EVALUATION OF PERFORMANCE PARAMETERS AND COMBUSTION CHARACTERISTICS OF A DIESEL ENGINE WITH VEGETABLE OIL OPERATION

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Abstract : As the fossil fuels are fast depleting day by day, the investigations with alternative fuels has been the topic of the highest priority. Non-edible vegetable oils can be used as the alternative fuels in diesel engines as they are not only renewable in nature but also contain comparable cetane number and calorific value of that of diesel fuel. In the present work, the experiments were conducted on the diesel engine, using jatropha oil as the fuel, to evaluate the performance and combustion characteristics. In the present work, the jatropha oil (JO) is used as the alternative fuel for diesel fuel (DF). Experiments were conducted on the diesel engine to evaluate the performance and combustion characteristics with JO operation, at different injection timings and injector opening pressures. The manufacturer's recommended injection timing is 27^0 bTDC (before top dead centre). Study was undertaken to match the injection timing which would bring in improved performance of the engine over that of manufacturer's recommended injection timing. The injection timing was varied from 27^0–34^0 bTDC. The injector opening pressure was varied from 190 bar to 270 bar (in steps of 40 bar). At the recommended injector opening pressure of 190 bar, the optimum injection timing was found to be 31^0 bTDC for diesel operation while it was 32^0 bTDC for JO operation. At the optimum injection timing of 32^0 bTDC, JO operation showed comparable performance when compared with diesel operation at recommended injection timing.

Key Words **- Jatropha oil, Performance, Combustion characteristics, Injection Timing, Injector opening pressure**

I. INTRODUCTION

Diesel fuel (DF) is consumed in many sectors like transport, agricultural etc. But due to depletion of fossil fuels and fluctuating fuel prices in International Market, there is strong necessity for alternative fuels. Vegetable oils are important substitutes for diesel fuel as they are renewable in nature. Vegetable oils have comparable cetane number (in the range of 40–45) and energy content as of diesel and therefore they can be effectively used in diesel engines.

The use of vegetable oils as diesel fuels dates back to several decades. The vegetable oils have comparable properties with those of diesel fuel. Edible oils cannot be considered as diesel engine fuels due to socio economic restrictions. However, non-edible vegetable oils can be conveniently used in CI engines. The researchers [1-8] conducted experimental investigations on diesel engine using vegetable oil and reported that the engine performance slightly deteriorated, when compared with that of the diesel fuel. On the other hand, the researchers [9-13] reported improvement of engine performance.

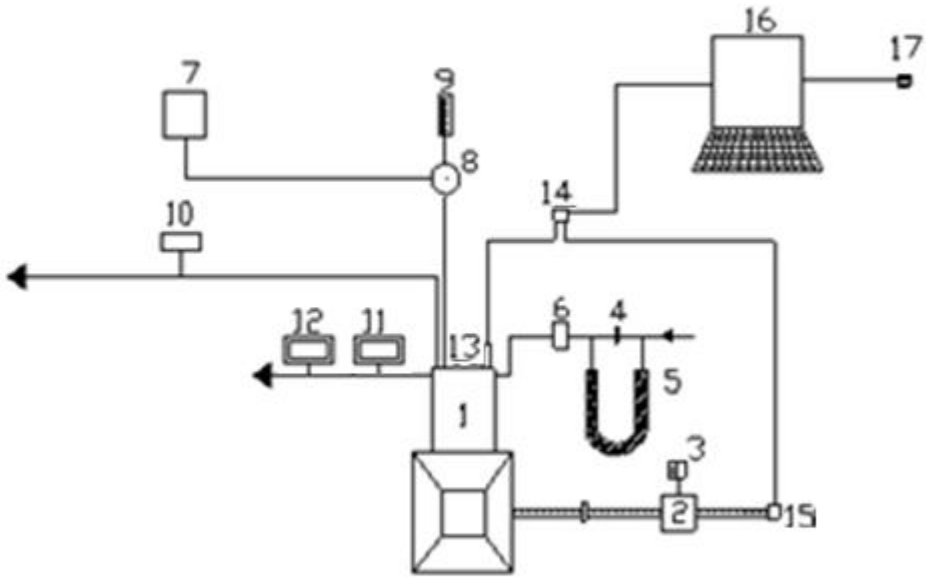
Investigations were carried out by various researchers [14-15] on the influence of injection timing on the performance of diesel engine fuelled with vegetable oil. They reported that with the advancing of injection timing, the performance parameters improved.

