Chapter 3

Experimental Test Rig

An experimental test rig is developed to undertake the thermal performance evaluation and emission characteristics evaluation of a variable compression ratio compression ignition engine fuelled with Karanja biodiesel and its blends with Diesel oil. The experimental test rig is suitably developed to conduct various test runs under different working conditions to evaluate the thermal performance and emission constituents of a bio-diesel run engine in comparison with that of a conventional diesel operated engine. This chapter is organized in two sections. Section 3.1 describes the hardware used in the main experimental test rig. Various measurement systems incorporating sensors and instruments are described in Section 3.2.

3.1 Description of Experimental Test Rig

The experimental test rig consists of a variable compression ratio compression ignition engine, eddy current dynamometer as loading system, fuel supply system for both Diesel oil oil supply and biodiesel supply, water cooling system, lubrication system and various sensors and instruments integrated with computerized data acquisition system for online measurement of load, air and fuel flow rate, instantaneous cylinder pressure, injection pressure, position of crank angle, exhaust emissions and smoke opacity. Plate 3.1 is the photographic image of the experimental setup used in the laboratory to conduct the present study and Figure. 3.1 represents the schematic representation of the experimental test setup. Table 3.1 gives the technical specifications of different components used in the test rig. The setup enables the evaluation of thermal performance and emission constituents of the VCR engine. The thermal performance parameters include brake power, brake mean effective pressure, brake thermal efficiency, volumetric efficiency, brake specific fuel consumption, exhaust gas temperature, heat equivalent of brake power and heat equivalent of exhaust gas. Commercially available labview based Engine Performance Analysis software package “EnginesoftLV” is used for on line performance evaluation. The exhaust emissions of the engine are analysed using an exhaust gas analyser. The constituents of the exhaust gas measured are CO (% and ppm), CO_2 (%), ,

O_2 (%), HC (ppm), NO_x (ppm) and SO_x (ppm). The smoke intensity is measured in terms of Hartridge Smoke Unit (HSU in %) /K(the light absorption coefficient (m^{-1}).

Table 3.1 Technical Specifications of Experimental Test Rig

Engine	Type - single cylinder, four stroke Diesel, water cooled, rated power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm. 661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18
Dynamometer	Type eddy current, water cooled, with loading unit
Piezo sensor	Range 5000 psi, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Data acquisition device	NI USB-6210, 16-bit, 250kS/s.
Piezo powering unit	Make-Cuadra, Model AX-409.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K
Temperature transmitter	Type two wire, Input RTD PT100, Range 0–100 Deg C, Output 4–20 mA and Type two wire, Input Thermocouple, Range 0–1200 Deg C, Output 4–20 mA
Load indicator	Digital, Range 0-50 Kg, Supply 230VAC
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Fuel flow transmitter	DP transmitter, Range 0-500 mm WC
Air flow transmitter	Pressure transmitter, Range (-) 250 mm WC
Software	"EnginesoftLV" Engine performance analysis software
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Exhaust gas analyzer	Make – Indus Scientific, Five gas analyzer
Smoke meter	Make – Indus Scientific, Range – 0 to 100% HSU

Plate 3.1 Experimental Test Rig

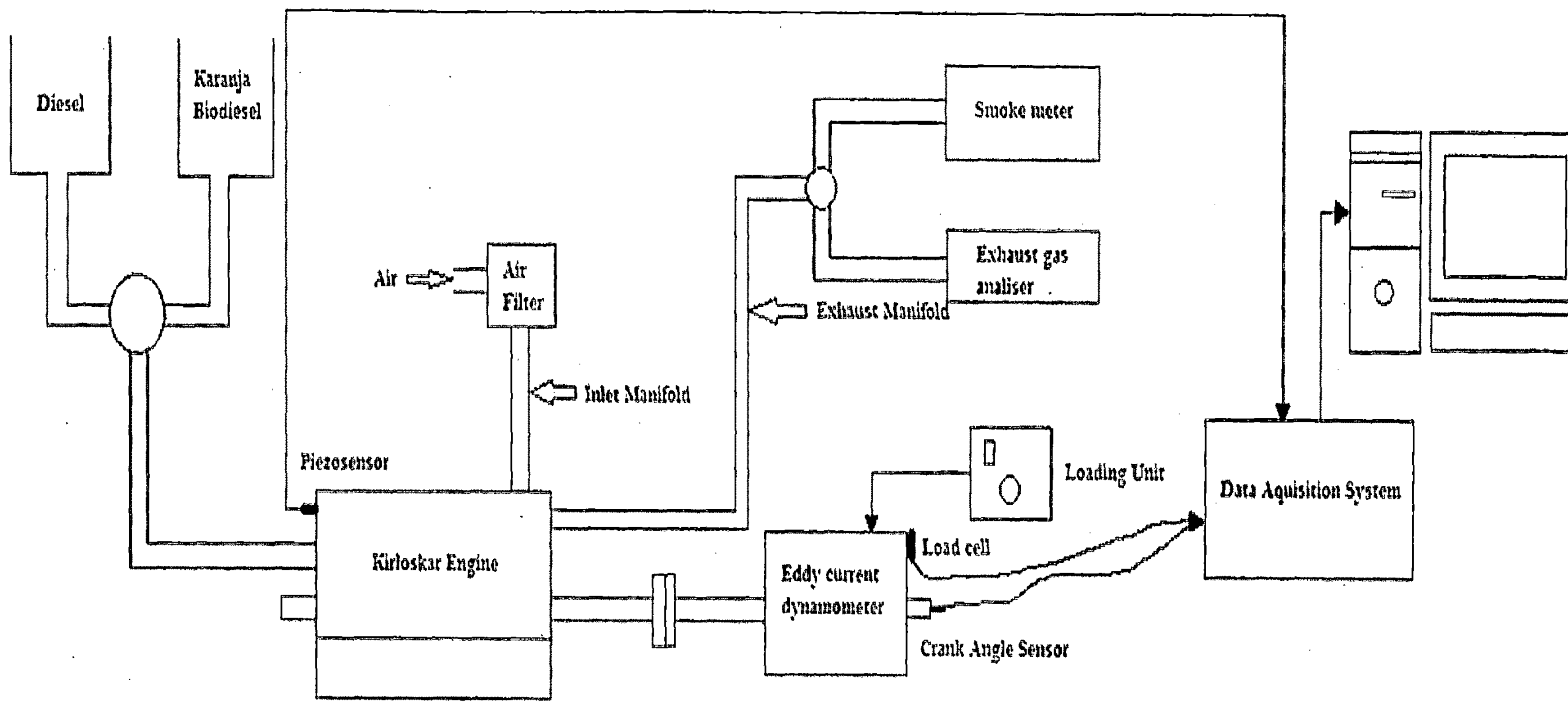

Figure. 3.1 Schematic Diagram of Experimental Test Rig

3.1.1 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 technical specifications of the engine are given in Table 3.2. The engine is mounted on a stationary frame with a suitable cooling system. The lubricating system is inbuilt in the engine. Two different photographic images of the engine are given in Plates 3.2 and 3.3.

