Palestine Polytechnic University

College of Engineering & Technology
Mechanic Engineering Department

Graduation Project

Computerized Electrical Dynamometer

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جامعة بوليتكنك فلسطين

الخليل – فلسطين

كلية الهندسة والتكنولوجيا

اسم المشروع

Computerized Electrical Dynamometer

أسماء الطلبة

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بناءً على نظام كلية الهندسة والتكنولوجيا وإشراف ومتابعة المشرف المباشر على المشروع وموافقة أعضاء اللجنة الممتحنة تم تقديم هذا المشروع إلى كلية الهندسة والتكنولوجيا وذلك للوفاء بمتطلبات درجة لبكالوريوس في الهندسة تخصص هندسة السيارات.

توقيع المشرف

5.2.14

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توقيع اللجنة الممتحنة

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توقيع رئيس الدائرة

....

Dedication

To our parents who

Spent nights and days doing their best

To give us the best…

To our supervisor

Dr. Zuhdi Sallhab

To all students and who

Wish to look for

The future…

To who love the knowledge and

To light his avenue

Of life…

To our beloved country

Palestine…

To the souls of Palestine martyrs…

To who believe just in

Peace as a right of all nations…

To all our friends….

To unknown love

To our love

Bashar Rojoub

Islam Abu-Zahra *Ismail Amre*

Abstract

In this project,we take the engine in the internal combustion engine laboratory without a load unit, and it’s difficult to be purchased due to its expensive price, so we design a new load unit, contains an electric generator, thermal resistance with its control panel, and load cell. All these component has been fitted to the engine and the data has been analyzed using computer software.

The gathered data have been processed using VDAS and the engine cycle analyzer, also we calculate the engine performance like engine speed, torque, break power, fuel consumption and graph P-V and P-α diagrams.

Table of Contents

List of Tables

List of Figures

List of Equations

CHAPTER ONE

Introduction

1.1 Introduction

Internal combustion engine is the main component of automotive mechanical engineering. It convert the chemical energy in a fuel into mechanical energy, usually made available on a rotating output shaft, to provide power and torque in order to propulsion of vehicles, or other applications include stationary engines to drive generators or pumps, and portable engines for things like chain saws and lawn mowers.

1.2 Project Overview

Building an electrical dynamometer as a part of the internal combustion engine laboratory atmechanical engineering department inPalestine polytechnic university,for purposes of scientific researches in the field of engine performance, and to examine engine performance in different circumstances during experiments especially for the automotive engineers.

So the current project i.e. "Building an Electrical Dynamometer" is paramount importance since it intend to bridge the gap between the theory and its applications. Since the previous projects emphasized on the theoretical aspects of the student course, our current project emphasized upon collecting actual data as a result of applying different loads on the engine.

1.3 Project Objectives

The main purpose of the dynamometer is to test the power characteristic of internal combustion engine under different loads. All measurements of different loads and torque will be adapted and processed using "Versatile Data Acquisition System (VDAS)" of a computerized dynamometer.

This will be done by using combination of electrical resistance connected to the generator to change the value of load with known power of the input through applying the power equations. The devices will be connected as shown in the figure 1.1.

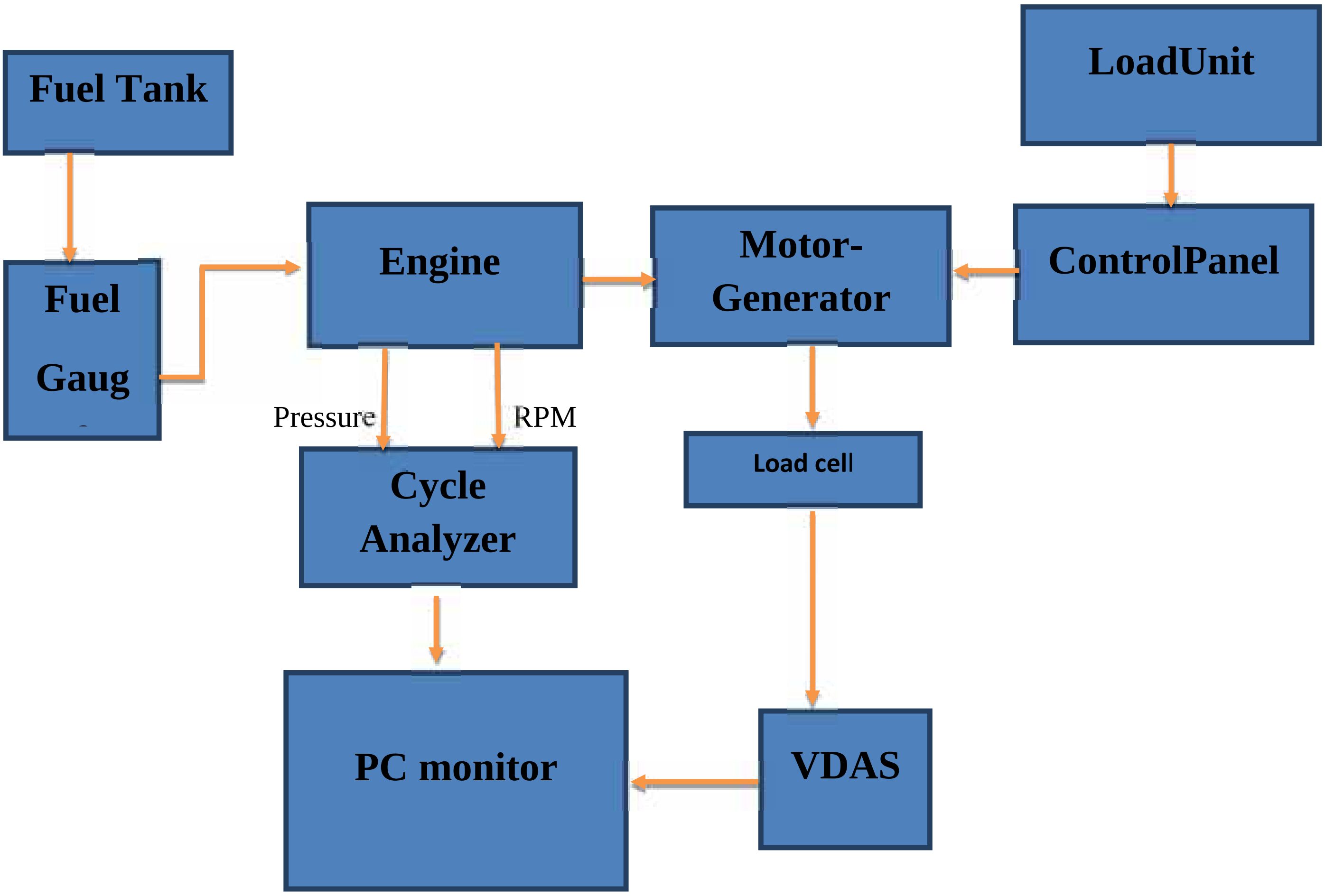

Figure1:1 ElectricalDynamometer

1.4 LiteratureReview

The dynamometer is a device used to measure force and mechanical power. It invented by Edmand Regnire and described by him in 1798.There is many types of dynamometers in use, the solid friction dynamometers, Air dynamometers, Hydraulic dynamometers, electrical dynamometers.

1.4.1 Solid Friction Dynamometers

These are the simplest type in construction as well as in operation figure 1.2. The prony brake and the rope brake dynamometers are the typical examples of the solid friction type. In these dynamometers the friction between the wooden blocks or the rope and the flywheel rim is used to absorb the engine output and convert it into heat.

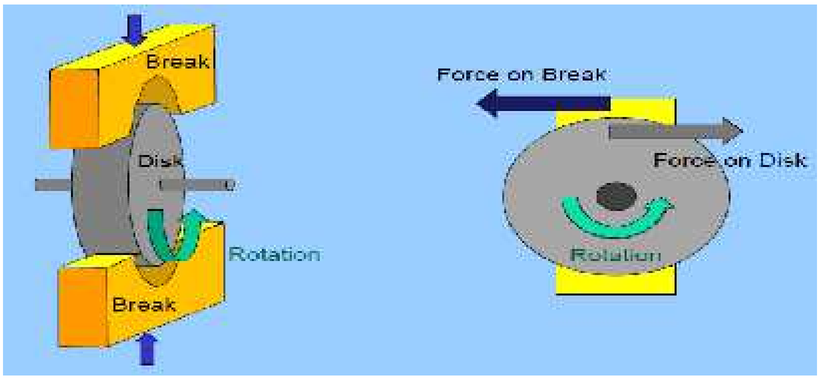

Figure 1.2: Solid Friction Dynamometer

1.3.2 Air Dynamometer

This type does not find muchuse in the present day automotive engine industry figure. 1.3. The shaft spins a fan, which moves air. The fan must be calibrated on africtional dynamometer before use, and its load is a function of temperature,barometric pressure and humidity.

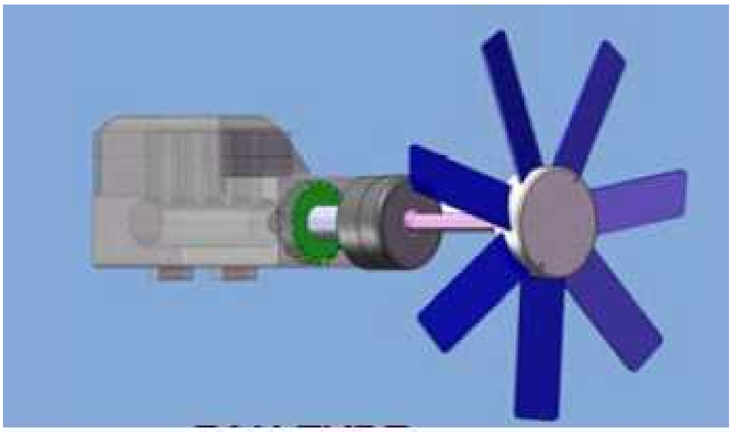

Figure1.3: Air Dynamometer

1.4.3 Dynamometer

It is a traditional water brake dynamometer figure 1.4, and this type of dynamometers can handle huge loads than other ones, the ability of varying load on engine while the engine speed can be held constant, it is also easier to set up new engine quickly and accurately as compared to other types of dynamometer.

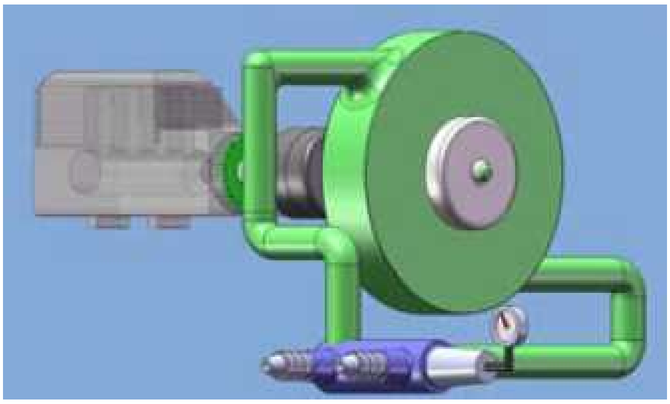

Figure 1.4:Hydraulic Dynamometer

1.4.4Eddy Current Dynamometer

The shaft spins a disk located inside a housing containing large electromagnet coils. Figure 1.5when current passes through the coils they create a strong magnetic field in the disk. This creates “eddy currents” in the disk, whichresist rotation, creating a torque between the housing and the disk. Varyingthe current varies the torque.

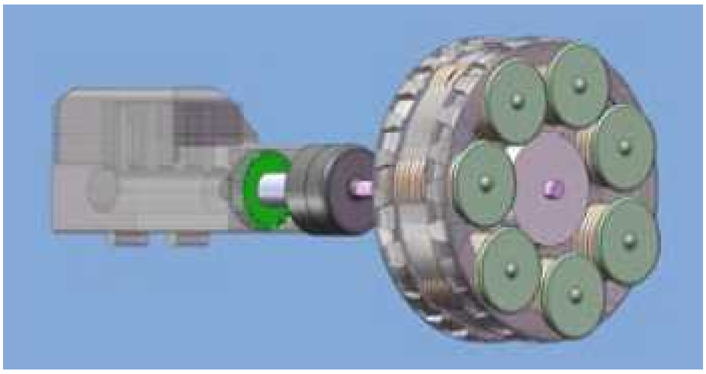

Figure 1.5: Eddy Current Dynamometer

1.4.5 Generator TypeDynamometer

The electric dynamometer is actually an electricgenerator, which generates an electric current when driven by the engine undergoing the test figure. 1.6. The current developed may be absorbed through suitable resistance or may be used for lightening and other uses.

