PERFORMANCE TEST OF CVCRV ENGINE USING BLENDS OF SOYABEAN AND MUSTARD OILS WITH PETROL

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ABSTRACT

Since fossil fuels are limited sources of energy, the increasing demand for energy has led to a search for alternative sources of energy that would be economically efficient, socially equitable, and environmentally sound. Variations in the heat release rate with respect to crank angle have been observed and compared using blends of soyabean and mustered oils with petrol at different engine loads in computerized variable compression ratio multi-fuel (CVCRM) engine test rig.

It is concluded that the maximum heat release rate angle (429.45^0) is observed by using the blend of 20-PRM at the engine load of 5 Kg while minimum pressure increase rate (265.83^0) is observed by using the same blend at the engine load of 2.5 Kg. Similarly maximum mechanical efficiency of 35.8% is obtained by using the blend of 20-PRM at the engine load of 5.0 Kg while minimum mechanical efficiency of 11.8% is obtained by using 20-PRS at the engine load of 2.5 Kg.

Keywords: Heat release rate, Bio-fuels, Blends of soyabean and mustard oil, CVCRM engine test rig, crank angle, engine loads

Nomenclature

Following terms are used in this paper:

15PRS = Blending of 15% soya-bean oil with the petrol

20PRS= Blending of 20% soya-bean oil with the petrol

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15PRM = Blending of 15% mustard oil with the petrol

20PRM= Blending of 20% mustard oil with the petrol

CO = Carbon monoxide , CO_2 = Carbon dioxide

HC's = Hydrocarbons

CVCRM = Computerized variable compression ratio multi-fuel

p = Pressure (in bar), θ = Crank angle (in degree)

V = Volume (in %), MFB = Mass Fraction Burnt (in percentage)

BP = Brake Power (in KW), EEOC = Estimated end of combustion angle

1.0 Introduction

The concept of using vegetable oil as a transportation fuel oil goes back to 1893, when Dr. Rudolf Diesel developed the first diesel engine to run on vegetable oil. Vegetable oil is one of the renewable fuels. Vegetable oils have become more attractive recently because of its environmental benefits and the fact that it is made from renewable resources. Vegetable oils have the potential to substitute a fraction of petroleum distillates and petroleum-based petro chemicals in the near future. The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise 90 to 98% triglycerides and small amounts of mono and diglycerides. These usually contain free fatty acids (FFAs), water, sterols, phospholipids, odorants and other impurities.

When compared to several other alternative fuels available, bio-diesel comes out way ahead. Most alternative fuels require changes to a vehicle to be used. Natural gas & propane require special tanks to be installed and changes to the fuel injection system must be made as well. Ethanol also requires specialized changes to the fuel injection system. Electricity requires a completely different engine. In most cases, once a vehicle undergoes the conversion necessary to run the alternative fuel, there's no going back.

2.0 Literature Review

Various efforts have been made to use various alternative fuels and literature review is summarized in this section.

Kim et al. (2004) worked on the production of bio-diesel using the heterogeneous catalyst and prepared the biodiesel using transesterification process. A study for optimizing the reaction time, the stirring speed, use of coolant oil to methanol ratio and the amount of catalysts was performed. The catalyst used was Na/NaOH/y-Al_2O_3 as a base catalyst which shows the same activity as by the conventional homogenous catalyst. The basic strength of Na/NaOH/y-Al_2O_3 catalyst was estimated. Sethi and Salariya (2004) performed the experiment using Kerosene, LPG gas and Diesel to calculate the exhaust emission from the engine. Kerosene and LPG gas were mixed with diesel fuel in different ratios. With diesel-kerosene blends minimum exhaust emissions were observed at 30% kerosene blend. Exhaust gas emissions, namely, CO, UHC, and SO2 reduced by 40%, 18% and 19%, respectively, when compared with pure diesel emissions. Slight increase in the NO_x exhaust emission (2.4%) was observed. SFC was also observed to be minimal at 20% LPG mix and decreased by about 20% as compared to pure diesel value at the same brake power output.

Meher et al. (2006) used biodiesel and verified technical aspects so as to get the best combination of the reactants used for the production. The biodiesel from the vegetable oil was produced by transesterification process by using monohydric alcohol in the presence of a suitable catalyst. The various parameters which affect the transesterification process are molar ratio of alcohol to oil, type of alcohol, type and amount of catalyst, reaction time and temperature and purity of reactant. Barnard et al. (2007) studied the continuous flow preparation of bio-diesel using commercially available scientific microwave apparatus and presented that microwave heating for the production of biodiesel. Biodiesel proved to be the better way as it offers fast and better way. The vegetable oil to alcohol molar ratio used was 1:6. Reaction rate is about 7.2L/min. using a 4L reaction vessel. Results showed that transesterification reaction was better than the conventional heating process. Refaat et al. (2008) produced the biodiesel, using waste vegetable oil and concluded that biodiesel from the waste vegetable oil can be helpful in reducing the pollution from the water ways. Best yield of biodiesel was obtained at the molar ratio of 6:1 of methanol to oil. The yield percentage obtained was about 96% which is very close to the recommended standards of the biodiesel.

