# Engine Performance and Emission having Jatropha-Diesel Blend

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**Abstract-** The performance of a four stroke, single cylinder, direct injection CI engine is evaluated having fuel as neat Jatropha-diesel blend in proportion 2:1 on a volume basis. The experimentations were conducted to test engine performance and emission characteristics at different throttle settings and loads. The effect of Jatropha blend on engine brake power, brake thermal efficiency and specific fuel consumption were observed at different loads and throttle openings along with exhaust emissions and exhaust gas temperatures. Compared to Jatropha blend diesel provides better performance for entire operating range (of loads and throttle openings) but effect of varying load /throttle settings on performance characteristics are of similar nature. The Jatropha blend produces lower hydrocarbon and $NO_x$ emission, highlights the positive aspects of combustion and the allowance of higher effective compression ratio of the blend.

**Keywords** Jatropha-diesel blend, brake power (BP), brake thermal efficiency (BTE), specific fuel consumption (SFC), emission.

## 1. Introduction

The present world is confronted with the twin crisis of fast depleting fossil reserves and increasing environmental threats. The indiscriminate extraction and lavish consumption of fossil fuels promotes search for alternative fuels. Fuels obtained from bio- origin can provide a physible solution to this worldwide petroleum crisis. Bio-diesel obtained from vegetable oil is comparable to diesel from the point of calorific value and emission quality. India imports about 40-50% edible oil to meet domestic need, and therefore production of biodiesel from edible oil resources is not justified [1], but can be obtained from a huge potential of non-edible oil. Feedstock of mainly pongamia (karanja), neem, mahua, cotton seed, castor, rubber seed, tobacco, jojoba, kusum and Jatropha Curcas are the most prominent species for bio-diesel production. Oil can be extracted using various methods which include: mechanical extraction, solvent extraction or enzymatic extraction. As per Government of India survey, has vast area of degraded and waste land (60 Mha), railway network of 63,140 km, 3 million km road network (third largest in Asia) [2]. Jatropha and Karanja crops can be grown on the wasteland and land on the road sides and railway tracks, in addition to check soil erosion and improve fertility of land. Jatropha Curcas is a shrub of upto 6 m height, native to Haiti and is adapted to low rainfall, now available throughout the tropical and subtropical areas. Due to presence of toxic cursive and curcasive, the cattle do not graze the plant, seed and oil. The Jatropha oil is odorless, colourless if fresh but becomes yellow on storing, a slow-drying oil. The Jatropha seed contains oil in the ranges from 30 to 35 % by weight [3]. From the point of calorific value of Jatropha it can be compared well to any bio diesel as well as to diesel also (Table 1). It is reported [5] that viscosity of the oil obtained from Jatropha seed is more compared to petro-diesel, have higher cloud points with minimal sulphur content and more reactive to excess oxygen. In Jatropha oil longer carbon chain with less number double bond is responsible for higher viscosity, Cetane number and calorific value. Due to incomplete combustion the high viscous Jatropha Curcas oil forms carbon deposits and reduces life of the engine. Vegetable oil can be converted into bio-diesel by various methods e.g. transesterification, thermal cracking, micro-emulsions etc. CI engines can be operated with little or no design modifications using these bio diesels [6 &7].

Bio-diesel obtained in the form of methyl ester has lower carbon chain length, as a result viscosity reduces, and improves cetane number [9]. The Jatropha methyl esters results in soot emission of 110 ppm which is nearly comparable to 100 ppm for fossil diesel [10]. At full load the similar results were obtained having direct use of the oil, produces 130 ppm soot and smoke levels (4.0 BSU) compared to diesel level (3.8 BSU). Smoke level obtained by direct use of oil was also higher (4.4 BSU). Conventional diesel is a mixture of alkanes, alkenes, alkynes and small traces of sulphur. Bio-diesel is environment friendly because it is obtained from renewable resources, no stresses of sulfur and aromatics and produces less emission than diesel. Vegetable oil has better oiliness and improves life of fuel pumps reducing premature wearing [11]; on the other hand vegetable oils having high viscosities cause problems during injection process, increases the smoke levels. Because of low volatility of vegetable oil it sticks to the cylinder wall or injector, and interferes lubrication and combustion process [12]. Bari et al [13] studied a short term performance test of a CI engine having crude palm oil as fuel and concluded as suitable replacement of diesel. It is also reported that, uses of CPO for long run deteriorate the engine performance, reduces the maximum brake power (BP) by 20% after 500 h of cumulative running, while specific fuel consumption increases by about 26%. It also reveals that combustion chamber suffers from heavy carbon deposition; traces of wear on the piston rings; slight scuffing of the cylinder liner; and uneven spray from the nozzles.

