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Performance Test On VCR Engine Working with Juliflora and Radish Bio Diesel Blended with Diesel

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ABSTRACT

The performance of the engine is considered to be as one of the most important factor for any automobile. Biodiesel as a renewable source of fuel for diesel engine application. In this work, biodiesel is fumigated and diesel fuel will be used as an ignition source. The comparable study of emission and performance characteristics of biodiesel and diesel fuel is carried out in this project. The performance characteristics like BMEP, IP, IMEP, BSFC, BTE, ITE, Mechanical Efficiency and Heat in exhaust are compared.

To overcome the need of alternate fuels in the field of automobile in upcoming years due to over population and less availability of field like diesel, we tried out various proportion of Juliflora and Radish along with desired quantity of diesel considering various engine and environmental facts. The fuel properties of Juliflora were found to be similar to the diesel fuel and DEE has high volatility and high cetane number hence used for a alternative fuel for diesel. The experiments were conducted on a VCR engine with different blends like D, B_{20}, B_{40}. The engine performance characteristics and emission characteristics were compared.

Keyword: Energy, Bio Fuel, Bio Diesel

1. INTRODUCTION

The resources of petroleum as fuel are dwindling day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of biology, it has provided an effective way to fight against the problem of petroleum scarce and the influences on environment. Biodiesel is a renewable, clean-burning diesel replacement that is reducing. Made from a diverse mix of feedstock including recycled cooking oil, soybean oil, and animal fats, it is the first and only EPA-designated Advanced Biofuel in commercial-scale production across the country and the first to reach 1 billion gallons of annual production. Meeting strict technical fuel quality and engine performance specifications, it can be used in existing diesel engines without modification and is covered by all major engine manufacturers' warranties, most often in blends of up to 5 percent or 20 percent biodiesel. It is produced at plants in nearly every state in the country. Bio-diesel is the most valuable form of renewable energy that can be used directly in any existing, unmodified diesel engine. Biofuels are diversified as alcohols, ethers, esters, carbonates and acetate compounds, containing inbuilt oxygen, and are emerging as potential substitute for diesel. Significantly, these less viscous biofuel which are deemed to be synthesized from plants parts, unlike the triglycerides (vegetable oils), have one phenomenon in unison, which relates to their lower cetane number and viscosity. Despite their lower ignition quality, these fuels could be used in diesel engine by blending it with diesel, which is regarded as the simplest way to use alcohol or other less viscous fuels. The above discussion on fuels with lower viscosity and cetane number identifies three new research scopes: (1) Though a variety of vegetable oil based fuels have been conceived, lesser attention or interest has been paid to conceive less viscous biofuel

in the likes of ethanol and methanol (2) There seems to be a lack in sufficient data on fumigation studies for fuels with lower viscosity and cetane number, whereas a lot of data have been made available for the operation of these fuels in blend fuel mode. (3) Absence of contributions to examine the fundamental study on vaporization of the fuels being fumigated and couple it with engine fumigation study. With the above stated shortcoming, it is decided to embark on a research work that would address the limitations of previous research works. A new renewable fuel derived from as a potential candidate for diesel engine. Rather than using it in blends with diesel, it was inducted into the engine cylinder through inlet manifold, while diesel was supplied through main injection system. Further, the inlet air was also preheated to evaporate the injected fuel, whereby, hot vaporized biodiesel/air mixture was inducted into the cylinder. The preheat temperature was decided based on the outcome of suspended droplet evaporation study, conducted prior to engine study. Biodiesels have calorific values close to diesel fuel which makes it a potent candidate for replacement of diesel. However, it has very high viscosity but that can be reduced by transesterification. There are different methods available to reduce viscosity of the vegetable oils such as Preheating, Transesterification, pyrolysis etc. A lot of researchers and scientists are already working on developing new and efficient methods of synthesizing biodiesel from biofuel. This biodiesel can be used as an alternate fuel. It can be directly fuelled in CI engine without much engine modifications.

1.1 Advantages of Vegetable Oils as Diesel Fuel

The advantages of vegetable oils as diesel fuel are

- Liquid nature-portability
- Ready availability
- Renewability
- Higher heat content (about 88% of no. 2 diesel fuel)
- Lower sulfur content
- Lower aromatic content
- Biodegradability

Bio-fuels contain carbon that was taken out of the atmosphere by plants and trees as they grew. The fossil fuels are adding huge amounts of stored carbon dioxide (CO_2) to the atmosphere, where it traps the Earth's heat like a heavy blanket and causes the world to warm. Studies show that bio-diesel reduces CO_2 emissions to a considerable extent and in some cases all most nearly to zero.

- Biodiesel can be used in the existing engines without any modifications.
- Biodiesel obtained from vegetable sources does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.

PRODUCTION OF BIODIESEL AND TESTING

Production:

Biodiesel is typically produced by the reaction of a vegetable oil or animal fats with an alcohol such as methanol or ethanol in the presence of catalyst to yield mono-alkyl esters (biodiesel) and glycerin. This reaction is called transesterification. Raw or refined vegetable oil or recycled greases that have not been processed into biodiesel are not biodiesel. Care must be taken to then separate the finished biodiesel from the glycerin, catalyst, soaps and any excess alcohol that may remain.

Different methodologies used for production of biodiesel are: I Direct Use and Blending

II Transesterification Process

III Thermal Cracking (Pyrolysis)

IV Micro-emulsion.

Direct Use and Blending:

The animal fat or vegetable oil can be used as a fuel in direct injection engines; it has a good heating value and could give a sufficient power. But it has some problems due to its unacceptable properties, so it cannot be used in DI engine without any modification. To avoid such problems, the alternative fuel sources are directly blended with conventional fossil fuels. This kind of blending will improve the fuel quality, reduces the fossil fuel consumption, etc., so it is also preferable as a most convenient way to use an alternative fuels such as biofuel. The bio oil and diesel blends will be in different ratio like 10:1,10:2, 10:3, etc.,

Transesterification:

The transesterification process is a reaction between triglycerides in the vegetable and alcohol which produces the biodiesel (mono alkali ester) and glycerol.

In this process some catalyst also used to increase the speed of the reaction and quality of the outcome product. The amount and types of catalyst are decided by the amount of free fatty acid present in the feed stock oil. The higher amount of free fatty acid is unfavorable for biodiesel production which leads to formation of soap and biodiesel yield efficiency.

Base catalyst transesterification process

In this stage of process, potassium Hydroxide (KOH), sodium hydroxide (NaOH) and sodium methoxide are used as a catalyst. The sodium methoxide is most efficient catalyst but it is not economic. It is a reaction between alcohol and oil with the presence of base catalyst. The reaction temperature (500°C –600°C) should also be maintained in order to get highest biodiesel yield. The reaction temperature should be below of methanol boiling point. Otherwise methanol is wasted due to vaporization. The stirring process (1300 rpm) is carried throughout the process for dynamic mixing to increase the rate of reaction. Nearly one hour it will take place to complete the reaction. By the above reaction the biodiesel and glycerol producedwill be separated.

Steps involved in production of Biodiesel

- Jatropha oil is preheated to 65°C.
- 100 gm of preheated Jatropha oil is poured into a round bottom flask.
- 1.8 ml of concentrated sulfuric acid is added to flask and stirred well.
- Then 60 ml of methanol is added.
- Temperature is kept at 60 °C and agitated at 400 rpm for 2.5 hrs.
- After 2.5 hrs the mixture heated to 85 °C for 20 min to remove excess methanol and impurities.
- Then the contents are transferred to separating funnel for further separation and kept undisturbed for 2 hours.
- Drain off the lower layer.

Acid catalyst esterification process

Some feed stock oil has more than 1% free fatty acid; this free fatty oil cannot be converted into biodiesel. So the yield of biodiesel from the transesterification process will be very low. In this case the feed stock oil is involved to the acid catalyst esterification before the base catalyst transesterification process. Here the free fatty acid is converted into the ester. This process also can used to convert the triglycerides into the biodiesel but it will take more time so it is not preferable. In this process the alcohol will reacts with oil using acid catalyst and produces the biodiesel and water, the water must be removed immediately because the water will leads to the formation of soap while in base catalyst transesterification process. Here phosphoric acid or sulphuric acid is used as a catalyst. The product obtained from acid catalyst is use to produce biodiesel through base case catalyst transesterification process stock for 12 hours to 24 hours. The upper layer is biodiesel and the lower will be the glycerol.

Thermal Cracking (Pyrolysis):

Thermal cracking is a process of convert the complex structure of hydrocarbons into its simplest structure with or without catalyst. Due to this process the density and viscosity of oil will reduce. In vegetable oil as an alternative fuel this two properties are affecting the atomization of engine. So the fuel treated by this process which could be use directly in diesel engine without any modification. Generally alumina, zeolite and redmud are used as a catalyst in thermal cracking process for biodiesel production. The thermal cracking process will happens by the temperature between 250O°C and 350O°C. The thermal cracking biodiesel plant has a reactor with safety valve, drain pipe, temperature indicator, etc., the oil or animal fat need to be converting into the biodiesel is placed inside the reactor, then heat is applied to the reactor. Now the oil or animal fat get vaporized and reach the condenser through pipe. The condenser cools the vapor in the liquid.

Microemulsion

The micro emulsion is defined as thermodynamically stable, isotropic liquid mixtures of oil, water and surfactant (compounds that lower the surface tension of a liquid, the interfacial tension between two liquids). This process will solve the problem in viscosity and some other atomization properties of oil. Generally the alcohol used to increase the volatile property of oil, it reduces the smoke. Alkyl nitrate will be the cetane number improver. The micro emulsion process also used to get a good spry property when injected into the engine by nozzle. If micro emulsified. Diesel used in diesel engine, some problems will arise such as incomplete combustion, carbon deposit and nozzle failure collected in the beaker which is called as biodiesel.
Evaluated the combustion and emission characteristics of fumigation pine oil as a biofuel.Pine oil biofuel, obtained by the distillation of oleoresins of pine tree, has been chosen as a new renewable fuel for its operation in diesel engine. From this study, it was observed that at higher air temperature (150°C), evaporation of pine oil was more effective than at lower temperatures (100°C and 50°C) and therefore, 150°C was chosen as preheat temperature for engine fumigation study. The fumigated pine oil has been reported to be better, with 36% injection of pine oil showing 10.3% higher in-cylinder pressure than that for 6% injection of pine oil at 100% load. From the emission analysis, the relative emission of HC, CO and smoke were noticed to be lower than diesel, while NO_X emission was higher.

VARAIABLE COMPRESSION RATIO DIESEL ENGINE

Variable compression ratio (VCR) diesel engine

The variable compression ratio (VCR) diesel engine used to conduct the experiments is a single cylinder, four stroke, water cooled, direct injection engine. The engine is mounted on a stationary frame with a suitable cooling system. The lubricating system is inbuilt in the engine. Designing high performance vehicles that are fuel efficient and clean is difficult since we also want them to remain inexpensive.

It is therefore necessary to find simple, low cost and effective solutions, and that is the whole strategy of the Variable Compression Ratio (VCR) engine producers. Far from being a revolution, VCR engines are a major evolution of conventional engines. The concept of variable compression ratio (VCR) promises improved engine performance, efficiency, and reduced emissions. The higher cylinder pressures and temperatures during the early part of combustion and small residual gas fraction owing to higher compression ratio give faster laminar flame speed.

Therefore, the ignition delay period is shorter. As a result, at low loads, the greater the compression ratio, the shorter is the combustion time. Time loss is subsequently reduced. Therefore, it seems reasonable that fuel consumption rate is lower with high compression ratios at part load. The VCR can make a significant contribution to thermodynamic efficiency. The main feature of the VCR engine is to operate at different compression ratios, depending on the vehicle performance needs. A VCR engine can continuously vary the compression ratio by changing the combustion chamber volume. In a VCR engine, thermodynamic benefits appear

throughout the engine map. At low power levels, the VCR engine operates at a higher compression ratio to capture high fuel efficiency benefits, while at high power levels the engine operates at low compression ratio to prevent knock. The optimum compression ratio is determined as a function of one or more vehicle operating parameters such as inlet air temperature, engine coolant temperature, exhaust gas temperature, engine knock, fuel type, octane rating of fuel etc. In a VCR engine, the operating temperature is more or less maintained at optimum, where combustion efficiency is high.

A summary of VCR concepts

Historically, every mechanical element in the power conversion system has been considered a way to achieve variable compression ratio. Designs presented solutions which modifies the compression ratio by:

- moving the cylinder head;
- variation of combustion chamber volume
- variation of piston deck height
- modification of connecting rod geometry
- moving the crankshaft axis

In many cases, the deviation from conventional production engine structure or layout represents a significant commercial barrier to wide spread adoption of the technology.

Compression ratio setting

The engine with fixed compression ratio can be modified by providing additional variable combustion space. There are different arrangements by which this can be achieved. Tilting cylinder block method is one of the arrangements which can be used to vary the combustion space volume. The engine is made to operate as a variable compression ratio (VCR) engine by providing a tilting block arrangement to suitably change the compression ratio (CR) to the desired value in the given range without stopping the engine and without altering the combustion chamber geometry.

The tilting cylinder block arrangement consists of a tilting block with six allen bolts, a compression ratio adjuster with lock nut and compression ratio indicator. For setting a chosen compression ratio, the allen bolts are to be slightly loosened. Then, the lock nut on the adjuster is to be loosened and the adjuster is to be rotated to set a chosen compression ratio by referring to the compression ratio indicator and to be locked using lock nut. Finally all the allen bolts are to be tightened gently. The compression ratios considered for conducting the experiments are 14, 15, 16, 17,
17.5 and 18. Due to rough running of the engine and greater vibration, the compression ratio below 14 is not set though there is a provision to set the CR value up to 12.

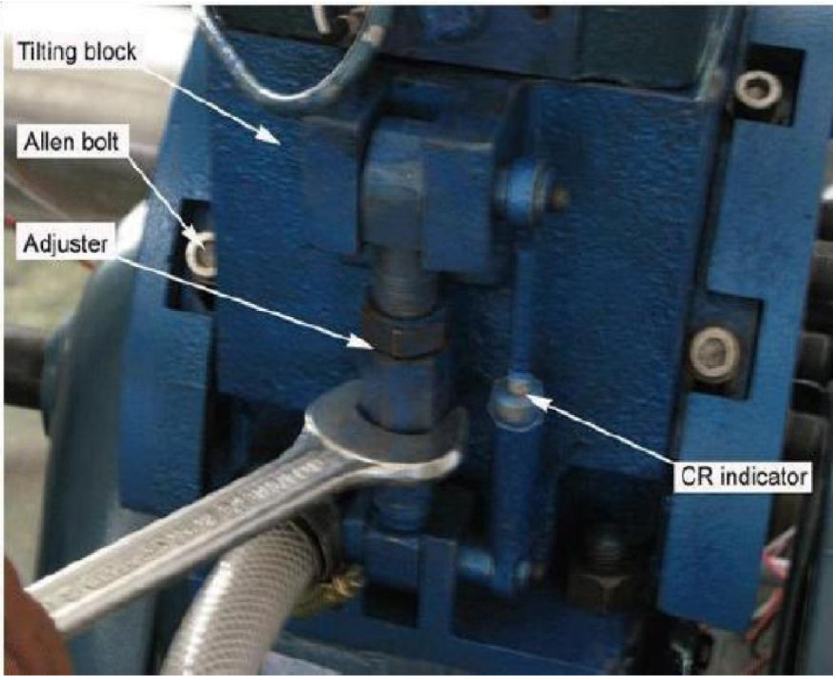


Figure 4.1 Compression Ratio Setting

Measurement systems

Various measurement systems used to capture the experimental data used in the test rig are load measurement system, fuel injection pressure measurement system, cylinder pressure measurement system, emission measurement system and data acquisition system.

Load measurement system

The experimental study is conducted at various loads and hence an accurate and reliable load measuring system is a must. The load measuring system of this experimental test rig consists of a dynamometer of eddy current type, a load cell of strain gauge type and a loading unit. The load is applied by supplying current to the dynamometer using a loading unit. The load applied to the engine is measured by a load cell.

The VCR diesel engine is directly coupled to the eddy current dynamometer with a loading unit using which desired loads up to 12kg can be applied. The load measurement is made using a strain gauge load cell and the speed measurement is done using a shaft mounted on a crank angle sensor. The bearings rotate within the casing supported in ball bearing trunnions which form a part of the bed plate of the machine. Inside the casing, there are two field coils connected in series. Evaluated the combustion and emission characteristics of fumigation pine oil as a biofuel.Pine oil biofuel, obtained by the distillation of oleoresins of pine tree, has been chosen as a new renewable fuel for its operation in diesel engine. From this study, it was observed that at higher air temperature (150°C), evaporation of pine oil was more effective than at lower temperatures (100°C and 50°C) and therefore, 150°C was chosen as preheat temperature for engine fumigation study.