Akbar et al. (2009) worked on jatropha curcas oil and suggested to use it as a feedstock for biodiesel and presented that jatropha oil can be used as a source of energy very attractively. Lipid fraction of jatropha was calculated and analyzed for physical and chemical properties such as acid value, percentage free fatty acids, iodine value, density, viscosity etc. The oil extracts exhibited physicochemical properties and could be useful as Biodiesel. Matouq et al. (2009) studied the impact of blending of diesel with kerosene oil on diesel engine. The kerosene and diesel were mixed in different ratios ranging from 0 to 50%. It was observed that the efficiencies go on increasing when the kerosene percentage increases from 0 to 50 percent in diesel. The efficiency of the engine increases from 49 percent at 0^0C to 73 percent at 50^0C. The sulphur and carbon oxide emission also decreases. Singh and Singh (2010) presented that vegetable oil can be an alternative in the place of diesel fuel. But the major problems were the high viscosity, low volatility and poor cold flow properties. For this problem, the transesterification process was used in which vegetable oil was allowed to react with an alcohol in the presence of the catalyst. The main advantages of bio-fuel observed were their renewability, better quality exhaust emissions, its biodegrability and organic carbon present in it is photosynthetic in origin.

Obodeh and Isaac (2011) presented the tech economic effects of diesel-kerosene blends on operation of direct ignition diesel engine using a stationary LD20-D Nisan diesel. Values of pressure data of all petroleum fuel blends were higher when compared with that obtained when engine was running on Diesel. Pressure data for 30% Kerosene blend were higher than that at 40% kerosene blend from about 80 degrees after top dead centre. Exhaust temperature at 100% rated load was 16.7 % higher at 3% kerosene blend as compared with tat obtained with diesel fuel. Martin and Prithviraj (2011) measured the performance of compression ignition engine using blends of the cotton seed oil with diesel in C.I. engine. Performance, emission and combustion parameters were calculated at various loads using blended biodiesel and compared with the neat diesel. The 60% blend of biodiesel with the conventional diesel fuel gives the maximum efficiency and reduction in smoke or reduction in carbon monoxide and hydrocarbon emissions. Park et al. (2012) investigated the emission reduction characteristics of bio-ethanol blended diesel fuel at early injection condition including spray, atomization and evaporation characteristics. The spray atomization and evaporation characteristics were investigated using spray visualization system and KIVA-3V code, respectively. In their work, the effect of ethanol blending on the spray behavior was more evident at the early injection condition. They suggested to reduce the droplets size for better atomization characteristics. They found that HC emission increases and the CO emission decreases with the blending of the ethanol.

The details of apparatus and preparation of bio-fuels are discussed in the next section.

3.0 Description of apparatus and preparation of bio-fuels

The computerized variable compression ratio multi-fuel engine test rig is an automatic engine which makes our work easier by calculating the various parameters. Both petrol and diesel fuels may be used on this engine. The compression ratio can be varied from 5:1 to 20:1. The load can also be varied from 0-10 KG. By varying the load or the compression ratio the efficiencies and the specific fuel consumption may be calculated. The minimum fuel required for proper engine functioning is 5 litre. The engine contains two sensors one for petrol and other for diesel. Their main function is to decide the range of the fuel level. Specification of computerized variable compression ratio multi-fuel engine test rig is shown in Table 1.

Table 1 Specifications of computerized variable compression ratio multi-fuel engine test rig

Make	LEGION BROTHERS
BHP	3-5 HP
Speed	1450-1600 r.p.m. variable governed speed
No. of cylinder	1
Compression ratio	5:1 to 20:1
Bore	80 mm
Stroke	110 mm
Type of ignition	Spark ignition (time adjustment: 0-70 degree ATDC: 0-70 degree BTDC or Compression ignition
Method of loading	Eddy current dynamometer
Method of cooling	Water

4.1 Preparation of bio-fuel from vegetable oil

Production of bio-diesel was carried out using a bio-fuel reactor. Bio-fuel reactor contains magnetic stirrer, condenser, flask, pump and the tub. The raw material used was vegetable oil (mustard oil or refined Soyabean oil). One litre of vegetable oil along with methanol (in appropriate quantity, depending on the oil used) was mixed in the round bottom flask. Five grams of catalyst (potassium hydroxide) was added in the mixture. The whole mixture (oil + catalyst + methanol) is heated up to the temperature of about 60 degree Celsius and is stirred at a constant r.p.m. For Soyabean oil, the whole process is allowed to run for 1 hour 30 minutes and for mustard oil the whole process is allowed to run for 1 hour 15 minutes approximately.

When the process is over, the mixture is allowed to settle for at least 4 hours. Two layers are observed after settling of the mixture, the upper and the bottom layer. The ester is visible in the upper layer and the glycerol in the bottom layer. The layers are separated using separating funnel and the glycerol is removed from the mixture. After removing glycerol from the ester, the warm water is added to the remaining part of the ester. The mixture is shaken for 4 to 5 times and mixture is then kept undisturbed for next 1 hour. Again two layers are observed, the upper layer is of bio-fuel and the lower one is of impure solution of potassium hydroxide with the water.

