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Performance and emission characteristics of diesel engine working on Jatropha Methyl Ester and its blends.

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Abstract - *Jatropha oil (Jatropha Curcas) is non edible in nature and is available abundantly in India. But due to high viscosity this oil cannot be used directly in the engines since it leads to inferior performance of the engine. Transesterification of edible and non-edible oils is a process which brings viscosity into a range equivalent to that of diesel fuel. An experimental investigation has been made to evaluate the performance and emission characteristics of a diesel engine using different blends of methyl ester of Jatropha with mineral diesel. In this investigation Jatropha methyl ester was blended with diesel in proportions of 25%, 50%, 75% and 100% by volume and studied under various load conditions in a compression ignition (diesel) engine and performance and emission characteristics were studied and tabulated. The performance parameters of J25 were found to be very close to that of mineral diesel. The brake thermal efficiency decreased, brake specific fuel consumption increased with increase in the blending ratio. The Exhaust gas temperature was found to be increasing with blending ratio. The emission characteristics were found comparing CO_2, CO, HC, NOx, Smoke opacity with the diesel fuel. CO_2 and NOx were found to be higher than diesel emissions while the others were found to be decreasing with increasing blend ratio.*

Key Words*: *Alternate fuels, Biodiesel, Jatropha, Diesel engines, Performance, Emissions.

1. INTRODUCTION

The transport sector in India contributes to 6.4% share in India's GDP of which road transport accounts for 4.5–5% share [1]. In 1950s road transport carried 15% of passenger and 14% of freight movements with the total network length of 0.4million km. However, over the past two decades, road sector has evolved as a predominant mode of transport both in terms of the number of vehicles and road network length. This is evident from the fact that road transport now accounts for 86% of the passenger movements and 66% of freight movements with the total network length of 4.7 million km in 2011 (MoRTH, 2011) The rise in the share of road transport is attributed to its flexibility and adaptability in operation and is supported by massive investment in road infrastructure through government programmes like the National Highways Development Project (NHDP), Pradhan Mantri Gram Sadak Yojana (PMGSY) and Jawaharlal Nehru National Urban Renewal Mission (JnNURM). As far as energy consumptions are concerned, the transport sector of India accounts for 14% of the final energy consumption and has been associated with the highest growth rate in terms of energy consumption(annually 6.8% since 2000) among other end user sectors (IEA, 2015). A significant component of the transport sector energy consumption is dominated by the oil-fuelled road travel by freight vehicles. PCRA(2013) also highlights that "Of the total diesel consumed by road transport, trucks and buses accounted for about 77% with buses consuming around 7.08 million tonnes per annum and trucks consuming 24.25 million tonnes per annum. The use of various fuels in the transport sector has been shown in the below figure as per the EIA-2015 report.

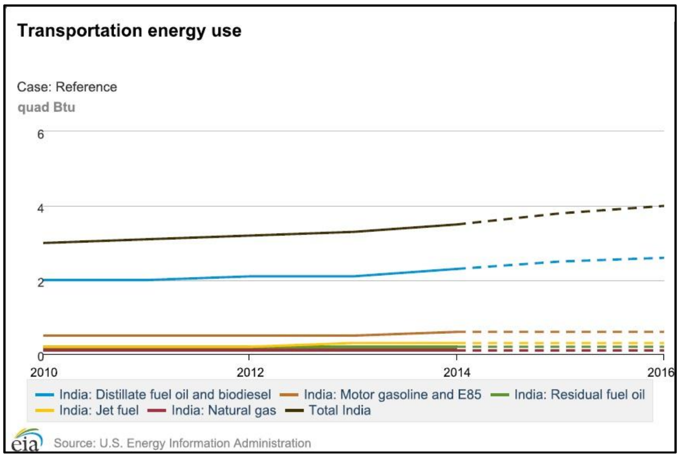

Fig. 1 Distribution of the fuels used in India from 2010-16 (as per EIA report)

1.1 Indian Energy scenario in Biodiesel

The government of India has formulated an ambitious National Biodiesel Mission (NBM) for fulfilling country's diesel requirements by 2016-2017.Requirement of bio fuel for blending under different scenario are given in Table 1. A commercialization period during 2012-2018 will continue for Jatropha cultivation and installation of more transesterification plants which will enable India to meet 20 per cent of its diesel needs through biodiesel.

Table 1: Demand of biodiesel according to the Diesel requirement.

