Palestine Polytechnic University

College of Engineering

Temperature measutment of engine cylinder wall by using thermocuple

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Abstract

Maintaining engine temperature is one of the most important things to consider in internal combustion engines manufacturing, as the temperature increases significantly the engine parts will be damaged, the vehicle will have poor performance and the air pollution caused by the engine will also increase.

This project focused on measuring the temperatures of the cylinder wall caused by air fuel mixture combustion inside the combustion chamber of the engine in order to make an educational model showing the values of these temperatures on a digital screen which was installed on the engine to reduce the gap between the actual concepts and the theoretical concepts that are learned in internal combustion 1 and 2 courses also this project will help in studying the heat transfer in the engine.

Methods of heat transfer in the gasoline engine and measure the temperature of the cylinder wall produced by the compustion of fuel and air was studed in this project, this project results that the maximun temperature for cylinder head is at ideal load then it decreases at part load then it increases again at full load but it does not reach the maximum temperature, the maximum temperature for the top dead center is at full load then it decreases at both ideal and part loads, then the maximum temperature for the middle of the cylinder at ideal load, then it sligtly decreases at full load and significantly decreases at part load, then the maximum temperature for the bottom dead center is at ideal and full loads, then it decreases at part load,also it was found that the calculated temperature value of the cylinder wall is about **10**^{o}C higher than the maximum measured value**.**

الملخص

المحافظة على درجة حرارة محرك معتدلة من أهم الأمور التي يجب مراعاتها في تصنيع المركبات ومحركات الاحتراق الداخلي حيث أن ارتفاع درجة الحرارة إلى حد كبير يؤدي إلى تلف أجزاء المحرك وضعف أداء المركبة وزيادة نسبة التلوث والانبعاثات الناجمة عن المحرك.

سيركز هذا المشروع على قياس درجات حرارة جدار الاسطوانة الناتج عن احتراق خليط الوقود والهواء داخل غرفة الاحتراق للمحرك من أجل عمل نموذج تعليمي يوضح قيم درجات الحرارة على شاشة رقمية تم تركيبها على المحرك لتقليل الفجوة بين المفاهيم الفعلية والمفاهيم النظرية التي يتم اعطاءها في مساقات الاحتراق الداخلي 1 و 2 أيضاً سيساعد هذا المشروع في تعلم انتقال الحرارة في المحرك.

تم دراسة طرق انتقال الحرارة في محرك البنزين وقياس درجة حرارة جدار الأسطوانة الناتج عن احتراق الوقود والهواء في هذا المشروع ، وينتج عن هذا المشروع أن أقصى درجة حرارة لرأس الأسطوانة هي عند سرعة دوران المحرك المنخفضة ثم تقل عند سرعة دوران المحرك المتوسطة ثم تزداد مرة أخرى عند سرعة دوران المحرك القصوى ولكنها لا تصل إلى درجة الحرارة عند سرعة دوران المحرك المنخفضة، وتكون أقصى درجة حرارة للنقطة الميتة العليا عند سرعة دوران المحرك القصوى، ثم تقل عند كل من السرعة المنخفضة والمتوسطة، ثم تكون درجة الحرارة القصوى لمنتصف الاسطوانة عند سرعة دوران المحرك المنخفضة ، ثم تنخفض بشكل ملحوظ عند السرعة القصوى وتنخفض بشكل ملحوظ عند السرعة المتوسطة، ثم تكون درجة الحرارة القصوى للنقطة الميتة السفلى عند السرعة المنخفضة والقصوى، ثم تقل عند السرعة المتوسطة، كما وجد أن قيمة درجة الحرارة المحسوبة لجدار الأسطوانة أعلى بحوالي 10 درجات مئوية من القيمة القصوى المقاسة.

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Chapter one

Introduction

1.1 Introduction

Combustion is the basic chemical process of releasing energy from a fuel and air mixture. In an internal combustion engine (ICE), the ignition and combustion of the fuel occurs within the engine itself, which partially converts the combustion energy into work to drive the load. In ICE's the heat is generated by burning the fuel-air mixture inside the combustion chamber. This combustion produces a high temperature inside the engine cylinder.

This project is important in studying the heat transfer in engine and to measure the temperature of the cylinder wall caused by the air-fuel combustion in gasoline engine by planting sensors in the cylinder head and cylinder of the engine.

1.2 Literature Review

A non-intrusive thermometry method using full spectral analysis of hot soot radiation is developed for use in large two stroke diesel engines. The investigation is performed as a proof of concept, focusing on reliability and accuracy of the method.

By performing quasi one-dimensional measurements of the soot luminescence intensity and comparing them to ideal values, temperatures and emissivity's are calculated. It is determined that for flame temperature measurements, the wavelength dependency of soot emissivity is of great influence on the estimated temperatures based on full spectral analysis. [1]

1.3 Project objectives

This project aims to build and test a temperature measurement system to be planted in the engine cylinder and head in order to help in studying the heat transfer in engine and to measure the temperature of the cylinder wall caused by the air-fuel combustion in gasoline engine by planting sensors in the engine head and cylinder. Then it will show the temperature measurements from the sensors on a digital screen and demonstrate the values on charts.

1. Search for the importance of Heat transfer in ICE's.
2. Discuss the results of measurement and calculations.
3. To make an educational prototype.

1.4 Project Schedule and Time Plan

Task 1: Select the idea.

Task 2: Searching for data in the field of the project in order to understand the concept of the project.

Task 3: Determining the needed mechanical and electrical hardware of the project.

Task 4: Fabricating the prototype.