**Table 1**. Comparison of Jatropha oil with diesel [1 & 8].

| Parameters | Jatropha Curcas | Diesel |
|---|---|---|
| Sp. gravity, kg/m$^3$ at 15ºC | 860 - 933 | 850 |
| Sulphur % | 0 | 1.2 |
| Viscosity, (cSt) at 30ºC | 37-54.8 | 2.6 |
| Pour point, ºC | -3 | -20 |
| Cloud point, ºC | 2 | -15 to -5 |
| Flash point, ºC | 210-240 | 68 |
| Heating value, MJ/kg | 37.83-42.05 | 42 |
| Cetane number | 38-51 | 40 – 55 |

A short term engine performance and emission characteristics test carried by Bajpai et al. [14] having fuel of 10% Karanja oil blended with diesel on a conventional CI engine showed the best performance at 60 % load and emission characteristics for the entire operation range. Chauhan et al made details observation on Jatropha as an alternative substitute for transportation of and concluded it with a reduction of $CO_2$ emission [15]. The performance comparison of a CI engine with Jatropha, Senthil et al [10] results in lower brake thermal efficiency (BTE), higher SFC, higher exhaust gas temperature and lower $NO_x$ emissions. Increasing the injection pressure and preheating decreases SFC, increases exhaust gas temperature, BTE and $NO_x$ emissions marginally. They also concluded that with the use of Jatropha the emission of hydrocarbon (soot) is higher and similar trends were observed for CO emissions. Furthermore, it is also noticed in case of Jatropha a rise in ignition delay and ignition duration compared to conventional diesel. Forson et al. [16] observed that blends of Jatropha (2.6% Jatropha and 97.4% diesel by volume) have lower SFC and higher BTE compared to diesel and blends having higher Jatropha proportion. A small amount of water was added during extraction of oil from Jatropha which emulsify its oil, as a result exhaust gas temperature decreases and reduces $NO_x$ emission.

Higher viscosity of bio-diesel can be reduced by heating [17], easier to inject and atomise the fuel [18]. The viscosity of Jatropha Curcas oil can be reduced by blending with conventional diesel and the feasibility of the blend to be used as fuel in CI engine can be carried out. The Jatropha oil was extracted from jatropha Curcas seed, filtered by 4 micron filter paper, blended with petro diesel on 2:1 volume basis and is used as the fuel for this experimentation. The aim of this study was to test the feasibility of the blended Jatropha and to compare the performance and emission of a CI engine having compression ratio 17.5, commonly used in agricultural purposes, to fulfill the requirements of the farmers.

## 2. Experimentation

A short term performance test were conducted on a water cooled, single cylinder, 4 stroke CI engine using Jatropha diesel blend as alternate fuel having an electrical dynamometer, with a load bank, as shown in Fig. 1. The objective of this observation is to judge the suitability of blend as alternative fuel. K-type thermocouples were installed to measure gas temperatures at the inlet and outlet of the ducts as well as to measure the cylinder wall temperature. An inclined manometer was used to record the pressure in the inlet manifold. In order to filter the straight fuel blend 4 micron filter paper was used. The fuel consumption rate by the engine was measured by means of gravimetric method. An orifice meter was used to measure the mass flow rate of air, placed at the entry of the stabilizing tank. The speed of the engine was recorded by means of an infrared digital tachometer. These basic measurements were made from no load to full load condition and having different throttle settings e.g. 50, 75 and 100 % for both the fuels. The experiment was replicated thrice to remove precision errors. The engine was allowed to run for at least one hour for every set of load condition to achieve steady state temperature of the lubricating oil, cooling water etc. The tests were carried out to observe various engine performance parameters e.g.; engine speed, braking torque, rate of fuel consumption (diesel and Jatropha blend), pressure drop across the orifice plate of the air stabilizing tank, emissions and exhaust gas temperature. The data obtained from the experiment is used to determine the performance parameters such as BP, SFC and BTE. The details of the engine used in this test rig as stated in Table 2.