Year	Diesel Demand (MT)	Blend @ 5% (MT)	Blend @ 10% (MT)	Blend @ 20% (MT)
2006-07	52.33	2.62	5.23	10.46
2011-12	66.90	3.34	6.69	13.38
2016-17	83.58	4.18	8.36	16.72

Jatropha curcas is becoming the promising future source of biodiesel for India. The planning commission and Government of India, has initiated an ambitious program of growing Jatropha curcas on waste land for biodiesel production. Among the different oil seeds, Jatropha curcas has been found more suitable for biodiesel production on the basis of various characteristics. The cultivation of Jatropha is possible under adverse condition and the oil of these species having various characteristics is more suitable for biodiesel production. Jatropha curcas has been scientifically developed by researchers to give better yield and productivity of oil. Jatropha oil has higher cetane no. (52) compared to other oils, which is compared to diesel (46–50), making it an ideal alternative fuel and requires no modification in the engine.

2. LITERATURE REVIEW

Priyabarta et.al. [2], Experiments were conducted on Diesel, preheated and crude Jatropha oil to evaluate the combustion characteristics of a DI (direct injection) diesel engine using PJO (preheated Jatropha oil). It exhibited a marginally higher cylinder gas pressure, rate of pressure rise and heat release rate as compared to HSD (high speed diesel) during the initial stages of combustion for all engine loadings. Ignition delay was shorter for PJO as compared to HSD. The results also indicated that BSFC (brake specific fuel consumption) and EGT (exhaust gas temperature) increased while BTE (brake thermal efficiency) decreased with PJO as compared to HSD for all engine loadings. The reductions in CO_2 (carbon dioxide), HC (hydrocarbon) and NOx (Nitrogen oxide) emissions were observed for PJO along with increased CO (carbon monoxide) emission as compared to those of HSD.

Mohammed EL-Kasaby, Medhat A. Nemit-allah [3], In this Jatropha-curcas is used as a non-edible methyl ester biodiesel fuel source to run single cylinder, variable compression ratio, and four-stroke diesel engine. Blends used were Diesel and 10, 20, 30, 50% JME. Combustion characteristics as well as engine performance were measured for different biodiesel–diesel blends. It has been shown that B50 (50% of biodiesel in a mixture of biodiesel and diesel fuel)gives the highest peak pressure at 1750rpm,while B10 gives the highest peak pressure at low speed,1000rpm. B50shows upper brake torque, while B0 shows the highest volumetric efficiency. B50 shows also, the highest BSFC by about (12.5–25%) compared with diesel fuel. B10 gives the highest brake thermal efficiency. B50 to B30 show nearly the lowest CO concentration, besides CO concentration is the highest at both idle and high running speeds. Exhaust temperature and NOx are maximum for B50. Delay period is measured and correlated for different blends. Modified empirical formulae are obtained for each blend. The delay period is found to be decreased with the increase of cylinder pressure, temperature and equivalence ratio.

M. Mofijur, H.H. Masjuki, M.A. Kalam, A.E. Atabani [4], This paper aims to study the feasibility of Jatropha as a potential biodiesel feedstock for Malaysia. Physico-chemical properties of Jatropha biodiesel and its blends with diesel followed by engine performance and emissions characteristics of B10, B20 and B0 were studied. The results show that viscosities of B10 and B20 are closer to diesel. Moreover, only the oxidation stability of B10 and B20 meet the European specifications (EN 590) of 20 h. Therefore, only B10 and B20 have been used to evaluate engine performance and emission. Compared to B0, the average reduction in brake power (BP) is 4.67% for B10 and 8.86% for B20. It was observed that brake specific fuel consumption (BSFC) increases as the percentage of biodiesel increase. Compared to B0, a reduction in hydrocarbon (HC) emission of 3.84% and 10.25% and carbon monoxide (CO) emission of 16% and 25% was reported using B10 and B20. However, the blends give higher nitrogen oxides (NOx) emission of 3% and 6% using B10 and B20. As a conclusion, B10 and B20 can be used in a diesel engine without any modifications.

