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PERFORMANCE & EMISSION CHARACTERISTICS OF CI ENGINE OPERATING ON PREHEATED OIL OF JATROPHA, MAHUA AND RICE BRAN: A REVIEW

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Abstract

Depletion of fossil fuels and continuous increment of petroleum prices have prompted the interest towards the use of inedible vegetable oils as alternate source of fuel for diesel engines. Increased viscosity and poor volatility is a major problem related to the use of straight vegetable oils (SVOs) which may cause a number of operational and durability problems. Preheating is a simple technique to lower the density and viscosity of vegetable oil before utilizing in an engine for getting better results. Exhaust gas can be used as the heat source for this purpose. In this paper, a comprehensive study has been conducted to review the performance and emission characteristics of a compression ignition engine fuelled with preheated Jatropha, Mahua and Rice Bran Oil. Diesel is taken as the baseline fuel for comparison of performance and emission characteristics for all the three cases [1]. A single cylinder, four stoke, constant speed, water cooled, direct injection diesel engine is used for the experiments. The acquired data were analyzed for various parameters such as thermal efficiency, brake specific fuel consumption (BSFC), smoke opacity, CO_2, CO and HC emissions.

Keywords:

Diesel Engine;

Jatropha Oil;

Mahua Oil;

Preheated;

Rice Bran Oil.

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1. Introduction

The developing countries like India were adversely impacted by the overexploitation of fossil fuels and continuing rise in global price of crude oil [2]. Renewable nature and significant environmental benefit of vegetable oils have keen the interest towards the use of both edible and non edible vegetable oils as fuel for Diesel engine. Studies involving the use of raw vegetable oils as a replacement for diesel fuel indicate that a diesel engine can be successfully fuelled with 100% vegetable oil on a short-term basis. However, long-term engine durability studies show that fuelling diesel engines with 100% vegetable oil causes engine failure due to engine oil contamination, stuck piston rings, and excessive carbon build-up on internal engine components. Short-term engine testing indicates that vegetable oils can readily be used as a fuel source when the vegetable oils are used alone or are blended with diesel fuel [3]. But if greater blend ratio of the oil and its long-term use is required, modification of the properties of the vegetable oil has to be done. Preheating of vegetable oil blends is one of the viable solutions of the problem. Preheating is done to obtain the properties of vegetable oil mainly viscosity and density close to that of diesel.

2. Literature Review

Explaining Agarwal D. et al. [4] investigated the performance and emission characteristics of a Diesel engine fuelled with Jatropha oil (preheated and blends). They have found that thermal efficiency of preheated Jatropha oil was slightly lower than diesel. However, thermal efficiency for preheated Jatropha oil was higher than unheated Jatropha oil. Unheated Jatropha oil shows exhaust temperature lower than preheated Jatropha oil but higher than diesel. Heating the Jatropha oil result in lower smoke opacity compared to unheated oil but it is still higher than diesel. Preheated Jatropha oil shows marginal increase in CO_2 emission compared to diesel. However, heating the Jatropha oil results in lower CO emission compared to unheated Jatropha oil at higher loads only. HC emissions are lower at partial load, but tend to increase at higher loads for all fuels. Diesel fuel operation produced lower HC emissions compared to Jatropha oil.

Pugazhvadivu et al. [5] experimented diesel engine using mahua oil (both unheated and preheated) as fuel. They have found that the BTE was lowered when it was running with mahua oil. The maximum BTE using unheated mahua oil was 20% as against 28% with diesel at 75% load. The maximum BTE of 22.8% was obtained at full load using preheated mahua oil. It is found that the smoke density of the engine with unheated mahua oil operation was higher than diesel and with preheating the smoke density was lower than that of diesel. HC emission was lowered for mahua oil combustion with preheating. The HC emission was 85 ppm with preheating compared to mahua oil (140 ppm) and diesel (120 ppm) at full load. CO concentration was higher with mahua oil operation compared to diesel at all loads. The CO concentration reduced significantly with preheating of mahua oil. It was reduced from 0.4% with mahua oil to 0.36% with preheating mahua oil to 130^0C. NO_X emission was lowered by about 60% compared to that of diesel. The NO_X concentration at maximum load increased by 13% with mahua oil preheated to 130^0C compared to mahua oil without preheating. However, the NO_X emission was significantly lower with preheated mahua oil compared to diesel at all power outputs.

Pugazhvadivu et al. [6] investigated the performance and exhaust emissions of a diesel engine using diesel, waste frying oil (without preheating) and waste frying oil (WFO) preheated to two different inlet temperatures (75^0C and 135^0C). Using preheated WFO, the BSEC and BTE were improved. The engine exhaust emissions such as CO and smoke were reduced considerably. Significant improvement in engine performance and maximum reduction in CO and smoke emissions were obtained using WFO (135^0C) compared to WFO (75^0C). From the experimental findings, it was concluded that WFO could be used as a diesel fuel substitute by reducing its viscosity to that of diesel by preheating it to a temperature of 135^0C.

Ragu et al. [7] have experimented a DI diesel engine fuelled with preheated Rice Bran Oil at 158^0C and its respective biodiesel. They have found that diesel has lower brake specific fuel consumption (BSFC) and Rice bran oil has a higher BSFC at all load. At full load, as compared to diesel and Rice bran oil, an increase of 8.9% and a reduction of 1.5% in BSEC with preheated Rice bran oil were observed. The BTE values for diesel, Rice bran oil, and preheated Rice bran oil are 29.5%, 26.7%, and 27.1% respectively at full load conditions. At full load conditions, the EGTs are 348^0C, 420^0C, and 405^0C for diesel, Rice bran oil, and preheated Rice bran oil respectively. NO_X values at full load conditions for diesel, Rice bran oil, and preheated Rice bran oil are 2048, 1853, and 1903 ppm respectively. The HC emissions for diesel, Rice bran oil, and preheated Rice bran oil are 197, 207, and 189 ppm respectively at full load conditions. At full load operation, the CO emissions are 0.29%, 0.33%, and 0.26% for diesel, Rice bran oil, and preheated Rice bran oil respectively.

