CHAPTER -3

EXPERIMENTAL SETUP AND TEST PROCEDURE
# CHAPTER 3

## CHAPTER – 3: EXPERIMENTAL SETUP AND TEST PROCEDURE

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3. EXPERIMENTAL SETUP AND TEST PROCEDURE

3.1 Introduction

Engine performance is a sign of degree of success with which it does its allotted work i.e. conversion of energy of fuel into helpful work. The engine performance is compared on the basis of certain performance indicators known as performance parameters. The most necessary performance parameters are load, speed, torque, brake power, brake thermal potency, specific fuel consumption and exhaust emissions. The data relating to different elements of the engine, modifications carried on them, the instrumentation used for conducting experiments to evaluate the performance and emission characteristics are mentioned in this chapter.

In the present work the complete experimental investigations were distributed in 3 phases. In the initial part the experimental investigations were carried out on a traditional (standard) four stroke diesel engine with completely 5 different Bio Diesel (Jatropha oil, Karanja oil, Mahua oil, cotton seed oil and Azadirachta (neem) oil) blended with diesel separately in various proportions is used as fuel one by one to judge optimum mix (blend) and best biodiesel. In the second part of work the experiments were conducted on air gap insulated piston engine by varied air gap between piston crown and piston skirt from 1mm to 2.5 mm with the optimum mix of best bio diesel (identified in 1st stage of experimentation) to seek out the best air gap.
Figure 3.1 Schematic Diagram of Experimental
Fig 3.2 Photographic view of the experimental setup

List of components:

1. Engine
2. Dynamo meter
3. Air intake system
4. Fuel tank
5. Data acquisition system
6. Fly wheel
7. Frame
8. Load cell
9. Exhaust system
In the last part of experimental work to scale back the thermal losses through the piston and to improve thermal potency of the engine the different piston crowns which are designed with completely different materials like cast iron, Copper and Brass, which are having different thermal conductivities. The experiments were conducted to seek out best crown material at the best air gap (identified in 2\textsuperscript{nd} stage of experimentation) and with the best biodiesel at optimum mix concentration as a fuel.

\section*{3.2 Experimental setup}

The study was carried out in the IC engines laboratory on an experimental engine test rig consisting of a single cylinder, water cooled, four stroke, vertical, stationary and constant speed diesel engine connected to eddy current type dynamometer for loading. It also contains the fuel supply system for supplying fuel, water cooling system for engine cooling, lubrication system and various sensors and instruments integrated with data acquisition system for online measurement of load, air and fuel flow rate, exhaust gas temperature, cooling water temperature.

The setup enables the evaluation of thermal performance and emission constituents of the engine. The thermal performance parameters include brake power, brake thermal efficiency, brake specific fuel consumption, and exhaust gas temperature. Thermocouples are provided at appropriate positions and are read by a digital temperature indicator with channel selector to select position. The setup also includes the necessary measuring instruments for the
measurement of smoke density and exhaust gas emissions. The exhaust emissions of the engine are analyzed by using an exhaust gas analyser. The constituents of the exhaust gas like CO, HC and NOx are measured with exhaust gas analyzer. The simple line diagram and photographic view of the experimental setup are shown in Fig 3.1 and 3.2 respectively.

### 3.2.1 ENGINE

The test engine used in the present work is a single cylinder, naturally aspirated, direct injection compression ignition engine of Kirloskar make. This diesel engine has a bore of 80mm and stroke of 110mm. The specification of the engine is shown appendix -A. The engine has a rated output of 5HP at a speed of 1500 rpm. The engine was coupled to an eddy current type dynamometer to apply the load on the engine with an electrical panel. The engine is mounted on a stationary frame with a suitable cooling system. The lubricating system is inbuilt in the engine.