K. Pramanik [5], In this the investigation the high viscosity of the jatropha curcas oil which has been considered as a potential alternative fuel for the compression ignition (C.I.) engine was decreased by blending with diesel. The blends of varying proportions of jatropha curcas oil and diesel were prepared, analyzed and compared with diesel fuel. The effect of temperature on the viscosity of biodiesel and jatropha oil was also studied. The performance of the engine using blends and jatropha oil was evaluated in a single cylinder C.I. engine and compared with the performance obtained with diesel. Significant improvement in engine performance was observed compared to vegetable oil alone. The specific fuel consumption and the exhaust gas temperature were reduced due to decrease in viscosity of the vegetable oil. Acceptable thermal efficiencies of the engine were obtained with blends containing up to 50% volume of jatropha oil. From the properties and engine test results it has been established that 40–50% of jatropha oil can be substituted for diesel without any engine modification and preheating of the blends.

3. METHODOLOGY

3.1 Transesterification process

Transesterification is the most common method of converting oil into biodiesel or fatty acid methyl esters

(FAME), that can be used thereafter directly or as blends with diesel in diesel engine. It is also called alcoholysis, is displacement of alcohol from an ester by another alcohol in a process similar to hydrolysis, except that an alcohol is being used instead of water. This process is widely used to reduce the viscosity of triglycerides [6]. A transesterification reaction is represented in Figure 2.

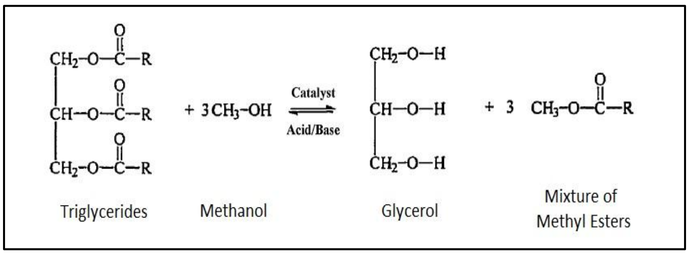

Fig. 2 Tranesterification Reaction

Transesterification is a method of transforming of highly viscous oil into lower viscosity oil. When a vegetable oil or non-edible oil is reacted with methanol (CH_3OH) in the presence of catalyst, it gives mixture of methyl ester also known as biodiesel and some amount of glycerin as the residue.

The best yield of about 95% is obtained if the Jatropha oil is acid pre-treated and the molar ratio of methanol and the oil is near about 6.5:1. The base (NaOH) being 1% by mass on oil basis [7, 8].The temperature of the above reactions being 60°C at which it gives the favourable results for maximum yield. The process is highly used for the production of methyl esters from VO's (Vegetable oils) and non-edible oils. The setup of the Transesterification apparatus is as shown in Figure 3

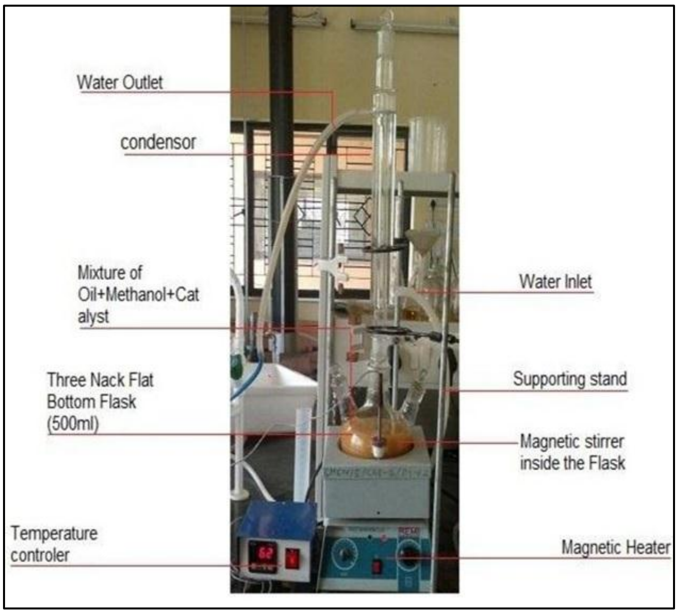

Fig. 3 Transesterification Apparatus

Properties of the Jatropha biodiesel and its blends are as shown in the table 2.