The eddy current dynamometer unit basically comprises of a rotor, shaft, bearings, casing and bed plate. The rotor is mounted on the shaft which runs in the bearings. The bearings rotate within the casing supported in ball bearing trunnions which form a part of the bed plate of the machine. Inside the casing, there are two field coils connected in series. When a direct current is supplied to these coils using

Assembly of Eddy Current Dynamometer and Engine

When the rotor turns in this magnetic field, eddy current gets induced creating a braking effect between the rotor and the casing. Water passes from the inlet to the casing through a flexible connection permitting movement of the casing. Water passes through loss (Grooved) plates in the casing positioned on either side of the rotor and absorbs the heat generated. Heated water discharges from the casing through a flexible connection to an outlet flange on the bed plate. Different components connected to the eddy current dynamometer.

A load cell is a transducer that is used to convert a mechanical signal (force) into an analogous electrical signal. This conversion of the signals from the mechanical to electrical is indirect and happens in two stages.. A load cell usually consists of four strain gauges in a Wheatstone bridge configuration. The electrical signal output is typically in the order of a few millivolts and requires amplification by an instrumentation amplifier before it can be used The loading unit consists of a dimmerstat to control the magnitude of the direct current flowing into the dynamometer and a switch to ON/OFF the loading unit. The current is supplied into the loading unit through the main power supply. The loading unit used in this experimental test rig is of make Apex, Model AX-155 and constant speed type. The load values used to conduct the experiment are 0kg, 3kg, 6kg, 9kg and 12kg which correspond to the torque values of 0Nm, 5Nm, 10Nm, 15Nm and 20Nm respectively. The loading unit used in this experiment is shown in figure 5.3. The assembly of the same into the engine panel box can be seen

FIGURE Dynamometer Loading

Data acquisition system

For acquiring in-cylinder pressure changes with respect to the crank angle, a high speed data acquisition system is required. Figure 6.9 shows the circuit where different sensors are interfaced to the system. This is used for analysing the measured cylinder pressure and injection pressure data. The pressure signals from the pressure sensors are converted into digital form considering the transducer sensitivity and the charge amplifier setting during experimentation. Transducers normally provide relative pressures. Therefore, it is necessary to have means of determining the absolute pressure at some point in the cycle, which is to be taken as reference.

The inlet manifold pressure is used as a reference pressure. The mean intake manifold pressure is usually an accurate indicator of the cylinder pressure when the piston is at the Bottom Dead Centre (BDC). The cylinder pressure variation with respect to piston displacement in terms of pressure and crank angle is logged into the computer via a data acquisition

Engine Panel Box

system. Further to get the valuable information from experimentation, the data is to be analysed after verifying whether the data is properly recorded or not. Therefore processing of data is an important step in the experimental investigation. The large data which is collected 27 during the experimentation has to be systematically processed as discussed in the following paragraph.
the cylinder pressure and injection pressure with respect to crank angle generally has large cycle to cycle variations and hence one such cycle data cannot be used to represent the particular operating condition. Usually an average of 100 cycles of pressure Vs crank angle data is chosen for quantitative analysis. The number of cycles to be averaged depends upon the repeatability of the pressure data. An appropriate calibration factor is calculated for conversion of the pressure signals in voltages to the conventional unit. Now the calibration factor is applied to the average cycle and the relative pressures are calculated. These relative pressures are again calibrated with the reference pressure, which is set equal to the pressure in the intake manifold while the piston is at bottom dead centre and the absolute pressure values for the average cycle are obtained. Now the pressure volume phasing can be easily done for the average cycle having the absolute pressure values.

Performance measurement

The measurement of the performance parameter are done automatically by collecting the data from the computerized system after setting the running engine at particular load level. The density and the calorific value of the respective fuel are included according to the requirement. The paramerters evaluated are air and fuel flow rates, air fuel ratio, power, mean effective pressure, efficiencies and heat balance.

Air and fuel flow measurement

Both air and flow measurement can be performed manually and automatically. Manual airflow measurement is carried out by recording the difference in height of water column in the manometer. It is interconnected across the orifice meter, through which air comes into the engine panel box, before leaving towards the engine manifold. Manual measurement of fuel i executed by transferring fuel from the tank through the measuring tube for known duration. Air flow transmitter and differential pressure transmitter that are lined with dac assess the automatic air and fuel flow account. Optical crank angle sensor is used to measure each degree rotation of crank with TDC pulse.

Temperature measurement

Four pt100 (RTD) temperature sensors measure the inlet and outlet temperatures of engine cooling water flow and calorimeter water flow. The inlet and outlet temperatures of exhaust gas to calorimeter are measured by two k type thermocouples. All of these are interfaced with computer for automatic data recording. The thermocouples used in this work, have a response time more than

0.08 seconds (for the 1500 rpm constant speed engine). Hence, they cannot show the pulsation nature of the exhaust gas in the form of temperature reading and are found almost steady after a certain time (nearly minutes) at a particular load.

Compression ratio variation control

The VCR diesel engine has provisions for eight (8) step CR variation from 12 to 18. This is done by tilting cylinder head with the help of locknut and adjuster arrangement. However, the engine starting should be done at the standard CR (17.5) and later on CR change is done online. There are six (6) socket headed vertical allen bolts fitted on two supporting blocks on the two sides of the cylinder.

EXPERIMENTAL SETUP

Experimental setup

The experiment was conducted at single cylinder four stroke VCR Engine. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement. The setup consists of single cylinder, four stroke, VCR (Variable Compression Ratio) Research engine connected to eddy current dynamometer. It is provided with necessary instruments for combustion pressure, crank-angle, airflow, fuel flow, temperatures and load measurements. These signals are interfaced to computer through high speed data acquisition device. The setup has stand-alone panel box consisting of air box, twin fuel tank, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rotameters are provided for cooling water and calorimeter water flow measurement. The Engine performance study includes brake power, indicated power, frictional power, brake means effective pressure.

Figure Experimental Setup of VCR Diesel Engine

Engine specification

S.NO	FEATURE	SPECIFICATION
1	Engine make	Kirloskar diesel engine
2	Engine type	TV1
3	No of cylinder	One
4	Loading device	Eddy current dynamometer
5	Cylinder bore diameter	87.5 mm
6	Stroke length	110 mm
7	Engine speed	1500 rpm
8	Combustion principle	Compression ignition
9	Engine capacity	3.5KW
10	Orifice diameter	20 mm
11	Brake horse power	4.69

12	Compression ratio	Variable from 12 to 18
13	Cubic capacity	661 litre
14	No of stokes	Four

Table Engine specification

Properties of Diesel – Juliflora

PROPERTY	DIESEL	JULIFLORA
Density(kg/m^3)	830	873
Viscosity (cS)	2.7	5.2
Auto ignition point (°C)	200-400	<380
Cetane number (CN)	50	51
Pour point (°C)	-20	471
Fire point (°C)	180-330	274
calorific value (KJ/Kg)	43800	42673
A/F ratio	14.9	12.5

Properties of Diesel -- Radish

PROPERTY	DIESEL	RADISH
Density(kg/m^3)	830	780.3
calorific value (KJ/Kg)	43800	41345
Cetane number (CN)	50	49
Fire point (°C)	180-330	263

It is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, water pump, and other auxiliary components like power steering pump, muffled exhaust system. Evaluated the combustion and emission characteristics of fumigation pine oil as a biofuel.Pine oil biofuel, obtained by the distillation of oleoresins of pine tree, has been chosen as a new renewable fuel for its operation in diesel engine. From this study, it was observed that at higher air temperature (150°C), evaporation of pine oil was more effective than at lower temperatures (100°C and 50°C) and therefore, 150°C was chosen as preheat temperature for engine fumigation study. The fumigated pine oil has been reported to be better, with 36% injection of pine oil showing 10.3% higher in-cylinder pressure than that for 6% injection of pine oil at 100% load.

PERFORMANCE CHARACTERISTICS

Brake Mean Effective Pressure (BMEP)

It is defined as the average pressure the engine can exert on the piston through one complete operating cycle. If N is the number of revolutions per second, and c the number of revolutions per cycle, the number of cycles per second is just their ratio (W) which can be expressed by

$$W = \frac{Pn_c}{N}$$

Brake Horsepower (BHP)

It is the measure of an engine's horsepower before the loss in power caused by the gearbox, alternator, water pump, and other auxiliary components like power steering pump, muffled exhaust system, etc
BHP = IHP-FP

where

Mechanical Efficiency

The work output is also defined as brake power and input is indicated power and the ratio of BP to IP is defined as mechanical efficiency.

Brake Specific Fuel Consumption (BSFC)

The BSFC is defined as the ratio between fuel flow rate and power output. It is a measure of the efficiency of the engine in using the fuel supplied to produced. It can be calculated by

BSFC $=W_f/BP$

where

W_f = fuel consumed (g/h) BP = Brake power (kW)

6.1 Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft
BTE $(_b) = BP/(m_f \times NCV)$

where

BP= Brake Power (kW)

m_f = fuel consumption (kg/sec) NCV = net calorific value (kJ/kg)

IC Engine Soft Test Report PERFORMANCE CR-16-Diesel with Different Loads

Engine Details

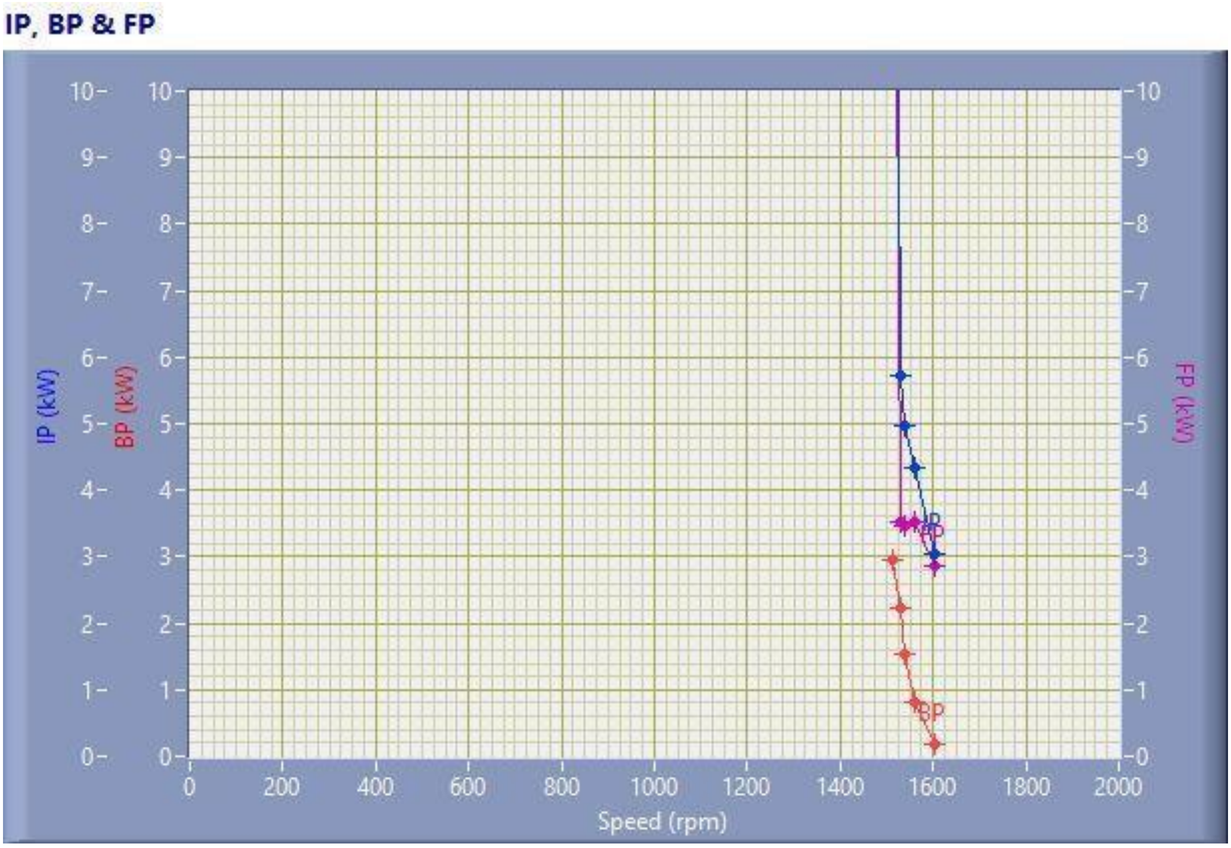
ICEngine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 16.00, Swept volume 661.45 (cc)

Combustion Parameters :

Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.26, Number Of Cycles : 10, Cylinder Pressure Referance
: 7, Smoothing 2, TDC Reference : 0

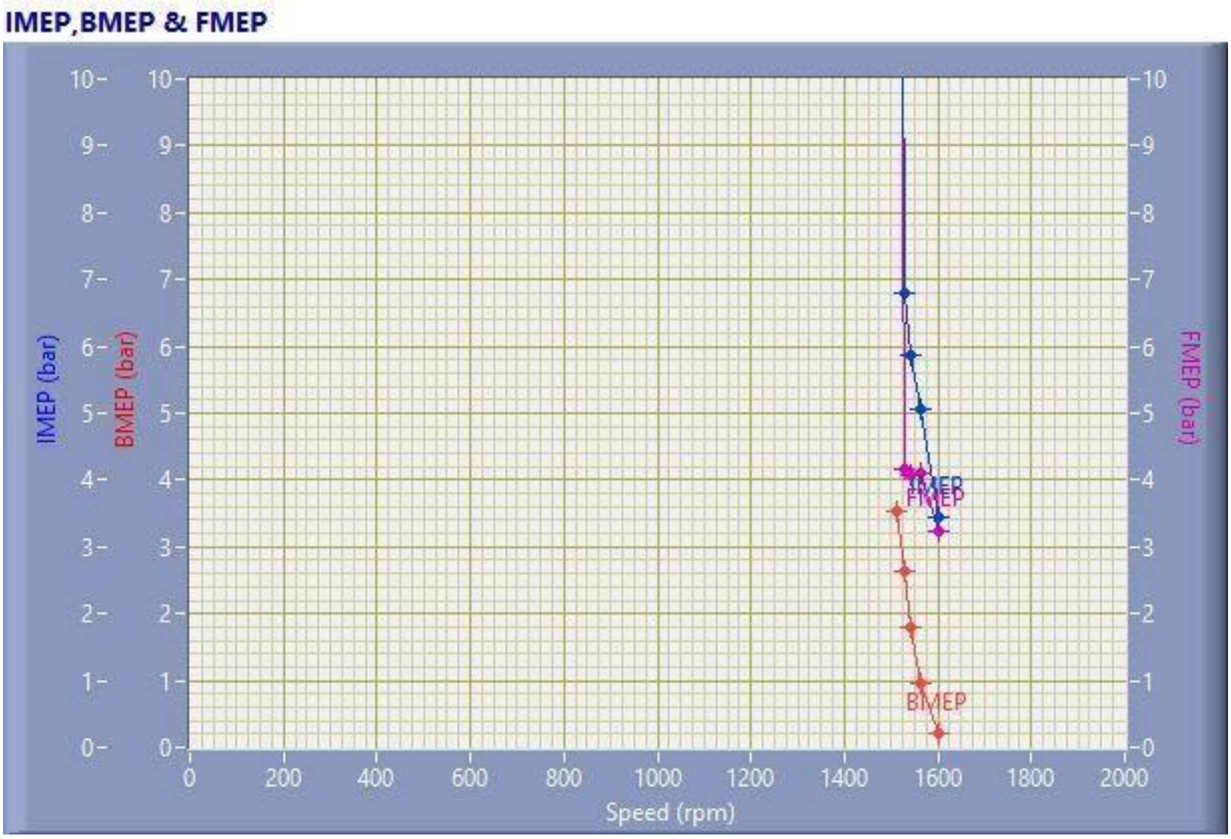
Performance Parameters :

Orifice Diameter (mm) : 20.00, Orifice Coeff. Of Discharge : 0.60, Dynamometer Arm Legnth (mm) : 185, Fuel Pipe dia (mm) : 12.40, Ambient Temp. (Deg C) : 27, Pulses Per revolution : 360, Fuel Type : Diesel, Fuel Density (Kg/m^3) : 879, Calorific Value Of Fuel (kj/kg) : 44500