Chauhan et al. [1] evaluated the suitability of Jatropha curcas oil (unheated and preheated) as an extended fuel for CI engine. Experimental results show that the engine performance with unheated Jatropha oil is slightly inferior to the performance with diesel fuel. As fuel inlet temperature of Jatropha oil increased, viscosity decreased and the engine performance improved. BTE of the engine was lower and BSEC consumption of the engine was higher when engine was fuelled with unheated Jatropha oil compared to diesel fuel. However, in case of preheated Jatropha oil, these parameters were superior to unheated Jatropha oil. NO_X from Jatropha oil during the whole range of experiment were lower than diesel fuel. However, for preheated Jatropha oil, NOx emissions were increased. CO, HC, CO_2 emissions from unheated Jatropha oil were found higher than diesel fuel during the whole experimental range. With preheated Jatropha oil, the value of CO, HC and smoke opacity was decreased and CO_2 emissions were slightly increased. Result shows that at 100^0C of fuel inlet temperature of Jatropha oil, performance and emissions were favourable but leakage of lube oil from the engine occurred. Therefore, 80^0C was evaluated as the optimal fuel inlet temperature, considering the BTE, BSEC and gaseous emissions and durability and safe operation of the engine.

Kadu et al. [8] used preheated neat karanja oil in a four stroke, single cylinder diesel engine. Preheating was done from 30^0C to 100^0C. They have found that at higher speed there was no significant difference in BSFC when the engine was operated with preheated and unheated vegetable oil fuels. In other words, BSFC is not affected due to temperature of fuel at inlet conditions. The karanja oil fuel produced the same BTE at high speed and low speed of the engine and slightly deviating in the mid of the speed range studied. The heated fuel showed a marginal decrease in BTE efficiency as compared to diesel fuel operation. Engine power increases with speed to a maximum value at an engine speed of 3500 rpm. At speeds more than 3500 rpm the power produced is slightly higher than that of ordinary diesel fuel. This clearly indicates that at higher engine speed conditions the performance of karanja oil fuel can exceed that of diesel fuel operation. There was significant increase in NO_X emissions when running on neat karanja oil compared to diesel fuel operation. The overall test results showed that fuel heating was not beneficial at low speed operation.

Based on the above comprehensive literature study, Preheating can offer significant reduction in viscosity with improved performance and reduced emissions. Specific energy consumption is reduced when preheated fuel is used. The most of the emission like CO, HC, and smoke are reduced when the vegetable oils are preheated compared to the unheated raw vegetable oil although the level of emissions is slightly higher compared to diesel [9]. But if the fuel is heated up to a maximum temperature then the emissions is somewhat lower than that of diesel. NO_X emission increases with preheating and in certain cases there may be slight increase in CO_2 emission. However, the fuel injection system is made up of parts that are very close fitting, such as the plunger–barrel assembly. High fuel intake temperature may have adverse effects on these closefitting parts since diesel engines normally run with fuel supplied at ambient temperature. Consequently, vegetable oil needs to be heated to a temperature that is high enough to give a low viscosity similar to diesels, but not so high as to damage the injection system [10]. Moreover, if heated to very high temperatures, low viscosity of the fuel can result in poor fuel droplet penetration and poor combustion.

In this review study, experimental results of Agarwal D. et al. [4], Pugazhvadivu et al. [5], and Ragu et al. [7] have been compared with each other and tried to find out the most feasible preheated oil which would provide the optimum performance and emission characteristics while comparing with Diesel fuel. The percentage differences in the optimum performance and emission results using preheated Jatropha, Mahua and Rice Bran oil with reference to Diesel fuel are being compared with each other.

3. Experimentation

The experimentation carried out by the Researchers can be divided into three groups: Fuel characterization, engine performance tests and emission measurements. The fuels (Jatropha SVO, Mahua SVO, Rice Bran SVO and diesel) were analysed for several physical, chemical and thermal properties and results are shown in Table.1.

Table 1: Properties of Diesel, Jatropha SVO, Mahua SVO, Rice Bran SVO [19, 18, 21]

Property	**Diesel**	**Jatropha SVO**	**Mahua SVO**	**Rice Bran SVO**
Density(kg/m^3)	840 ± 1.732	917 ± 1	912	995(at 15°C)
Kinematic viscosity at 40^0C(cst)	2.44 ± 0.27	35.98 ± 1.3	38.4	33.92
Cloud point(^{0}C)	3±1	9 ± 1	-	-
Pour point(^{0}C)	-6±1	4± 1	11	-
Flash point(^{0}C)	71±3	229 ± 4	186	198
Carbon residue(%,w/w)	0.1	0.8 ± 0.1	0.46	-
Calorific value(kJ/kg)	45343	39071	37082	36000

4. Results & Discussion

In this section, it is explained the results of research and at the same time is given the comparative review.

4.1 Engine Performance Results

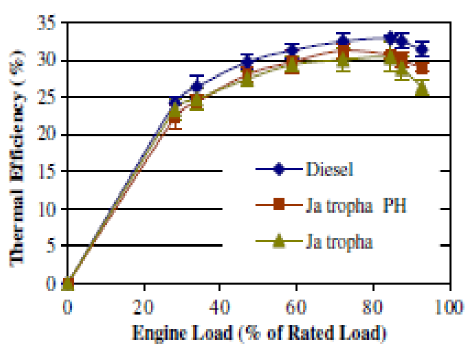
Agarwal D. et al. [4] conducted Engine tests for performance and emissions using unheated Jatropha oil and preheated Jatropha oil. The baseline data were generated using mineral diesel. A shell and tube type heat exchanger is designed to preheat the vegetable oil using waste heat of the exhaust gases. The temperature of the preheated Jatropha oil is controlled within a range of 80–90^0C, a by-pass valve provided in the exhaust gas line before the heat exchanger.

