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PERFORMANCE AND EMISSION STUDIES OF A SINGLE CYLINDER CRDI DIESEL ENGINE USING NEAT JATROPHA METHYL ESTER AS A REPLACEMENT TO DIESEL FUEL

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Abstract: *Experimentation was conducted on a single cylinder CRDI diesel engine using neat Jatropha methyl ester with arbitrarily defined load on the engine (2.695kW) at rated speed 1550 rpm. CRDI system provides us the facility to change the injection pressure and injection duration to commensurate with the load on the engine. In addition to the above facility, the injection can be retarded or advanced with respect to the designed injection advance for the diesel fuel as mentioned in the specification. In this paper, injection advance was taken up insteps of one degree viz.-22^0, -23^0 and -24^0. The experimental study reveals that the injection advancement with the use of biodiesel is not totally fruitful except in some emission cases and smoke levels. Hence, biodiesel with one degree retardation i.e.,-22^0 injection advance yielded better results in most of the cases of performance making it suitable for the replacement of diesel fuel with the biodiesel.*

Keywords: *CRDI Engine, Injection advancement, Injection pressure variation*

1. Introduction:

Renewable fuels are the methyl esters derived from edible and non-edible oils, these fuels are eco-friendly and emits less tail pipe emissions. The use of edible oil as biodiesel feedstock has raised concerns of a food crisis. The studies reveals the various non-edible oils soybean oil, canola oil, palm oil, Mahua oil ,Jatropha oil and sunflower oil can be directly used in diesel engines as biofuel[1]. The study reveals that 2% Hydrated ethyl alcohol as additive gives the better performance and emissions assisted by supercharged IDI diesel engine using Beef tallow Methyl Ester[2].The literature reveal that FFAs in the oil were converted to methyl esters in the pre-esterification step using sulfuric acid or solid prepared by calcining metatitanic acid as catalysts[3].The results evident that the performance evaluation of DI diesel engine using neat preheated Mahua methyl ester gives MME as a viable non edible oil alternative to the diesel fuel because of no injection problems and lesser emissions[4].A minor deterioration of fuel performance parameters with an increasing biodiesel share has been observed on CRDI engine[5]. Literature on the IDI engines reveals that poor quality fuels can be used in IDI engines. A Kolakoti & B V A Rao [6-7] conducted experimentation on a supercharged IDI engine with palm biodiesel and coconut biodiesel as an additive and the results envisage that 3% coconut in palm biodiesel gives better performance and reduction of NOx(44ppm), CO (Zero%) and CO_2(1.54%) emissions compared to diesel fuel. The experimental results exposed a substantial enhancement in the brake thermal efficiency and a marginal reduction in the harmful pollutants (such as CO, HC and smoke) for the nano particles blended biodiesel [8]. Alcohol fuels such as ethanol and Isopropanol can be made from a diverse group of biomass-based feed stocks and they can be used as additives with the diesel fuel in the diesel engines. According to the investigation of performance, combustion, injection and emission of ethanol-diesel and Isopropanol-diesel fuel blends in a CRDI diesel engine[9]. Investigation give emission results are reversed with 10% exhaust gas recirculation at 600 bar injection pressure of lemon peel oil blend. There is a significant reduction in NOx emission for low injection pressure of lemon peel oil blend at 10% pilot injection rate on CRDI engine[10].A low NOx and Fuel –efficient engine operating condition was achieved with 40 vol % biodiesel blend[11].The present study is using Jatropha methyl ester as a fuel for finding out of Impact of performance and emissions of CRDI engine for different injection pressure advancements.

2. Methods and Materials:

2.1 **Materials:** Raw Jatropha oil, 99.9% pure Methanol (CH_3OH), Sulphuric acid (H_2SO_4), Sodium Hydroxide (NaOH), Distilled water.

2.2 **Esterification:** In this study Jatropha Methyl Ester (JME) was used to examine the performance and emission characteristics. For this purpose, Raw Jatropha oil was used to convert Jatropha Methyl Ester which was prepared by the method Esterification followed by Transesterification. In the Esterification, 3 ml of Sulphuric acid which acts as an acid catalyst and 90 ml of pure methanol was added to 1000 ml of filtered raw Jatropha oil and by maintaining 60^0C temperature the mixture was kept stirring for 3 hours. After the reaction period, the mixture was transferred to separating funnel and left it for overnight. Then glycerin and chemical water was removed from the esterified oil.

2.3 **Transesterification:** For each liter of Jatropha oil, 210 ml of methanol was measured in a measuring jar and to which 9 grams of sodium hydroxide pellets were added. This mixture was thoroughly stirred until all the pellets were melted in the methanol to form sodium methoxide. The sodium methoxide solution was added to pre heated esterified oil and stirred for 7 hours by maintaining 70^0C temperature. After the reaction period, this mixture was poured into separating funnel and left it for overnight. Then glycerin was completely separated from methyl ester and finally methyl ester was thoroughly washed with distilled water until the clear separation of distilled water and methyl ester appear. The collected methyl ester was heated at 110^0C temperature to remove any left over water droplets and then stored. Fuel properties of JME are compared with diesel in the following table 1.