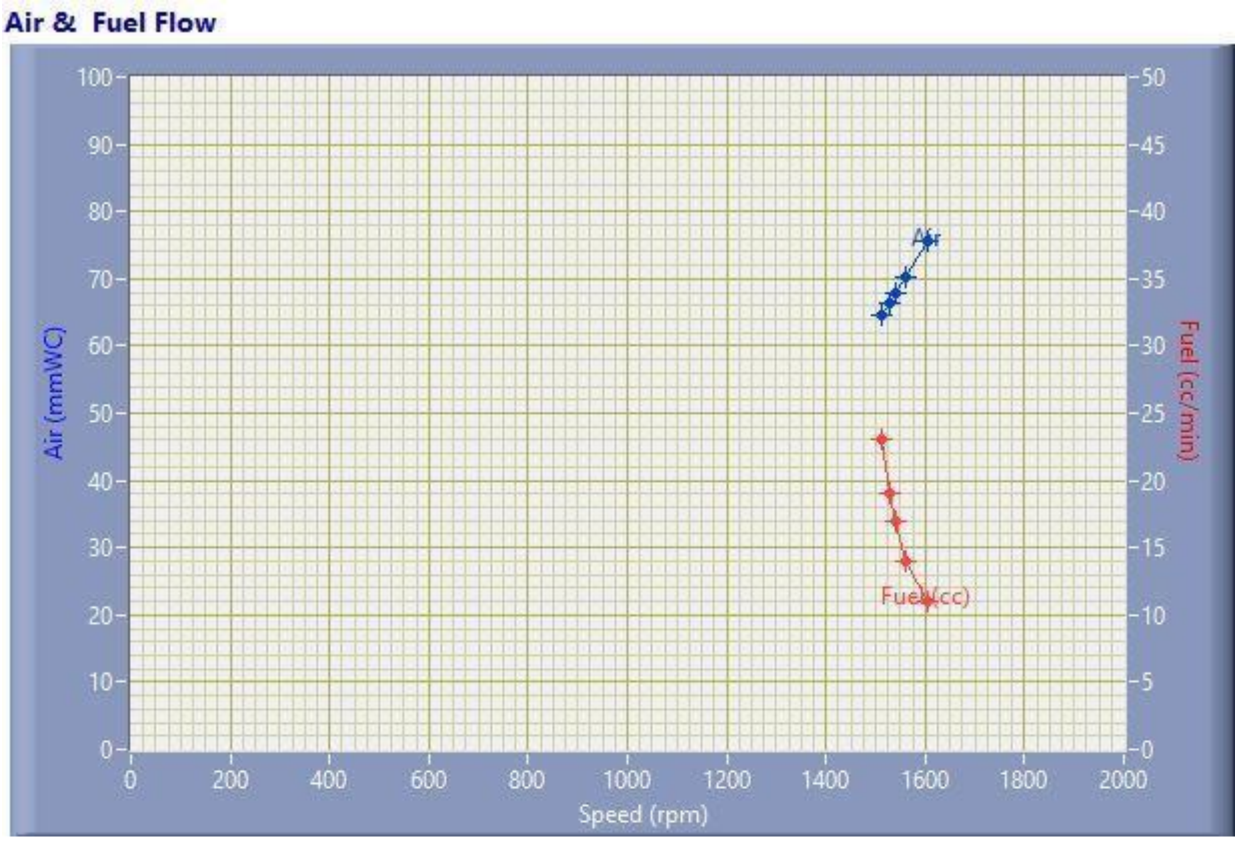
IP, BP & FP

Speed (rpm)	Load (kg)	IP (kW)	BP (kW)	FP (kW)
1603.00	0.57	3.03	0.17	2.86
1562.00	2.77	4.35	0.82	3.53
1540.00	5.20	4.97	1.52	3.45
1529.00	7.64	5.74	2.22	3.51
1512.00	10.27	21.17	2.95	18.22



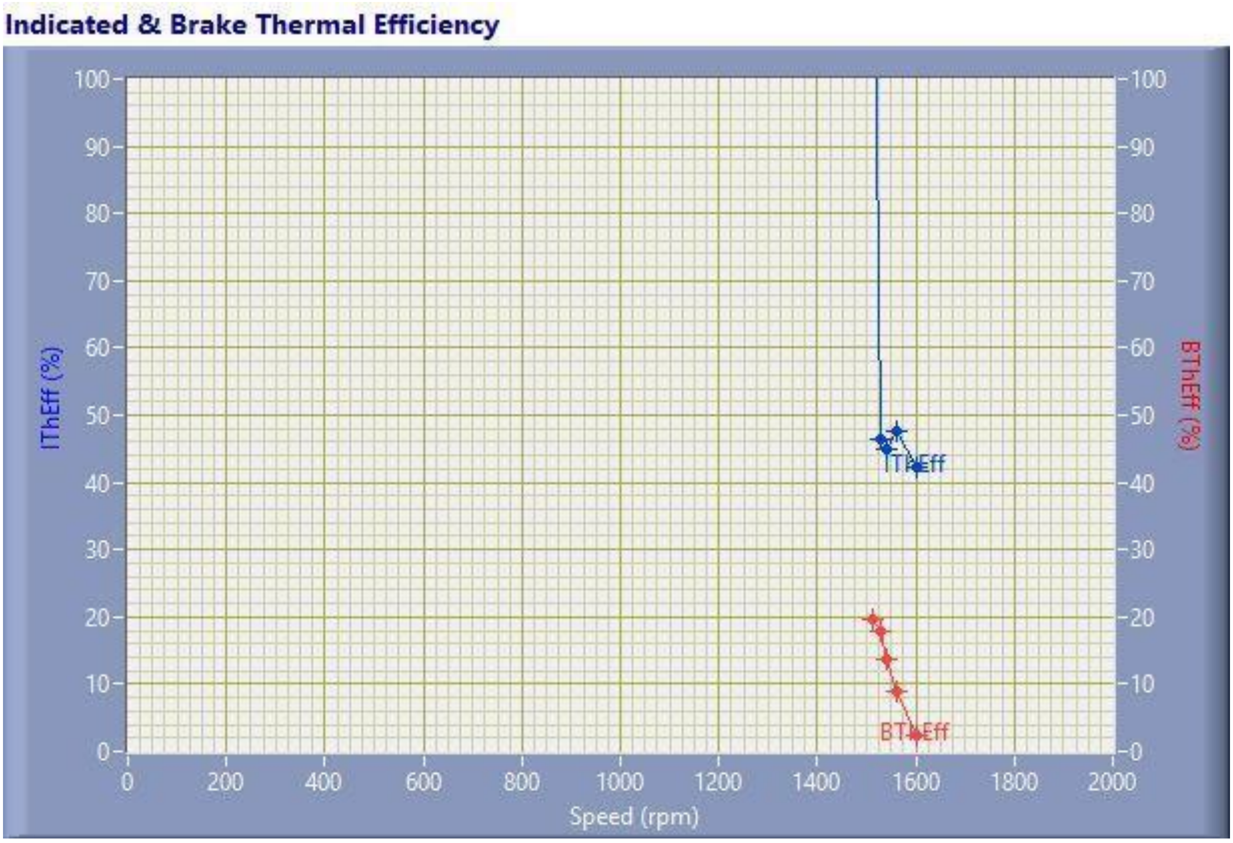
IMEP,BMEP & FMEP

Speed (rpm)	Load (kg)	IMEP (bar)	BMEP (bar)	FMEP (bar)
1603.00	0.57	3.43	0.20	3.23
1562.00	2.77	5.05	0.96	4.10
1540.00	5.20	5.86	1.79	4.07
1529.00	7.64	6.80	2.63	4.17
1512.00	10.27	25.40	3.54	21.86



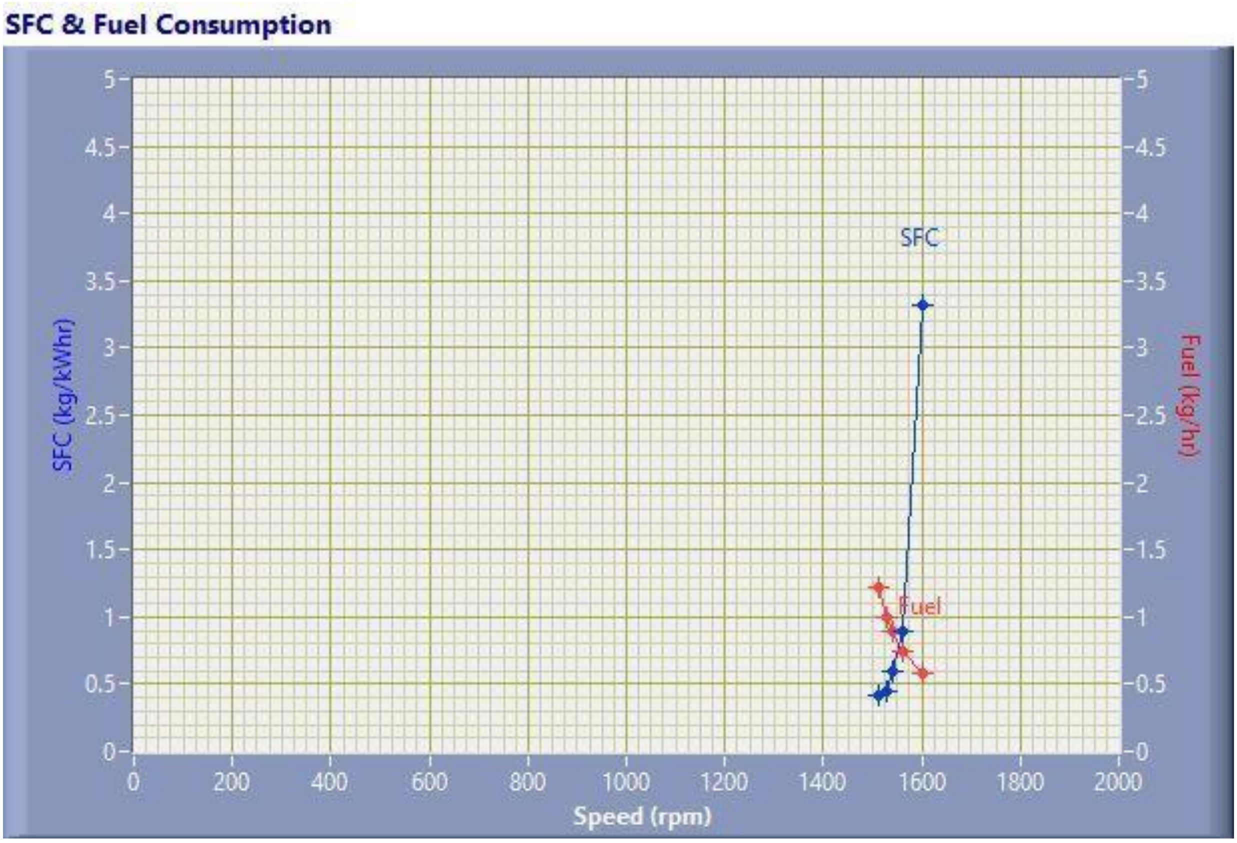
Air & Fuel Flow

Speed (rpm)	Load (kg)	Air (mmWC)	Fuel (cc/min)
1603.00	0.57	75.65	11.00
1562.00	2.77	70.35	14.00
1540.00	5.20	67.93	17.00
1529.00	7.64	66.49	19.00
1512.00	10.27	64.73	23.00



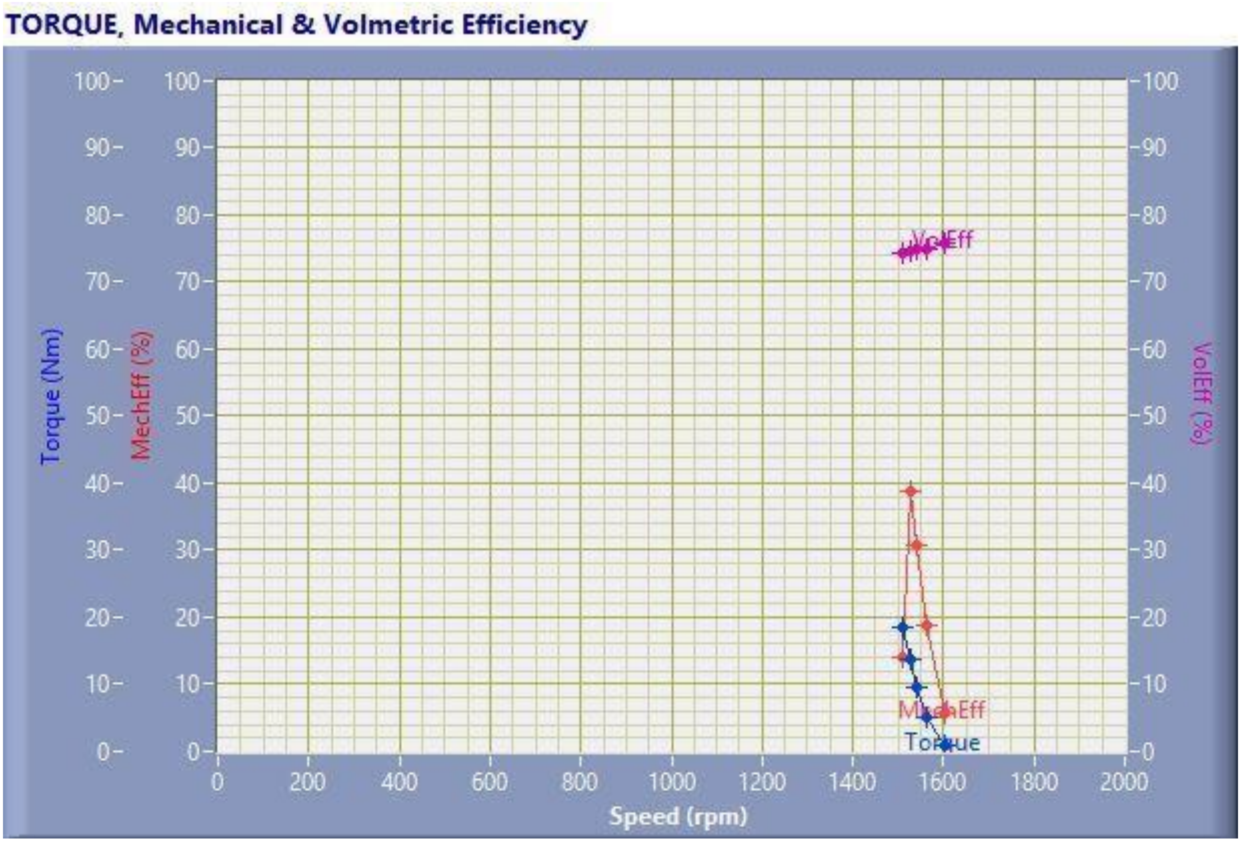
Indicated & Brake Thermal Efficiency

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1603.00	0.57	42.25	2.43
1562.00	2.77	47.65	9.01
1540.00	5.20	44.88	13.73
1529.00	7.64	46.30	17.93
1512.00	10.27	141.20	19.68



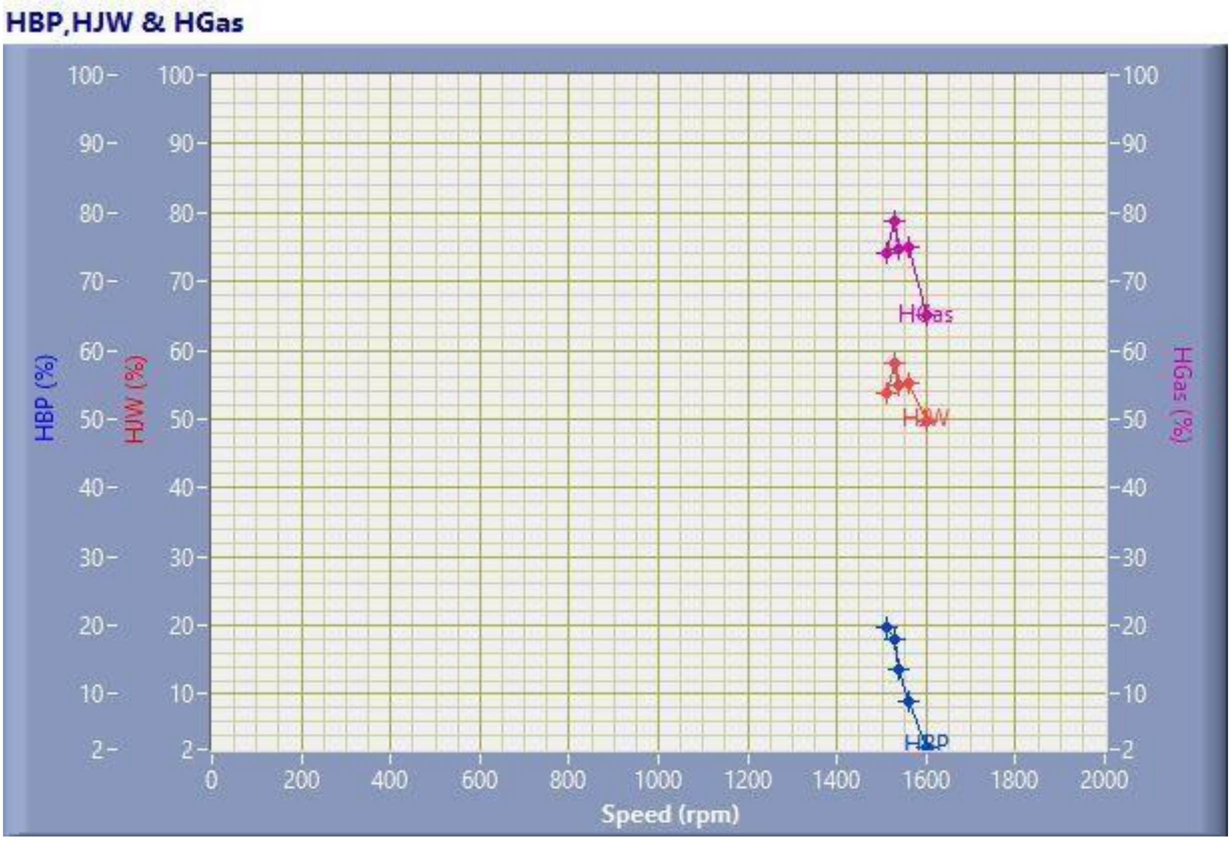
SFC & Fuel Consumption

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1603.00	0.57	3.32	0.58
1562.00	2.77	0.90	0.74
1540.00	5.20	0.59	0.90
1529.00	7.64	0.45	1.00
1512.00	10.27	0.41	1.21



