CHAPTER 4
EXPERIMENTAL SETUP AND METHODOLOGY

4.1 INTRODUCTION

This chapter represents installation of present work test setup in the laboratory and methodology. The CI engine is made to convert to work on both single fuel mode and dual fuel mode operation. Initially the engine run with biodiesels and their Diesel blends in single fuel mode operation and then Bio-CNG with Diesel blends of PME and KME fuels in dual fuel mode operation. The test setup is attached with all essential instruments to evaluate its performance, combustion and emission parameters for chosen fuel combinations at various operating conditions. The complete details of the experimental setup, instruments used and development of additional required components are furnished below.

4.2 TEST ENGINE SETUP

Experimental tests are carried out on single cylinder, water cooled, and constant speed naturally aspirated DI Kirloskar TV-1 model diesel engine. Fig.4.1 and Fig.4.2 shows the schematic of engine test set up and the overall photographic view of engine test set up, respectively. Specifications of engine are given in Appendix 1. For all engine tests are conducted at a rated speed of 1500 rpm. The test setup of DI Diesel engine is equipped with eddy current type dynamometer for loading and used with essential measuring instruments for measurement of cylinder pressure and crank angle. With the interfacing of personal computer with these signals through engine indicator to draw Pressure-Crank Angle (P-θ) and Pressure-Volume (P-V) diagrams. This set up has stand-alone panel box containing air box, manometer; burette with stop watch for air and liquid fuel flow measurements. Rotameters are provided separately for measuring water flow rate of engine jacket for cooling and calorimeter. The data acquisition system of the setup enables measurement of engine performance parameters like engine speed, brake power, brake thermal efficiency, fuel flow rate, Air flow rate and exhaust gas temperature(measured with k-type thermocouple). The manufacturer set standard fuel injector opening pressure and the fuel standard injection timings as 200bar and 230 bTDC, respectively. In addition to investigate the effect of injection timings of 200 bTDC, 260 bTDC and 290 bTDC are manually
adopted apart from the manufacturer set injection timing of 230 bTDC. The injection timings are varied by adding and removing of shims at the underneath of the fuel pump. By adding of each shim injection timing is advanced by 1.5 degree of crank angle while removing of one shim it is retarded by 1.5 degree of crank angle. The fuel injection pressure manufacturer set value as 200bar and the fuel injection pressures can be varied from 200 to 240bar instep of 10bar. Injection pressure is changed by the adjustment of spring force in the injector. The fuel injection pressures are tested by fuel injection tester.

![Schematic of experimental test set up for single fuel operation](image)

T1- Water inlet Temperature
T2- Engine outlet Water Temperature
T4- Calorimeter water outlet
T5- EGT calorimeter inlet
SM- Smoke meter

T6- EGT calorimeter outlet
F1- Fuel flow differential pressure unit
PT- Pressure transducer
N- RPM encoder
EGA- Exhaust gas analyzer

Fig. 4.1 Schematic of experimental test set up for single fuel operation
The DI diesel engine has provided with a hemispherical type combustion chamber accommodated with over head inlet and exhaust valves. The engine cylinder pressure is measured through pressure transducer (piezoelectric type) which is mounted on the cylinder head surface and projected into the combustion chamber.

4.2.1 Bio-CNG Induction System

The induction system consists of a venturi gas mixing chamber which is fitted in the inlet manifold to supply Bio-CNG to the engine along with air in the mixture form for the dual fuel operation. Fig. 4.3 shows the overview of experimental setup with Bio-CNG induction facility for dual fuel mode operation. Bio-CNG, usually, stored at high-pressure (about 40bar) in the cylinder, is reduced to 1.5-2bar through a double stage pressure regulator and then flow through fine control valve to regulate the flow for providing smooth flow. Bio-CNG is then allowed to pass through gas rotameter which meters according to selected flow rate of compressed Biogas in liters per minute. The Bio-CNG flow rate could be selected for varying from 0.25kg/h to 1 kg/h with this facility. Later Bio-CNG is passed through a dry type flame arrester and then wet type arrester which is used to reduce possible fire hazards in the fuel flow line. The basic principle of flame arrester is that the flame gets quenched if sufficient heat can be removed from the gas. Fig 4.4 shows holder for different venturi mixers.
designed for proper mixing of gas with air in the intake manifold. The flame trapper is shown in Fig. 4.5. A two stage pressure regulator used to regulate the Bio-CNG, is shown Fig. 4.6.