Table.1: Comparision of Diesel with JME

S.No	**Properties**	**Diesel**	**JME**
1	Density (kg/m^3)	830	875
2	Calorific value (kJ/kg)	43000	38468
3	Cetane number	45	52
4	Viscosity (cSt)	2.75	4.2
5	Flash point (^{0}C)	62	168
6	Boiling point (^{0}C)	180-330	370
7	Pour point (^{0}C)	-4	<-3
8	Latent heat (MJ/kg)	0.280	0.259
9	Auto ignition temperature (^{0}C)	235	>300

3. Experimentation:

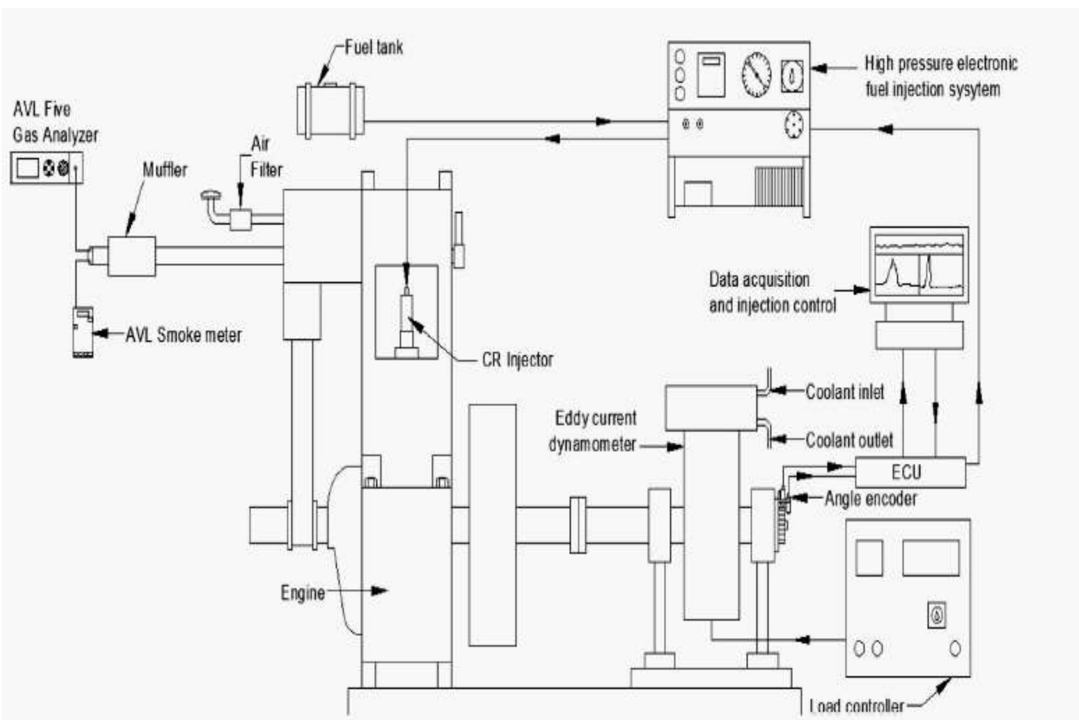

Figure 1: Experimental setup

The experiments were conducted on Kirloskar AV1, four stroke single cylinder diesel engine assisted by common rail direct injection (CRDI) system. The rated power of the diesel engine is arbitrarily fixed. The engine was operated at a constant speed of 1550 rpm by maintaining the injection pressure from 200 to 500 bar at various load conditions. The fuel injection duration was maintained at 1000 to 1060 μsec to maintain the engine speed 1550 rpm for the corresponding pressure. The engine was fuelled with neat diesel to provide the baseline data and then it was fuelled with Jatropha Methyl Ester (JME) at different injection pressure advancement angles i.e; -22^0, -23^0, -24^0 respectively. The details of the engine specifications are shown in table 2. Eddy current dynamometer was used for loading the engine. The AVL smoke meter was used to measure the smoke present in the exhaust. AVL gas analyzer was used to measure HC, CO, CO_2, O_2 and NOx emissions.

Table 2: Specifications of engine:

Type	Vertical four stroke cycle, single cylinder diesel engine
Number of cylinders	1
Bore (mm)	80
Stroke (mm)	110
Compression ratio	16.5:1
Maximum power (kW)	3.7
Speed (rpm)	1550
Dynamometer	Eddy current type
Injection timing	23^0 BTDC
Injection pressure (minimum)	200-205 bar

4. Results and Discussion:

The engine's actual injection advance is -23^0 before TDC. With the new biodiesel fuel, the engine is run at -22^0,-23^0, and -24^0 to verify the engine performance. It is finally concluded that -22^0 injection advancement with one degree retardation proved beneficial to replace diesel fuel. Sporadic benefits were observed at isolated emission results are observed but conclusively -22^0 proved efficient in most of the aspects of performance.

In this section, based on the combustion data, cylinder pressure is plotted against the crank angle. Based upon the performance data BSFC, BTE, Equivalence Ratio are plotted against the Brake power and also injection duration and Injection pressure is plotted against the fuel consumption. Based upon emissions data HC, CO, CO_2, O_2 , NOx, Lambda and smoke are plotted against Load.

Figures 2 to 8 reveal that the -22^0 injection advancement with the implementation of biodiesel proved beneficial. There is a 0.3376 kg/kW-hr for biodiesel at -22^0, 0.3487 kg/kW-hr for diesel fuel making advantage in brake specific fuel consumption difference of 0.011 kg/kW-hr.

Similarly for diesel fuel brake thermal efficiency 24% and for the biodiesel at -22^0 injection advancement the brake thermal efficiency level is 27.72%, with an obvious increase of 3.72%.

