Chapter 4

EXPERIMENTAL WORK

4.1 INTRODUCTION

Though, some of the available experimental results were taken from the literature, some more experiments are planned in this work to generate the additional data to validate the theoretical predictions using the present modelling technique. The details of the work taken up and experimental set up and procedures are given in this chapter. The information about various components, the modifications or alterations made to them, the instrumentation adopted etc., are described.

The experimental set-up is designed and fabricated keeping in mind, the objectives of the present work. The details are given below.

4.2 EXPERIMENTAL SET-UP

The various components of the experimental setup are given below. Fig.4.1 gives the schematic diagram of the layout of experimental setup. The important components of the set up are

i) The engine
ii) Dynamometer
iii) Fuel injection pump
iv) Device for changing / starting of fuel injection
v) Indicator for dynamic injection
vi) Data acquisition equipment
vii) Exhaust gas analyzer
viii) Smoke meter
4.2.1 The Engine

A single cylinder, water cooled, vertical, direct injection, diesel engine, whose specifications are given in Appendix - I, is used in the present work.

4.2.1.1 Reasons for Selecting the Engine

The above engine is one of the extensively used engines in agricultural and industrial sectors in India. This engine can withstand the peak pressures encountered because of its original high compression ratio. Further, the necessary modifications on the cylinder head and piston crown can be easily carried out in this type of engine. Hence this engine is selected for the present research work.

4.2.2 Dynamometer

The engine is coupled to a hydraulic dynamometer which is provided for starting as well as motoring of the engine at any desired speed. It is capable of maintaining the selected speed very accurately. The torque is measured using a pendulum type of load indicator. The dynamometer is calibrated statically before use.

4.2.3 Device for Changing Start of Injection

This device is used for the test engine whose mechanism is indicated in Fig. 4.3. This device can start of fuel injection timing from $35^\circ$ after bottom dead center (aBDC) to top dead center (TDC) when the engine is operating at any load. This device uses a cam type mechanism in the injection pump rocker arm. The fuel injection pump rocker arm, which oscillates between the fuel injection timing cam in the cam shaft and fuel injection pump plunger, is
hinged on a cylindrical shaft at its center. The cylindrical shaft is replaced by an eccentric shaft which is connected to a worm wheel gear assembly with a reduction ratio of 30:1. The worm is rotated by reversible geared D.C. motor (wiper motor) with a remote control. Depending on the position of the eccentric in the rocker arm hinge, injection pump plunger is moved either earlier or later than the normal timing. This advances or retards the start of fuel injection timing. Since only the hinge is rotated and no other moving part of the injection system is used, this device is equally useful for both the operating and non-operating engines. This device is found to be extremely useful during the course of experimentation for different fuel injection timings as discussed in the experimental results and discussion chapter.

4.2.4 Dynamic Injection

The start of fuel injection timing indicator which is used along with the dynamic injection timing changing device indicates the start of fuel injection time in degrees of crank angle (CA), with an accuracy of $0.01^\circ$ CA. The digital device uses three magnetic pickups namely, the needle lift pick up (mounted on the fuel injector), a TDC pick up and a calibration pick up. Three signal conditioning circuits convert the magnetic pickup signals into square wave signals.

The selector switch is used to select any one of the two positions namely, fuel injection timing position or the calibrating position. In the fuel injection time measuring position the TDC signal and the needle lift are selected in the calibrating position of the TDC signal and the calibrating signal are selected. Any one of the said pair of signals is connected input flip-flop circuit to generate the pulse width signal. The pulse width is equal to the time gap in milli seconds between the needle lift signal and the TDC signal or the gap between the electronic ignition and TDC signal. The pulse width is
proportional to the engine speed. At higher engine speeds for the same pickup positions, the pulse width will be shorter and at slower speeds the pulse width will be longer. The pulse width signal from flip-flop is given to the chopper circuit (AND gate) for chopping the pulse width signal using a variable frequency square wave circuit. The output from the AND gate is given to counter, latch seven segment display converter and driver circuit.

The pulse width is displayed in degree crank angles in the digital display using the variable frequency square wave oscillator. Depending on the accuracy requirement at a particular engine speed, the frequency of the square wave oscillator has to be increased. In the present circuit, the display accuracy is $0.1^\circ$ crank angle at 1500 rpm. If the engine speed is changed, then the device must be calibrated for that particular engine speed to get accurate readings. For calibration of this instrument, the selector switch is changed to calibration position and changed to a new value, until the display reads $70^\circ$ crank angle. In this way the instrument can be calibrated for any particular engine speed.

4.2.5 Data Acquisition Equipment

PC AT-386, provided with Analog to Digital convector is to record both the pressure and TDC signals.