The researchers [16-18] have studied the influence of injector opening pressure on the performance of DI diesel engine with vegetable oil operation. An increase in injector opening pressure resulted in improved performance.

The present work consists of investigations on the performance and combustion characteristics with crude jatropha oil (CJO) operation at different injection timings (27-34 ^{0}bTDC). The injector opening pressure was varied from 190 bar to 270 bar. The results thus obtained were compared with that of the diesel operation.

II. EXPERIMENTAL PROCEDURE

The schematic diagram of the experimental set up is shown in Fig.1. The specifications of the engine are given in Table-1. The amount of air sucked into the cylinder was measured by air-box method. The consumption of fuel was measured by burette method. The jatropha oil is injected into the engine by fuel injector, similar to that of diesel fuel injection. The Table-2 gives the properties of diesel fuel and jatropha oil.



1. Engine, 2.Electical Dynamometer, 3.Load Box, 4.Orifice meter, 5.U-tube water manometer, 6.Air box, 7. Diesel tank, 8.Three-way valve, 9.Burette, 10.Exhaust gas temperature indicator, 11.Outlet jacket water temperature indicator, 12.Outlet-jacket water flow meter, 13.Piezo-electric pressure transducer, 14.Console, 15.TDC encoder, 16.Personal Computer and 17. Printer

Fig.1 Experimental set-up

Table-1: Specifications of test engine

Description	**Specification**
Engine make and model	Kirloskar (India) AV1
Maximum power output at a speed of 1500 rpm	3.68 kW
Number of cylinders ×cylinder position× stroke	One × Vertical position × four-stroke
Bore × stroke	80 mm × 110 mm
Method of cooling	Water cooled
Rated speed (constant)	1500 rpm
Fuel injection system	In-line and direct injection
Compression ratio	16:1
Aspiration	Natural
BMEP @ 1500 rpm	5.31 bar
Manufacturer's recommended injection timing and injector opening pressure	27^0 bTDC × 190 bar
Dynamometer	Electrical dynamometer
Number of holes of injector and size	Three × 0.25 mm
Type of combustion chamber	Direct injection type
Fuel injection nozzle	Make: MICO-BOSCH No- 0431-202-120/HB
Fuel injection pump	Make: BOSCH: NO- 8085587/1

The injector opening pressure was varied from 190 bar to 270 bar using a nozzle testing device. The injection timing was varied from 27^0bTDC to 34^0bTDC. Effect of injection timing and injector opening pressure, on the performance of the engine was studied. The combustion chamber pressure was measured by a pressure transducer and the crank angle was measured by TDC encoder. The transducer and encoder were connected to a computer. The combustion characteristics such as peak pressure (PP), time of occurrence of peak pressure (TOPP) and maximum rate of pressure rise (MRPR) were evaluated at full load operation of the engine with the help of a P-θ software package.

Table-2: Properties of test fuels

Test Fuel	Kinematic Viscosity at 40^0C (mm^2/s)	Specific gravity at 15^0C	Cetane number	Lower Calorific value (kJ/kg)
Diesel	3.07	0.84	55	42000
JO	31.05	0.92	48	36000

III. RESULTS AND DISCUSSIONS

The experiments were conducted on the engine with diesel operation as well as jatropha oil operation, with varied injection timings and injector opening pressures. The investigations for evaluating the performance of the engine were categorized into two parts – (i) evaluation of performance parameters and (ii) evaluation of combustion characteristics. The results obtained with jatropha oil operation were compared with that of diesel operation.

A. Performance Parameters

Fig.2 shows the variation of BTE with BMEP with diesel fuel operation on the engine, at an injector opening pressure of 190 bar. The injection timing was varied from 27^0–34^0bTDC.

