

بِسْمِ اللَّهِ الرَّحْمَنِ الرَّحِيمِ

Palestine Polytechnic University



College of Engineering

Mechanical Engineering Department

**A Load Unit Design For
An Experimental
Single Cylinder Engine Test Set**

Project Team

Bader Burhan Al-muhtaseb

Hamza Hasan Zamareh

Nader Ahmad Saleh

Project Supervisor :

Dr.Zuhdi Sallhab

Hebron - Palestine

2018

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Submitted to the College of Engineering in partial fulfillment of the requirements
for the Bachelor degree in Mechanic Engineering

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...

And Jerusalem is the eternal capital

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

Bader Al-muhtaseb

Acknowledgment

We would like to express our gratitude for everyone who helps us during the graduation project, starting with endless thanks for our supervisor Dr. Zuhdi salhab who didn't keep any effort in encouraging us to do a great job, providing us with valuable information and advices to be better each time. Thanks for the continuous support and kind communication which great effect regarding to feel interesting about what we are working on.

Finally thanks Chairman and team of Mechanical Engineering Department in Palestine Polytechnic University.

Abstract

The internal combustion laboratory is an important laboratory for students in automotive engineering department because of its importance to consolidate the theoretical information that obtained by the student in theoretical studying . There are a lot of experiences that every student must do in the internal combustion laboratory do this in the laboratory to apply the information obtained through the theoretical study, including the calculations of engine efficiency, and the calculation of the indicated power and brake power, where we need to reach the measurements required to complete the experiment , the pressure value inside the cylinders and in the combustion chamber, and the piston location at different point and times by the crankshaft position and the RPM, then we can make the calculation in different loading conditions depending on the loads occur , as well as the measurements and analysis of the combustion products ,this requires a special system for obtaining this information and measurements. In our project we can redesign the single cylinder internal combustion in the university and provide some additions to have the necessary information by experiments, to make an interpretation where it measurements and graphical signal is not true and accurate . Firstly we redesigned a heavy base and frame to reduce vibrations, also we have change the coupling joint between the engine and dynamometer with safe cover and designed a new safe and more accurate load unit containing a generator (thermal resistance) with switch control and cell carriers , in addition checked the pressure gauge sensor inside the cylinder head (Piezoelectric) with a new encoder to locate the piston position and the number of engine cycles , and strain-gage load cells ,with data processing and conversion programs , each program on the computer to process data collected using VDAS (Versatile Data Acquisition System) and ECA100 (engine cycle analyzer), we also calculated performance for such as speed, torque, power, fuel consumption, PV graph and P- α charts.

الملخص

يعتبر مختبر الاحتراق الداخلي من المختبرات المهمة لطلاب تخصص هندسة السيارات ، لما لأهميته في ترسيخ المعلومات النظرية التي يحصل عليها الطالب في المواد النظرية ، حيث أن هناك العديد من التجارب العملية التي يجب على كل طالب في تخصص هندسة السيارات إجرائها في هذا المختبر لتطبيق المعلومات التي حصل عليها من خلال دراسته النظرية ، ومن ضمن هذه التجارب حسابات كفاءات المحرك المختلفة، وحسابات أخرى من ضمنها حساب القدرة المكبحية ، وعليه يلزم الحصول على قراءات من أجل إتمام هذه التجارب ومنها ، درجة حرارة المحرك ، وقيمة الضغط داخل الأسطوانات وفي غرفة الاحتراق ، وموقع المكبس في أوقات مختلفة من خلال تحديد موقع عمود المرفق وعدد دوراته ، حيث أنه يمكن معرفة وإجراء الحسابات في أوضاع التحميل المختلفة ، وكذلك قراءة وتحليل نواتج الاحتراق ، هذا يتطلب توفير نظام من أجل الحصول على هذه المعلومات والقراءات ، وفي مشروعنا هذا استخدمنا محرك اسطوانة واحدة من مختبر محرك الاحتراق الداخلي حيث كانت القراءات و المنحنيات غير صحيحة وغير دقيقة، قمنا بإعادة تصميم وتركيب قاعدة وهيكل خارجي لتقليل الاهتزازات ، كما قمنا بتغيير وصلة الربط بين المحرك والمولد الكهربائي وتزويدها بوحدة حماية وأمن ، كذلك قمنا بإصلاح حساس الحمل وتصميم وتركيب دائرة الكترونية جديدة خاصة به ، وصممنا وركبنا وحدة حمل كهربائية جديدة أكثر أماناً ودقة تحتوي على مقاومات حرارية مزودة بمفاتيح تحكم ، بالإضافة إلى فحص حساس قياس الضغط داخل رأس الأسطوانة ، والأهم استبدال Encoder جهاز تحليل موقع المكبس وعدد دورات المحرك ومعالج البيانات وتثبيت وتحديث برامج التحويل على الكمبيوتر لمعالجة البيانات المجمعة باستخدام (محلل دورة المحرك) ، لقراءة السرعة وعزم الدوران وقوة الحمل المؤثرة ، وصولاً لحساب استهلاك الوقود تبعاً لمقدار الحمل ، عن طريق الرسم البياني PV والرسوم البيانية $p\alpha$ والحسابات .

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CHAPTER ONE

Introduction

- 1.1 Introduction**
- 1.2 Project Overview**
- 1.3 Project Objectives**
- 1.4 Project Description**
- 1.5 Tasks Description Table**
- 1.6 Time Table**
- 1.7 Cost Estimation and Budget Breakdown**

1.1 Introduction

Internal combustion engine is the main component of automotive mechanical engineering. It converts the chemical energy in fuel into mechanical energy, usually it will be available on a rotating output shaft, to provide power and torque in order to 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

The internal combustion engine is an engine in which the burning of a fuel occurs in a confined space called a combustion chamber. Combustion of a fuel occurs with an oxidizer, usually air in a combustion chamber. The combustion process in spark ignition engines plays a key role in the conversion of fuel energy into mechanical energy. The gasoline or spark-ignition (SI) internal combustion engine uses the Otto cycle and externally supplied ignition. It burns an air/fuel mixture and in the process converts the chemical energy in the fuel into kinetic energy. After ignition at the spark plug, the mixture of fuel and air starts to burn and continues burning until consuming the whole of the fuel of the charge in the cylinder. After the combustion process ends, exhaust gases are rejected from the engine to the surrounding atmosphere. The major exhaust emissions are Unburned Hydrocarbons (HC), Nitrogen Oxides (NO_x) and Carbon Monoxide (CO).

The electrical dynamometer was built as a part of the internal combustion engine laboratory at mechanical engineering department in Palestine 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 is of paramount importance since it intends 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 .

1.3 Project Objective:

The objective of this project is to build, design and ensure that the system works well, it was necessary to perform some maintenance and rehabilitation in the system in order to obtain, operate and deliver the correct results of the experimental work by a strain gauge sensor that will be able to test any rotating equipment, it has an electric and sensitive load unit that shows the effective load. An engine load dynamometer (often called absorber or load dyne) using an single cylinder gasoline engines and AC generator drive to simulate an electrical load. This model helps the student to identify and test and characterize rotating equipment and to provide simulated road loading of either the engine. All measurements of different loads and torque will be adapted and processed using the VDAS for a computerized dynamic scale and ECA100 engine cycle analyses. This will be done using a combination of electrical resistance related to the generator to change the load value with the known capacity of the input through the application of energy equations. The devices will be connected as shown in Figure 1.1.

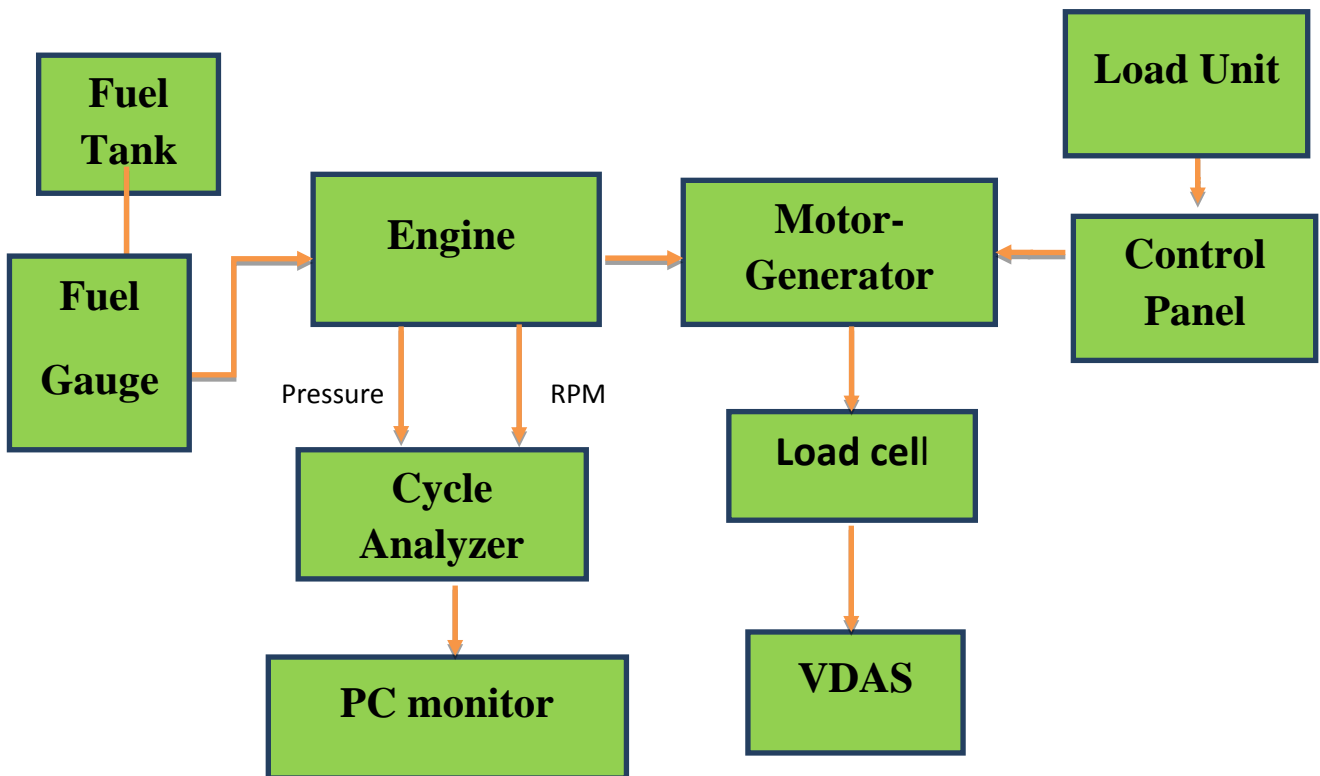


Figure 1.1 : Electrical Dynamometer

1.4 Project Description:

Contributing to the development and provide a device in the internal combustion laboratory for engines tests through Load Unit Single Cylinder Engine test bed with comprehensive instrumentation ,for optional ancillaries are available to extend the range of study, demonstrations and investigations even further.

1.1 Tasks Description Table:

In this section the tasks table will be determined as shown in table 1.1 .

Table 1. 1 : Tasks Description

Task ID	Task Description
1st semester	
T1	Project selection
T2	Collection references from library and website
T3	Selecting the project scope and the operation model
T4	Selecting the major parameter
T5	Study and analysis of information on the project
T6	collection of information that have been studied
T7	Maintenance and repairs
T8	Write the project and preparing the 1 st semester presentation
2nd semester	
T9	Editing the introduction of the project
T10	check the missed and damaged parts of the test unit
T11	Finding, buying and preparing the replacement parts
T12	Preparing the test unit for operation and replacing the missed and damaged parts
T13	Calibrating the equipments and testing it
T14	Performing the experiment and collecting data
T15	Analyzing the collected data
T16	Write the project and preparing the 2nd semester presentation

1.2 Time Table:

In this section the time table will be determined as shown in table1.2 .

Table 1.2 : Time Table

Task/Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1st semester															
T1	■	■													
T2			■	■											
T3					■	■									
T4						■	■	■							
T5								■	■						
T6									■	■	■				
T7							■	■	■	■	■	■			
T8								■	■	■	■	■	■	■	■
2nd semester															
T9	■	■													
T10			■	■											
T11					■	■									
T12					■	■	■	■	■						
T13								■	■						
T14									■	■	■				
T15											■	■			
T16												■	■	■	■

1.3 Cost Estimation and Budget Breakdown:

This section lists the overall cost of the project. The cost includes the hardware, as shown in table 1.3 .

Table 1.3 : Cost And Budget

Component	Price (NIS)
Encoder Sensor	2000
Encoder belt	100
Load cell/ Electronic Circuit	300
Electrical Equipment	900
Temperature Sensor	350
Electrical Load Unit	150
Curved Tooth Coupling	200
Frame And Welding	500
Total	4500

CHAPTER

TWO

Project Components and Specifications

2.1 Introduction

2.2 Internal Combustion Engine

2.3 Four-Stroke Petrol Engine

2.4 Thermodynamic Cycles for SI Engine

2.5 Volumetric Fuel Gauge

2.6 Engine Cycle Analyzer

2.7 Crank Angle Encoder

2.8 Pressure Sensor

2.9 Strain Gauge Load Cell

2.10 Electric Generator

2.11 Versatile Data Acquisition System (VDAS)

2.12 Load Unit

2.13 Nylon Sleeve Series Flexible Couplings

2.14 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:

As shown in figure 2.1 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.



Figure 2. 1 : Internal Combustion Engine

2.3 Single Cylinder Four- Stroke Petrol Engine:

The test unit in this project consists of a one cylinder, 4-stroke, gasoline internal combustion engine, a conventional carburetor with manual choke, electric spark ignition, overhead valve, Splash lubrication, modified the cylinder head and crank output shaft. equipped to comply with the cylinder head pressure sensor and crank angle encoder (incremental encoder) These sensors are connected to the engine cycle analyzer, which is used with the Tec-equipment ECA 100 to view The engine and Versatile Data Acquisition System (VDAS). the engine is used to operate an AC generator, The generator is connected to the load unit. Which consist of a five thermal resistors, the power of each one is 600 and 400 watt .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 2.2 shows the single cylinder four stroke engine and table 2.2 specifications of the engine.