#### 3.2.1.1 Reasons for choosing the Engine

This engine can with stand higher pressures encountered and conjointly used extensively in agricultural and industrial sectors. Thus this engine is chosen for carrying experiments. The necessary modifications on the piston needed for this work will simply be created.
3.2.1.2 Modification of test Engine

In this experimental work the test engine is modified into an Insulated engine with following necessary modifications.

i) Diesel engine with air gap insulated piston.

ii) Diesel engine with thermal barrier piston crown.

3.2.1.3 Diesel engine with air gap insulated piston

So as to reduce the heat transfer through the piston in this experimental work an air gap insulated piston engine is developed that cut back the heat losses from the piston crown to the piston skirt. This will increase the warmth within the chamber and heats the incoming charge of induction stroke. Thus with the air gap insulated piston the combustion and thermal efficiency are improved by reducing the heat losses. The insulated piston is to be just like the first piston with relation to dimensions and also the form of combustion chamber. The air gap insulated piston is shown within the figure3.3

Fig. 3.3 Air gap insulated piston
Fig: 3.4 Photographic view of thermal barrier piston crown

List of components:

1. Piston crown
2. Piston skirt
3. Piston ring groove
4. Screw
5. Piston pin seat

3.2.1.4 Diesel engine with thermal barrier piston crown

Piston is capable of holding heat from the combustion gases throughout the combustion and provides a similar to the incoming charge throughout the suction and compression strokes of consecutive cycle. This preheats the intake air, improves the
combustion potency and brake thermal potency [187]. So for this experimental work three thermal barrier piston crowns are designed with whole completely different materials like cast iron, Copper alloy and Brass to scale back the heat losses from the piston crown to the piston skirt. The photographic views of the piston crowns used for the experiments are shown within the following figures 3.4

3.2.1.5 Development of thermal barrier piston

The aim of insulating the piston is to scale back the speed of warmth transfer from the crown to skirt and also the most potential space of the crown is to be insulated to realize this goal. Further, the insulated piston is to be just like the standard piston with relation to dimensions and also the form of combustion chamber [188]. The piston material selected should need high strength and toughness to face high temperature, pressure and should offer resistance to reaction of corrosion. Thus in this work the metallic piston with air-gap insulation is preferred.

In this piston modification, air with its low thermal conductivity phenomenon, it serves as better insulator to heat transfer and hence it is employed as an insulating medium [189]. An air-gap is created between a metallic crown and the skirt of the standard piston manufactured from metallic element alloy. The two pieces of the piston are separated by gaskets of appropriate materials and fastened together tightly. The piston crown has to work at elevated temperatures (about 900-1000°C) and high pressures (90 bar). Thus this material has to face the both mechanical and thermal stresses.
This material also exhibit high resistance to corrosion and oxidation reaction under those conditions.

The crown is manufactured from the selected piston material of eighty five millimeter diameter to the form of the crown within the original piston. The hemispherical shape is turned with the necessary turning tools. A thickness of five millimeter is maintained on the projection and bowl space of the crown. The recess for valves clearance is provided by end milling.

The total height of the unmodified piston is 106mm and this height should be maintained within the insulated piston. This is possible by maintaining the height of piston skirt as 99mm, the height of piston crown as 5mm and the gasket which is used between piston crown and skirt as 2mm thickness may be retained original height of the unmodified piston (106mm)

The gasket separates the piston crown and skirt and it should serve the following purpose:

(i) To stop the run of combustion gases from the combustion chamber to the air-gap space.

(ii) To function as Spacer rings to regulate the thickness of the air-gap: and

(iii) To cut back the heat transfer from crown to the piston skirt.

Materials like reinforced asbestos, ceramic fiber are tried out as materials for this seal (gasket) however they disintegrated when 10-15 minutes of engine operation. It’s then determined to use metals of low thermal conductivity phenomenon materials as seal. Gaskets are
turned out of skinny (thin) plates of chrome steel (1.0 mm) and copper (0.5mm). A seal of chrome steel sandwiched between skinny gaskets of copper is employed for the present purpose.