Task 5: Preparing the presentation.

Table 1.1: Second semester time plan.

Week Task	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
T1																
T2																
T3																
T4																
T5																

Chapter Two

Theory

Theory

This chapter explain the heat generated by gasoline engine and the importance of heat transfer and studies the methods of heat transfer and explains it in a simplified form, also it discusses the engine used in the project.

2.1 Temperature in internal combustion engine

In internal combustion engines the heat generated by the burning of fuel and air inside the combustion chamber that raises the pressure inside the combustion chamber that generates energy to affect the piston surface of this piston and generate force to moving it.

The chemical energy has been converted into kinetic energy to drive the vehicle and take advantage of other things.

2.2 Important of Heat Transfer

The high burned gas temperature in internal combustion engine is about 2500 K. the max metal temperatures for the inside of engine cylinder space are limited to much lower values by a number of considerations, and cooling for the cylinder head, cylinder, and piston must therefore be provided. These conditions lead to heat fluxes to the chamber walls that can reach as high as 10 MW/m^2 during the combustion period. [2]

The flux change substantially with location: regions of the chamber that are contacted by rapidly moving high-temperature burned gases generally experience the highest fluxes. In regions of high heat flux, thermal stresses must be kept below levels that would cause failure (so temperatures must be less than about 400 ^oC for cast iron and 300 ^oC for aluminum). [2]

The gas-side surface of the cylinder wall must be kept below about 200 ^oC to prevent declining of the lubricating oil. Valves and Spark plug must be kept cool to avoid knock and pre-ignition problems which result from overheated spark plug electrodes or exhaust valves. Solving these engine heat-transfer problems is obviously a major design task.

Heat transfer affects engine performance, emissions and efficiency. For a given mass of fuel within the cylinder, higher heat transfer to the combustion chamber walls will lower the average combustion gas temperature and pressure, and reduce the work per cycle transferred to the piston.

Thus specific power and efficiency are affected by the quantity of engine heat transfer. Heat transfer between the unburned charge and the chamber walls in spark-ignition engines affects the onset of knock which by limiting the compression ratio, also affects power and efficiency. Most critical is heat transfer from the hot exhaust valve and piston to mixture in the end-gas region. Changes in gas temperature due to the heat-transfer impact on emission formation processes, both within the engine's cylinder and in the exhaust system where afterburning of CO and HC occurs.

2.3 Heat Transfer Mechanisms

In the internal combustion engine, there are three mechanisms of heat transfer:

1. Convection
2. Conduction
3. Radiation

2.3.1 Convection

Convection heat transfer is energy transport due to bulk fluid motion. Convection heat through gasses and liquids from a solid boundary results from the fluid motion along the surface.

Newton determined that the heat transfer/area **Q/A**, is proportional to the fluid solid temperature difference (TS-Tf). The temperature difference usually occurs across a thin layer of fluid adjacent to the solid surface. The constant of proportional is called the convection heat transfer coefficient.

Newton's Equation [3].

$$Q/A = h\,(T_s - T_f) \qquad (2.1)$$

The convection heat transfer coefficient depends on the type of fluid (density) and the fluid velocity. The heat flux depends on the area of interest either the local or the average area.

2.3.2 Conduction

Conduction heat transfer as shown in Figure 2.1 is energy transport due to molecular motion and interaction. Conduction heat transfer through solids is due to molecular vibration. Fourier determined that Q/A, the heat transfer per unit area (W/m^2), is proportional to the temperature gradient dT/dx. The constant of proportionality is called the material thermal conductivity.

Fourier's equation [3].

$$Q/A = -K\frac{dT}{dx} \qquad (2.2)$$

The thermal conductivity also depends somewhat on the temperature of the material.

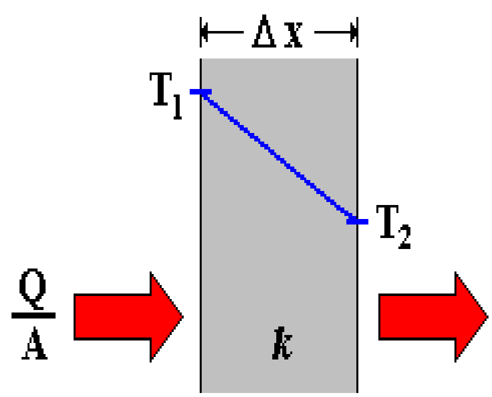


Figure 2.1: Conduction heat transfer

2.3.3 Radiation

Radiation heat transfer is energy transport due to emission of electromagnetic waves or photons or volume. The radiation does not require a heat transfer medium and occur in a vacuum. The heat transfer by radiation is proportional to the fourth power of the absolute material temperature. The proportionality constant sigma is the Stefan-Boltzmann constant which equals $5.76*10^{-8}$ W/m^2k^4 .The radiation heat transfer also depends on the material represented by ε, the emissivity of the material.

$$Q/A = \varepsilon\sigma\ T^4 \tag{2.3}$$

2.4 Engine cylinder heat transfer

In engine cylinder the heat transfer begin from the center of the combustion chamber, it has high temperature values, then heat transfer with convection gas has convection heat transfer coefficient from the center of the combustion chamber to the piston face , cylinder head and cylinder wall, then conduction throw walls with cylinder , piston and cylinder head which have thermal conductivity, then convection from these walls to cooling water into water jackets which have convection heat transfer coefficient and the temperature of cooling water is(tc), then radiation to outer environment as shown in Fig 2.2.

