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Experimental Investigations on a Four Stroke Compression Ignition Engine using Neat Tobacco Seed Oil as an Alternate Fuel

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Abstract - Performance, emission and combustion tests were carried out on a four stroke compression ignition engine using tobacco seed oil by varying fuel injection pressure and fuel injection timing and compared with base line diesel. The main objective of conducting the performance test on a most widely used agricultural segment engine with tobacco seed oil to help the farming community to use tobacco seed oil in case of emergency and short term applications. At 260 Bar and 26° BTDC the performance of the engine is quite encouraging compared to the operation of the engine at standard injection pressure of 205 bar and 23° BTDC.

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EXPERIMENTAL INVESTIGATIONS ON A FOUR STROKE COMPRESSION IGNITION ENGINE USING NEAT TOBACCO SEED OIL AS AN ALTERNATE FUEL

Strictly as per the compliance and regulations of :

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Dr.C.V.MohanRao [α], Dr.A.V.Sita Rama Raju [σ] & Dr.K.Govindarajulu [ρ]

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I. Introduction

The depletion of fossil fuels all over the world is pressing the people to search for alternative fuels. Mostly the research is going on tree based oil seeds for the extraction of oil and conversion of these oils as bio diesel for the purpose of IC engine applications. The tree based oil seed production takes longer time compared to plant based oil seed production. Countries like Argentina, China, Brazil, Bulgaria, Greece, India, Indonesia, Turkey, Tunisia, etc are cultivating tobacco for commercial purpose. In majority of the tobacco cultivation process only the tobacco leaves are used and the tobacco seeds are unused (1,2,3). Due to the worldwide tobacco abuse the crop cultivation is coming down. If the tobacco seeds which are left out in the tobacco fields are used for tobacco seed oil extraction then it can be used for many useful applications. emergency and short term application for the agricultural segment engines like water pumps, diesel generators, power tillers etc. In some of the tobacco growing countries due to the shortage of cooking oil the tobacco seed oil is being used as edible oil after due processing of this oil after removal of toxic contents as it contains omega-3 fatty acid which is essential for human body(1).

The oil cake emerging from the tobacco seed oil extraction can be used as a good manure for the agricultural fields moreover the fuel import bills will come down and this will strengthen any nation for its energy self sufficiency. For this purpose if the engine is tuned by varying the fuel injection pressure and timing to yield best performance such that the unused tobacco seeds can be converted to most useful fuel. In the present experimental investigation the engine performance, emission and combustion characteristics using tobacco seed oil as fuel at fuel injection pressures of 205, 220, 240 and 260 bar and fuel injection timing of 23°, 26°, 28° BTDC were evaluated and compared with base line diesel operation.

II. Characterisation of Tobacco Seed Oil

The details of tobacco plant and properties of tobacco seed oil are given below.

a) Tobacco Plant

Initially the tobacco plants are raised from tobacco beds as is done in the case of paddy plantation. The small tobacco plants are then planted in an array and frequently irrigated. The tobacco plant grows from 1 meter to 2 meters in height and after attaining maximum height beautiful pink flowers will emerge. These flowers will turn to green capsules containing numerous tobacco seeds. When these green capsules turn to brown colour after considerable drying the tobacco seeds will be ready for oil extraction and the oil yield will be around 25 to 30%.

b) Tobacco seed oil

The tobacco seed oil in sufficient quantities were procured from Sri Laxmi venkatesh wara oil mill, Santhanuthalapadu, Prakasham district, Andhra Pradesh. The fatty acid composition of tobacco seed oil is shown in Table.1 and the fuel properties are shown in Table 2.