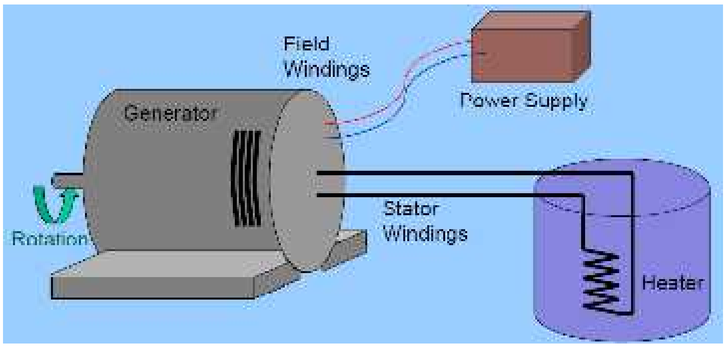

Figure1.6:Generator TypeDynamometer

The output produced by the generator is known as the electric horsepower and is always less than the horsepower of the engine that drives it; due to friction in the generator and other uses.

Knowing the efficiency and the electric horsepower of the generator can readily be converted into actual brake horsepower developed by the engine.

We will build the load unit to prepare the electric dynamometer for experiments in the internal combustion laboratory.

1.5 Project Scope

This project consists of three chapters as follows:

<u>Chapter One:</u> “Introduction”, overview for the total project, objectives, time schedule.

<u>Chapter Two:</u> “Project Component and Specification” it is include the component of the project.

Chapter Three: “Hardware connection and analysis”, specifying the component and fitting it to the engine.

1.6 Time Schedule

The time schedule shows the stages of developing in our work and the process of project growth that include Project determination, studying, collecting data, designing the entire system. Table 1.1; shows the first semester project growth. All tasks are referred to the theoretical background and the whole system analysis.

Table 1-1 Time Schedule (1)

Time(Week) / **activity**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**
Specify project title and team																
Writing abstract																
Literature review and previous work																
Writing the proposal																
Specify the components																
Printing documentation																
Editing the project and prepare for presentation																
Project presentation																

Table 01-2Time Schedule (2)

Time(Week) / activity	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Determine the plan of action	■	■														
Hardware Implementation		■	■	■	■	■	■	■	■	■						
Software Design and Testing									■	■	■	■				
Hardware Testing								■	■	■	■	■	■			
Hardware Instillation												■	■	■		
Documentation						■	■	■	■	■	■	■	■	■	■	
Project presentation															■	■

1.7Cost Estimation and Budget Breakdown

This section lists the overall cost of the project. The cost includes the hardware, and the human resources costs.

Table 01-3Cost and Budget.

Component	**Price (NIS)**
Encoder sensor	1300
Generator	1000
Pillow Block Bearing	70
Curved Tooth Coupling	100
Load cell	250
Electrical equipment	700
Turning and wilding	٥٠٠
Total	3920

CHAPTER TWO

Project Component and Specification

2.1 Introduction

٢.٢Internal Combustion Engine

٢.٢.١Four-Stroke Petrol Engine

٢.٢.٢Thermodynamic Cycles for SI Engine

٢.٣Volumetric Fuel Gauge

٢.٤Engine Cycle Analyzer

٢.٥Crank Angle Encoder

٢.٦Pressure Sensor

٢.٧Strain gauge load cell

٢.٨Electric Generator

٢.٩Versatile Data Acquisition System (VDAS)

٢.١٠Load Unit

٢.١١Nylon Sleeve Series Flexible Couplings

2.12 Pillow Block Ball Bearing

2.1 Introduction

This chapter contains project parts with its properties and focuses on the technical specifications.

2.2 Internal Combustion Engine

The internal combustion engine where the combustion of fuel (normally a fossil fuel) occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine (ICE) the expansion of the high-temperature and high-pressure gases which produced by the combustion apply a direct force to some component of the engine. The force applied typically to pistons. This force moves the component a specified distance, transforming chemical energy into useful mechanical energy. Etienne Lenoir created the first commercially successful internal combustion engine.

2.2.1 Four- Stroke Petrol Engine

Four–stroke petrol engine with modified cylinder head and crank output shaft. These are to comply with the cylinder head pressure sensor and crank angel encoder.

The engine specifications are:

1- Overhead valve
2- A conventional carburetor with manual choke
3- Electric spark ignition
4- Splash lubrication

The fins around the engine provide forced air – cooling. The engine is starts by handle and cord, wrapped around a pulley on the flywheel.

The flywheel has a permanent magnet fixed to it edge , as the fly wheel turns , the magnet passes the primary winding of the electric ignition coil and forces an electric current to flow in the coil . The ignition system uses this to create spark at the spark plug.

The engine include an on off switch that connects the primary winding to ground to stop the ignition circuit, this stops the engine .Figure 2.1 shown the four stroke engine.

Figure 2.1: Four-Stroke Petrol Engine.

Table 02-1: Engine specification

Item	Specification
Dimensions (when fitted to Base Plate) Net Weight (with Base Plate)	Width 400 mm Height 400 mm Depth 300 mm 20 kg
Fuel Type	Petrol (Gasoline)
Fuel Tank	Red - Painted steel with vent and filler cap
Exhaust outlet	Nominally 1"BSP
Ignition system Absolute Maximum Power	Electric 4.4 kW (6 hp) at 4000 $rev.min^{-1}$
Continuous Rated Power	2.6 kW at 3000 $rev.min^{-1}$ 2.9 kW at 3600 $rev.min^{-1}$
Bore	67 mm
Stroke/Crank Radius Connecting Rod Length	49 mm/24.5 mm 85 mm
Engine Capacity	172 cm^3 (0.172 L) or 172 cc
Compression Ratio Oil Type*	8.5:1 SAE20, SAE30 or Multigrade 10W-30
Oil Capacity	0.65 Litre

2.2.2 Thermodynamic Cycles for SI Engine

Spark ignition internal combustion engines has classified to; Tow-stroke engines and Four-Stroke engines, represented by Otto cycle.

Four-stroke engines is clarifying in four stages as in the pressure-volume (P-V) diagram as shown below in figure 2.2. In addition to, Fig. 2.3

1-Process 1-2

Piston moves from crank end (bottom dead center) to cover end (top dead center) and an ideal gas with initial state one compressed isentropically to state point 2, through compression ratio (V_1/V_2). Mechanically this is the adiabatic compression of the air/fuel mixture in the cylinder, also known as the compression stroke. Generally, the compression ratio is around 9-10:1 for a typical engine.

2- Process 2-3

The piston is momentarily at rest at TDC and heat added to the working fluid at constant volume from an external heat source, which brought into contact with the cylinder head. The pressure rises and the ratio (P_3/P_2) called the "explosion ratio". At this instant, the air/fuel mixture compressed at the top of the compression stroke with the volume essentially held constant, also known as ignition phase.

3- Process 3-4

The increased high pressure exerts a greater amount of force on the piston and pushes it towards the BDC. Expansion of working fluid takes place isentropically and work is done by the system. The volume ratio (V_4/V_3) called "isentropic expansion ratio". Mechanically this is the adiabatic expansion of the hot gaseous mixture in the cylinder head, also known as expansion (power) stroke.

4- Process 4-1

The piston is shortly at rest at BDC and heat rejected to the external sink by bringing it in contact with the cylinder head. The process controlled so that ultimately; the working fluid comes to its initial state 1 and the cycle is completed.

Exhaust stroke-ejection of the gaseous mixture via an exhaust valve through the cylinder head. Induction stroke-intake of the next air charge into the cylinder. The volume of the exhaust gasses is the same as the air charge.

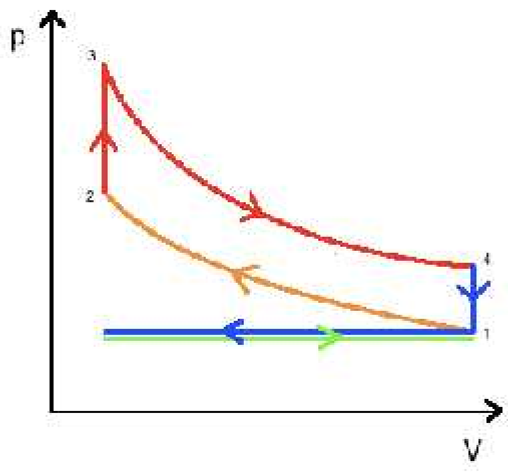

Figure 2.2.Pressure-Volume (Otto cycle) Diagram.

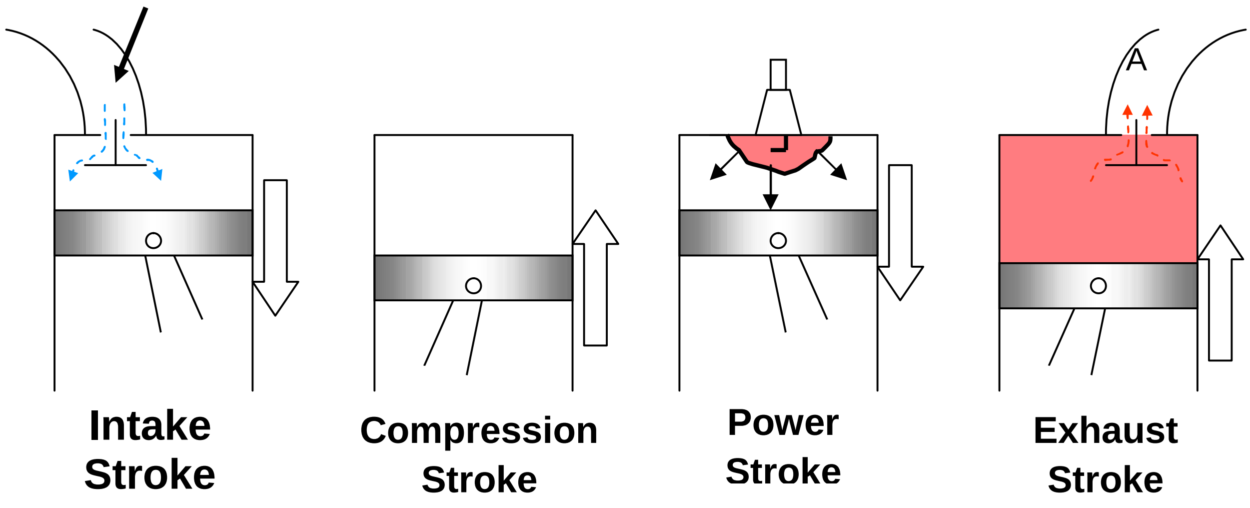

Figure 2.3: Four-Stroke Stages as in the Spark Ignition Engines Cylinders.

In the Otto cycle, it is assumed that the heat is release instantaneously. A finite heat release model specifies heat release as a function of crank angle.

This model can be used to determine the effect of spark timing or heat transferon engine work and efficiency. As shown in the figure 2.4 below.

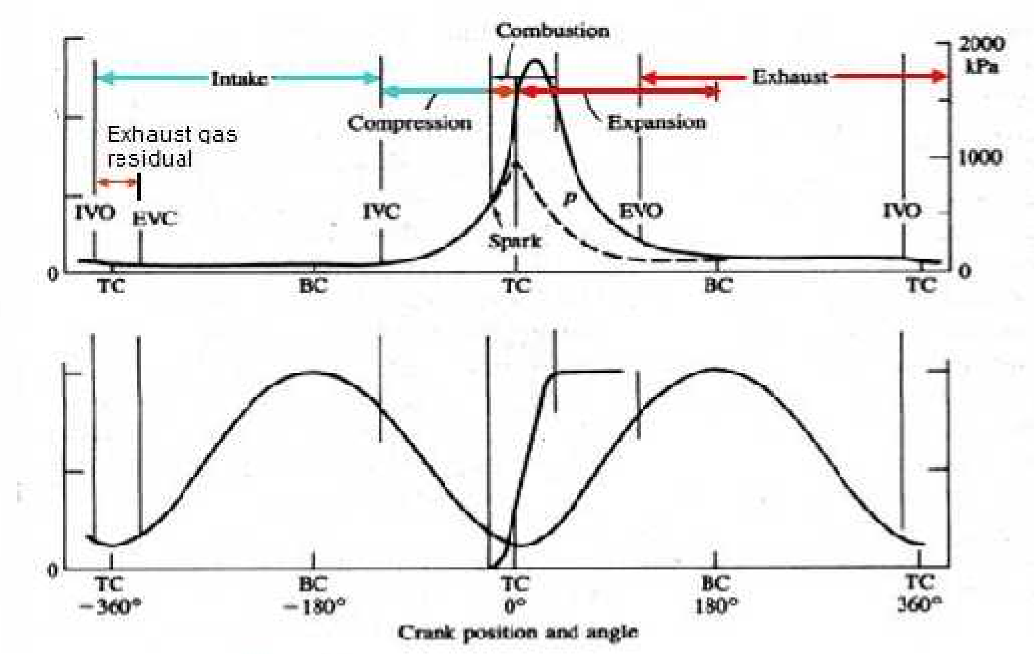

Figure 2.4:Crank Position and Angle.

2.3 Volumetric Fuel Gauge

In this laboratory, a volumetric flow gauge is available to measure the fuel flow, which is a manually operated fuel pipette, to be used with suitable timer or stopwatch. Figure 2.5 shown the Fuel Flow Meter.

Figure 2.5: Fuel Flow Meter

2.4 Engine Cycle Analyzer

The engine cycle analyzer consist of two parts:

1- A Hardware unit interface with charge Amplifier. The hardware unit includes LED indicators to show the process readiness, encoder top dead center position and PC communication status.