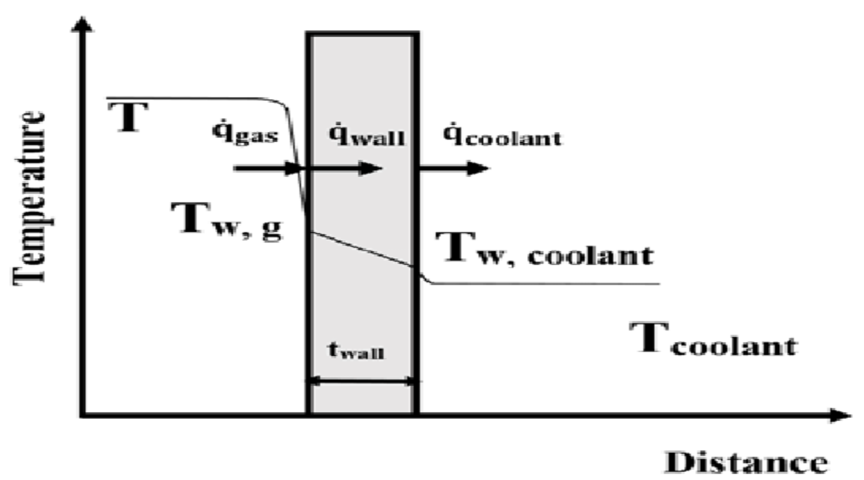


Figure 2.2: Heat transfer between cylinder gas and engine coolant

There are several factors that greatly affect the heat transfer in Gasoline engines. Mention and explain them in the next section.

2.5 Parameters Affecting engine heat Transfer

From the above discussion, it may be noted that the engine heat transfer depends upon many parameters. Unless the effect of these parameters is known, the design of a proper cooling system will be difficult. In this section, the effect of various parameters on engine heat transfer is briefly discussed.

1-Fuel – air ratio (F/A):

A change in F/A ratio will change the temperature of the cylinder gases and affect the flame speed. The maximum gas temperature will occur at an equivalence ratio of about 1.12, at F/A ratio about 0.075. At this F/A ratio ΔT will be a maximum.

2- Compression ratio:

An increase in compression ratio cause only a slight increase in gas temperature near the top dead center, but, because of greater expansion of the gases, there will be a considerable reduction in gas temperature near bottom dead center where a large cylinder wall is exposed.

3- Spark timing:

A spark advance more than the optimum as well as lee than the optimum (retard) will result in increased heat rejection to the cooling system. This is mainly due to the fact that the spark timing other than MBT (Minimum spark advance for Best Torque) will reduce the power output and thereby more heat is rejected.

4- Pre-ignition and knocking:

Effect of Pre-ignition is the same as advancing the ignition timing. Larger spark advance might lead to erratic running and knocking. Though knocking causes larger changes in local heat transfer conditions, the effect of Pre-ignition and knocking on engine heat transfer.

5- Engine output:

Engines which are designed for high mean effective pressure or high piston speed, heat transfer will be less.

2.6 Single-cylinder engine

A single-cylinder engine as shown in Figure 2.3 is a type of internal combustion engine that is based on the conversion of chemical energy to mechanical energy. The most common cylinder engines are gasoline or diesel. These engines are often seen on motorcycles, rickshaws, scooters, dirt bikes, small cars and radio-controlled models, and have many uses in portable tools and garden machines.

Figure 2.3 A single-cylinder motorcycle engine

2.6.1 Engine specification

Sym Wolf 125 Classic Engine	
Engine type - Number of cylinders	**Single cylinder, four-stroke**
Fuel system	**Carburetor**
Engine size - Displacement - Engine capacity	**124.60 ccm (7.60 cubic inches)**
Bore x Stroke	**56.5 x 60.5 mm (2.2 x 1.9 inches)**
Compression Ratio	**9.0:1**
Number of valves per cylinder	**4**
Maximum power - Output - Horsepower	**8 HP (6.0 kW) @ 2400 RPM**
Maximum torque	**5.80 Nm @ 2400 RPM**
Engine Maximum RPM	**2400**
Cooling system	**Air**

2.7 Engine sketch

Chapter Three

Implementation and Design

Implementation and Design

In the process of implementation of the project many problems occurred and some of them were a bit difficult, these problems included failure of the engine due to the damage of several mechanical components, and difficulty of reading the sensors measurements because they needed a MAX6675 module to amplify the sensors output voltage in order to allow the Arduino to read the measurements correctly, finally after solving all the problems, the project was implemented properly and the results were taken.

This chapter will focus on the problems and their solutions also the Arduino code and finally the measured results.

3.1 Engine maintenance

A SYM engine (San-Yang Motor) was chosen for the project, at the beginning the engine did not work at all. After the diagnoses it was found that the ignition timing regulator is damaged. The problem was solved by replacing it. Then the engine was dismantled and sent to a lathe in order to plant the sensors in place as explained in chapter two.

After the operation of the lathe, the engine was assembled and tested but there was no enough pressure. After checking the problem, the pressure rings were found to not work properly. The engine was disassembled again, the rings were replaced, the engine was assembled, the sensors were implemented and the engine was turned on.

After the maintenance, the engine was ready to work and the temperature measurements were ready to be taken after the implementation of the electrical connection.

3.2 Design

An air cooled SYM single-cylinder engine and a thermocouple J type sensors to measure the temperature were used, Figure 3.1 shows the thermocouple sensors, which were planted in four different places: the first sensor is located at the cylinder head as shown in figure 3.2, the second sensor was located at the top dead center (TDC), the third sensor is located at the middle as shown in Figure 3.3, and the fourth sensor is located at the bottom dead center as shown in figure 3.4.