Table 2: Properties of the biodiesel and its blends

Property	J0	J25	J50	J75	J100
Density (ρ)	837	-	-	-	883
Calorific value, CV (KJ/Kg)	44237	43090	41957	40817	39594
Viscosity, ν (mm^2/s)	3.41	-	-	-	4.51
Flash pt. (°C)	73	-	-	-	164
Cetane No.	48	-	-	-	52

3.2 Compression Ignition Engine setup

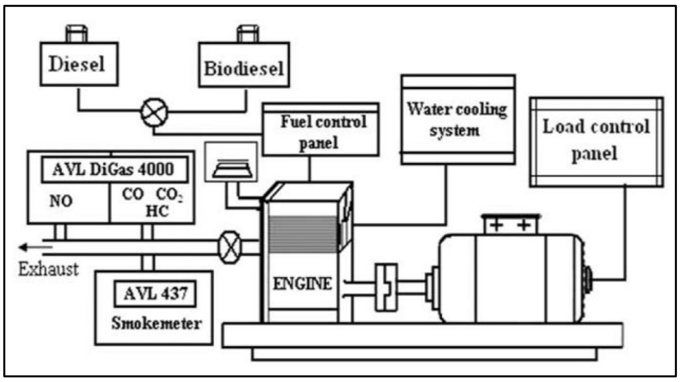

Fig. 4 Schematic diagram of the Experimental Engine setup

The engine set up shown is single cylinder, water cooled, diesel engine. The engine has rated output 5.2 kW at constant speed 1500rpm with compression ratio 17.5:1, injection pressure 180-200 bar and is coupled to eddy current dynamometer. Performance test were carried out on compression ignition engine using various blends of biodiesel and diesel as fuel.

The exhaust smoke emissions were analyzed by using five gas analyzer. . For the measurement of the CO, CO_2, HC the principle used is Infrared measurements while for measuring the NOx and O2 it uses the Electrochemical measurements as the working principle. For measuring smoke opacity we have used AVL-437 smokemeter. The smoke meter is an opacity measuring device working on the partial flow principle, as opposed to full flow and free flow principles, where a sample of smoke is taken from the tailpipe for analysis in the chamber.

4. RESULTS AND DISCUSSIONS

4.1 Brake Thermal Efficiency (η)

The variation of brake thermal efficiency (BTE) is as shown in the Figure 5. The efficiency for J0 (diesel) at full load (15 Kg) is 24.64%, while for J100 it is 21.72% i.e. there is decrease in efficiency. There is about 11.85% decrease in efficiency from J0 to J100. This could be possibly due to high specific fuel consumption (sfc) and high rate of heat release with the exhaust.

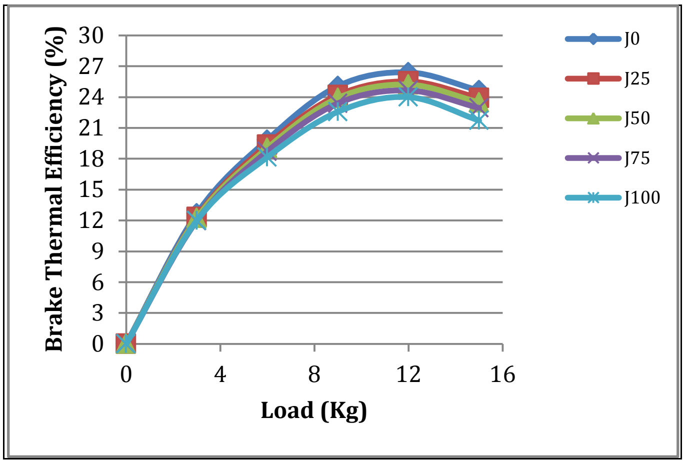

Figure 5 Variation of BTE (%) with load (Kg)

4.2 Brake Specific Fuel Consumption (BSFC)

The BSFC of J0 at full load is about 0.33 Kg/KWhr while that of J100 is 0.42 Kg/KWhr. This shows an increase in fuel consumption of about 27.3%.Though fuel consumption follows decreasing nature of curve with increase in the load. The percentage increase for other blend follows 5.84%, 10.72%, 16.51% respectively for J25, J50, J75. This is mainly caused due to decrease in the calorific value of the fuel which is about 11% lower than diesel due to which it needs more fuel to produce the same output. The variation as shown in the figure 6.