Table 3.2 Technical Specifications of VCR Diesel Engine

Make & Model	Kirloskar Oil Engine, TV1
Type	Four stroke, Water cooled, Diesel
Number of cylinder	One
Bore and Stroke	87.5 mm and 110 mm
Combustion principle	Compression ignition
Cubic capacity	0.661 litres
Compression ratio	17.5 :1 (modified to work at 12, 13, 14, 15, 16, 17.5 and 18 compression ratios)
Peak cylinder pressure	77.5 kg/cm^2
Direction of rotation	Clockwise
Maximum speed	2000 rpm
Minimum idle speed	750 rpm
Minimum operating speed	1200 rpm
Fuel injection timing for standard engine	23^0 BTDC
Valve clearances at inlet and exhaust	0.18 mm and 0.20 mm
Bumping clearance	0.046"-0.052"
Lubricating system	Force feed system
Power rating 1. Continuous 2. Intermittent	 7/1500 hp/rpm 7.7/1500 hp/rpm
Brake mean effective pressure at 1500	6.35 kg/cm^2

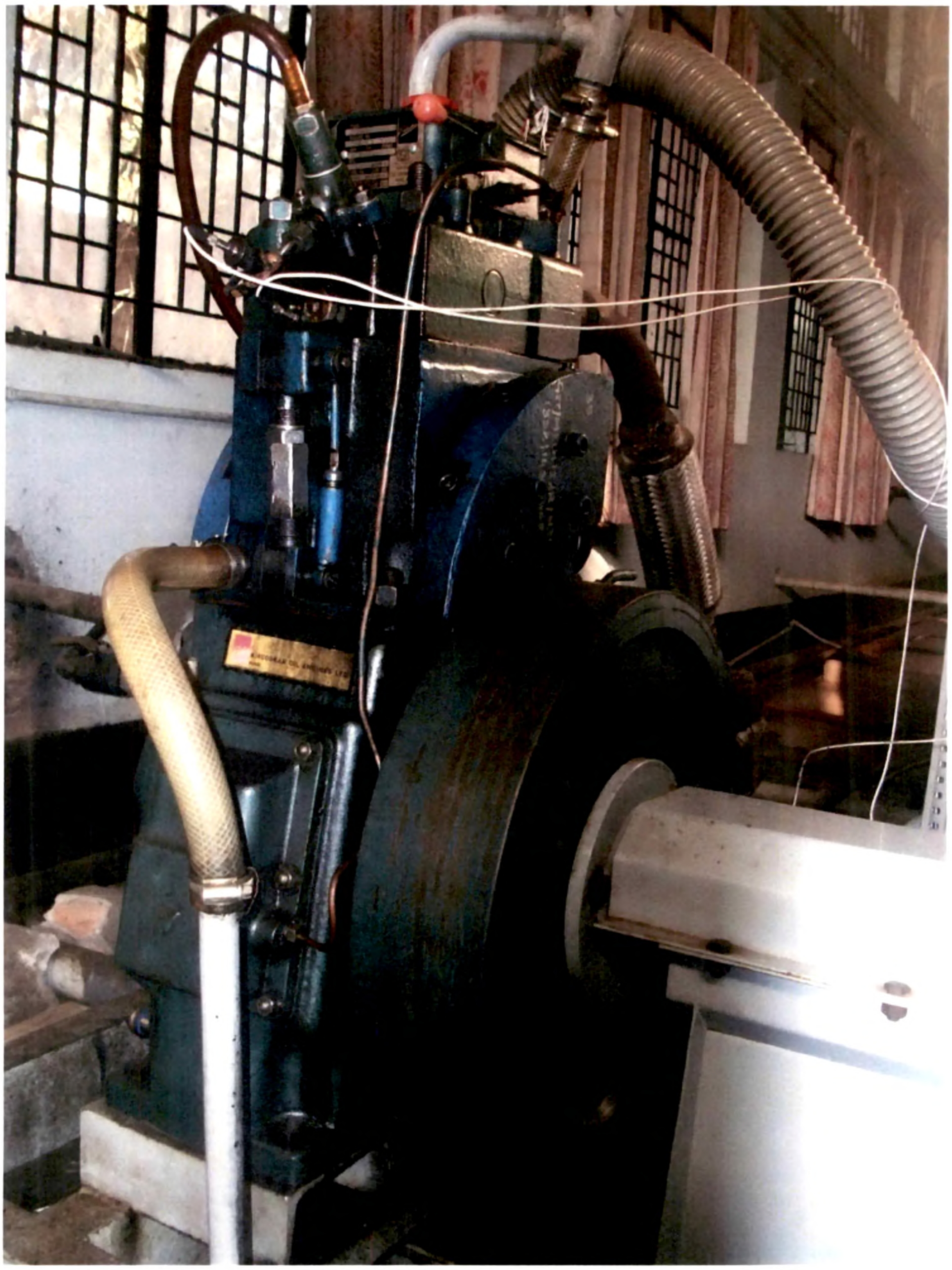

Plate 3.2 Variable Compression Ratio Diesel Engine

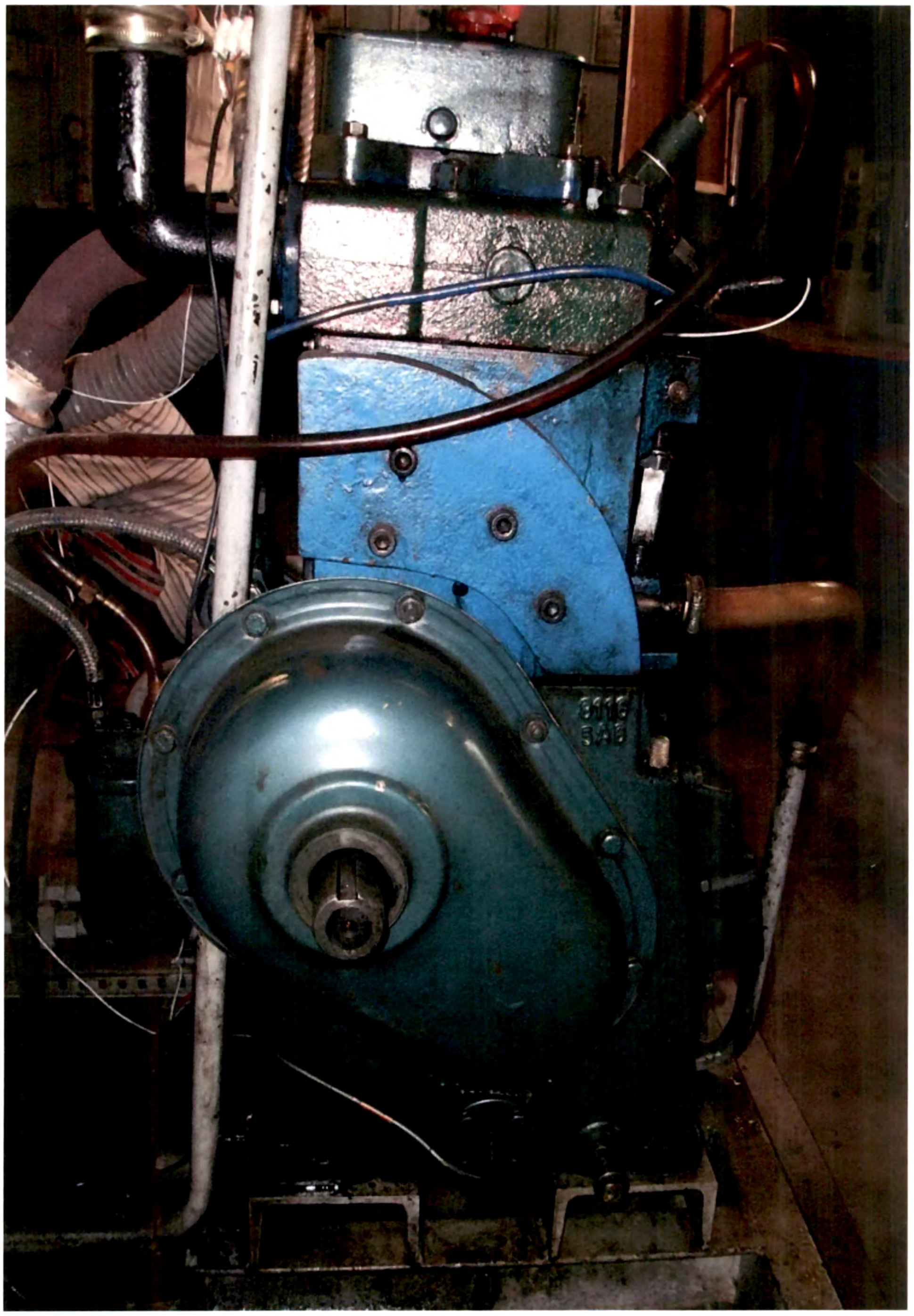

Plate 3.3 Rear View of the Engine

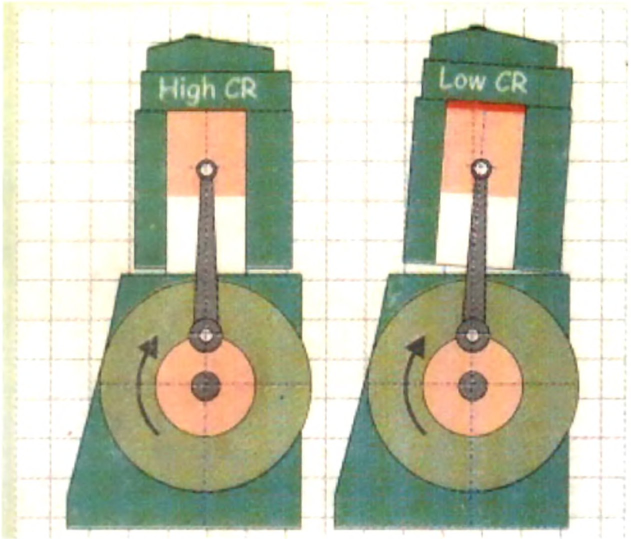

Figure 3.2 Principle of Tilting Cylinder Block Assembly

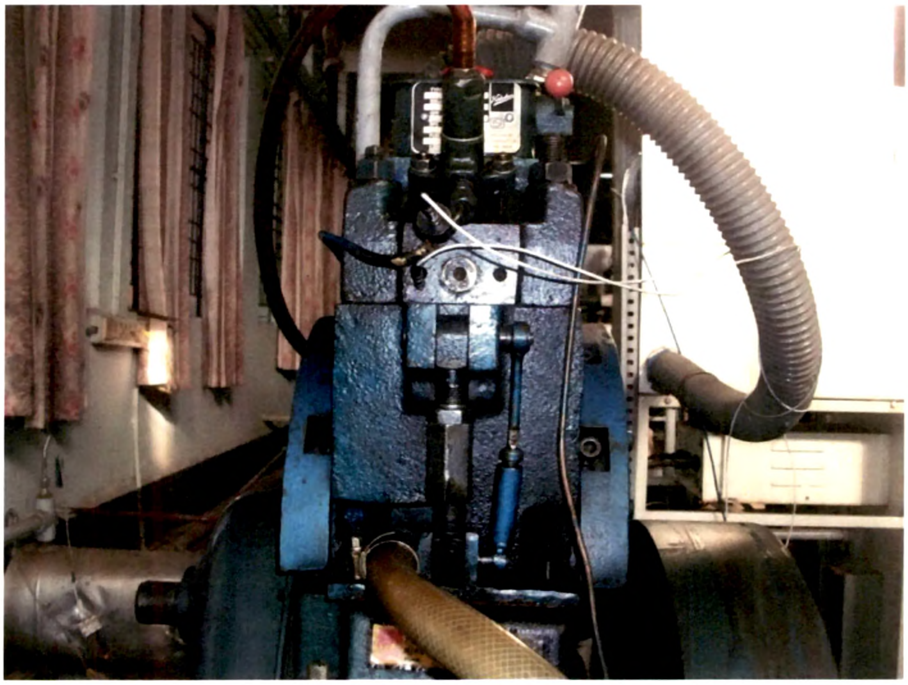

Plate 3.4 Tilting Cylinder Block Arrangement

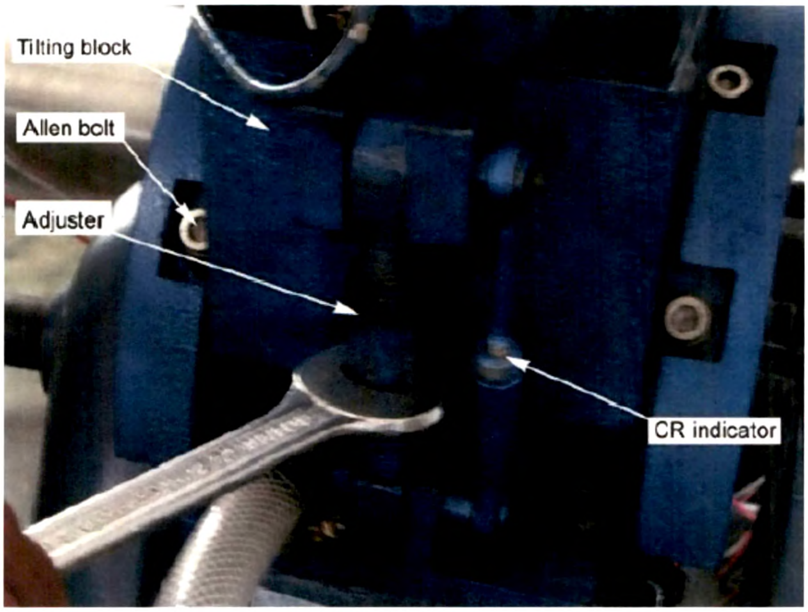

Plate 3.5 Compression Ratio Setting

3.1.3 Fuel Injection Pump

The fuel injection pump manufactured by MICO BOSCH is used for injecting Diesel oil or bio-diesel in to the VCR engine (Plate 3.6). The fuel injection pump is operated by the cam shaft and the fuel injection timing can be varied by adding/removing shims placed beneath the pump and pump mounting bracket.