Figure 3.1. Thermocouple J Type

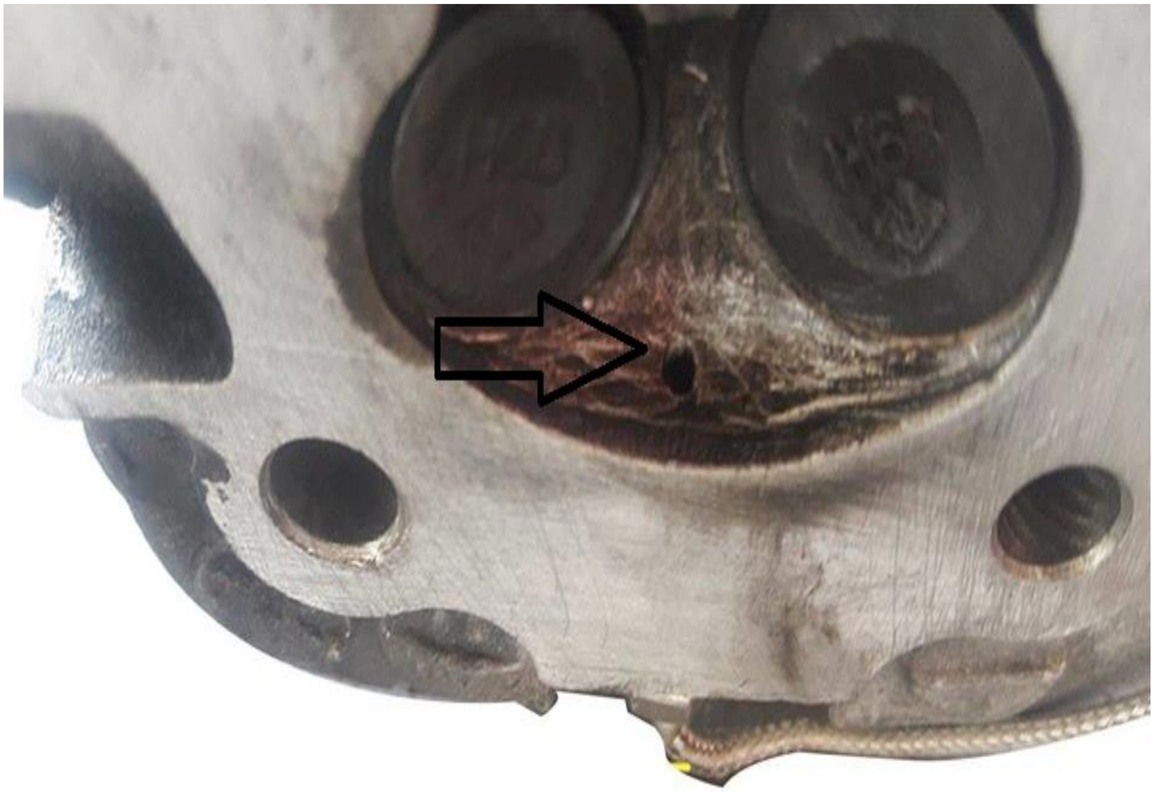


Figure 3.2 Location of sensor in cylinder head

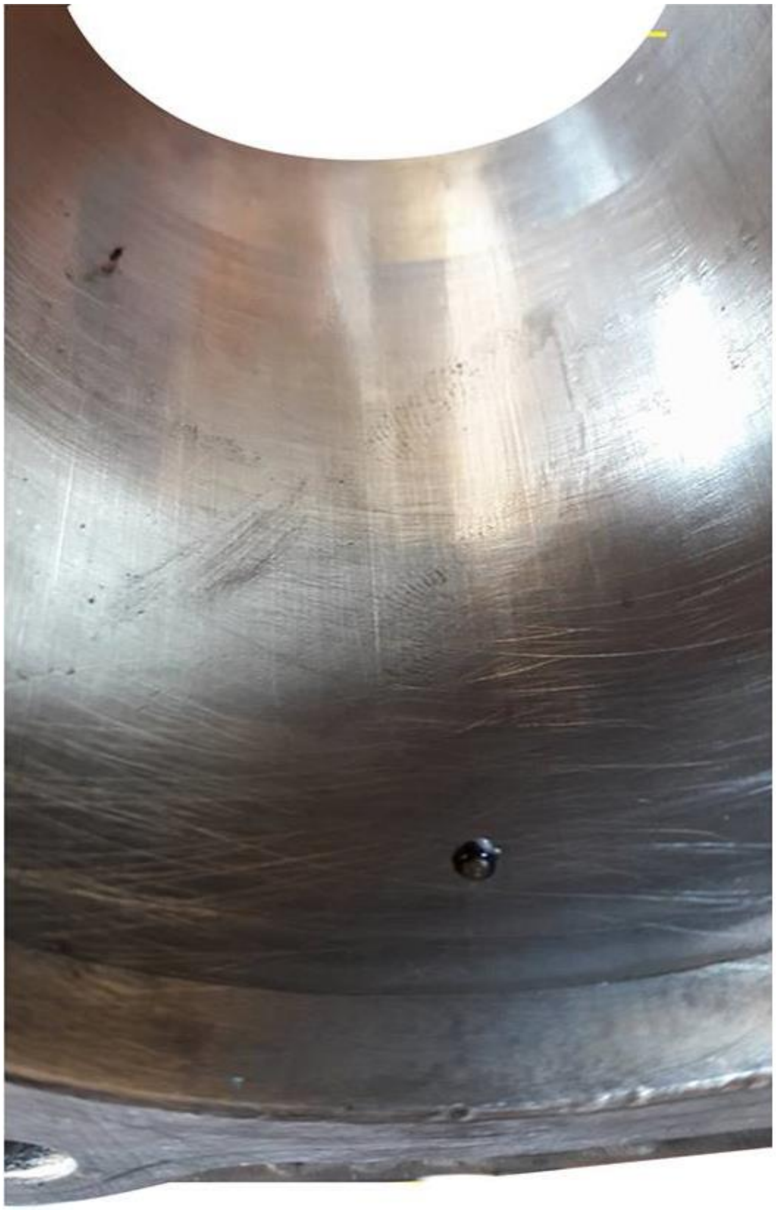


Figure 3.3. Location of sensor in top dead center (TDC)