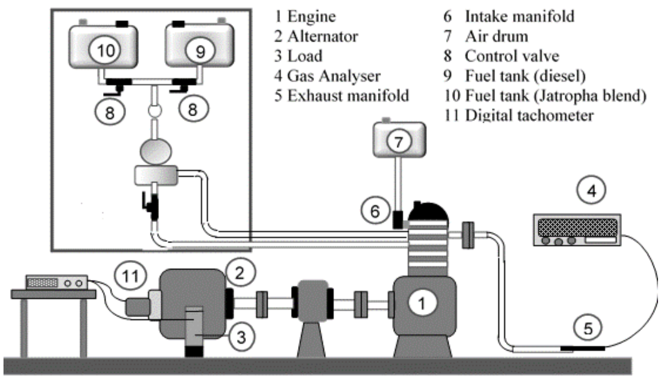


**Fig. 1.** Experimental set up.

**Table 2.** Engine details

| | |
|---|---|
| Type | Vertical, single cylinder CI engine |
| Bore | 114 mm |
| Stroke | 140 mm |
| Compression ratio | 17.5 |
| Rated power | 6.2 HP at 670 rpm |
| Start of fuel injection | 18.6° before TDC |
| Duration of fuel injection | 31.1° |
| Governor | Manually controlled |
| Method of cooling | Water cooled |

## 3. Results and Discussions

The performance of the engine were computed at various braking torques and throttle setting using Jatropha blends in terms of BP, BTE, SFC, temperature of exhaust gas and exhaust emissions. The effect of braking torque and percentage throttle opening on different performance parameters engines operated by Jatropha blend are presented and compared with that of diesel.

### *3.1 Effect of braking torque on brake power and specific fuel consumption*

The braking torque on the engine was varied gradually to observe the effect on BP and SFC for different throttle openings having the fuels, diesel and the Jatropha blend are depicted in Figs 2, 3 & 4. It can be seen that the variation in BP and SFC having Jatropha blend as fuel is similar to that of diesel. The performance of the engine for higher power development and also for economic power development was found better having diesel as fuel compared to that of blend. It can be seen that in each of these observations maximum outputs (best power capacity) obtained were higher for diesel. It can be seen also that for any throttle opening or braking torque SFC was found higher for the blend. Moreover, braking torque capacity for minimum SFC was also obtained lower for Jatropha compared to that of diesel for all throttle openings. At full throttle opening the reduction in maximum developed power using blend compared to diesel is lowest. The maximum developed power increases gradually with reduction in throttle openings. As the SFC curves having blend as fuel for all throttle settings are nearly parallel to that of diesel.

### *3.2 Effect of braking torque on speed of the engine*

Variations of speed with braking torque on engine at full and at part throttle operation with both the fuels are presented in Fig. 5. Engine always has developed higher speed with diesel for any braking torque or throttle run. Rate of fall in speed with increasing braking torque on engine for any throttle run (full and part) is same for both the fuels up to operating braking torque for respective throttle. Beyond this braking torque nature of rapid fall in speed is also similar for both the fuels irrespective of throttle condition.