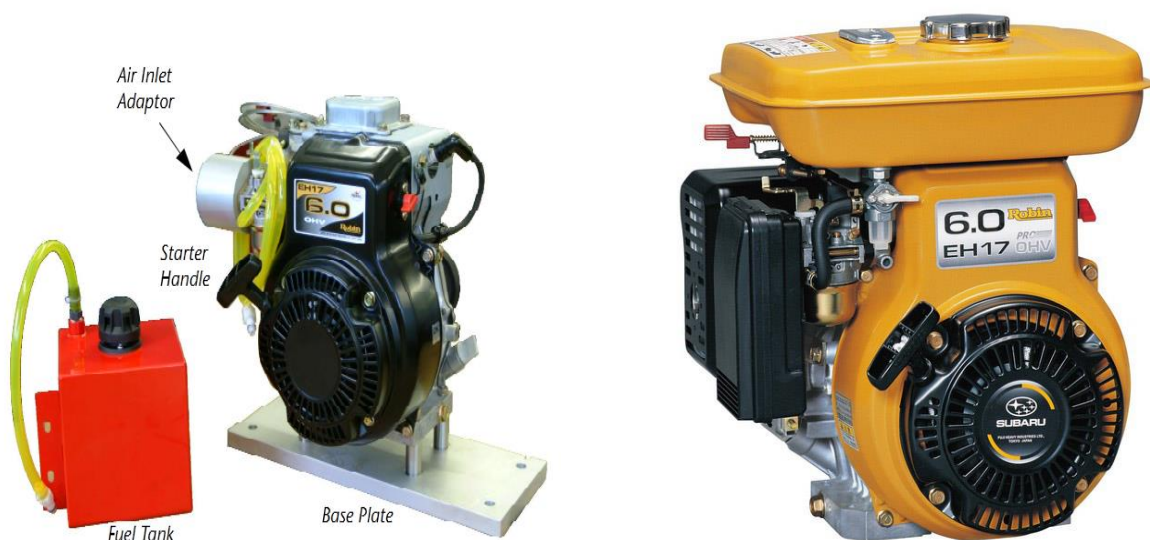


Figure 2.2 : Four-Stroke Petrol Engine

Table 2. 1 :Specifications Of Engine

Item	Specifications
Dimension (when fitted to base plate)	W 400 mm H 400mm D 300 mm
Net weight (with base plate)	20 KG
Fuel Type	petrol (gasoline)
Fuel Tank	Red- painted steel with vent and filler cap
Exhaust Outlet	Nominally 1" BSP
Ignition System	Electric
Absolute maximum power	4.4 KW (6.0 HP) at 4000 RPM
Continuous rated power	2.6 KW (3.5 HP) at 3000 RPM 2.9 KW (4.0 HP) at 3600
Bore	67 mm
Stroke/crank radius	49 mm/24.5mm
Connecting rod length	85 mm
Engine capacity	172cm ³ (0.172)L
Compression ratio	(8.5) : (1)
Oil type	SAE 20, SAE 30 or multi grade 10W-30
Oil capacity	0.62 litre

2.4 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 2.3 In addition to, Fig. 2.4.

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 . Mechanically this is the adiabatic compression of the air/fuel mixture in the cylinder, also known as the compression. 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 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 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.

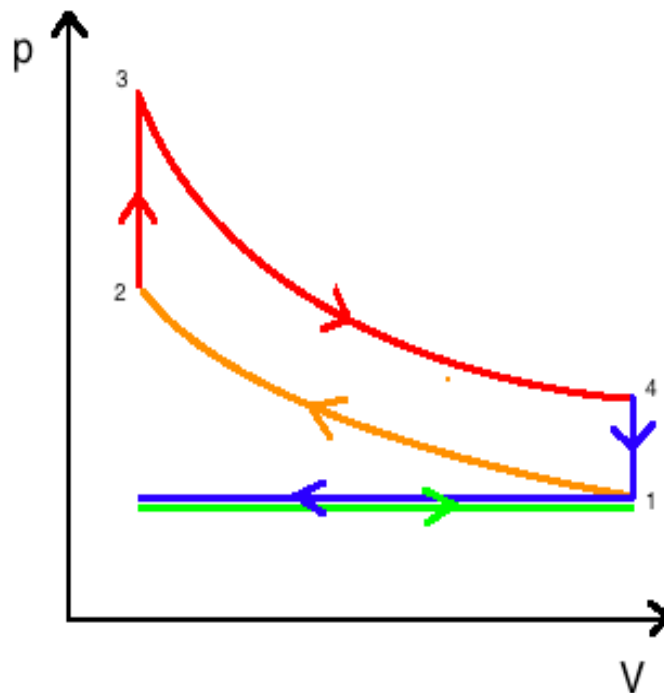


Figure 2.3 : Pressure-Volume (Otto cycle) Diagram.

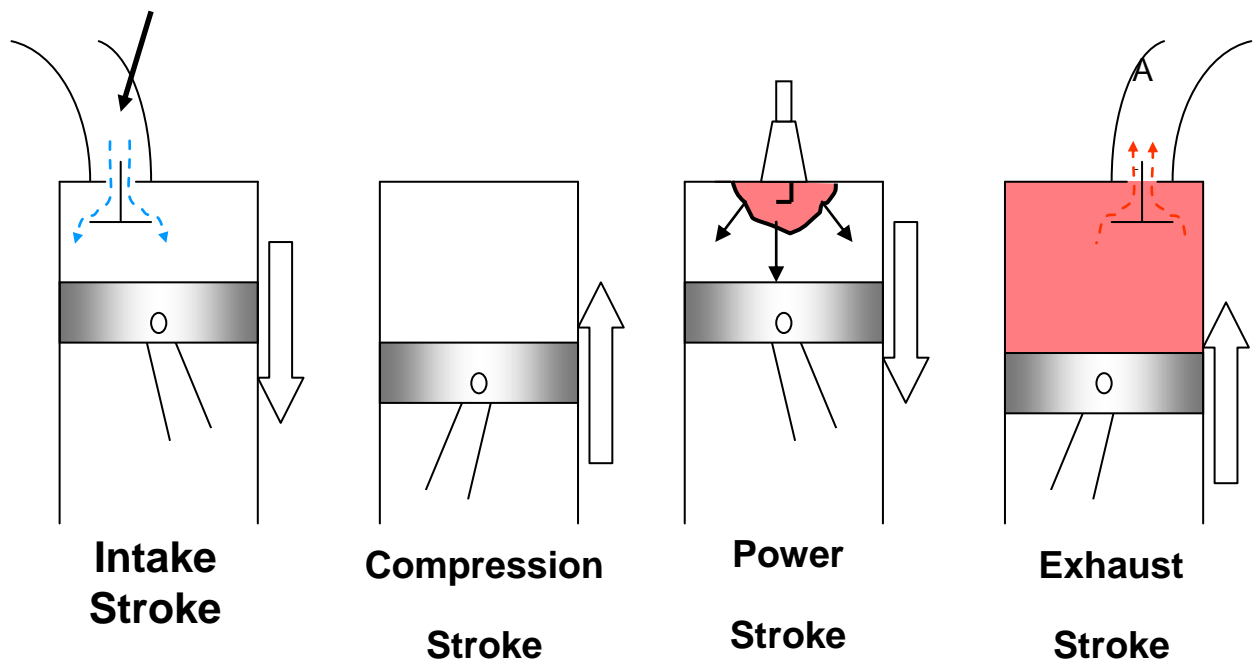


Figure 2.4 Four-Stroke Stages As in the Spark Ignition Engines Cylinders.

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

This model can be used to determine the effect of spark timing or heat transfer on engine work and efficiency. As shown in the figure 2.5 below.

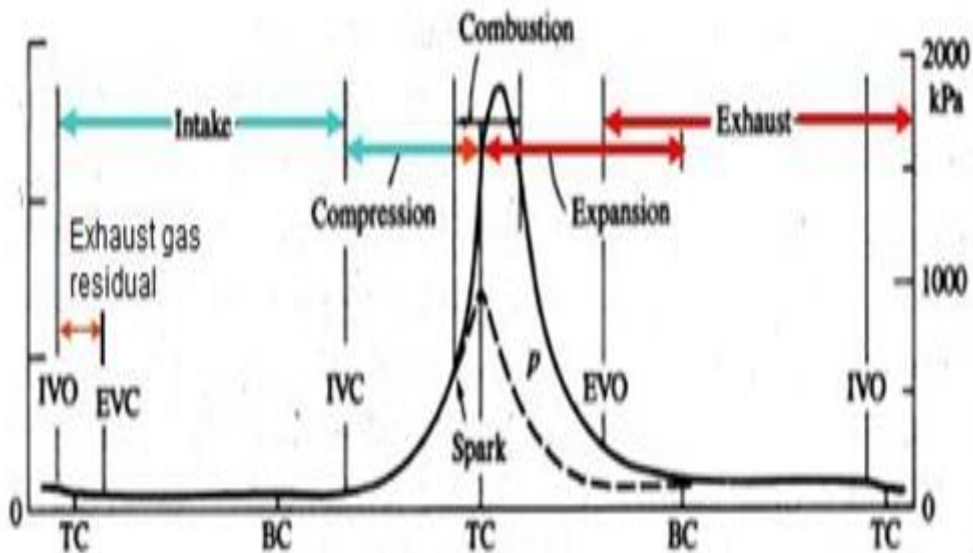


Figure 2.5: Crank Position and Angle.

2.5 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 as shown in figure 2.6 the Fuel Flow Meter.

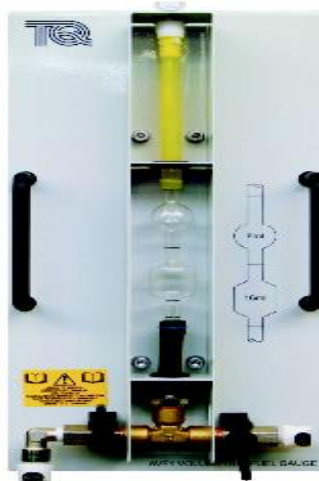


Figure 2.6 : Fuel Flow Meter

2.6 ECA100 Engine Cycle Analyses:

As shown in figure 2.7 hardware and software to measure internal combustion engine cylinder pressure and crank angle.

A versatile engine cycle analyzer to allow investigations into the relationship between crank angle or volume and the cylinder pressure in an internal combustion engine.

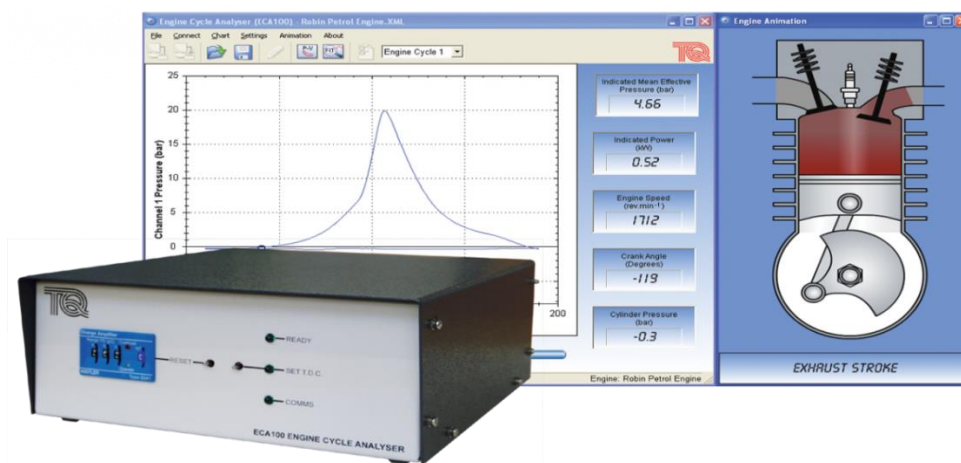


Figure 2.7 : ECA100 Engine Cycle Analyzer

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. As shown in figure 2.8 the engine cycle analyzer .



Figure 2.8 : Engine Cycle Analyzer

2.7 Crank Angle Encoder:

The crank angle encoder contains a precision marker disk with a trigger mark and 360 pulse 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 2.9 shown crank angle encoder.

An incremental encoder provides a specified amount of pulses in one rotation of the encoder. The output can be a single line of pulses (an “A” channel) or two lines of pulses (an “A” and “B” channel) that are offset in order to determine rotation. This phasing between the two signals is called quadrature ,the typical assembly of an incremental

encoder consists of a spindle assembly, PCB, and cover. The PCB contains a sensor array that creates just two primary signals for the purpose of position and speed ,optionally, additional signals can be provided.

As shown in figure 2.9 an index or ‘Z’ channel can be provided as one pulse per revolution signal for homing and pulse count verification on the A and/or B channels. This index can be gated to either A or B in their various states. It can also be un-gated and vary in width , commutation channels can also be provided on some encoders, these signals are aligned to the commutation windings found on servo motors, they also ensure that the drive or amplifier for those motors apply current to each winding in the correct sequence and at the correct level.

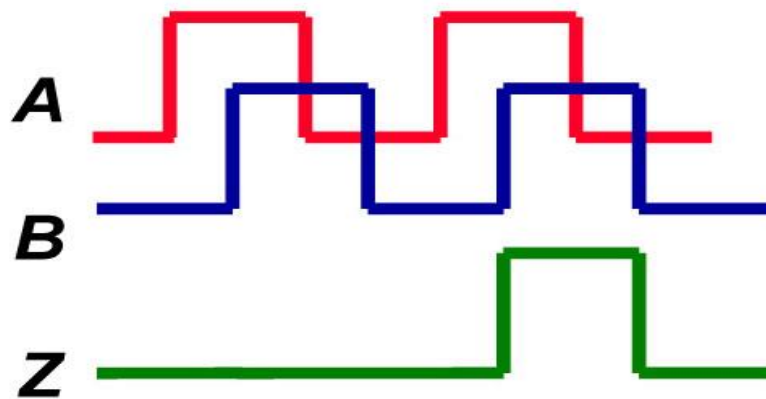


Figure 2.9 : Encoder Channels

2.8 Pressure Sensor:

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 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. As shown in figure 2.10 the pressure sensor .



Figure 2.10: Pressure Sensor

The use of a new Kistler Piezo Star 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.

Advantages

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

2.9 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.

As shown in figure 2.13 convert the load acting on them into electrical signals. The gauges themselves are bonded onto a beam or structural member that deforms when weight is applied. In most cases, four strain gauges are used to obtain maximum sensitivity and temperature compensation , two of the gauges are usually in tension, and two in compression, and are wired with compensation adjustments , when weight is applied, the strain changes the electrical resistance of the gauges in proportion to the load , other load cells are fading into obscurity, as strain gage load cells continue to increase their accuracy and lower their unit costs.

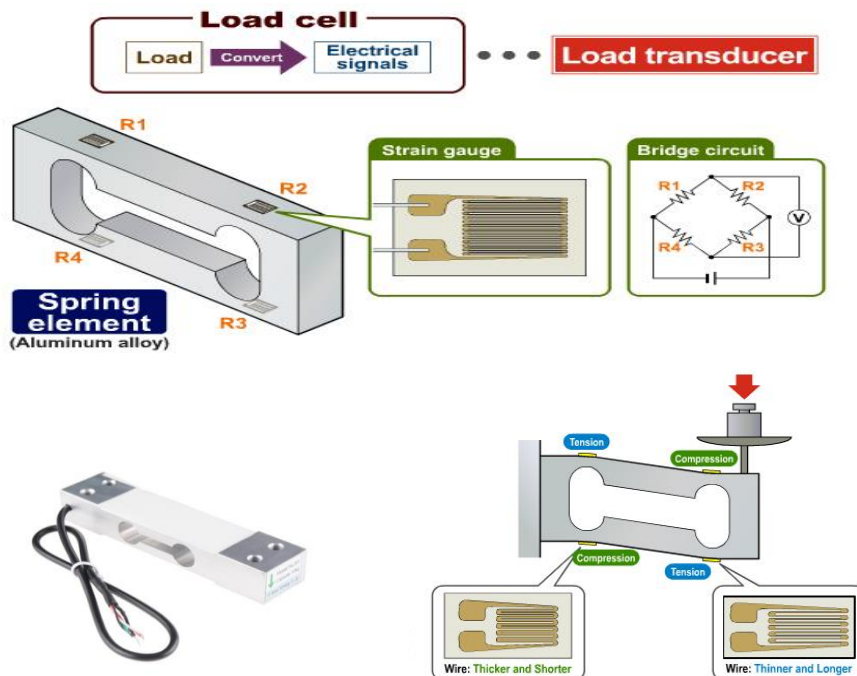


Figure 2.11 : Strain-Gage Load Cells

2.10 Electric Generator

As shown in table 2.2 the generator specification so the alternator is an electromechanical device that converts mechanical energy to electrical energy in the form of alternating current.

