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# Performance Study of CI Engine Using Computerized Test Rig

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**ABSTRACT:** 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. The setup has stand-alone panel box consisting of air box, twin fuel tank for duel fuel test, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and piezo powering unit. Rota meters are provided for cooling water and calorimeter water flow measurement. The setup enables study of VCR engine performance for both Diesel and Petrol, for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis.

**KEYWORDS:** Variable Compression Ratio

### I. INTRODUCTION

The IC engine testing facilities are designed and developed for single cylinder, naturally aspirated, direct injection diesel engine with suitable instrumentation to measure performance. The engine test rig consist of dynamometer, fuel consumption measurement, air flow measurement system, speed and load measurement systems along with its fine control, innovative cooling system to maintain uniform engine temperature, calorimeter to measure heat balance, data collection and combustion analysis system including cylinder pressure sensor, crank angle encoder, data acquisition card and data processing software.

### II. EXPERIMENTAL SETUP

In this experimental investigation a naturally aspirated four stroke, single cylinder, water cooled, direct injection diesel engine was used. This engine is typically used for agricultural applications like water pump-sets and normally runs about eight hours a day continuously in the field. It had single barrel fuel injection pump and inline fuel injector with a three holed nozzle, located near the combustion chamber centre with an opening pressure of 18 MPa. The diagram of diesel engine test facility along with all the instrumentation for the present investigation is shown in Figure 1

The experimental setup required for sensing various engine performance, installed at the appropriate points in the experimental set up. By using these instruments the basic quantities that were measured during the engine tests are engine speed, load on engine, consumption of fuel, crank angle, cylinder pressure, temperature of water inlet, cooling water outlet, exhaust gas and water flow rate. The details of these instruments with corresponding parameters are as follows:

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Figure 1: Overall view of experimental test rig

### Dynamometer

The measurement of engine Brake Power (BP) involves determination of the torque and angular speed of the engine output shaft. This torque-measuring device is called a dynamometer. The engine was clamped on a test bed and the shaft is connected with the help of propeller shaft to an eddy current dynamometer for loading the engine. Eddy current dynamometer consists of a stator and a rotor disc and it is coupled to the output shaft of the engine. On stator a number of electromagnets are fitted. When rotor rotates eddy currents are produced in the stator due to magnetic flux set up by the passage of field current in the electromagnets. These eddy currents oppose the rotor motion, thus loading the engine. These eddy currents are dissipated in producing heat so that this type of dynamometer needs cooling arrangement. A moment arm measures the torque. Engine load was controlled by varying excitation current to the eddy current dynamometer using dynamometer controller.



Figure 2: dynamometer setup in test rig

The Brake Power (BP) of the engine was calculated as follows:

$$BP = 2\pi NT \times 10^{-3}$$

where,

BP = Brake power in kW.

N = Engine speed in rev/sec. T

= Torque in N-m = W×R

W = Load in kg. = 9.81×W in Newton

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R= Dynamometer arm length (in this case 0.185 m)

## Cylinder Pressure Transducer

To measure the cylinder gas pressure, a piezoelectric pressure transducer with built in amplifier was installed in the cylinder head. A special arrangement on the engine cylinder head was made to mount the pressure transducer. A continuous circulation of engine cooling water was maintained in the cylinder head for cooling the transducer to maintain the temperature of sensor within prescribed limits. The charge amplifier was used to amplify the charge sensed by the pressure transducer and to convert into voltage. The signals from charge amplifier were fed to a data acquisition card linked to the computer.

## Crank Angle Encoder

For analysing the combustion characteristics in an engine, it is necessary to obtain the pressure-time data. To plot and study the cylinder pressure, the knowledge of crank angle corresponding to each pressure data is necessary. For this purpose, a high precision crank angle encoder was used for delivering signals for top dead centre (TDC) and crank angle position, which produces 360 square pulses per rotation (one pulse per crank angle). Crank angle encoder was fitted on the dynamometer. To adjust the TDC position a decompression lever on the rocker box was kept in vertical position and the flywheel was rotated slowly in clockwise direction (viewed from dynamometer end) till the CA mark on the flywheel matches with the reference pointer provided on the engine body and the TDC light on the piezo powering unit glows. Similarly, the encoder body was rotated slowly till the TDC light on the piezo powering unit glows.

For all data presented, the 0° crank angle (CA) was defined as TDC at the end of the compression stroke. The signals from crank angle encoder were fed to a data acquisition card linked to the computer.

## Temperature Measuring Instruments

In this investigation the temperatures of air inlet, engine cooling water inlet, cooling water outlet, exhaust gas, calorimeter inlet and calorimeter outlet are measured with various temperature sensors. The ambient temperature was measured using a mercury thermometer.