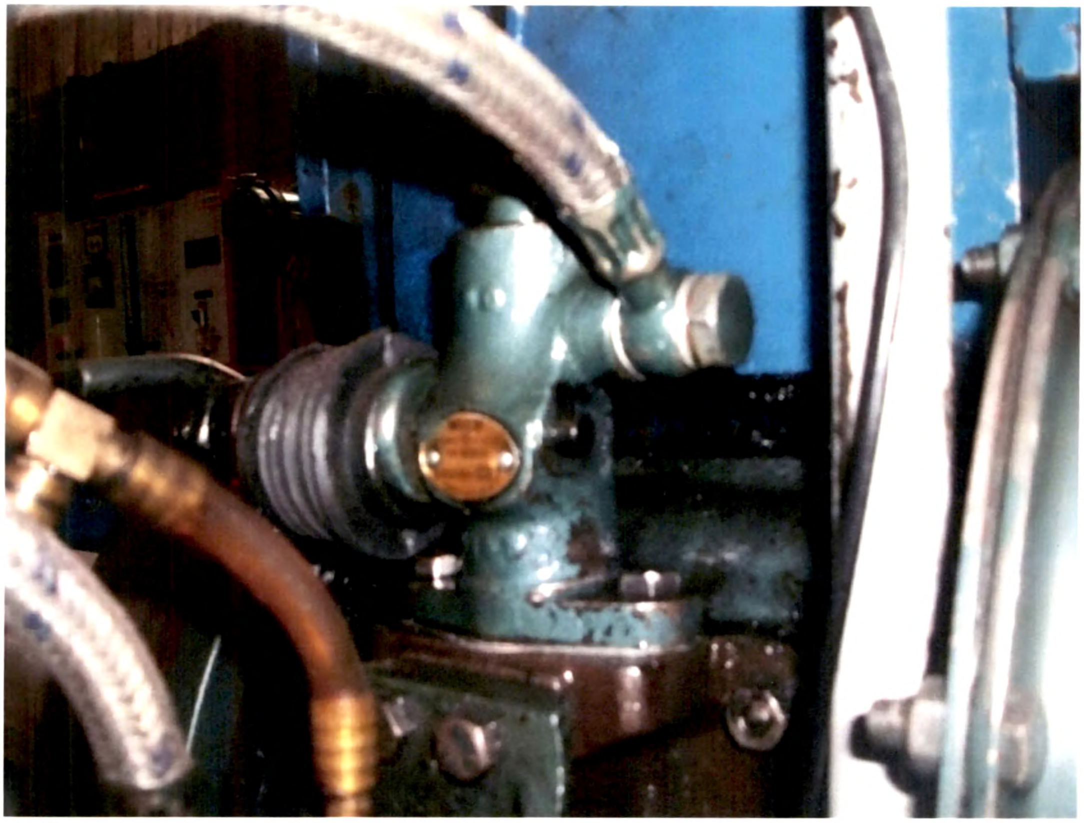

Plate 3.6 Fuel Injection Pump

3.2 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.

3.2.1 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 dynamometer, load cell and loading unit are discussed in the following paragraphs.

A dynamometer is a device which is used for measuring force, torque or power produced by an engine. It can also be used to apply load or torque on the engine. The dynamometer used in this study is an eddy current type with a water cooling system. The eddy current dynamometers provide an advantage of quicker rate of load change for rapid load setting. 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. Plate 3.7 shows the image of the eddy current dynamometer used in this study. Plate 3.8 depicts the assembly of the eddy current dynamometer and the engine. The technical specifications of the dynamometer are given in Table 3.3.

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 a loading unit, a magnetic field is created in the casing across the air gap on either side of the rotor. The details of the loading unit are given later in this section.

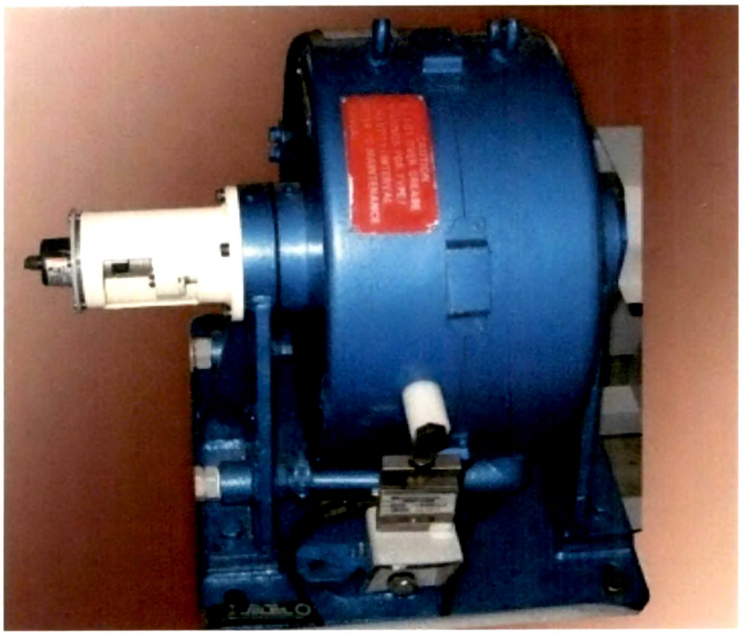

Plate 3.7 Eddy Current Dynamometer

Plate 3.8 Assembly of Eddy Current Dynamometer and Engine

Table 3.3 Technical Specifications of Eddy Current Dynamometer

Model	AG-10
Make	SAJ Test Plant Pvt. Ltd
End flanges both side	Carbon shaft model 1260 type A
Water inlet	1.6bar
Minimum kPa	160
Pressure lbf/in^2	23
Air gap mm	0.77/0.63
Torque Nm	11.5
Hot coil voltage max	60
Continuous current amps	5
Cold resistance ohms	9.8
Speed max.	10000 rpm
Load	3.5 kg
Bolt size	M12×1.75
Weight	130 kg
Arm Length mm	185

When the rotor turns in this magnetic field, eddy current gets induced creating a braking effect between the rotor and the casing. The rotational torque exerted on the casing is measured by a strain gauge load cell incorporated in the restraining linkage between the casing and the dynamometer. To prevent over heating of the dynamometer, cooling water is circulated with the help of a water pump through the cooling passages of 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 are shown in Plate 3.9.

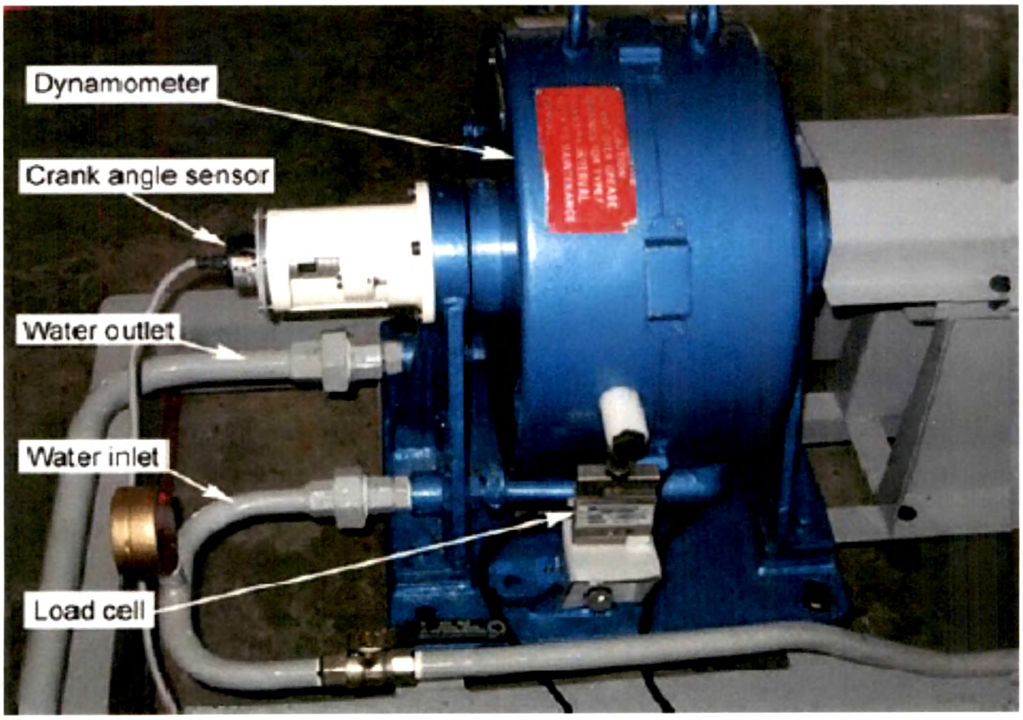

Plate 3.9 Components Connected to the Eddy Current Dynamometer

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 mechanical arrangement is provided due to which the force being applied deforms a strain gauge. The strain gauge consisting of an electrical wire measures the deformation (strain) as an electrical signal, because the strain changes the effective electrical resistance of the wire. 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 output of the transducer is plugged into an algorithm to calculate the force applied to the transducer. A photographic image of the load cell used and its technical specifications are given in Plate 3.10 and Table 3.4 respectively.