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II. Experimental Setup

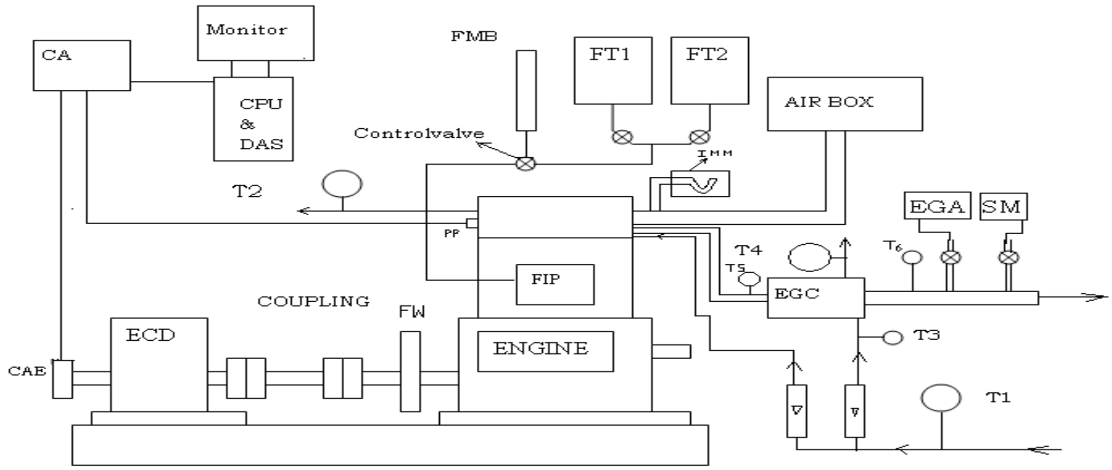

Figure 1 : Schematic diagram of experimental set-up

FW – Fly Wheel
ECD – Eddy Current Dynamometer
CAE – Crank Angle Encoder
CA – Charge Amplifier
CPU & DAS – Central Processing Unit & Data Acquisition System
PP – Pressure Pickup Transducer
FMB – Fuel Measuring Burette
FT1 & FT2 – Fuel Tanks
FIP – Fuel Injection Pump
IMM – Inlet Manifold Manometer
EGC – Exhaust Gas Calorimeter
EGA – Five Gas Exhaust Gas Analyzer
SM – Smoke Meter
T1 – Engine Inlet Water temperature
T2 - Engine Outlet Water temperature
T3 – Inlet Cooling Water Temperature To the exhaust Gas Calorimeter
T4 - Outlet Water Temperature of the exhaust Gas Calorimeter
T5 – Exhaust Gas Temperature before Calorimeter
T6 - Exhaust Gas Temperature after Calorimeter

III. Experimental Procedure

A four stroke single cylinder direct injection water cooled computerized Kirloskar TV1 diesel engine shown in fig.1 is used for testing the performance by enhancing fuel injection pressure and fuel injection advance. After ensuring no load on the eddy current dynamometer the engine was started on base line diesel and performance, emission and combustion tests were conducted using base line diesel as fuel at manufacturers recommended fuel injection pressure of 205 Bar and fuel injection timing of 23° BTDC. The performance, emission and combustion characteristics are plotted by varying 20, 40, 60, 80 and 100% load with base line diesel operation.

The performance emission and combustion tests were conducted using tobacco seed oil following the above procedure to evaluate the performance and emission analysis at different injection pressures (205, 220, 240 and 260 bar) and keeping the fuel injection timing at 23° BTDC. Before introducing tobacco seed oil as test fuel, the engine was run on base line diesel for 10 to 15 minutes and after stabilizing the engine parameters, the tobacco seed oil was introduced. After running the engine for 10-15 minutes on the tobacco seed oil and stabilizing the parameters with the tobacco seed oil the readings were recorded and after completion of the tests with tobacco seed oil the engine was switched over to base line diesel and run for 10 to 15 minutes on base line diesel before stopping the engine to avoid cold starting and fuel injector and fuel pump plunger sticking problems.

The above test procedure is repeated by keeping the fuel injection timing at 26° and 28° BTDC and the fuel injection pressure at 205, 220, 240 and 260 Bar.