Pugazhvadivu et al. [5] conducted engine performance and emissions tests with diesel fuel, mahua oil and mahua oil preheated to 130°C with the help of a manually operated electrical heating arrangement.

Ragu et al. [7] preheated Rice bran vegetable oil to 158°C to bring its viscosity closer to diesel by using the heat from the exhaust gas and used as fuel. A heat exchanger is used for preheating. The comparative results obtained for diesel fuel, preheated Jatropha, preheated Mahua and preheated Rice Bran oil in terms of engine performance parameters like Brake Thermal Efficiency (BTE), Brake Specific Energy Consumption (BSEC), and Exhaust Gas Temperature (EGT) at various loading conditions of the Engine are described in the following subsections.

4.1.1 Brake Thermal Efficiency (BTE)

Brake thermal efficiency of preheated Jatropha oil was found slightly lower than diesel. The possible reason may be higher fuel viscosity. Higher fuel viscosity results in poor atomization and larger fuel droplets followed by inadequate mixing of vegetable oil droplets and heated air. However, thermal efficiency for preheated Jatropha oil was higher than unheated Jatropha oil. The reason for this behavior may be improved fuel atomization because of reduced fuel viscosity [4]. The maximum thermal efficiency using Jatropha oil was 30% as against 33% with diesel at 85% load. The maximum thermal efficiency (31%) was obtained at 75% load using preheated Jatropha oil. As compared to diesel and Jatropha oil, a reduction of 2% and an increase of 1% in brake thermal efficiency with preheated Jatropha oil were observed. Fig. 1 gives the percentage change of brake thermal efficiency of diesel, Jatropha oil and preheated Jatropha oil with the engine load.



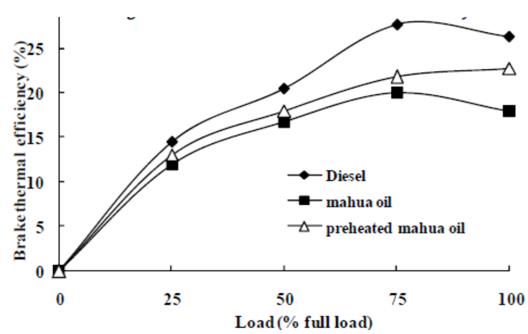


Fig. 1: Variation of Brake Thermal Efficiency With load for different Test Fuels

Fig.2: Variation of Brake Thermal Efficiency with load for Test Fuels

The variation of brake thermal efficiency of the engine using diesel, mahua oil and preheated mahua oil is shown in Fig. 2. The engine thermal efficiency was lowered when it was running with mahua oil. The maximum thermal efficiency using mahua oil was 20% as against 28% with diesel at 75% load. The poor combustion behaviour due to lower volatility and higher molecular weight caused a decrease in thermal efficiency compared to diesel [5]. Fig. 2 also shows that the thermal efficiency was improved with preheated mahua oil. The reduction in viscosity of preheated mahua oil observed better evaporation and mixing with air resulting in more complete fuel combustion. The maximum thermal efficiency (22.8%) was obtained at full load using preheated mahua oil. As compared to diesel and mahua oil, a reduction of 5.2 % and an increase of 2.8 % in brake thermal efficiency with preheated mahua oil were observed.

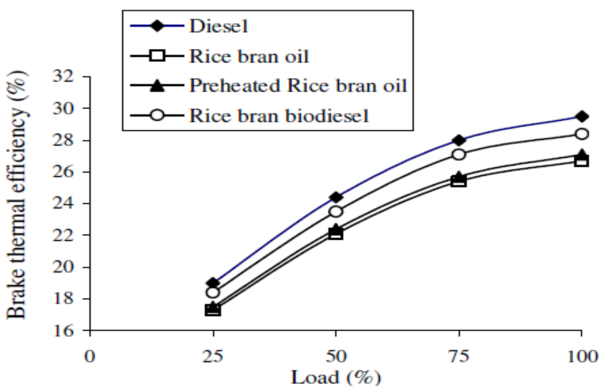


Fig.3: Variation of Brake Thermal Efficiency with Load for Different Test Fuels

At all loads, the engine with diesel operation showed a higher efficiency than both unheated and preheated Rice Bran oil. At full load, the brake thermal efficiency values for diesel, Rice bran oil and preheated Rice bran oil are 29.5 %, 26.7 % and 27.1 % respectively [7]. As compared to diesel and Rice bran oil, a reduction of 2.4 % and an increase of 0.4 % in brake thermal efficiency with preheated Rice bran oil were observed. Fig. 3 gives the percentage change of brake thermal efficiency of diesel, Rice Bran oil and preheated Rice Bran oil with the engine load.

A comparative result of variation in maximum brake thermal efficiencies of the test fuels is shown in Fig.4. Out of all other test fuels, Maximum brake thermal efficiency of Preheated

Jatropha Oil is only 2% less than that of corresponding diesel fuel. However, the effect of preheating is highly seen in case of Mahua oil showing an increase of 2.8% in maximum brake thermal efficiency in preheated Mahua oil compared to raw or unheated Mahua oil.