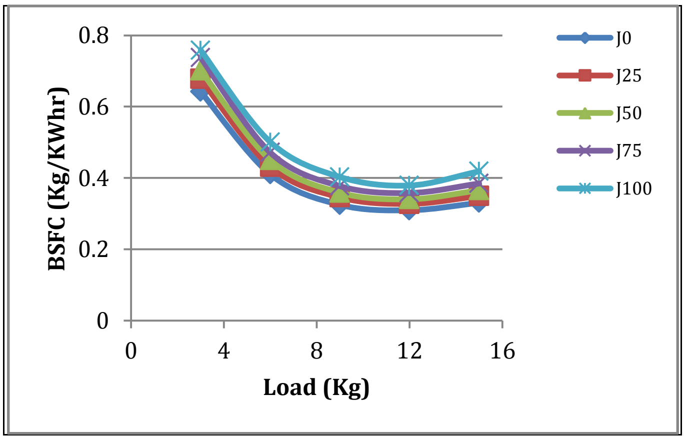

Figure 6 Variation of BSFC (Kg/KWhr) with load (Kg)

4.3 Exhaust Gas Temperature (EGT)

The analysis of this is important because it is an indicator of combustion characteristics also. The variation is almost negligible for the blends with lower percentage of Jatropha. The exhaust temperature for diesel (J0) is about 297°C while for the J100 it is about 320°C. But the variation is not linear with the increase in blending but the exhaust temperature is always greater for pure Jatropha throughout the loading.

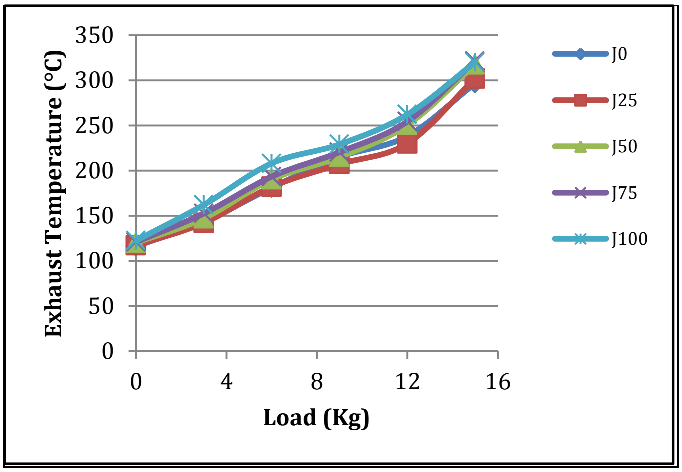

Figure 7 Exhaust gas temperature (°C) variation with loading (Kg)

4.4 Carbon Mono-Oxide (CO) emission

The variation of this gas with loading is as shown in the Figure 8. There is continuous decrease in the emission of the carbon monoxide (CO) with the increasing percentage of Jatropha biodiesel blend. There is maximum CO emission for diesel(J0) at peak load which is near to about 0.63% while for the neat biodiesel (J100) it is lower and near to value of about 0.38%. That gives us a decrease percentage of about 40% in the emissions of CO which is a better performance characteristic.

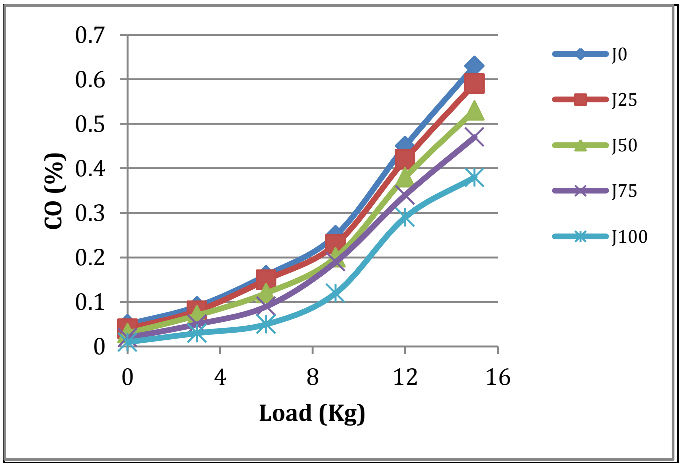

Figure 8 Variation of CO emission (%) with load (Kg)

4.5 Hydro-Carbon (HC) emission

The variation of the release of hydrocarbons is as shown in the Figure 9. The graph shows the decrease in the emissions of the hydrocarbon by the neat biodiesel. For all the loading conditions the value of the HC emission for J100 remains lower as compared to the neat diesel (J0). The value of hydrocarbon is measured in units of parts per million (ppm). The maximum value for diesel is obtained at the full load condition having a value of about 102 ppm while for J100 it is lower than J0 and is about 73 ppm.