Uncertainity Analysis: The experimental investigations involve the use of different instruments for measurement of different parameters. These instruments or equipment are made by different manufacturers using different technologies. The accuracy of measurement and their performance may vary depending on the operating and experimental environment. Hence the uncertainty occurs due to fixed or random errors. The uncertainty in the measured parameter can be estimated based on analytical methods. Thus the uncertainty can be estimated using Gaussian distribution method with confidence limits of 2 σ

Using the above equation for a given operating condition the uncertainties are computed for the measured quantities are listed below

N= Speed ± 1.0 %
W= Load ± 0.5 %
BP= Brake Power ± 0.5 %
BSFC= Brake specific fuel consumption ± 1.4 %
EGT= Exhaust gas temperature ± 0.2 %
BTE = Brake thermal efficiency ± 1.1 %
CO= carbon Monoxide ± 0.2 %
HC= Hydro carbon ± 0.2 %
NOx= Oxides of Nitrogen ± 0.3 %
SO= Smoke opacity ± 1.1 %
PP = Pressure pickup ± 1.0 %

S.No	Instruments	Measured Parameters	Measurement Accuracy	Percentage uncertainties
1	5GAS ANALISER	CO (0-15%) HC (0-30000PPM) NOx (0-5000PPM) O2 (0-25%) CO2 (0-20%)	0.01%	± 0.2%
			1PPM	± 0.2%
			1PPM	± 0.3%
			0.01%	± 1.1%
			0.01%	± 1.0%
2	SMOKE METER	SMOKE OPACITY(0-99.99)	1%	± 1.1%
3	LOAD INDICATOR	LOAD(0-50kg)	± 0.1kg	± 0.5 %
4	PRESSURE PICKUP	PRESSURE (0-110Bar)	±1 Bar	± 1.0 %
5	CRANK ANGLE ENCODER		±1°	±0.2%
6	EXHAUST GAS TEMPERATURE INDICATOR	TEMPERATURE (0-900°C)	±1°C	± 0.2%
7	SPEED	SPEED (0-10000RPM)	±10RPM	± 1.0%
8	FUEL MEASURING UNIT	FUEL CONSUMED (0-50CC)	0.2CC	± 1.4 %

S.NO	Parameters	Specification
1	Machine supplier	Apex innovations Pvt. Ltd., Sangli, Maharastra, India
2	Type	TV1. (Kirlosker make)
3	Software used	Engine Soft
4	Nozzle opening pressure	200-225 bar
5	Governor type	Mechanical centrifugal type
6	No of cylinders	Single cylinder
7	No of strokes	Four stroke
8	Fuel	H.S.diesel
9	Rated power	5.2kW(7HP)@1500rpm
10	Cylinder diameter	87.5mm
11	Stroke length	110mm
12	Compression ratio	17.5P:1

Air measurement manometer		
13	Made	MX 201
14	Type	U-type
15	Range	100-0-100mm
Eddy current dynamometer		
16	Model	AG-10
17	Type	Eddy current
18	Maximum	7.5kW at 1500-3000 rpm

IV. Results & Discussions

The variation of brake specific energy consumption of tobacco seed oil with respect to brake power is presented in Fig.2. For both diesel and tobacco seed oil operation the brake specific energy consumption was decreased with increase of brake power up to 80% load and at this point the lowest brake specific energy consumption for diesel, tobacco seed oil at best injection pressure and timing and tobacco seed oil at standard setting of injection pressure and timing are 12837.82, 14245.58, 16479.86 kJ/kWh respectively. Hence 19% saving in brake specific energy consumption with tobacco seed oil can be achieved by adopting best injection pressure and timing over standard setting of injection pressure and timing.

Fig.3. shows the variation of exhaust gas temperature with brake power. The exhaust gas temperature with tobacco seed oil is lower than diesel operation. This is due to higher heating value of diesel fuel. However with tobacco seed oil at standard setting of injection pressure and timing the exhaust gas temperatures are very close to diesel operation indicates the ineffective combustion due to lower injection pressure which leads to after burning.

The variation of brake thermal efficiency with brake power is shown in Fig.4. The highest brake thermal efficiency is obtained at around 4 kW with both diesel and tobacco seed oil. Throughout the operating range the brake thermal efficiency is higher with diesel compared to tobacco seed oil. The peak brake thermal efficiency with diesel, tobacco seed oil at best setting and tobacco seed oil at standard setting of injection pressure and timing are 28.05%, 24.92%, 21.54% respectively. The decreased values of brake thermal efficiency with tobacco seed oil over diesel indicates lower heating value and poor combustion due to high viscosity of tobacco seed oil. However with best setting of fuel injection pressure and timing there is 15.7% increase in brake thermal efficiency over standard setting with tobacco seed oil. This improvement in brake thermal efficiency can be attributed to improved combustion due to higher injection pressure and advanced injection timing.