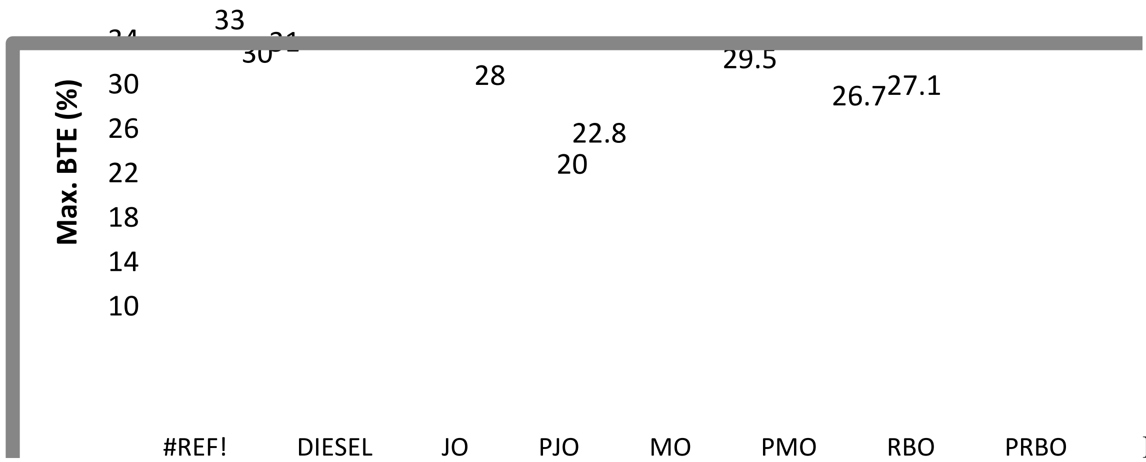


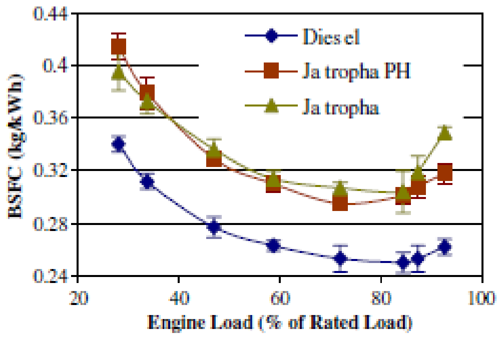
Fig. 4: Variation of maximum brake thermal efficiencies of the test fuels

4.1.2 Brake Specific Fuel Consumption (BSFC)

Diesel fuel operation shows lowest Brake Specific Fuel consumption (BSFC) throughout the operating range. Higher BSFC was observed when running the engine with Jatropha oil. Lower calorific value of Jatropha oil leads to increased volumetric fuel consumption in order to maintain similar energy input to the engine [4]. Fig. 5 gives the percentage change of BSFC of diesel, Jatropha oil and preheated Jatropha oil with the engine load. At 85% loading condition, Diesel and Jatropha oil shows its lowest BSFC of 0.25 and 0.305 kg/kWh respectively. Preheated Jatropha oil shows its lowest BSFC of 0.295 kg/KwH at 75% loading condition. As compared to diesel and Jatropha oil, an increase of 18 % and a reduction of 3.38 %, in BSFC with preheated Jatropha oil were observed.

Brake Specific Fuel consumption (BSFC) results are not shown by Pugazhvadivu et al. [5] in their experimentation. BSFC is reverse of BTE. So, the trend of BSFC for baseline Diesel, Raw Mahua Oil and Preheated Mahua Oil will be reverse of the trend for BTE shown by the fuels.

Due to the lower heating value, Rice bran vegetable oil has a higher Brake Specific Fuel consumption (BSFC) as compared to Diesel for all loads. When comparing the BSFC of preheated Rice bran oil and Rice bran oil without preheated, the former has a lower BSFC as compared to the later. This is due to the improvement in viscosity that leads to better atomization in the case of preheated Rice bran oil. Fig. 6 gives the percentage change of BSFC of diesel, Rice Bran oil and preheated Rice Bran oil with the engine load. At full load, the BSFC values for diesel, Rice bran oil, and preheated Rice bran oil are 0.291, 0.355 and 0.350 kg/kWh respectively. As compared to diesel and Rice bran oil, an increase of 20.3 % and a reduction of 1.4 %, in BSFC with preheated Rice bran oil were observed [7].



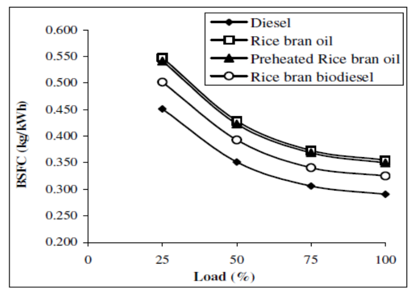


Fig.5: Variation of BSFC with load for different test fuels Fig.6: Variation of BSFC with load for different test fuels

A comparative result of variation in minimum BSFC of the test fuels is shown in Fig.7. Out of preheated Jatropha oil and preheated Rice Bran oil, Minimum BSFC of Preheated Jatropha Oil is only 18% more than that of corresponding diesel fuel whereas it is 20.3% for that of preheated Rice Bran oil. The effect of preheating is highly seen in case of Jatropha oil showing a reduction of 3.38% in minimum brake specific fuel consumption of preheated Jatropha oil compared to raw or unheated Jatropha oil. Exhaust Gas Temperature results are not shown by Pugazhvadivu et al. [5] in their experimentation.

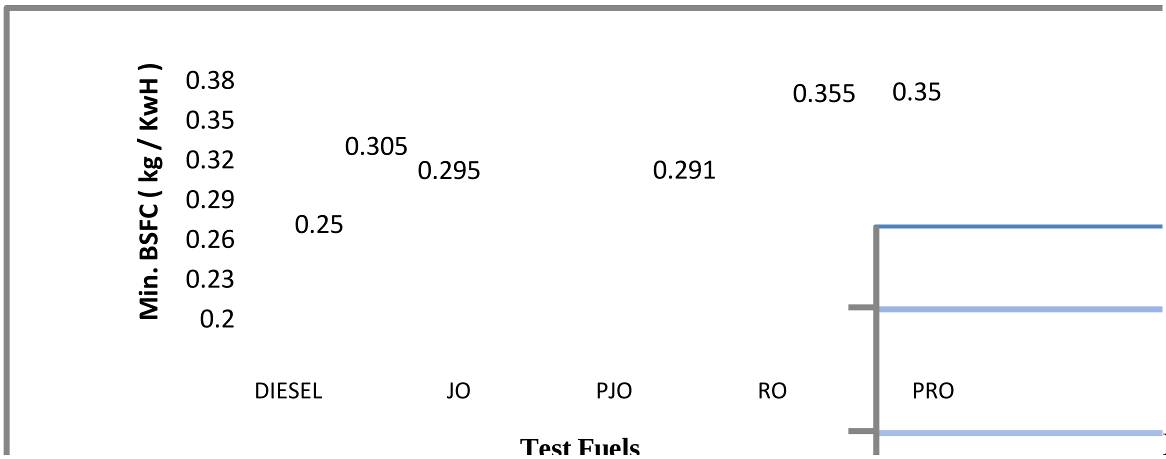
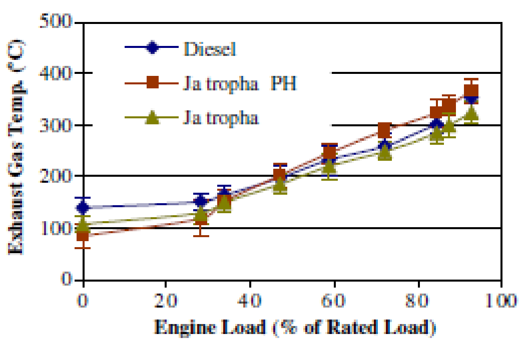