2- Dedicated software, to log the data, create charts of pressure against crank angle and pressure against volume. The figure 2.6 shown The Engine Cycle Analyzer

Figure 2.6: Engine Cycle Analyzer

2.5 Crank Angle Encoder[1]

The crank angle encoder contains a precision marker disk with a trigger mark and 360 angle marks, which are scanned by a transmission photoelectric cell. Their light intensity is regulated in order to compensate for any soiling. The disk and the photoelectric cell are encased in dustproof housing. Figure 2.4 shown Crank Angle Encoder.

[1] Appendix A

Figure 2.7: Crank Angle Encoder

Incremental encoder:

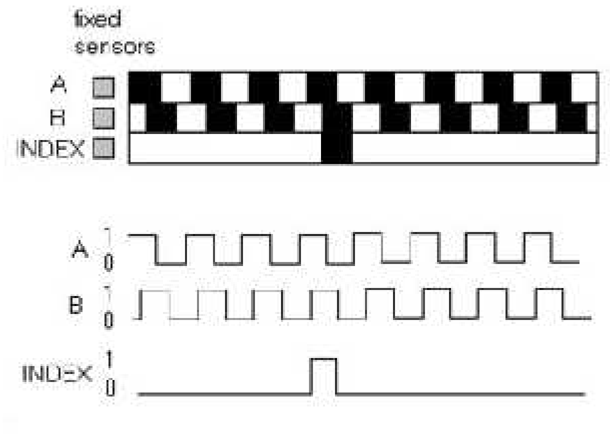

Fig. 2.8 Incremental Encoder Disk Track Patterns

The incremental encodersome-times called a relative encoder. It consists of two tracks and two sensors whose outputs are called channels A and B. As the shaft rotates, pulse trains occur on these channels at a frequency proportional to the shaft speed, and the phase relationship between the signals yields the direction of rotation. The code disk pattern and output signals A and B are illustrated in Figure 2.8 By counting the number of pulses and knowing the resolution of the disk, the angular motion can be measured. The A and B channels are used to determine the direction of rotation by assessing which channels "leads" the other. The signals from the two channels are a 1/4 cycle out of phase with each other and are known as quadrature signals. Often a third output channel, called INDEX, yields one pulse per revolution, which is useful in counting full revolutions. It is also useful as a reference to define a home base or zero position.

Figure 5 illustrates two separate tracks for the A and B channels, but a more common configuration uses a single track with the A and B sensors offset a 1/4 cycle on the track to yield the same signal pattern. A single-track code disk is simpler and cheaper to manufacture.

2.6 Pressure Sensor[2]

In piezoelectric pressure sensors, the pressure acts on the surface of a diaphragm that converts it into a proportional force. This force transmitted to a crystal, giving rise to an electric charge on the opposing surfaces. The pressure sensor has the ability to measure

[2]Appendix B

the pressure of combustion under high temperature environment. The pressure sensor connected to the engine analyzer and charge amplifier to process the signal and output it to the computer software.

The use of highly-sensitive piezoelectric combustion pressure sensors with built-in ground isolation can largely avoid the effects of electrical interference. The isolation of the sensing element prevents the generation of noise currents and allows interference-free measurements, even if potential differences exist between the engine and the measuring system. The new Kistler Type 6125C is the third generation of a combustion pressure sensor with built-in ground isolation.

Figure 2.9: Pressure Sensor

The use of a new Kistler PiezoStar crystal has made it possible to increase the sensitivity to –37 [pC/bar] and the pressure range to 300 bar. This innovative sensor ensures precise and reliable measurement data even under noisy testing conditions.

This sensor calibrated by Kistler Instrument AG, and sent to us calibration certificate. The calibration are clarify in Appendix [A].

Advantages

- Pressure range up to 300 bar.
- High sensitivity due to new PiezoStar crystal.
- Ground-isolated.
- Low thermal shock error, very low load-change drift.
- PiezoSmart sensor identification.

2.7 Strain Gauge Load Cell

Strain gauge load cells are the most common in industry. These load cells are particularly stiff, have very good resonance values, and tend to have long life cycles in application. Strain gauge load cells work on the principle that the strain gauge (a planar resistor) deforms/stretches/contracts when the material of the load cells deforms appropriately. These values are extremely small and are relational to the stress and/or strain that the material load cell is undergoing at the time. The change in resistance of the strain gauge provides an electrical value change that is calibrated to the load placed on the load cell.

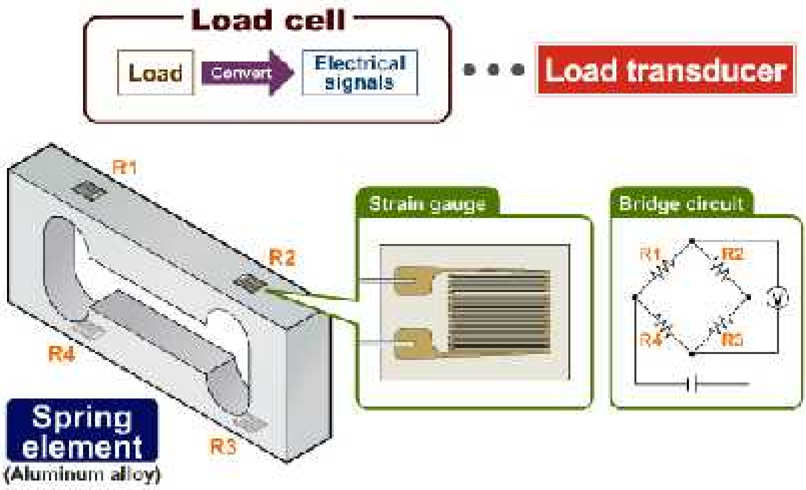

Figure 2.10: Strain Gauge Load Cell

2.8Electric Generator

An alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current.

Most alternators use a rotating magnetic field with a stationary armature, when the magnetic field around a conductor changes, a current induced in the conductor. Typically, a rotating magnet, called the rotor turns within a stationary set of conductors wound in coils on an iron core, called the stator. The field cuts across the conductors, generating an induced EMF (electromotive force), as the mechanical input causes the rotor to turn.

The relation between speed and frequency $N = 120f/P$ is, where f the frequency in Hz is (cycles per second). P Is the number of poles (2, 4, 6...) and N is the rotational speed in revolutions per $f\,(\mathrm{Hz}) = RPM\frac{P}{120}$ minute (RPM).

We chose an electric generator with the following specification:

Table 02-2: Generator Specification

Manufacturer	No. of phases	Revolution speed[RBM]	Frequency [H_z]	Rated current [A]	Rated Voltage[V]	Power output[kW]
Partner Alternator	1 Phase	3000	50	30 A	220	4.4

2.9Versatile Data Acquisition System (VDAS)

The purpose of data acquisition is to measure an electrical or physical phenomenon such as voltage, current, temperature, pressure, or sound. Computer-based data acquisition uses a combination of modular hardware, application software, and a computer to take measurements.

Data acquisition begins with the physical phenomenon or physical property of an object (under investigation) to be measured.

Typically involves acquisition of signals and waveforms and processing the signals to obtain desired information.The components of data acquisition systems include appropriate sensors that convert any measurement parameter to an electrical signal, then conditioning the electrical signal, which can then be acquired by data acquisition hardware.

The VDAS is from TecQuipment Company, and its two-part product (Hardware and Software) as shown in figure 2.11 and 2.12 respectively, which allow the user to:

- Reduce errors.
- Save experiment time.
- Automatically calculate important values.
- Produce high quality chart and results.

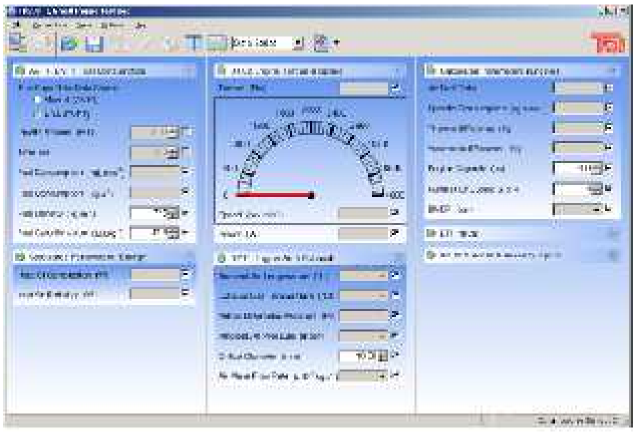

Figure 2.11: VDASHardware   Figure 2.12: VDAS Software

2.10Load Unit

One of the important devices in this project is load unit. It is the source of load that will be applied to the alternator and eventually to the engine to test its power characteristics.The load unit consist of electric resistances, which can be built by several types of electric resistances, but we chose electro thermal resistance as a source of load because it consumes high current and generating the required load.

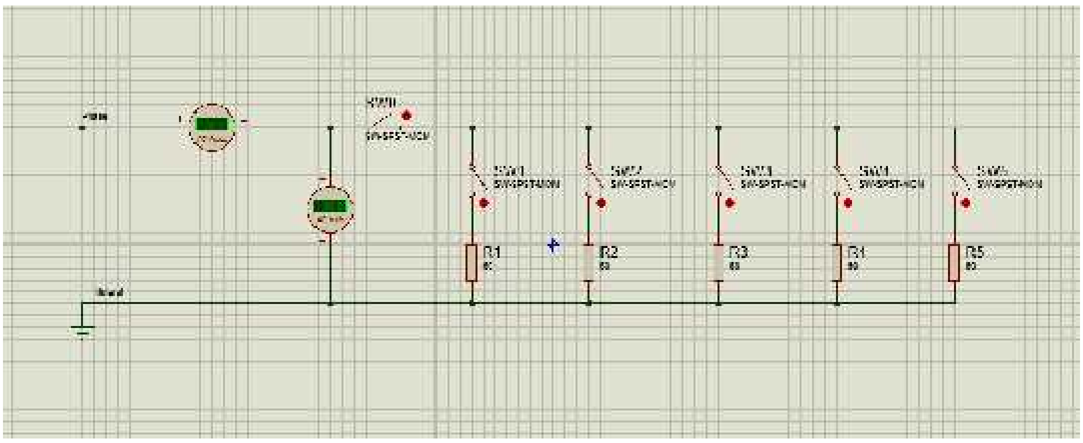

Figure2.13:Electrical Load

2.11 Nylon Sleeve Series Flexible Couplings[3]

The series is a standard coupling with two hubs, a nylon sleeve, and retaining rings depending on the modelselected. The coupling has a precision molded nylon sleeve and powder metal hub with no bolts, pins,flanges, or protrusions that could have an effect on balance or operational safety. Since no lubrication isused, the couplings can readily be adapted to many applications including vertical and blind installations.

Features:

- Compact in size
- Maintenance Free – No Lubrication required.
- Can accommodate axial, angular, and parallel misalignment.
- Easy to assemble.
- Electrically insulating.
- Can be used in temperature ranges from -25° to 80° C (optional 140° C).
- Nylon sleeve has high resistance to condensation and water, hydrocarbon based petroleum's, and alcohols.
- Not ideal for use with acids, benzyl based products, cresol, or glycols.

Figure2.14:Coupling Joint

2.12 Pillow Block Ball Bearing[4]

Pillow block bearings, the most commonly used type of mounted units, are designed to provide shaft support where the mounting surface is parallel to the shaft axis. The bolt holes are usually slotted for adjustment during mounting. Pillow blocks are supplied in a variety of configurations.

[3]Appendix C
[4]Appendix D

Pillow blocks are usually referred to the housings which have a bearing fitted into them & thus the user need not purchase the bearings separately. Pillow blocks are usually mounted in cleaner environments & generally are meant for lesser loads of general industry. These differ from "Plummer blocks" which are bearing housings supplied without any bearings & are usually meant for higher load ratings & corrosive industrial environments. However, the terms pillow block &Plummer-block are used interchangeably in certain parts of the world.

Fig. 2.15: Pillow Block Ball Bearing

CHAPTER THREE

Hardware Connection and Analysis

3.1 Introduction

Testing of engine performance is often important in the development of engine and fuel technologies. To test engine performance in the laboratory, the engine is coupled to a dynamometer, which may be either an engine dynamometer (connected directly to the engine output shaft) or a chassis dynamometers (connected to the drive wheels). The dynamometer, which provides a load to the engine, can be easily controlled to allow testing under a wide range of speeds and torque. In our project, an electrical generator connected directly to the engine output shaft.

