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Data Acquisition System for I.C.Engine

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ABSTRACT

A data acquisition system is a device designed to measure various parameters. The purpose of the data acquisition system is generally the analysis of the data and the improvement in accuracy of measurements. The data acquisition system is normally electronics based, and it is made of hardware and software. The hardware part is made of sensors, signal conditioners & data acquisition card and computer. The data acquisition system increases efficiency of measurement and lowers the cost for test, through easy to integrate software like Visual Basic. With this system, Engineers can use graphical representation to meet their specific needs – very different from the conventional and traditional measurements. Additionally, data acquisition system capitalized on the ever-increasing performance of personal computers. In test, measurement, and control, the system experiences up to a 10 times increase in efficiency at a fraction of the cost, in a fraction of time, of traditional measurement system. This Dissertation work involves testing of internal combustion engine using data acquisition system. For this the data is acquired from internal combustion engine and send to computer after required conditioning. The parameters of internal combustion engine which can be measured are speed, load, temperature and vibrations . The graphical display on the computer screen can be made by using any software like Visual Basic . This is an attempt to develop a Computerized Test Rig for measurements of Speed , Load & Temperature, Vibrations using Software like Visual Basic , Hardware PCI 1050 Card with Signal Conditioning using INA128 IC and Sensors like Proximity Sensor, Load Cell and RTD .

Introduction

The paper consists of testing of internal combustion engine with measurements of various parameters using computer. For this the data is acquired from internal combustion engine and send to computer after required conditioning. The entire system is called as data acquisition system. The parameters of internal combustion engine which can be measured are speed, load, temperature, pressure and vibrations. The essential components of the data acquisition system are sensors, signal conditioners, ADC Card and computer. The display forms on the computer screen can be made by using any software like Visual Basic , C++ , MATLAB or Lab VIEW .The data acquisition system increases efficiency of measurement and lowers the cost for test, through easy to integrate software like Visual Basic , C++ , MATLAB or Lab VIEW. With this system , engineers can use graphical representation to meet their specific needs – very different from the conventional and traditional measurements. Additionally, data acquisition system capitalized on the ever-increasing performance of personal computers. For example, in test, measurement, and control, engineers are using this system to experience up to a 10 times increase in efficiency at a fraction of the cost , in a fraction of time , of traditional This paper is an attempt to build a computerized test rig for measurement of various parameters of internal combustion engine and present the data for further calculation using a personal computer and an inter-facing card.This paper includes the developing of data acquisition system using computer and interfacing of software and hardware for the measurement of various parameters. The essential components of the data acquisition system are sensors, signal conditioners, ADC card and a computer monitor for display of final results. This project involves developing a data acquisition system using Visual Basic for following measurements of internal combustion engine.

- Measurement of Load
- Measurement of Temperature
- Measurement of Speed
- Measurement of pressure
- Measurement of Vibrations

For developing Data Acquisition System following units are need to be studied.

- Transducers/ Sensors
- Signal Conditioning
- Data Acquisition System
- Software (Visual Basic or MATLAB)

Temperature Measurement

Resistance temperature detectors (RTDs), are temperature sensors that uses the change in electrical resistance of some materials with change in temperature. As they are almost invariably made of platinum, they are often called platinum resistance thermometers (PRTs).Wire-wound thermometers can have greater accuracy, especially for wide temperature ranges. The most common devices used in industry have a nominal resistance of 100 ohms at 0 °C, and are called Pt-100 sensors

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('Pt' is the symbol for platinum). The sensitivity of a standard 100 ohm sensor is a nominal 0.385 ohm/°C. RTDs with a sensitivity of 0.375 and 0.392 ohm/°C are also available.

Principle of Working

- Resistance thermometers use electrical resistance and require a small power source to operate. The resistance ideally varies linearly with temperature.
- Resistance thermometers are usually made using platinum, because of its linear resistance-temperature relationship and its chemical inertness. The platinum detecting wire needs to be kept free of contamination to remain stable.