Fig. 7: Variation of minimum Brake Specific Fuel Consumption of the test fuels

4.1.1 Exhaust Gas Temperature (EGT)

Unheated Jatropha oil shows exhaust gas temperature lower than that of preheated Jatropha oil and diesel throughout all the loading conditions of the engine. On higher loading conditions, EGT of preheated Jatropha oil is more than that of diesel. At 95% loading condition, Preheated Jatropha oil, Diesel and Unheated Jatropha oil shows EGT of 370^0C, 350^0C and 320^0C respectively. Fig.8 indicates increase in the exhaust gas temperatures of the preheated Jatropha oil over other fuels [4]. As compared to Diesel and Jatropha oil, an increase of 5.71% and 15.62% in exhaust gas temperature with preheated Jatropha oil was observed at full load.



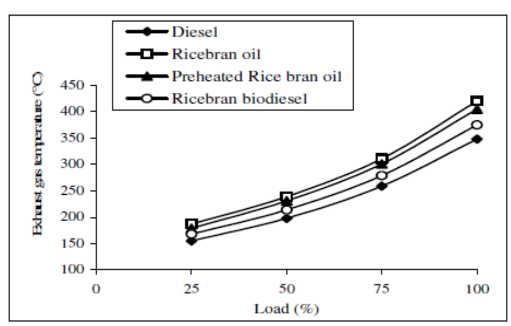


Fig.8: Increase in the exhaust gas temperatures Fig.9: Variation of EGT with load for different

Of the Test fuels Preheated Jatropha oil

Over other fuels

At a given load the Diesel has lower value and Rice bran oil shows a higher value of exhaust gas temperature. The variation of exhaust gas temperature with load for different test fuels is depicted in Fig.9. At full load, the exhaust gas temperatures are 348°C, 420°C and 405°C for diesel, Rice bran oil, and preheated Rice bran oil respectively. This can be due to the fact that the higher viscosity and poor volatility of Rice bran oil lead to poor mixture formation and hence diffusion combustion phase is more dominant which prolongs the heat release process. This may lead to higher exhaust gas temperature. As compared to diesel and Rice bran oil, an increase of 16.4 % and a reduction of 3.6 % in exhaust gas temperature with preheated Rice bran oil were observed at full load [7].

A comparative result of variation in EGT of the test fuels is shown in Fig.10. Out of preheated Jatropha oil and preheated Rice Bran oil, an increase of 5.71% in EGT is obtained with preheated Jatropha oil compared to baseline diesel and an increase of 16.4 % in EGT is obtained with preheated Rice Bran oil compared to baseline diesel. However, a reduction of 3.6% in EGT is seen with preheated Rice Bran oil compared to that of unheated Rice Bran oil. In case of Jatropha oil, no improvement in EGT is seen with preheating.

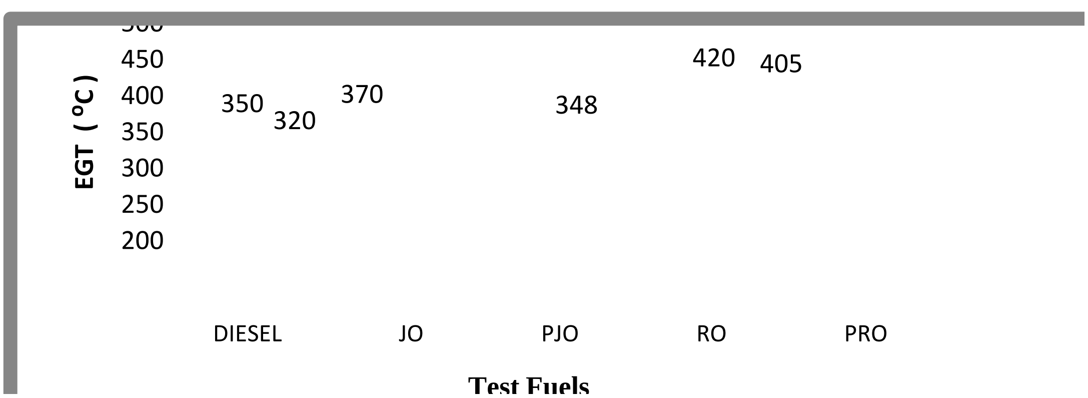


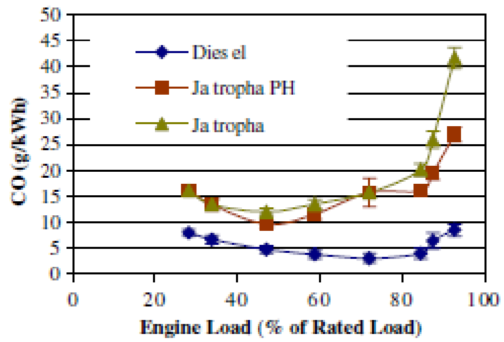
Fig.10: A comparative result of variation in EGT of the test fuels

4.2 Emission Results

4.2.1 CO Emission

At lower loads, CO emissions were nearly similar for Diesel, unheated Jatropha oil and preheated Jatropha oil. But at higher loads, CO emissions were higher for Jatropha oil compared to that of diesel as shown in Fig.11. This is possibly a result of poor spray atomization and non-uniform mixture formation with Jatropha oil. However, heating the Jatropha oil results in lower

CO emission compared to unheated Jatropha oil at higher loads only. Maximum CO emission for all the three test fuels occurs at 95% loading condition. At 95% load, CO emission for Diesel, unheated Jatropha oil and preheated Jatropha oil are 9 g/KWh, 40 g/KWh, 26 g/KWh respectively. As compared to diesel and Jatropha oil, an increase of 65.38 % and a decrease of 35 % in CO emission with preheated Jatropha oil were observed [4].