Plate 3.10 Load Cell

Table 3.4 Technical Specifications of the Load Cell Used

Make	Sensotronics
Model	60001
Type	S – Beam Universal
Capacity	0 – 50 kg
Mounting thread	M10 × 1.25 mm
Full scale output (mV/V)	3.00
Tolerance on output (FSO)	+/-0.25%
Zero balance (FSO)	+/-0.1mV/V
Non-linearity (FSO)	<+/-0.025%
Hysteresis (FSO)	<+/-0.020%
Non-repeatability	<+/-0.010%
Creep (FSO) in 30 min	<+/-0.020%

Operating temperature range	-20 ^{0}C to +70 ^{0}C
Rated excitation	10V AC/DC
Maximum excitation	15V AC/DC
Bridge resistance	350 Ohms (Nominal)
Insulation resistance	>1000 Meg ohm @ 50VDC
Span / ^{0}C (of load)	+/-0.001%
Zero / ^{0}C (of FSO)	+/-0.002%
Combined error (FSO)	<+/-0.025%
Safe overload (FSO)	150%
Ultimate overload (FSO)	300%
Protection class	IP 67
Overall dimensions	51 L x 20 W x 76 H mm
Weight	380 gm

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 Plate 3.11. The assembly of the same into the engine panel box can be seen in Plate 3.12.

Plate 3.11 Dynamometer Loading Unit

Plate 3.12 Engine Panel Box

The schematic diagram of the dimmerstat used in the loading unit is given in Figure. 3.3. Figure. 3.4 shows the circuit diagram of dimmerstat. It consists of a high conductivity insulated copper wire wound over an insulated toroidal core made of magnetic material. The free ends of the wire are marked A and C in Figure 3.4. A carbon brush (marked E) traverses over this coil. The carbon brush attached to a manually rotating handle makes contact with different number of turns. The number of turns between E & C, can be varied from zero to a maximum of total number of turns between A & C. Therefore the load applied to the engine which is proportional to output voltage can be varied smoothly from zero to the value of the input voltage simply by rotating the handle in the clockwise direction.

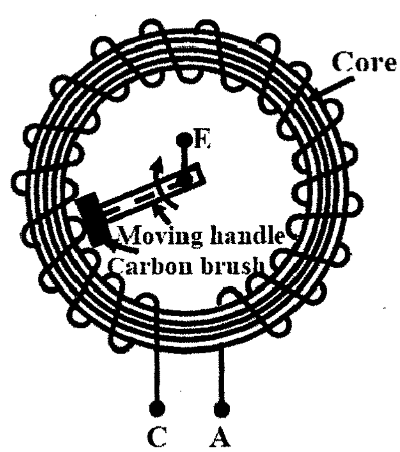

Figure 3.3 Schematic Diagram of the Loading Dimmerstat

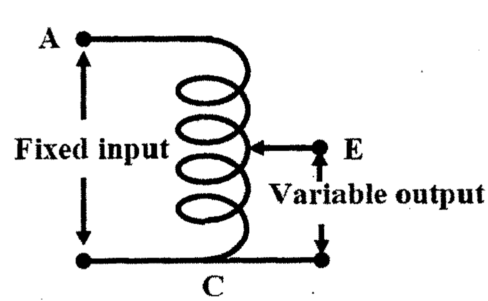

Figure 3.4 Circuit Diagram of the Loading Dimmerstat

3.2.2 Fuel Injection Pressure Measurement System

Fuel injection system is a system for admitting the fuel into an internal combustion engine. Fuel injection pressure (also called as fuel inline pressure) is the pressure at which fuel is injected into the engine cylinder. In the present experimental study, a Piezo Sensor, Make PCB Piezotronics, Model HSM111A22, Range 5000 psi (345 bar), is used to record the fuel injection pressure (Refer Plate 3.13). The technical details of this sensor are given in Table 3.5. The sensor consists of a diaphragm made of stainless steel and of hermetically sealed type. The sensor is installed in a specially made high pressure pipe line. The location of fuel injection pressure sensor is indicated as No. 1 in Plate 3.14. Initially the default value of pressure is 210 bar. During experimentation it is adjusted approximately for about 150bar, 200bar and 250bar. The injection pressure is changed by adjusting the fuel injector spring tension which is carried out by tightening or loosening the nut for higher or lower injection pressures respectively (Refer Plate 3.14). The nut is tightened by rotating it clockwise and loosened by rotating it anticlockwise.

Plate 3.13 Piezosensor

Table 3.5 Technical details of Injection pressure sensor

Make	PCB Piezotronics
Model	SM111A22
Serial No	15345
Description	Pressure Sensor
Type	ICP

Sensitivity	1.001 mV/PSI
Linearity	0.4 % FS
Uncertainity	+/- 1%
Bias	10.67 V DC

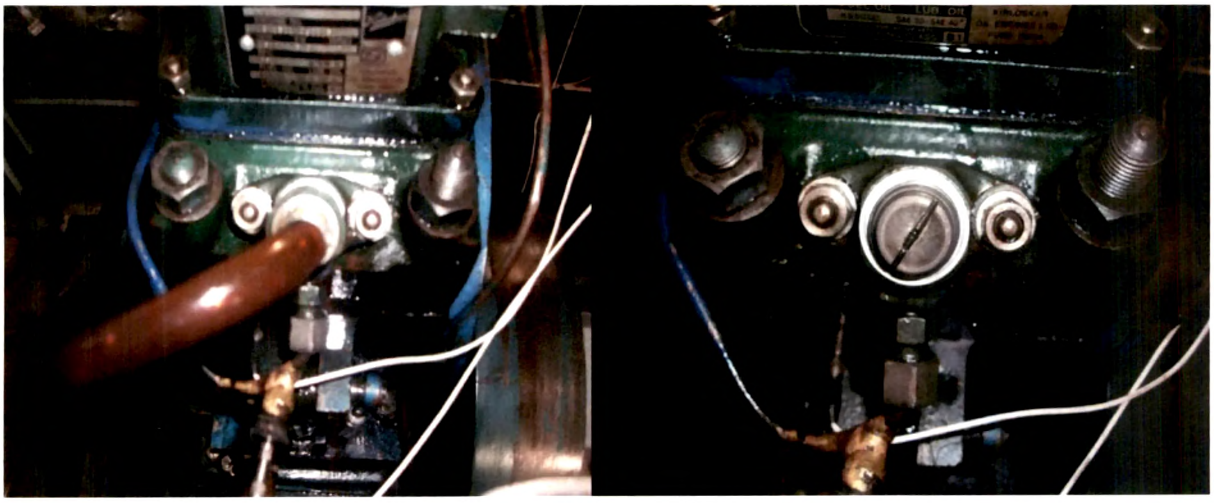

Plate 3.14 The Nut Adjustment for Setting Injection Pressure

The piezosensor is interfaced with a data acquisition system (discussed later in the chapter) so that the pressure is displayed on the computer screen. The data acquisition system reads the pressure signals from the sensor and sends it to the computer which is installed with commercial software (Enginesoft LV). The software displays the value of pressure in bar on the monitor.