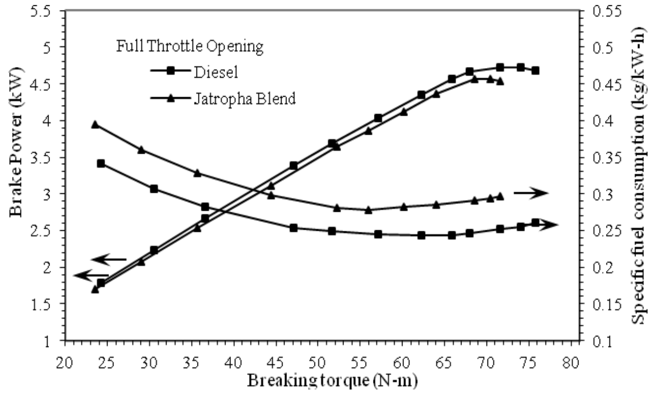


**Fig. 2.** Variation of BP and SFC as function of braking torque at full throttle opening.

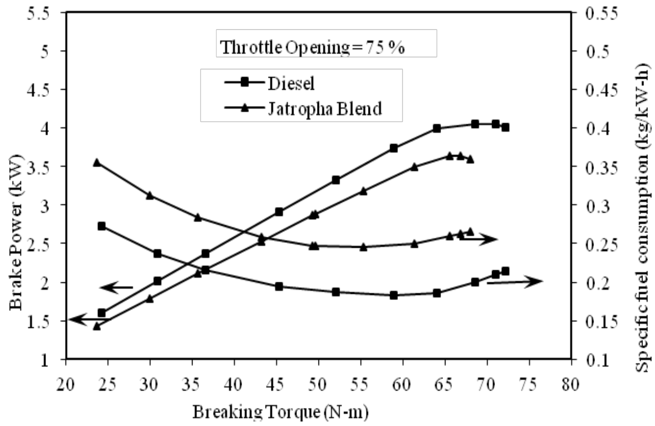


**Fig. 3.** Variation of BP and SFC as function of braking torque at 75 % throttle opening.

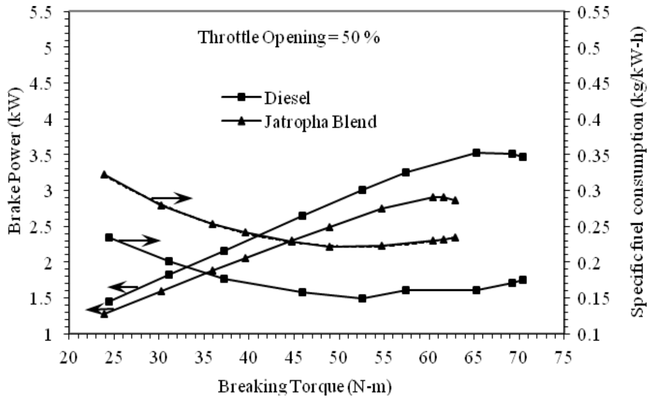


**Fig. 4.** Variation of BP and SFC as function of braking torque at 50 % throttle opening.

### *3.3 Effect of BP on SFC of the engine*

The effects of BP on SFC at various throttle settings are plotted in Fig. 6. It can be seen that the natures of these plots are very much similar to that of the diesel at respective throttle run. Diesel has always maintained economy in power development for any throttle run compared to blend. At respective throttle settings diesel has shown always minimum SFC with higher output. Figure 6 shows the effect of BP on BTE also for different throttle settings having both the fuels. It can be confirmed that diesel has more efficient power transfer and BTE at different braking torque although the rate of change in thermal efficiency with change in output is similar for both the fuels for all throttle settings. The values of best power & minimum SFC of the engine at respective throttle settings have been tabulated separately for both the fuels against corresponding braking torques in Table 3. It can be observed that at full throttle opening specified rated output of this engine lies between best power & best economy zone. Rated torque obtained using diesel is 67 N-m.