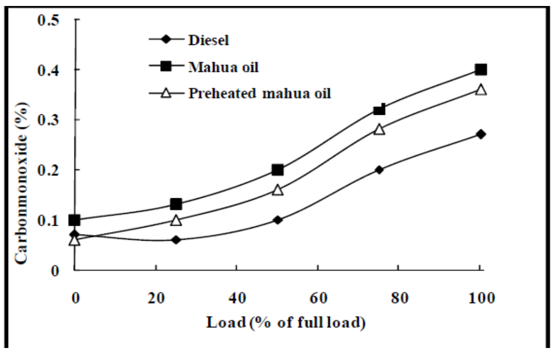


Fig.11: Variation of CO emission of test fuels fuels with with load

Fig.12: Variation of CO emission of test load

CO concentration was higher with mahua oil operation compared to diesel at all loads. This was due to the improper mixing of mahua oil with air. Fig.12 shows the variation of CO concentration at various loads on the engine. It is seen that the CO concentration reduced significantly with preheating mahua oil. CO concentration was reduced from 0.4% with mahua oil to 0.36% with preheating mahua oil to 130°C. On full load, CO concentration for Diesel was 0.25%. As compared to diesel and Mahua oil, an increase of 30.55 % and a decrease of 10 % in CO emission with preheated Mahua oil were observed [5].

Carbon monoxide in diesel engines is formed during the intermediate stages of hydrocarbon fuel oxidation. Rice bran oil results in higher CO emission as compared to diesel. Fig.13 shows the variation of CO concentration at various loads on the engine.

At full load, the CO emission with Rice bran oil and diesel are 0.33 % and 0.29 % respectively. The higher CO may be due to the poor spray characteristics as a result of higher viscosity of Rice bran oil, some of the fuel droplets will not get burned. When these droplets mix with the hot gases in the later part of the power stroke and early exhaust stroke, oxidation reaction of the fuel occurs but do not have enough time to undergo complete combustion. However, the CO emission with preheated Rice bran oil is lower when

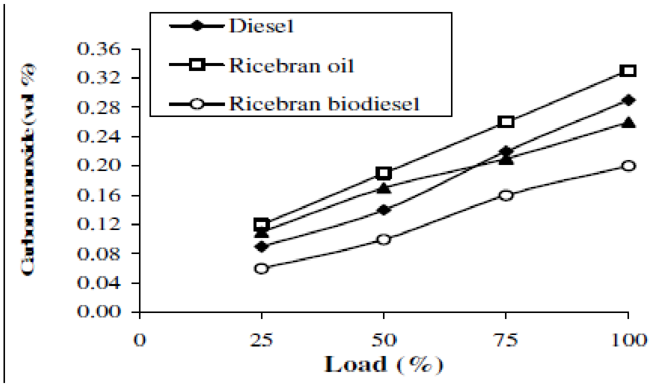


Fig.13: Variation of CO concentration at various loads on the engine.

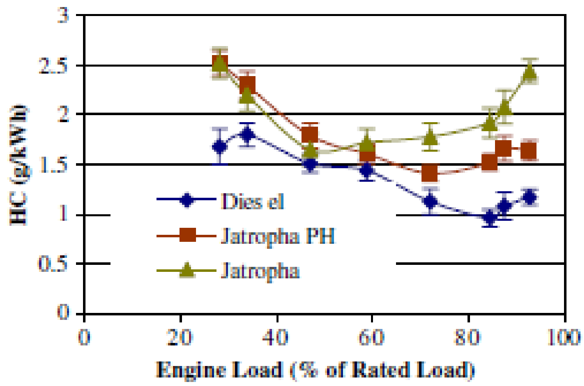
Compared to diesel at full load. As the fuel temperature increases, the CO emission decreases. The decrease in CO emission is an outcome of improved oxidation of carbon monoxide to carbon dioxide. The increase in fuel temperature of preheated oil will result in finer spray and thus good oxidation occurs. This is the reason for reduced CO with high fuel temperature. At full load; the carbon monoxide emissions are 0.29 %, 0.33% and 0.26 % for diesel, Rice bran oil and preheated Rice bran oil respectively. As compared to diesel and Rice bran oil, a reduction of 10.3 % and 21.2 %, relatively in carbon monoxide emission with preheated Rice bran oil were observed at full load [7].

Out of all other test fuels, at full load, preheated Rice Bran oil shows a reduction of 10.3% in CO emission as compared to Diesel. However, the effect of preheating is highly seen in case of Jatropha oil showing a decrease of 35% in CO emission of preheated Jatropha oil compared to that of raw or unheated Jatropha oil.

4.2.2. HC Emission

Diesel fuel operation produced lower HC emissions compared to Jatropha oil. HC emissions are lower at partial load, but tend to increase at higher loads for all fuels as shown in Fig.14. This is due to lack of oxygen resulting from engine operation at higher equivalence ratio. At 95% load, HC emission of Diesel, unheated Jatropha oil and preheated Jatropha oil are 1.2 g/KWh, 2.4

g/KWh and 1.6 g/KWh respectively. As compared to Diesel and Jatropha oil, an increase of 25 % and a decrease of 33.33 % in HC emission with preheated Jatropha oil were observed [4].