Concentration of unburnt hydrocarbon emission variation with brake power is represented in Fig.5. Higher values of unburnt hydrocarbon with tobacco seed oil over diesel indicates improper combustion of tobacco seed oil due to more heterogeneous mixture formation resulting from higher viscosity and low volatility.

Emission of carbon monoxide variation with brake power is indicated in Fig.6. The carbon monoxide emissions are very low in all the cases as expected in any of the compression ignition engines due to the presence of excess air. However there is an indication of slightly higher values of carbon monoxide with tobacco seed oil over diesel operation.

The variation of Oxides of Nitrogen emissions with brake power is shown in Fig.7. There is higher Oxides of Nitrogen concentration in the exhaust of tobacco seed oil operation when compared to diesel. This is obvious due to the more availability of oxygen with tobacco seed oil as the tobacco seed oil itself contains oxygen in its molecular structure. However with tobacco seed oil at best injection pressure and timing the Oxides of Nitrogen emissions are higher over that of at standard setting due to prevailing of higher combustion temperatures. When the engine was operated on tobacco seed oil at best setting of injection pressure and timing at 80% load Oxides of Nitrogen emissions were 425 ppm and that of base line diesel operation were 126 ppm. At standard setting of injection pressure and timing Oxides of Nitrogen were 299 ppm.

Fig.8. shows the variation of smoke opacity with brake power. The smoke intensity is higher with tobacco seed oil as compared to diesel due to higher viscosity of tobacco seed oil leading to thermal cracking. At 80% load when the engine operated on tobacco seed oil at best setting of injection pressure and timing smoke level is 46% lower compared to the tobacco seed oil operation at standard setting of injection pressure and timing.

Fig.9 explains pressure versus Crank Angle data pertaining to tobacco seed oil at standard and best injection pressure at 80% load. The effect of increase in fuel injection pressure from 205 bar to 260 bar and advancing the fuel injection timing from 23° BTDC to 26° BTDC improves the peak pressure from 65.38 bar to 74.9 bar. This may be due to the decrease in ignition delay as a result of enhanced injection pressure and advanced fuel injection timing.

Fig.10 indicates the rate of pressure rise versus Crank Angle and when the injection pressure is increased the maximum rate of pressure rise increased from 3.77 bar /°Crank Angle to 4.85 bar/°Crank Angle.

Fig.11 shows the highest net heat release rate which increases from 35.9 Joules /°Crank Angle to 44.11 Joules/°Crank Angle indicating the improvement of net heat release rate with the increase in fuel injection pressure and advanced fuel injection timing.

The cumulative heat release is shown in Fig.12 There is an improvement of highest cumulative heat release from 1.14 kJ at 509 °Crank Angle to 1.17 kJ at 423 ° Crank Angle. For diesel the highest cumulative heat release value of 0.91 kJ at 391°Crank Angle was observed.

The mass fraction burnt in % is shown in Fig.13 The 5% mass fraction burnt for diesel, tobacco seed oil at standard and best settings are 354, 358 and 354°Crank Angle respectively. The 90% mass fraction burnt for diesel, tobacco seed oil at standard and best settings are 375, 381 and 379°Crank Angle respectively. The occurrence of 5% and 90% mass fraction burnt with best setting of injection pressure and timing has been advanced by 4° and 2° crank Angle compared to standard setting of injection pressure and timing.

