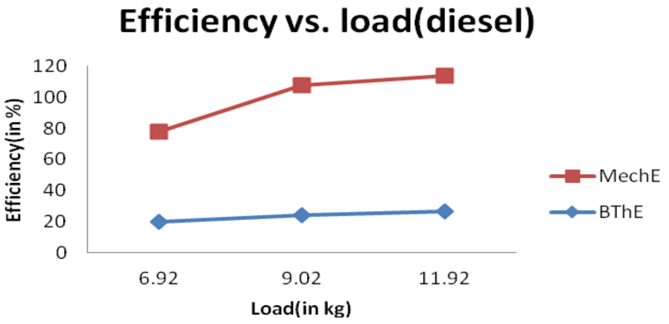

Fig. 14 Efficiency vs. load (diesel)

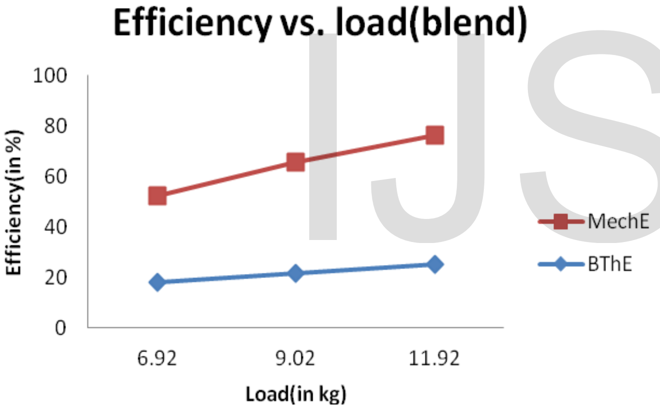

Fig. 15 Efficiency vs. load (blend)

Indicated thermal efficiency, Brake thermal efficiency and specific fuel consumption:

For 100% pure diesel we find for loads 6.02, 9.02 and 11.92 kg, the indicated thermal efficiencies to be 33.97, 29.48 and 31.24% respectively. And for 20 % blend, the indicated thermal efficiencies to be 53.47, 49.82 and 49.07 % for the same loads. Thus we observed that for 100% pure diesel the indicated thermal efficiency first decreases with an increase in load, and then it again increases. But for 20% blend, it decreases gradually with an increase in load.

And for 100% pure diesel we find for loads 6.02, 9.02 and 11.92 kg, the brake thermal efficiencies are 19.76, 24.47 and 27.01 % respectively. And for 20% blend, the brake thermal efficiencies are 18.28, 21.83 and 25.16 %. Thus we observed that both for 100% pure diesel and 10% blend, the brake thermal efficiencies increases gradually with an increase in load.

For 100% pure diesel, the specific fuel consumption is found to be 0.43, 0.35 and 0.32Kg/Kw-Hr for loads 6.02, 9.02 and 11.92 kg respectively. And for 20% blend, it is 0.47, 0.40 and 0.34Kg/Kw-Hr respectively for the same loads. In this case we observed that the specific fuel consumption decreases gradually with an increase in load for both pure diesel and 20% blend.

Here in this case the indicated thermal efficiency is an ideal efficiency. Again brake thermal efficiency deals with the efficiency deals with the measure of the output power that transfer from the engine. And specific fuel consumption is the fuel consumed per unit kilo-Watt per unit time. And in can increases with the increases with load increases

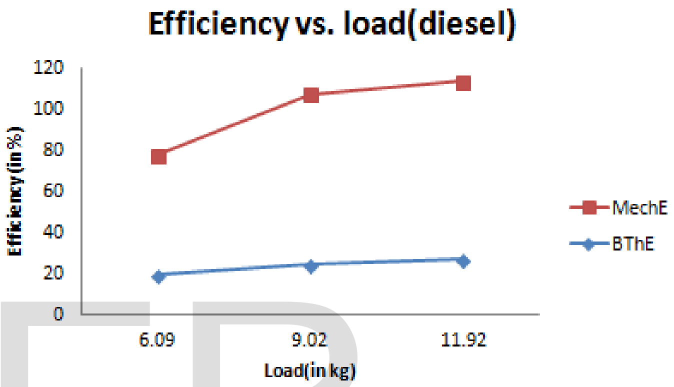

Fig. 16 Efficiency vs. load (diesel)

HBP, HJW and HExh:

For 100% pure diesel, we find for loads 6.02, 9.02 and 11.92 kg, the HBP to be 19.76, 24.47 and 27.01 %. And for 20 % blend, it is 18.28, 21.83 and 25.16 %. Thus in both the cases we se that there is an increase in HBP with a gradual increase in load.

And for 100 % pure diesel, we find that for loads 6.02, 9.02 and 11.92 kg, the HJW to be 33.69, 32.70 and 30.71 %. And for 20 % blend, it is 33.03, 28.83 and 29.42 % respectively for the same loads.

We observe that for 100 % pure diesel the HJW decreases gradually with an increase in load. And in all cases of 20% blend all the parameters are increases gradually. This happen due to friction cause for hbp,colling water for the calorimeter in case for hjw,and the dissociation loss for the heat loss at exhaust gas.

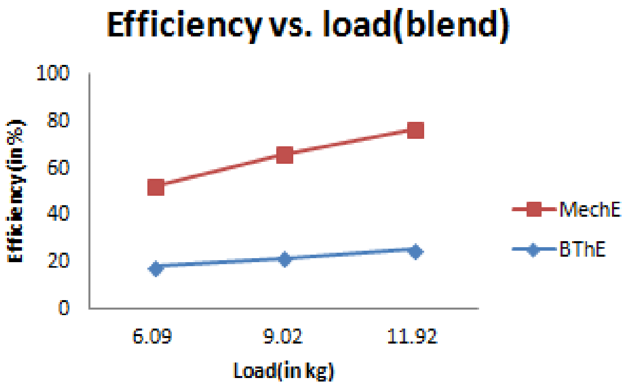

Fig. 17 Efficiency vs. load (blend)

6 Conclusions

From results obtained above, it was concluded that blends of Jatropha biodiesel proved to be both a better and undesired fuel than that of pure diesel, depending on the type of working conditions. But the IP seems to be quite higher in case of bio-diesel than diesel. This is mainly due to the more viscosity of 20% blended fuel. So, it will have a low calorific value as indicated from the set of results. At any load, the specific fuel consumption is higher for pure diesel than its blends of Jatropha bio-diesel. For all fuels tested , specific fuel consumption

increases with increase in load. One possible explanation for this increment could be due to higher percentage of increase in brake power with load as compared to fuel consumption. The heat loss in brake power is more for pure diesel than the blends. This could be due to better atomization and easy formation of volatile compounds in the blends of biodiesel tested due to availability of oxygen in the blended fuel. The presence of oxygen in the biodiesel helps for complete combustion of fuel in the engine. Addition of a small quantity of biodiesel with diesel increases the flash point of diesel. Hence, it is safer to store biodiesel. The greater heat content in jacket cooling water for pure diesel is mainly due to poor combustion, slow mixing and poor atomization. But in the case of blended fuels, viscosity gets reduced, hence frictional power decreases. So, the heat circulated by the coolant decreases, hence there is lesser heat content in Jacket Cooling Water. These results indicate that radiated heat loss for blended fuels are less than that of pure diesel. This could be mainly due to better combustion of blended fuels as they are of low viscosity and more volatile than that of diesel. So, viscosity gets reduced, hence frictional power decreases. On the whole it is concluded that the Jatropha oil will be a good alternative fuel for diesel engine both for agricultural and industrial applications.

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