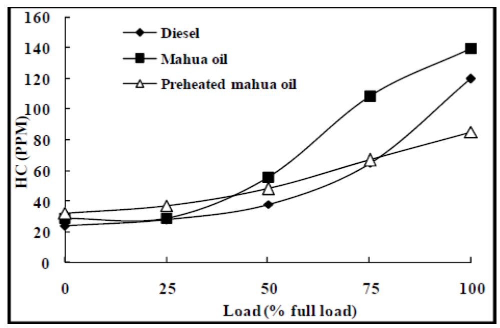


Fig.14: Variation in HC emission at various loads of the various Test fuels

Fig.15: Variation in HC emission at various loads of the Test fuels

It is seen that with Mahua oil operation the HC concentration was higher compared to diesel. It is seen that the HC emission was higher at all loads with Mahua oil. The poor injection of Mahua oil and its improper mixing with air during preparation phase resulted in incomplete combustion and higher HC emission. It is seen that the HC emission was lowered for Mahua oil combustion with preheating. Preheating caused more complete combustion of Mahua oil. As shown in Fig.15, the HC emission was 85 ppm with preheating compared to Mahua oil (140 ppm) and Diesel (120 ppm) at full load. As compared to Diesel and Mahua oil, a decrease of 29.16 % and 39.28 % in HC emission with preheated Mahua oil was observed [5].

From the Fig.16, it can be observed that the HC emission with Rice bran oil is higher when compared to diesel. Higher density and viscosity of Rice bran oil cause poor mixture formation which results in partially burned hydrocarbons during combustion process. Hence the hydrocarbon emissions are higher for Rice bran oil. The HC emission for Rice bran oil decreases with increase in fuel temperature. The reduction in HC emission at higher fuel temperature is due to better vaporization, as a result of improved atomization. At full load, the hydrocarbon emissions for Diesel, Rice Bran oil and preheated Rice Bran oil are 197, 207 and 189 ppm respectively. As compared to Diesel and Rice bran oil, a reduction of 4.1 % and 8.7 % in hydrocarbon emissions with preheated Rice Bran oil were observed [7].

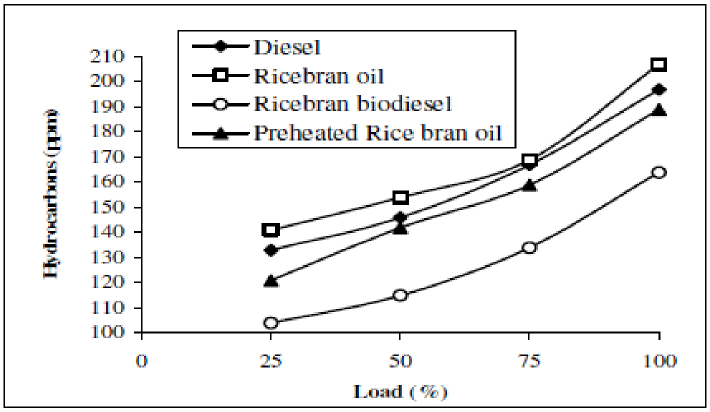
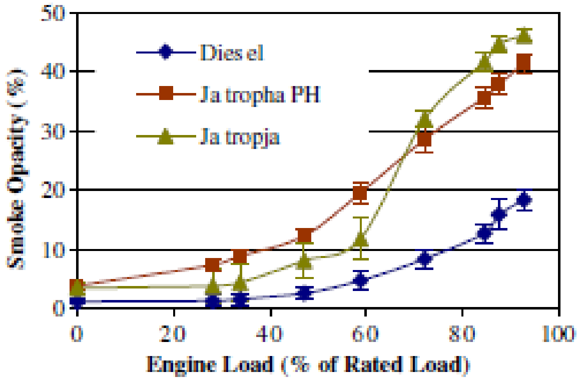


Fig.16: Variation in HC emission at various loads of the test fuels

Out of all other test fuels, at full load, preheated Mahua oil shows a reduction of 29.16% in HC emission as compared to Diesel. The effect of preheating is also highly seen in case of Mahua oil showing a decrease of 39.28% in HC emission of preheated Mahua oil compared to that of raw or unheated Mahua oil.

4.2.3. Smoke Opacity/ Smoke Density

Smoke opacity for Jatropha oil operation was greater than that of diesel. Heating the Jatropha oil result in lower smoke opacity compared to unheated oil but it is still higher than diesel as shown in Fig.17.At 95% load, smoke opacity of Diesel, Jatropha oil and preheated Jatropha oil are respectively 19%, 45% and 40%. As compared to diesel and Jatropha oil, an increase of 21% and a decrease of 5% in smoke opacity with preheated Jatropha oil were observed [4].



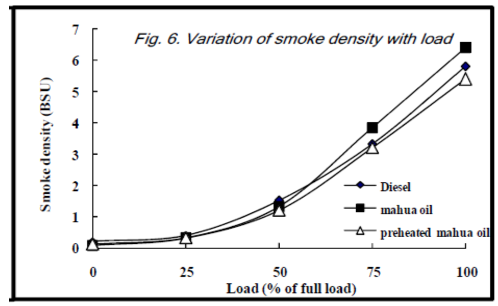


Fig.17: Variation in smoke opacity at various loads for test fuels

Fig.18: Variation in smoke opacity at various loads for test fuels

The variation of smoke density with engine load is shown in Fig.18. It is found that the smoke density of the engine with Mahua oil operation was higher than diesel. This negative effect is mainly due to the high viscosity and poor volatility of Mahua oil compared to diesel. The high viscosity and poor volatility of Mahua oil caused poor fuel injection and mixing characteristics and incomplete combustion. Further, the mean diameter fuel droplet was higher for vegetable oil than diesel. The smoke density was higher at full load and it was 6.4 BSU with Mahua oil operation and 5.7 BSU with Diesel fuel operation. It is also seen from Fig. 18, that the smoke density was reduced with preheating. The smoke density was 5.4 BSU with preheated Mahua oil operation. As compared to Diesel and Mahua oil, a reduction of 5.2 % and 15.6 % in smoke density with preheated Mahua oil was observed. The reduction in smoke density may be due to the reduction in viscosity and subsequent improvement in spray and fuel air mixing causing good combustion. The results show that higher reduction in smoke density was achieved at part and full load conditions. However, only a marginal reduction was observed at low loads. This may be due to the dilution effect caused by the presence of excess air available at low loads [5].