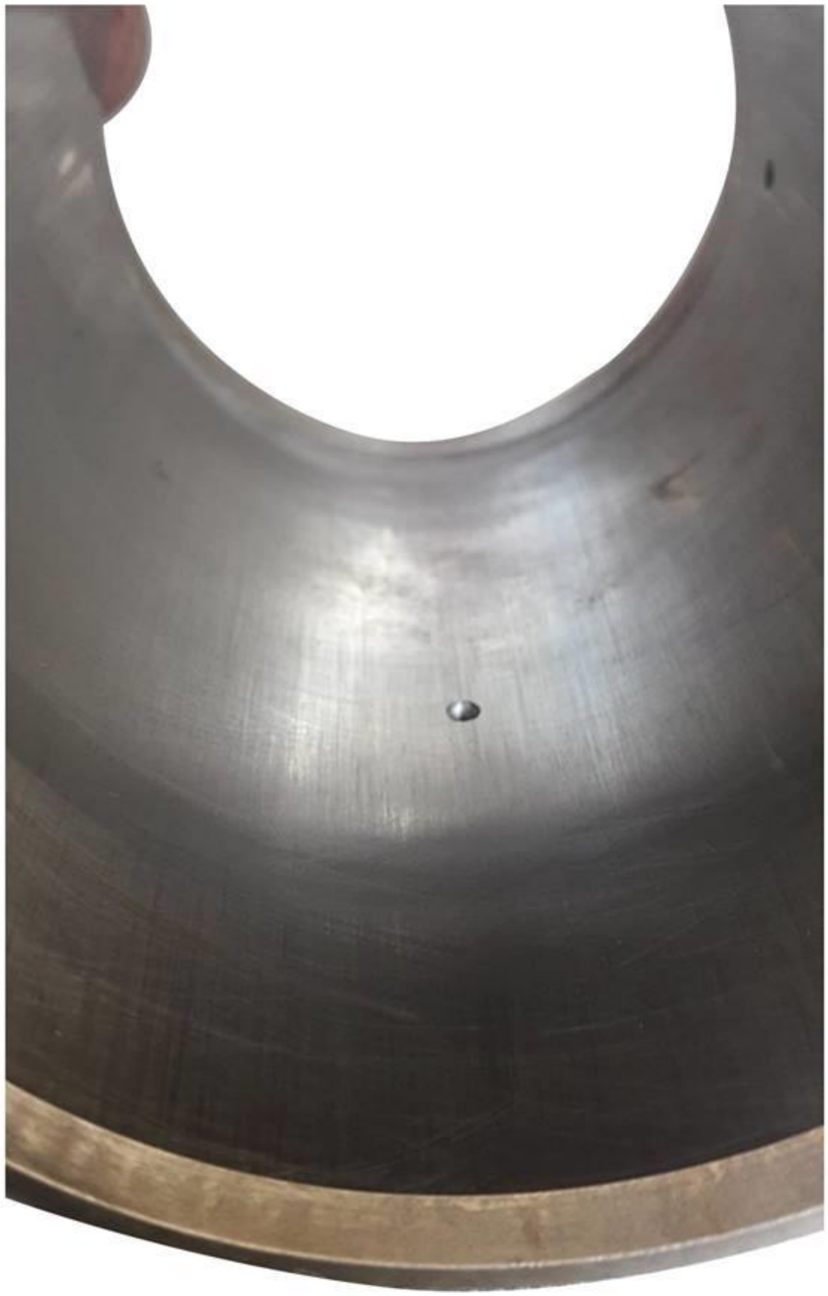


Figure 3.4 Location of sensor in the middle of cylinder

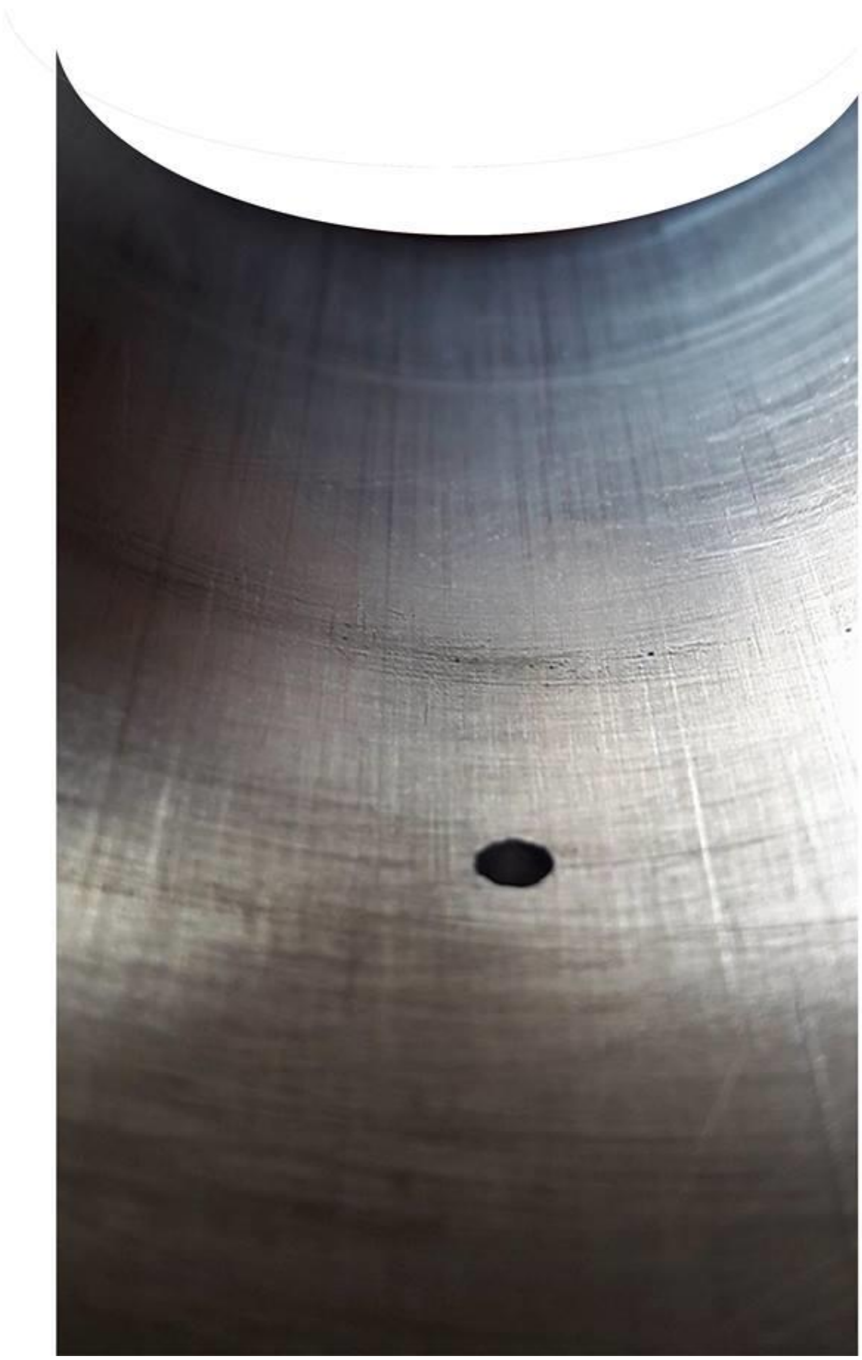


Figure 3.5 Location of sensor in bottom dead center

3.3 Thermocouple J Type

A thermocouple Type J is made up of two dissimilar conductors (Iron and Constantan) is contact with one another, which produce a voltage when heated. Thermocouples are used as temperature sensors for measurement and control and can also be used to convert a temperature gradient into electricity as shown in Figure 3.6.

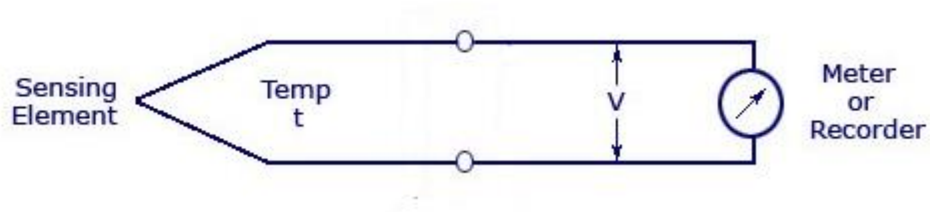


Figure 3.6 Internal connection for Thermocouple

The J Type thermocouple (iron–constantan) is a common, general purpose thermocouple with a temperature range of approximately −40 to +750 °C, and sensitivity of 55 µV/°C. Wire color standard is red (+) and blue (-).

Commercial thermocouples are inexpensive, [4] interchangeable, are supplied with standard connectors, and can measure a wide range of temperatures. In contrast to most other methods of temperature measurement, thermocouples are self-powered and require no external form of excitation. The main limitation with thermocouples is accuracy; system errors of less than one degree Celsius (° C) can be difficult to achieve. [5]

Thermocouples are widely used in science and industry. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes. Thermocouples are also used in homes, offices and businesses as the temperature sensors in thermostats, and also as flame sensors in safety devices for gas-powered appliances.

Advantages of thermocouples

- Interchangeable with well-defined and repeatable output.
- Self-Exciting (no external power supply required, and hence no self-heating problem).
- Wide temperature measurement range -200°C to 1350°C. (Note: the MAX6675 operates from 0°C to 1024°C).
- NIST Reference tables exist to allow error correction.
- Possibility if error correction compensation using polynomial functions.
- Very fast response time.
- Convenient and small measurement probe - therefore low thermal mass.

Disadvantages of thermocouples

- Cannot measure lower temperature ranges at high accuracy e.g. 0.1°C (without clever circuits).
- Not too accurate: Typically 2.2°C for Type K (the thermocouple response alone).
- Requires no thermal gradient across the system i.e. draughts will cause errors
- Requires correct thermocouple extension wire to reach distant measuring points.
- Errors can easily be introduced by incorrect thermal mounting of chip.