There is consistent lower equivalence ratio (Figure 8) for the biodiesel as mentioned above. The injection pressure variation is marginal and for the biodiesel mentioned above the injection pressure at the maximum load is 436bar where as for other fuels with different advancements is focused around 450 bar (figure 5). The injection duration as observed from the figures 9 and 10 indicate some change in the case of diesel fuel as sudden change has been observed at maximum load. This increase is adjusted subject to the smoke performance of the engine. HC , NO_x, and CO performance is better for the biodiesel implementation at -22^0 before TDC (figures 11,12,15). Figure 17 indicate smoke levels which envisage better performance at -24^0 injection advancement for biodiesel application. In a overall view, the biodiesel application at -22^0 injection advancement is yielding better results.

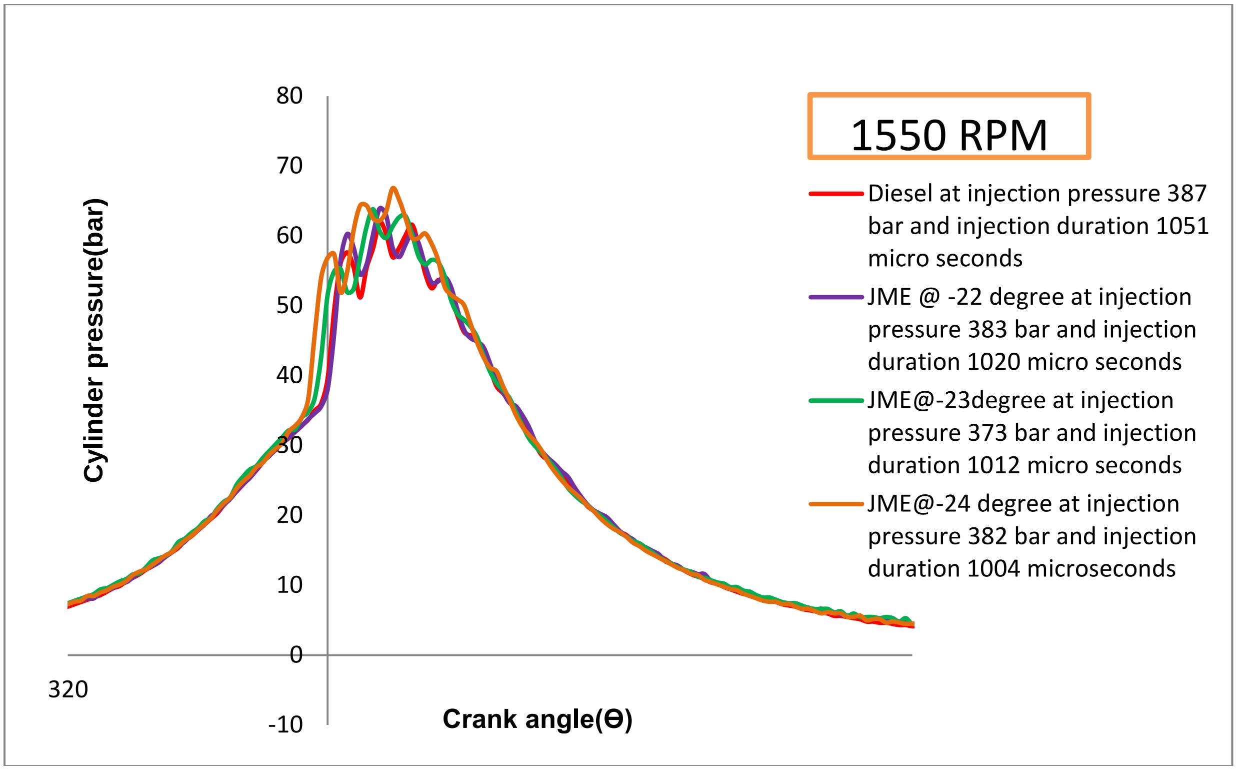