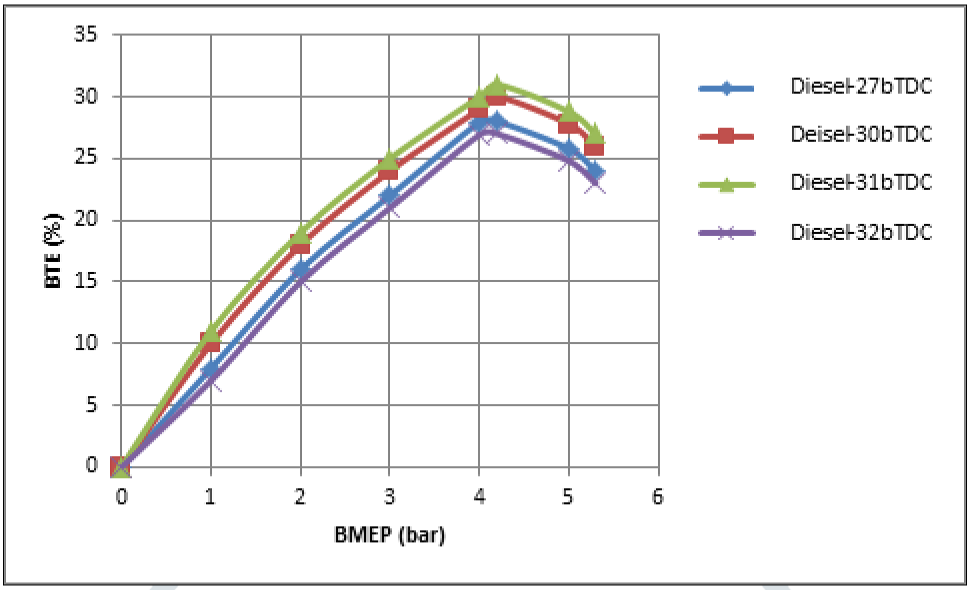


Fig.2 Variation of BTE with BMEP with diesel operation

At all the injection timings, the BTE increased up to 80% of the full load operation. This might be due to the increase of fuel conversion efficiency of the engine. Beyond that load, BTE decreased due to reduction of air-fuel ratio, volumetric efficiency and mechanical efficiency [19]. This was accepted trend in all engines. BTE increased with the advancing of injection timing up to 31^0 bTDC. This might be due to the early initiation of combustion with an increase of peak pressure. Beyond that, the performance deteriorated, which might be due to the increase of ignition delay. So 31^0 bTDC is considered as the optimum injection timing with diesel operation.

Fig.3 gives the variation of BTE with BMEP, with jatropha oil operation, at different injection timings, at an injector opening pressure of 190 bar.

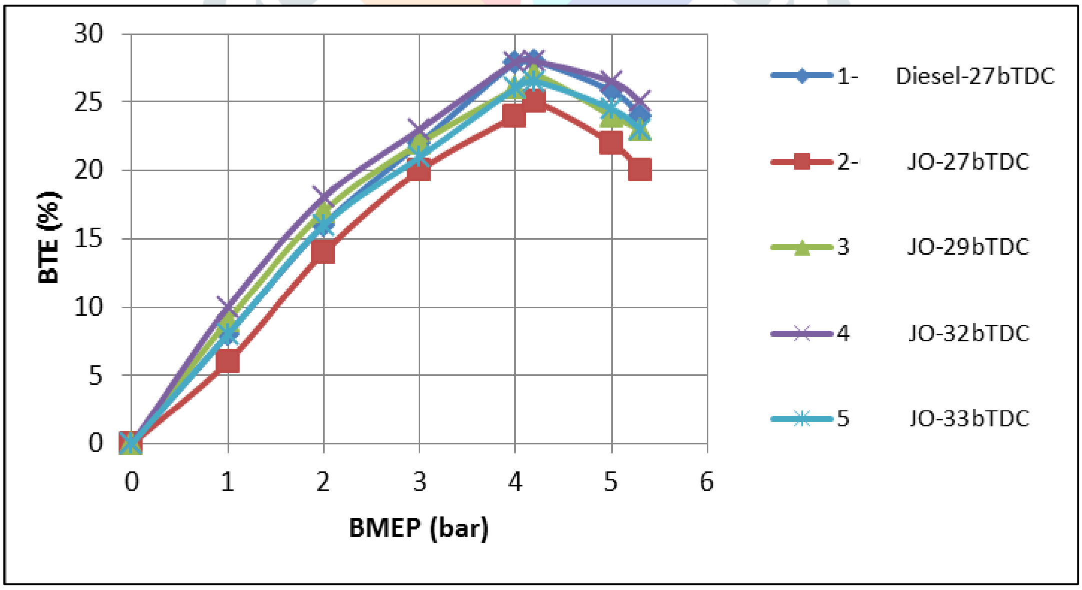


Fig.3 Variation of BTE with BMEP with JO operation

At the recommended injection timing of 27^0 bTDC, the jatropha oil operation showed deterioration in performance compared with that of diesel operation. This might be due to the non-volatility and high viscosity of jatropha oil. From the figure, it is also evident that BTE increased with the advancement of injection timing (up to 32^0 bTDC) and later on decreased. So the optimum injection timing with JO operation is 32^0 bTDC. The higher value of BTE at optimum injection timing over the recommended injection timing was due to its longer ignition delay and combustion duration, which are essential to burn the highly viscous fuel like JO.