The high speed reciprocatory movement of the piston demanded a really secure technique of fastening the crown to the piston. Thus 3 number of chrome steel screws of size 4 X 20 millimeter are employed as fasteners. These areas are then smoothed equally by machining.

3.2.2 Dynamometer

The engine is connected to a swinging – field electrical generator meter with Ward – Leonard control that allowed the engine to be started and motored likewise. The load is controlled by dynamic changing the field sector current. The reading of load (voltage and current) is noted from the data acquisition panel board fixed to engine test setup by the manufacturer and the power absorbed is calculated. The specification of the dynamometer is shown appendix -B

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.

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 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, 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. 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. A load cell is a
transducer that is used to convert a mechanical signal (force) into an
analogous electrical signal. The loading unit consists of a dimmerstat
to control the magnitude of the direct current flowing into the
dynamometer

3.2.3 Speed measure

The speed of the engine is measured by using an electro-
magnetic pickup in conjunction with a digital indicator fixed to data
acquisition panel board. A magnetic pickup is fitted near the fly wheel
of the engine with pins mounted on the periphery. The signals
generated are fed to the show unit that is graduated to point the speed directly in range of revolutions per minute (rpm).

### 3.2.4 Measurement of Fuel Consumption

Fuel is provided to the engine from the fuel tank through the measuring instrument fixed to data acquisition panel board. The rate of fuel flow is found by measuring the time required for the consumption of a known amount of fuel i.e. 10 cc from the measuring instrument.

### 3.2.5 Exhaust Gas Temperature measurement

A Nickel-Nickel chromium thermocouple fixed to the exhaust manifold of the engine exhaust valve is employed for measure of exhaust gas temperature. The reading of Exhaust gas temperature is noted from the data acquisition panel board fixed to engine test setup by the manufacturer.

### 3.3 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 monoxide (CO), Oxides of nitrogen (NOx) and Unburnt Hydrocarbons (HC). The smoke meter is used to measure the intensity of exhaust smoke

#### 3.3.1 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. A gas analyzer (Delta 1600S), is used for analysis of the pollutants within the exhaust gas. This gas analyzer is connected to the engine exhaust pipe. This instrument is employed to measure three necessary pollutants i.e. carbon monoxide gas (CO), NOx and unburnt Hydrocarbons (HC). The specification of the exhaust gas analyzer is shown appendix –C.

In the exhaust gas analyzer 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.

3.3.2 Smoke Density meter

Bosch smoke meter is used to measure the smoke density. 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 specification of the smoke meter is shown appendix –D.
3.4 Test procedure

Initially the experiments were conducted on the engine with diesel to find optimum cooling rate and further all the experiments are conducted on the engine by maintaining this optimum rate of engine cooling.

The performance test is conducted using Diesel as fuel. The following step by step procedure is adopted for the test:

1. Give the necessary electrical connections to the panel.
2. Check the lubricating oil level in the engine.
3. Check the fuel level in the tank.
4. Allow the water to flow to the engine and the calorimeter and adjust the flow rate.
5. Release the load if any on the dynamometer.
6. Open the fuel flow cock so that fuel flows to the engine.

7. Start the engine by cranking.

8. Allow the engine to run under idling condition (no load) for 10 minutes to ensure warm and steady operating conditions.

9. Record all the thermal performance parameters for no load condition through a data acquisition system.

10. Repeat the experiment for different loads and note down the readings.

12. After the completion release the load and then switch of the engine.

13. Allow the water to flow for few minutes and then turn it off.

The performance tests on the engine was conducted one by one with diesel and biodiesel blends (B05, B10, B15, B20, and B25) and compared. The experiments replicated for 3 times and mean values of the readings are recorded. Each and every time, when the biodiesel or blend proportion is changed the engine was run with diesel fuel for few minutes to wash the fuel lines. The performance of the engine is evaluated in terms of Brake thermal potency, Brake specific fuel consumption, Exhaust gas temperature, Smoke density and the emissions of HC, CO and NOx.