We chose an electric generator with the following specification:

Table 2.2 : Generator Specification

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

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 f (Hz) as shown in equation 2.3.

Equation 2.3 : The Equation Relation Between Speed And Frequency

$$(n(RPM) = 120 * f / P)$$

$$(f (Hz) = n * P / 120)$$

where f the frequency in Hz is (cycles per second). P Is the number of poles and N is the rotational speed in revolutions per minute (RPM).

2.11 Versatile 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 2.14 and 2.15 respectively, which allow the user to:

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



Figure 2.12: VDAS Hardware

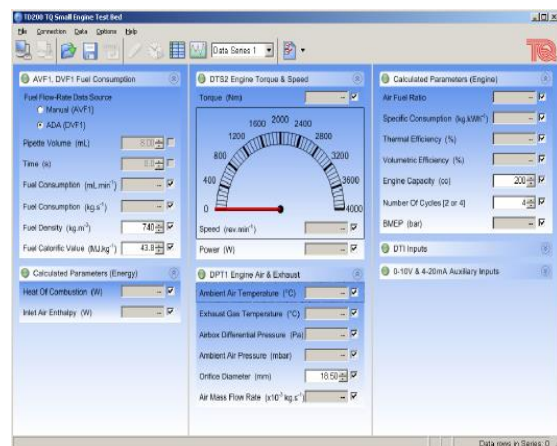


Figure 2.13: VDAS Software

2.12 Electrical Load 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 consists 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 as shown in figure 2.16.

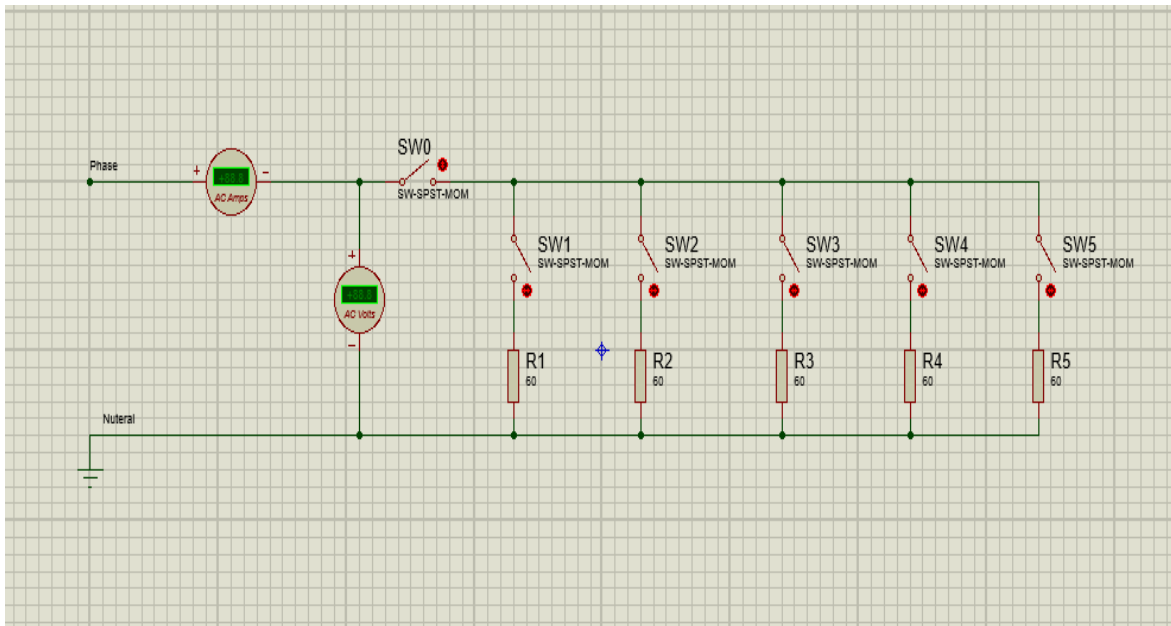


Figure 2.14 : Electrical Load

2.13 Nylon Sleeve Series Flexible Couplings:

The series is a standard coupling with two hubs, a nylon sleeve, and retaining rings depending on the model selected. 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 is issued, the couplings can readily be adapted to many applications including vertical and blind installations.

2.13.1 : Nylon Sleeve Series Flexible Couplings 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.

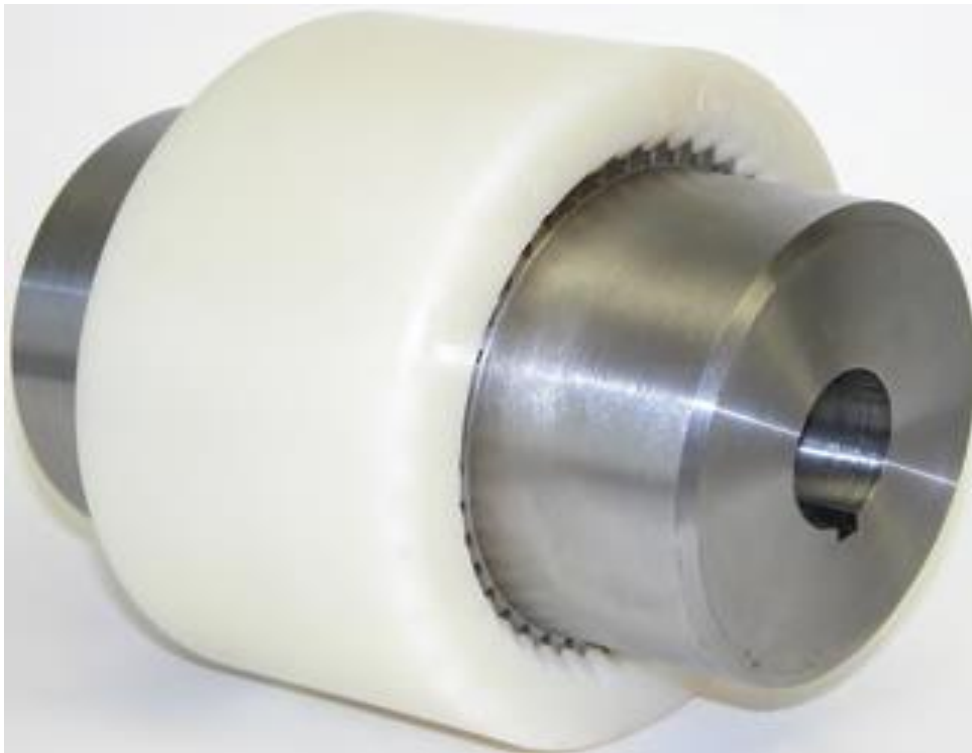


Figure 2.15 : Coupling Joint

2.14 Pillow Block Ball Bearing:

As shown in figure 2.18 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.

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.

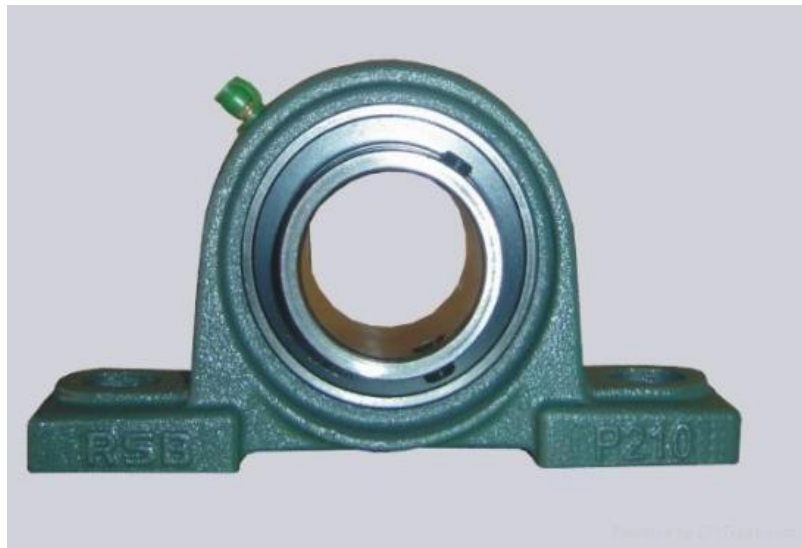


Figure 2.16 : Pillow Block Ball Bearing

CHAPTER THREE

Hardware Connection and Analysis

- 3.1 Introduction**
- 3.2 Engine Fitting**
- 3.3 Engine Cycle Analyzer**
 - 3.3.1 ECA100 Engine Cycle Analyzer Learning Outcomes**
 - 3.3.2 Essential Ancillaries**
 - 3.3.3 Ancillary For**
 - 3.3.4 Standard Features**
- 3.4 Coupling**
- 3.5 Generator**
- 3.6 Load Cell**
 - 3.6.1 Load Cell Design**
 - 3.6.2 Signal Conditioning for Strain Gauges**
 - 3.6.3 Improving The Simple Difference Amplifier With Input Buffering**
- 3.7 Versatile Data Acquisition System (VDAS)**
 - 3.7.1 The Hub Board**
 - 3.7.2 The DTI Input Board**
 - 3.7.3 The Analogue Input Board**
- 3.8 Load Unit**
 - 3.8.1 Control Unit**
 - 3.8.2 Thermal Resistor Power**

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 below in figure 3.1 .

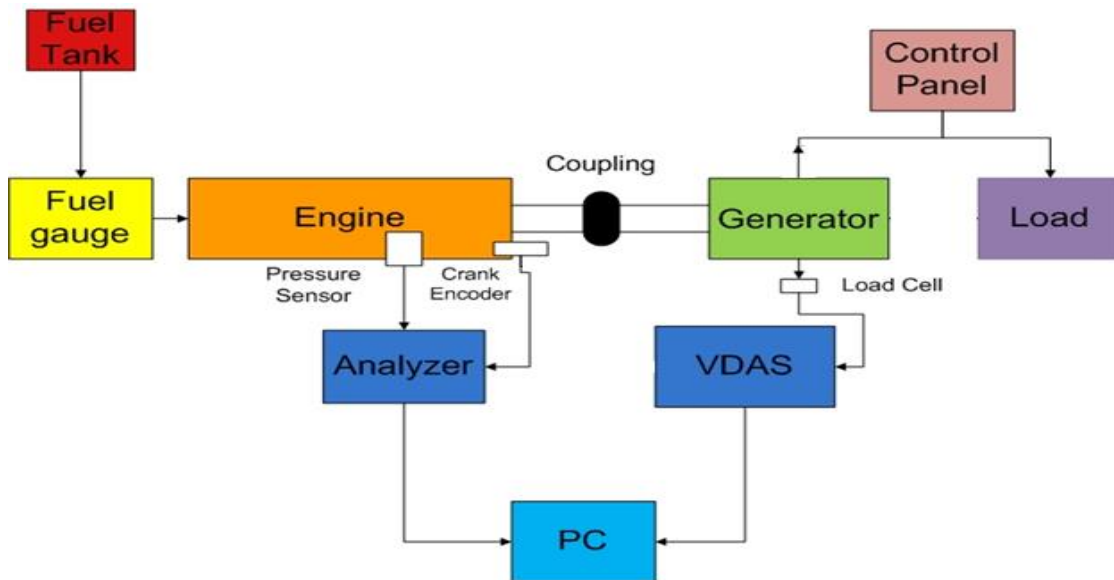


Figure 3.1 : Installation Overview

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 experiment system contain of the components that mentioned in the previous section, as shown in the figure 3.2 .

The engine have been placed on a steel frame with dimension 1.5-meter length and 0.8-meter width and 1 meter height, 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..



Figure 3.2 : Engine Fitting

3.3 Coupling :

For the purpose of transmitting power, coupling joint as shown in the figure 3.5 It have been chosen according to the engine output shaft which have a diameter $\phi 18$ mm and the alternator input shaft with a diameter $\phi 30$ mm, the available standard coupling diameters ϕ_1 28 mm, ϕ_2 14 mm, so the coupling have been lathe by inner turning to the required diameters.

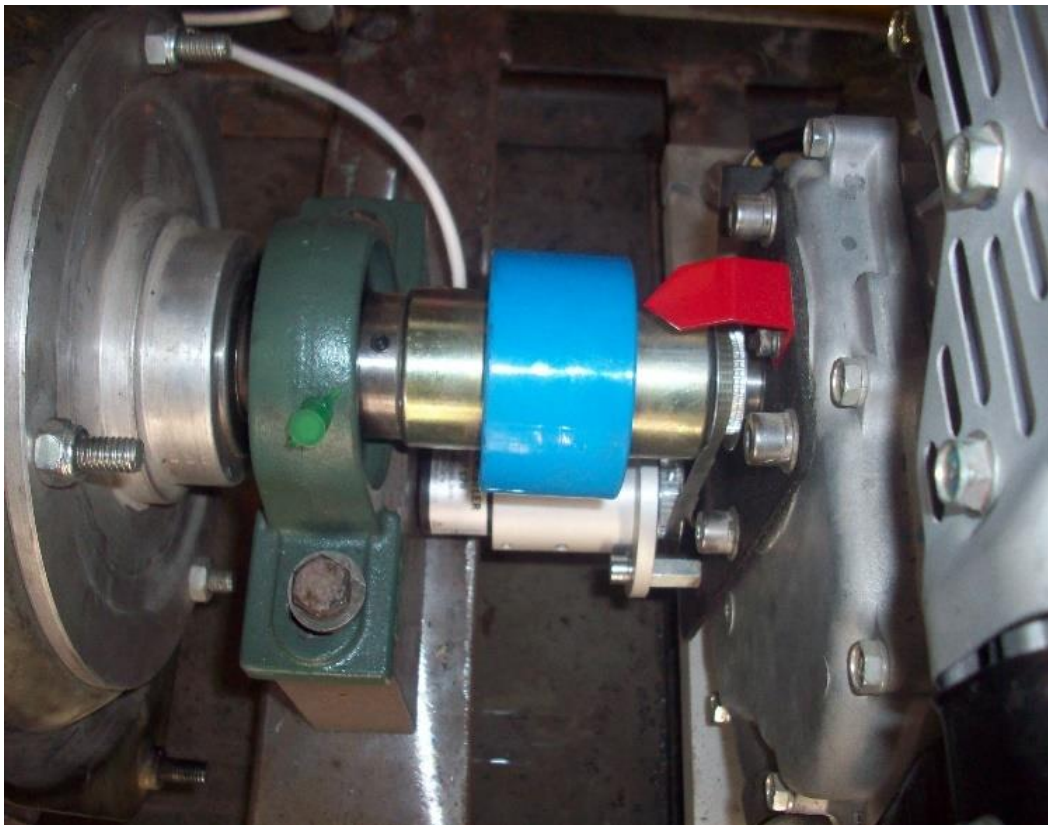


Figure 3.3 : Coupling Joint

3.4 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 from the engine to the generator by the coupling joint.