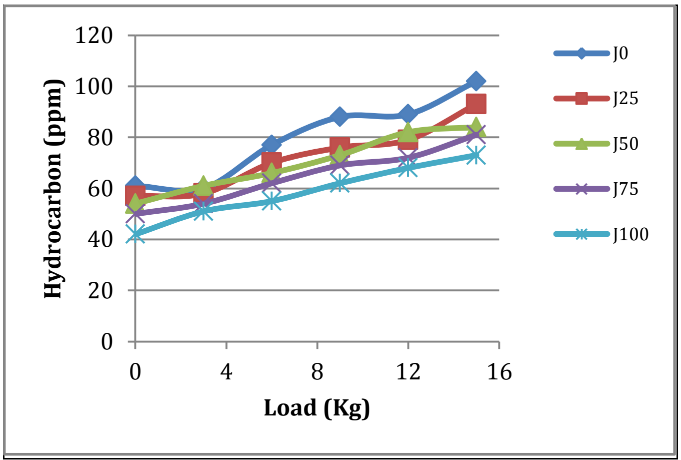

Figure 9 Variation of HC emission (ppm) with the load (Kg)

4.6 Carbon-Di-Oxide (CO_2) emission

The variation of Carbon Dioxide is as shown in Figure 10. The value of carbon dioxide at full load condition for diesel (J0) is 8.9% while that of the pure Jatropha (J100) is 10.5%. This shows a increase in percentage of emission of about 18% for the full load condition. This increase in CO_2 can be assessed to be due to decrease in CO content as seen above. Due to excess of oxygen present in the Jatropha biodiesel, the reaction of CO with oxygen tends to increase the CO_2 emissions.

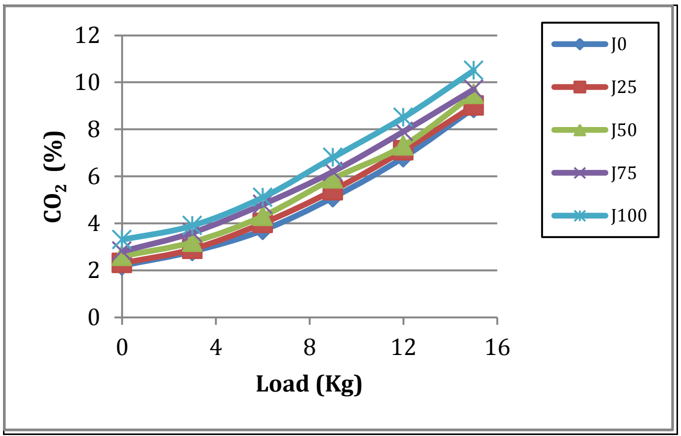

Figure 10 CO_2 emission (%) variation with loading (Kg)

4.7 Nitrogen Oxides (NOx) emission

The variation of NOx emission (ppm) with the load(Kg) is as shown in Figure 11. At full load the value of NOx for diesel (J0) is 1698ppm while that of the J100 is 2468ppm. This shows an increase of about 32%. The increase is more for increasing blend ratio and is least for J25.

The excess formation of NOx can be due to the high temperature of the combustion chamber because though nitrogen being neutral for combustion, due to creation of favourable condition of high temperature nitrogen and oxygen reacts to form NOx compounds.

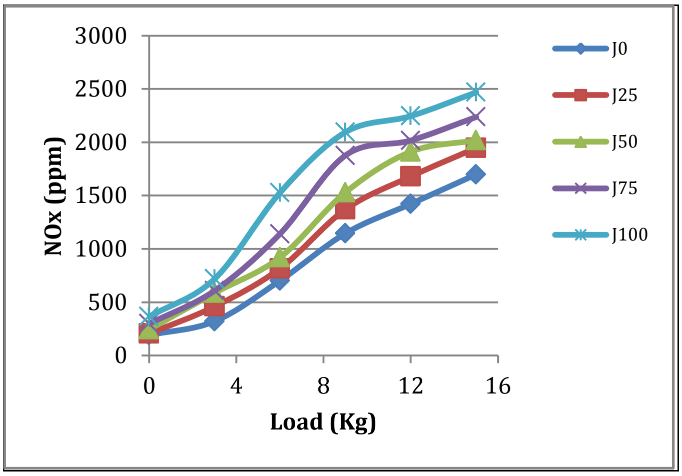

Figure 11 Variation of NOx (ppm) with load (Kg)

4.8 Smoke Opacity

The variation of smoke opacity is as shown in Figure 12. The graph shows the variation of the smoke with the increasing load conditions. The value is maximum for diesel (J0) throughout the loading conditions while that of neat Jatropha is lower than the diesel for all blends. J100 has the lowest smoke opacity throughout the loading. At full load the opacity value for diesel is 84.5% while that of J100 is 60.4% showing an effective decrease of about 29%.