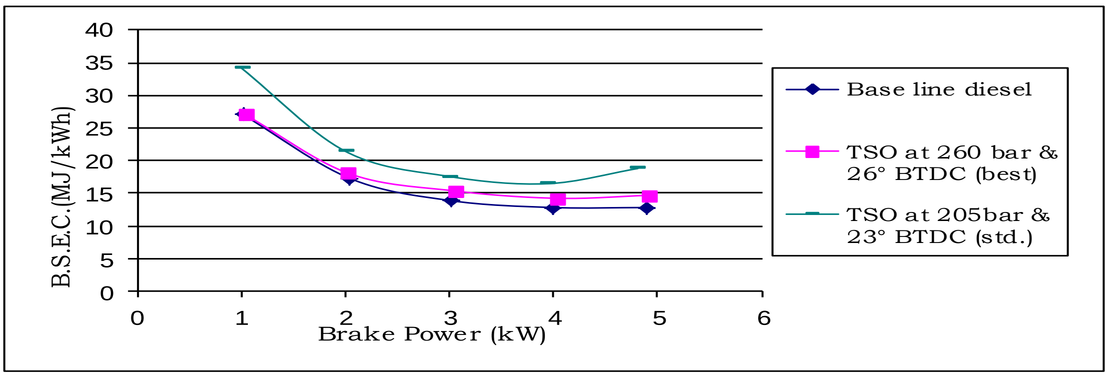

Figure 2 : BSEC Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

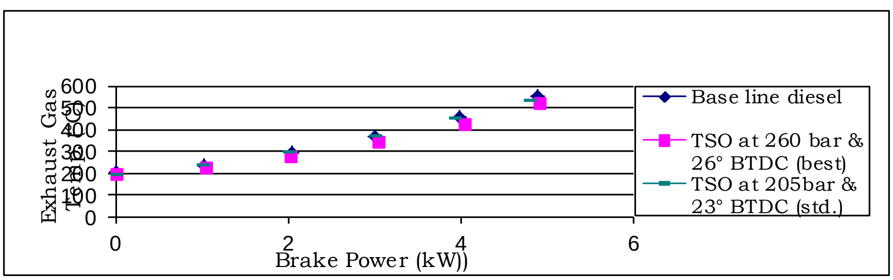

Figure 3 : Exhaust Gas Temperature Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

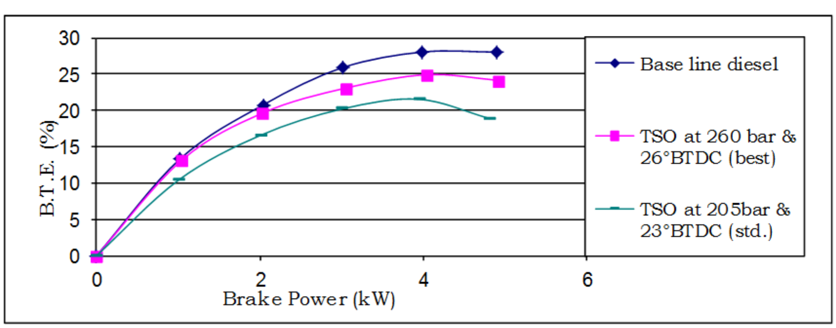

Figure 4 : Brake Thermal Efficiency Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

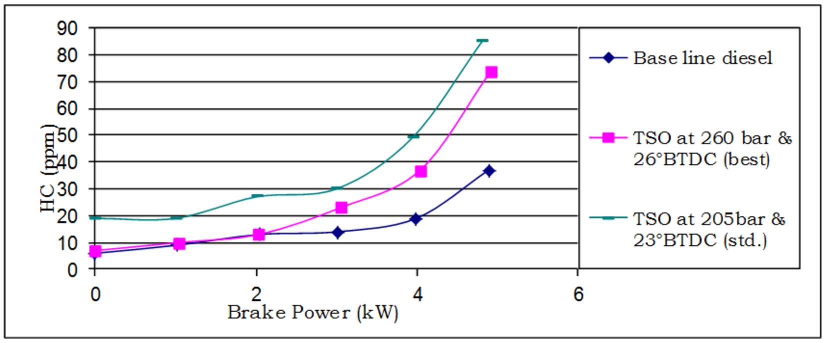

Figure 5 : Unburnt Hydro Carbon Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