This chapter contains project components as shown in the figure bellow:

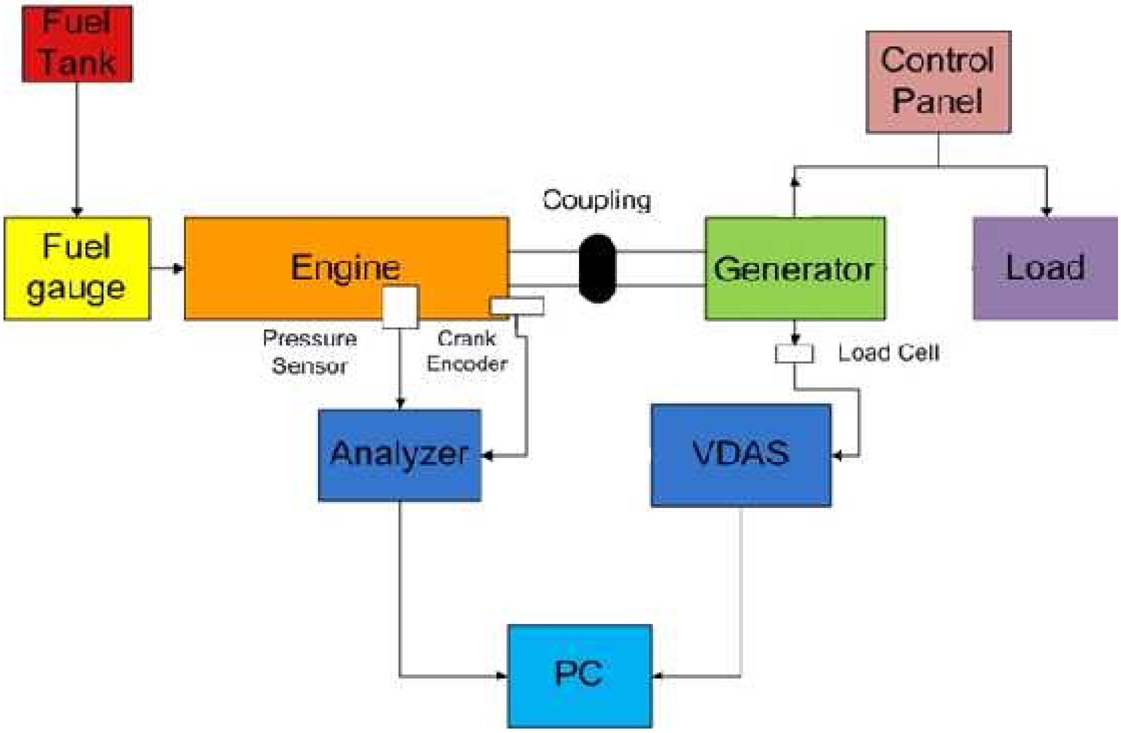

Figure 3.1: InstallationoverView

Table 03-1: Project Component

1. Gasoline Engine	2. Motor/Generator
3. Control Panel	4. Personal computer (PC)
5. VDAS	6. Engine Cycle Analyzer
7. Fuel Tank	8. Pressure Sensor
9. Load cell	10. Couple
11. Crank Angle Encoder	12. Fuel Flow meter

3.2 Engine Fitting

The engine have beenplaced on a steel frame with dimension 1.5-meter length and 0.8-meter width, designed to match the dimension of the engine.Then a fuel tank and fuel gage, connected to the engine, it mounted on a platform to facilitate fuel consumption measurement.

A Pressure sensor is fitted to cylinder head and exposed to cylinder pressure to measure its value. The encoder assembled under the crankshaft to receive mechanical motion from it by using two Pulleys, one of the pulleys mounted to the crankshaft and the other connected to the encoder shaft and attached to each other with a transmission belt.

3.3 Engine Cycle Analyzer

Ideal for student experiments, laboratory demonstrations or project work,Engine Cycle Analyzerenables students to investigate a variety of engineperformance characteristics.The versatile equipment consists of both hardware andsoftware figure [3.2] and [3.3], specially designed for educational use. It enables students to investigate the relationship between crankangle or volume and the cylinder pressure in an internalcombustion engine.

Figure 3.2: Hardware ECA

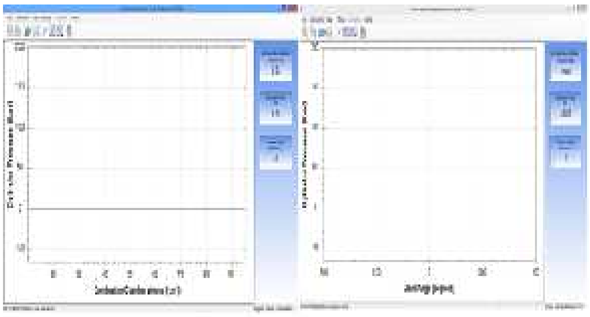

Figure 3.3: Software ECA

The equipment consists of a hardware unit withconnectors and leads, plus Windowsbased dataacquisition and analysis software. The hardware consists of a microprocessor-based signal conditioning unit with high-speed PC interface, housed in a rugged, protectiveenclosure. It accepts and conditions signals from the Cylinder Head Pressure

Transducer and Crank Angle Encoder. The cylinder pressure input includes a precision charge amplifier with a digital thumb-wheel for calibration.As well as crank angle position, the signal from the CrankAngle Encoder is also used to determine engine speed.

The output from the hardware unit connects to acomputer running the EngineCycle Analyzer software. The hardware unit includes LED indicators to show the processor readiness, encoder topdead-center position and PC communication status.The software provides real-time display of pressure versuscrank angle (p-θ) andpressure versus volume (p-V) plots. Itperforms calculations on the data to accurately displayindicated mean effective pressure (IMEP), indicated power, and engine speed.

3.4 Coupling

For the purpose of transmitting power, couplingjoint shown in the figure 3.4.It have been chosen according to the engine output shaft which have a diameter ϕ 18 mm and the alternator input shaft with a diameter ϕ 30 mm, the available standard coupling[2] diameters ϕ_1 28mm, ϕ_2 14 mm, so the coupling have been lathe by inner turning to the required diameters.

Figure 3.4:Coupling Joint

3.5 Generator

To measure the engine torque using a load cell the generator has been placed on two bearings, to allow radial motion to the generator. Therefore, we fabricate a disc with a shaft at the center of it and nailed it.

To the bottom with a bunch of screws, this shaft has been sit in one of the bearings, both of it mounted to the frame of the engine. Taking in consideration that the generator is balanced in (x, y, z) coordinates of the engine center, and the motion is transmitted to from the engine to the generator by the coupling joint.

3.5.1 Steel Frame

A steel frame used to mount the generator, the engine and the load cell. The frame mounted to the floor to reduce vibration.

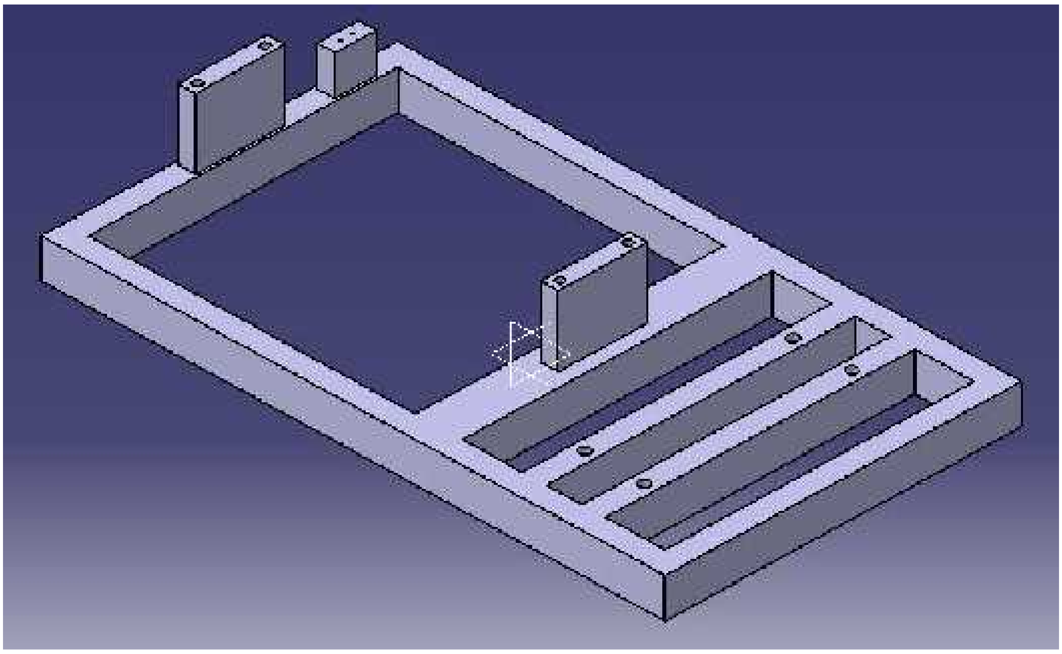

Figure 3.5:Steel Frame

3.5.2 Generator Holder

A steel disk with a shaft at it's center used to hold the backward side of the generator as shown in the figure.

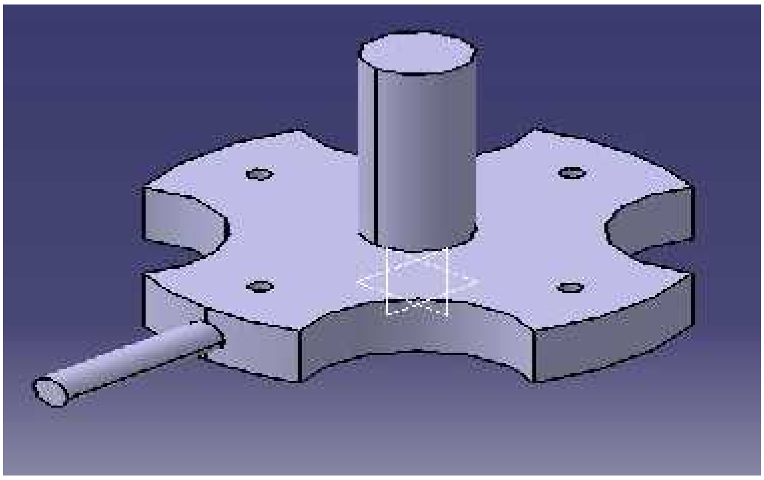

Figure 3.6:Generator Holder

3.6 Load Cell[5]

A load cell is a transducer, which converts force into a measurable electrical output, Strain-gage load cells convert the load acting on them into electrical signals.The gauges themselves bonded onto a beam or structural member that deforms when weight is applied.

Four strain gages, full bridge are used to obtain maximum sensitivity and temperature compensation. Two of the gauges are usually in tension, and the other are in compression, wired with compensation adjustments. When weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load.

The load cell sensor is 120*35 mm, it has four wires; two for positive and negative input, the others for positive and negative signals, the rated loud is 30 Kg.

A holding beam welded to the engine base considering that the load cell will be on the level of the center of the generator, a shaft nailed to the generator body is set.The center of the shaft is perpendicular to the generator shaft, Figure 3.6 applying pressure on the load cell to let it measure the torque generated after making calibration.

Figure 3.7:Load Cell Position

The output of strain gagesis relatively small. In practice, strain gage bridges and strain-based transducers output is1.9609 mV/V (10 mV of output per volt of excitation voltage).

[5]Appendix E

Therefore, strain gage signal conditioners include amplifiers to boost the signal level to increase measurement resolution and improve signal-to-noise ratios.

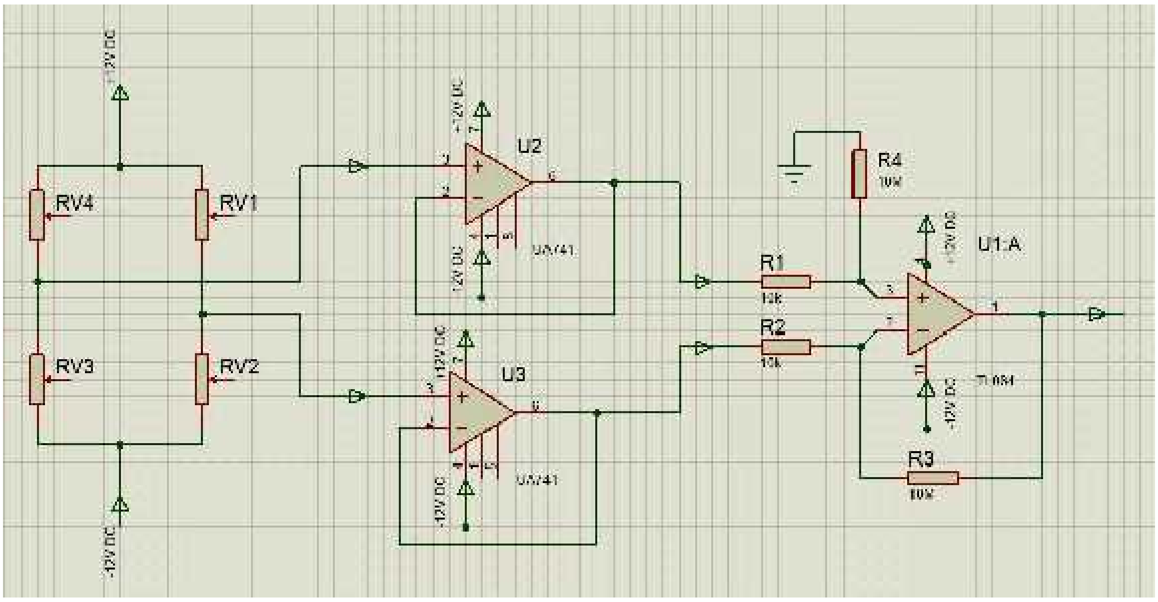

Figure 3.8: Construction Load Cell

An operational amplifier, or op-amp, is a differential amplifier with very high differential-mode gain, very high input impedances, and a low output impedance. By applying negative feedback, an op-amp differential amplifier,Figure 3.8 with predictable and stable gain must built. Some kinds of differential amplifier usually include several simpler differential amplifiers. For example, an instrumentation amplifier, a fully differential amplifier, an instrument amplifier, or an isolation amplifier are often built from several op-amps.