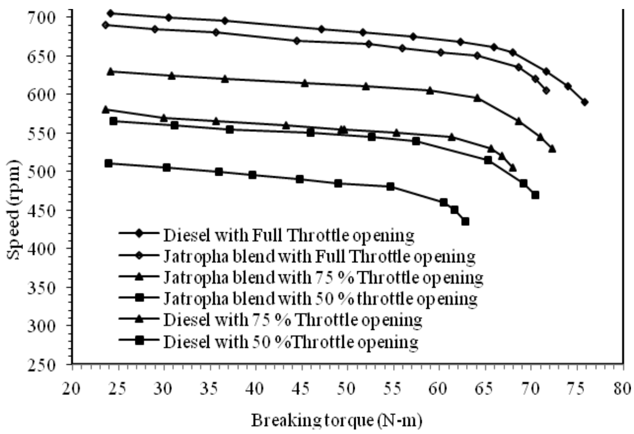


**Fig. 5.** Speed as function of braking torque at different throttle opening.

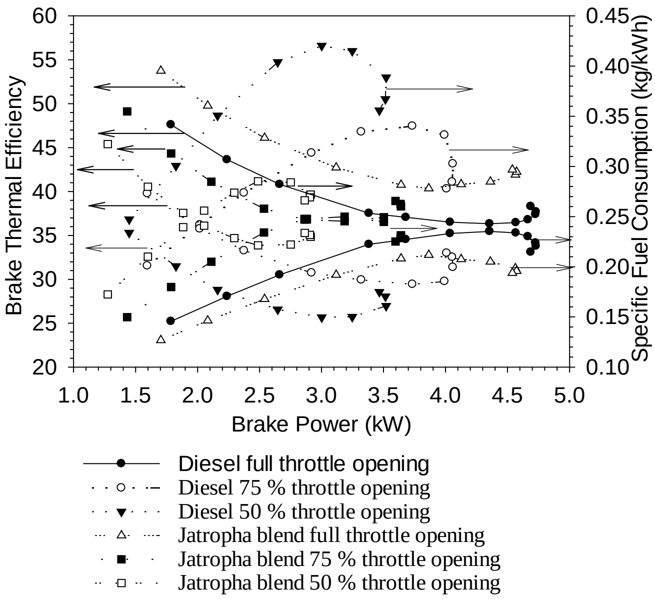


**Fig. 6.** BTE and SFC as function of BP at different throttle opening.

### *3.4 Comparison between performance characteristics of the engine for constant braking torque operation with diesel and Jatropha blend*

Since at existing operating set, the engine could not be running at constant rated braking torque (67 N-m) for diesel, with the blend at part throttle operation (less than 50 %), these observations as well as performance comparison have

**Table 3.** Output power as function of braking torque for best power and best economy run

| Throttle opening % | Fuel | Best Power | | Best Economy | |
|---|---|---|---|---|---|
| | | Braking torque (N-m) | BP (kW) | Braking torque (N-m) | BP (kW) |
| 100 | Diesel | 72 | 4.75 | 62 | 2.40 |
| 100 | Blend | 70 | 4.55 | 60 | 2.80 |
| 75 | Diesel | 68 | 4.10 | 56 | 1.80 |
| 75 | Blend | 66 | 3.60 | 54 | 2.45 |
| 50 | Diesel | 65 | 3.55 | 53 | 1.50 |
| 50 | Blend | 60 | 2.90 | 52 | 2.20 |

been made with constant braking torque of 62 N-m (the mean braking torque between minimum SFC and maximum output for the blend. This set of observations for constant braking torque characteristics were made with gradually increasing rpm (throttle). These are presented in Figs. 7 and 8 and followings have been observed;

i) Variation of engine speeds with increasing throttle as shown in Fig. 7, indicate that both the fuels exhibit a change in average rate of speed after certain range of throttle openings. This fall is more prominent with diesel approximately after 50 % throttle opening in this run and is also occurs less significantly with the blend at comparatively higher throttle opening (about after 75 % throttle in this run). More uniformity in the rise in speed with increase in throttle has been observed with the blend for entire range of throttle.

ii) As other operating constraints are same in this set of observations with both the fuels, the relatively higher fall in speed-rate with diesel with higher injection duration (highest throttle) may be due to excessive richness of combustible mixture corresponding to load on engine. This obviously has reduced energy release rate from diesel with respect to the rise in fuel consumption rate. In contrast to this, the braking torque is more suitable for the blend to maintain more uniformity in the rise in speed rate with increase in throttle. However, effect of higher calorific value and suitability of other existing operating variables for diesels enables diesels to maintain higher speed all through the throttle range. Average linear variation in engine output (brake-power) with increasing speed is little bit more effective with the blend than that with the diesel at this selected braking torque on engine. The percentage reduction in BP of the blend in comparison with diesel gradually reduces as the throttle opening increases or with the increase in rpm of engine. This performance variation in power output is mainly due to part braking torque operation with the diesel & with most effective braking torque operation with the blend in existing engine setting which has been made for diesel oil.

iii) Superiority in performance for power output with diesel at higher throttle range has been improved with the engine load close to rated load for diesel and this has also made over-loading performance with the blend are shown in Fig. 8. Nature of variation of output for Jatropha is fantastically similar with that of diesel. Diesel has always maintained higher output capacity for entire throttle range in part as well as in full braking torque operation.

iv) At this constant braking torque operation, with increase in speed or throttle settings SFC increases for both the fuel (Jatropha-blend and diesel). Jatropha-blend always has provided higher SFC and lower output than the diesel for entire throttle range. Variation of SFC from lowest to highest operating speed (for the throttle range) is less with the blend than that with diesel.