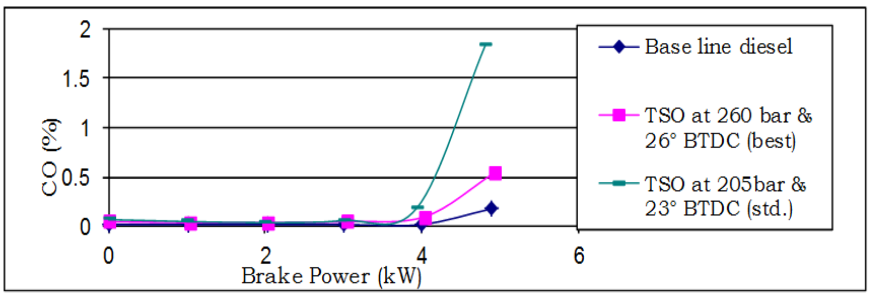

Figure 6 : Carbon Monoxide Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

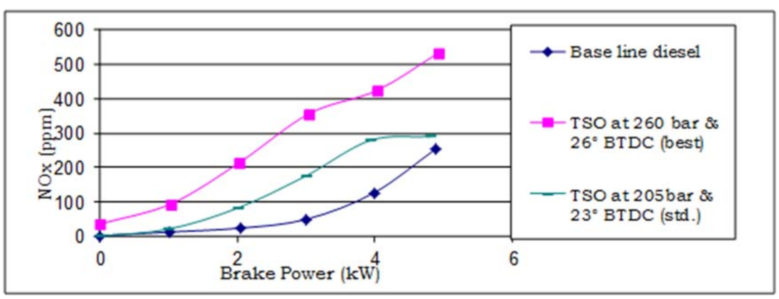

Figure 7 : Oxides of Nitrogen Vs Brake Power of tobacco seed oil at standard and best injection ressure and timing

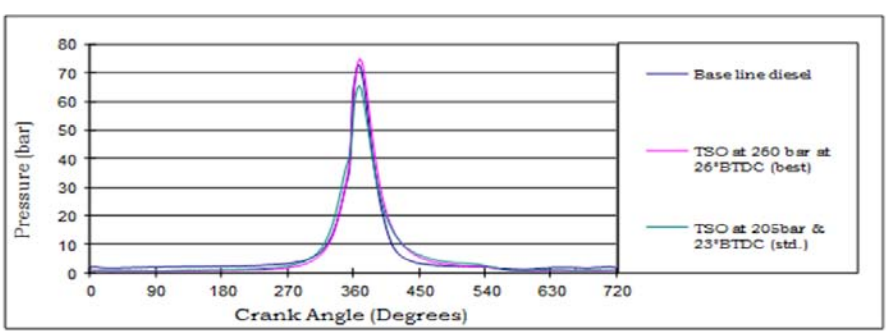

Figure 8 : Smoke Opacity Vs Brake Power of tobacco seed oil at standard and best injection pressure and timing

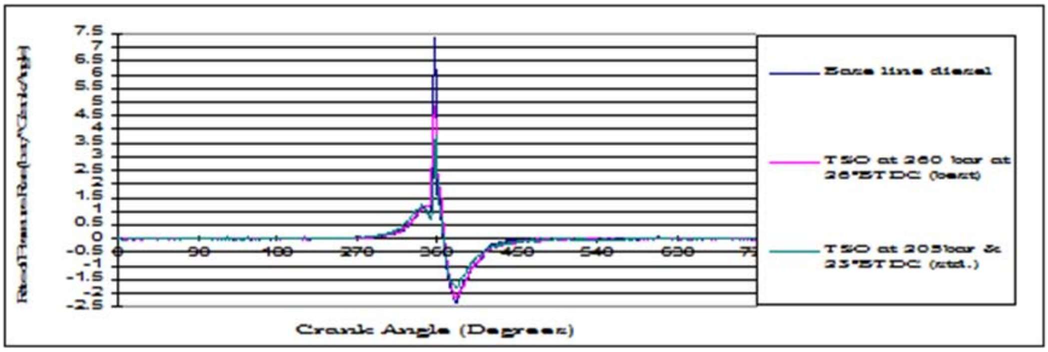

Figure 9 : Pressure Vs Crank angle of tobacco seed oil at standard and best injection pressure and timing at 80% load