3.2 YIELD OF BIO-FUEL

The details of the mixture of the two fuels are as follows:

(i) Soyabean Mixed fuel:

Soyabean oil = 1 litre, Methanol used = 168 ml

Catalyst used: Potassium hydroxide (KOH) = 5 gm

Time taken for experiment = 1.30 hours

Temperature = 61^0 C, Maximum yield of bio-fuel = 900 ml

(ii) For Mustard oil,

Mustard oil = 1 litre, Methanol used = 220 ml

Catalyst used: Potassium hydroxide (KOH) = 5 gm

Time taken for experiment = 1.15 hours

Temperature = 59^0 C, Maximum yield of bio-fuel = 983 ml

For soyabean oil 168 ml is the maximum amount of methanol, which may be added in the vegetable oil for the transesterification reaction and for the mustard oil, the maximum amount of methanol added is 220 ml. If more methanol is added then it remains un-reacted in the mixture and floats on the top surface which leads to the wastage of methanol and money.

3.3 PERFORMANCE OF ENGINE WITH VARIOUS BLENDS OF FUELS

The performance of the engine is observed by using 20-PRS (blending of 20% soya-bean oil with the petrol) and 20-PRM (blending of 20% mustard oil with the petrol) by varying loads from 2.5 Kg and 5.0 Kg at the compression ratio of 10.

3.3.1 Performance of engine, using 20% blends of soyabean oil with petrol (20-PRS)

The performance of the engine by using 20% blends of soyabean oil with petrol (20-PRS) at the engine loads of 2.5 Kg is observed and discussed in this section.

3.3.1.1 Performance of engine using 20-PRS at the load of 2.5 Kg

The variation of pressure w.r.t. to crank angle at 2.5 Kg load for 20-PRS is shown and discussed in this section.

(a) Pressure v/s crank angle

Following values of the parameters are observed by using the blend of 20-PRS at the engine load of 2.5 Kg:

Maximum pressure raise rate angle = 363.10^0

Maximum pressure raise rate = 2.90 bar/degree

Spark angle = 337.00^0

Maximum pressure crank angle = 369.21^0

Maximum pressure = 72.52 bar

EEOC = 431.06^0

The maximum pressure increase rate angle is 363.10^0. It is shown by the dashed line in red colour as shown in Fig. 2. The maximum pressure raise rate is equal to 2.90 bar/degree. The red line which is continuous shows the crank angle for estimated end of combustion (EEOC) and its value is equal to 431.06^0. EEOC is required for determining the normalizing value for mass burnt fraction and heat release rate. The maximum pressure angle is 369.21^0 with a maximum pressure of 72.52 bar. The variation in the pressure w.r.t. crank angle at the load of 2.5 Kg for 20-PRS is shown in Fig. 2.

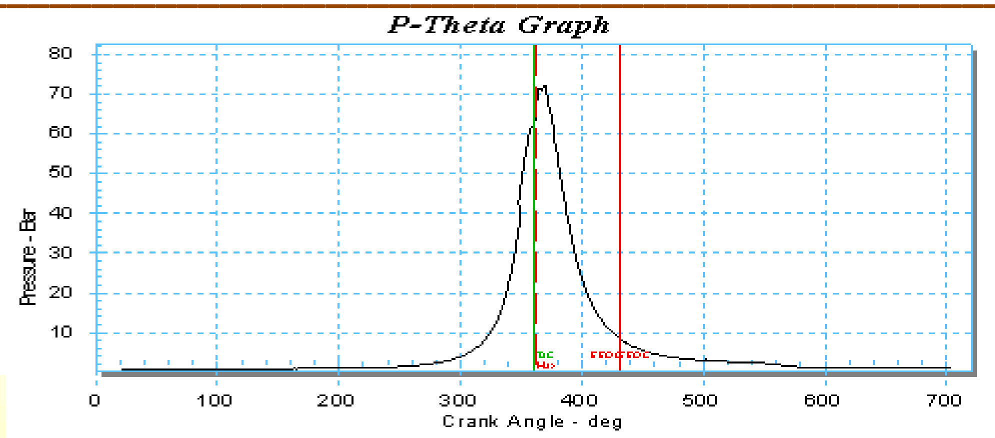

Fig. 2 Pressure V/S crank angle at a load of 2.5 Kg for 20-PRS

(b) Pressure V/S volume

Following values of the parameters are observed by using the blend of 20-PRS at the engine load of 2.5 Kg:

Indicated mean effective presure = 11.14 bar

Brake mean effective pressure = 1.31 bar

Frictional mean effective pressure = 9.83 bar

Indicated power = 8.53 KW

Brake power = 1 KW Frictional power = 7.52 KW

Mechanical efficiency = 11.8 %

The mechanical efficiency of 11.8% and indicated mean effective pressure (imep) of 11.14 bar are observed at 2.5 Kg load for 20-PRS. In the pressure-volume plot, the area which is encircled clockwise represents the positive work produced by combustion. The very narrow area which is encircled counterclockwise represents the work required to pump gases through the cylinder is counted as negative work. The variation in pressure w.r.t. to volume at a load of 2.5 Kg for 20-PRS is shown in Fig. 3.