TORQUE, Mechanical & Volmertic Efficiency

Speed (rpm)	Load (Kg)	Torque (Nm)	Mech Eff. (%)	Vol Eff. (%)
1603.00	0.57	1.04	5.76	75.86
1562.00	2.77	5.03	18.92	75.07
1540.00	5.20	9.44	30.60	74.82
1529.00	7.64	13.87	38.72	74.56
1512.00	10.27	18.64	13.94	74.39



HBP,HJW & HGas

Speed (rpm)	Load (kg)	HBP (%)	HJW (%)	HGas (%)	HRad (%)
1603.00	0.57	2.43	47.26	15.32	34.99
1562.00	2.77	9.01	46.14	19.74	25.11
1540.00	5.20	13.73	41.31	19.53	25.42
1529.00	7.64	17.93	40.06	20.86	21.16
1512.00	10.27	19.68	34.06	20.35	25.90

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1603	0.57	16.00	19.11	33.63	19.11	27.26	140.99	89.22
1562	2.77	16.00	19.18	37.22	19.19	28.76	219.65	133.72
1540	5.20	16.00	19.27	38.89	19.28	29.67	261.14	159.48
1529	7.64	16.00	19.29	40.56	19.29	31.11	308.24	188.80
1512	10.27	16.00	19.24	41.13	19.25	32.64	360.98	215.62

Observation Data

Air (mmWC)	Fuel (cc/min)	WaterFlow Engine (lph)	WaterFlow Cal (lph)
75.65	11.00	200	125
70.35	14.00	200	125
67.93	17.00	200	125
66.49	19.00	200	125
64.73	23.00	200	125

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
1.04	0.17	2.86	3.03	0.20	3.43	2.43	42.25	5.76
5.03	0.82	3.53	4.35	0.96	5.05	9.01	47.65	18.92
9.44	1.52	3.45	4.97	1.79	5.86	13.73	44.88	30.60
13.87	2.22	3.51	5.74	2.63	6.80	17.93	46.30	38.72
18.64	2.95	18.22	21.17	3.54	25.40	19.68	141.20	13.94

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/k Wh)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	HGas (%)	HRad (%)
28.33	0.58	3.32	75.86	48.83	2.43	47.26	15.32	34.99
27.31	0.74	0.90	75.07	36.99	9.01	46.14	19.74	25.11
26.84	0.90	0.59	74.82	29.94	13.73	41.31	19.53	25.42
26.56	1.00	0.45	74.56	26.50	17.93	40.06	20.86	21.16
26.20	1.21	0.41	74.39	21.60	19.68	34.06	20.35	25.90

CHAPTER 8

IC Engine Soft Test Report PERFORMANCE CR-16-B40- Juliflora & Radish

Engine Details

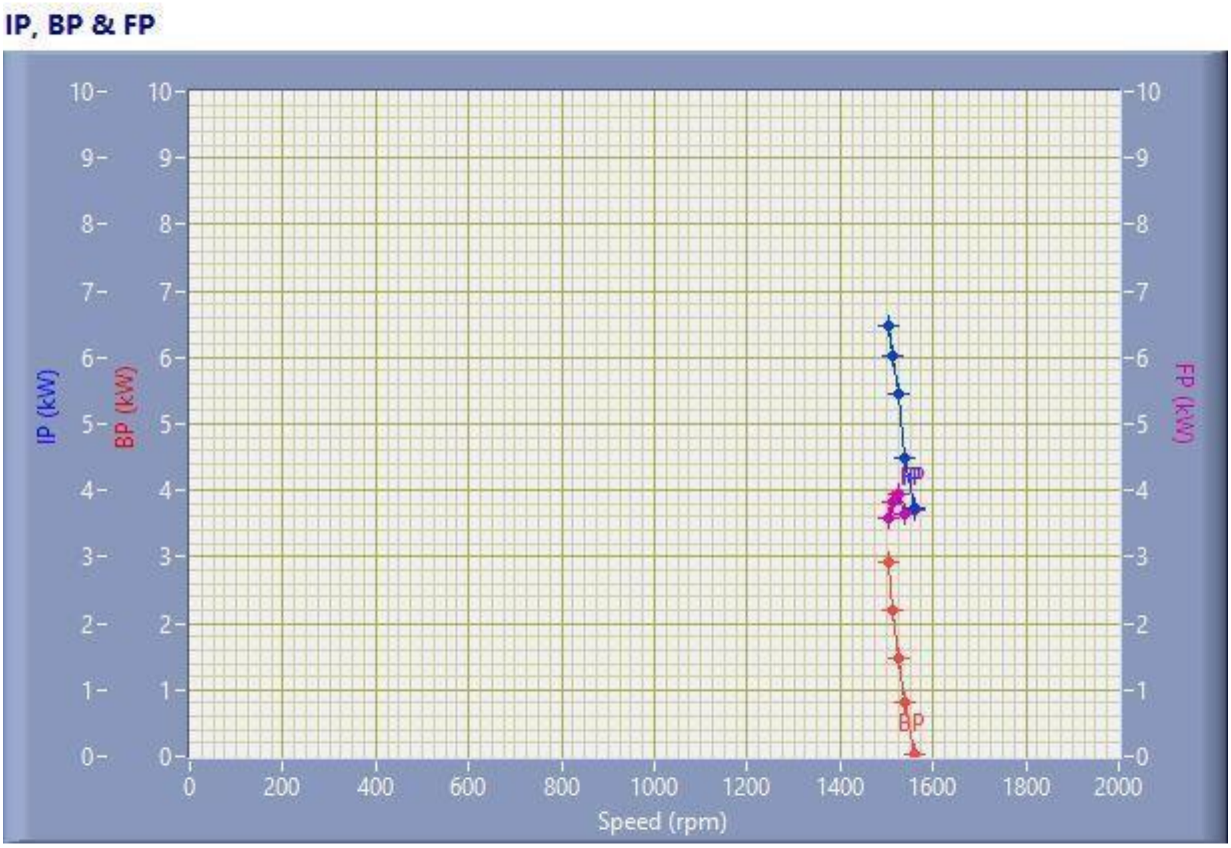
ICEngine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 16.00, Swept volume 661.45 (cc)

Combustion Parameters

Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.26, Number Of Cycles : 10, Cylinder Pressure Referance
: 7, Smoothing 2, TDC Reference : 0

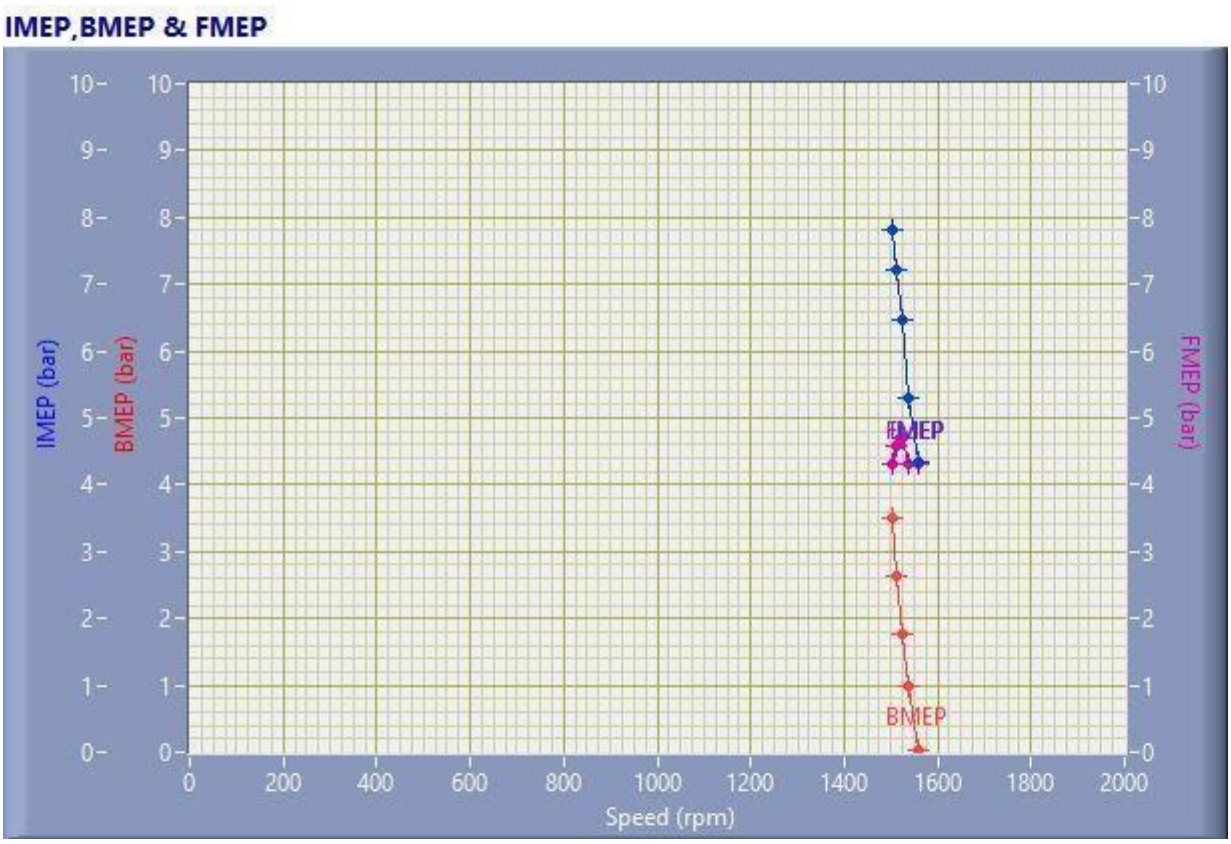
Performance Parameters

Orifice Diameter (mm) : 20.00, Orifice Coeff. Of Discharge : 0.60, Dynamometer Arm Legnth (mm) : 185, Fuel Pipe dia (mm) : 12.40, Ambient Temp. (Deg C) : 27, Pulses Per revolution : 360, Fuel Type : Diesel, Fuel Density (Kg/m^3) : 879, Calorific Value Of Fuel (kj/kg) : 40756



IP, BP & FP

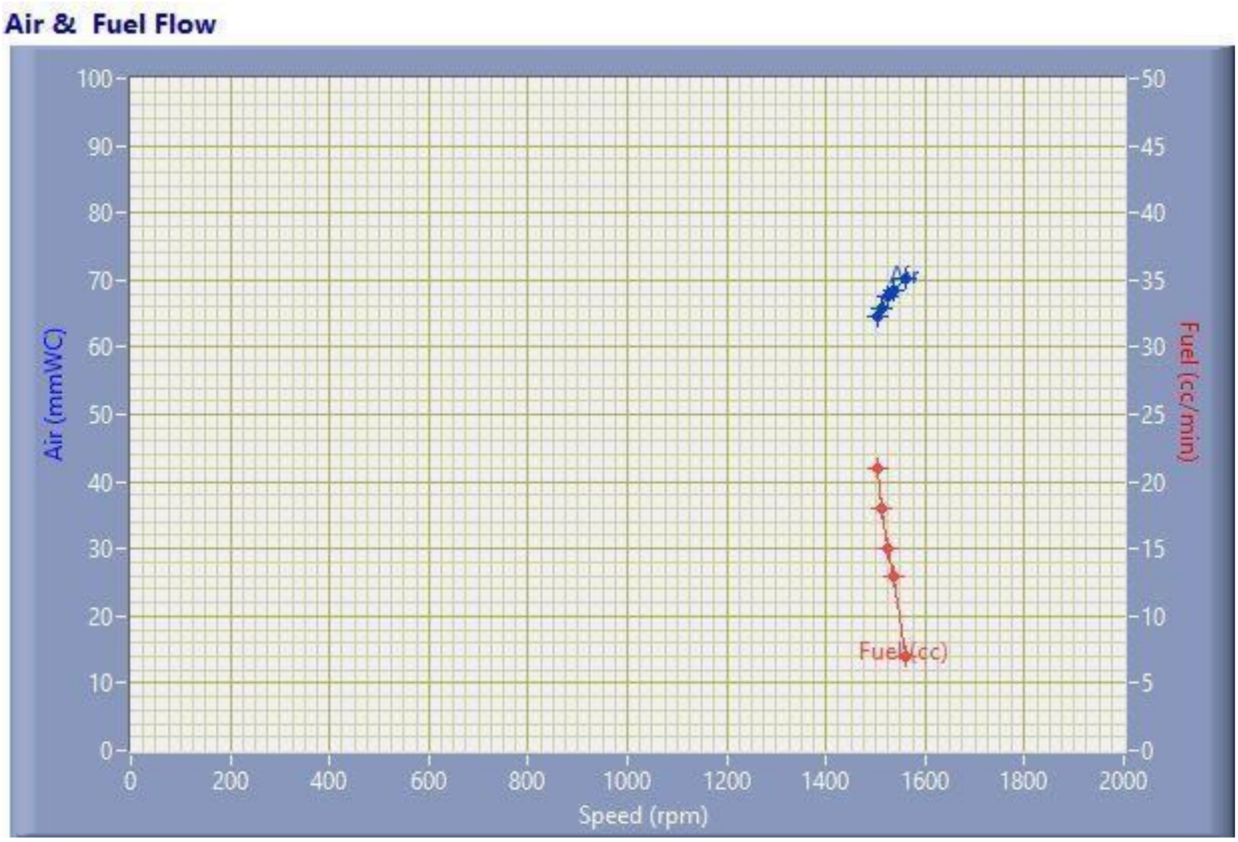
Speed (rpm)	Load (kg)	IP (kW)	BP (kW)	FP (kW)
1559.00	0.07	3.73	0.02	3.70
1537.00	2.83	4.49	0.83	3.66
1525.00	5.10	5.44	1.48	3.96
1513.00	7.64	6.01	2.20	3.82
1504.00	10.18	6.49	2.91	3.57