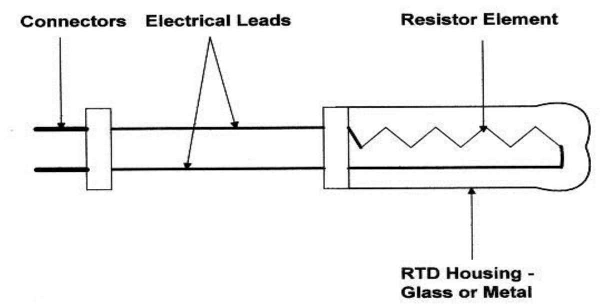


Figure 1. RTD (Resistance Temperature Detector)

Load Measurement

S-Beam load cell is a tension-compression load cell with a humidity-resistant coating and shielded cables, which enable use in harsh environments while maintaining operating specifications. Additional sense wires compensate for changes in lead resistance due to temperature change or cable extension. Ideally suited for force measurement and a wide range of other industrial applications.

Features:

- Designed for single or multiple load cell applications
- Constructed of high quality alloy tool steel

Nickel plated for outstanding corrosion resistance

Figure 2. S-Beam Load Cell

Speed Measurement

Sensor used : Proximity Speed sensor

Proximity sensors are sensors able to detect the presence of nearby objects without any physical contact.

- A proximity sensor often emits an electromagnetic or electrostatic field, or a beam of electromagnetic radiation (infrared, for instance), and looks for changes in the field or return signal.
- The object being sensed is often referred to as the proximity sensor's target. Here the sensor target is the crank as it senses the crank speed of the engine .
- Different proximity sensor targets demand different sensors. For example, a capacitive sensor might be suitable for a plastic target; an inductive proximity sensor requires a metal target.

The maximum distance that this sensor can detect is defined "nominal range". Some sensors have adjustments of the nominal range . Proximity sensors can have a high reliability and long functional life because of the absence of mechanical parts and lack of physical contact between sensor and the sensed object.

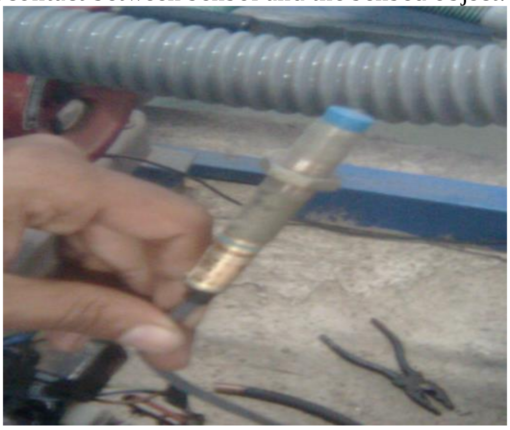


Figure 3. The proximity sensor that is used in the 4 stroke single cylinder petrol engine

Pressure Measurement

Sensor used : Piezoelectric Tranducer

Pressure analysis consists of recording the pressure inside the combustion chamber throughout the combustion cycle.

The most common method of recording cylinder pressure in internal combustion engines is using an electrical pressure transducer. The electric pressure transducers work by emitting an electronic signal proportional to the deflection of a diaphragm when exposed to cylinder pressures.

The piezoelectric transducer is commonly used because of its wide frequency response and linearity over a large range. The piezoelectric transducers are water-cooled to help prevent overheating which causes the quartz elements to break up, deteriorating the performance of the transducer. The transducers need to be located flush with the walls of the cylinder for best results. The output of a pressure transducer subjected to thermal shock will generates false readings on the pressure record.

Vibration Measurement

Accelerometers are a very common way to measure vibration. However, acceleration vibration data is most useful for high frequencies while velocity data is suited to lower frequencies and in particular vibration found in most rotating machinery. Velocity vibration data is also a much better indicator of machinery health as it changes with a linear relationship to machine health.