3.4 Max6675

MAX6675 show Figure 3.7, is a thermal temperature sensor amplifier that connect with Arduino having linear correction, thermal break detection and ADC serial output, in this connection the temperature range from -40 to 900 ° C, wide operating voltage range 3.0 ~ 5.5 volts.

Four modules of MAX6675 were used in the project where each sensor needed one MAX6675 module to allow the Arduino to read the temperature.

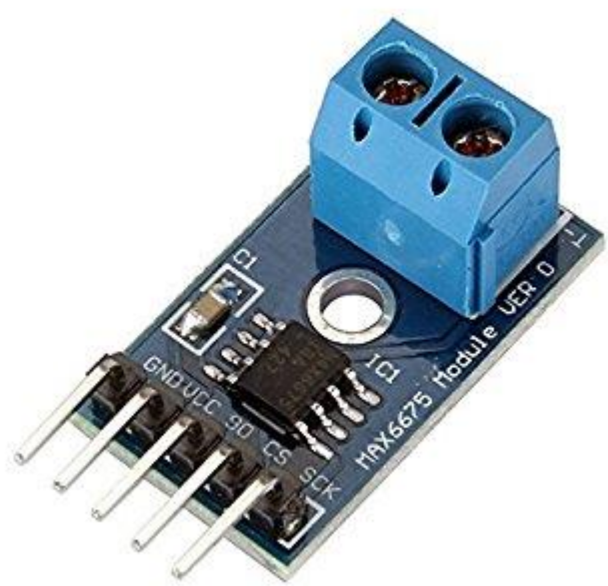


Figure 3.7 MAX6675

3.5 Arduino Uno

Arduino Uno as shown in Figure 3.8 is a microcontroller board It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller, simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

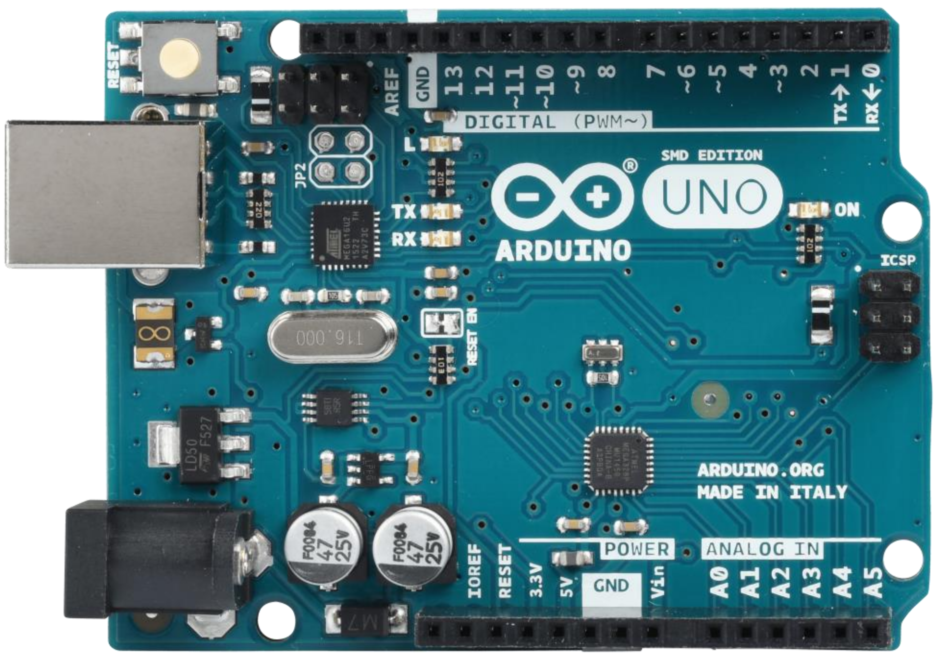


Figure3.8 Arduino Uno

Arduino has been used in thousands of different projects and applications. The Arduino software is easy-to-use for beginners, yet flexible enough for advanced users. It runs on Mac, Windows, and Linux. Teachers and students use it to build low cost scientific instruments, to prove chemistry and physics principles, or to get started with programming and robotics. Designers and architects build interactive prototypes, musicians and artists use it for installations and to experiment with new musical instruments. Makers, of course, use it to build many of the projects exhibited at the Maker Faire, for example.

Arduino is a key tool to learn new things. Anyone - children, hobbyists, artists, programmers - can start tinkering just following the step-by-step instructions of a kit, or sharing ideas online with other members of the Arduino community.