The performance tests are conducted on air gap insulated piston engine by varied the air gap from 1 mm to a 2.5 mm between piston crown and piston skirt to seek out the result of air insulation on the performance of the engine. For conducting these tests the
standard piston of the engine was replaced with air gap insulated piston of same size and shape (shown in fig. 3.3).

The performance tests are also conducted on air gap insulated piston engine with different piston crowns like brass, copper and cast iron separately to find the effect of the crown material. For conducting these tests the standard piston of the engine was replaced with thermal barrier crown piston as shown in fig. 3.4.

3.5 Performance parameters

Internal combustion engine generally operates with in a useful range of speed. Some engines are made to run at fixed speed (optimum speed) by means of speed governor which is its rated speed. At each speed within the useful range the power output varies and it has maximum usable value. The ratio of power developed to the maximum usable power at the same speed is called the load. The specific fuel consumption varies with load and speed. The performance of the engine depends on inter-relationship between power developed, speed and specific fuel consumption at each operating condition within the useful range of speed and load.

The term performance usually means how well an engine is doing its job in relation to the input energy or how efficiently it provides useful energy in relation to some other comparable engines. The performance of an engine judged from the point of view of the two main factors, which are engine power and engine efficiency. Further to see how efficiently the conversion of fuel energy to engine power is
carried out, is studied from the efficiency and specific fuel consumption curves.

3.6 Performance evaluation procedure

The performance parameters of four stroke diesel engine like Brake power, mass of fuel consumption, brake thermal efficiency and brake specific fuel consumption are measured as mentioned below:

3.6.1 Brake power (B.P)

The power available at the delivery point, at the engine crank shaft (drive shaft) is interchangeably referred as brake power or shaft power or delivery power. The brake power is usually measured by attaching a power absorption device to the drive shaft of the engine. The brake power of the engine at different operating conditions was determined using the following equation:

\[ BP = (V \times I)/1000 \quad \text{--- kW.} \]

Where,

\[ BP = \text{Brake power in kW.} \]
\[ V = \text{Voltmeter reading in Volts.} \]
\[ I = \text{Ammeter reading in Amps.} \]

3.6.2 Mass of fuel consumed (mf)

The fuel consumption of an engine is measured by determining the time required for consumption of a given volume of fuel. The mass of fuel consumed can be determined by multiplication of the volumetric fuel consumption to its density. The mass of fuel consumed by the engine at different operating conditions was determined using the equation given below:
Mass of fuel consumption

\[ M_f = \frac{X_{cc} \times \text{Specific gravity of fuel}}{1000} \times t \text{ kg/sec} \]

Where,

- \( X_{cc} \) is the volume of the fuel consumed = 10ml
- \( t \) is the time taken in seconds

**3.6.3 Brake specific fuel consumption (BSFC)**

The brake specific fuel consumption of the engine is the ratio between the fuel consumed per hour to the brake power. The brake specific fuel consumption of the engine at different operating conditions was determined using the equation as given below:

\[ \text{BSFC} = \frac{m_f \times 3600}{B.P} \text{ kg/kW - hr.} \]

Where,

- \( m_f \) is mass of fuel consumed in kg/sec.
- B.P is brake power in kW.

**3.6.4 Brake Thermal Efficiency (BTE)**

The brake thermal efficiency of the engine gives an idea of the power output generated by the engine with respect to the heat supplied in the form fuel. The brake thermal efficiency of the engine at different operating conditions was determined using the following equation:

\[ \text{BTE} = \frac{3600}{(CV \times \text{BSFC})} \]

Where,

- BTE = Brake thermal efficiency, %
- CV = Calorific value of fuel used, kJ/kg
- BSFC = Brake specific fuel consumption, g/kW - hr