Figure 2: Cylinder pressure Verses Crank angle at ¾ th load

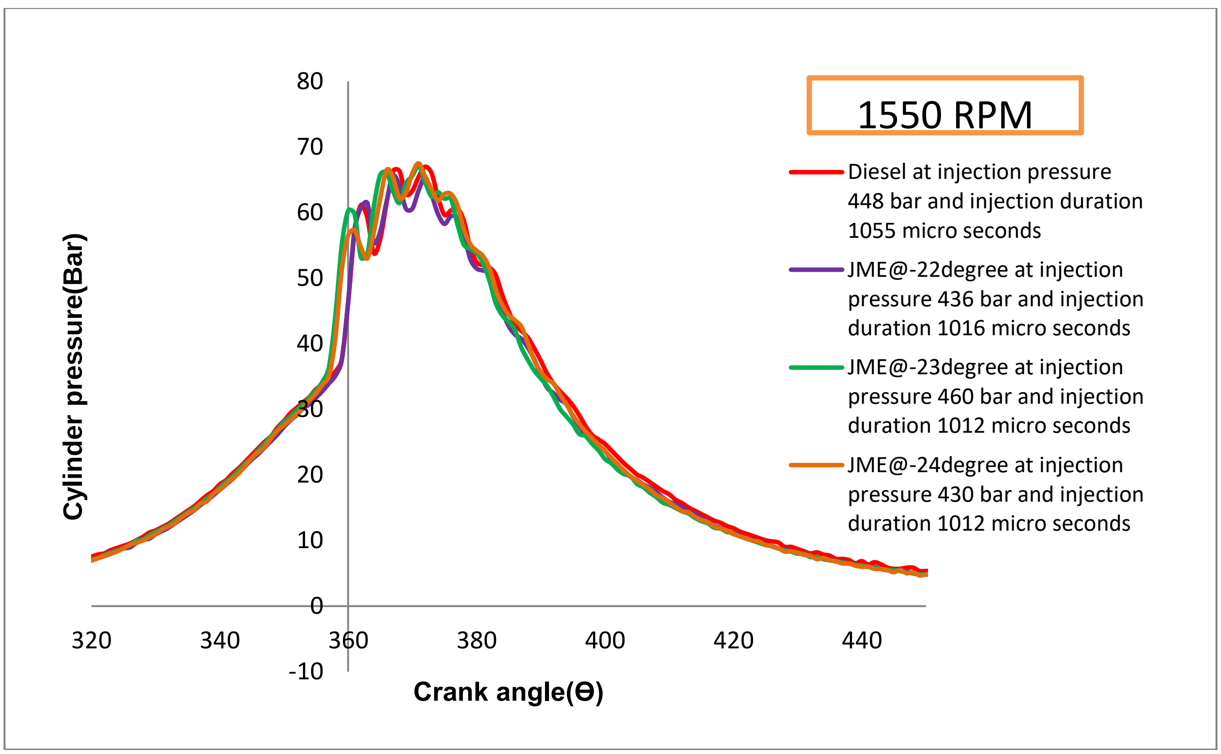

Figure 3: Cylinder pressure Verses Crank angle at full load

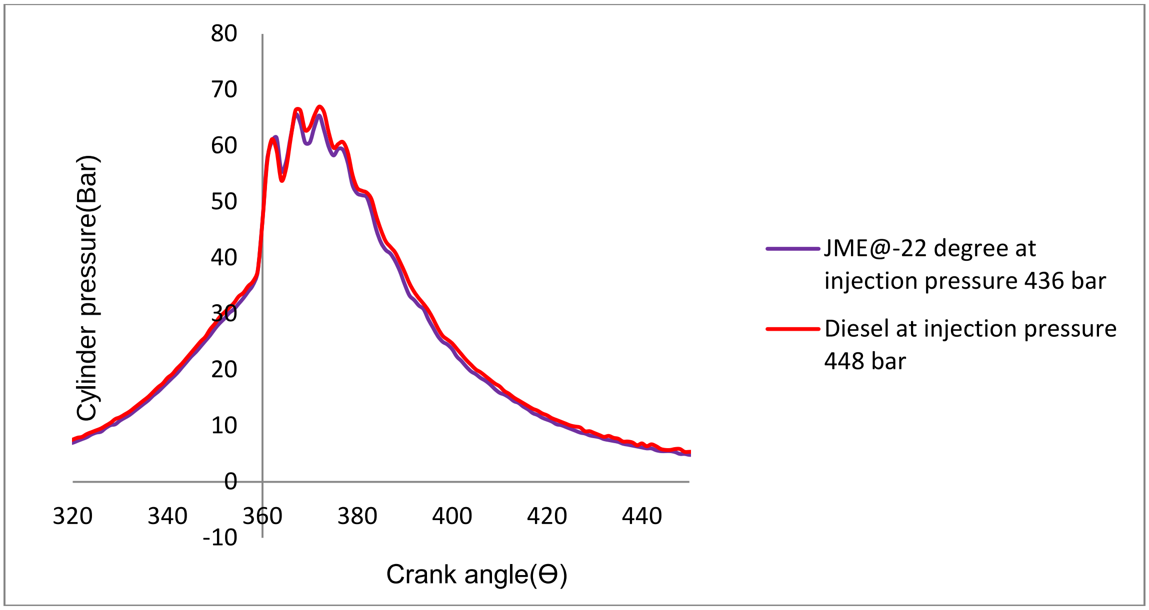

Figure 4: Cylinder pressure vs Crank angle at Full load

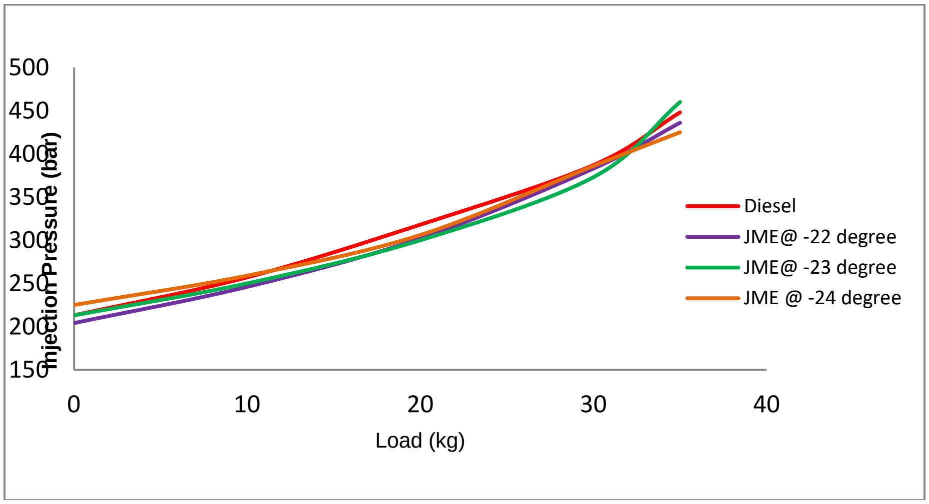

Figure 5: Injection pressure Verses load

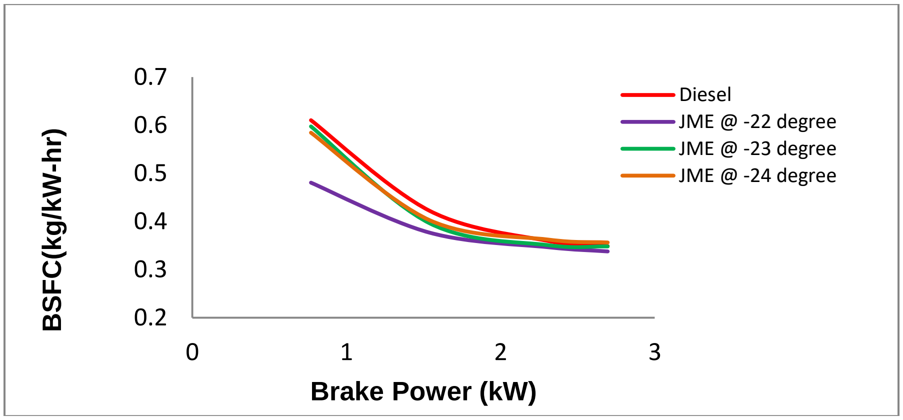

Figure 6: BSFC Verses Brake Power

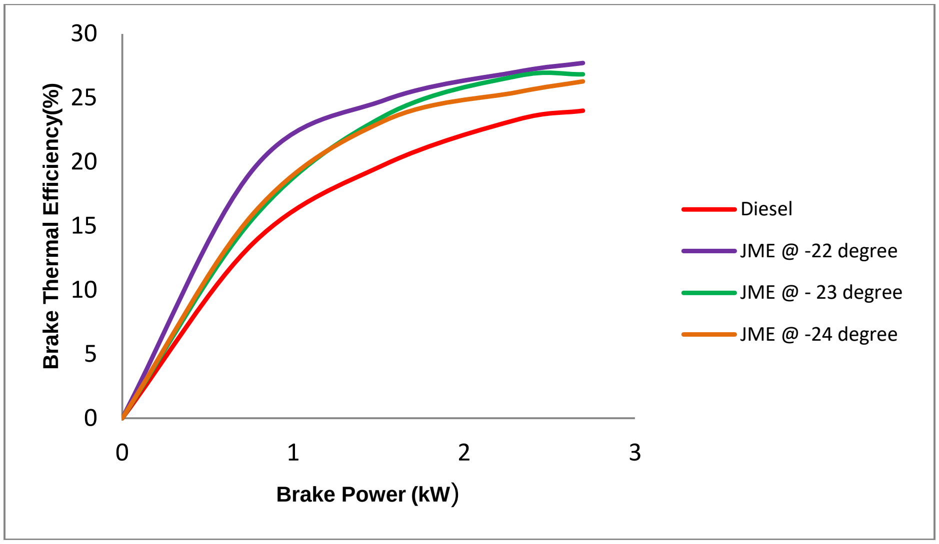