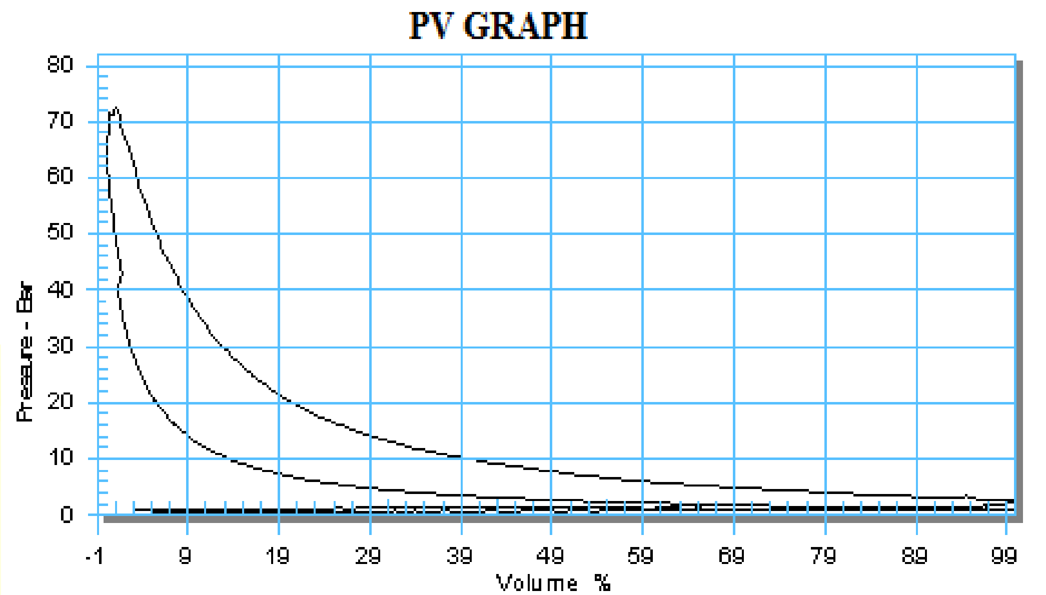

Fig. 3 Pressure V/S volume at 2.5 KG load for 20-PRS

(c) Heat Release Rate

Maximum heat release rate angle = 336.90^0

Combustion starts at an angle = 374.8^0

The heat release rate varies as the crank angle changes as shown in Fig. 4. The dashed green line shows the top dead centre position. The maximum heat release rate angle is observed as 336.90^0. If the heat release rate decreases then it occurs due to unburnt fuel and the increased heat release rate shows the proper burning of the fuel. The variation in heat release rate w.r.t. crank angle at a load of 2.5 Kg for 20-PRS is shown in Fig. 4.

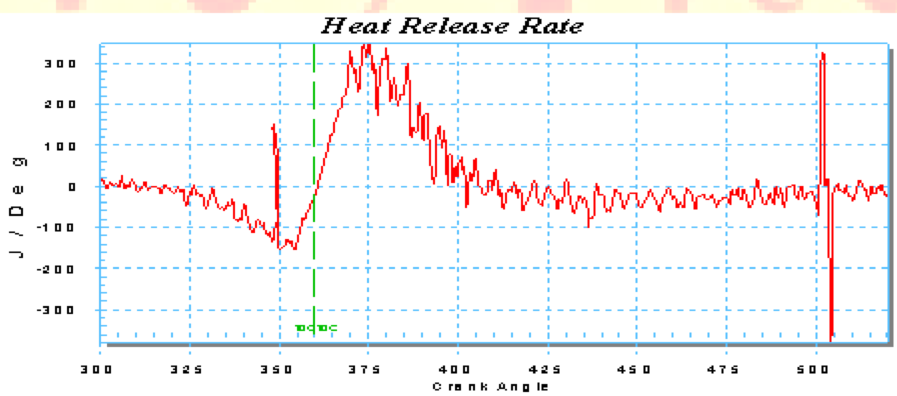

Fig. 4 Heat release rate V/S crank angle at the load of 2.5 Kg for 20-PRS

3.3.1.2 Performance of engine using 20-PRS at the load of 5.0 Kg

The variation of pressure w.r.t. to crank angle at 5 Kg load for 20-PRS is shown and discussed in this section.

(a) Pressure v/s crank angle

Following values of the parameters are observed by using the blend of 20-PRS at the engine load of 5.0 Kg:

Maximum pressure raise rate angle = 363.10^0

Maximum pressure raise rate = 2.90 bar/degree

Spark angle = 337.00^0

Maximum pressure crank angle = 369.21^0

Maximum pressure = 72.52 bar, EEOC = 431.06^0

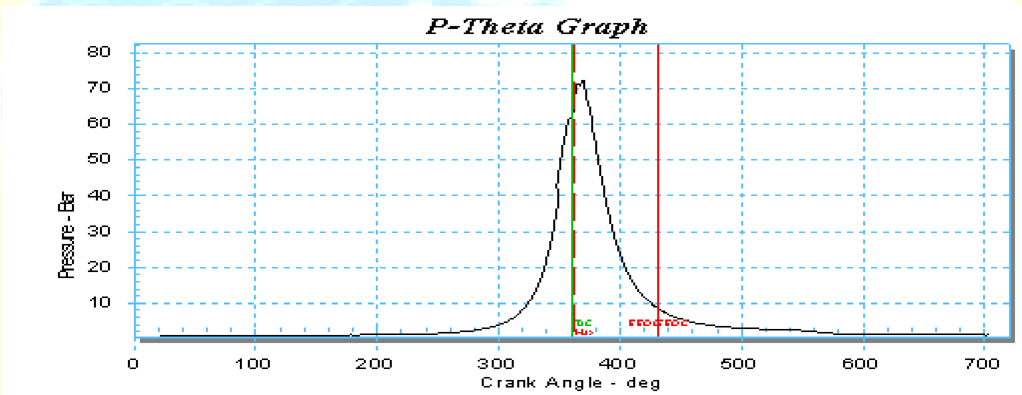

Fig. 5 Pressure V/S crank angle at a load of 5 Kg for 20-P

(b) Pressure V/S volume

Indicated mean effective presure = 12.18 bar

Brake mean effective pressure = 2.63 bar

Frictional mean effective pressure = 9.55 bar

Indicated power = 8.98 KW, Brake power = 2 KW

Frictional power = 7.04 KW, Mechanical efficiency = 21.6 %

The variation in pressure w.r.t. volume at the load of 5.0 Kg for 20-PRS is shown in Fig.6.