As the part load variations of the parameters with respect to BMEP were small, bar charts were drawn for the performance parameters at full load operation of the engine at an injector opening pressure of 190 bar.

The Fig.4 shows the bar chart, giving the variation of peak BTE at recommended and optimum injection timings at an injector opening pressure of 190 bar.

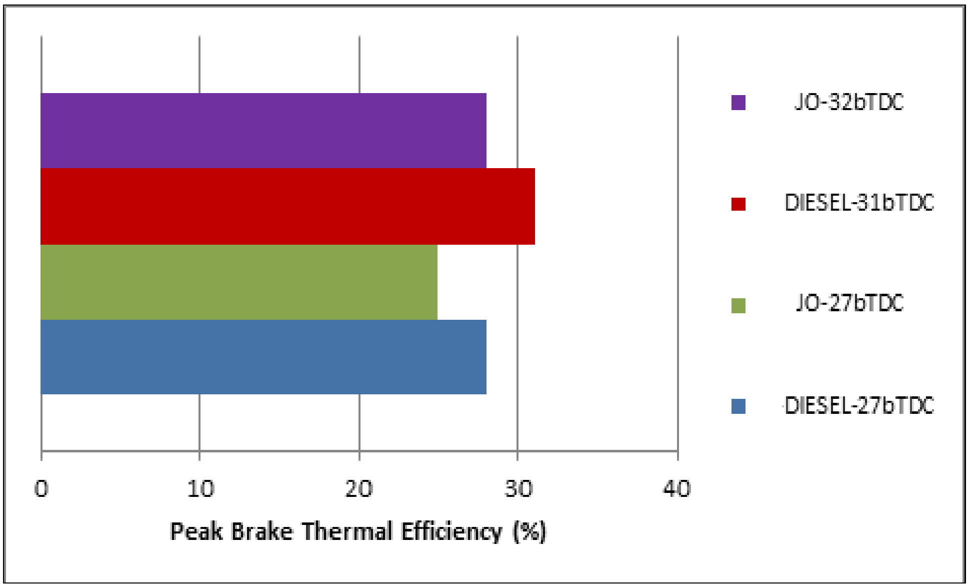


Fig.4 Bar chart showing the variation of peak BTE

With jatropha oil operation, the peak BTE is lower by 11% at recommended injection timing and lower by 10% at optimum injection timing when compared with diesel operation. Increase of ignition delay with jatropha oil operation might have contributed for the inferior performance. The jatropha oil operation at optimum injection timing gave performance comparable to diesel operation at recommended injection timing.

Table 3 shows the comparative data on peak BTE at different injection timings and injector opening pressure.

Table-3: Data of peak BTE

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	28	29	30
	JO	25	26	27
31	DF	31	30.5	30
32	JO	28	27	26

The brake specific fuel consumption (BSFC) is defined as fuel consumed per unit brake power output of the engine. A s the different fuels (diesel and jatropha oil) with different caloric values were used in the investigations, brake specific energy consumption (BSEC) was used instead of BSFC. The BSEC is defined as energy supplied through the fuel per unit power output of the engine. The Fig.5 shows the bar chart, giving the variation of BSEC at full load at recommended and optimum injection timings at an injector opening pressure of 190 bar.