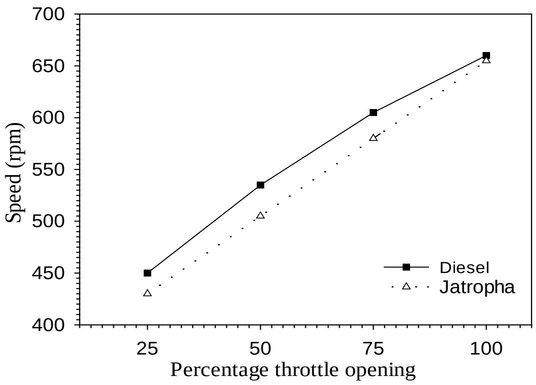


**Fig. 7.** Engine speed as function of throttle opening at constant effective braking torque (blend).

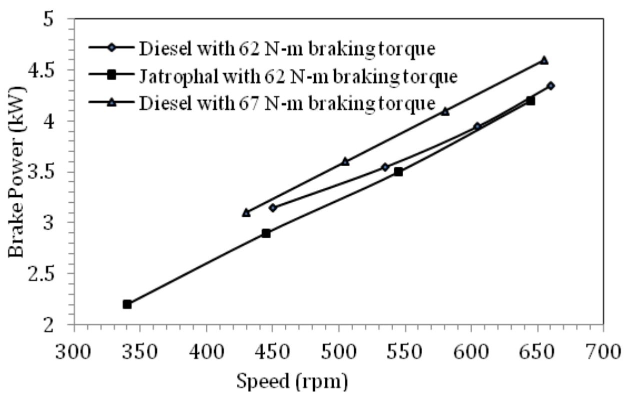


**Fig. 8.** BP as function of speed at constant effective braking torque (blend) and for rated braking torque for diesel.

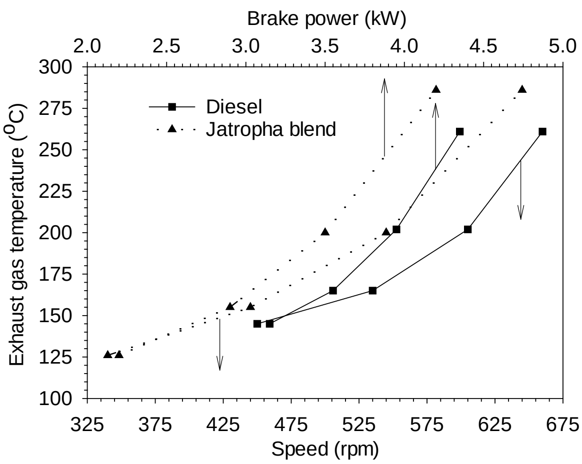


**Fig. 9.** Exhaust gas temperature as function of speed and BP at constant effective load of blend.

v) The rise in throttle/ speed at constant load operation affect fuel economy more adversely at higher range of throttle/ speed for both the fuels, but this effect is more severe with the diesel.

vi) Lower calorific value of the blend has made higher fuel consumption per output for entire range of operation, but change in fuel economy is less affected for rise in speed/ output with the blend than that with the diesel.

Variation of exhaust gas temperatures (EGT) as function of speed and BP at constant braking torque for Jatropha blend as well as diesel is presented in Fig. 9. The followings are observed;

i) Jatropha–blends always have shown higher EGT for any operating speed or any power development of the engine.

ii) Rate of increase in EGT with rise in speed is more or less same in the range of rated operating speed or for over speed run of the engine, however for low speed operation rate of increase in EGT is more in the case of blend in comparison with diesel.

iii) Rate of increase in temperature of exhaust gas with increase in BP has appeared similar for both the fuels.