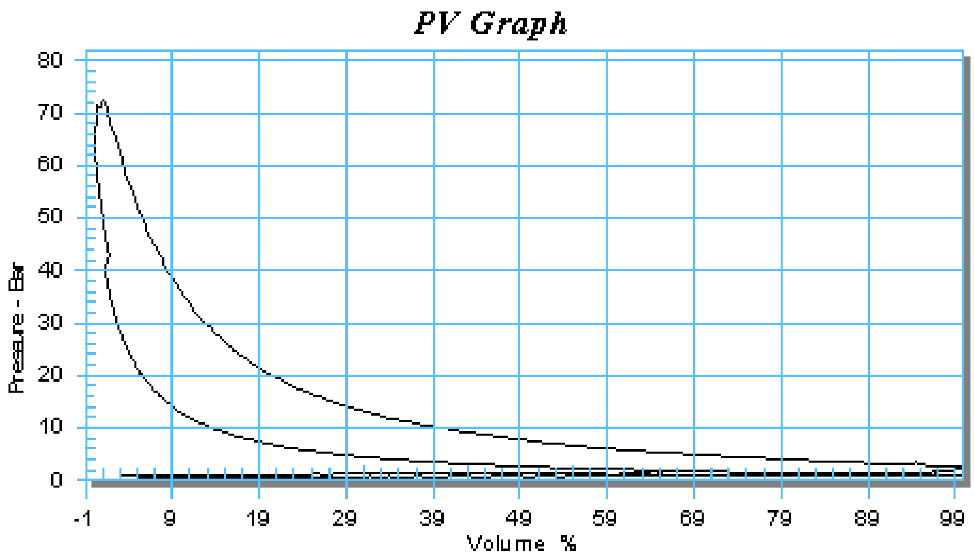

Fig. 6 Pressure V/S volume at 5 Kg load for 20-PRS

(c) Heat Release Rate

Maximum heat release rate angle = 333.52^0

Maximum heat release rate = 575.86 J/degree

Combustion starts at an angle = 374.8^0

The variation in heat release rate w.r.t. crank angle at the load of 5.0 Kg for 20-PRS is shown in Fig. 7.

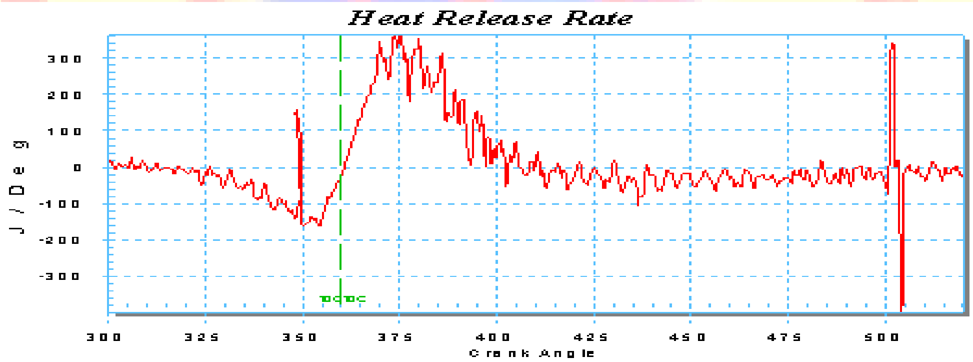

Fig. 7 Heat release rate V/S crank angle at a load of 5.0 Kg for 20-PRS

3.3.2 Performance of engine, using 20% blends of mustard oil with Petrol (20-PRM)

The performance of the engine by using 20% blends of mustard oil with petrol (20-PRM) at the engine loads of 2.5 Kg is observed and discussed in this section.

3.3.2.1 Performance of engine using 20-PRM at the load of 2.5 Kg

The variation of pressure w.r.t. to crank angle at 2.5 Kg load for 20-PRM is shown and discussed in this section.

(a) Pressure v/s crank angle

Following values of the parameters are observed by using 20-PRM at the engine load of 2.5 Kg:

Maximum pressure raise rate angle = 363.10^0

Maximum pressure raise rate = 2.90 bar/degree

Spark angle = 337.00^0

Maximum pressure crank angle = 369.21^0

Maximum pressure = 72.52 bar

EEOC = 431.06^0

The variation in the pressure w.r.t. crank angle at the load of 2.5 Kg for 20-PRM is shown in Fig. 8.