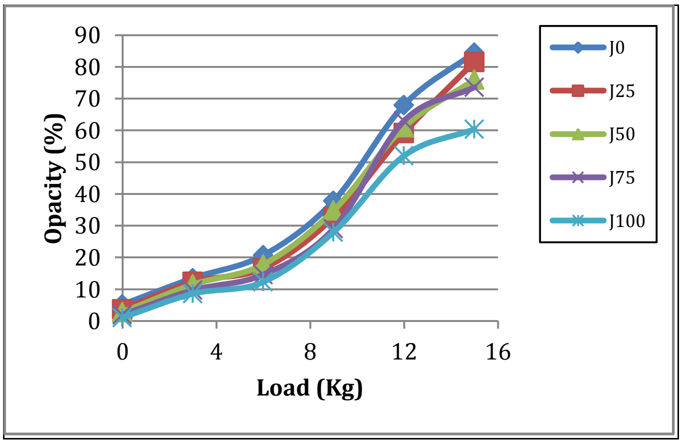

Figure 12 Variation of the smoke opacity (%) with load (Kg)

5. CONCLUSIONS

The present study was about technical feasibility of Jatropha biodiesel in the Compression Ignition engine without any modification. The engine performance and various emission characteristics were analyzed. The characteristics were briefly discussed in the previous chapter through which we can make following conclusions.

5.1 Performance of the engine

1) The brake thermal efficiency (η) for J100 and J0 at full load are 21.72% and 24.64% respectively, indicating decrease in efficiency. But J25 has only marginal performance decrease of 2.92%. This may be due to high BSFC and high heat release with exhaust.

2) The brake specific fuel consumption (BSFC) increases with increase in blend ratio. It is highest for J100 for all loading condition. Percentage increase in BSFC at full load for J100 is 27.3% more than neat diesel (J0). This may be due to low calorific value (CV) due to which J100 burns more fuel for same power output.

3) Exhaust gas temperature increases with increase in blending ratio. It becomes 320°C for J100 while for J0 it is 297°C at full load condition. The increase in temperature can be attributed to the property of biodiesel having high oxygen percentage, due to which it leads to complete combustion situation. J25 performs better in this also.

5.2 Emission characteristics

1) There is about 40% decrease in Carbon monoxide (CO) emission for J100 than diesel (J0) at full load conditions. The value of CO for J100 is 0.38% while for diesel it is 0.63% at full load condition. There is decrease in CO emission with increase in blend ratio. The decrease in CO emissions may be due to the property of the biodiesel containing less percentage of Carbon.

2) The Hydrocarbon(HC) emissions for J100 is well below the J0. There is a decrease of about 29% in HC emissions for J100 at full load condition. The J100 released 73ppm of HC while J0 had 102ppm of HC released. This may be due to high temperature in combustion chamber due to which HC chains are broken.

3) The Carbon dioxide (CO_2) emission is more J100 than J0 for all loading conditions. The J100 has 10.5% CO_2 emitted while J0 emitted 8.9% CO_2, showing an increase of about 18%. The CO_2 emission increased with the blend ratio. This may be due to complete oxidation of CO and forming bonds with carbon atoms from dissociated HC's. J25 had only marginal difference from diesel and emitted less CO_2.

4) There was also an increase in the emission of Nitrogen Oxides (NOx) for J100. The J100 emitted 2468ppm while J0 emitted 1698ppm at full load conditions. The increase percentage was found to be 32%. There is increase in NOx emission with increase in blend ratio. This is mainly due to the reason of high temperature and pressure created in the combustion chamber due to more oxygen present in fuel, creating favourable condition for NOx creation.

5) There is a decrease of Smoke opacity as the blend ratio is increased. It is least for J100 at 60.4% while for J0 it is 84.5%, showing a decrease of about 29%. Opacity indicates the combustion characteristics of the fuel, which is showing better performance for biodiesel.

So the conclusion after complete analysis is that the Jatropha biodiesel has feasible properties of becoming a substitute for diesel used in engines. But there are some characteristics that give inferior performance to biodiesel in engines when used in pure form. So it is advisable to blend the ratio of Jatropha upto 25% only. The Jatropha fuel blend competed favorably with diesel fuel and offers a reasonable, if not even a better, substitute for pure diesel fuel.

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