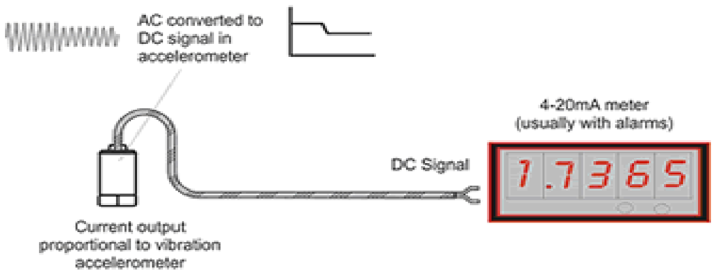


Figure 4. Accelerometer for vibration measurement

Signal Conditioners

The signal from any sensor must be converted from its analog form into a digital signal that the computer or controller can understand. This can be done by a transducer in the field, a local signal conditioner, or by the analog-to-digital (A/D) converter on a data acquisition board. [2]

Signal conditioners are available to handle virtually every sensor on the market today, including mV, V, mA, and resistance signals from RTD, thermocouple, potentiometer, strain gage, load cell, LVDTs, and frequency sensors, to name the most common. [5]

In many cases, the signal conditioning consists of signal isolation, filtering, amplification, and linear conversion of signals ranging from ±10 mV to ±40 V to a more usable voltage. For sensors that require an excitation voltage, such as a strain gage or load cell, the signal conditioner supplies it.

Sensor signals are often incompatible with data acquisition hardware. To overcome this incompatibility, the signal must be conditioned. For example, you might need to condition an input signal by amplifying it or by removing unwanted frequency components.

In electronics, signal conditioning means manipulating an analogue signal in such a way that it meets the requirements of the next stage for further processing.

For example, the output of an electronic temperature sensor, which is probably in the millivolts range is probably too low for an Analog-to-digital converter (ADC) to process directly. In this case the signal conditioning is the amplification necessary to bring the voltage level up to that required by the ADC.[4]

The signal from any sensor must be converted from its analog form into a digital signal that the host computer or controller can understand. This can be done by a signal conditioner, or-if close enough-by the analog-to-digital (A/D) converter on a data acquisition board.

More generally, signal conditioning can include amplification, filtering, converting, and any other processes required to make sensor output suitable for conversion to digital format using signal conditioners. It is primarily utilized for data acquisition, in which sensor signals must be normalized and filtered to levels suitable for analog-to-digital conversion so they can be read by computerized devices.[6]

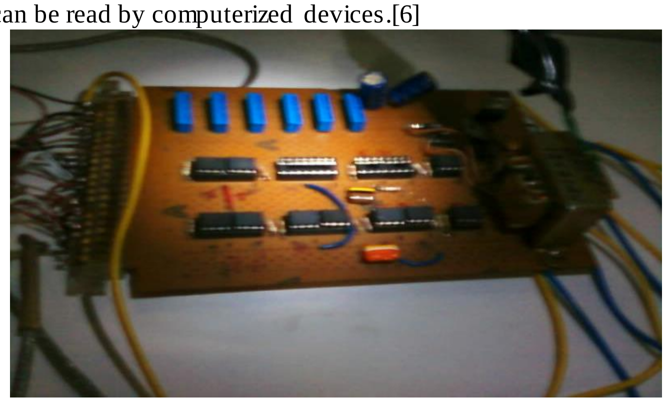


Figure 5. Signal Conditioner for Load cell , Temperature and Vibrations

Gain of Designed Signal Conditioner

$$Gain = \frac{V_{out}}{V_{in}} = 1 + \frac{50k\Omega}{R_G}$$

INA128 : Instrumentation Amplifiers used in Signal Conditioners

Description

The INA128 and INA129 are low power, general purpose instrumentation amplifiers offering excellent accuracy. Their versatile 3-op amp design and small size make them ideal for a wide range of applications. Current-feedback input circuitry provides wide bandwidth even at high gain (200kHz at G = 100).A single external resistor sets any gain from 1 to 10,000. INA128 provides an industry standard gain equation; INA129's gain equation is compatible with the AD620. The INA128/INA129 is laser trimmed for very low offset voltage (50mV), drift (0.5mV/°C) and high common-mode rejection (120dB at G ³ 100). It operates with power supplies as low as ±2.25V, and quiescent current is only 700mA—ideal for battery operated systems. Internal input protection can withstand up to ±40V without damage. The INA128/INA129 is available in 8-pin plastic DIP, and SO-8 surface-mount packages, specified for the –40°C to +85°C temperature range. The INA128 is also available in dual configuration, the INA2128.