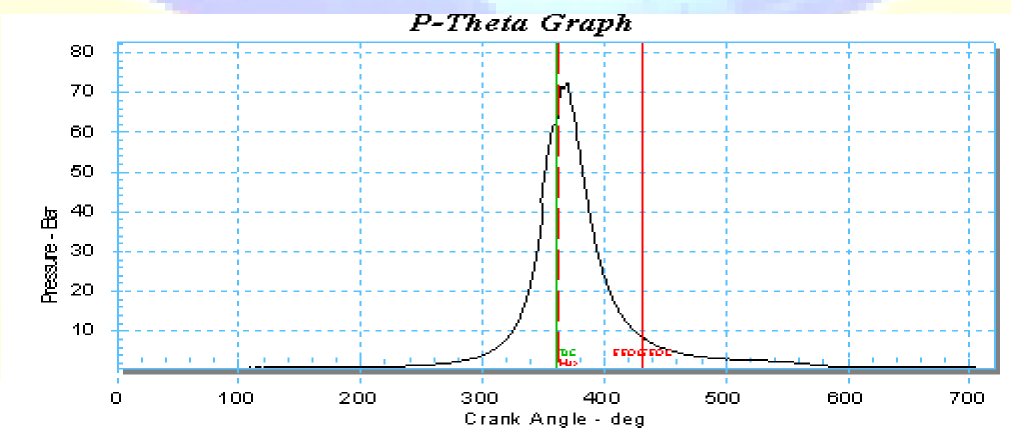

Fig. 8 Pressure V/S crank angle at a load of 2.5 KG for 20-PRM

(b) Pressure V/S Volume

Indicated mean effective pressure = 6.22 bar

Brake mean effective pressure = 1.32 bar

Frictional mean effective pressure = 4.91 bar

Indicated power = 4.82 KW, Brake power = 1 KW

Frictional power = 3.80 KW, Mechanical efficiency = 21.2 %

The mechanical efficiency of 21.2% is obtained at 2.5 Kg load for 20-PRM which is more than the petrol. The indicated mean effective pressure (imep) is 6.22 bar. In pressure-volume plot, the area which is encircled clockwise represents the positive work produced by combustion. The very narrow area which is encircled counterclockwise represents the work required to pump gases through the cylinder as is counted as negative work. The variation in pressure w.r.t. volume angle at the load of 2.5 Kg for 20-PRM is shown in Fig. 9.

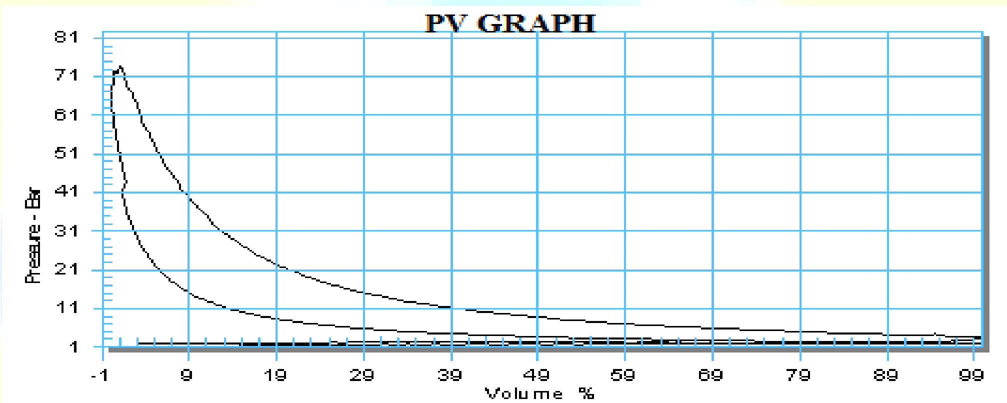

Fig. 9 Variation of pressure V/S volume at 2.5 Kg load for 20-PRM

(c) Heat release rate

Maximum heat release rate angle = 265.83^0

Combustion starts at an angle = 374.8^0

The heat release rate varies as the crank angle changes, as shown in Fig. 10. The dashed green line shows the top dead centre position. The maximum heat release rate angle is found to be 265.83^0. The variation in heat release rate w.r.t. crank angle at the load of 2.5 Kg for 20-PRM is shown in Fig. 10.

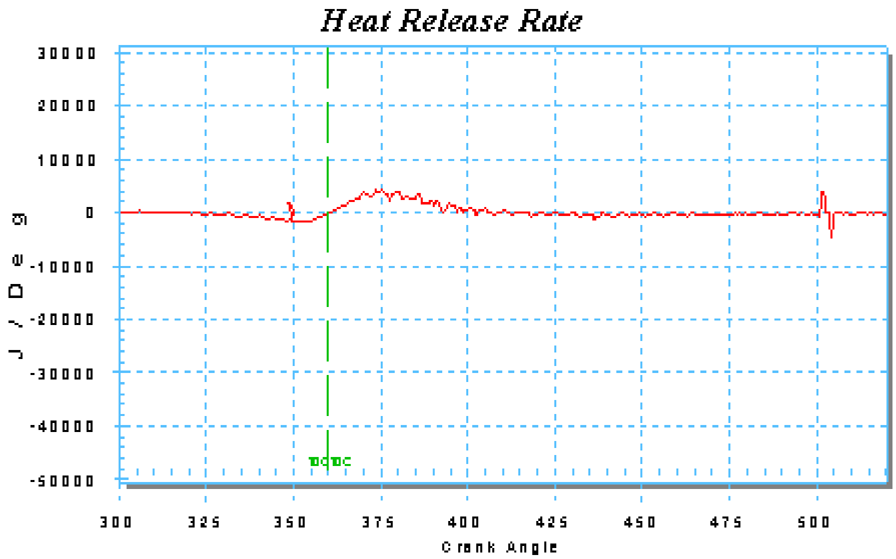

Fig. 10 Heat release rate V/S crank angle at 2.5 Kg load for 20-PRM

3.3.2.2 Performance of engine using 20-PRM at the load of 5.0 Kg

The variation of pressure w.r.t. to crank angle at 5.0 Kg load for 20-PRM is shown and discussed in this section.