We used it in the project to make difference between two readings, in the equilibrium gives zero output, and innon-equilibrium gives changeable reading.

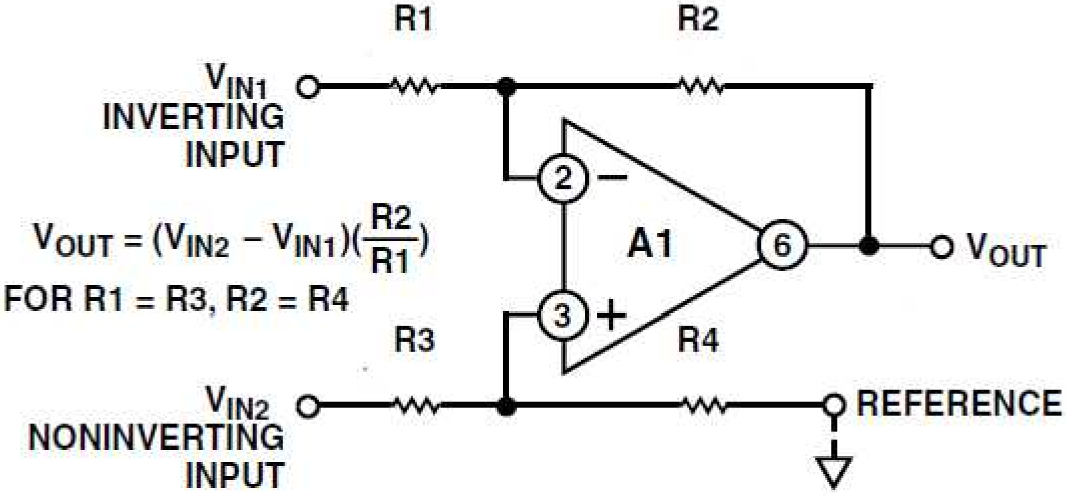

Figure 3.9Differential Amplifier

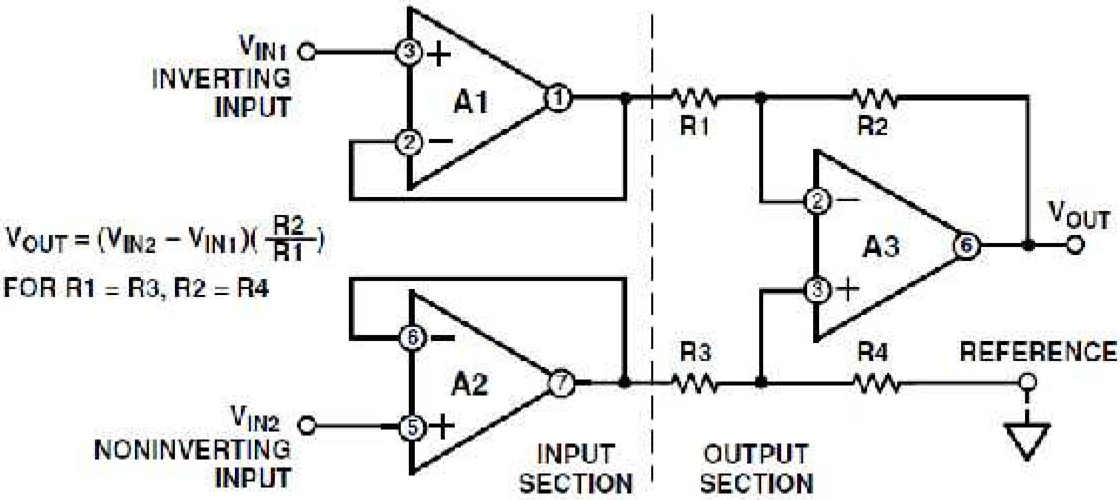

Figure 3.10Differential Amplifierwith input buffering.

Improving the Simple difference amplifier with Input Buffering:

An obvious way to significantly improve performance is to add high input impedance buffer amplifiers ahead ofthe simple difference amplifier or subtractor circuit, as shown in the 3-op amp instrumentation amplifier circuit of Figure 3-9.

This circuit provides matched, high impedance inputsso that the impedances of the input sources will have aminimal effect on the circuit's common-mode rejection.The use of a dual op amp for the 2-input buffer amplifiersis preferred because they will better track each otherover temperature and save board space. Although theresistance values are different, his circuit has the sametransfer function as the circuit of Figure 3-8.

Differential amplifier in our project works to minus values and double the value of 1000 times magnification, because the value of the sensor voltages is very little, and to read voltages by the VDAS.

The output relationship between voltage and masses is closed to linear with the range of 0.5 kg gives 0.4 volt with voltage input +,-12 Vdc as shown in Figure 3.10.

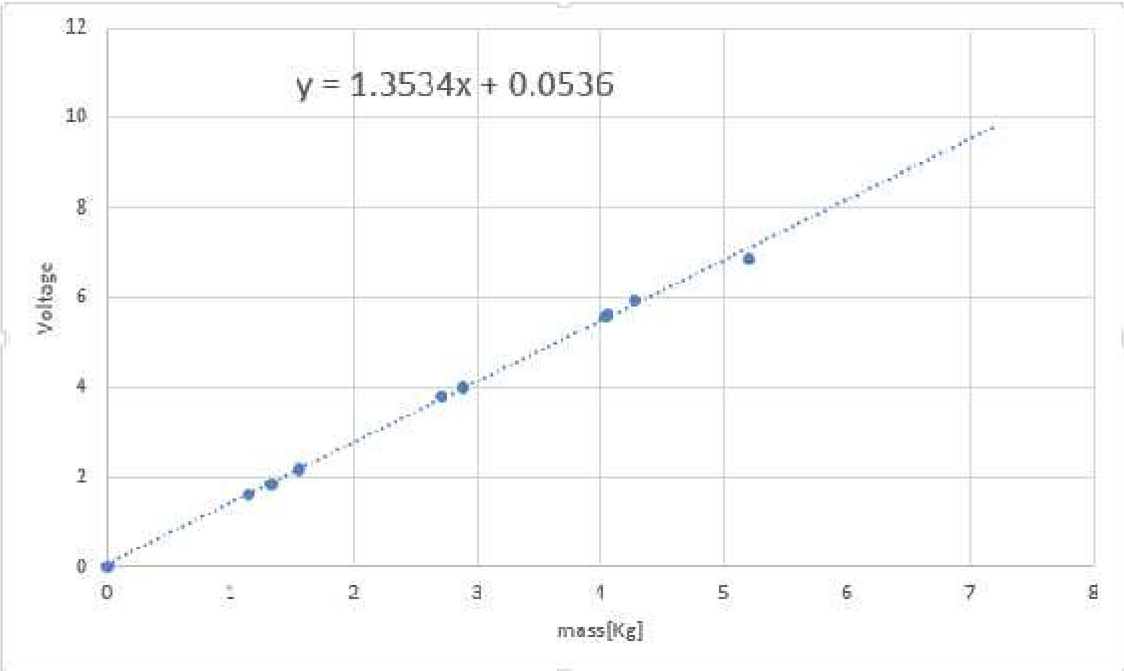

Figure 3.11:Relationship Between Mass & Voltage

3.7 VersatileData Acquisition System (VDAS)

The VDAS is from TecQuipment Company and its two-part product (Hardware and Software) as shown in Figure 2.6, 2.7 mentioned in chapter two. The hardware VDAS have three sections:

1. The Hub Board
2. The DTI Input Board
3. The Analogue Input Board

3.7.1 The Hub Board.

The VDAS compatible modules connect by means of the six sockets, marked ‘Digital Inputs’ (cables are supplied). The computer connects by means of the USB type socket (cable supplied), or the RS232 Serial D-type socket. The Hub Board has two lamps - ‘POWER’ indicates that its power input is good, ‘COMMS’ flashes to show that the HUB-to-computer communications are good.

Figure 3.12: Hub Board

3.7.2 The DTI Input Board.

This board connects up to four VDAS compatible digital transducers (or dial test indicators) on the TecQuipment product to the Hub Board. This does not used in our project but in future time if the project needs to add other instrumentation it can used.

Figure 3.13: DTI Input Board

3.7.3 The Analogue Input Board.

This board connects any suitable industry sensors on the Hub Board. This board allows connection of up to two 0 to 20 mA output sensors and up to two 0 to 10 Voutput sensors.This socket is the source and the input signal of the load cell, such that the connections are as in Figure 3.13. It shows the output source and the input signals.

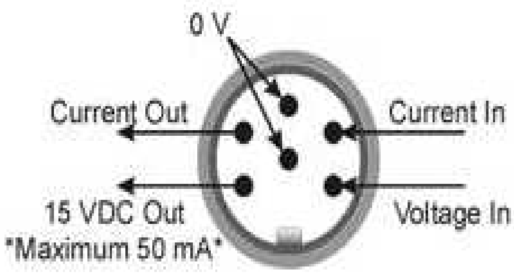

Figure 3.14: Analogue Input Board Figure 3.15: Socket Connections

3.8 Load Unit

An electricalLoad,used to dissipate the current generated from the generator in order to make dynamic braking on the engine. It consist of two parts:

1.Control Unit.

2.ThermalResistor Power.

3.8.1 Control unit

The unit is for use with 220/240 V single-phase 50 HZ supplies, It contains 5 circuit breakers to activate the required load (which is consist of 5 thermal resistances used to consume current produced from the generator), and another circuit breaker used as an overload protection to limit the current drop by the loads to 30 A as maximum current produced by the generator is 30 A.

Figure 3.16: Control Load Unit

In addition, it have a voltmeter and ammeter used for calculating the power dissipated [watt] by the resistance such that the power = I * V.

3.8.2 Thermal Resistor Power

When an electrical current passes through a resistor, electrical energy is lost by the resistor in the form of heat and the greater this current flow the hotter the resistor will get. This is known as the Resistor Power Rating. Resistors are rated by the value of their resistance and the power in watts that they can safely dissipate based mainly upon their size. Every resistor has a maximum power rating which is determined by its physical size as generally, the greater its surface area the more power it can dissipate safely into the ambient air or into a heat sink.

These resistors are constructed by coiling wire and supported by ceramic insulators on a steel strip. The resistive element is of stainless steel. The standard end terminal is screwed firmly to the resistive element, which provides good electrical connections to the resistive elements.

Figure 3.17: Thermal Resistance

For resistors in AC circuits the phase angle φ between the voltage and the current is zero, then the power factor of the circuit is given as cos 0^o = 1.0. The power in the circuit at any instant in time can be found by multiplying the voltage and current at that instant. Then the power (P), consumed by the circuit is given as P = V_{rms}*I* cos Φ in watt's. However, since cos Φ = one in a purely resistive circuit, the power consumed is simply given as, P = V_{rms}*I the same as for Ohm's Law.

Then the power dissipated in a purely resistive load fed from an AC rms supply is given as

$$P = V_{R(rms)} \times I_{rms} = I_{rms}^2 R = \frac{V_{rms}^2}{R} \qquad (3.1)$$

Where:

- P is the average power in Watts
- V_{rms} is the rms supply voltage in Volts
- I_{rms} is the rms supply current in Amps
- R is the resistance of the resistor in Ohm's (Ω)

To determine the specifications of our resistance applying the above equations, since the generator current is 30A and the voltage is 220V, the power is:

$P = V_{rms} * I_{rms} = 270*30 = 8100$ watt; 270V at 3500 rpm

For five resistor 8100/5 = 1620 watt for each resistor

I= P/V =1620/270 = 6amps

R=V/I = 270/6 = 45 ohm

Chapter Four

Performance Parameters and Characteristics

4.1Introduction

Internal combustion engine generally operates within a useful range of speed. Some engines are made to run at fixed speed by means of a speed governor, which is its rated speed. At each speed within the useful range the power output varies and it has a maximum usable power 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 the specific fuel consumption at each operating condition within the useful range of speed and load.

The following factors are to be considered in evaluating the performance of an engine:

- Maximum power and torque available at each speed within the useful rang of speed.
- The range of power output at constant speed for stable operation of the engine. The different speeds should be selected at equal interval within the useful speed range.
- Brake specific fuel consumption at each operation condition within the useful range of operation.

Engine performance characteristics can be determined by the following two methods:

- ❖ By using experimental results obtained from engine tests.
- ❖ By analytical calculation based on theoretical data.