## Measurement of Air Consumption

The flow of air is pulsating due to reciprocating nature of the engine and air is a compressible fluid (Heywood, 1988). So, for satisfactory measurement of air consumption an air box of suitable volume is fitted with orifice. The air box is used for damping out the pulsations. The diameter of the orifice is 20 mm and the discharge coefficient of flow is 0.6. The orifice was connected to U-shaped tube manometer of scale resolution of 1 mm to measure the differential pressure across the orifice.

The engine output is limited by the maximum amount of air that can be taken in during the suction stroke, because only a certain amount of fuel can be burned effectively with a given quantity of air. Volumetric efficiency is one of the important parameters used to measure the effectiveness of four stroke engines induction process. It is an indication of the „breathing“ability of the engine and is defined as the ratio of the volume of air actually inducted at ambient conditions to swept volume of the engine. However, on mass basis it is defined as the ratio of the actual mass of air drawn into the engine during a given period of time to the theoretical mass which should have been drawn in during that same period of time, based upon the total piston displacement of the engine, and the temperature and pressure of the surrounding atmosphere. This definition is applicable only to the naturally aspirated engine.

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## Measurement of Fuel Consumption

In this experiment the fuel consumption was measured by two methods, volumetric method and gravimetric method as the blended oxygenated fuel were highly volatile. In gravimetric method, the time to consume a given mass of the fuel is measured. The Differential Pressure (DP) transmitter working on hydrostatic head principles was used for fuel consumption measurement.

In volumetric method, the fuel consumed by an engine was measured by determining the volume flow of the fuel in a given time interval (typically 60 sec.) with a stop watch. A glass burette having graduations in ml was used for volume flow measurement. Time taken by the engine to consume this volume is measured by stopwatch.

A measure of overall efficiency of the engine is given by the brake thermal efficiency (BTE). Brake thermal efficiency is the ratio of energy in the brake power to the input fuel energy in appropriate units.

The fuel consumption characteristics of an engine are generally expressed in terms of brake specific fuel consumption (BSFC) in kilograms of fuel per kilowatt-hour. It is one of the important parameters that reflect how good the engine performance is. It is inversely proportional to the brake thermal efficiency of the engine (Heywood, 1988).

## Rotameters

While carrying out engine tests, it is necessary to keep engine cooling water temperature constant throughout the test, which can influence mainly the exhaust emission levels, thus increasing the credibility for comparing the measured values. Engine cooling water temperature was kept constant for all the tests by varying cooling water flow rate which was measured by rotameter. Two rotameters are fitted in the panel box structure are shown in Plate 3.6. The rotameters are used to regulate and measure the water flow of engine cooling system and calorimeter. Rotameter works on the principle of variable area. Float is free to move up and down in a tapered measuring glass tube. Upward flow causes the float to take up a position in which the buoyancy forces and the weight are balanced. The vertical position of the float as indicated by scale is a measurement of the instantaneous flow rate.

## AcquisitionSystem

Engine setup was provided with necessary data acquisition system for engine performance and combustion analysis. The instruments were provided for combustion pressure and crank-angle measurements. These signals were interfaced to computer through engine indicator for P $\theta$ -PV diagrams. Provision was also made for interfacing airflow, fuel flow, temperatures and load measurement. The setup had stand-alone panel box consisting of air box, manometer, fuel measuring unit, transmitters for air and fuel flow measurements, process indicator and engine indicator. The signals from various instruments were fed to a data acquisition card linked to the computer.

## III. TESTING METHODOLOGY

Before conducting the actual engine tests, the engine was overhauled with necessary replacements, fresh lubricating oil was filled in the oil sump and the various measuring devices were calibrated. In order to maintain consistency of the experimental observations and to establish a basis of comparison of the results, preliminary performance tests were carried out with the neat diesel only. After warming up the engine and reaching the stable operating conditions, experimental data were collected for every loading condition.

Ensure cooling water circulation for eddy current dynamometer and piezo sensor, engine and calorimeter. Start the set up and run the engine at no load for 4-5 minutes. Switch on the computer and run "EnginesoftLV". Gradually increase

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load on the engine. Wait for steady state (for @ 3 minutes) and log the data in the “EnginesoftLV”. • Gradually decrease the load

Engine temperature was kept constant for all the tests by varying cooling water flow rate which was measured by rotameter. Before running the engine to a new fuel, the fuel tank and the fuel injection system were cleaned and it was allowed to run for a sufficient time to consume any remaining fuel from the previous experiments. The required engine combustion performance are recorded and analyzed.