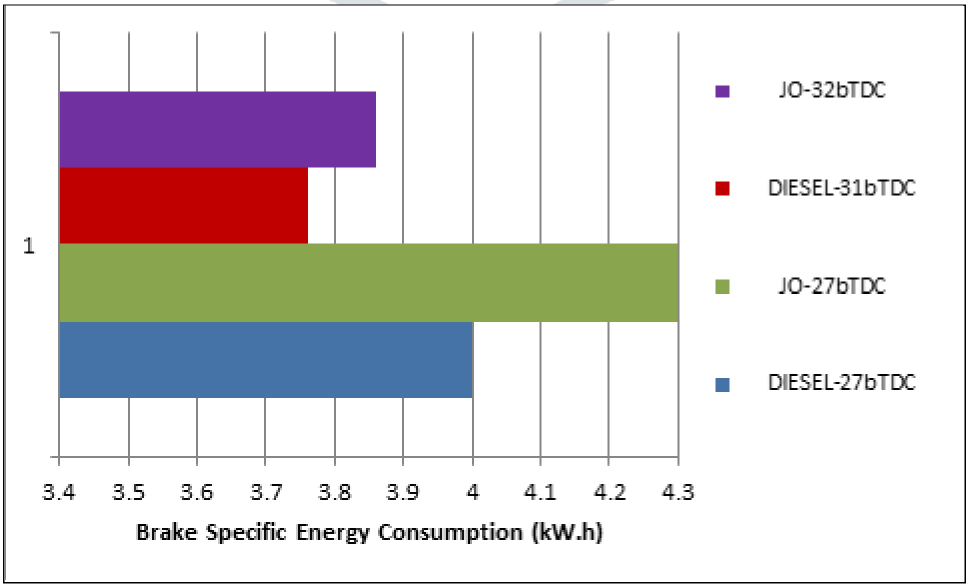


Fig.5 Bar chart showing the variation of BSEC at full load operation

The jatropha oil operation gave higher BSEC when compared with diesel operation both at recommended and optimum injection timings. Low volatility, high viscosity and low heating value of vegetable oil might be the reason for higher BSEC values with jatropha oil operation. BSEC decreased with advanced injection timing with test fuels which might be due to the early initiation of combustion.

Table 4 shows the comparative data on BSEC at full load operation at different injection timings and injector opening pressures.

Table-4: Data of BSEC at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	4.0	3.92	3.84
	JO	4.30	4.26	4.22
31	DF	3.76	3.80	3.84
32	JO	3.86	3.90	3.94

From the Table-5, it is evident that BSEC at full load with jatropha oil operation is higher than that of diesel operation. At an injector opening pressure of 190 bar, the BSEC for jatropha oil operation was higher by 7.5% at recommended injection timing and 2.66% at optimum injection timing in comparison with diesel operation. Poor volatility, high viscosity and low calorific value of the jatropha oil might have led to deterioration in performance. BSEC at full load operation decreased with an increase of injector opening pressure, which might be due to the decrease of mean diameter of the fuel droplet with an increase in injector opening pressure.

The Fig.6 shows the bar chart, showing the variation of exhaust gas temperature (EGT) with test fuels at recommended and optimum injection timings at an injector opening pressure of 190 bar.

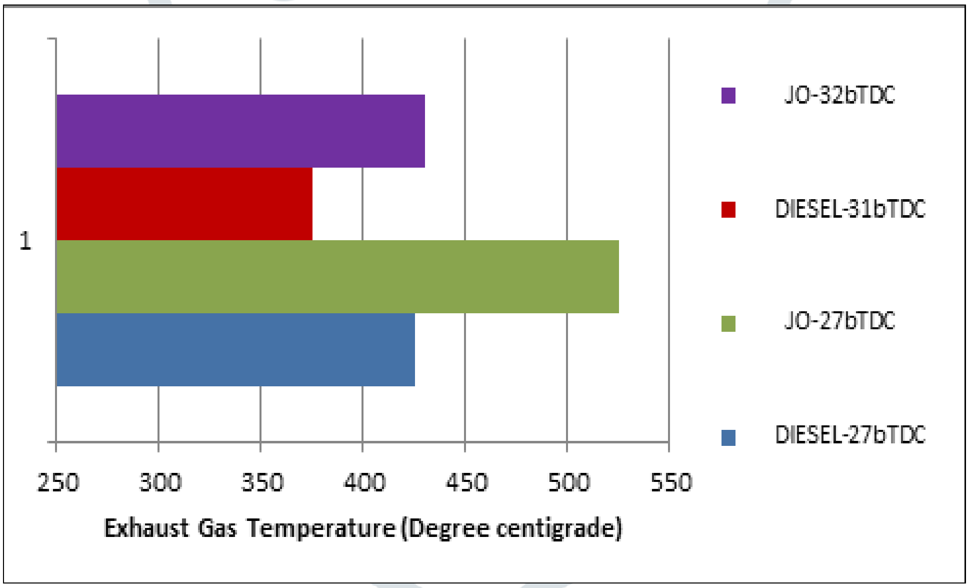


Fig.6 Bar Chart Showing The Variation Of EGT

From the Fig.6, it can be seen that the EGT decreased with advanced injection timing for both the fuels. The jatropha oil operation gave higher values of EGT compared with Diesel operation both at recommended and optimum injection timings. Though the calorific value of jatropha oil is less than that of diesel, the density of the vegetable oil was higher and therefore, greater amount of heat was released in the combustion chamber leading to higher EGT.