Engine performance is really a relative term. It is represented by typical characteristic curves, whichare functions of engine operating parameters. The term performance usually means how well an engine is doing its job in relation to the input energy or how effectively it provides useful energy in relation to some other comparable engines.

4.2 Engine power

In general, the energy flow through the engine is expressed in three distinct terms. They are indicated power (ip), friction power (fb), and brake power (bp). indicated power can be computed from the measurement of forces in the cylinder and brake power may be computed from the measurement of force at the crank shaft of the engine but in this project the force will be measured by a load cell .the friction power can be estimated as the difference between the (ip) and (bp) if these two are known, then,

ip= bp + fb (4.1)

fb = ip – bp (4.2)

4.2.1 Indicated Mean Effective Pressure (p_{im})

It has been stated in section 4.2 that 'ip' can be computed from the measurement of forces in the cylinder, with the pressure of the expanding gases.

The pressure in the cylinder varied through the cycle and the variation can be expressed with respect to volume or crack angle rotation to obtain 'P-V' or 'P-α' diagrams respectively. However, such a continuous variation does not readily lend itself to simple mathematical analysis in the computation of (ip). If an average pressure for one cycle can be used, then the computation becomes far less difficult.

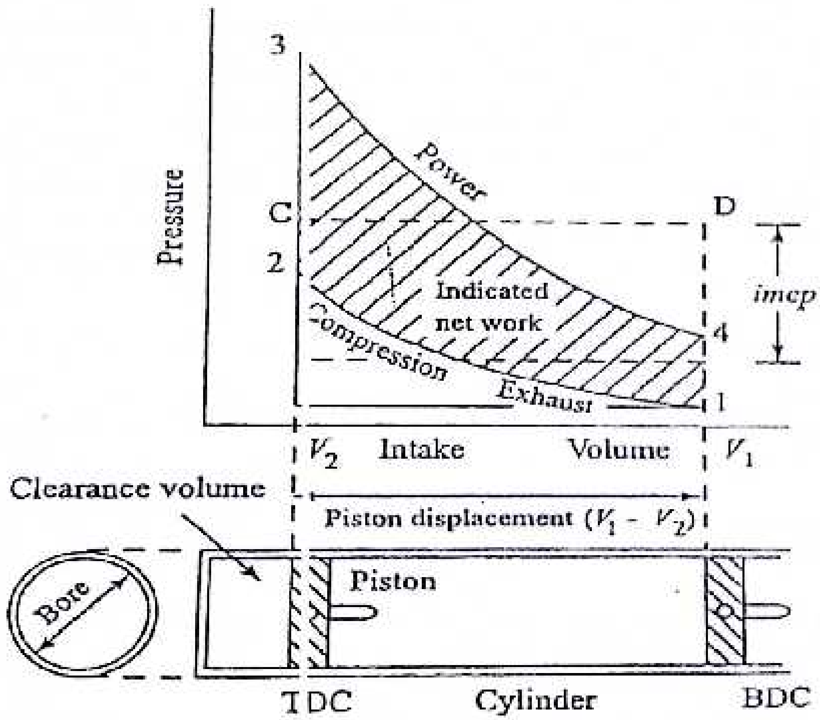

Figure 4.1: P-V Diagram for an Ideal Four-Stroke Cycle Engine

As the piston moves back and forth between TDC and BDC Figure.4.1, the process lines on the P-V diagram indicate the successive states of the working fluid through the cycle. The indicated network of the cycle is represented by the area 1234 enclosed by the process lines for that cycle. If the area of rectangular ABCD equals area 1234, the vertical distance between the horizontal lines AB and CD represents the indicated mean effective pressure 'p_{im}', it is a mean value expressed in N/m^2 , which, when multiplied by the displacement volume, $V_{s,}$ gives the same indicated net work as is produced with the varying pressures.

$$p_{im} = \frac{Net\ work\ of\ cycle}{Vs} \qquad (4.3)$$

$$p_{im} = \frac{Area\ of\ the\ indicator\ diagram}{Length\ of\ the\ indicator\ diagram} \qquad (4.4)$$

On an actual engine, the P-V diagram (called the indicator diagram) is obtained by a mechanical or electrical instrument attached to the cylinder. The area enclosed by the actual cycle on the indicator card when divided by the piston displacement, results in the mean effective pressure.

4.2.2 Indicated power (ip)

Power is defined as the rate of doing work. In the analysis of cycles, the net work is expressed in 'KJ/Kg' of air. This may be converted to power by multiplying by the mass flow rate of air through the engine in kg per unit time. So indicated power of an engine tells about the health of the engine and also gives an indication regarding the conversion of chemical energy in the fuel into heat energy. Indicated power is an important variable because it is the potential output of the cycle. In working with actual engines, it is often desirable to compute (ip) from a given (p_{im}) and given engine operating condition. The necessary formula nay be developed from the equation of net work based on the mean effective pressure and piston displacement.

$$ip = \frac{pim\ Vs\ n\ K}{60000}\ kW \qquad (4.5)$$

Where ip: indicated power (KW)

p_{im} :indicated mean effective pressure (N/m^2)

L: length of the stroke (m)

A: area of the piston (m^2)

N: speed (rpm)

n: number of power stroke per minute (N/2 for a four-stroke engine)

K: number of cylinders

The two indicated power and indicated mean effective pressure calculated in our project by the analyzer and its software using the signals of piezoelectric sensor mounted on the cylinder as discussed in chapter 2 and chapter 3.

4.2.3 Brake Power (bp):

Brake power used to indicate the power actually delivered by the engine, so the brake power usually measured by attaching a power absorbing device to the drive shaft of the engine. Such a device sets up measurable forces counteracting the forces delivered by the engine, and determined value of these measured forces is indicative of forces being delivered.

Measurement of brake power is one of the most important measurements, it involves the determination of the torque and angular speed of the engine output shaft. The torque-measuring device is called a dynamometer. In the dynamometer, the rotor of the generator driven by the engine under test. By using geometry, the shaft that mounted on the body of the generator known dimension (length) work as the torque arm, this arm with the strain gauge work ease the load cell.

The work done by the engine (Torque) has been defined as the product of a force and the distance (shaft length from the center of the generator) through which the point of application of force movement.

$$T = R * F \qquad (4.6)$$

$$\text{Power} = T * \omega \qquad (4.7)$$

$$bp = \frac{2\pi NT}{60000} \qquad (4.8)$$

Where T: the torque produced by the engine (N.m)

F: The force (N)

R: The arm length (m)

bp = Brake power (KW)

N: The engine speed (rpm)

ω: Angular speed of the engine (rad/sec)

4.3 Efficiencies (ζ)

The volumetric efficiency (ζ_v) is a measure of the success with which the air supply, and thus the charge, is inducted into the engine. It is a very important parameter, since it indicates the breathing capacity of the engine. The volumetric efficiency it is defined as the ratio of the actual mass of air to the theoretical mass which should have been in during that same period of time.

$\zeta_v = \dot{m}_{act} / \dot{m}_{th}$ (4.9)

The Mechanical efficiency (ζ_m), it takes into account the losses in an engine. Mechanical losses of an engine may be farther subdivide into following groups:

- ✓ Friction losses in case of piston, bearings, gears, valve mechanisms.
- ✓ Power is absorbed by engine auxiliaries.
- ✓ Ventilating action of the flywheel.
- ✓ Work of charging the cylinder with fresh and discharging the exhaust gases during the exhaust stroke.

The mechanical efficiency is defined as the ratio of the brake power to the actual net indicated power.

$\zeta_m = \frac{bp}{ip} * 100\%.$ (4.10)

Chapter Five

Practical Test and Discussion

5.1 Introduction

In this chapter, we will record and calculate experimental engine data (torque, power, and fuel consumption and the ratedefficiency) with its graphs and create P-V & P- α Diagrams.

5.2 Experiment No 1:

Brake Power Calculation

Brake power measured firstly by turning the engine on then apply the load by the dynamometer; we can the se the force on the load cell and engine rotation speed by the analyzer.

Objectives:

To measure the brake power of the engine.

Procedure:

1. Check Engine Oil
2. Fill your tank with correct fuel for your test engine.
3. Open both valves on the fuel gauges and make sure that the fuel has passed down in the fuel feed pipes toward the test engine.
4. Make sure that your computer is operating correctly and has started TQ software (VDAS software, Engine Cycle Analyzer Software).
5. Check load control panel connections, and make sure that all loads switched off.
6. Turn ignition switch to on position, rotate the output shaft to the TDC mark, and start the engine.
7. Allow the engine to reach normal operating temperature
8. Increase Engine speed until the generator start supplying output.
9. Start applying loads sequentially one by one, record all engine test results and fill the table.

10. Calculate the brake power using its equation and graph it proportional to engine speed.

11. Graph the torque proportional to engine speed.

Shut Down:

1.Use engine throttle lever to reduce engine speed to minimum.

2.Allow engine to run for two minutes at minimum speed.

3.Turn off all loads switches in the load control panel.

4.Turn ignition switch to off position.

5.Turn off fuel supply to the engine.

Calculation:

Table 05-1Constant Speed [2500 rpm], Variable Load.

Load [KW]	**Torque [N.m]**	**Current [A]**	**Voltage [V]**	**Brake Power [Kw]**	**η [%]**
0.45	2.6	3	150	0.68	66.2
0.8	3.8	5	160	0.995	80.4
1.073	4.7	6.5	165	1.231	87.1
1.5	6	10	150	1.57	95.5
1.44	5.6	12	120	1.466	98.2

Table 05-2Constant Speed [3000 rpm], Variable Load.

Load [KW]	**Torque [N.m]**	**Current [A]**	**Voltage [V]**	**Brake Power [Kw]**	**η [%]**
0.63	3.05	3	210	0.958	65.7
1.54	6.02	7	220	1.891	81.4
1.89	6.7	9	210	2.05	89.8

Load [KW]	**Torque [N.m]**	**Current [A]**	**Voltage [V]**	**Brake Power [Kw]**	**η [%]**
1.2	5.8	5	240	2.186	54.8
2.3	7.6	10	230	2.8	82.1

Table 05-3Constant Speed [3600 rpm], Variable Load.

Table 05-4Variable Speed, Variable Load.

Speed [rpm]	Load [Kw]	Torque [N.m]	Current [A]	Voltage [V]	Brake Power [Kw]
3700	0.900	3.4	3	300	1.3174
3400	1.500	6.4	6	250	2.2787
2900	1.760	6.8	10	220	2.0651
2700	1.980	7.2	11	180	1.0358
2500	1.440	5.7	12	120	1.4923

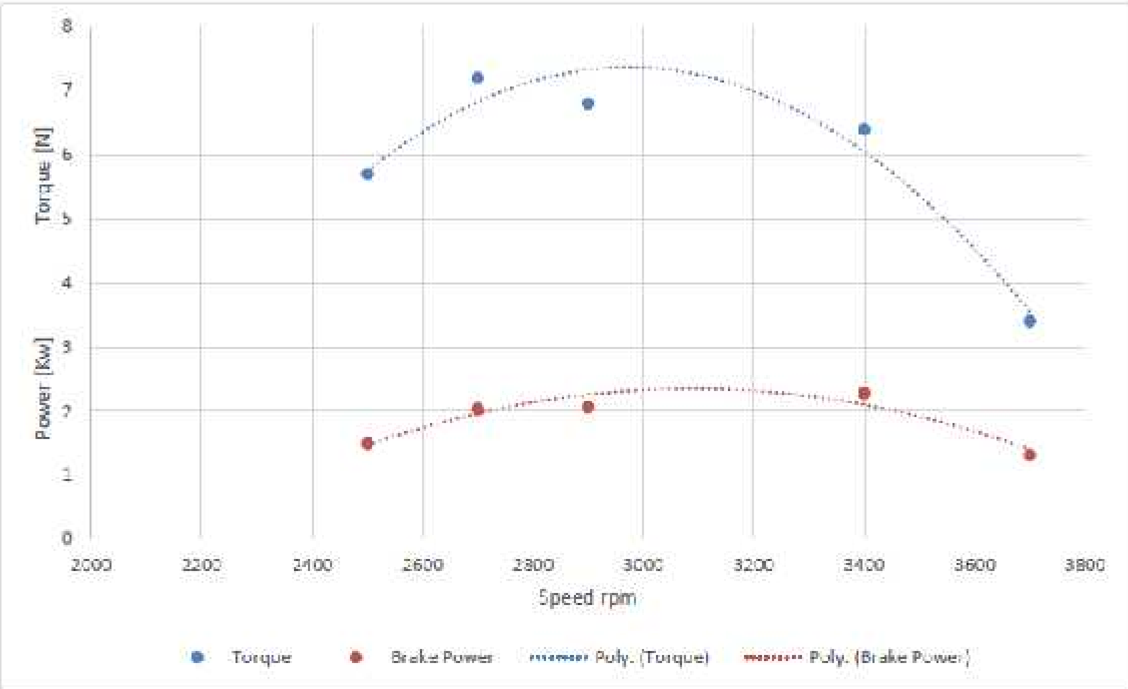

Figure 5.1:Torque and Brake Power Vs Speed

Result discussion:

Figure 5.1 show the engine brake power with engine speed , with various load at constant speed operation starting in the last speed in the table and decreasing by applying load sequentially, every load applied we record the data .