IMEP,BMEP & FMEP

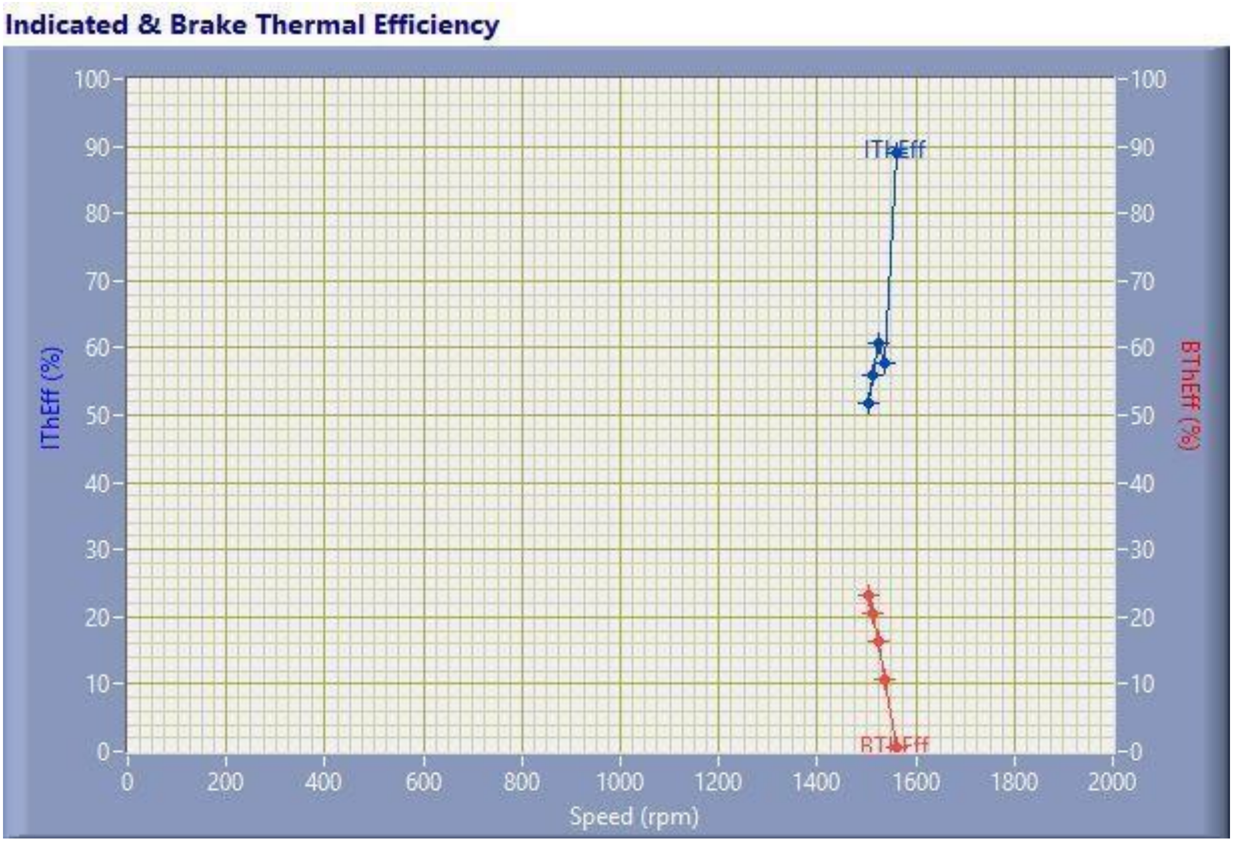
Speed (rpm)	Load (kg)	IMEP (bar)	BMEP (bar)	FMEP (bar)
1559.00	0.07	4.33	0.02	4.31

1537.00	2.83	5.29	0.97	4.32
1525.00	5.10	6.47	1.76	4.71
1513.00	7.64	7.21	2.63	4.58
1504.00	10.18	7.82	3.51	4.31



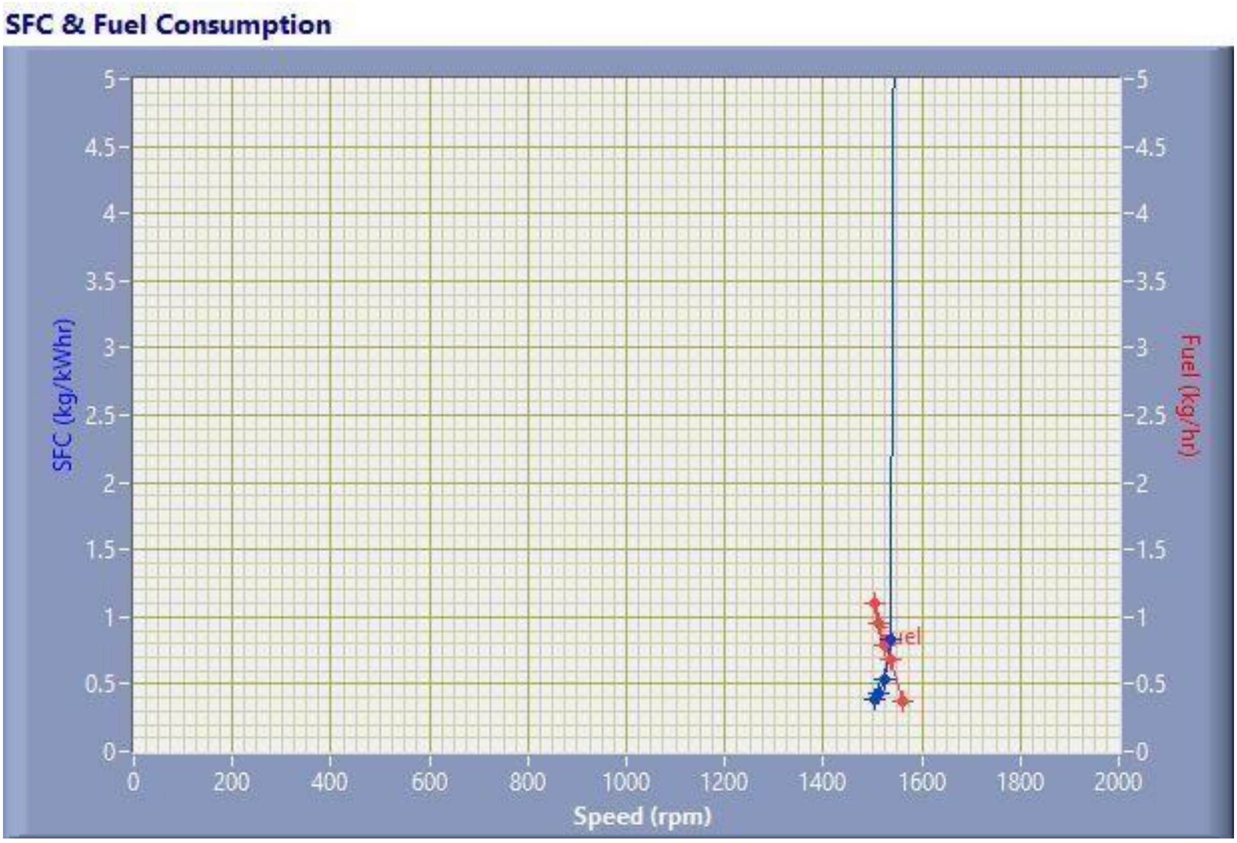
Air & Fuel Flow

Speed (rpm)	Load (kg)	Air (mmWC)	Fuel (cc/min)
1559.00	0.07	70.25	7.00
1537.00	2.83	68.59	13.00
1525.00	5.10	67.45	15.00
1513.00	7.64	65.76	18.00
1504.00	10.18	64.47	21.00



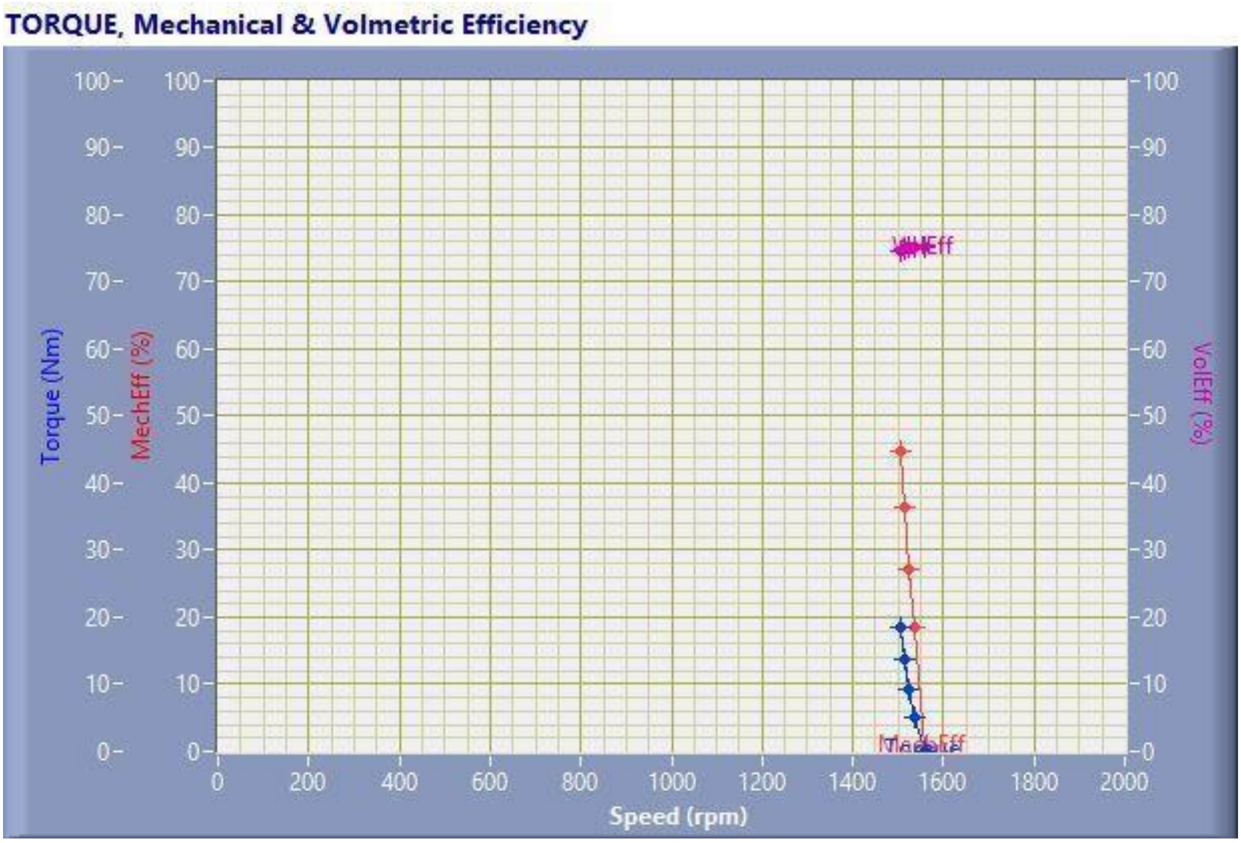
Indicated & Brake Thermal Efficiency

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1559.00	0.07	89.13	0.51
1537.00	2.83	57.79	10.64
1525.00	5.10	60.71	16.50
1513.00	7.64	55.97	20.44
1504.00	10.18	51.72	23.21



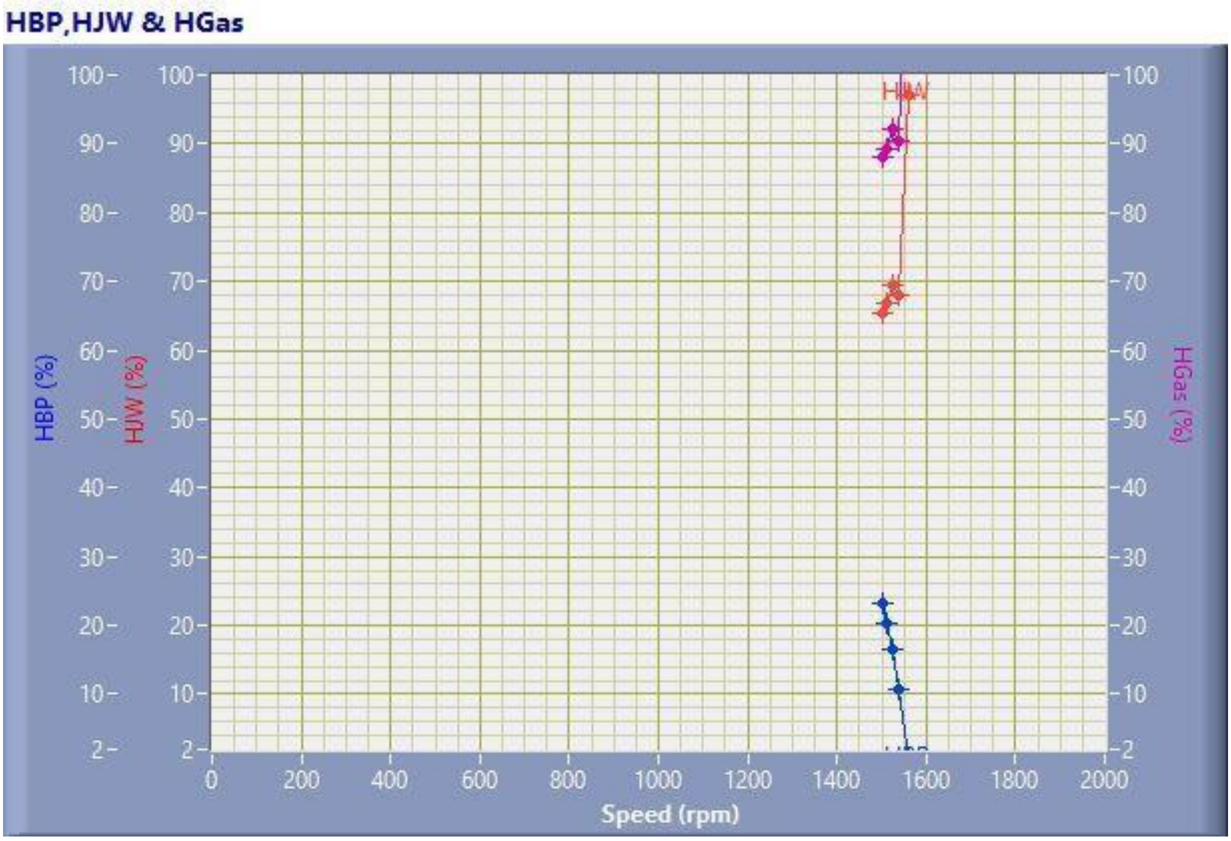
SFC & Fuel Consumption

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1559.00	0.07	17.24	0.37
1537.00	2.83	0.83	0.69
1525.00	5.10	0.54	0.79
1513.00	7.64	0.43	0.95
1504.00	10.18	0.38	1.11



TORQUE, Mechanical & Volmertic Efficiency

Speed (rpm)	Load (Kg)	Torque (Nm)	Mech Eff. (%)	Vol Eff. (%)
1559.00	0.07	0.13	0.57	75.16
1537.00	2.83	5.13	18.41	75.33
1525.00	5.10	9.25	27.17	75.29
1513.00	7.64	13.87	36.53	74.93
1504.00	10.18	18.48	44.88	74.63



HBP,HJW & HGas

Speed (rpm)	Load (kg)	HBP (%)	HJW (%)	HGas (%)	HRad (%)
1559.00	0.07	0.51	96.68	29.74	0.00
1537.00	2.83	10.64	57.31	22.34	9.71
1525.00	5.10	16.50	52.86	22.90	7.75
1513.00	7.64	20.44	46.29	22.43	10.83
1504.00	10.18	23.21	42.29	22.65	11.84

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1559	0.07	16.00	18.71	36.02	18.72	29.19	161.81	121.69
1537	2.83	16.00	18.70	37.77	18.70	29.89	215.11	141.04
1525	5.10	16.00	18.71	38.99	18.71	30.61	250.42	161.10
1513	7.64	16.00	18.69	40.02	18.70	31.47	291.36	181.76
1504	10.18	16.00	18.70	41.42	18.70	32.21	339.58	207.22

Observation Data

Air (mmWC)	Fuel (cc/min)	WaterFlow Engine (lph)	WaterFlow Cal (lph)
70.25	7.00	200	125
68.59	13.00	200	125
67.45	15.00	200	125
65.76	18.00	200	125
64.47	21.00	200	125

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.13	0.02	3.70	3.73	0.02	4.33	0.51	89.13	0.57
5.13	0.83	3.66	4.49	0.97	5.29	10.64	57.79	18.41
9.25	1.48	3.96	5.44	1.76	6.47	16.50	60.71	27.17
13.87	2.20	3.82	6.01	2.63	7.21	20.44	55.97	36.53
18.48	2.91	3.57	6.49	3.51	7.82	23.21	51.72	44.88

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/k Wh)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	HGas (%)	HRad (%)
27.30	0.37	17.24	75.16	73.94	0.51	96.68	29.74	0.00
26.97	0.69	0.83	75.33	39.34	10.64	57.31	22.34	9.71
26.75	0.79	0.54	75.29	33.81	16.50	52.86	22.90	7.75
26.41	0.95	0.43	74.93	27.82	20.44	46.29	22.43	10.83
26.15	1.11	0.38	74.63	23.61	23.21	42.29	22.65	11.84