The Table 5 shows the comparative data on EGT at full load operation at different injection timings and injector opening pressures.

Table-5: Data of EGT at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	425	410	395
	JO	525	500	475
31	DF	375	400	425
32	JO	430	450	470

From the Table, it is noticed that, with jatropha oil operation, the EGT at full load increased by 23% at recommended injection timing and 15% at optimum injection timing in comparison with diesel operation.

The Fig.7 gives the bar chart, showing the variation of volumetric efficiency with test fuels at recommended and optimum injection timings at an injector opening pressure of 190 bar. Diesel fuel at optimum injection timing showed higher volumetric efficiency. This might be due to clean combustion at optimum injection timing with diesel fuel.

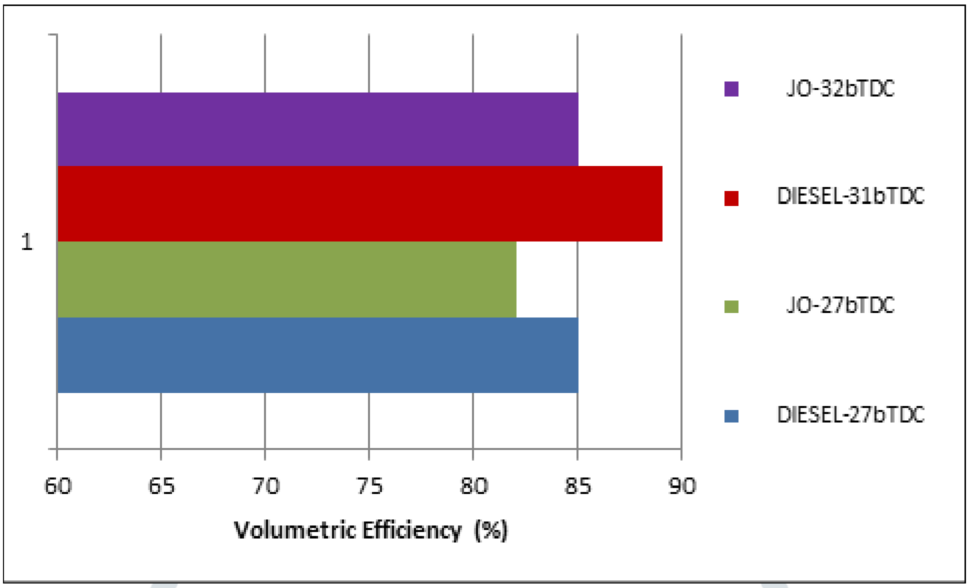


Fig.7 Bar Chart Showing The Variation Of Volumetric Efficiency

With the advanced injection timing, the volumetric efficiency increased due to the decrease of combustion wall temperatures with improved oxygen-fuel ratios. From the Fig.7, it is also observed that, with jatropha oil operation, volumetric efficiency decreased in comparison with diesel operation.

The Table 6 shows the comparative data on volumetric efficiency (VE) at full load operation at different injection timings and injector opening pressures.

Table-6: Data of VE at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	85	86	87
	JO	82	83	84
31	DF	89	88	87
32	JO	85	84	83

From the same Table, it is observed that, volumetric efficiency was lower with JO operation than with diesel operation. This might be because of higher cylinder temperatures with JO operation. At recommended injection timing, the volumetric efficiency increased marginally with an increase of injector opening pressure. .

C. Combustion Characteristics

The combustion characteristics like peak pressure (PP), time of occurrence of peak pressure (TOPP) and maximum rate of pressure rise (MRPR) were determined for the diesel engine from pressure-crank angle diagrams obtained with piezoelectric pressure transducer, TDC encoder and a pressure-crank angle (p-θ) software package.

The Fig.8 gives the bar chart, showing the variation of peak pressure with test fuels at recommended and optimum injection timings at an injector opening pressure of 190 bar. Jatropha oil at recommended injection timing gave lower value of PP when compared with other operating conditions. Low calorific value of the fuel with retarded heat release rates might have been the reason for lower PP with jatropha oil operation. PP decreased with jatropha oil operation when compared with diesel operation both at recommended and optimum injection timing. This might be due to increase of ignition delay, as vegetable oil requires large duration of combustion, meanwhile the piston started making downward motion thus increasing volume when the combustion takes place in the engine.