Variation of HC, CO, $CO_2$ and $NO_x$ emission as function of brake power is plotted in Fig.10.

i) Diesel produces much higher HC emission at low load in comparison with having Jatropha blend. As BP increase, HC emission reduces gradually for both the fuels. The rate of change HC emission for diesel is higher compared to that Jatropha blend. The HC emission reaches nearly same for both the fuel at rated power of the engine.

ii) Diesel also produces higher NOx for the entire range of BP. NOx emission reaches its maxima at rated power for both respective fuels.

iii) With the increase in BP the rate of emission of $CO_2$ increases having both the fuels.

iv) With the increase in BP CO emission decreases gradually and attains minima for both the fuels, with increase in BP further CO emissions increases at a very higher rate.

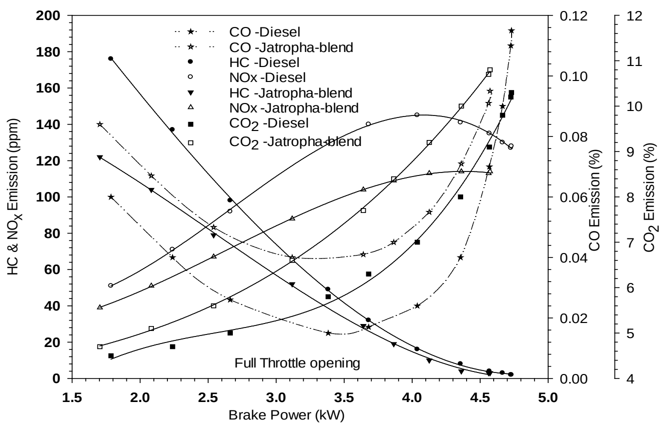


**Fig. 10.** Exhaust gas emission as function of BP for full throttle opening.

## 4. Conclusion

Based on experimental observation it can be concluded that Jatropha- diesel blend may be used as a suitable substitute in existing CI engines.

1. A CI engine can be operated with crude Jatropha-diesel blend (2:1 on a volume basis) for short term operation.
2. The performance of engine at full and at part throttle operation having Jatropha blend as fuel is fantastically similar with that of diesel.
3. Diesel always exhibits better performance compared to that of Jatropha blend for entire range of throttle openings and loads operations.
4. Rated capacity of the engine having Jatropha blend is very much compatible with diesel at full throttle openings.

| Fuel | Rated operating condition at full throttle | | |
|---|---|---|---|
| | Power (kW) | rpm | Rated braking torque (N-m) |
| Diesel | 4.6 | 670 | 67 |
| Jatropha blend | 4.2 | 650 | 62 |

5. The minima of SFC and maxima of BTE reduce with reduction of throttle openings for both the fuels.
6. a. The rate of decrease in maximum BP using blend reduces compared to that of the diesel with decrease in throttle opening.

   b. The rate of decrease in minimum SFC using Jatropha blend increases compared to that of diesel with decreasing throttle settings.
7. For entire operating range, effect of increase in throttle at constant rated braking torque on average linear rate of rise in BP is similar for both the fuels. Also this power peaking–up characteristics with the blend is more effective than diesel for constant effective braking torque for the blend on engine in existing set up.
8. Adjustment of operating variables will make existing compression ignition engine more suitable for operation with Jatropha blend at variable braking torque and speeds.
9. In general with respect to change in BP, the emission of HC, $NO_x$, CO and $CO_2$ are similar for both the fuels. For the entire range of operations diesel emits less CO and $CO_2$, while Jatropha blend emits less hc and NOx.

In addition to the above there were no trace of any gum deposition or any other adverse effect on any engine components after the experimentation. CI engine generally used for agricultural purposes can safely be operated using Jatropha blend. The farmers can produce and extract their own fuel; just filtering it can use it without any design modification of existing engines.

In order to get best performance minor change in design parameters (compression ratio, injection timings, exhaust valve timing etc.) needs to be established. Possibility of better performance (with the blend) than that with mineral diesel may be apprehended with the adoption of preheating of the blend along with exhaust gas.

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