The engine shaft spins the rotor of a generator. As electrical load applied to the output of the generator, an electromagnetic force resists motion of the rotor rotation. The load represented by a variable thermal resistor. Figure 3.6 shown the generator.

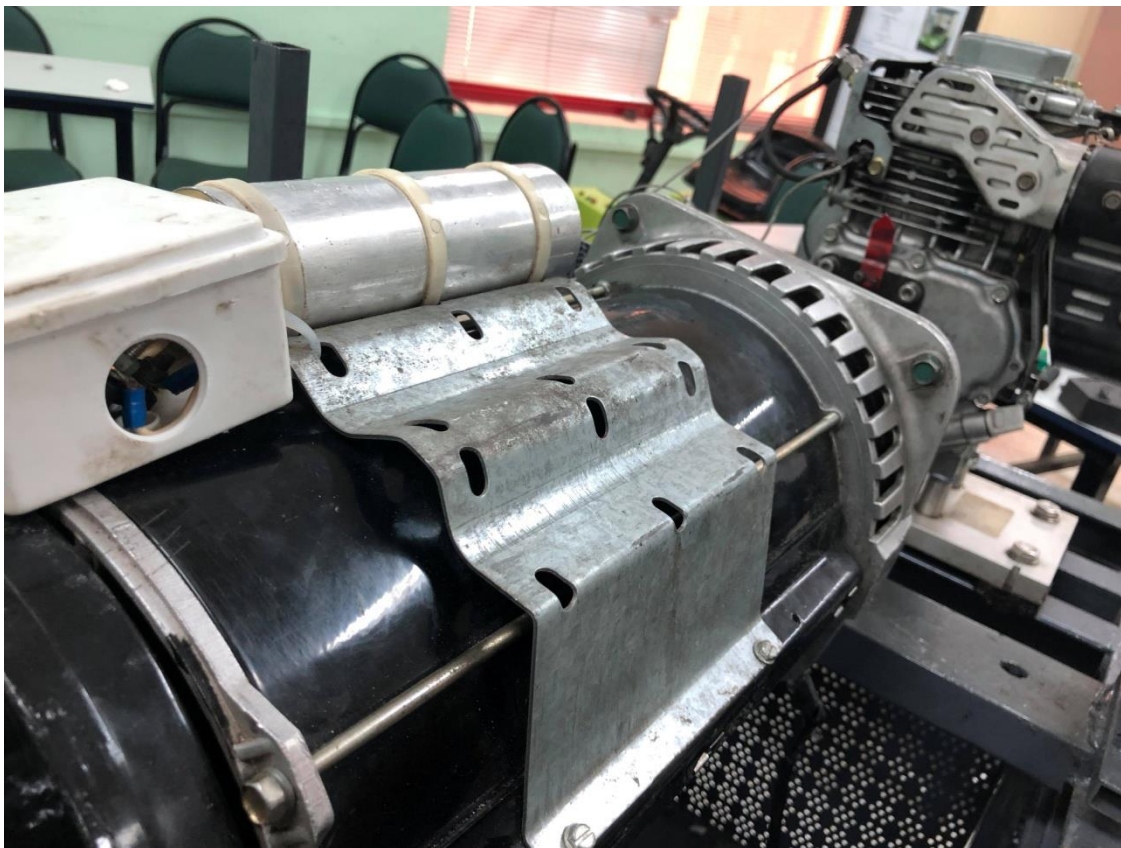


Figure 3.4 : The Generator

3.5 Load Cell Design :

As shown in Figure 3.8 illustrate the schematic diagram of the sensor and its conditioning circuit, the sensor is composed from a strain gauge, and the strain gauge is a sensor whose resistance varies with applied force, it converts force, pressure, tension, weight, etc., into a change in electrical resistance which can then be measured.

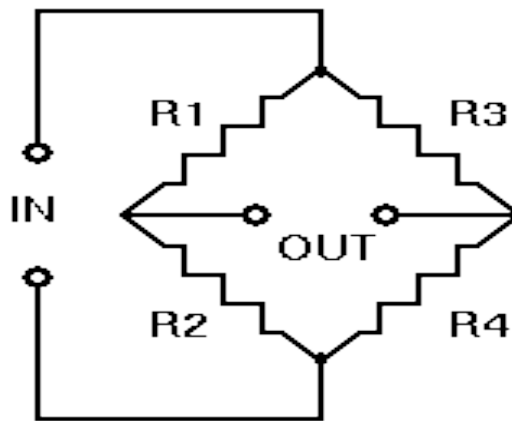


Figure 3.5 : Schematic Diagram Of The Sensor

In practice, the strain measurements rarely involve quantities larger than a few milli- strain ,therefore, measuring the strain requires accurate measurement of very small changes in the resistance. To measure such small changes in resistance, strain gauges are almost always used in a bridge configuration with a voltage or current excitation source , the general wheatstone bridge illustrated consists of four resistive arms with an excitation voltage, V_{in} , that is applied across the bridge.

The output voltage of the bridge, V_{out} , will be equal as shown in Equation 3.1.

Equation 3.1 The Output Voltage Of The Bridge

$$V_{out} = \left[\frac{R3}{R3 + R4} - \frac{R2}{R1 + R2} \right] * V_{in}$$

From this equation, it is apparent that when $R1/R2 = R3/R4$, the voltage output V_{Out} will be zero. Under these conditions, the bridge is said to be *balanced*. Any change in resistance in any arm of the bridge will result in a nonzero output voltage.

In order to increase the sensitivity of the circuit, all of the four arms of the bridge can be active strain gauges, mounted as two gauges in tension and two gauges in compression.

The selected strain gauge can be forced with a weight up to 30Kg, and at this weight the full scale voltage is 2.0 mV when excited with 10 V, with a linear relation retained among the scale.

3.6 Signal Conditioning for Strain Gauges

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.

The measurements involves measuring the difference voltage between the bridge arms as shown in figure 3.6 , the voltage difference represent the stress generated from the applied weight, the measurement can be implemented with instrumentation amplifier, the amplifier measure and amplify the voltage difference such that at full scale the amplifier gives a maximum value.

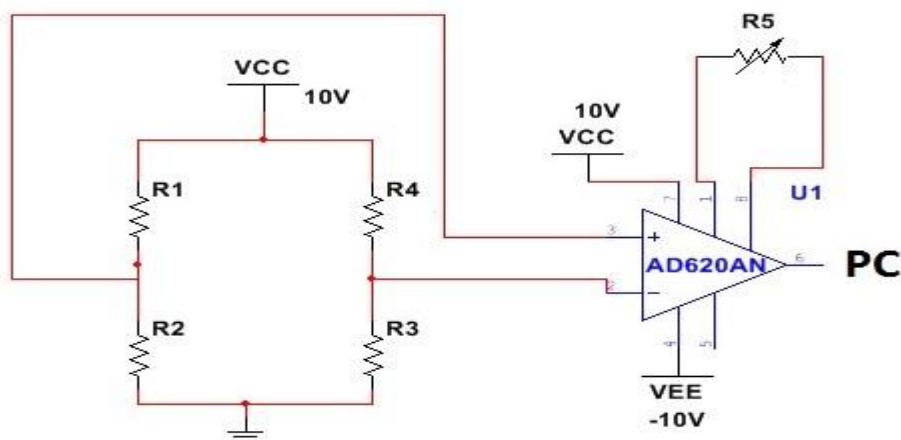


Figure 3.6 : Signal Conditioning for Strain Gauges

In order to select the amplifier gain, the conditioning circuit should output 10 V when loaded with a 15 Kg, and accordingly, the gain can be calculated as shown in Equation 3.2.

Equation 3.2 The Gain Calculated

$$G = \frac{\text{full scale voltage}}{\text{full scale(sensor)}/2} = \frac{10 \text{ V}}{1.0\text{mV}} = 10000$$

For the current application the instrumentation amplifier should provide a selection gain up to 10000 with a high input impedance in order to prevent loading effect on the bridge , such a specification can be satisfy with AD620 instrumentation amplifier.

According to the instrumentation amplifier datasheet(AD620), the gain can be practically adjusted by connecting a resistor between pin 1 and 8, the resistor value can be calculated as shown in Equation 3.3 .

Equation 3.3 : The Resistor Value

$$R_G = \frac{49.4 \text{ k}\Omega}{G-1}$$

Where G is the desired amplifier gain.

According to the load cell datasheet, the sensor can generate a 2 mV for each volt supplied to the cell by the voltage source, hence the relation between the output voltage(V) and the applied weight (W) can be expressed by equation as shown in Equation 3.4 .

Equation 3.4 : The Relation Between The Output Voltage(V) And The Applied Weight (W)

$$V = W * \frac{\text{full scale voltage}}{\text{full scale weight}} * G$$

$$V = W * \frac{2.0}{30} * 10000 = W * 667\text{mV}$$

For example, for each 1Kg applied to the cell, a 0.66 volts are generated from the circuit.

3.7 Improving the Simple difference amplifier with Input Buffering:

An obvious way to significantly improve performance is to add high input impedance buffer amplifiers ahead of the simple difference amplifier or subtractor circuit, this circuit provides matched, high impedance inputs so that the impedances of the input sources will have a minimal effect on the circuit's common-mode rejection. The use of a dual op amp for the 2-input buffer amplifiers is preferred because they will better track each other over temperature and save board space. Although their gain values are different, the circuit has the same transfer function.

Differential amplifier in our project used to measure the difference voltage of the bridge and amplify it to suitable for the VDAS device.

The output relationship between voltage and masses is closed to linear with the range of 0.666V for each 1Kg, as shown in Figure 3.7.

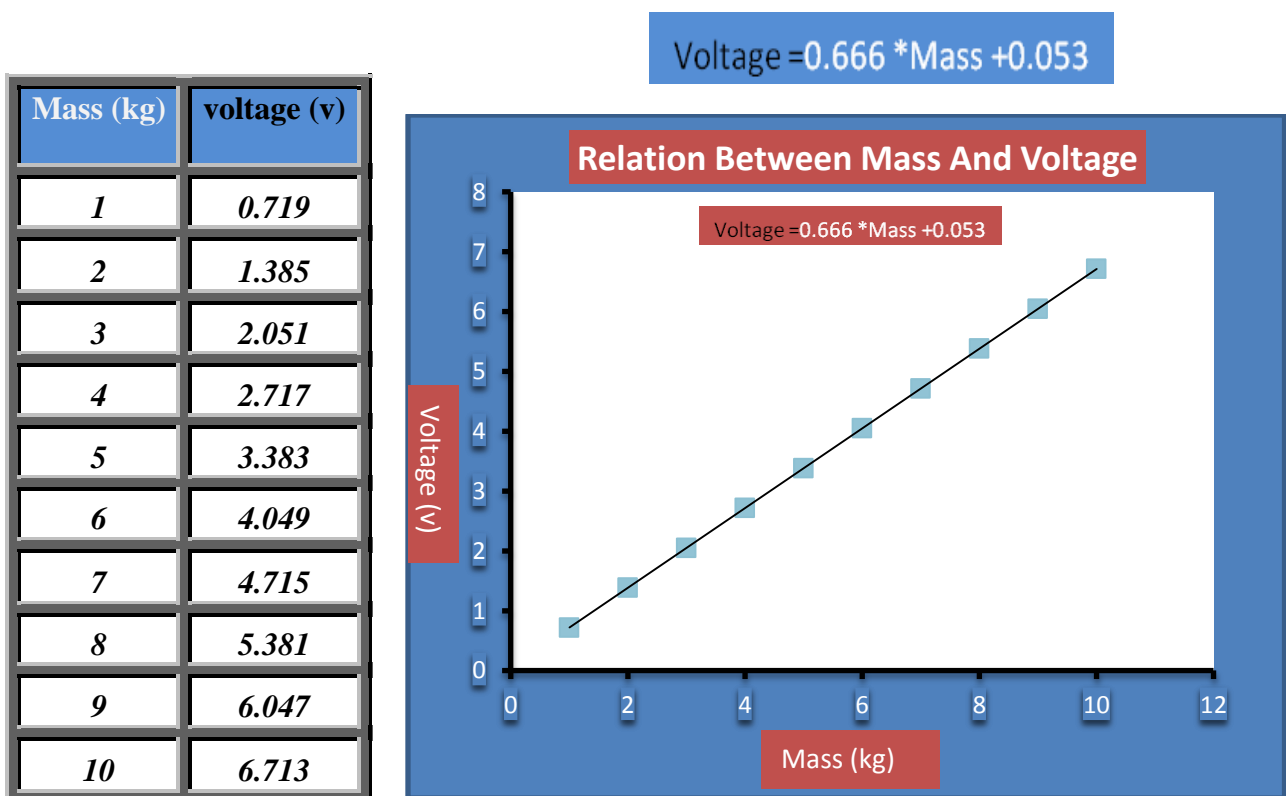


Figure 3.7 : Relationship Between Mass And Voltage

3.7.1 The Hub Board.

The VDAS compatible modules connect by means of the six sockets, marked 'Digital Inputs'. The computer connects by means of the USB type socket, 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 3.8: 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.

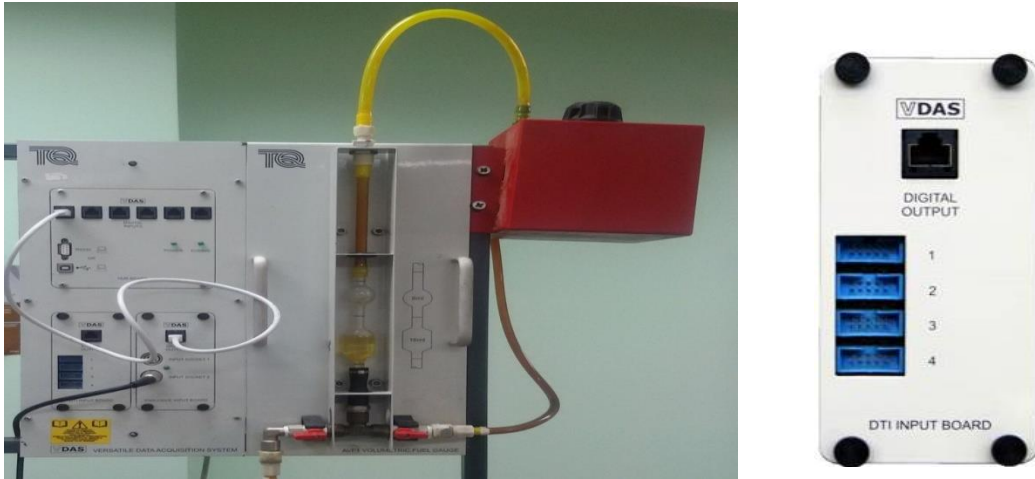


Figure 3.9: DTI Input Board

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 V output sensors. This socket is the source and the input signal of the load cell, such that the connections are as in Figure 3.10. It shows the output source and the input signals.