## IV. RESULT AND DISCUSSION

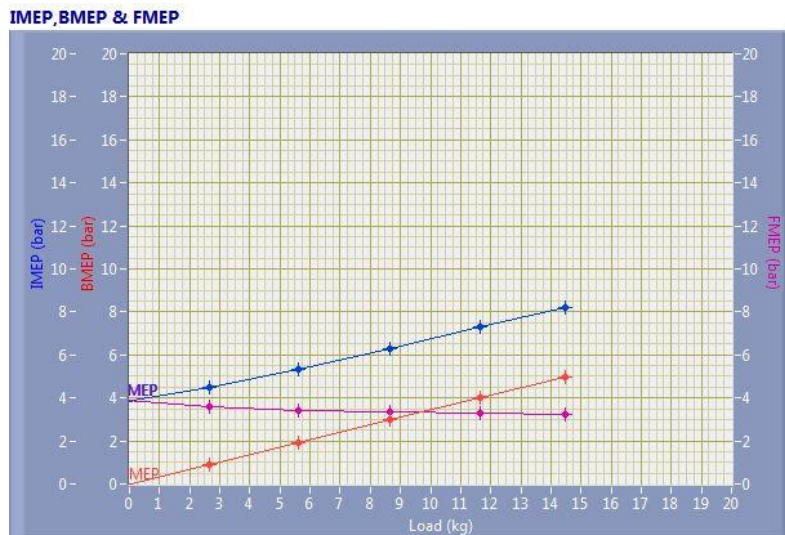


Fig 3. Load Vs IMEP, BMEP, FMEP

In Fig 3 show the graphical representation of Indicated mean effective pressure and Mean effective pressure with change in load. It has been seen that IMEP and BMEP increasing with load. When increasing the IMEP means the heat energy generated within the combustion chamber is increasing with respected to that the mean pressure acting on the surface of the piston increases and Brake mean effective pressure also increases. The above fig shows that slight decreasing characterises of Fractional Mean effective pressure with increasing of load.



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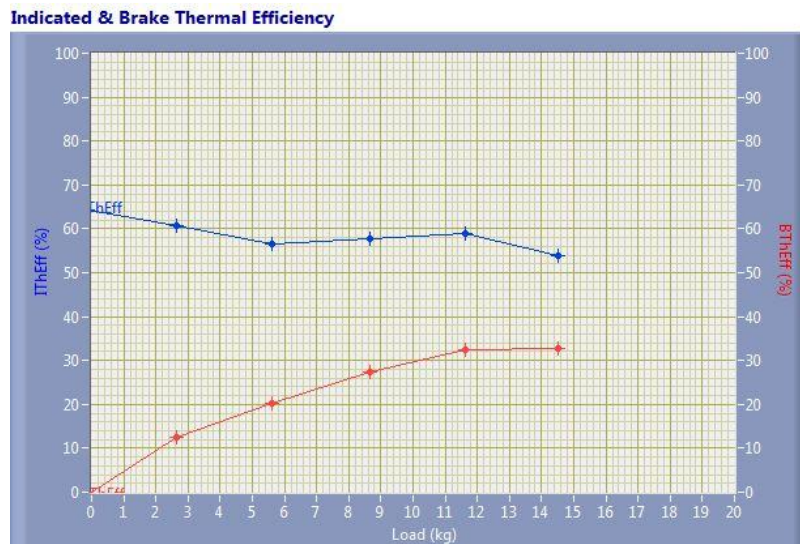


Fig 4. Load Vs ITh Efficiency, BTh Efficiency

The Fig 4 shows that the Indicated and brake thermal efficiency of engine with load. When load increases the brake thermal efficiency increases but Indicated thermal efficiency decreases. When load increases the amount of fuel accumulated within the combustion chamber are also increases with respect to that the indicated thermal efficiency decreases. When input power increases the power generated in the output shaft also increases then brake thermal efficiency also increases.



Fig 5. Load Vs SFC, TFC

The Fig 4 shows that Specific fuel combustion decreases with increasing of load, when load applied on the output shaft increases means that the engine required more input power generation within the combustion chamber. Due to that the rate of fuel accumulated to the combustion chamber increases. With respect to that the total fuel burning inside the combustion chamber also increases.

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## V. CONCLUSION

The present study of compression ignition engine by using computerised test rig gives detailed performance of the engine. As compared to manual analysis the computerised test rig result shows more accurate result and performance characteristics curves. The performance characteristics curve of load Vs BMEP, IMEP, Efficiency, SFC and TFC shows that when varying load on the engine that affect the performance of engine change the parameters as mentioned in the result analysis. And In this work also gives initiation of exhaust gas analysis and pressure distribution inside the combustion chamber in future.

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