![Fig. 4.3 Overall view of Experimental Setup with Bio-CNG induction arrangement](image)
Fig. 4.4 (a) Bio-CNG induction arrangement (b) Venturi Gas Mixer type

Fig 4.5 Pictorial view of Flame Arrester in the Experimental set up
4.3 MEASUREMENT OF LOAD AND SPEED

For the measurement of load, the test engine is directly coupled to an eddy current dynamometer that permitted engine loading fully or partially. Both the engine and dynamometer are interfaced to a control panel of DAS. The speed of the engine is measured by a photo sensor along with a digital rpm indicator. The dynamometer specifications are given in Appendix [2].

4.4 AIR FLOW MEASUREMENT

Turbine type air-flow meter is used to measure air inducted to the engine. Usually, the air flow may be subjected to fluctuations during induction through inlet manifold of engine. Therefore, a large air-surge tank is installed in before the engine and the turbine flow meter to ensure smooth laminar flow in the inlet manifold. The counter on the air flow meter indicates the amount of air drawn by the engine. The air flow rate is determined by the time required for definite quantity of air to be consumed by the engine.
4.5 FUEL (LIQUID AND GASEOUS) MEASUREMENT

Liquid fuel flow rate is measured on the volume basis using a graduated burette and stopwatch. A particular type of calibrated gas flow rotameter and digital mass flow meter with a digital pressure transducer is used for measuring the Biogas flow rate supplied to the engine.

4.6 TEMPERATURE MEASUREMENT

Exhaust gas temperature is measured with Chromel-Alumel (k-Type) thermocouples. A digital indicator with automatic room temperature compensation facility is used. Periodical calibration of temperature indicator is done.

4.7 CYLINDER PRESSURE MEASUREMENT

In-cylinder pressure is measured by a piezoelectric transducer (Fig. 4.7). The pressure pick up unit is mounted on the cylinder head by a suitable adaptor. A transducer having a sensitivity of 0.145mV/kPa was used for the purpose. The strength of charge output of a transducer is proportional to the in-cylinder pressure. A charge amplifier has received signals of charge output and then it is amplified for an equivalent voltage. During suction the cylinder pressure at bottom dead centre is assumed to be equal to the average inlet manifold pressure and it is measured by the transducer. The complete details of the instruments used for measuring cylinder pressure are given in Appendix [4].

4.8 MEASUREMENT OF HC, CO AND NO\textsubscript{x} EMISSIONS

The exhaust gas emissions such as carbon monoxide, hydro carbon and oxides of nitrogen are measured by an exhaust gas analyzer (Fig.4.8). A sufficient flue gas sample is allowed to pass through the multi component analyzer which works on non-descriptive infrared technology. CO and HC emission compositions are measured by directing infrared beam through the sample cell of analyzer. NOx composition is measured by electrical response of fuel cell in proportional to the concentration of sample. Analyzer is shown in Fig. The detailed specification of Gas Analyzer is given in Appendix [5].

4.9 MEASUREMENT OF SMOKE

The composition of smoke of flue gas is measured by a smoke meter which works on the principle of comparative basis with clean air. The smoke sample of flue gas is allowed to pass through the smoke tube and then moving light and photo
electric cell to it for relative reading. Smoke Meter is shown in Fig.4.9. The detailed specification of smoke Meter is given in Appendix [6].

Fig. 4.7 Position of Piezo sensor in the DI Diesel engine
Fig. 4.8 Exhaust Gas Analyser

Fig. 4.9 Smoke meter
4.10. PRESENT EXPERIMENTAL WORK DETAILS

4.10.1 Diesel blends of Polanga oil methyl ester and Karanja oil methyl ester fuels

The selected test fuels for the present experimentation includes the blends of Polanga oil methyl ester - Diesel (PME20, PME40, PME80 and PME) and Karanja oil methyl ester - Diesel (KME20, KME40, KME60, and KME80 and KME). The methyl ester fuels are blended with diesel fuel on volume basis and stirred adequately to ensure effective mixing. The nomenclature of the prepared blends is as follows:

PME20 – Blend of 20% polanga oil methyl ester and 80% of diesel fuel
PME40 – Blend of 40% polanga oil methyl ester and 60% of diesel fuel
PME60 – Blend of 60% polanga oil methyl ester and 40% of diesel fuel
PME80 – Blend of 80% polanga oil methyl ester and 20% of diesel fuel
PME – pure polanga oil methyl ester
KME20 – Blend of 20% karanja oil methyl ester and 80% of diesel fuel
KME40 – Blend of 40% karanja oil methyl ester and 60% of diesel fuel
KME60 – Blend of 60% karanja oil methyl ester and 40% of diesel fuel
KME80 – Blend of 80% karanja oil methyl ester and 20% of diesel fuel
KME – pure karanja oil methyl ester

4.10.2. Properties of the fuels

The physico-chemical fuel properties of fuels have played significant effect on the performance, emission and combustion characteristics of an engine. Some of the important physico-chemical properties of test fuels (including Bio-CNG) such as density, viscosity, calorific value, etc. were measured. The properties of polanga oil methyl ester, karanja oil methyl ester and high speed diesel fuels are shown in table 3.2 and the properties of Bio-CNG are given in table 3.4.
4.11 METHODOLOGY

All experimental tests are carried out on DI Diesel engine at the rated speed of 1500 revolutions per minute. Each test has to be conducted after the engine attained steady condition. The engine jacket water temperature is maintained at 70°C for any mode of operation. The engine has had a standard injection timing of 23°bTDC, standard injection pressure of 200bar, compression ratio of 17.5 and rated speed of 1500rpm for the Diesel engine operation at rated load of 5.2kW (100% of load). The tests are conducted to investigate the performance of biodiesels and their diesel blends under varying loads from 0 to 100% in steps of 20% load. For each load test, for each fuel performance, combustion and emission parameters are measured and calculated. HC, CO, Smoke, and NOₓ emissions are noted and also the combustion parameter such as heat release rate and cylinder pressure are measured with the help of engine soft software loaded PC for all test fuels.

For SFM operation, changing of fuel injection timing (FIT) is done by adding or removing of the shims which are at underneath of mechanical fuel injection pump of diesel engine. Each shim can alter 1.5° of fuel injection timing. With the addition of shims the fuel injection timing can be advanced from standard fuel injection timing, where as fuel injection timing can be retarded from standard fuel injection timing by removing of shims. And also the fuel injection pressure can be varied by adjustment of spring force in a fuel injector.

For DFM operation, the Bio-CNG is supplied through intake manifold to the engine through pressure regulator, gas flow meter and flame arrester. Exhaust emission gas analyzer and smoke meter are switched on for allowing it to reach steady condition before measurements of exhaust gas emission composition. All instruments are periodically calibrated for accuracy measurements. In each stage of experiments the performance of diesel engine either single or dual fuel mode are found in terms of Brake thermal efficiency, BSEC and emissions such as carbon monoxide, hydro carbon, oxides of nitrogen and smoke.

The following stages, with different techniques are used to improve performance of the single fuel mode and dual fuel mode DI diesel engine operation at the load conditions 0-100% in steps of 20% increment.
I  Use of High Speed Diesel, Diesel blends of Polanga oil methyl ester fuel and Diesel blends of Karanja oil methyl ester fuel

In the first phase of work, experiments are conducted on performance of DI Diesel engine fuelled with high speed Diesel, Diesel blends of Polanga oil and Diesel blends of Karanja oil methyl ester to find the best Diesel blends of each methyl ester, at standard operating conditions.

II  Variation of fuel injection timing (FIT)

In the second phase of work, experiments are conducted on the same mode of Diesel engine fuelled with the best diesel blends under same the loading conditions for fuel injection timings of 20°, 23° (standard), 26° and 29° CA bTDC.

III  Variation of fuel injection pressure (FIP)

In the third phase of work the tests are repeated on the same mode of Diesel engine fuelled with PME20 and KME20 fuels at the best fuel injection timing at four injection pressures of 210, 220, 230 and 240 bar.

IV Dual fuel mode Diesel engine with different flow rates of Bio-CNG

Experiments are conducted on dual fuel mode DI Diesel engine with Bio-CNG flow rates of 0.25kg/h, 0.5kg/h and 1kg/h with PME20 and KME20 fuels.

V  Dual fuel mode Diesel engine with different geometry venturi gas mixers

In the fifth phase of work the experiments are conducted with VGM1 (3mm hole geometry), VGM2 (5mm) and VGM3 (7mm) gas mixing chambers at the best Bio-CNG flow rate with PME20 and KME20 fuels at the best fuel injection timing and fuel injection pressure.