(a) Pressure v/s crank angle

Following values of the parameters are observed by using 20-PRM at the engine load of 5.0 Kg:

Maximum pressure raise rate angle = 363.10^0

Maximum pressure raise rate = 2.90 bar/degree

Spark angle = 337.00^0, Maximum pressure crank angle = 369.21^0

Maximum pressure = 72.52 bar, EEOC = 431.06^0

The variation in pressure w.r.t. crank angle at the load of 5.0 Kg for 20-PRM is shown in Fig. 11.

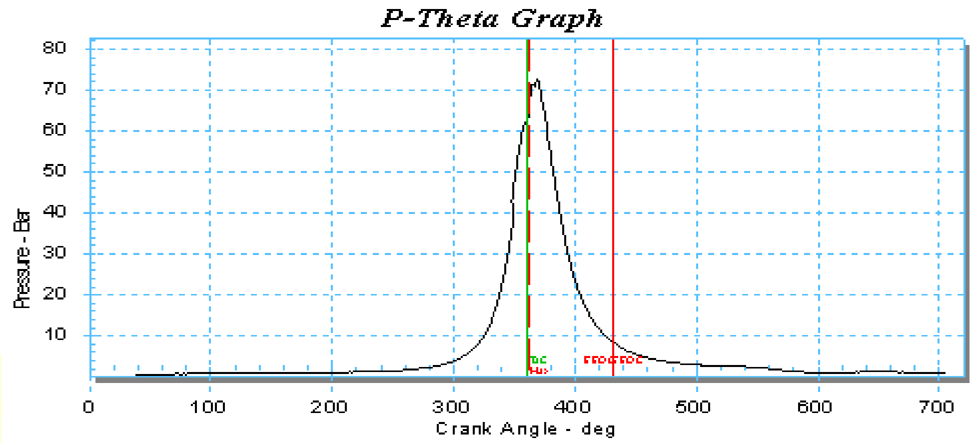

Fig. 11 Pressure V/S crank angle at a load of 5 Kg for 20-PRM

(b) Pressure V/S volume

Indicated mean effective presure = 7.766 bar

Brake mean effective pressure = 2.78 bar

Frictional mean effective pressure = 4.985 bar

Indicated power = 5.865 KW, Brake power = 2.1 KW

Frictional power = 3.76 KW, Mechanical efficiency = 35.8 %

The variation in pressure w.r.t. volume at the load of 5.0 Kg for 20-PRM is shown in Fig. 12.

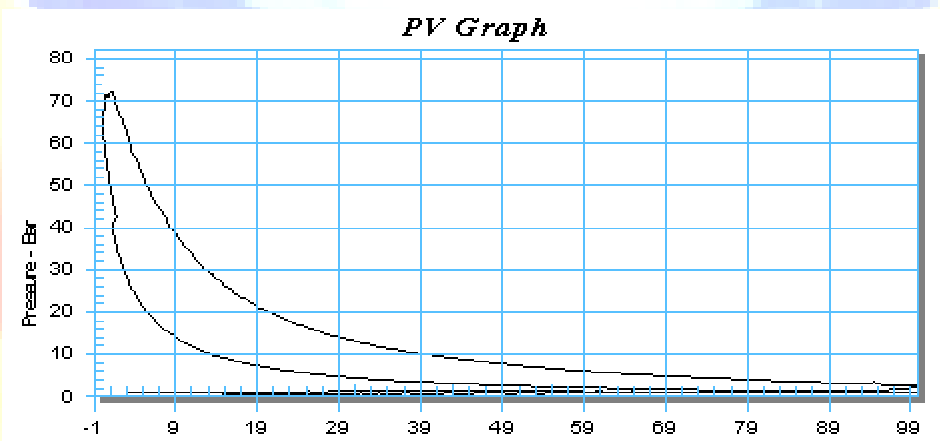

Fig. 12 Pressure V/S volume at 5 Kg load for 20-PRM

(c) Heat Release Rate

Maximum heat release rate angle = 429.45^0

Combustion starts at an angle = 374.8^0

The variation in heat release rate w.r.t. crank angle at the load of 5.0 Kg for 20-PRM is shown in Fig. 13.