The engine torque with engine speed, also in this calculation using the mode of constant speed with varied load, using the load cell.

The load applied in all the experiments as the power consumed in the thermal resistance, from the ammeter device collecting the current with the value if the resistance, the load power has been calculated by the equation [3.1].

The rated efficiency, the efficiency from the out power consumed by the thermal resistance on the input power as the brake power.

5.3Experiment N_O 2:

Fuel consumption

Objective

To measure the fuel consumption and specific fuel consumption.

Theory:

Specific Fuel consumption calculation:

The fuel mass of the engine calculated by the relation:

M fuel = V * ρ (5.1)

Where:

V = the volume of fuel, which can used [m^3].

= 8 ml*10^{-6}

ρ = the density of fuel = 740 [kg/m^3].

Another definition is a fuel mass flow per second and calculated as in the relation:

$\dot{M}_{fuel} = \frac{m\ fuel\ X\ 3600}{t}$ [Kg/ hr.] (5.2)

Where:

t: the time which can be calculated [s].

In engine test, the fuel consumption measured as a flowrate-mass flow per unit time. A more useful parameter is Specific Fuel Consumption (SFC), the fuel flow rate per unit power output. It measures hoe efficiently an engine is using the fuel supply to produce work:

SFC = $\frac{}{bp}$ (5.3)

Procedure:

To measure the fuel consumption of the engine.

1.Fill your tank with correct fuel for your test engine.

2. Connect the exhaust pipe of the engine to the laboratory exhaust system.

3. Open both valves on the fuel gauges (turn the valves so that they are in-line) and make sure that the fuel has passed down in the fuel feed pipes toward the test engine.

4. Make sure that your computer is operating correctly and has started TQ software (VDAS software, Engine Cycle Analyzer Software).

5. Check load control panel connections, and make sure that all loads switched off.

6. Turn ignition switch to on position, rotate the output shaft to the TDC mark, and start the engine.

7. Allow the engine to reach normal operating temperature

8. For the manual fuel gauge shut the fuel inlet valve and use stop watch to measure the time taken to drain 8 ml at varies engine speed

9. Increase Engine speed until the generator start supplying output.

10. Start applying loads sequentially one by one, record all engine test results and fill the table.

11. Calculate the fuel consumption and specific fuel consumption of the engine, and then graph the mass flow rate proportional to engine speed.

12. In the same, graph in point 10 and graph (SFC) proportional to engine speed.

Shut Down:

1. Use engine throttle lever to reduce engine speed to minimum.
2. Allow engine to run for two minutes at minimum speed.
3. Turn off all loads switches in the load control panel.
4. Turn ignition switch to off position.

5. Turn off fuel supply to the engine.

Results:

Table 0-5 Fuel Flow Rate [Without load]

Speed[rpm]	Mass Flow Rate[kg/hr]
1351	0.2
1794	0.264
1950	0.286
2309	0.323
2607	0.349
2809	0.355
3396	0.487
3593	0.553
4001	0.707

Table 5-6 Fuel Flow Rate and Specific Fuel Consumption [With applying loads]

Speed [rpm]	Time [sec]	Flow rate [kg/hr]	Sfc [kg/kw.hr]
2500	30.96	0.688372	0.461375
2700	28.13	0.757625	0.372297
2900	27.54	0.773856	0.374749
3400	24.25	0.878845	0.385797
3700	21.74	0.980313	0.744127

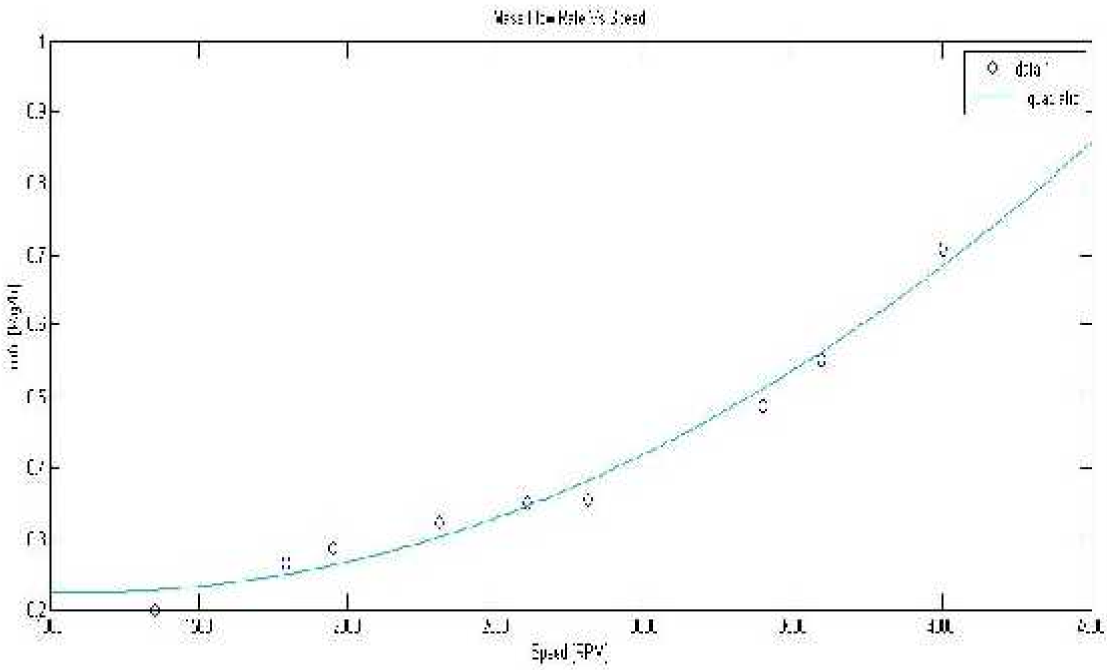

Figure 5.3: Mass Flow Rate Vs Speed (Without Load).

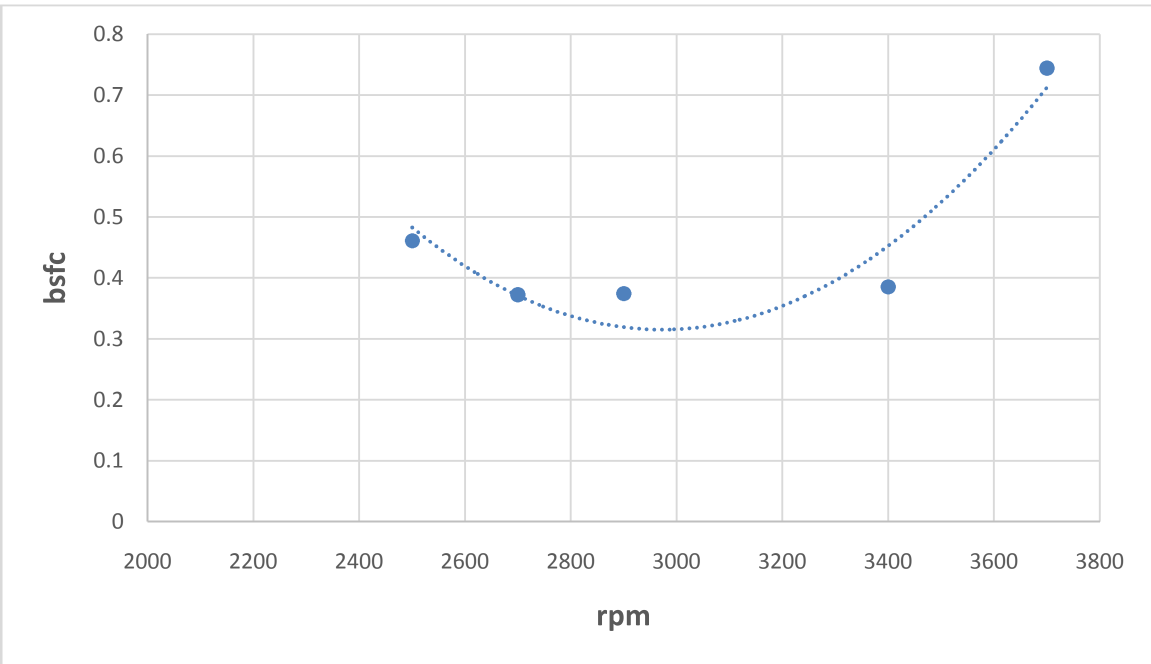

Figure 5.4: Specific Fuel Consumption Vs Speed.

Result discussion:

All gathered results taken, after 2400-rpm engine speed because it’s the minimum operation speed of the generator to make an output.

Figure 5.3 show the mass flow rate for the first table, and it increased with speed increasing, without any load applied.

Figure 5.4 show the specific fuel consumption of the engine, this parameter depends on the brake power and the mass flow rate. The specific fuel consumption decreases firstly until it reaches the economic fuel consumption at approximately 2800 rpm, then starts increasing.

5.5 Experiment No 3:
P-α and P-V Diagrams

Objective:

1- To facilitate understanding the thermodynamic processes occurring inside the engine cylinder such as variation in pressure.

2- To help the student to notice the actual pressure cycle (p-α and p-V) diagrams compared with the theoretical knowledge.

Procedure:

1- Fill your fuel tank with the correct fuel for your test engine.

2- Connect the exhaust pipe of the engine to the laboratory exhaust system.

3- Open both valves on the Fuel Gage-(turn the valves so that they are in-line with the fuel pipe).

4- Make sure that the fuel has passed down the fuel feed pipe to the test engine.

5- Check load control panel connections, and make sure that all loads switched off.

6- Turn on the engine cycle analyzer and make reset.

7- Make sure that your computer is operating and has started the Tecquipment software

8- Turn the ignition switch to the on position and run the engine.

9- Allow the engine to reach normal operating temperature.

10- Make connection between engine cycle analyzer and the pc computer.

11- After engine reaches the normal operating temperature, make the reset to the engine cycle analyzer.

12- Start applying loads sequentially one by one, record all engine test results and fill the table.

13- Record all test results.

14- Turn off the engine.

Results:

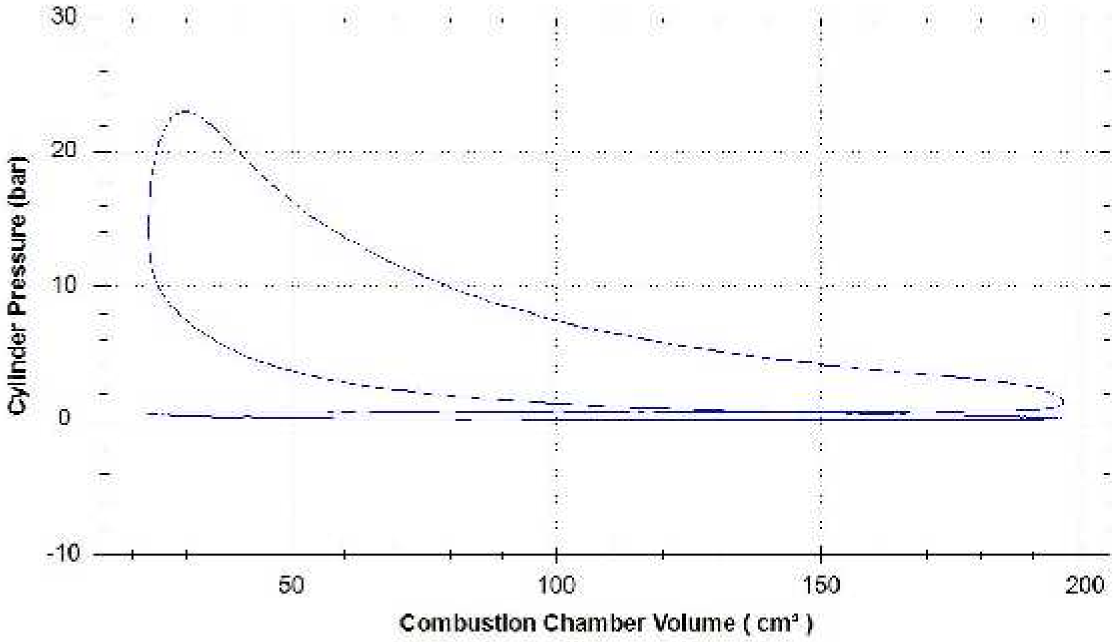

Figure5.5.a:Pressure-Volume (P-V) at T=6[Nm], 2500[rpm]