CHAPTER 9

IC Engine Soft Test Report PERFORMANCE CR-16-B-20 Julifora & Radish Blends

Engine Details

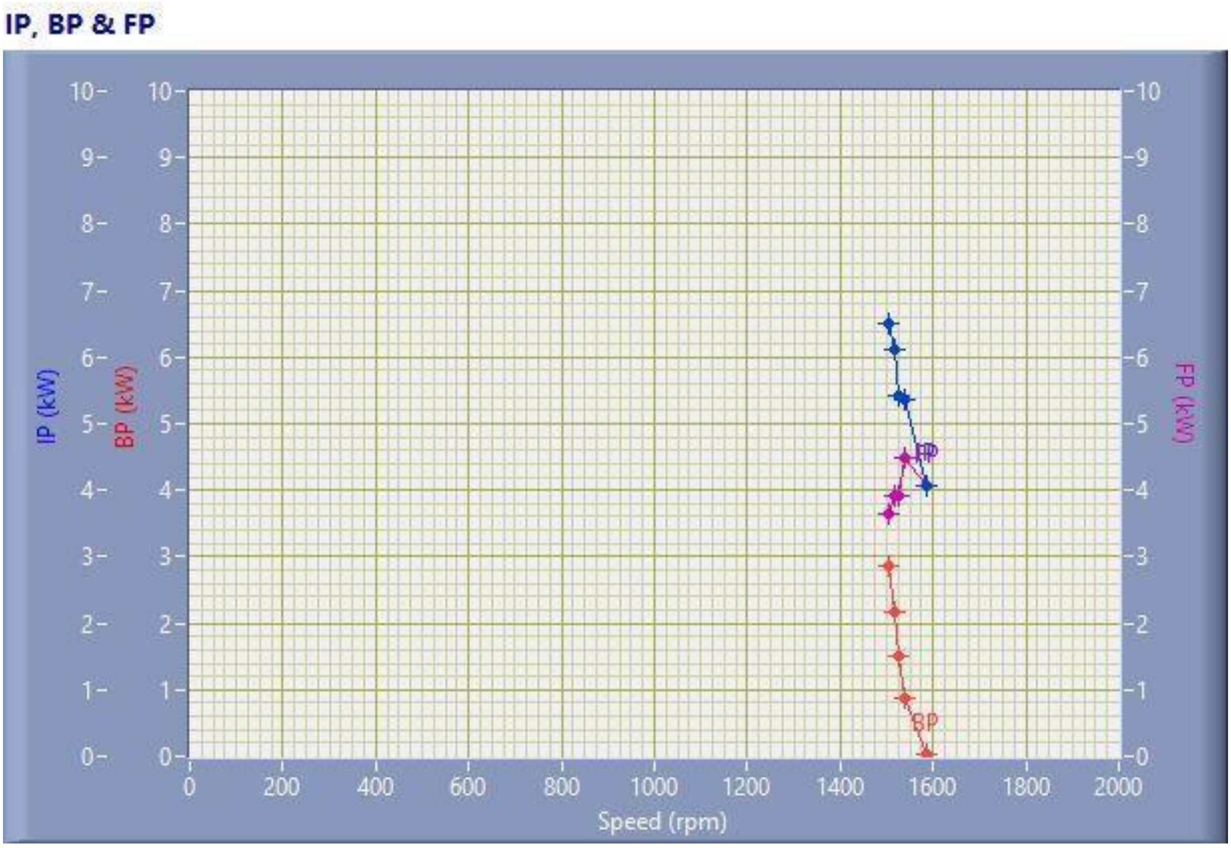
IC Engine set up under test is Kirloskar TV1 having power 5.20 kW @ 1500 rpm which is 1 Cylinder, Four stroke , Constant Speed, Water Cooled, Diesel Engine, with Cylinder Bore 87.50(mm), Stroke Length 110.00(mm), Connecting Rod length 234.00(mm), Compression Ratio 16.00, Swept volume 661.45 (cc)

Combustion Parameters

Specific Gas Const (kJ/kgK) : 1.00, Air Density (kg/m^3) : 1.17, Adiabatic Index : 1.41, Polytrophic Index : 1.26, Number Of Cycles : 10, Cylinder Pressure Referance
: 7, Smoothing 2, TDC Reference : 0

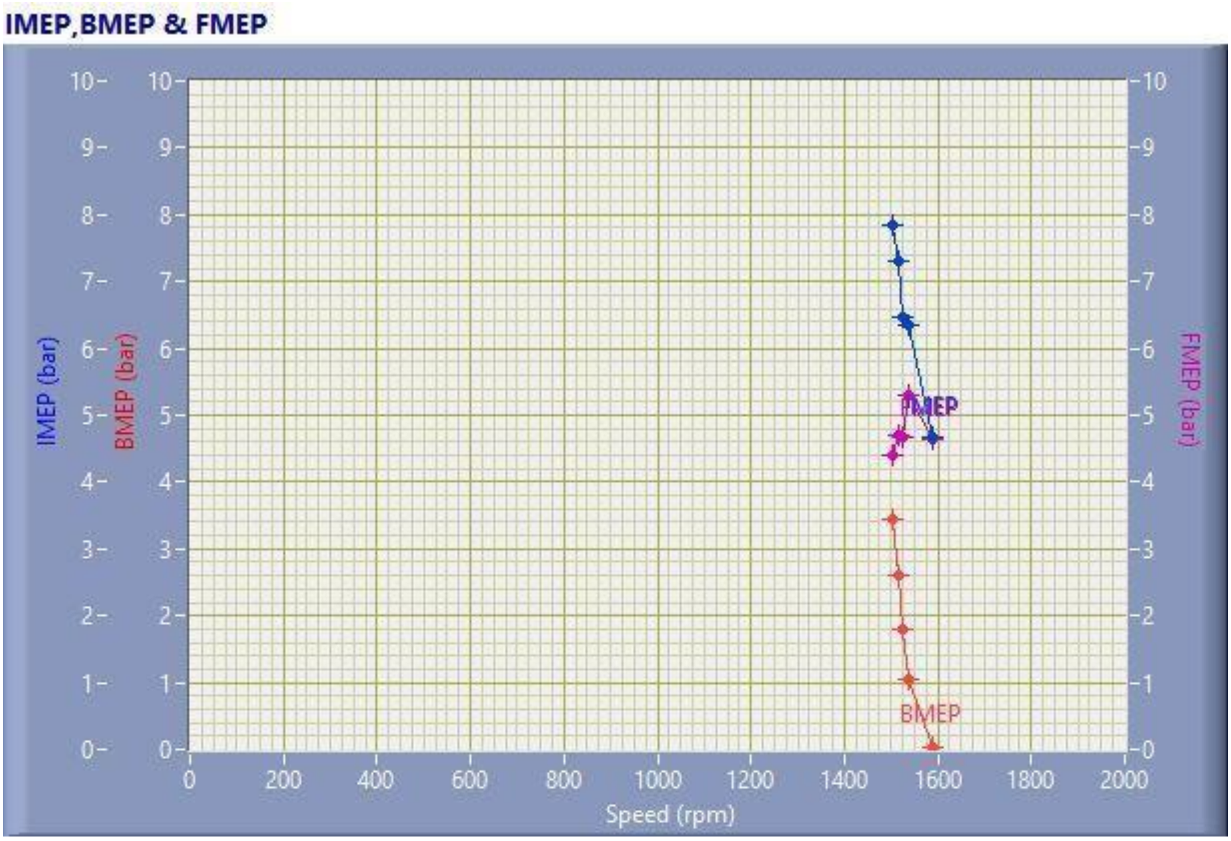
Performance Parameters

Orifice Diameter (mm) : 20.00, Orifice Coeff. Of Discharge : 0.60, Dynamometer Arm Legnth (mm) : 185, Fuel Pipe dia (mm) : 12.40, Ambient Temp. (Deg C) : 27, Pulses Per revolution : 360, Fuel Type : Diesel, Fuel Density (Kg/m^3) : 879, Calorific Value Of Fuel (kj/kg) : 40756



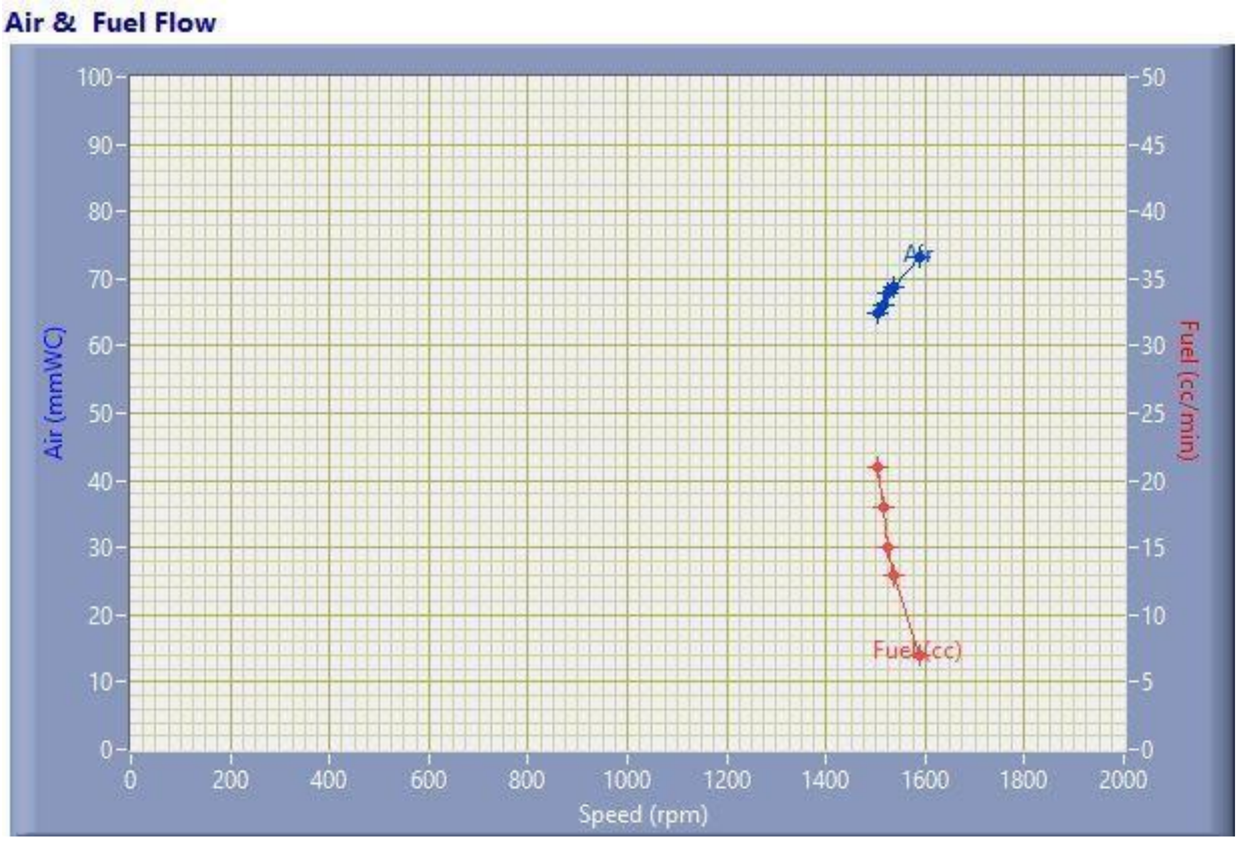
IP, BP & FP

Speed (rpm)	Load (kg)	IP (kW)	BP (kW)	FP (kW)
1588.00	0.08	4.08	0.03	4.05
1537.00	3.00	5.38	0.88	4.50
1524.00	5.18	5.42	1.50	3.92
1516.00	7.57	6.10	2.18	3.92
1503.00	9.97	6.49	2.85	3.65



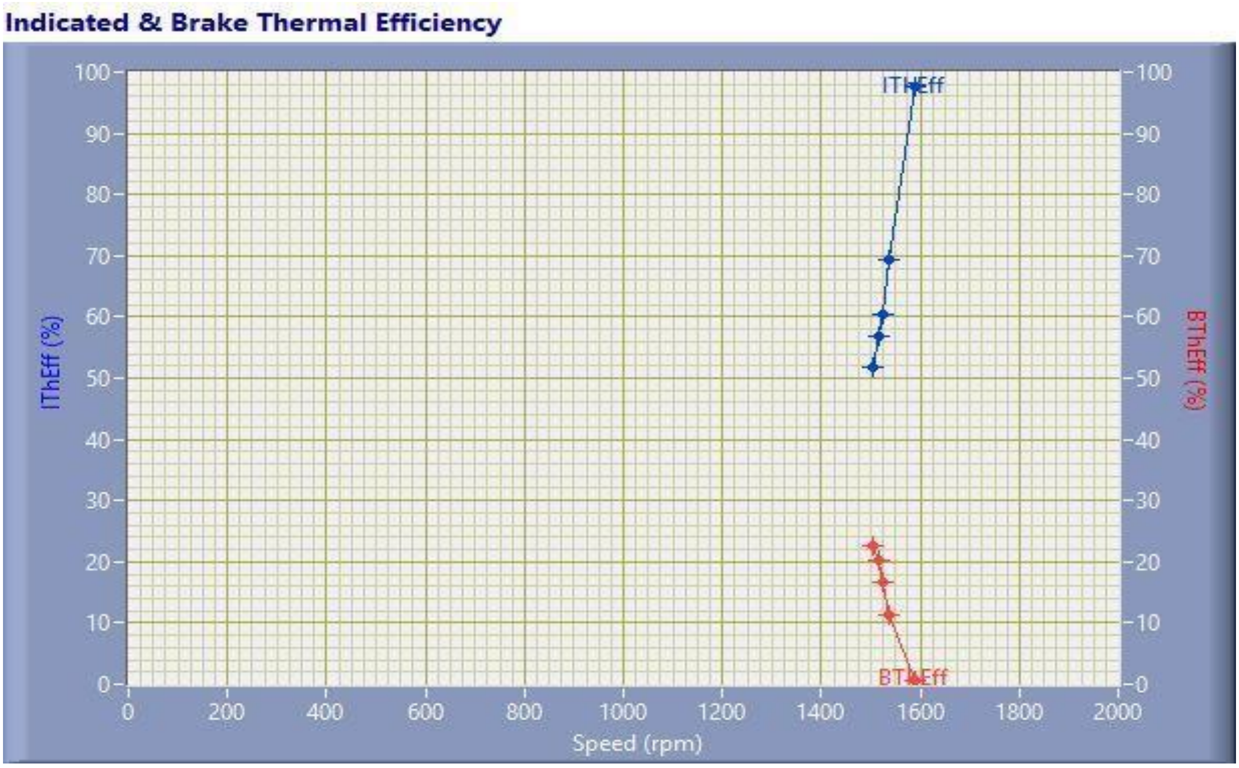
IMEP,BMEP & FMEP

Speed (rpm)	Load (kg)	IMEP (bar)	BMEP (bar)	FMEP (bar)
1588.00	0.08	4.66	0.03	4.63
1537.00	3.00	6.34	1.03	5.31
1524.00	5.18	6.45	1.79	4.67
1516.00	7.57	7.30	2.61	4.69
1503.00	9.97	7.84	3.44	4.40



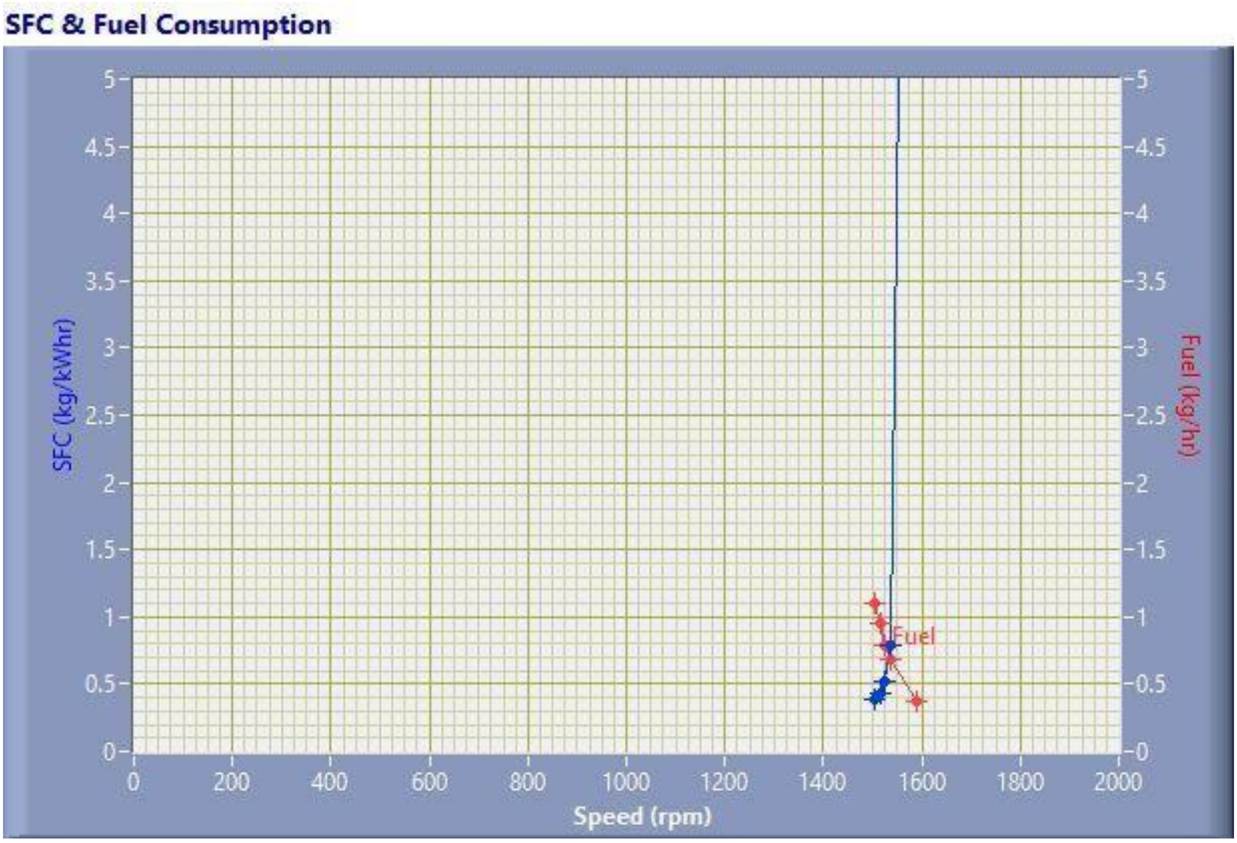
Air & Fuel Flow

Speed (rpm)	Load (kg)	Air (mmWC)	Fuel (cc/min)
1588.00	0.08	73.28	7.00
1537.00	3.00	68.82	13.00
1524.00	5.18	67.74	15.00
1516.00	7.57	65.98	18.00
1503.00	9.97	64.87	21.00