Figure 7 : Brake Thermal efficiency(%) Verses Brake Power

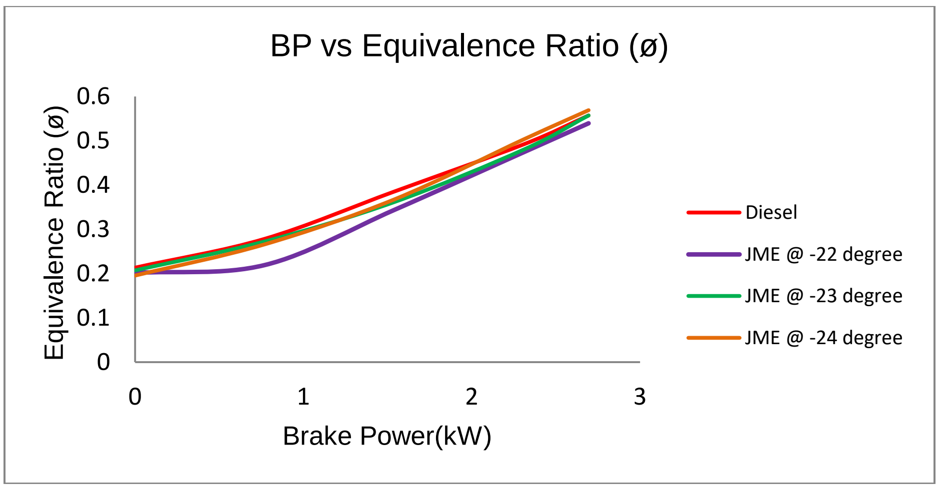

Figure 8: Equivalence Ratio Verses Brake Power

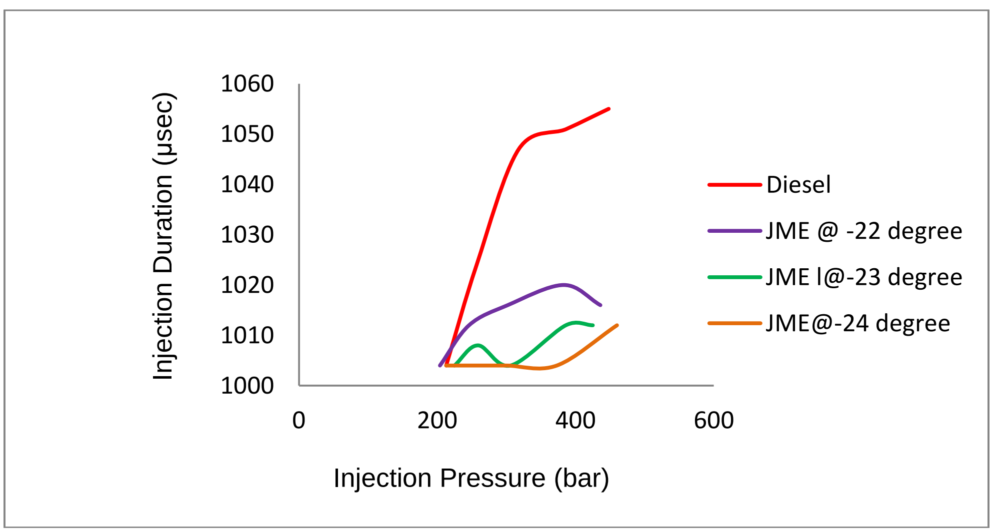

Figure 9: Injection Duration Verses Injection Pressure

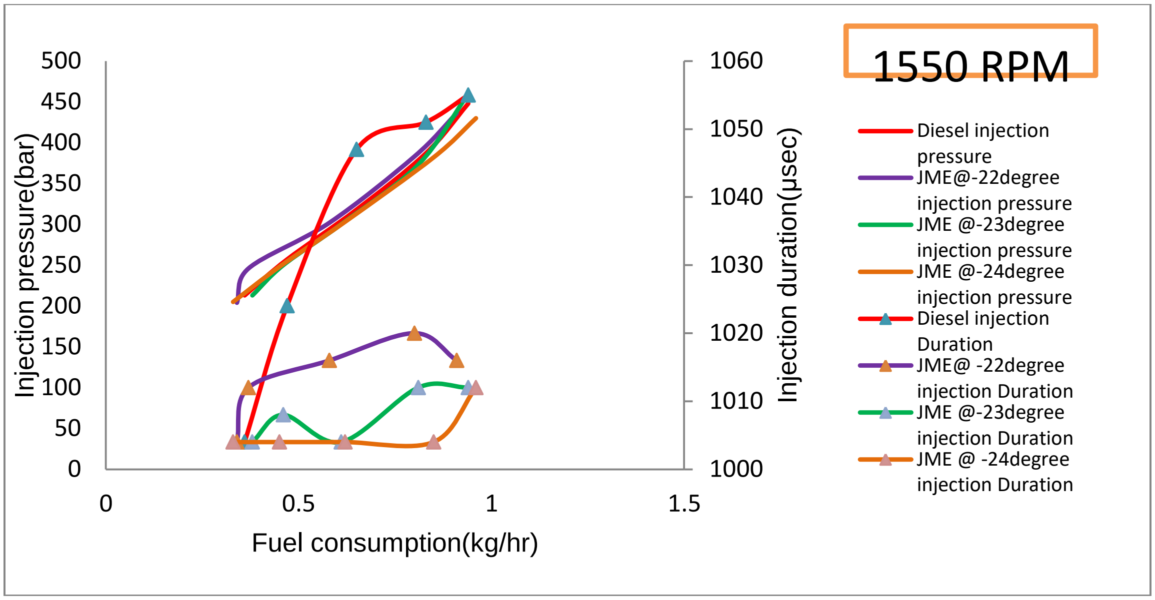

Figure 10: Injection pressure and Injection duration Verses Fuel consumption

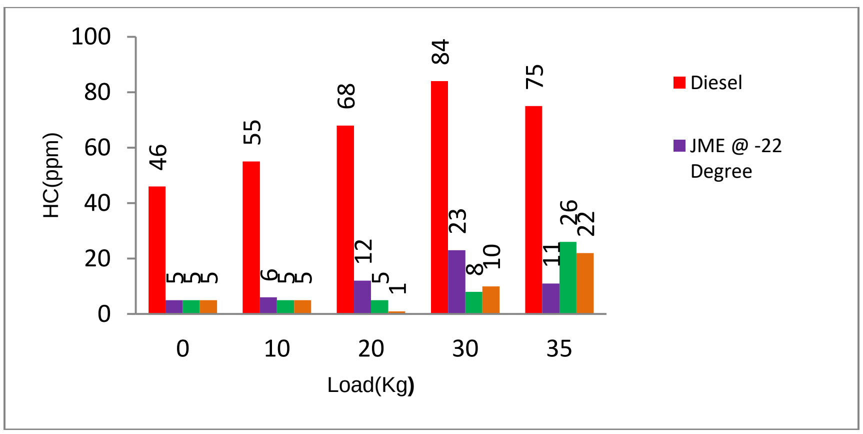

Figure 11: HC(PPM)verses Load(Kg)