3.2.3 Cylinder Pressure Measurement System

The cylinder pressure is measured using a Piezo sensor of Make PCB Piezotronics, Model HSM111A22, Range 5000 psi (345 bar), and diaphragm stainless steel & hermetically sealed type, by mounting it on the cylinder head. The piezo sensor is mounted on engine head. Its location is indicated as No. 2 in the Plate 3.15. The piezoelectric transducer produces a charge output, which is proportional to the in-cylinder pressure. This charge output is supplied to a piezo powering unit which is of Make Cuadra AX- 104 Model.

The piezo sensor consists of a quartz crystal. One end of the sensor is exposed to the cylinder pressure through the diaphragm. As the pressure inside the cylinder increases the crystal is compressed. Since the piezoelectric crystals have a tendency to generate electric charge when deformed, the sensor generates electric charge proportional to the pressure. The charge generated is smaller in magnitude and difficult to measure. Hence a charge amplifier is incorporated in the sensor to produce an output voltage proportional to the charge.

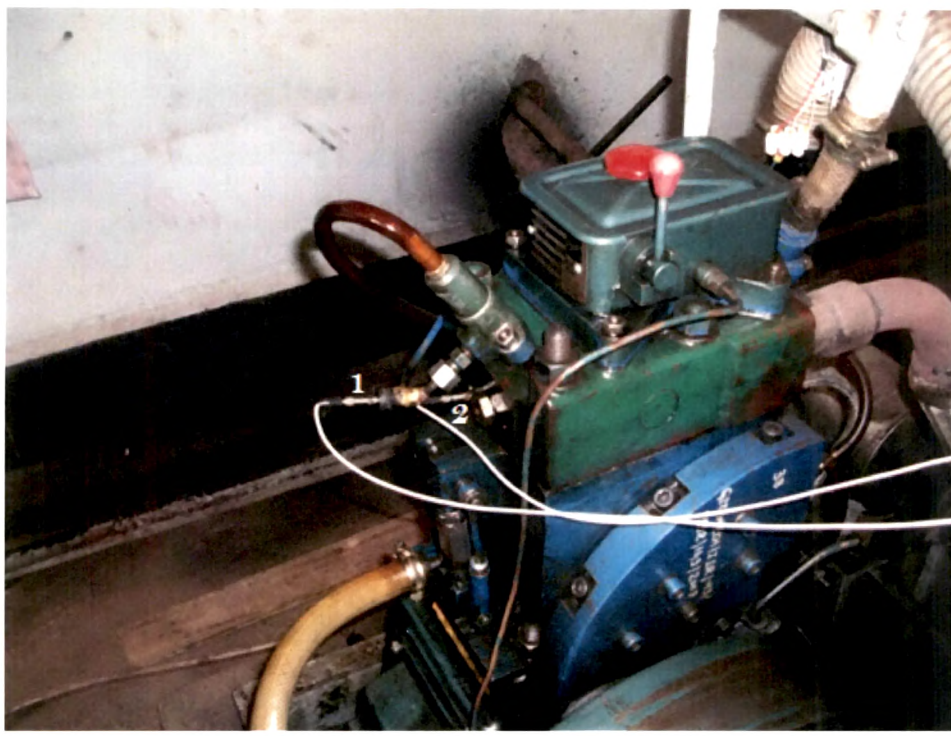

Plate 3.15 Location of Pressure Sensors

3.2.4 Data Acquisition System

For acquiring in-cylinder pressure changes with respect to the crank angle, a high speed data acquisition system is required. Plate 3.16 shows the circuit where different sensors are interfaced to the system. This is used for analyzing 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 Center (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 system. Further to get the valuable information from experimentation, the data is to be analyzed 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 during the experimentation has to be systematically processed as discussed in the following paragraph.

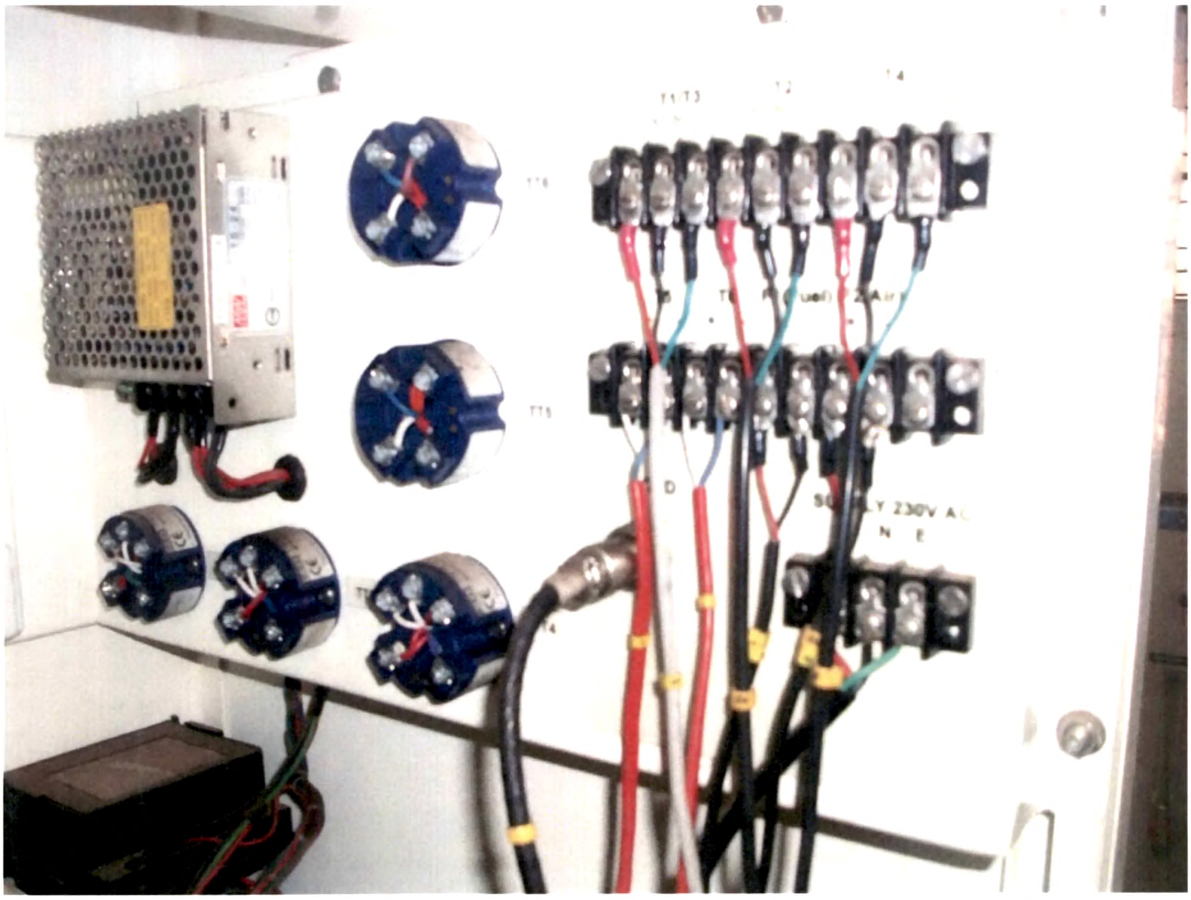

Plate 3.16 Sensors Interface Circuit

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 center 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. The experimental data captured is given in Appendix III and sample calculations are given in Appendix IV.