Signal Conditioning for Temperature

- Sensor used: RTD Pt 100
- Type of sensor : passive sensor (resistance varies linearly with temperature)

INA 128 is used for signal conditioning . It has 8 pins . Resistor Rg (Rg = 51 KΩ) is connected in between the pins 1 and 8. The value 51 KΩ of resistance is selected according to the desired gain. The gain of INA 128 is given by

$$Gain = \frac{V_{out}}{V_{in}} = 1 + \frac{50k\Omega}{R_G}$$

The amplification required is 2 (the expected gain is assumed to be 2 as the voltage should not exceed 2.5 V max.) . For adjustment of the gain , a preset of 5 KΩ is fitted in the circuit. This preset acts as a potentiometer and the value of resistance can be varied according to the gain required. The resistance of RTD is Rt and is connected to the pins 2 and 3 of INA 128. This is the input from RTD and output is obtained at pin no. 6 . (output is Vo) Pin 5 acts as a reference and Vcc is given to the pin 4 (-ve Vcc) and pin 7 (+ve Vcc) . The Vcc supplied is 5 V d.c.

The change in resistance Rt connected to pins 2 and 3 is converted into voltage as the current flowing in the circuit is constant and is about 10 mA. The voltage output of RTD is in mV which can not be sensed by ADC card and hence amplified to obtain volt (Vo) by using preset and adjusting the gain.

Resistor Rg of 51 KΩ can be identified by colour code Green---Brown---Orange.

CMRR : Common mode Rejection Ratio can be defined as a ratio of differential mode gain to the common mode gain. (CMRR = Ad / Ac)

Ac = gain of common signals like noise , air and environmental signals.

Ad = Gain of differential mode

CMRR is theoretically infinite .

Maximum CMRR is desirable.

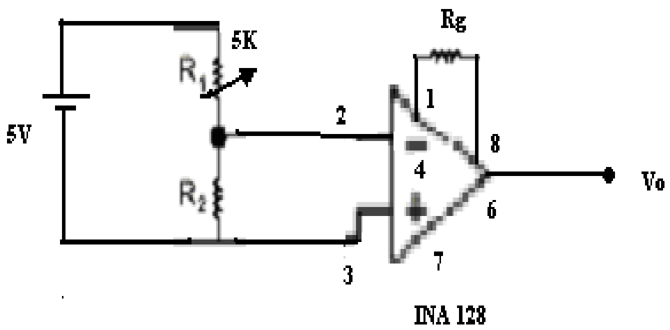


Figure 6. Signal Conditioning for Temperature

Signal Conditioning for Load

- Sensor used: Load Cell
- Type of sensor : passive sensor
- Strain Gauge is used.

When load is applied on the IC Engine, with the help of Hydraulic Dynamometer , a proportional amount of force is developed (∵ F= P/A) . This force causes the strain in the

Wheastone bridge circuit. Strain produces the change in resistances of the Wheastone bridge . The resistance difference in the bridge is directly proportional to the strain which means that it is proportional to the force and hence to the load.The difference in arms of a Wheastone bridge resistances is given as input to INA128 Instrumentation Amplifier.

The change in resistance connected to pins 2 and 3 is converted into voltage as the current flowing in the circuit is constant and is about 10 mA. The voltage output of Loadf cell is in mV which can not be sensed by ADC card and hence amplified to obtain volt (Vo) by using preset and adjusting the gain.