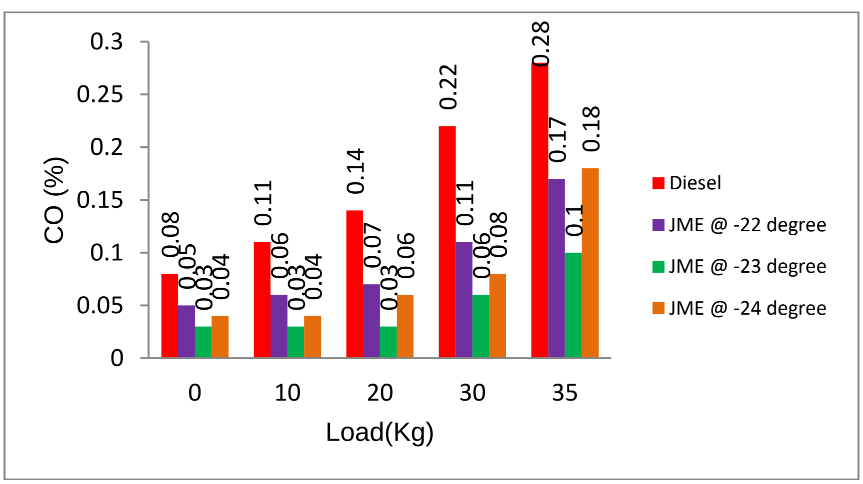

Figure 12: CO verses Load

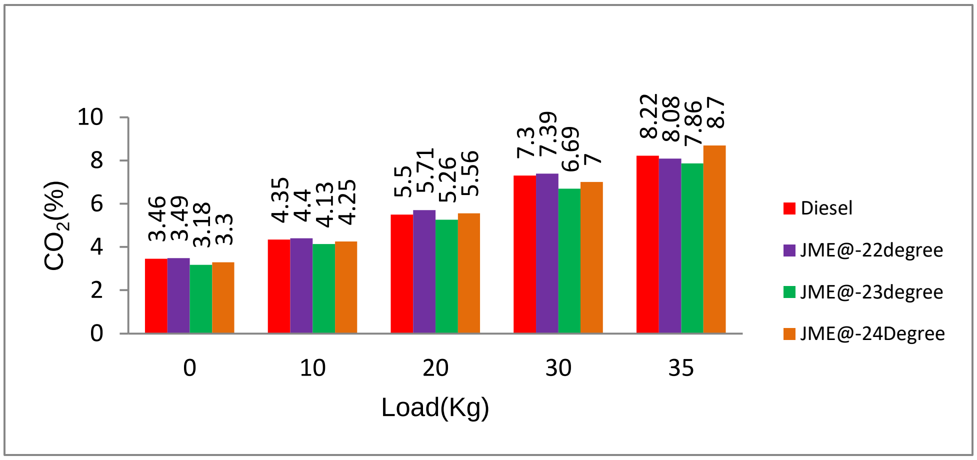

Figure 13:CO_2 verses Load

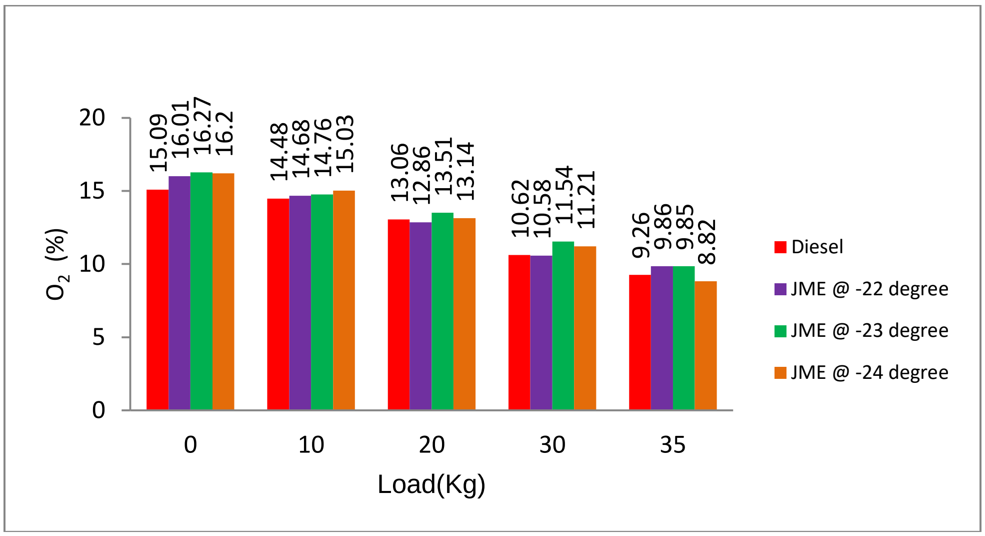

Figure 14: O_2 verses Load

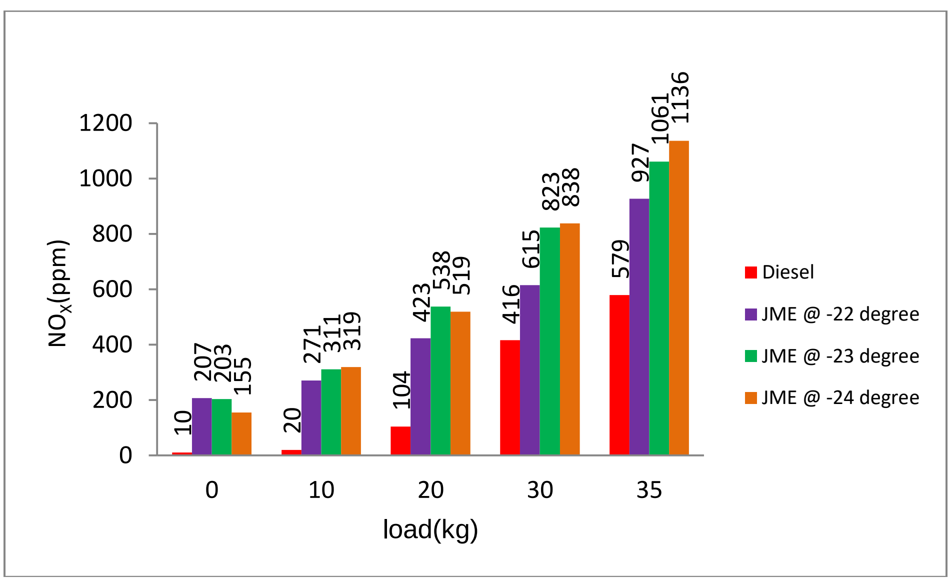

Figure 15: NO_x verses Load

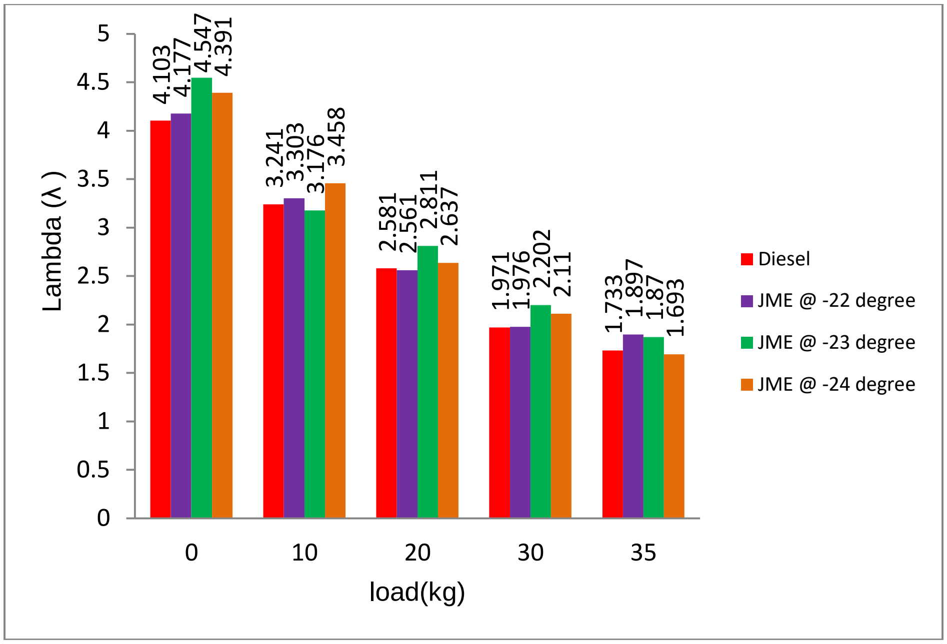

Figure 16: Lambda verses Load

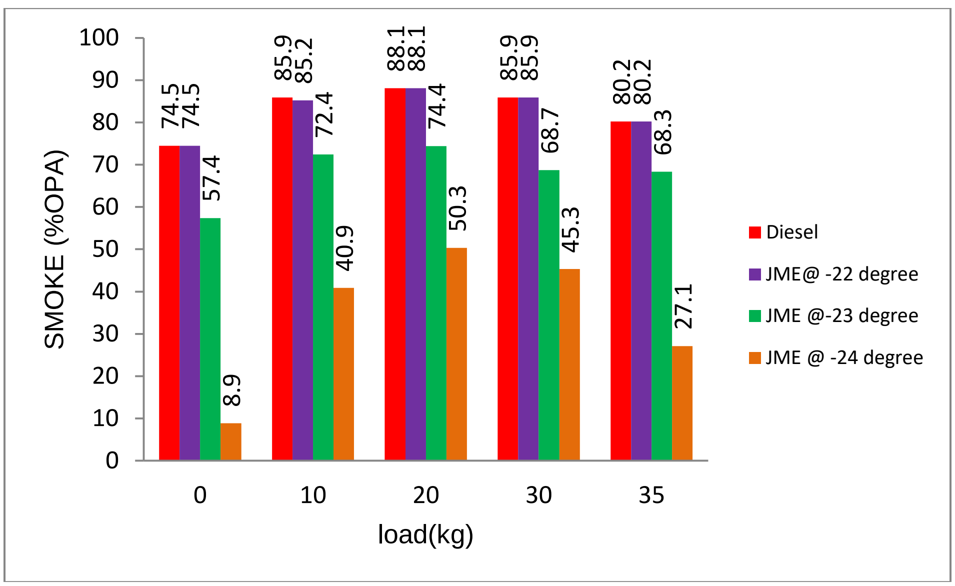

Figure 17: Smoke verses Load

5. Conclusion:

1. Better BSFC and brake thermal efficiency performance for Jatropha methyl ester at higher injection pressure at maximum load with -22^0 injection advancement.

2. Reduction in CO, NO_x , and HC is exemplary in the case of the biodiesel selected.

3. Recommended replacement of diesel fuel with biodiesel with one degree injection retardation with reference to the engine specified injection advancement, i.e., -23^0 before TDC.

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