The variation of smoke density with load for the test fuels is shown in Fig.19. At full load, the smoke density is 3.2 Bosch Smoke Units (BSU) with Rice bran oil and 2.9 BSU with diesel. With Rice bran oil, due to its heavier molecular structure and higher viscosity, atomization becomes poor and this may lead to a higher smoke emission as compared to diesel. However, the smoke density decreases with preheated Rice bran oil. The smoke emission is 2.8 BSU with preheated Rice bran oil, which is lower than that of diesel. With preheated Rice bran oil, lower smoke level as a result of improved combustion can be achieved due to the reduction in viscosity and a better fuel air mixing rates. As compared to Diesel and Rice Bran oil, a reduction of 3.4 % and 12.5 % in smoke density with preheated Rice bran oil were observed [7].

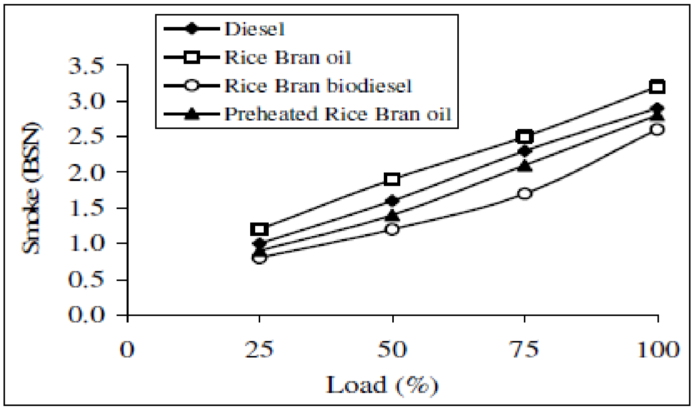


Fig.19: Variation of smoke density with load for the test fuels

Out of preheated Jatropha oil, Preheated Mahua oil and preheated Rice Bran oil, at full load, preheated Mahua oil shows a reduction of 5.2% in smoke density as compared to Diesel. The effect of preheating is also highly seen in case of Mahua oil showing a decrease of 15.6% in smoke density of preheated Mahua oil compared to that of raw or unheated Mahua oil.

5. Conclusion

It can be concluded from the above-summarized studies that use of preheated vegetable oil is a better option than unheated raw vegetable oil in compression ignition engine. Preheating brings the performance and emission characteristics of a diesel engine close to that of an engine run by mineral diesel. The review conclusively establishes that maximum brake thermal efficiency (BTE) of Jatropha Oil preheated to 80^0C to 90^0C is only 2% less than that of corresponding diesel fuel. However, the effect of preheating is highly seen in case of Mahua oil preheated to 130^0C, showing an increase of 2.8% in maximum brake thermal efficiency compared to raw or unheated Mahua oil. Maximum brake thermal efficiency of preheated Rice Bran oil is 2.4% less than Diesel whereas it is 5.2% less than diesel in case of preheated Mahua oil. Out of preheated Jatropha oil and preheated Rice Bran oil, Minimum BSFC of Preheated Jatropha Oil is only 18%

more than that of corresponding diesel fuel whereas it is 20.3% for that of preheated Rice Bran oil. The effect of preheating is highly seen in case of Jatropha oil showing a reduction of 3.38% in minimum brake specific fuel consumption of preheated Jatropha oil compared to raw or unheated Jatropha oil. Out of preheated Jatropha oil and preheated Rice Bran oil, an increase of 5.71% in EGT is obtained with preheated Jatropha oil compared to baseline diesel and an increase of 16.4 % in EGT is obtained with preheated Rice Bran oil compared to baseline diesel. However, effect of preheating is highly seen in Rice Bran oil showing a reduction of 3.6% in EGT compared to that of unheated Rice Bran oil. In case of Jatropha oil, no improvement in EGT is seen with preheating. Out of all other test fuels, at full load, preheated Rice Bran oil shows a reduction of 10.3% in CO emission as compared to Diesel. However, the effect of preheating is highly seen in case of Jatropha oil showing a decrease of 35% in CO emission of preheated Jatropha oil compared to that of raw or unheated Jatropha oil. Carbon monoxide emission of both preheated Jatropha oil and Mahua oil are more than Diesel. Out of all other test fuels, at full load, preheated Mahua oil shows a reduction of 29.16% in HC emission as compared to Diesel. The effect of preheating is also highly seen in case of Mahua oil showing a decrease of 39.28% in HC emission of preheated Mahua oil compared to that of raw or unheated Mahua oil. Preheated Rice Bran oil shows a reduction of 4.1% in HC emission compared to Diesel. Hydrocarbon emission of preheated Jatropha oil is more than Diesel. Out of preheated Jatropha oil, Preheated Mahua oil and preheated Rice Bran oil, at full load, preheated Mahua oil shows a reduction of 5.2% in smoke density as compared to Diesel. The effect of preheating is also highly seen in case of Mahua oil showing a decrease of 15.6% in smoke density of preheated Mahua oil compared to that of raw or unheated Mahua oil. Preheated Rice Bran oil shows a decrease of 3.4% in smoke density compared to diesel, whereas preheated Jatropha oil shows an increase of 21% in smoke density compared to Diesel. Considering both performance and emission results shown by preheated Jatropha oil , preheated Mahua oil and preheated Rice Bran oil, Rice Bran oil preheated to a temperature of 158^0C is considered to be the most efficient fuel which is comparable to that of Diesel and it is followed by preheated Mahua oil at 130^0C and preheated Rice Bran oil at 80-90^0C.

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