3.2.5 Emission Measurement System

The emission measurement system is used to measure the constituents of exhaust gas and its opacity (smoke number). This system consists of an exhaust gas analyzer and a smoke meter. The exhaust gas analyzer measures the exhaust gas constituents of Carbon dioxide (CO_2), Carbon monoxide (CO), Oxides of nitrogen (NO_x), Unburnt Hydrocarbons (HC), Oxygen (O_2) and Oxides of sulphur (SO_x). The smoke meter is used to measure the intensity of exhaust smoke and it is measured in terms of Hartrigde Smoke Unit (%) and light absorption coefficient (K expressed in m^{-1}). A photographic image of the assembly of the emission measurement systems used in the experiment is given in Plate 3.17. The range, data resolution and accuracy of the exhaust measurement systems are given in Table 3.6. The calibration certificate of exhaust gas analyser and smoke meter are given in Appendix V.

Table 3.6 Range, Resolution and Accuracy of Exhaust Measurement Systems

Gas	Range	Data Resolution	Accuracy
CO	0-15.00%, 0-4000ppm	0.01%, 1ppm	± 0.06%, ±5%
CO_2	0-20.00%	0.01%	± 0.5%
HC	0-30000 ppm	0.01%	± 12 ppm
O_2	0-25.00%	1 ppm	± 0.1%
NO_x	0-5000 ppm	1 ppm	± 3 ppm
SO_x	0-5000 ppm	1 ppm	± 5%
Smoke	0-100% HSU	0.1%	±0.1%

3.2.5.1 Exhaust Gas Analyzer

An instrument used to analyze the chemical composition of the exhaust gas released by a reciprocating engine is called exhaust gas analyzer. An image of the exhaust gas analyzer used in this study is given in Plate 3.18. The analyser (Model PEA205) is of make INDUS *Scientific* Pvt Ltd, Bengaluru. The instrument measures the concentrations of Carbon monoxide (CO in % & ppm), Carbon Dioxide (CO_2) and Oxygen (O_2) in percentage, Hydrocarbons (HC), Nitric Oxide (NO_x) and Oxides of Sulphur (SO_x) in ppm in the engine exhaust gas. The technical specifications of the exhaust gas analyser are given in the Table 3.7.

Table 3.7 Technical Specifications of Exhaust Gas Analyzer

Gases Measured	Carbon Monoxide, Hydrocarbon, Carbon dioxide, Oxygen, NO_x and SO_x
Principle	Non-Dispersive Infrared Sensors for CO, CO_2, HC and Electrochemical sensors for O_2, NO_x and SO_x
Data Resolution, Accuracy, Range	Given in Table 3.6
Startup Time	< 2 minutes from power ON. Full accuracy in 3 minutes
Auto Zero	Every 24 minutes with automatic fresh air intake
Gas Flow Rate	500 – 1000 ml per minute
Sample Handling System	S.S. Probe, PU Tubing with easily detachable connectors, water separator cum filter, disposable particulate fine filter.
Operating conditions	Temperature : 5 to 45 ^0C Pressure : 813 to 1060mbar Humidity: 0-90%

Plate 3.17 Assembly of Emission Measurement Systems

Plate 3.18 Exhaust Gas Analyzer

The analyzer uses the principle of Non-Dispersive Infra Red (NDIR) for measurement as shown in Figure. 3.5. In this technique, an infrared light is passed through the exhaust gas. Most molecules of gas can absorb the infrared light, causing it to bend, stretch or twist. The amount of infrared light absorbed by the gas molecules is proportional to their concentration in the exhaust gas. This method of detection does not cause ionization of gas molecules because the energy of the photons is not high enough. The source of infrared light is an incandescent bulb. The type of molecule absorbing the light depends on the wavelength of light absorbed by the molecule.

CO, HC & CO_2 are sensed measured by NDIR principle while O_2 ,NO_x, SO_x use Electro Chemical(EC) sensors, for their measurement.

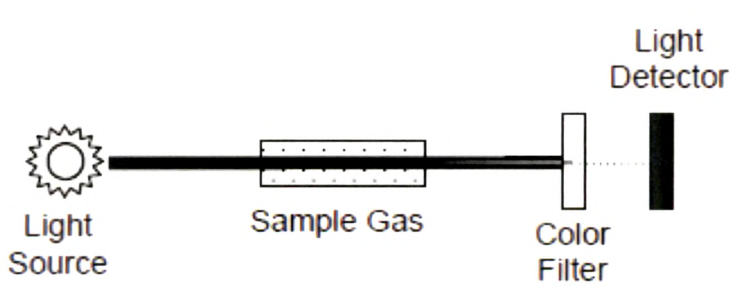

Figure. 3.5 Principle of Non-Dispersive Infra Red Technique

When the probe is inserted into the exhaust pipe (Plate 3.19) of the engine the exhaust gas is passed through a metal mesh screen. The screen filters the soot and dust particles after which it is allowed to pass through a fine fibre element which filters the entire gas for any foreign particles. After this, the clean and cool sample gas enters the direct sensor measurement through a filter arrangement and the readings are displayed on the screen and are recorded. The emission measurements are carried out on dry basis.

Plate 3.19 Measurement of Exhaust Gas Constituents

3.2.5.2 Smoke Meter

Photographic image of the Smoke Meter (Automotive Exhaust Monitor) given in Plate 3.20 is of make INDUS *Scientific* Pvt Ltd, Bengaluru. The smoke meter is used for measuring the opacity of the exhaust gas from the engine. The instrument measures the smoke opacity in terms of Hartridge smoke unit (HSU) which is measured in % and in terms of light absorption coefficient K (1/m).

The exhaust monitor consists of a smoke chamber which contains the smoke column through which the smoke from exhaust pipe of the engine is passed and smoke density is measured. The gas to be measured is fed into the smoke chamber. The gas enters the smoke column at its center. The smoke column is a tube, which has a light source and a detector placed at one end. The opacity of smoke is directly proportional to the attenuation of light between a light source and a detector. The technical details of Smoke Meter are given in Table 3.8.

Plate 3.20 Smoke Meter

Table 3.8 Technical Details of the Smoke Meter

Principle of Operation	Attenuation of light beam
Geometry	Folded Hartridge Geometry
Measurement	Smoke density in Hartridge smoke units (HSU) & K (m^{-1})
Range	0 to 100% in HSU, 0.01 m^{-1} in K
Resolution	Given in Table 3.6
Time Constant	Physical 0.4 second, Electrical 1m second
Temperature Sensor	RTD (PT-100) or Thermocouple
Light Source	LED, Green Spectrum (567 nm)
Detector	Photocell
Probe	A steel probe with synthetic rubber connecting hose
Warmup Time	20 minutes
Operating Temperature	5 to 50 ^{0}C
Measuring Temperature	80 ^{0}C

The working of smoke meter based on the principle of folded geometry is illustrated in Figure. 3.6. The light source is a green LED, marked as **'S'.** The light beam from **'S'** falls on a partially coated mirror **'PM',** gets reflected to the right and passes through the smoke column in the pipe **'P'.** The beam hits a mirror **'M'** located at the end of the smoke column and gets reflected in the opposite direction. The beam passes through the lens **'L'** for the second time to get focused on the detector **'D'** after transiting the partially coated mirror. The net result of this beam folding is that the beam travels through the smoke column twice, thus making the traversed length twice the length of the smoke column.