Figure 3.10: Analogue Input Board

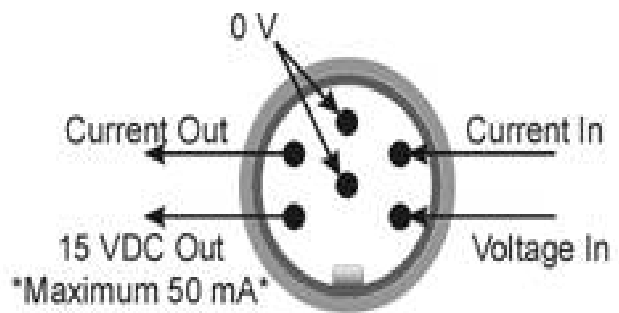


Figure 3.11: Socket Connections

3.8 Load Unit

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

1. Control Unit.
2. Thermal Resistor 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 as shown in figure 3.12.



Figure 3.12 : 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 of thermal neon as shown in figure 3.13 . The standard end terminal is screwed firmly to the resistive element, which provides good electrical connections to the resistive elements.



Figure 3.13 : 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 $\cos 0^\circ = 1.0$. 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 $P = V_{\text{rms}} * I * \cos \phi$ in watt's. However, since $\cos \phi = \text{one}$ in a purely resistive circuit, the power consumed is simply given as, $P = V_{\text{rms}} * I$, 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 shown in Equation 3.5 .

Equation 3.5 The Power Dissipated

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

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:

$$P = V_{\text{rms}} * I_{\text{rms}} = 155 * 30 = 4500 \text{ watt ; } 270\text{V at } 3500 \text{ rpm}$$

$$\text{For five resistor } 4500/5 = 900 \text{ watt}$$

$$I = P/V = 900/270 = 3.33 \text{ amps}$$

$$R = V/I = 270/3.33 = 81.1 \text{ ohm}$$

CHAPTER FOUR

Engine Performance Parameters

And

Mathematical Relationships

4.1 Introduction

4.2 Engine Swept Volume

4.3 Compression Ratio

4.4 Engine power

4.4.1 Engine Brake Power (bp)

4.4.2 Engine Indicated Power (ip)

4.4.3 Engine Friction Power

4.4.4 Indicated Mean Effective Pressure (imep)

4.5 Efficiencies (ζ)

4.5.1 Engine Volumetric Efficiency

4.5.2 Engine Mechanical Efficiency

4.5.3 Engine Brake Thermal Efficiency

4.6 Fuel Consumption SFC

4.7 The Torque

4.1 Introduction:

To check engine performance well , we must check engine efficiencies by loading the engine with different loads and analyzing emissions, these efficiencies are includes (engine swept volume, compression ratio, engine indicated power, engine brake power, engine friction power, engine mechanical efficiency, specific fuel consumption SFC, engine brake thermal efficiency, and engine volumetric efficiency). These all parameters which used to check an engine performance and describe an engine efficiencies completely , we have to learn about energy flow in an engine which desirable to have a general knowledge of the energy flow or energy balance of the engine so that we become familiar with the various performance parameters to determine the performance by different loads.

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 range 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, which are 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 Swept Volume:

Table 4. 1 Engine Swept Volume Equation

$V_e = \left(\frac{\pi}{4} B^2 \times L\right) \times n = A_{cyl} \times L \times n = V_{cyl} \times n \quad [m^3]$		
V_e	Engine swept volume	m³
B	Cylinder bore (diameter)	M
L	Stroke length	M
N	Number of cylinders	
A_{cyl}	Cylinder (piston) area	m²
V_s	Cylinder volume	m³

4.3 Compression Ratio:

Table 4.2 Compression Ratio Equation

$r = \frac{V_c + V_s}{V_c} = 1 + \frac{V_s}{V_c}$		
R	Compression ratio	
V_c	Clearance volume	m³
V_s	Cylinder volume	m³

4.4 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 (KW)	fb = ip – bp (KW)
-------------------------	--------------------------

4.4.1 Engine 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 scale makes it easier to load the 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.

Table 4.3 Engine Brake Power (bp) Equation

$P_b = T_e \times \omega = T_e \frac{2\pi N}{60} \text{ [kW]}$		$T = R * F$
Pb	Engine brake power	kW
Te	Engine torque produced by the engine	kN.m
ω	Engine angular speed of the engine	rad/sec
N	Engine speed (RPM)	rev/min
F	The force by the arm	N
R	The length arm	m

4.4.2 Engine 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 may be developed from the equation of net work based on the mean effective pressure and piston displacement.

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.

Table 4.4 Engine Indicated Power Equation

$P_i = imep \times A \times L \times n \times \frac{N}{2 \times 60 \times 1000} = imep \times V_e \times \frac{N}{2 \times 60 \times 1000} \quad [\text{kW}] \text{ (Four stroke engine)}$		
$P_i = imep \times A \times L \times n \times \frac{N}{60 \times 1000} = imep \times V_e \times \frac{N}{60 \times 1000} \quad [\text{kW}] \text{ (Two stroke engine)}$		
Pi	Engine indicated power	kW
Imep	Indicated mean effective pressure	N/m²
A	Cylinder (piston) Are	m²
L	Stroke	m
N	Number of cylinders	
N	Engine revolution per minute	rpm
Ve	Engine volume	m³

4.4.3 Engine Friction Power:

Table 4.5 Engine Friction Power Equation

$P_f = P_i - P_b$ [kW]		$P_i = b_p + f_p$ /kW
Pf	Engine friction power	kW
Pi	Engine indicated power	kW
Pb	Engine brake power	kW

4.4.4 Indicated Mean Effective Pressure (imep):

It has been stated in section 4.1 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 crank 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.

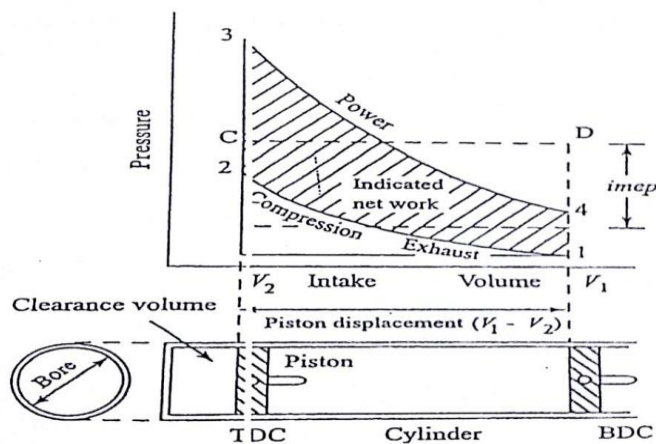


Figure 4. 1 P-V Diagram for an Ideal Four-Stroke Cycle Engine

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 CD rectangular equals area 1234, the vertical distance between the horizontal lines CD represents the indicated mean effective pressure 'imep', 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.

Table 4.6 Indicated Mean Effective Pressure (imep) Equation

$\text{imep} = \frac{\text{Net work of cycle}}{V_s}$	$\text{imep} = \frac{\text{Area of the indicator diagram}}{\text{Length of the indicator diagram}}$
--	---

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 divided by the piston displacement, results in the mean effective pressure.

4.5 Efficiencies (ζ) :

4.5.1 Volumetric Efficiency:

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 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.

Table 4.7 Engine Volumetric Efficiency Equation

$\eta_v = \frac{V_{air}}{V_s}$		$\zeta_v = m_{act} / m_{th}$
η_v	Volumetric efficiency	%
V_{air}	Actual air volume intake	m^3
V_s	Cylinder volume	m^3

4.5.2 Mechanical Efficiency:

The mechanical efficiency (ζ_m) it takes into account the losses in an engine. Mechanical losses of an engine may be further 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.

Table 4.8 Engine Mechanical Efficiency Equation

$\zeta_m = \frac{bp}{ip} * 100\%$		
η_m	Mechanical efficiency	%
Pb	Engine brake power	kW
Pi	Engine indicated power	kW

4.5.3 Engine Brake Thermal Efficiency:

Brake Thermal Efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel.

It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy.

Table 4.9 Engine Brake Thermal Efficiency Equation

$\eta_{th} = \frac{P_b \times 3600}{m \cdot CV} = \frac{P_b \times 3600}{V \cdot \rho \times CV}$		
η_{th}	Thermal efficiency	%
Pb	Engine brake power	kW
m.	Mass of fuel consumed per hour	kg/h
V	Volume of fuel consumed per hour	m³/h
ρ	Fuel density	Kg/m³
CV	Fuel calorific (heat) value	kJ/kg

4.6 Fuel Consumption SFC:

Table 4.10 Specific Fuel Consumption SFC Equation

$SFC = \frac{m_f}{P_b} \quad \left[\frac{\text{kg}}{\text{kW h}} \right]$		
SFC	Specific fuel consumption	kg/(kW.h)
m.f	Mass of fuel consumed per hour	kg/h
Pb	Engine brake power	kW

4.7 Torque :

We can know the torque by the force acting or by known Amp, voltage and speed in N.m .

The Torque Equation

$$T = F * R \quad [N.m]$$

OR

$$T = \frac{I * V * 1.73 * 60}{2 * 3.14 * N} \quad [N.m]$$

CHAPTER FIVE

Practical Test and Discussion

5.1 Introduction

5.2 Engine Operation Modes

5.2.1 Warming up

5.2.2 Constant Speed Wide Open Throttle (WOT) With Variable Loads

5.3 Experiment No 1: Brake Power Calculation

5.4 Experiment NO 2: Fuel Consumption

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

5.6 Maintenance And Rehabilitation

5.1 Introduction:

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

5.2 Engine Operation Modes:

5.2.1 Warming up :

In this mode, the engine requires high amount of fuel to allow it reach normal operation temperature quickly, so the intake choke valve must be closed. To allow fast warming, ignition timing must be retarded to appropriate value which achieved by automatic ignition control device.

- Do not increase engine speed until the oil reaches all engine parts normally. Shut the engine immediately down if any Suspicious notices.
- Explosion hazard warning: Do not use volatile starting aids such as ether, propane, or gasoline in the air intake system. The glow plugs/AIH will ignite the vapors and cause severe engine damage or personal injury.

5.2.2 Constant Speed Wide Open Throttle (WOT) With Variable Loads:

In the operating mode the throttle valve must be opened to the maximum limit, the engine speed increased to specific speed then hold it constant until the end of experiment, then start applying loads sequentially until maximum load applied on the engine.

5.3 Experiment No 1:

Brake Power Calculation

Brake power measured firstly by turning the engine on then apply the load by the dynamometer; we can see 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. Calculate the brake power using its equation and graph it proportional to engine speed.
9. 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: 5.1 Constant Speed at 2500 RPM , Variable Load.

Load/Power [KW]	Torque [N.m]	Current [A]	Voltage [V]	Brake Power [Kw]
0.38	2.53	2.5	153	0.66
0.71	4.7	4.5	158	1.22
0.93	6.14	5.7	163	1.6

Table: 5.2 Constant Speed at 3600 RPM , Variable Load.

Load/Power[KW]	Torque [N.m]	Current [A]	Voltage [V]	Brake Power [Kw]
0.92	4.2	4	230	1.58
1.14	5.32	4	285	1.97

Table: 5.3 Variable Speed, Variable Load.

Speed [rpm]	Load/power [Kw]	Torque [N.m]	Current [A]	Voltage [V]	Brake Power [Kw]
2500	1.440	9.5	12	120	2.6
2700	1.980	12.12	11	180	3.4
3100	1.800	9.81	8	230	3.1
3600	1.14	5.32	4	285	1.97

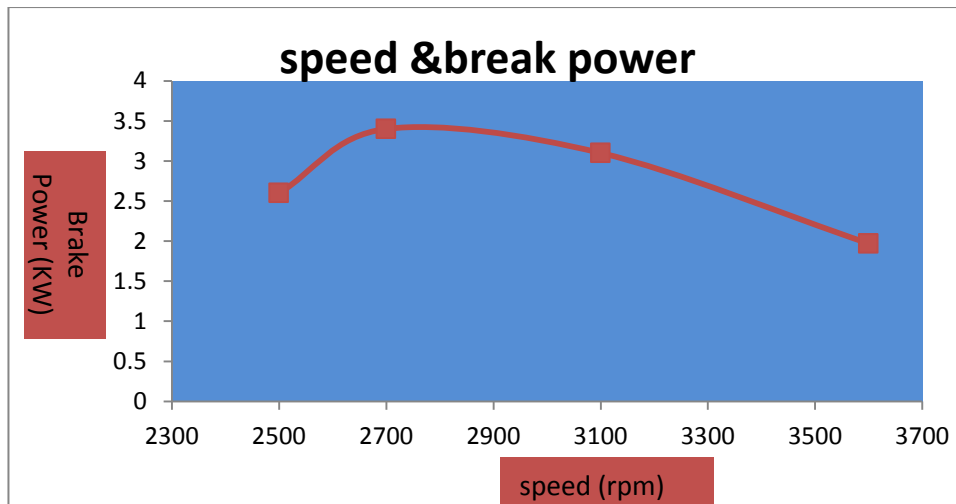


Figure 5.1: Brake Power And Speed

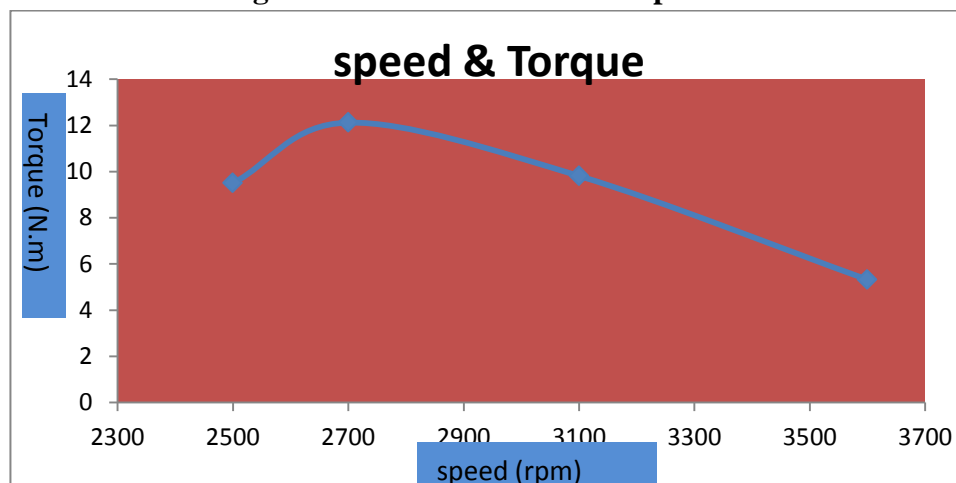


Figure 5.2: Torque And Speed

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 .

Figure 5.2 show 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 rated efficiency, the efficiency from the out power consumed by the thermal resistance on the input power as the brake power.

5.4 Experiment 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 as shown in table 5.4 .

Table 5.4 The Fuel Mass Of Engine Calculation Equation

$m_{\text{fuel}} = V * \rho$		
M	Mass of fuel	Kg
V	Volume of fuel, which can used	8 ml*10⁻⁶ m³
ρ	Fuel density	740 Kg/m³

Another definition is a fuel mass flow per second and calculated as in the relation that shown un table 5.5 .