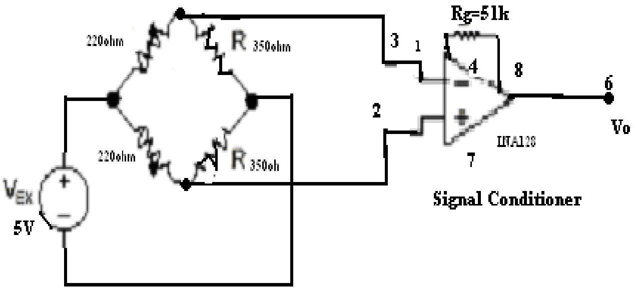


Figure 7. Signal Conditioning for Load Cell

Strain gauge measurement involves sensing extremely small changes in resistance. Therefore, proper selection and use of the bridge, signal conditioning, wiring, and data acquisition components are required for reliable measurements. To ensure accurate strain measurements, it is important to consider the following:

Amplification

Filtering

Amplification – The output of strain gauges and bridges is relatively small. Therefore, strain gauge signal conditioners usually include amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios.

Filtering – Strain gauges are often located in electrically noisy environments. It is therefore essential to be able to eliminate noise that can couple to strain gauges. Low pass filters, when used in conjunction with strain gauges, can remove high-frequency noise prevalent in most environmental settings.

Signal conditioning for Vibration Measurement

It is carried out in following stages

a) Signal Transducer / Sensor

b) Preamplification and use of Low Pass Filter

c) Averaging of output signal

d) Obtaining d.c output

e) Calibration / Scaling

Signal Tranducer / Sensor :

- Sensor used: Piezoelectric Transducer
- Instrument used: Accelerometer
- Type of sensor : Active

Piezoelectric transducer is a crystal type electrostatic sensor which is in the form of a buzzer/ diaphragm. The change in pressure produced because of vibrations is sensed by diaphragm of a piezielectric transducer and gets converted into voltage signal . The voltage produced is directly proportional to the change in pressure because of vibrations.

Preamplification and Low Pass Filter :

The voltage input signal is given to pins 2 and 3 of INA128 Instrumentation Amplifier . A known value of resistance according to the desired gain is connected at pins 1 and 8 of INA128 . The output voltage after Preamplification is obtained at pin no. 6 of INA128 . This output signal contains the noise signals , environmental distortion and air signals alongwith the vibration signals. These produces undesirable effect and our output gives high level of inaccuracy. These undesirable signals needs to be filtered out using Low Pass Filter. The noise signals of the order of about 30 Hz are getting mixed with the actual signalsof vibrations. These are removed using low pass filter circuit . Two resistors of value R1= 100KΩ and R2= 100 KΩ are connected to INA128 Instrumentation Amplifier alongwith the output signals at pin 6. The capacitors are designed using relation

$$f_c = \frac{1}{2\pi\sqrt{R_1}R_2C_1C_2}$$

simplifying we can write $fc = \frac{1}{2\pi \mathrm{R\,C}}$

$(\because R_1 = R_2 = \mathrm{R} \text{ and } C_1 = C_2 = C)$

For f_c = 300 Hz and R=100 KΩ , C= 0.47 nF , two capacitors C_1 and C_2 of values 0.47 nF are used in the low pass filter circuit alongwith $R_1 = R_2$ = 100 KΩ to filter out the undesirable noise signals from the output signal.

Averaging circuit and d.c conversion

The output voltage signals are in the form of a.c. which needs to be converted to d.c. output . This is achieved by using a diode 1N4001 which acts as a half wave rectifier. The peak inverse voltage of diode is 50 V . This diode averages the output signal which is a d.c signal.

A to D Conversion

The averaged d.c.output signal which is Analog signal is to be converted to Digital signals for display on computer. This is achieved by use of ADC Card . The input of d.c signal is connected to ADC Connector and output is obtained in Digital form.

Scaling and Calibration

The output obtained from ADC card is then calibrated and magnified according to the need. This is called as Scaling.