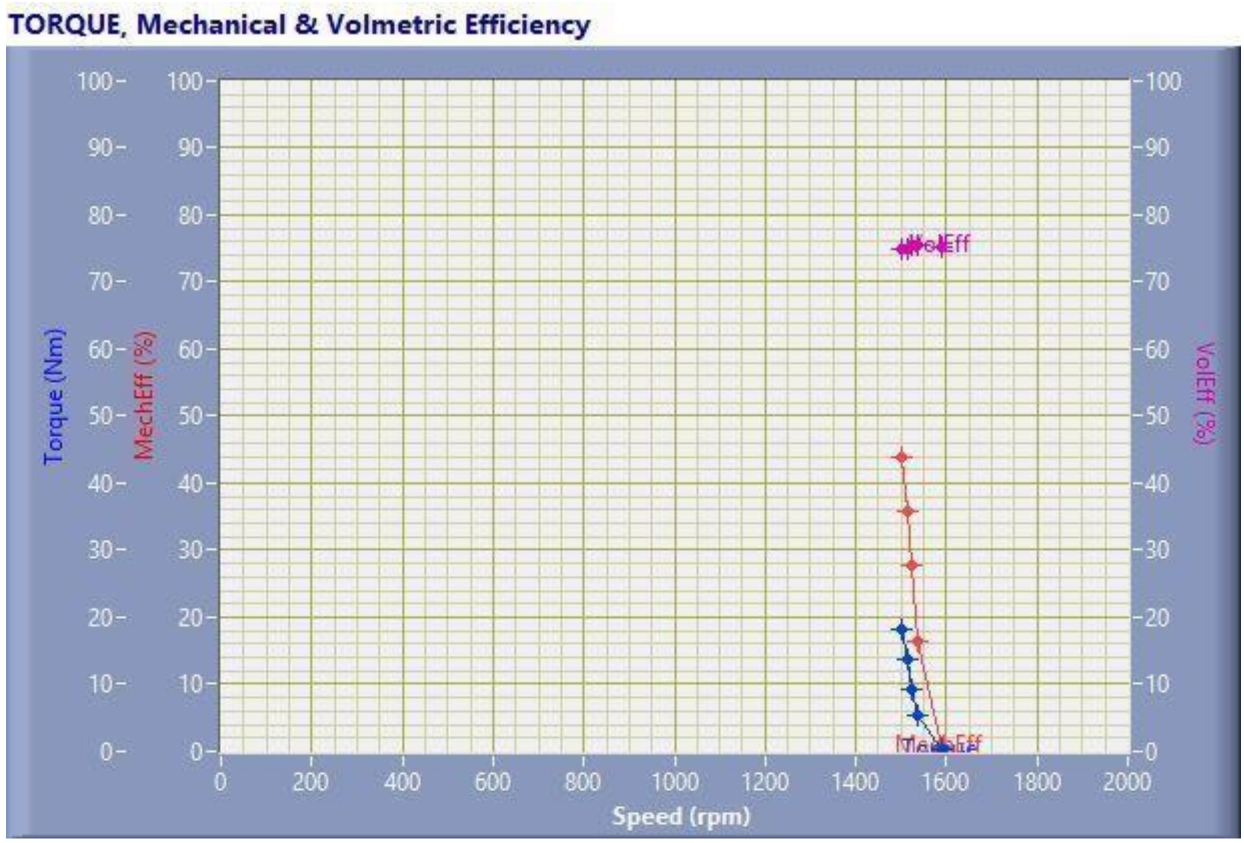
Indicated & Brake Thermal Efficiency

Speed (rpm)	Load (kg)	IThEff (%)	BThEff (%)
1588.00	0.08	97.55	0.60
1537.00	3.00	69.25	11.29
1524.00	5.18	60.54	16.75
1516.00	7.57	56.77	20.29
1503.00	9.97	51.79	22.71



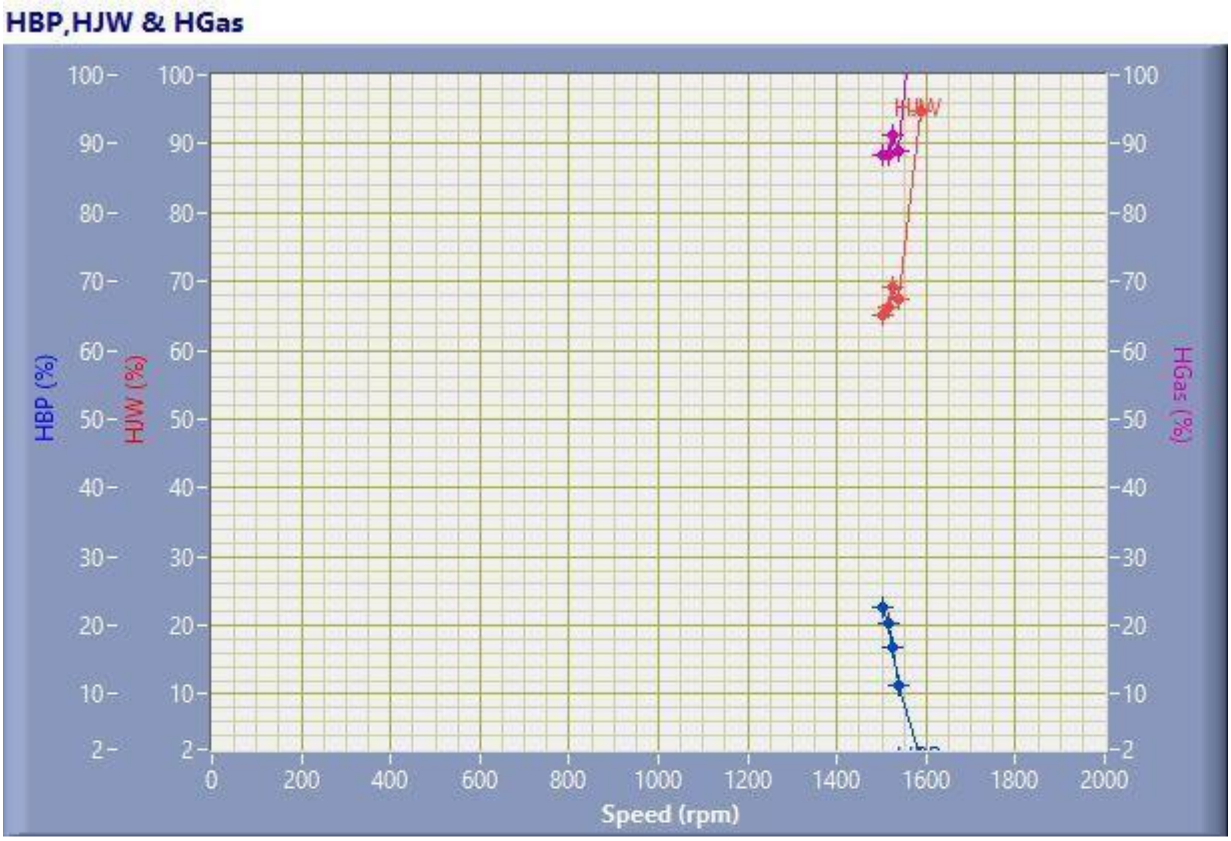
SFC & Fuel Consumption

Speed (rpm)	Load (kg)	SFC (kg/kWh)	Fuel (kg/h)
1588.00	0.08	14.69	0.37
1537.00	3.00	0.78	0.69
1524.00	5.18	0.53	0.79
1516.00	7.57	0.44	0.95
1503.00	9.97	0.39	1.11



TORQUE, Mechanical & Volmertic Efficiency

Speed (rpm)	Load (Kg)	Torque (Nm)	Mech Eff. (%)	Vol Eff. (%)
1588.00	0.08	0.15	0.62	75.37
1537.00	3.00	5.45	16.31	75.46
1524.00	5.18	9.40	27.66	75.50
1516.00	7.57	13.74	35.75	74.91
1503.00	9.97	18.09	43.85	74.91



HBP,HJW & HGas

Speed (rpm)	Load (kg)	HBP (%)	HJW (%)	HGas (%)	HRad (%)
1588.00	0.08	0.60	94.23	26.00	0.00
1537.00	3.00	11.29	56.14	21.44	11.13
1524.00	5.18	16.75	52.31	22.34	8.61
1516.00	7.57	20.29	46.01	22.02	11.68
1503.00	9.97	22.71	42.44	23.21	11.64

Observation Data

Speed (rpm)	Load (kg)	Comp Ratio	T1 (deg C)	T2 (deg C)	T3 (deg C)	T4 (deg C)	T5 (deg C)	T6 (deg C)
1588	0.08	16.00	18.47	35.35	18.47	28.80	142.41	103.13
1537	3.00	16.00	18.48	37.16	18.49	28.90	207.18	130.17
1524	5.18	16.00	18.50	38.58	18.51	29.80	244.54	152.58
1516	7.57	16.00	18.51	39.71	18.53	30.67	286.07	176.13
1503	9.97	16.00	18.58	41.39	18.59	32.41	346.42	215.55

Observation Data

Air (mmWC)	Fuel (cc/min)	WaterFlow Engine (lph)	WaterFlow Cal (lph)
73.28	7.00	200	125
68.82	13.00	200	125
67.74	15.00	200	125
65.98	18.00	200	125
64.87	21.00	200	125

Result Data

Torque (Nm)	BP (kW)	FP (kW)	IP (kW)	BMEP (bar)	IMEP (bar)	BTHE (%)	ITHE (%)	Mech Eff. (%)
0.15	0.03	4.05	4.08	0.03	4.66	0.60	97.55	0.62
5.45	0.88	4.50	5.38	1.03	6.34	11.29	69.25	16.31
9.40	1.50	3.92	5.42	1.79	6.45	16.75	60.54	27.66
13.74	2.18	3.92	6.10	2.61	7.30	20.29	56.77	35.75
18.09	2.85	3.65	6.49	3.44	7.84	22.71	51.79	43.85

Result Data

Air Flow (kg/h)	Fuel Flow (kg/h)	SFC (kg/k Wh)	Vol Eff. (%)	A/F Ratio	HBP (%)	HJW (%)	HGas (%)	HRad (%)
27.88	0.37	14.69	75.37	75.52	0.60	94.23	26.00	0.00
27.02	0.69	0.78	75.46	39.41	11.29	56.14	21.44	11.13
26.80	0.79	0.53	75.50	33.88	16.75	52.31	22.34	8.61
26.45	0.95	0.44	74.91	27.87	20.29	46.01	22.02	11.68
26.23	1.11	0.39	74.91	23.68	22.71	42.44	23.21	11.64

CHAPTER 10 RESULTS AND DISCUSSION

The performance characteristics like BTE, ITE, Mechanical Efficiency, SFC, Volumetric Efficiency with different proportions and different compression ratios like 16, of Biodiesel is compared with Diesel fuel.

8.1 Performance characteristics for compression ratio 16

The performance characteristics like BTE, ITE, Mechanical Efficiency, SFC,and Volumetric Efficiency of CR `17.5 run on VCR engine the resulting curves are following figures

- Load Vs Brake Thermal Efficiency
- Load Vs Indicated Thermal Efficiency
- Load Vs Mechanical Efficiency
- Load Vs Specific Fuel Consumption
- Load Vs volumetric Efficiency

Evaluated the combustion and emission characteristics of fumigation pine oil as a biofuel. Pine oil biofuel, obtained by the distillation of oleoresins of pine tree, has been chosen as a new renewable fuel for its operation in diesel engine. From this study, it was observed that at higher air temperature (150°C), evaporation of pine oil was more effective than at lower temperatures (100°C and 50°C) and therefore, 150°C was chosen as preheat temperature for engine fumigation study. The fumigated pine oil has been reported to be better.

8.2 LOAD Vs BRAKE THERMAL EFFICIENCY

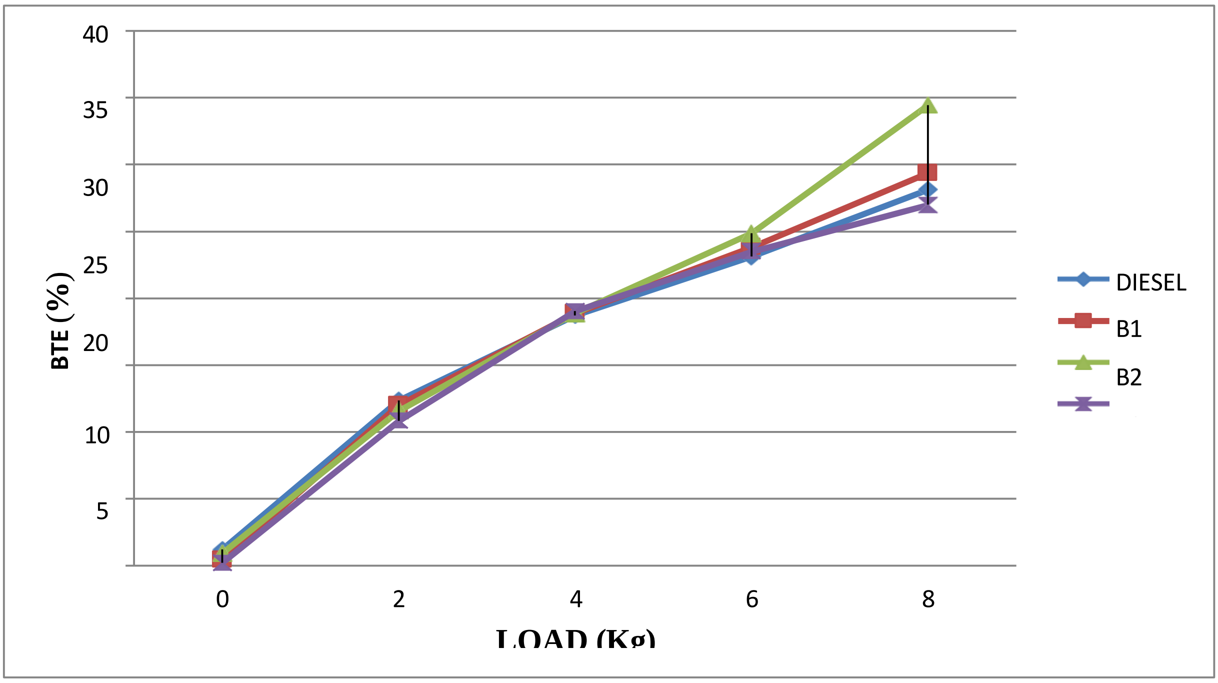


FIG 8.2 Load Vs Brake Thermal Efficiency

The above figure shows the variation of BTE with load. The maximum BTE of 34.44 % was achieved with B_2. The performance of BTE increases at 6.32 % than diesel as a fuel.The drop in BTE with increases in proportion of Jatropha Curcus biodiesel must be attributed to the poor combustion characteristics of biodiesel due to their high viscosity and poor volatility hence B_2 blending mode result has higher BTE.