Table 5.5: The Fuel Mass Of Engine Calculation Equation

$\dot{M}_{\text{fuel}} = \frac{m_{\text{fuel}} * 3600}{t} \text{ [Kg/ hr.]}$		
T	The time which can be calculated	S

In engine test, the fuel consumption measured as a flow rate-mass flow per unit time. A more useful parameter is Specific Fuel Consumption (SFC), the fuel flow rate per unit power output. It measures efficiently an engine is using the fuel supply to produce work as shown in table 5.6 :

Equation The Specific Fuel Consumption

$SFC = \frac{\dot{M}}{bp}$

Procedure:

To measure the fuel consumption of the engine.

1. Fill your tank with correct fuel for your test engine.
2. 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.
3. Make sure that your computer is operating correctly and has started TQ software (VDAS software, Engine Cycle Analyzer Software).
4. Check load control panel connections, and make sure that all loads switched off.
5. Turn ignition switch to on position, rotate the output shaft to the TDC mark, and start the engine.
6. Allow the engine to reach normal operating temperature
7. 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
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 fuel consumption and specific fuel consumption of the engine, and then graph the mass flow rate 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 5.6 : Fuel Flow Rate [Without Load]

Speed[rpm]	Mass Flow Rate[kg/hr]
1350	0.2
1951	0.286
2600	0.350
3396	0.487
4007	0.707

**Table 5.7 : Fuel Flow Rate and Specific Fuel Consumption
[With Applying Loads]**

Speed[rpm]	Time[sec]	Flow rate kg/hr	SFC kg/kw.hr
2510	30.01	0.710	0.1038
2572	30.67	0.696	0.0923
2742	30.76	0.692	0.0831
2873	30.52	0.698	0.08420
3080	33.05	0.650	0.1001
3255	36.78	0.578	0.1357

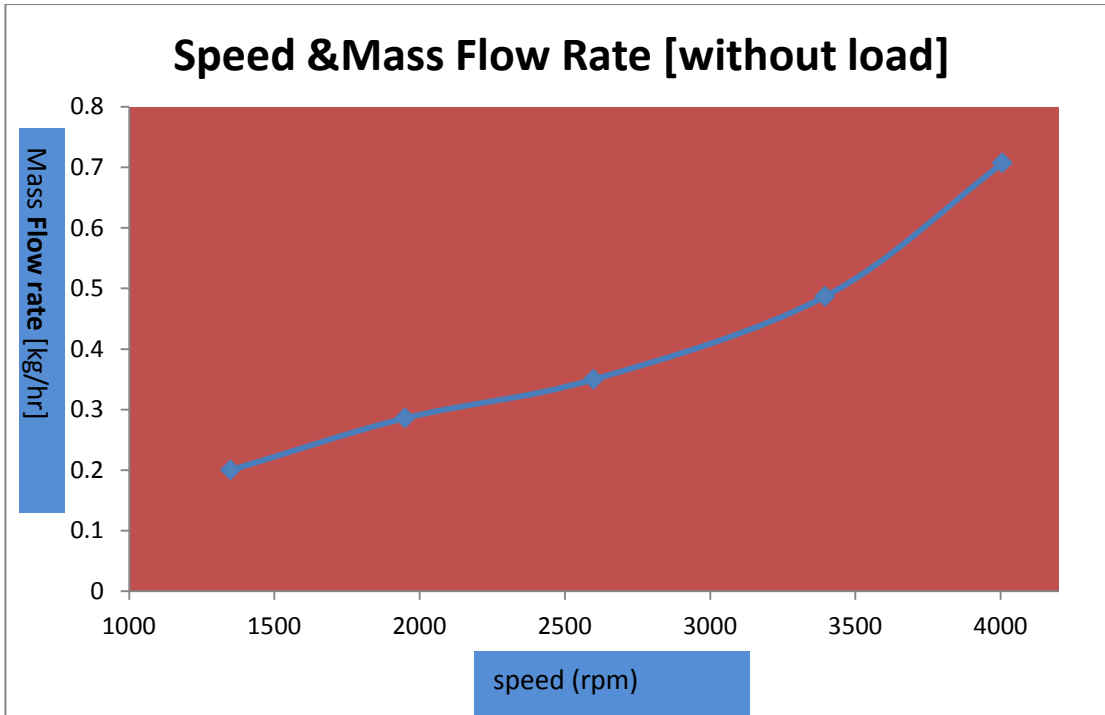


Figure 5.3: Mass Flow Rate Vs Speed [Without Applying Loads]

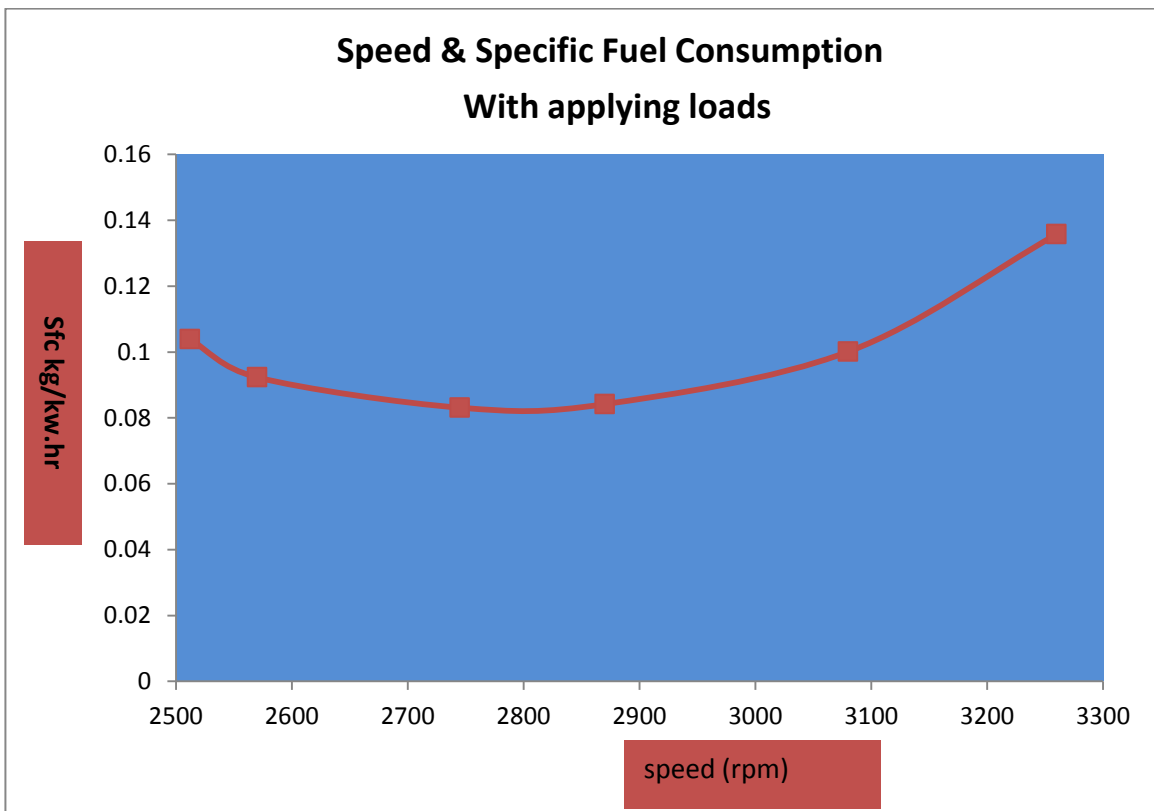


Figure 5.4: Specific Fuel Consumption Vs Speed [With Applying Loads]

Result Discussion:

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:

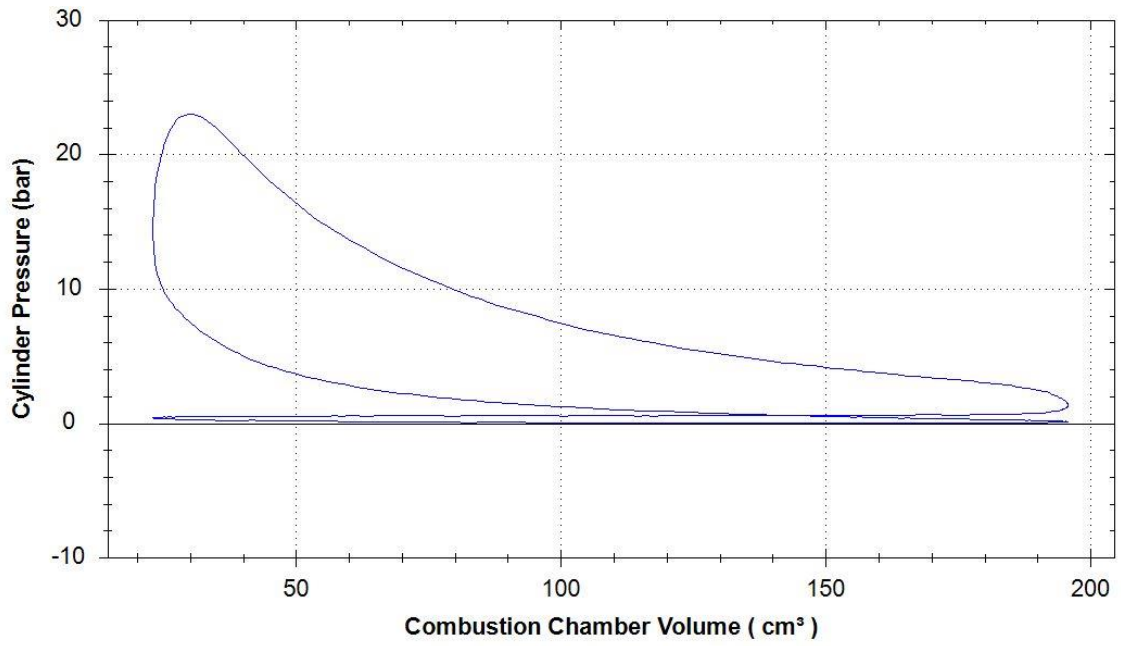


Figure 5.5.1: Pressure-Volume (P-V) at T=6[Nm], 2500[RPM]

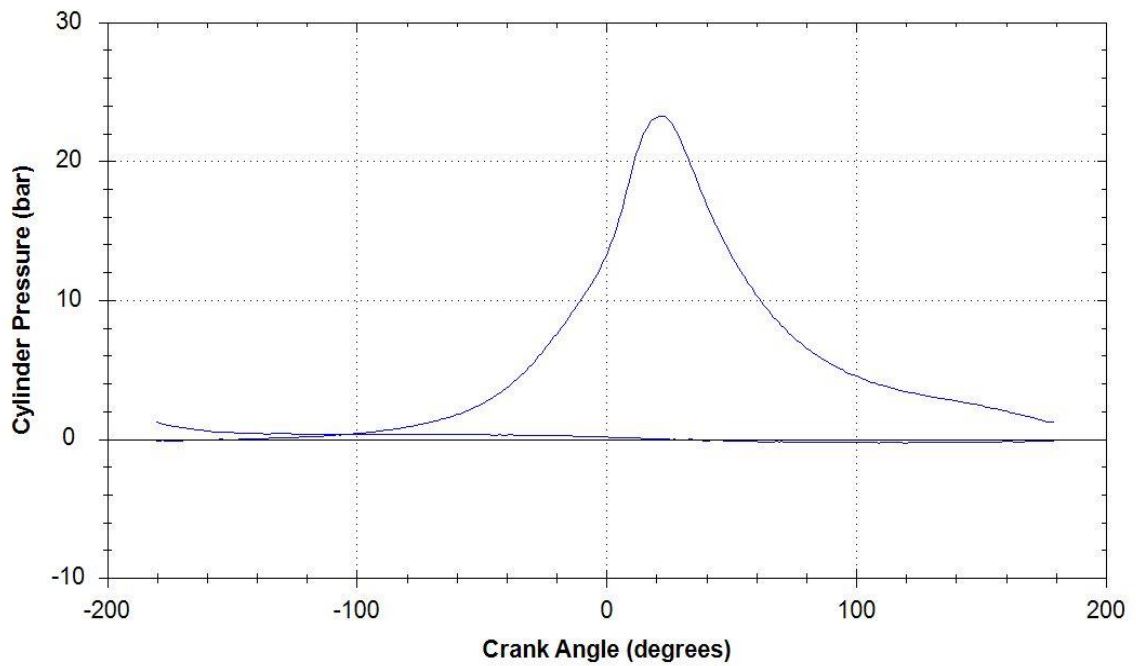


Figure 5.5.2: Pressure-Crank Angle Diagram (P-θ) at T=6[Nm], 2500[RPM]

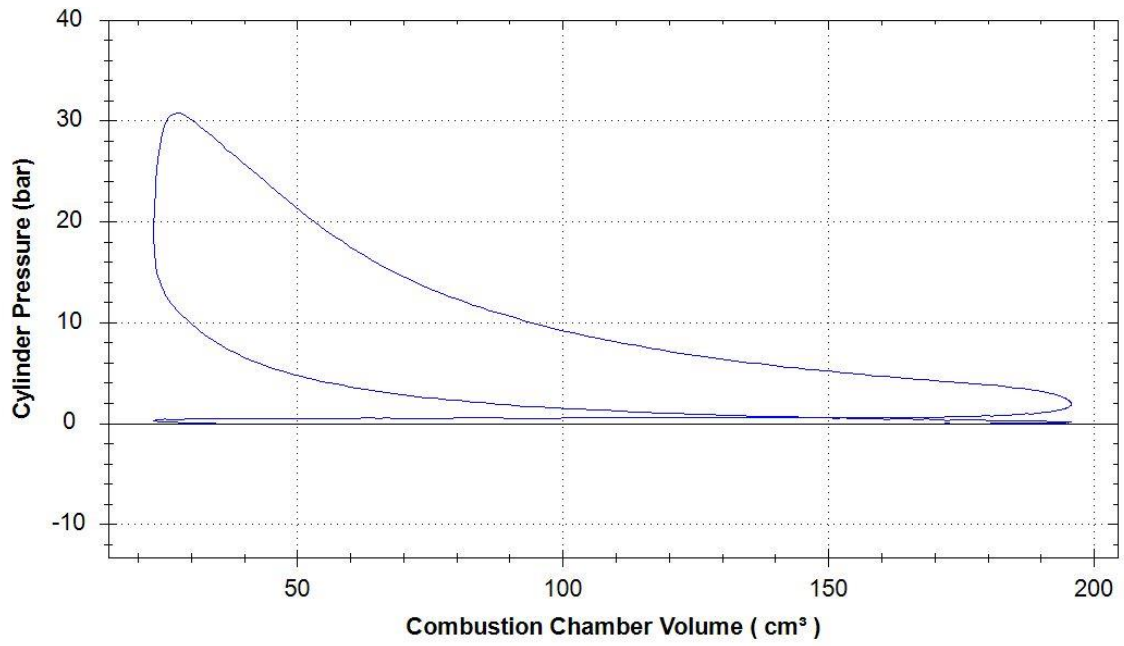


Figure 5.6.1: Pressure-Volume (P-V) at $T=10$ [Nm], 3500 RPM

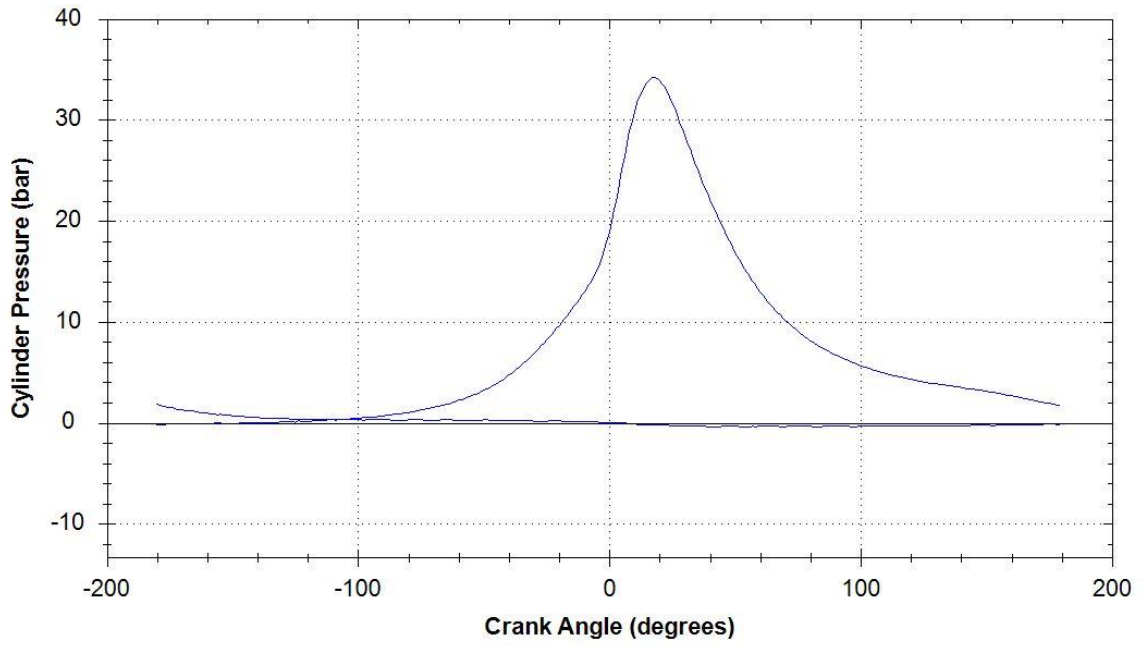


Figure 5.6.2: Pressure-Crank Angle Diagram (P- α) at $T=10$ [Nm], 3500 RPM

Result discussion:

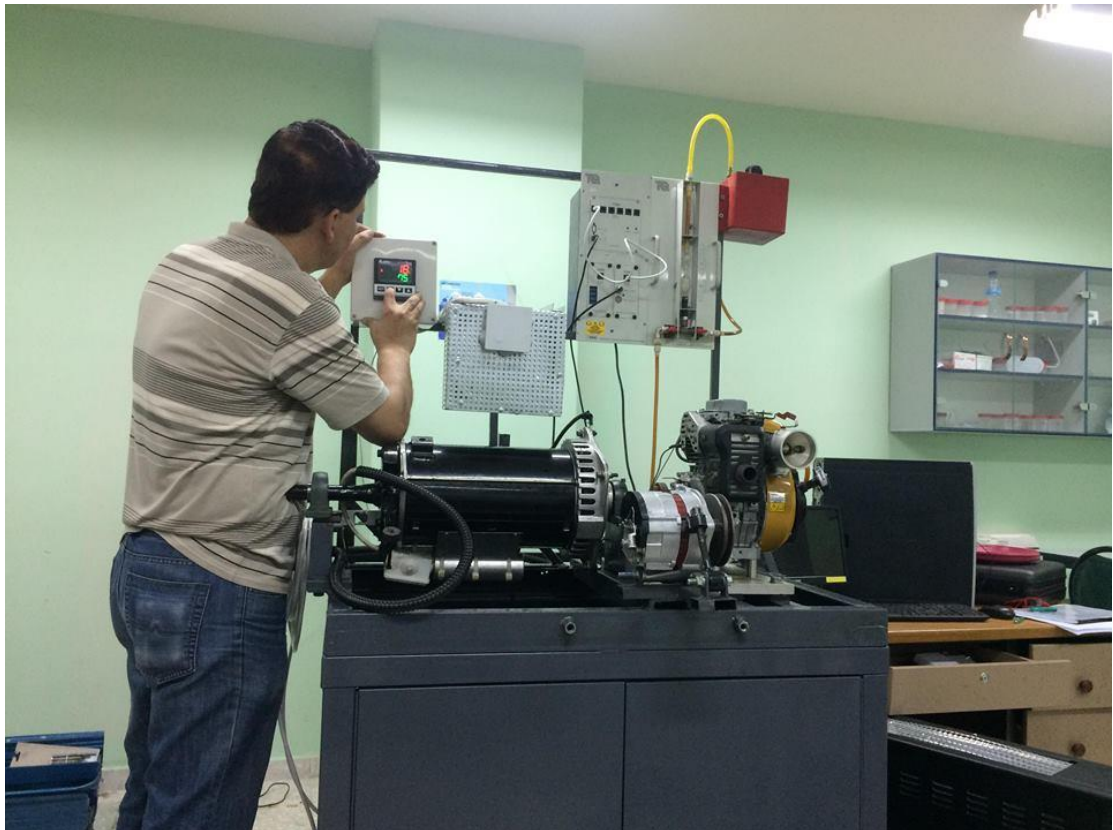
When the piston is at bottom dead center, the cylinder will have its largest volume. As the piston moves up the cylinder, the volume is reduced. At top dead center, the cylinder is at its minimum volume.

Once the piston reaches top dead center 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.

5.6 Maintenance And Rehabilitation :

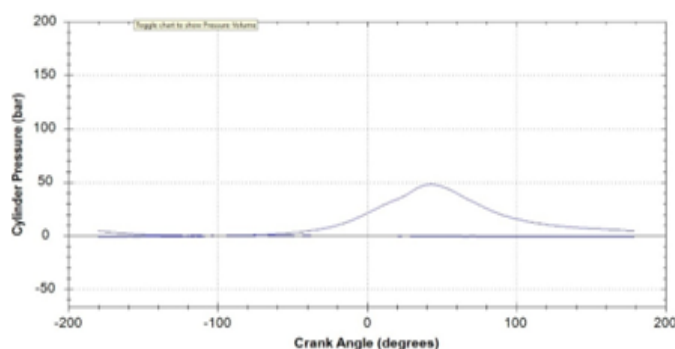
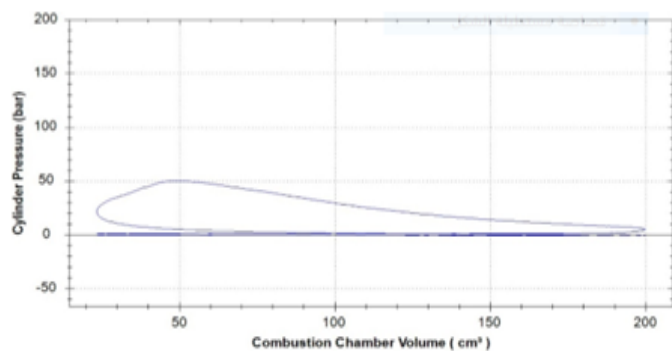




Some maintenance and rehabilitation on the system, and was represented:

1. Change the encoder (to determinate piston location analyzer and the number of engine cycles and data processor).
2. Install and update software on the computer to process data collected using (engine cycle analyzer).
3. Repair the load sensor (load sell)and design a new electronic circuit of its own.
4. Design and install a new, safer and more accurate electrical load unit containing thermal resistors with control switches.
5. Design and installation of a heavy frame to reduce vibration, and provide it with protection and safety.
6. Install temperature sensor to measure engine temperature, in the outer surface of the engine block .
7. Change the coupling between the motor and the generator.

As shown in figure below compare the results before and after the maintenance and repair work.



The Signal Before The Maintenance And Rehabilitation

CHAPTER SIX

Internal Combustion Engine

Heat Transfer

6.1 Internal Combustion Engine Heat Transfer

6.2 The Main Idea

6.3 Component And Specification

6.4 Type Heat- Transfer

6.4.1 Convection

6.4.2 Conduction

6.4.3 Radiation

6.5 Areas

6.6 Heat Transfer Without Fan

6.7 Heat Transfer By Using Fan

6.8 Heat Transfer And Engine Energy Balance

6.9 Technical Justification

6.1 Internal Combustion Engine Heat Transfer

As shown in figure 6.1 Internal Combustion Engines generate mechanical power by extracting energy from heat flow, and the difference between the mechanical power (out) and the heat flow (in) is the waste heat the waste heat must be removed.

Combustion engines can remove the waste heat by many ways such as exhaust, gases, and engine cooling.

High temperature will damage the engine materials and lubricants, so cooling is very important for engines.

The internal combustion engines are mostly fluid cooled usually by using water, and that is with a circulation pump to cool the engine.

Other engines use air-cooled, that is by using air with a special fan submissive by electricity.

In air-cooled Event fins addition is necessary to increase the area of heat transfer

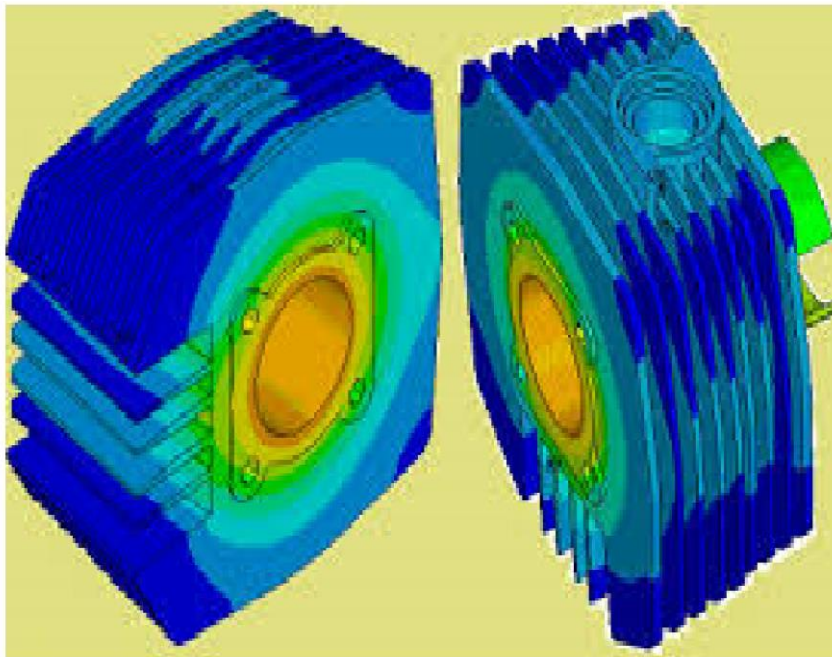


Figure 6.1 : Engine Heat Transfer

6.2 The Main Idea:

As shown in figure 6.2 below the design structure and the objective of this project is to build and design and ensure that is system provide us with system information with an air-cooled unit is to know the physical changes that occur in engine working conditions, and the amount of fuel consumption. when the engine starts and rise due to the warm up temperature the measurement through a sensor which is installed on the outer body of the engine block , as when the temperature rises to a value higher than 75°C , the cooling system controller command for the first stage, which operates the first speed which is 100 CFM ,and when the temperature reach 85°C ,the cooling system controller command for the second stage which operates the second speed which is 150 CFM .

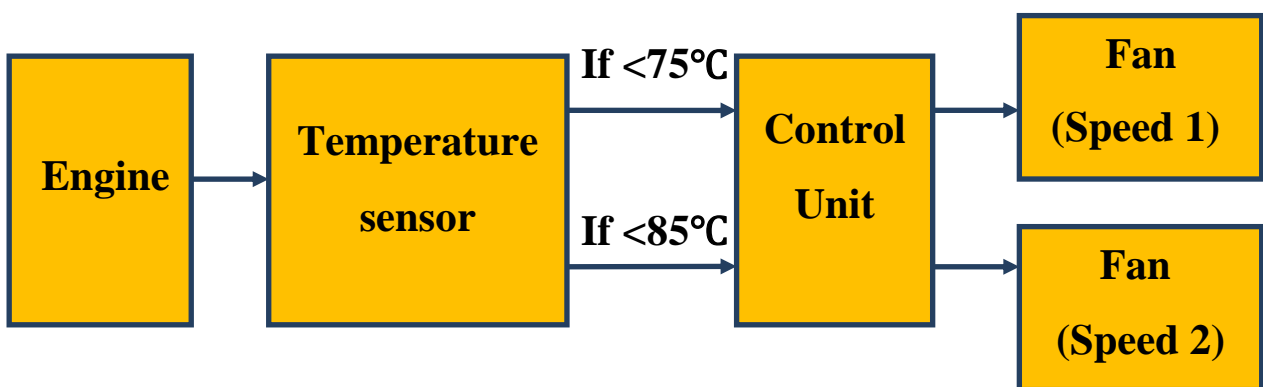


Figure 6.2 :Design Structure

In this project we assembled an air-cooled heat-transfer system , which include the following :

6.3 The Component and Specification :

6.3.1 Temperature Sensor (Thermocouple):

As shown in figure 6.3 the type J thermocouple: The type J is also very common. It has a smaller temperature range and a shorter lifespan at higher temperatures than the Type K. It is equivalent to the Type K in terms of expense and reliability , and type J thermocouple grade wire thermocouple grade wire, -346 to $1,400\text{F}$ (-210 to 760C) extension wire, 32 to 392F (0 to 200C) , consideration for bare wire type J thermocouple applications, the type J is well suited to oxidizing atmospheres.



Figure 6.3 : Temperature Sensor (Thermocouple)

6.3.2 Temperature Controller :

DTK obtains the temperature of the controlled environment from the sensor and sending the measured data to the electronic processor , after computing and under a fixed control cycle, it proportionally sends the heating signal via different output interfaces such as relays, voltage pulse or DC currents. By providing power to the heater and raise temperature, DTK will then control the temperature variation ,within a specific range.