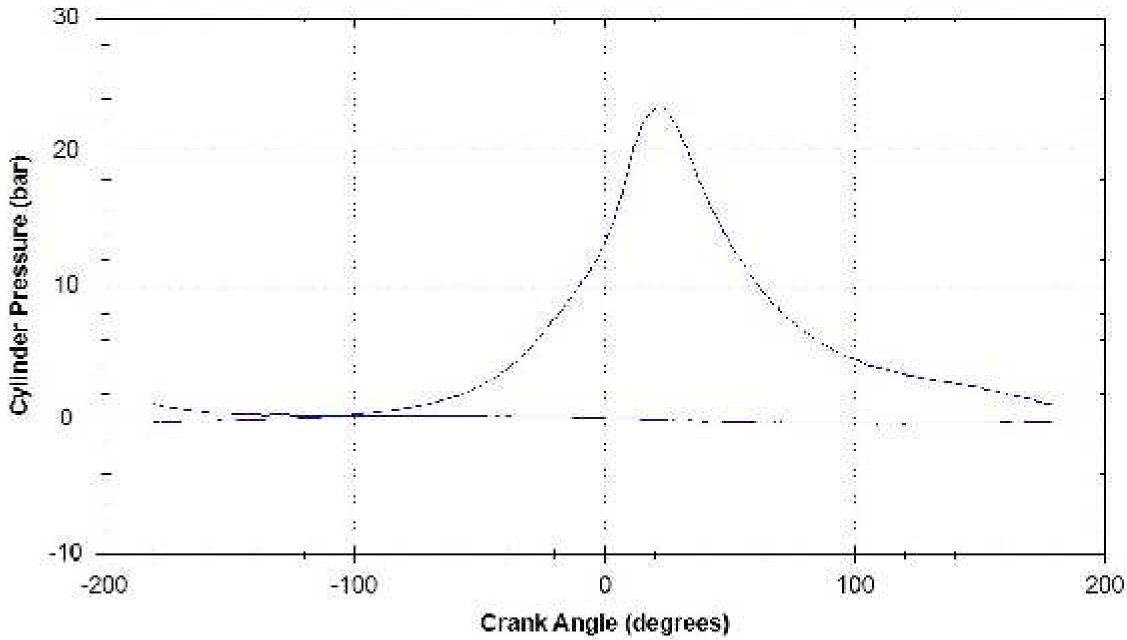

Figure5.5.b: Pressure-Crank Angle Diagram (P-α), 2500[rpm]

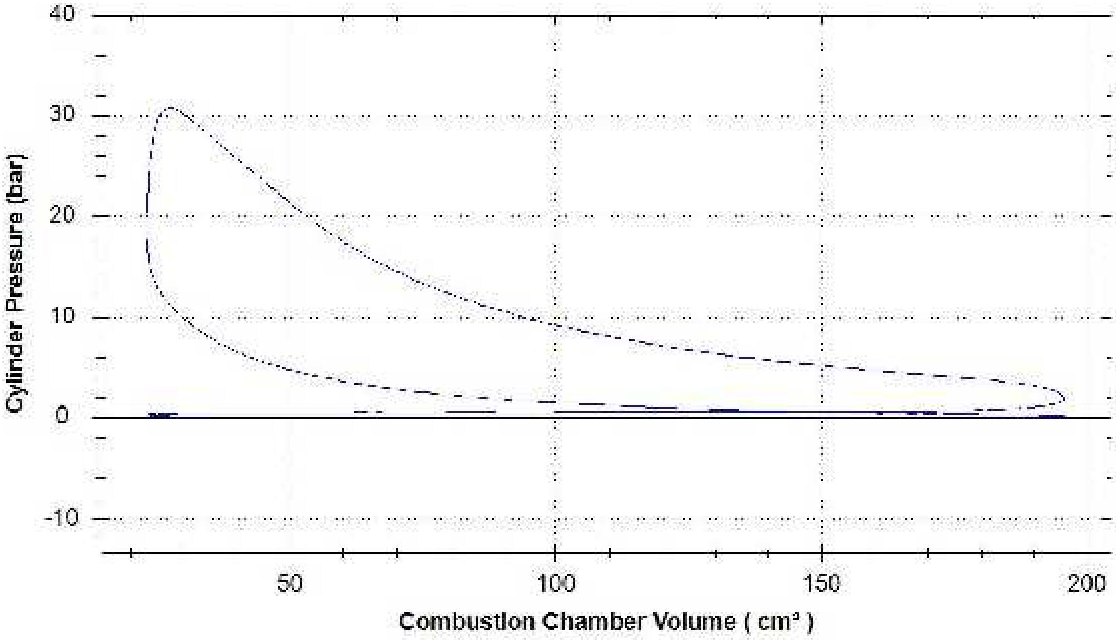

Figure5.6.a:Pressure-Volume (P-V), 300rpm

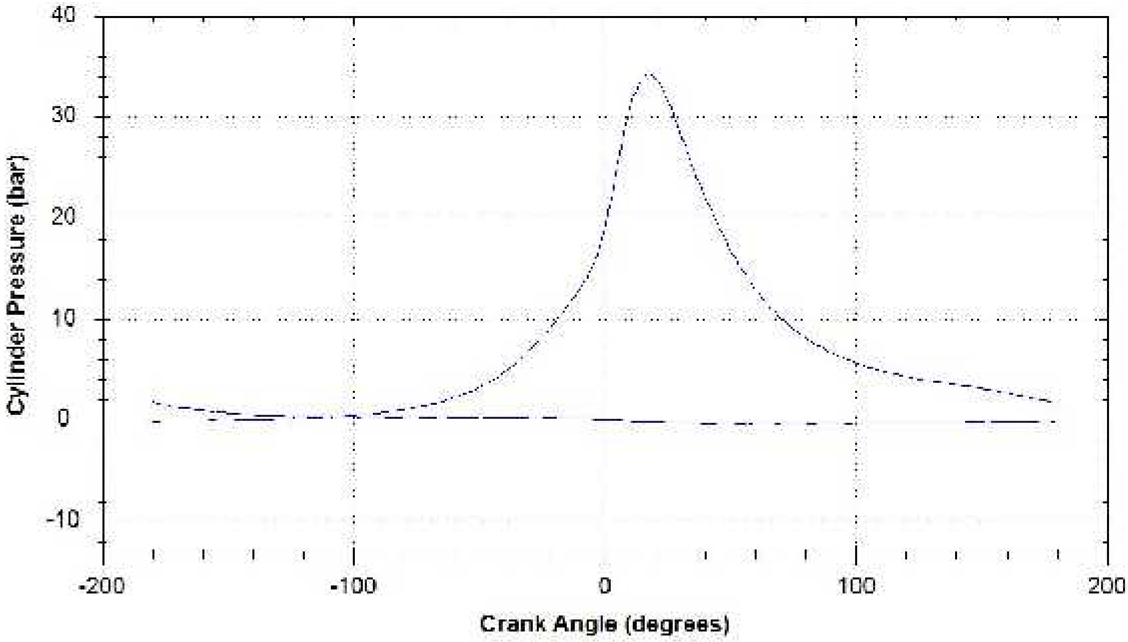

Figure 5.6.b: Pressure-Crank Angle Diagram (P-α), 3000 rpm

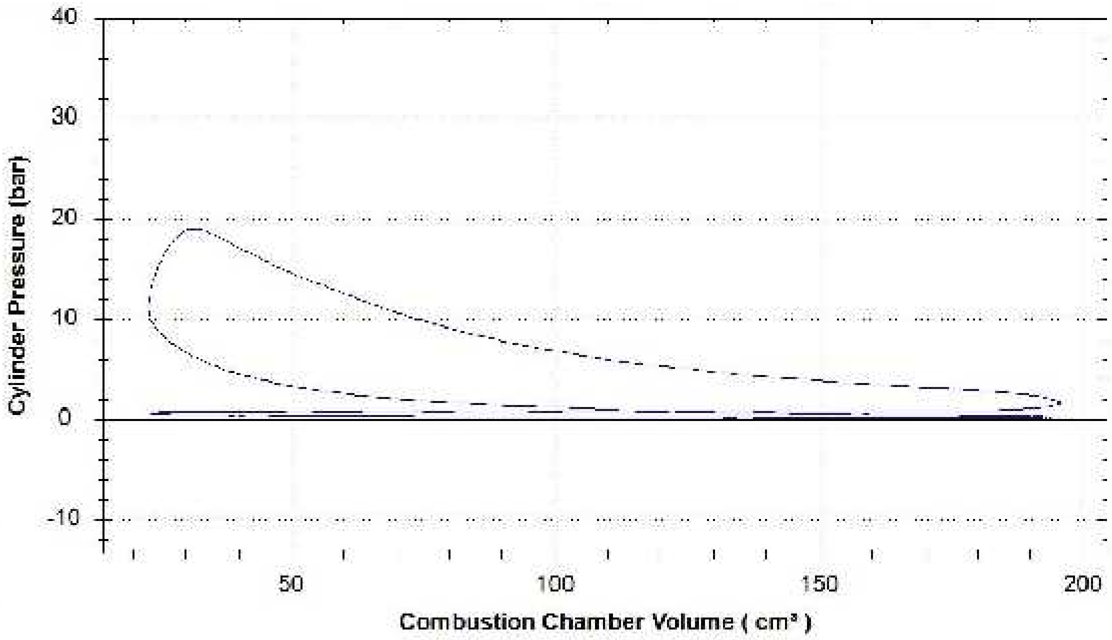

Figure 5.7.a:Pressure-Volume (P-V), 3700 rpm

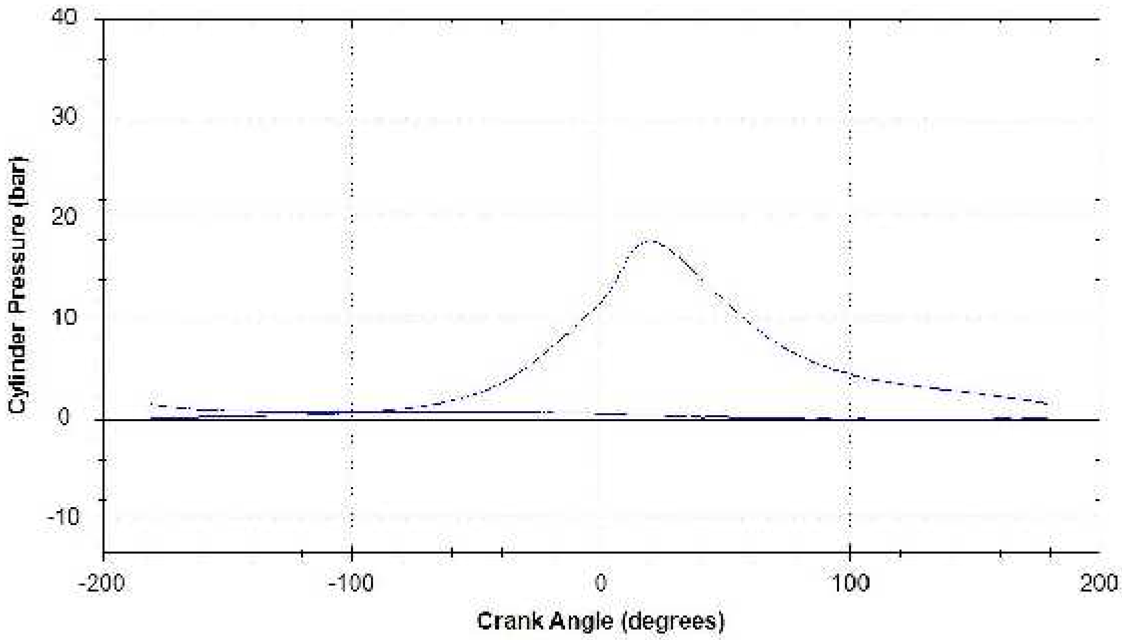

Figure 5.7.b: Pressure-Crank Angle Diagram (P-α), 3700 rpm

Result discussion:

When the piston is at bottom dead center, the cylinder will have its largest volume. As the piston moves up the cylinder, the volume is reduced. At top dead center, the cylinder is at its minimum volume.

Once the piston reaches TDC on the exhaust stroke, it starts back down the cylinder for the intake stroke. If the intake manifold is restrictive (or you have a small carb), the pressure in the cylinder will drop (more vacuum) as the piston moves down the cylinder during the intake stroke. This is represented by the line being at an even lower level as it moves back to the right during the intake stroke.

The piston now moves back up the cylinder on the compression stroke. This is represented on the diagram by the line swinging up the graph as the line moves back to the left. Near the end of the compression stroke, the ignition starts the combustion, at this point the line turns sharply and heads up to the peak pressure again.

Conclusion:

After the project is finished successfully, and the objectives achieved, all the devices and the dynamometer have been assembled and especially maintained carefully. The electric dynamometer operated and experiments have done.

In this project, after the studying and making a practical experiment on the performance and characteristics of the engine, the student of the internal combustion engine will be able to apply all the theoretical studies into practical tests.

Now the student of internal combustion can plot and understand the P-V and P-α diagram actually by the computer with a specific mode of operation by controlling the speed and the load on the dynamometer.

The electric dynamometer is now ready as a part of the internal combustion engine laboratory in the mechanical department for the Automotive Engineering in the Polytechnic University for using and make a research on the engine. The results gained by the dynamometer are real and close to the standard.

Recommendation:

- Safetyinstruction must taken in consideration during the experiments, by following the operation procedure strictly.
- The need for appropriate wear to the student when making the experiment.
- The need for appropriate cover for the dynamometer.

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Appendixes