8.3 LOADVs INDICATED THERMAL EFFICIENCY

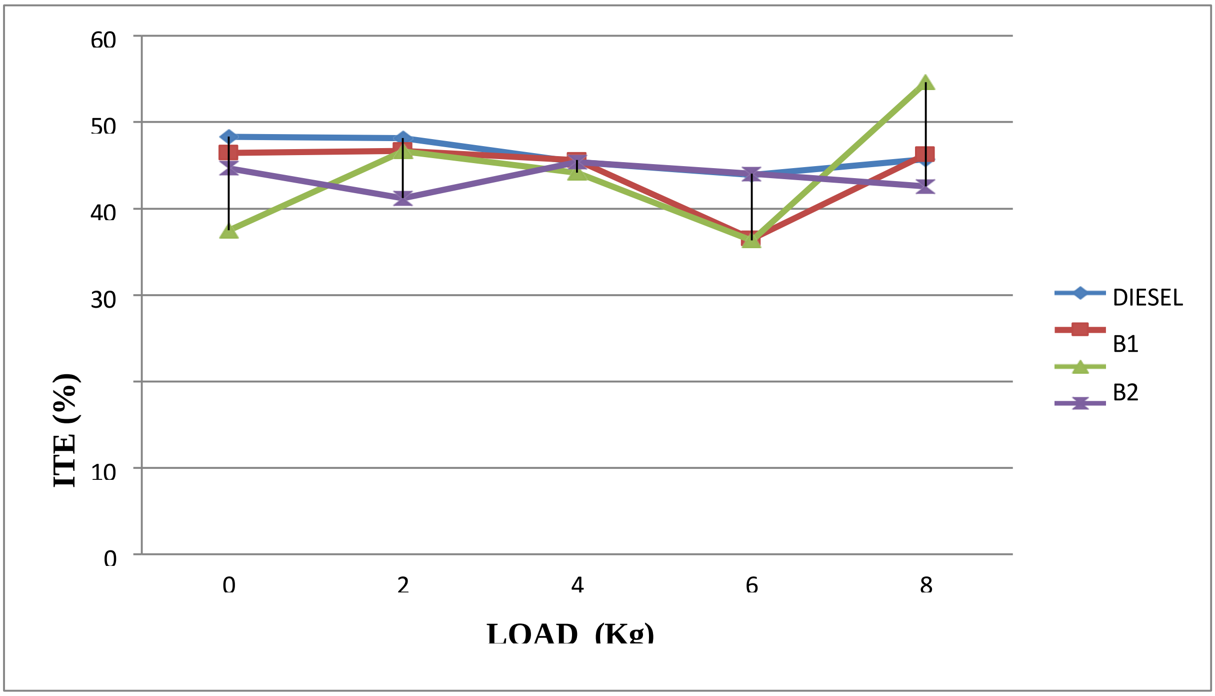


FIG 8.3. LoadVs Indicated Thermal Efficiency

The above figure shows the variation ofITE with loads. The maximum ITE of

54.62 % was achieved with B_2. The drop in ITE with increases in proportion of Jatropha Curcus biodiesel must be attribute to the poor combustion characteristics of biodiesel due to their high viscosity and poor volatility hence B_2 blending result has higher ITE.

8.4 LOAD Vs MECHANICAL EFFICIENCY

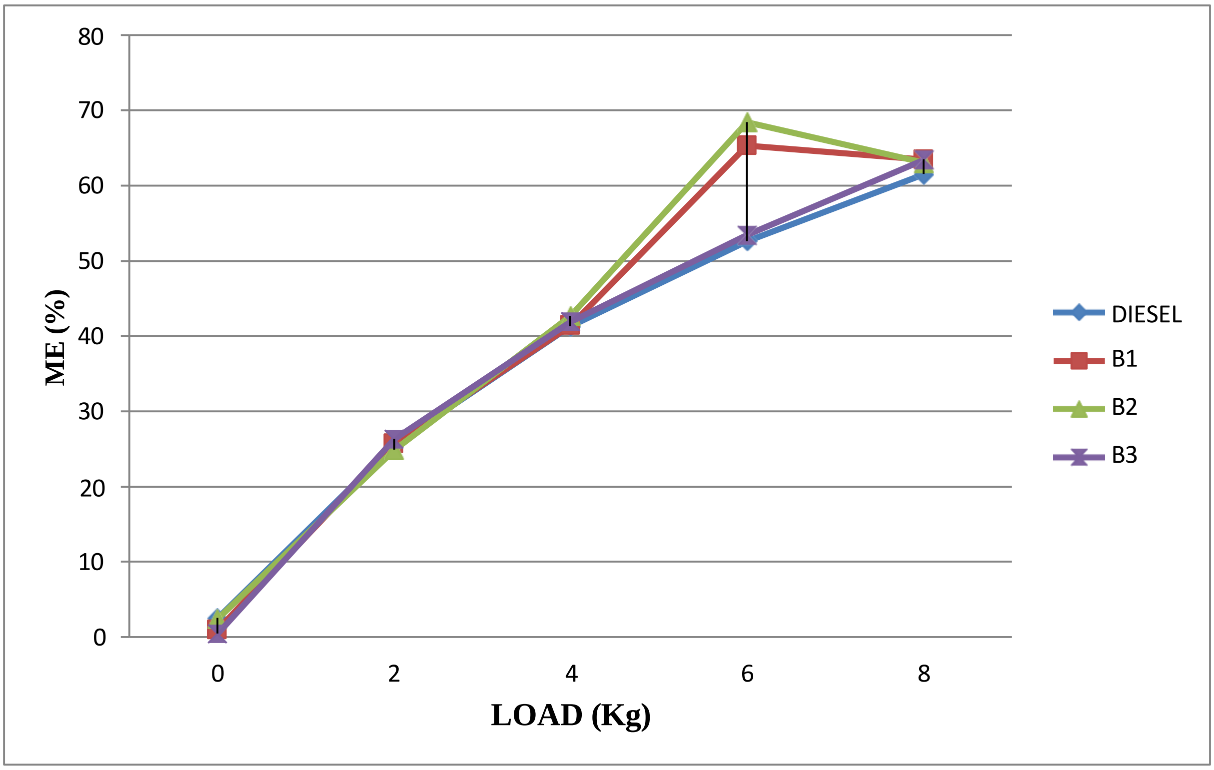


FIG 8.4 Load Vs Mechanical Efficiency

The above figure shows the variation of Mechanical Efficiency with load. The maximum Mechanical Efficiency of 63.47 % was achieved B_1 at full load condition but 75 % load condition B_2 has maximum Mechanical Efficiency of 68.41 % than diesel as a fuel.

8.5 LOAD Vs SPECIFIC FUEL CONSUMPTION

The above figure shows the variation of SFC with load.The BSFC with alternative fuel is lower than the diesel for full load condition. For no load condition and 25% load condition diesel has better SFC than alternative fuel.

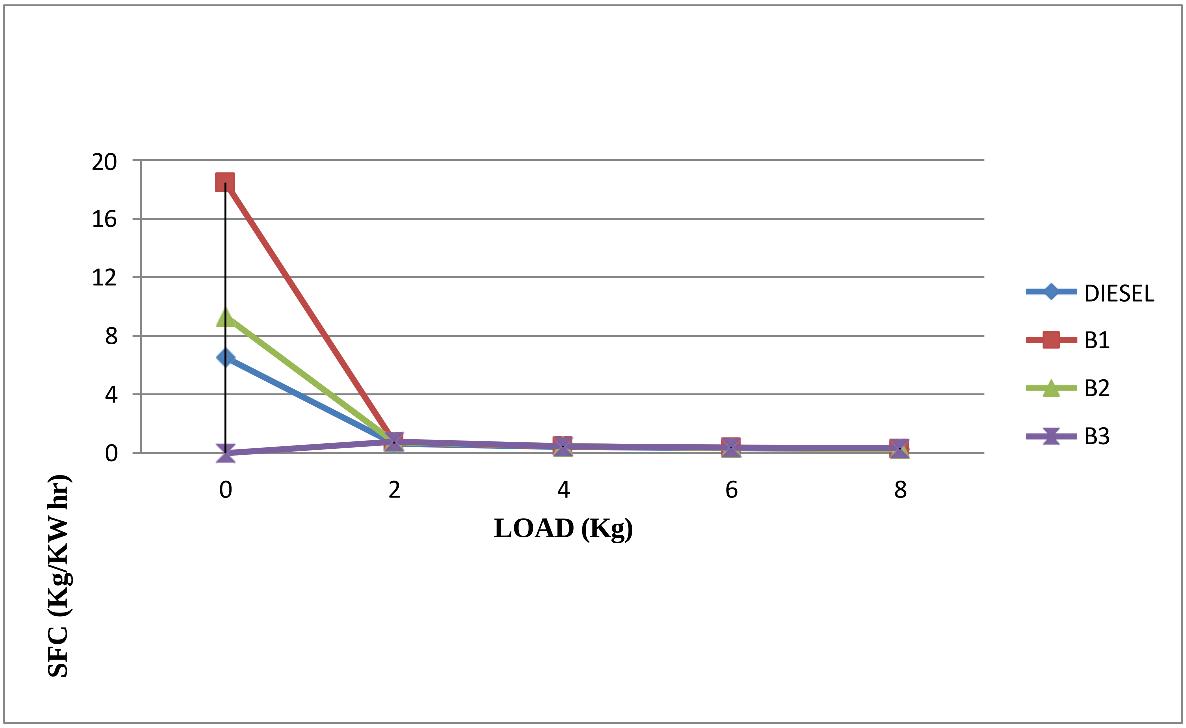


FIG 8.5 Load Vs Specific Fuel Consumption

8.6 LOAD Vs VOLUMETRIC EFFICIENCY

The above figure shows the variation of Volumetric Efficiency with load. The maximum Volumetric Efficiency of 78.53 % was achieved with diesel the blended biodiesel are lower Volumetric Efficiency than diesel fuel.

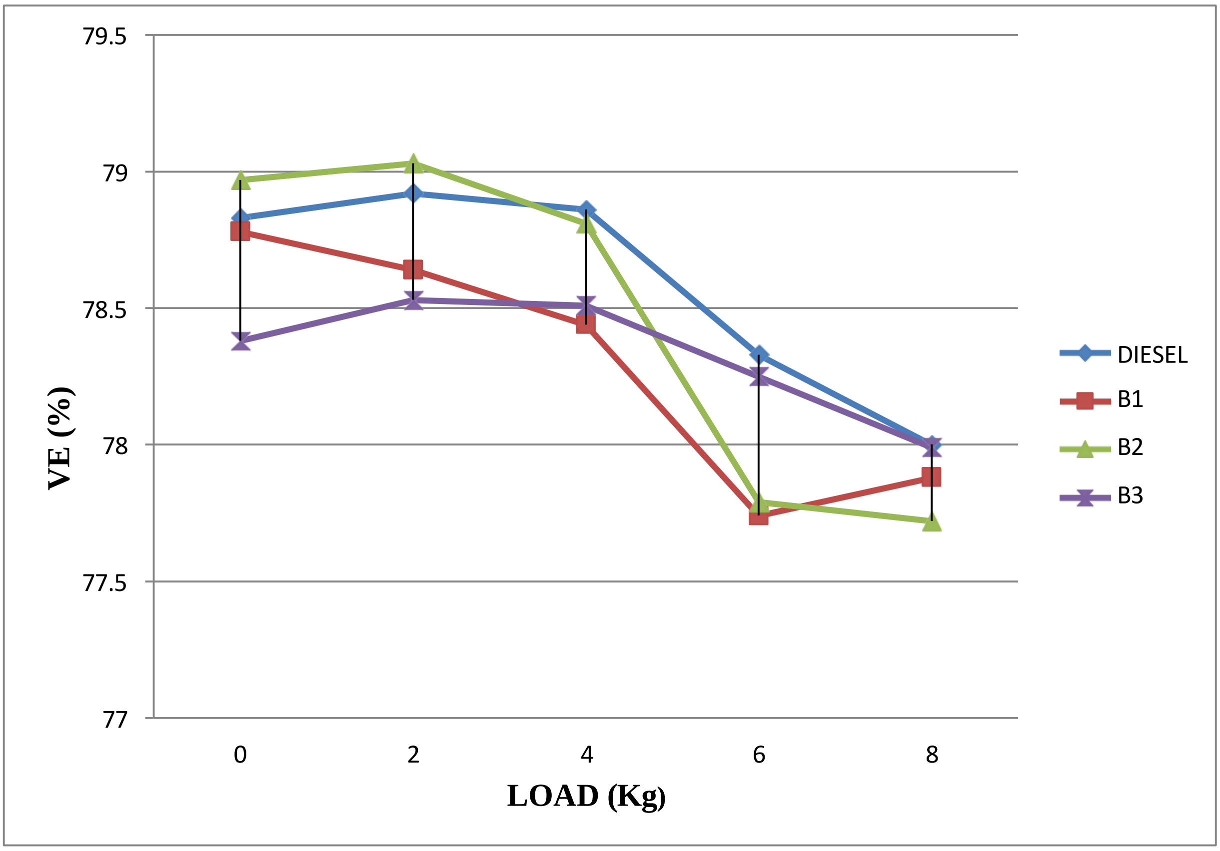


FIG 8.6 Load Vs Volumetric Efficiency

CHAPTER 11 CONCLUSION

To overcome the need of alternate fuels in the field of automobile in upcoming years due to over population and less availability of field like diesel, we tried out various proportion of Juliflora and Radish along with desired quantity of Diesel considering various engine and environmental facts. The fuel properties of Juliflora were found to be similar to the diesel fuel and DEE has high volatility and high cetane number hence used for a alternative fuel for diesel.

The experiments were conducted on a VCR engine with different blends like D, B_{20}, B_{40}. The engine performance characteristics and emission characteristics were compared.

It was found that the VCR engine with Compression ratio of 16 and the blend proportion B_2produced best results.

The proportion of B_2 is

DIESEL - 80%

JULIFLORA - 10%

RADISH - 10%

The Brake Thermal Efficiency increased b 6.32%, Mechanical Efficiencyincreased by 3.15% and the Emission characteristics like HC, NO_X emissions has reduced than Diesel.

REFERENCE

1. R. Vallinayagam, S. Vedharaj, W.M. Yang, V. RaghavanInvestigation of evaporation and engine characteristics of pine oil biofuel fumigated in the inlet manifold of a diesel engine Applied Energy 115 (2014) 514–524
2. B Anirudh, M. Gowtham, C.G. Mohan and R.Prakash Effect of fumigated biodiesel on the performance and emission characteristics of a single cylinder diesel engine Volume 8, Issue 12, December 2017, pp. 847–855.
3. R. Vallinayagam, S. Vedharaj, W.M. Yang, C.G. Saravanan, P.S. Lee, K.J.E. Chua, S.K. Chou Impact of pine oil biofuel fumigation on gaseous emissions from a diesel engine Fuel Processing Technology 124 (2014) 44–53
4. A.Imrann, M. Varman, H. H. Masjuki, M. A. Kalam Review on alcohol fumigation on diesel engine: a viable alternative dual fuel technology for satisfactory engine performance and reduction of environment concerning emission Renewable and Sustainable Energy Reviews 26(2013) 739–751
5. R. Vallinayagam, S. Vedharaj, W.M. Yang, C.G. Saravanan, P.S. Lee, K.J.E. Chua, S.K. ChouPine oil-biodiesel blends: A double biofuel strategy to completely eliminate the use of diesel in a diesel engine Applied Energy 130 (2014) 466–473

6. A Imran, M.Varman,H.H.Masjuki,M.A.KalamReview on alcohol fumigation on diesel engine: A viablealternative dual fuel technology for satisfactory engine performance and reduction of environment concerning emission Renewable and Sustainable Energy Reviews 26 (2013)739–751
7. Zivile Cerniauskien, Algirdas Jonas Raila, EgidijusZvicevi_cius, Zydre Kadziuliene, Vita Tilvikiene Analysis of Artemisia dubia Wall. Preparation
8. for biofuel and thermal conversion properties Renewable Energy 118 (2018) 468e476
9. Rajalingam, S. P. Jani1, A. Senthil Kumar and M. Adam Khan Production methods of biodiesel A Journal of Chemical and Pharmaceutical Research, 2016, 8(3):170-173
10. Gaurav Dwivedi, Siddhartha Jain, M.P. Sharma*J.* Mater. EnvironDiesel engine performance and emission analysis using biodiesel from various oil sources - Review. Sci. 4 (4) (2013) 434-447
11. J.M. Marchetti_, V.U. Miguel, A.F. ErrazuPossible methods for biodiesel production Renewable and Sustainable Energy Reviews11 (2007) 1300–1311
12. Xing-cai L, Jian-Guang Y, Wu-Gao Z, Zhen H. Effect of cetane number improver on heat release rate and emissions of high speed diesel engine fueled withethanol–diesel blend fuel. Fuel 2004; 83:2013–20.
13. Vallinayagam R, Vedharaj S, Yang W, Lee P, Chua K, Chou S. CombustionPerformance and emission characteristics study of pine oil in a diesel engine. Energy 2013; 57:344–51.
14. S-Y. Inedible vegetable oils and their derivatives for alternative diesel fuels in CI engines: a review. Renew Sust Energy Rev 2011; 15:131–49.
15. Sayin C, Ilhan M, Canakci M, Gumus M. Effect of injection timing on the Exhaust emissions of a diesel engine using diesel–methanol blends. Renew Energy 2009; 34:1261–9.