4.2.6 Exhaust Gas Analyzer

All the emission measurements are on dry basis. A Non-dispersive infra-red gas analyzer (FUJI, Japan make) is used to measure HC and CO emissions. Cold traps are provided to prevent moisture from entering the exhaust gas analyzer.
4.2.7 Smoke Meter

Smoke measurements are made using a standard BOSCH smoke measuring apparatus consisting of a sampling pump which allowed a specific volume (330 cc) of exhaust gas through a filter paper. This filter paper is then analyzed for blackness by a photoelectric sensor based indication meter which will be directly read in standard Bosch smoke units.

4.3 EXPERIMENTATION

Different load tests are conducted at the different operating conditions during the experimentation. The cooling water outlet temperature is maintained at 70°C separately for both the cylinder liner and the cylinder head. The lubrication oil temperature is maintained at 60°C for all the experiments. In the experimentation, load, fuel injection timing, compression ratio and the speed are the four important parameters selected. First, the load is going to vary by keeping other three parameters as constant. Likewise, next FIT is varied, compression ratio is varied and speed is varied respectively after keeping remaining three parameters as constant. At each operating condition, dynamometer load, speed, air flow rate, fuel flow rate, exhaust temperature, manifold pressure, cooling water flow rate, cylinder, head and cylinder liner temperatures, pressure time signal, TDC marker signal, dynamic injection timing, HC, CO and smoke readings are noted and recorded after allowing sufficient time for the engine to stabilize.

The exhaust gas analyzer is switched on quite early so that all its systems will get stabilized before the commencement of the experiment. The data length, frequency range to trigger the data acquisition for computer are carefully selected, based on the approximate cycle time of the engine operation, such that there appeared three TDC signals on the display, with the combustion period occupying the center stage.
pressure and temperature are noted. After the starting of the engine and stabilizing it, airflow, fuel flow, inlet manifold vacuum, temperatures of ambient air, temperature of exhaust gases etc., are noted. The dynamometer readings such as load and speed are also noted. The pressure and TDC signals are recorded on the mini floppy disc, averaged for 100 consecutive cycles.

4.4 DATA PROCESSING

Processing the data is an important step in the experimental investigation. The processed data is to be analyzed to yield valuable information conforming to the objectives which are set up for the work. The data collected in the present investigation is quite large and it has to be systematically processed and analyzed. The important steps of data processing are indicated in the following sections.

4.4.1 Stages in Processing

The various stages in experimental data processing are described below.

4.4.2 Absolute Pressure Signal

The averaged pressure and TDC traces recorded during the experimentation are called into the memory of the computer from the mini floppy disc, with the aid of the address. The pressure signal in terms of voltage is first converted into digital form considering the transducer sensitivity and charge amplifier setting during experimentation. Since the Piezoelectric transducer provides only the relative pressures, it is necessary to have means of
determining the absolute pressure at some point in the cycle. The inlet manifold vacuum, measured during the experimentation is used for this purpose. The mean intake manifold pressure is usually an accurate indicator of the cylinder pressure when the piston is at the BDC after the intake stroke and hence the pressure trace is corrected on this basis to give the absolute pressure. The absolute pressure signal is referred hereafter as the pressure signal.

4.4.3 Indicated Work

The indicated work of the cycle is calculated from pressure-volume (p-V) diagram.

4.4.4 Parameters of Performance

At each setting, brake power, indicated power, brake thermal efficiency, indicated thermal efficiency, indicated mean effective pressure (imep), brake mean effective pressure (bmep), volumetric efficiency and mechanical efficiency are calculated.

4.4.5 Combustion Characteristics

Ignition delay, peak pressure and the combustion duration are usually referred as combustion characteristics. The values of these parameters in terms of crank angle are determined from the computer. Further, peak pressure, occurrence of peak pressure and maximum rate of peak pressure rise are also determined.
4.5 PROGRAM FOR DATA PROCESSING

A program in Fortran which was developed by the research scholar in this department is used to work out the parameters of performance and combustion characteristics.

The quantities determined, using the program are

i) Speed
ii) Ignition delay
iii) Combustion duration
iv) Brake power
v) Indicated power
vi) imep
vii) bmep
viii) Peak pressure and it’s occurrence

With this it is enough if the file numbers of the pressure and TDC signals are given, pertaining to the point of engine operation, under consideration, together with the relevant data to obtain the results. The program is run on the computer AT-386, under Micro-soft disc operating system. At the end, all the results are displayed on the terminal of the computer and also recorded in a file. The data subsequently can be read from it for the purpose of analysis.
Fig 4.1 Experimental setup layout

Fig 4.2 Thermocouple location in cylinder head and cylinder liner