A heater is placed around the smoke pipe in order to raise the temperature of the smoke. This will prevent condensation of smoke inside the smoke column. A centrifugal fan is mounted at the either end of smoke column to drive out the smoke after measurement. The smoke opacity is measured by inserting the probe of the smoke meter in the exhaust pipe of the engine (Refer Plate 3.21).

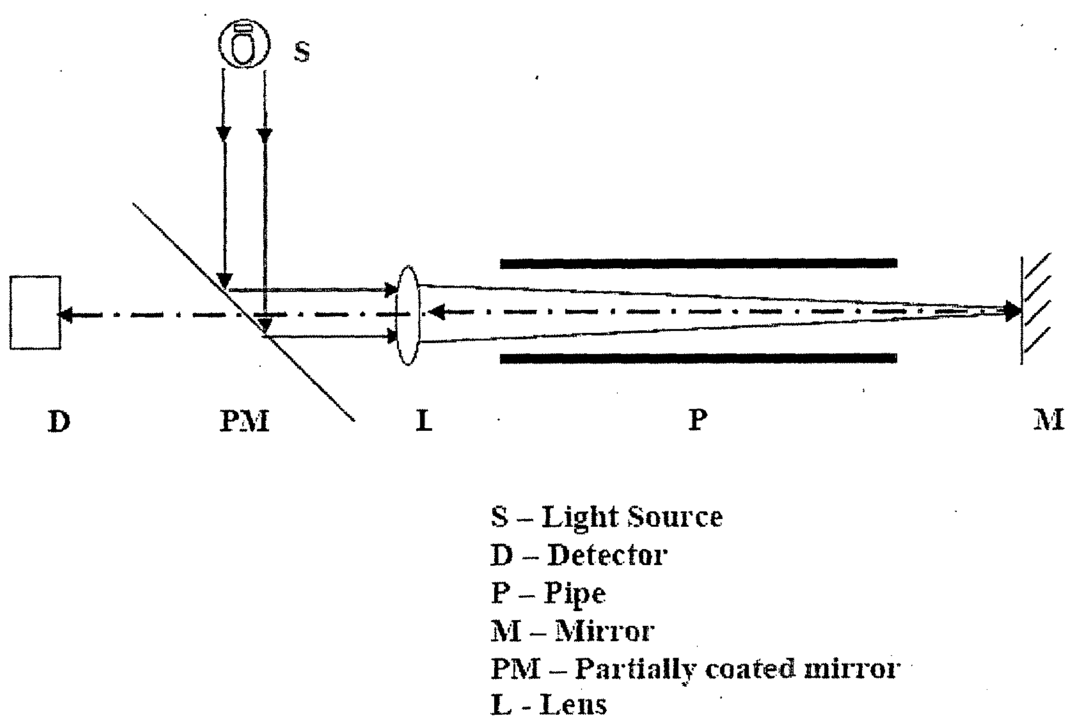

Figure 3.6 Principle of Folded Geometry

Plate 3.21 Measurement of Exhaust Smoke

3.2.6 Commercial Software - EnginesoftLV

Labview based Engine Performance Analysis software package “Enginesoft LV” is used for the on line performance evaluation. Plate 3.22 gives an image of a typical menu during interface with Enginesoft LV. EngineSoftLV can serve most of the engine testing application needs including monitoring, reporting, data entry, data logging. The software evaluates power, efficiencies, fuel consumption and heat release. It is configurable as per engine set up. Various graphs are obtained at different operating conditions. While on line testing of the engine is in RUN mode necessary signals are scanned, stored and presented in the form of graphs. Stored data file is accessed to view the data graphical and tabular formats. The results and graphs can be printed. The data in excel format can be used for further analysis.

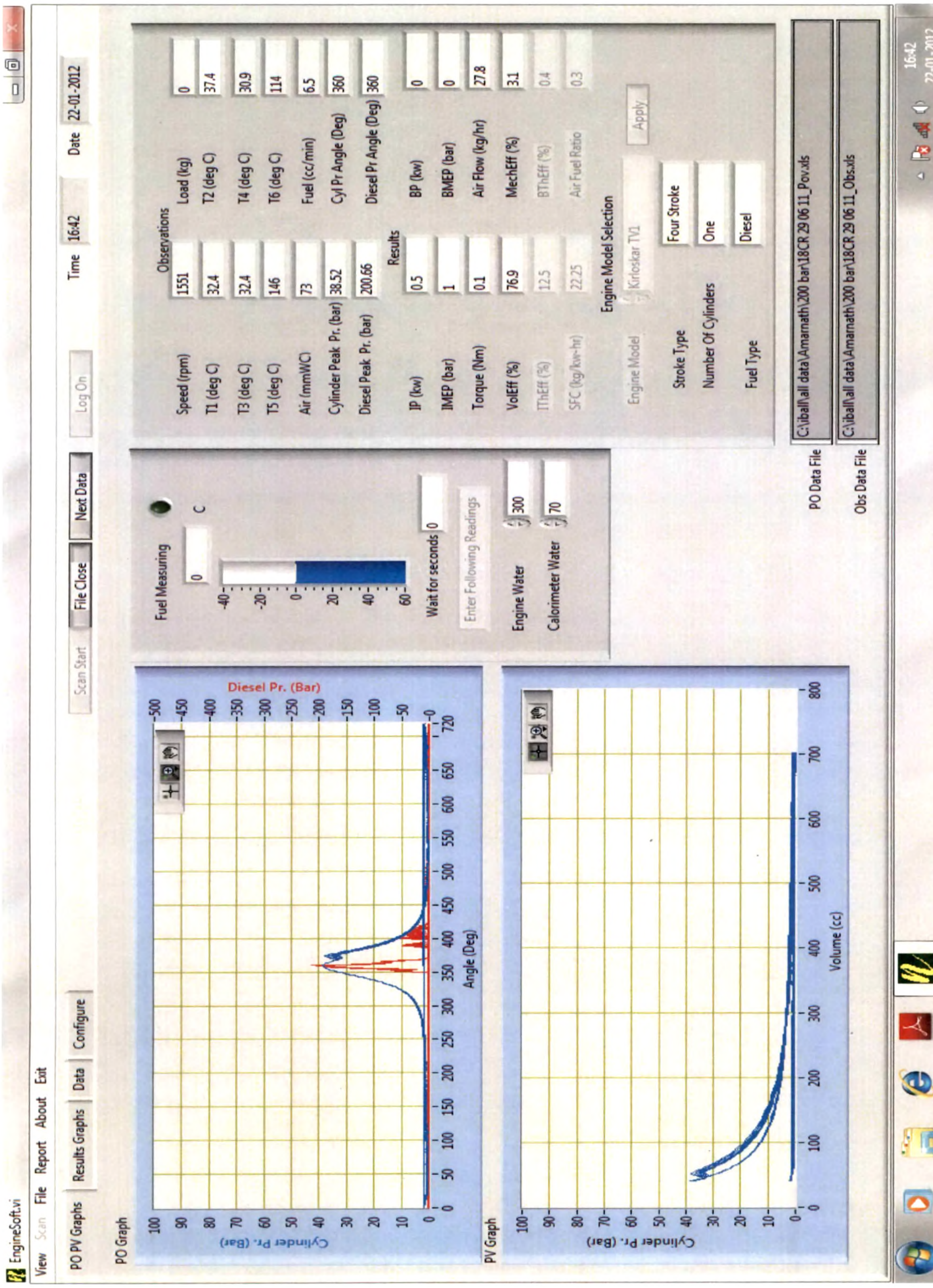

Plate 3.22 Interface of EnginesoftLV