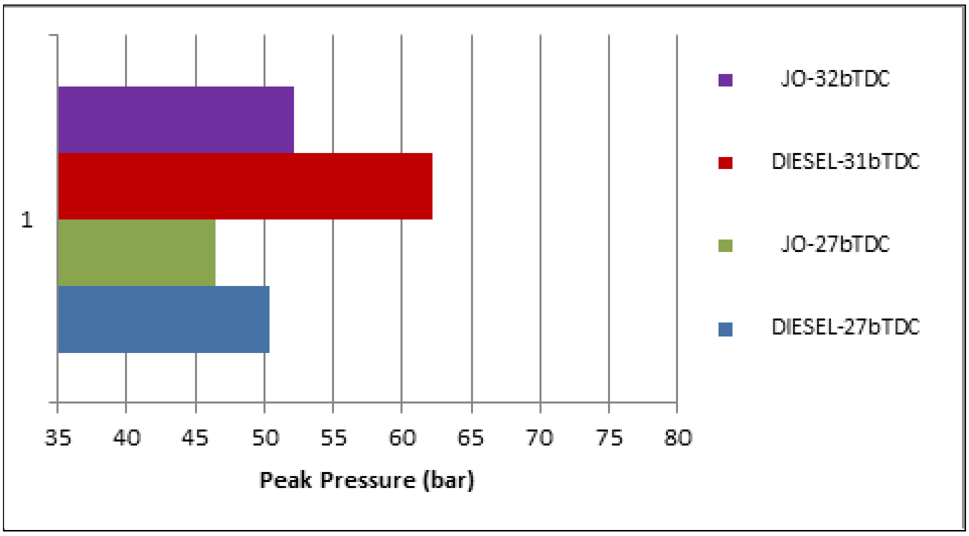


Fig.8 Bar Chart Showing The Variation Of Peak Pressure

The value of peak pressure increased with advancing of the injection timing with test fuels. This might be due to accumulated and sudden explosion of the fuel with advanced injection timing.

The Table 7 shows the comparative data on peak pressure at full load operation at different injection timings and injector opening pressures.

Table-7: Data of PP at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	50.4	51.7	53.5
	JO	46.5	47.5	48.5
31	DF	62.2	62.6	63.2
32	JO	52.2	54.2	56.2

Peak pressures increased with an increase of injector opening pressure. This may be due to smaller Sauter mean diameter, shorter breakup length, improved dispersion and improved spray and atomization characteristics. This improves combustion rate in the premixed combustion phase.

The Fig.9 presents the bar chart, showing the variation of TOPP with test fuels at recommended and optimum injection timings at an injector opening pressure of 190 bar.

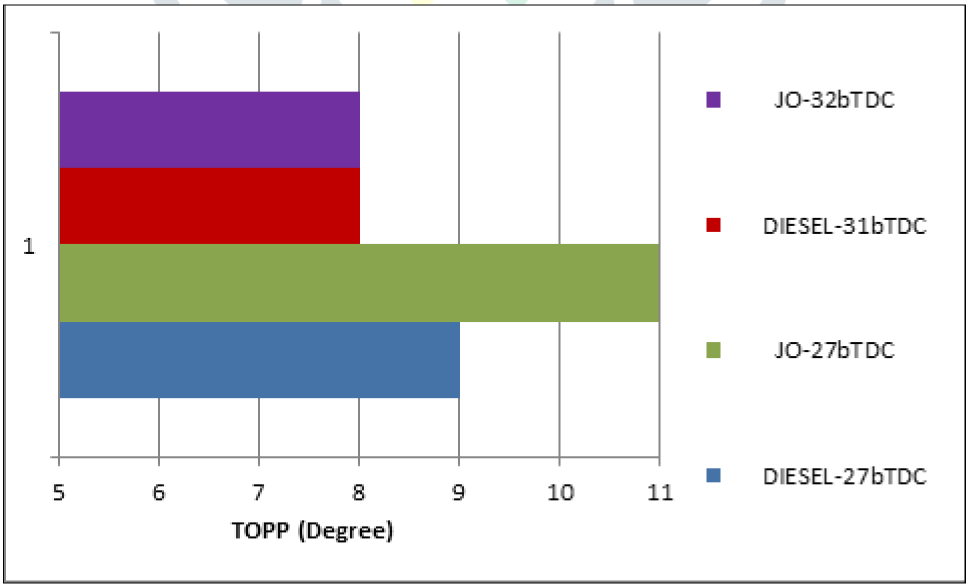


Fig.9 Bar Chart Showing The Variation Of TOPP

TOPP decreased with advancing of the injection timing with the test fuels. Jatropha oil operation at recommended injection timing gave higher TOPP in comparison with other operating conditions. Increase of combustion duration and retarded heat release rate might be the reason.