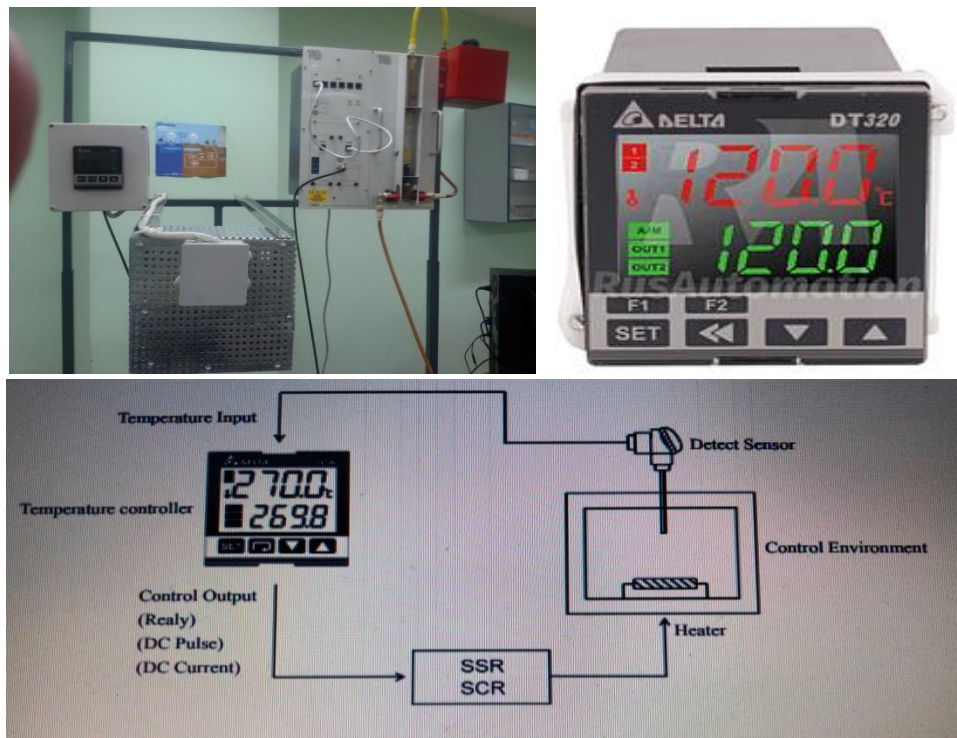


Figure 6.4 : Temperature Controller

6.3.3 Centrifugal Fan :

A typical backward-curved centrifugal fan, where the blades curve away from the direction they rotate , a centrifugal fan is a mechanical device for moving air or other gases. The terms "blower" and "squirrel cage fan", (because it looks like a hamster wheel), are frequently used as synonyms ,these fans increase the speed and volume of an air stream with the rotating impellers ,centrifugal fans use the kinetic energy of the impellers to increase the volume of the air stream, which in turn moves them against the resistance caused by ducts, dampers and other components. Centrifugal fans displace air radially, changing the direction (typically by 90°) of the airflow ,they are sturdy, quiet, reliable, and capable of operating over a wide range of conditions ,centrifugal fans are constant displacement devices or constant volume devices, meaning that, at a constant fan speed, a centrifugal fan moves a relatively constant volume of air rather than a constant mass, this means that the air velocity in a system is fixed even though the mass flow rate through the fan is not centrifugal fans are not positive displacement devices and centrifugal fans have certain advantages and disadvantages when contrasted with positive-displacement blowers: centrifugal fans are more efficient, whereas positive-displacement blowers may have a lower capital cost ,the centrifugal fan is one of the most widely used fans. Centrifugal fans are by far the most prevalent type of fan used in the HVAC industry today , they are often cheaper than axial fans and simpler in construction , they are used in transporting gas or materials and in ventilation systems for buildings and vehicles. They are also well-suited for industrial processes and air pollution control systems , the centrifugal fan has a drum shape composed of a number of fan blades mounted around a hub. As shown in figure 6.5 , the hub turns on a driveshaft mounted in bearings in the fan housing., the gas enters from the side of the fan wheel, turns 90 degrees and accelerates due to centrifugal force as it flows over the fan blades and exits the fan housing.



Figure 6.5 : Centrifugal Fan

6.4 Type Of Heat- Transfer :

We can enclose heat-transfer in three ways:

6.4.1 Convection:

As shown in figure 6.2 Generally convection heat transfers through gases and liquids from a solid boundary, results from the liquid or fluid motion along the surface.

There are two types of convection:

- Normal Convection: where the fluid flows by its self with no force .
- Forced Convection: where the fluid does not flow of its own accord but is pushed.

The Equation Of Convection Heat Transfer As shown In Table 6.1.

Table 6.1 Equation For Convection Heat Transfer

<i>Newton's Equation</i>		
$\frac{Q}{A} = h (T_s - T_f)$		
Q/A	heat transfer per unit area	W /m ²
Ts - Tf	the temperature difference	°C
h	convection heat transfer coefficient	w/m ² .K

In Convection heat transfer we need to find the value of h and the steps for that is :

1. We need to find ronald numbers (Re)

1. If $Re < 5 * 10^5$ → *Laminar Flow then Nuslet Number (Nu) will be:*

Table 6.2 Equation Of Laminar Flow then Nuslet Number (Nu)

<i>Nuslet Number (Nu)</i>
$(Nu)=0.664* Re^{0.5}*Pr^{0.33}$

$Re = \rho * v * d / \mu$
$h = Nu * K / L$

And

Q/A	heat transfer per unit area	W /m²
Ts - Tf	the temperature difference	°C
h	convection heat transfer coefficient	w/m².K

2.0 If $Re < 5 * 10^5 \longrightarrow$ *Turbulent flow:*

<i>Nuslet Number (Nu)</i>
$(Nu) = 0.036 * Re^{0.8} * Pr^{0.33}$

And

$h = Nu * \frac{K}{L}$

$Pr = \mu * \frac{Cp}{K}$	
Pr	Prandtel number

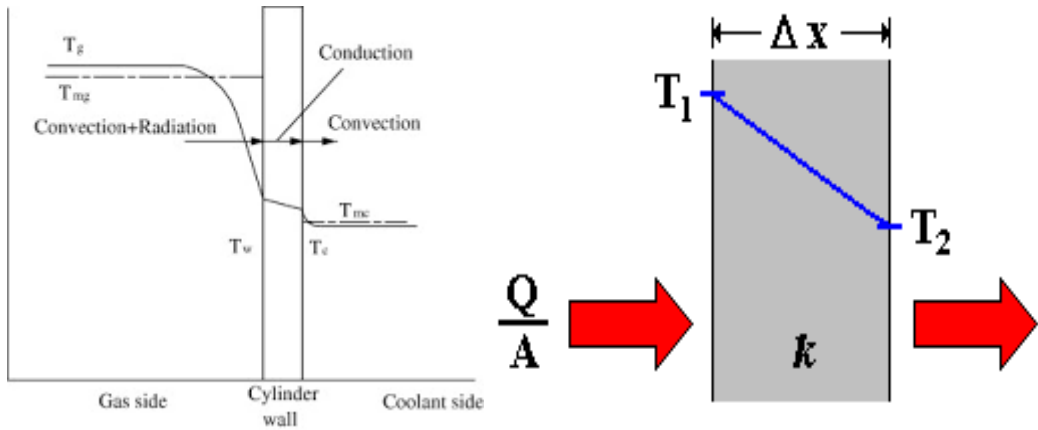


Figure 6.6 : Convection Heat Transfer

6.4.2 Conduction:

Conduction heat transfer means transportation of energy in a solid body by vibration of atoms, so molecules and electrons carry the heat from one atom to another in the solid.

The equation for the conduction of heat transfer:

Fourier's Equation:

Equation For Conduction Heat Transfer

$$\frac{Q}{A} = K * \frac{dt}{dx} \quad [W/ m^2]$$

Where K thermal conductivities (W/m.k)

Thermal conductivity changes from material to another.

6.4.3 Radiation :

Heat transfer by radiation is energy transportation due to emission of electromagnetic waves or photons from a surface or volume.

Radiation heat transfer can occur in a vacuum so it does not need a medium.

The heat lost by radiation is described by the Stefan Boltzmann Radiation Law which is expressed as:

Table 6.3 Equation For Radiation Heat Transfer Table

$qr = \epsilon \sigma * (T^4 - T_o^4)$		
Qr	the heat flow per unit time and per unit area	W /m²
ε	material emissivity	
Σ	the Stefan Boltzmann Constant	
$\sigma = 5.67 * 10^{-8} \quad [W/m^2.K^4]$		

In our case, in a one cylinder –four – stroke cycle engine we are going to make the calculation for the heat transfer for the engine:

There Are Three Ways:

- 1- By Convection from combustion room to cylinder wall
- 2- By Conduction through Cylinder wall
- 3- By Convection from Cylinder wall to surrounding

6.5 Areas

Cylinder internal wall area= $2 r \pi L$

6.6 Heat Transfer Without Fan :

1- We find Renold's number (Re):

$$Re = \rho * v * L / \mu$$

IF $Re < 5 * 10^5 \rightarrow$ Laminar Flow

2- We find Prandel Number (Pr) :

$$Pr = \mu * Cp / k$$

3- We find Nuslet Number (Nu):

$$(Nu) = 0.664 * Re^{0.5} * Pr^{1/3}$$

4- We find h:

$$\text{Nu} = h * L/k \quad \text{Then } h = \text{Nu} * k/L$$

5- We find Fins Efficiency :

$$\eta_{\text{fin}} = \tanh ml / ml$$

6-We find heat resistance by conduction (Rcond) :

$$R_{\text{cond}} = [\ln (r_2/ r_1)/2\pi Lk]$$

7- We find heat resistance by convection (R conv) :

$$R_{\text{conv}} = [1/ A^0 * h^0 (1 + Af / A^0) \eta_{\text{fin}}]$$

8- We find q :

$$Q = T_i - T_{\infty} / R_c + R_v$$

6.7 Heat Transfer By Using Fan:

We find Q after we use a fan with 150 CFM and 6m/s.

1-We find Renolds number

$$= \rho * V * l / \mu :$$

$$= Re < 5 * 10^5 \rightarrow \text{Laminar Flow}$$

2-We find Prandel number (pr):

$$Pr = \mu * Cp/k$$

3-We find Nuslet number :

$$Nu = 0.664 * Re^{1/2} * Pr^{1/3}$$

4. We find h :

$$Nu = h * L / K \rightarrow h = Nu * K / L$$

5. We find fin efficiency :

$$\eta_{fin} = \tanh m_l / m_l$$

6-We find heat resistance by conduction (Rcond) :

$$R_{cond} = [\ln(r_2 / r_1) / 2\pi L k]$$

7- We find heat resistance by convection (R conv) :

$$R_{conv} = [1/A^0 * h^0 (1 + Af/A^0) \eta_{fin}]$$

$$Q = (T_i - T_\infty) / (R_c + R_v)$$

6.8 Heat Transfer And Engine Energy Balance :

We find that when Q increase the fuel (m) will increase and the temperature inside the cylinder will detracts and the following shown equation in Figure 6.7

The diagram shows the energy balance equation for an engine: $\dot{m}_f h_f + \dot{m}_a h_a = P_b + \dot{Q}_{coolant} + \dot{Q}_{misc} + (\dot{m}_f + \dot{m}_a) h_e$. Three blue arrows point from descriptive text below to terms in the equation: one from 'Brake power' to P_b , one from 'Heat rejected to oil (if separately cooled) convection + radiation engine's external surface.' to $\dot{Q}_{coolant}$, and one from 'Enthalpy of burned and unburned gas mixture' to $(\dot{m}_f + \dot{m}_a) h_e$.

$$\dot{m}_f h_f + \dot{m}_a h_a = P_b + \dot{Q}_{coolant} + \dot{Q}_{misc} + (\dot{m}_f + \dot{m}_a) h_e$$

Brake power

Heat rejected to oil (if separately cooled) convection + radiation engine's external surface.

Enthalpy of burned and unburned gas mixture

Figure 6.7 : Heat transfer and engine energy balance

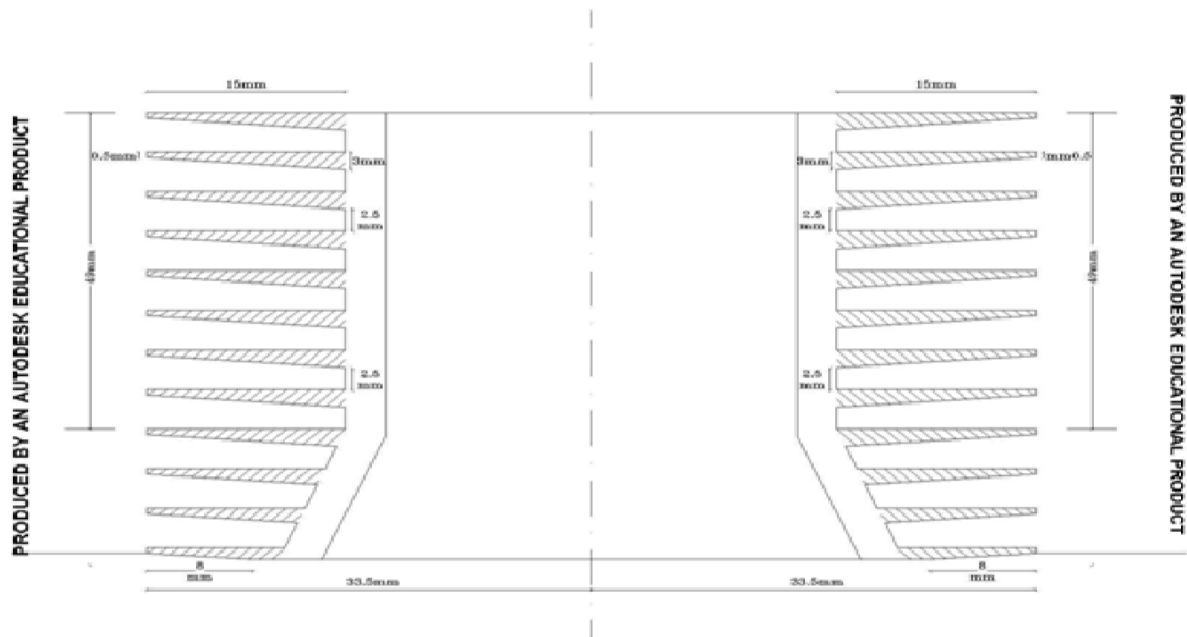


Figure 6.8 : Air - Cooled Event Fins

6.9 Technical Justification For Supplying A single Cylinder Engine With a Cooling System :

1. Specify the distance between the fan and the engine:

The angle and distance between the propeller and the engine were specified at a 30 and 50 cm angle in order to cover as much of the cylinder surface as possible without losing air using the air correctly and maintaining the appropriate temperature.

2 . Specify the sensor temperature location:

Where the sense of temperature attached to the outer surface of the cylinder and specified at the eighth fin at the bottom of the cylinder to measure the temperature of the surface cylinder when the piston at the bottom dead point

3. Specify how to choose the angle shape of the blade.

Where the shape of the angle of the blade was chosen to drive a suitable amount of air to cool the engine and with less noise

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 internal combustion can controlling the speed and the load on the dynamometer to record and analyses the results gained by the dynamometer are real and close to the standard to consolidate the theoretical information that obtained by the student in theoretical studying . and the student can do a lot of experiments in this laboratory to apply , including the calculations of engine efficiency, and the calculation of the indicated power and brake power, where we need to reach the measurements required to complete the experiment , , as well as the measurements and analysis of the combustion products ,and record the quantitative data and qualitative data for measurements required, to make an interpretation where it measurements and graphical signal is not true and accurate . In addition checked the pressure gauge sensor inside the cylinder head (Piezoelectric) and to know the locate the piston position and the number of engine cycles by encoder , and strain-gage load cells ,with data processing and conversion programs , each program on the computer to process data collected by using VDAS (Versatile Data Acquisition System) and ECA100 (engine cycle analyzer), we also calculated performance for such as speed, torque, separation power, fuel consumption, PV graph and P- α charts.

Recommendation:

- ❖ Occupational safety and health must be taken into account during testing
- ❖ Follow the correct operating procedures accurately.
- ❖ Add a special sensor to calculate the amount and temperature of air entering the combustion chamber.
- ❖ Perform periodic maintenance of the engine by estimating the number of engine working hours.
- ❖ Provide an oxygen sensor on the exhaust gas outlet for the λ calculation.

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