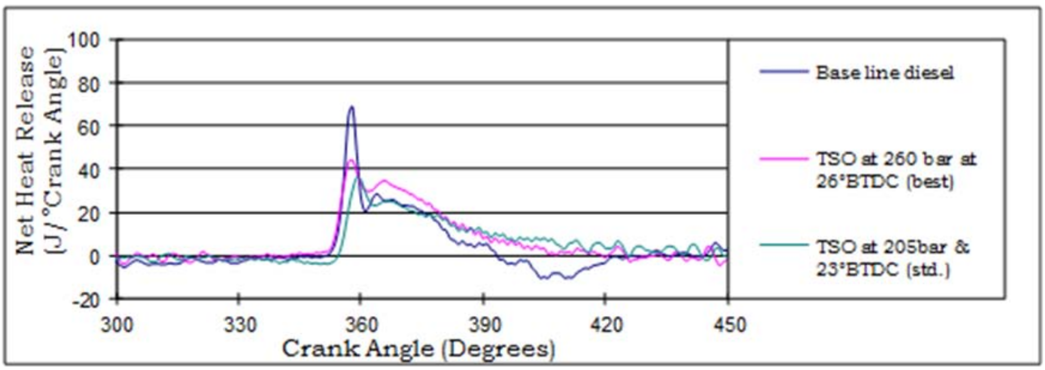

Figure 10 : Rate of Pressure Rise VsCrank angle of tobacco seed oil at standard and best injection pressure and timing at 80% load

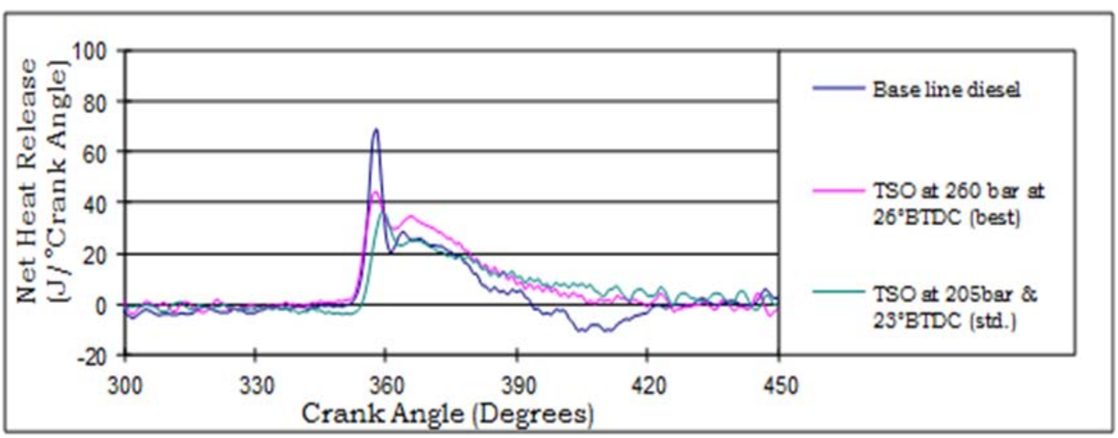

Figure 11 : Net Heat Release Vs Crank angle of tobacco seed oil at standard and best injection pressure and timing at 80% load

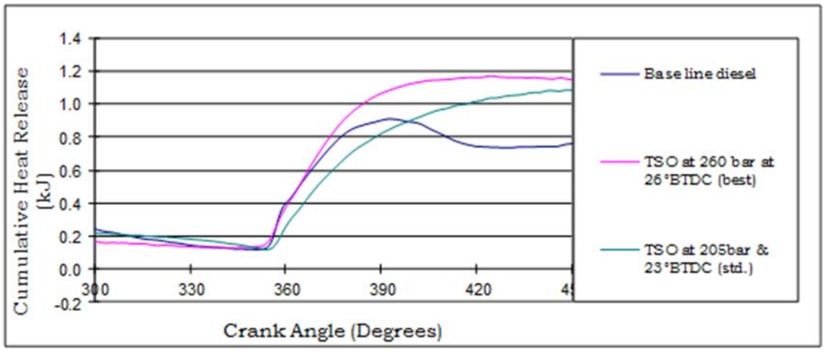

Figure 12 : Cumulative Heat Release Vs Crank angle of tobacco seed oil at standard and best injection pressure and timing at 80% load