The Table 8 shows the comparative data on TOPP at full load operation at different injection timings and injector opening pressures.

Table-8: Data of TOPP at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	9	9	8
	JO	11	11	11
31	DF	8	9	9
32	JO	8	9	9

Fig.10 presents the bar chart, showing the variation of MRPR with test fuels at recommended and optimum injection timings at an injector opening pressure of 190 bar.

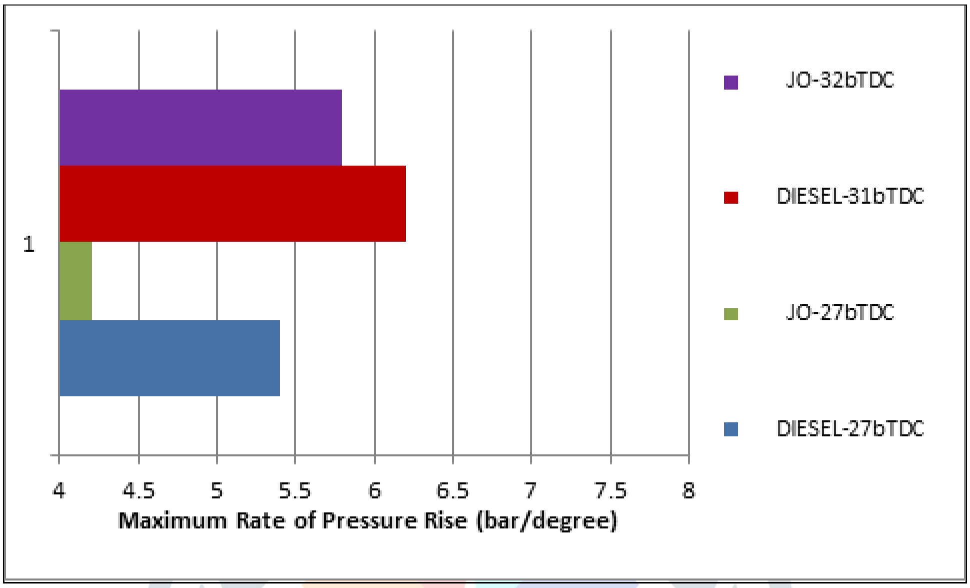


Fig.10 Bar chart showing the variation of MRPR

Jatropha oil operation at recommended injection timing gave lower MRPR in comparison with other operating conditions. Retarded heat release rate, higher duration of combustion of jatropha oil in addition to its lower calorific value might have contributed for the lower MRPR with jatropha oil operation at recommended injection timing. MRPR increased with advanced injection timing with test fuels, which might be because of initiation and continued combustion at early period.

Table 9 shows the comparative data on Maximum Rate of Pressure Rise (MRPR) at different injection timings and injector opening pressures.

Table-9: Data of MRPR at full load operation

Injection Timing (^{0}bTDC)	Fuel	Injector opening pressure (bar)		
		190	230	270
27	DF	5.4	5.6	6.0
	JO	4.2	4.4	4.6
31	DF	6.2	6.0	5.8
32	JO	5.8	6.0	6.2

IV. CONCLUSIONS

1. The optimum injection timing was found out to be 31^0 bTDC for the diesel operation while it was 32^0 bTDC for the jatropha oil operation.
2. The JO operation showed the deterioration in the performance when compared with diesel operation. It gave lower BTE, higher BSEC, higher EGT, lower volumetric efficiency at both recommended and optimum injection timings.
3. At the optimum injection timing of 32^0 bTDC, JO operation showed comparable performance when compared with diesel operation at recommended injection timing.
4. With the advancing of injection timing- BTE increased, BSEC decreased, EGT decreased, volumetric efficiency increased, PP increased, TOPP decreased and MRPR increased with test fuels.
5. PP decreased with JO operation when compared with diesel operation both at recommended and optimum injection timing.
6. The performance increased with increase of injector opening pressure with test fuels.

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