Signal Conditioning for Speed

- Sensor used: Magnetic pick-up (inductive type)
- Type of sensor : Active Sensor

Inductive type Magnetic pick up is used alongwith NPN transistor to sense the change in inductance produced because of change in speed. The NPN transistor acts as a two way switch. The Vcc (5 V) is given to NPN transistor and LED is connected in the emmitter circuit . When the transistor is on OFF mode, it draws full 5V Vcc and when there is a change in inductance , the transistor becomes ON and the voltage Vcc less than 0.60 V appears across it . This forms a square wave output making the circuit ON & OFF alternately. The d.c. voltage output peaks (which are square in nature) are counted for one minute which gives directly the value of RPM of I.C. Engine.

A/D Conversion using ADC Card

The PCI 1050 is a multichannel, multifunction DAS card for PCI bus. It features 16 single ended channels 12-bit A/D converter, a single channel 12-bit D/A converter, 16 digital inputs and 16 digital outputs. The input multiplexer used has a fault and overvoltage protection built in. It is supported by powerful 32-bit API functions for I/O processing under WIN98/2000 operating system.

All the user interface signals are terminated on rugged 62 pin high-density D-Type connector.

Software

The data acquisition system increases efficiency of measurement and lowers the cost for test, through easy to integrate software like VB,C++ , MATLAB or Lab VIEW. With this system, engineers can use graphical representation to meet their specific needs .

A powerful windows based software can be developed with the system. This software takes input values of speed , load , all temperatures and vibration of the engine and heat balance sheet can be obtained on the screen.

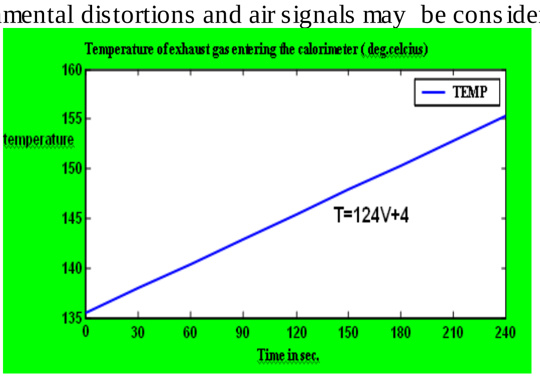
The software consists of two parts a) software for front end i.e. display screen

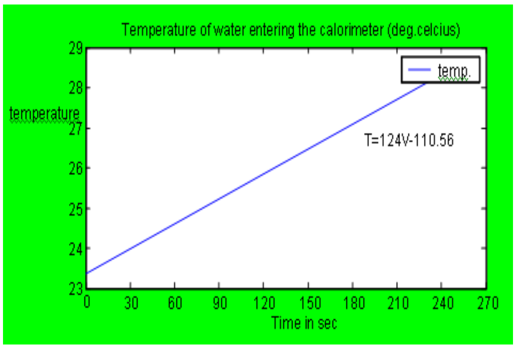
b) software for back end i.e. for calibration & computations.

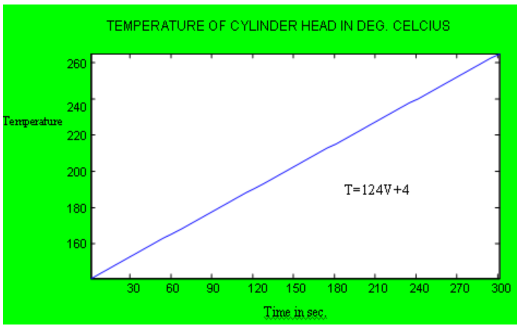
Results & Conclusion

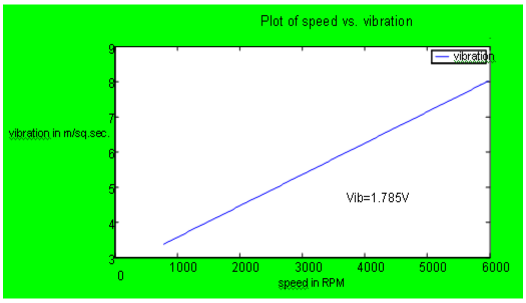
The testing & measurement of various parameters of an I.C.Engine can be done manually by operator or by using Data Acquisition System . it is done manually with the help of different mechanical measuring instruments as it is done as a conventional method. The human errors are likely to occure while manual measurement as operator is involved in the measurement process. Secondly calibration errore are likely to occure in the measuring instruments .