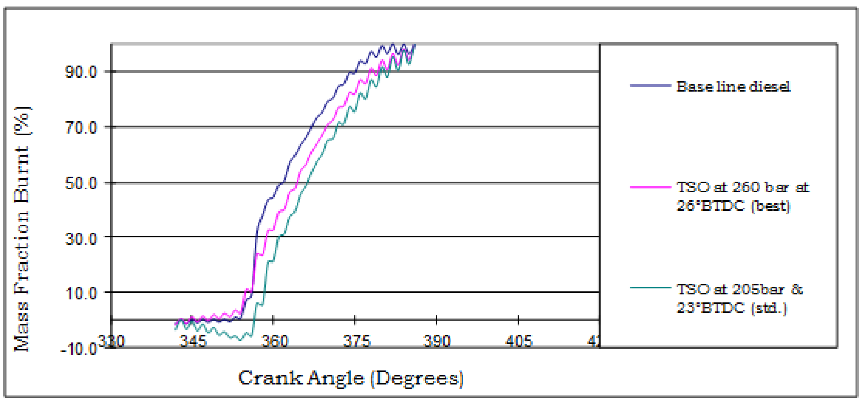

Figure 13 : Mass Fraction Burnt Vs Crank angle of tobacco seed oil at standard and best injection pressure and timing at 80% load

Table 1

Fatty acid composition	Tobacco seed oil
Myristic (14:0)	0.09-0.17
Palmitic (16:0)	10.96-8.87
Stearic (18:0)	3.34-3.49
Oleic (18:1)	14.54-12.4
Linoleic (18:2)	69.49-67.75
Linolenic (18:3)	0.69-4.20

Table 2

Properties	Tobacco seed oil	Base line diesel
Density at 32° C in gm/cc	0.915	0.82
Kinematic Viscosity at 32 °C in C s T	24	4
Flash point ° C	230	52
Fire point	248	57
Carbon residue (%)	0.45	0.1
Calorific value k J/kg	38438	42000

Table 3 : Test rig specifications

S. No.	Description	Specification
1	Test rig supplier	Apex Innovations Pvt.Ltd. Sangli Maharastra state, India
2	Type	TVI (Kirlosker make) vertical, water cooled
3	Software used	Engine soft
4	Nozzle opening pressure	200-260 bar
5	Governor type	Mechanical centrifugal type
6	No. of cylinders	Single cylinder
7	No. of strokes	Four stroke
8	Fuel	H.S. Diesel
9	Rated power	5.2 KW (7 HP) at 1500 rpm
10	Cylinder diameter (bore)	87.5 mm
11	Stroke length	110 mm
12	Compression ratio	17.5:1

V. Conclusions

The tobacco seed oil can be used as an alternate fuel in cases of emergency and short term use with proper precautions and tuning of the engine for best performance level. When the engine is operated with tobacco seed oil at best injection pressure and timing of 260 bar and 26° BTDC over standard setting of injection pressure and timing of 205 bar and 23° BTDC, 19% decrease in brake specific fuel consumption, 15.7% increase in brake thermal efficiency at 80% load and lower emissions were observed. The combustion data reveals improvement in peak pressure from 65.38 bar to 74.9 bar, maximum rate of pressure rise from 3.77 bar /°Crank Angle to 4.85 bar/°Crank Angle, highest net heat release rate from 35.9 Joules /°Crank Angle to 44.11 Joules/°Crank Angle, highest cumulative heat release from 1.14 kJ to 1.17 kJ and mass fraction burnt parameters. Hence for this particular engine 260 bar fuel injection pressure and 26° BTDC fuel injection timing is a best option to run with neat tobacco seed oil for emergency and short term applications.

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