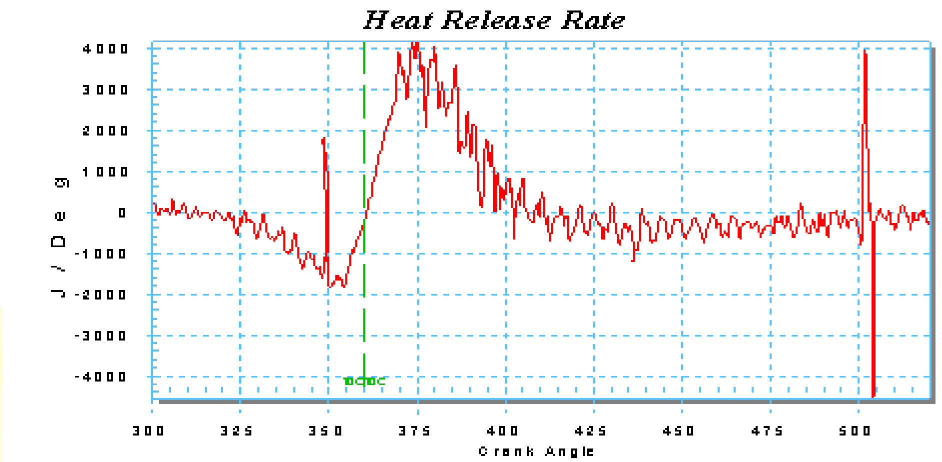

Fig. 13 Heat release rate V/S crank angle at the load of 5 Kg for 20-PRM

4.0 ANALYSIS AND COMPARISONS OF THE PERFORMANCE OF BOTH THE FUELS

Variations in the performance of both the blended fuels at the engine loads of 2.5 and 5.0 are presented in this section. Table 2 shows the performance comparisons of the fuels, used in the engine at various loads.

Table 2 Performance comparisons of the fuels

S. No.	Parameters	20-PRS		20-PRM	
		Load 2.5 Kg	Load 5.0 Kg	Load 2.5 Kg	Load 5.0 Kg
1.	Mechanical efficiency	11.8 %	21.6 %	21.2 %	35.8 %
2.	Indicated power	8.53 KW	8.98 KW	4.82 KW	5.865 KW
3.	Brake power	1.0 KW	2.0 KW	1 KW	2.1 KW
4.	Frictional power	8.53 KW	7.04 KW	3.80 KW	3.76 KW
5.	Maximum pressure increase rate	2.90 bar/degree	2.90 bar/degree	2.90 bar/degree	2.90 bar/degree
6.	Maximum pressure crank angle	369.21^0	369.21^0	369.21^0	369.21^0

7.	Maximum heat release rate angle	336.90^0	333.52^0	265.83^0	429.45^0
8.	Maximum pressure developed	72.52 bar	72.52 bar	72.52 bar	72.52 bar

Following facts are observed from the Table 2:

(i) The maximum mechanical efficiency of 35.8 % is obtained by using the blend of 20-PRM at the engine load of 5.0 Kg while minimum mechanical efficiency of 11.8% is obtained by using 20-PRS at the engine load of 2.5 Kg.

(ii) The maximum developed Indicated power (8.98 KW) is obtained by using the blend of 20-PRS at the engine load of 5.0 Kg while minimum developed Indicated power (4.82 KW) is obtained by using 20-PRM at the engine load of 2.5 Kg.

(iii) The maximum brake power (2.1 KW) is observed by using the blend of 20-PRM at the engine load of 5.0 Kg while minimum brake power (1.0 KW) is observed by using both the blends of fuel (20-PRS and 20-PRM) at the engine load of 2.5 Kg.

(iv) The maximum frictional power (8.53 KW) is observed by using the blend of 20-PRS at the engine load of 2.5 Kg while minimum frictional power (3.76 KW) is observed by using 20-PRM at the engine load of 5.0 Kg.

(v) The Maximum heat release rate angle (429.45^0) is observed by using the blend of 20-PRM at the engine load of 5 Kg while minimum pressure increase rate (265.83^0) is observed by using the same blend at the engine load of 2.5 Kg.

(vi) The values of maximum developed pressure (72.52 bar), maximum pressure increase rate (2.90 bar/degree) and maximum pressure crank angle (369.21^0) are maintained constant for all the fuels and engine loads.

(vii) The compression ratio of 10 is maintained for all the experiments performed in the computerized variable compression ratio multi-fuel (CVCRM) engine test rig.

7.0 CONCLUSIONS

Vegetable oils have the potential to substitute a fraction of petroleum distillates and petroleum-based petro chemicals in the near future. The basic constituent of vegetable oils is triglyceride. Vegetable oils comprise 90 to 98% triglycerides and small amounts of mono and diglycerides.

These usually contain free fatty acids (FFAs), water, sterols, phospholipids, odorants and other impurities. The advantages of vegetable oils as diesel fuel are their portability, ready availability, renewability, higher heat content (about 88% of D2 fuel), lower sulfur content, lower aromatic content, and biodegradability. The main disadvantages of vegetable oils as diesel fuel are high viscosity, low volatility, and the reactivity of unsaturated hydrocarbon chains.

A comparative study and comparisons of the various parameters have been presented in the paper. The comparisons have been made among the two blends of fuel which are prepared from the blending of soya-bean and mustard oils with petrol. It is found that the maximum mechanical efficiency of 35.8 % is obtained by using the blend of 20-PRM at the engine load of 5.0 Kg while minimum mechanical efficiency of 11.8% is obtained by using 20-PRS at the engine load of 2.5 Kg. The values of compression ratio (10), maximum developed pressure (72.52 bar), maximum pressure increase rate (2.90 bar/degree) and maximum pressure crank angle (369.21^0) are maintained constant for all the fuels and engine loads.

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