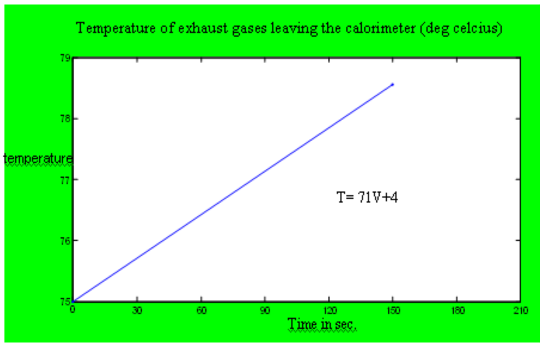
When data acquisition system is used for the testing/ measurement , the human errors are reduced to a large extent as operators involvement is very less in the measurement process but the errore due to noise signals from the surrounding , environmental distortions and air signals may be considerable.

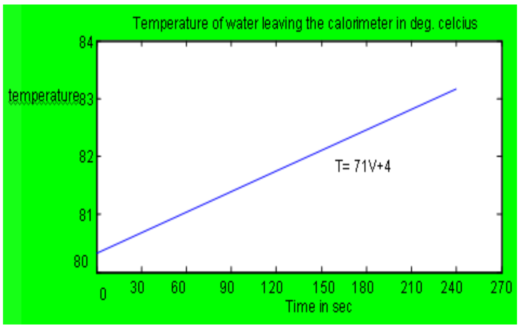


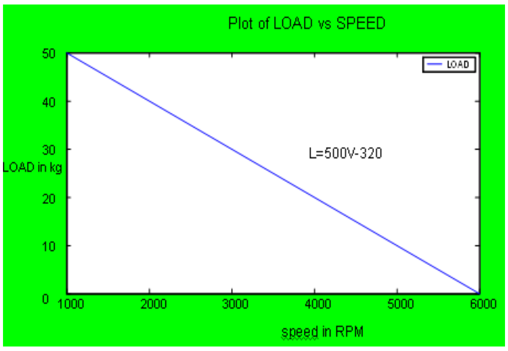












Internal combustion engines find applications in a wide range of fields including automobiles, industries and testing laboratories. Hence testing of these engines plays an important role in the applications that they are being used in. The testing of these engines is a laborious and time consuming process.

The basic task of the development engineer is to reduce the cost and improve power output and reliability of the engine. In trying to achieve these goals one has to try various design concepts. To find the engine performance one has to resort to testing .Thus in general, a development engineer will have to conduct a wide variety of tests. Computer aided testing helps to carry out these tests with ease. Hence computerization is used to greatly simplify the tedious and repetitive processes involved in testing .

A computerized test rig is useful for measurement of various parameters of internal combustion engine and present the data for further calculation using a personal computer and an inter-facing card .This is achieved by using data acquisition system with computer and interfacing of software and hardware for the measurement of various parameters.

The computerized internal combustion engine was installed and tested successfully for various parameters such as speed, temperature ,load and vibrations. During the course of the project various sensors were installed and suitably configured and calibrated so as to attain desired results. In order to condition the signals obtained from the various sensors a signal conditioner was also designed and assembled. The function of the signal conditioner is to amplify and make the signals noise free. In order to interface the analog signals with the digital code of the computer, an analog to digital converter ADC card PCI – 1050 was installed. And lastly, to display various measurement parameters software was developed using visual basic. The software converts the digital signals into corresponding units of the measured parameters.

Data acquisition system has the following advantages.

1. Since readings are obtained through sensors the factor of human error is removed from the process.

2. Since the process is automated manual work is drastically reduced, time consumption is less and the accuracy is improved.

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