3.5.1 Arduino code

There is a special code to sensor can read temperature and display the heat on digital screen , This code is built on Arduino program and store the temperature value on Excel.

```
#include "max6675.h"

#include <LiquidCrystal.h>


// initialize the library by associating any needed LCD interface pin

// with the arduino pin number it is connected to

const int rs = 13, en = 12, d4 = 11, d5 = 10, d6 = 9, d7 = 8;

LiquidCrystal lcd(rs, en, d4, d5, d6, d7);


int thermoD0=4;

int thermoCLK=6;

int thermoCS1=5;

int thermoCS2=3;

int thermoCS3=2;

int thermoCS4=1;
```

```
MAX6675 thermocouple1(thermoCLK,thermoCS1,thermoD0);

MAX6675 thermocouple2(thermoCLK,thermoCS2,thermoD0);

MAX6675 thermocouple3(thermoCLK,thermoCS3,thermoD0);

MAX6675 thermocouple4(thermoCLK,thermoCS4,thermoD0);

float temp1=0.0;

float temp2=0.0;

float temp3=0.0;

float temp4=0.0;

void setup() {

  // set up the LCD's number of columns and rows:

  lcd.begin(16, 2);

  Serial.begin(9600);

}

void loop() {

  Serial.print("s1= ");

  Serial.print(thermocouple1.readCelsius());

  Serial.print(" s2= ");

  Serial.println(thermocouple2.readCelsius());

  Serial.print("  s3= ");

  Serial.print(thermocouple3.readCelsius());
```

```
Serial.print("    s4= ");
Serial.print(thermocouple4.readCelsius());
temp1 = thermocouple1.readCelsius();
temp2 = thermocouple2.readCelsius();
temp3 = thermocouple3.readCelsius();
temp4 = thermocouple4.readCelsius();
delay(179);
lcd.setCursor(0, 0);
lcd.print("1=");
lcd.print(thermocouple1.readCelsius());
lcd.setCursor(7, 0);
lcd.print("2=");
lcd.print(thermocouple2.readCelsius());
lcd.setCursor(0, 1);
lcd.print("3=");
lcd.print(thermocouple3.readCelsius());
lcd.setCursor(7, 1);
lcd.print("4=");
lcd.print(thermocouple4.readCelsius());}
```

3.6 Electrical connection

MAX6675 and J type thermocouple sensor and Arduino Uno program as shown in Figure 3.9 is a ready-to-use combination for measuring temperatures over 1000 ° C. This connection for one sensor and one module of MAX6675.

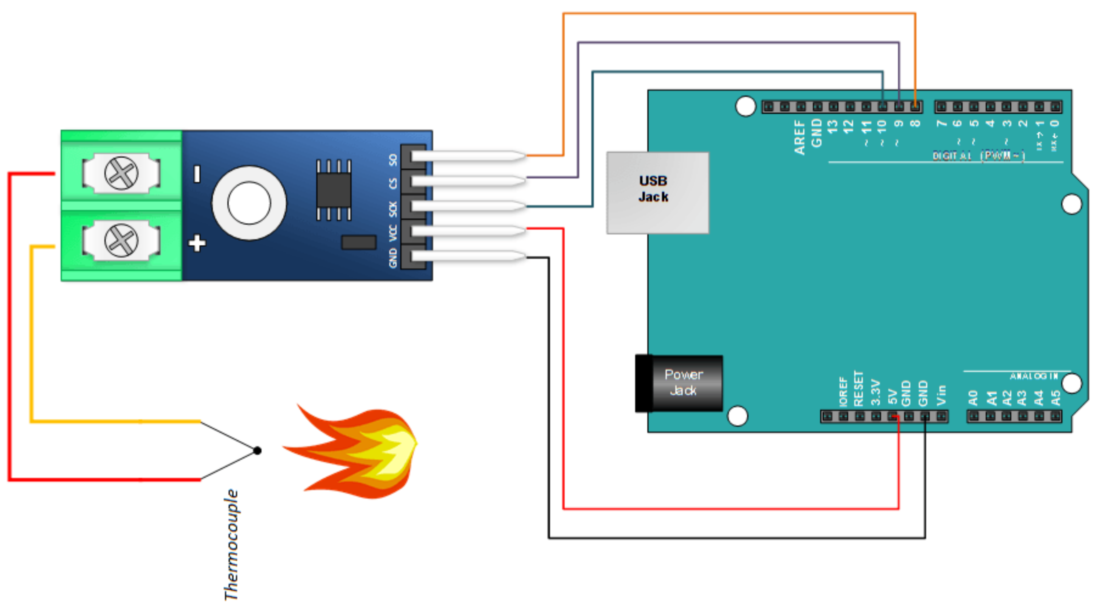


Figure 3.9 Electrical connection

3.6.1 Block Diagram for electrical connection

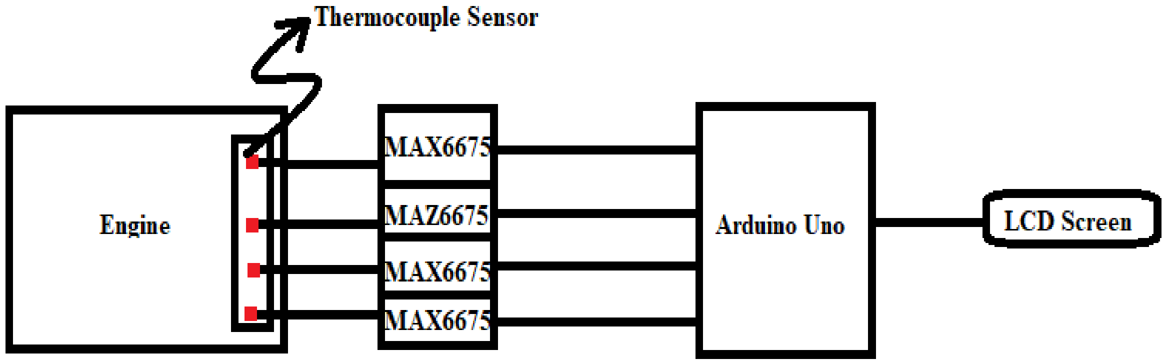


Figure 3.10. Bloke diagram

After creating the electrical connection mentioned earlier and writing the special code and flashing it to the Arduino and connect the Arduino to the computer, the Arduino program started so it is ready to read the heat generated from the combustion chamber and display temperature on LCD screen as shown in Figure 3.10, also drawing the relationship between temperature and operating time. where the readings of the four sensors that were planted in different working conditions, ideal load , partial load, and full load will be measured.

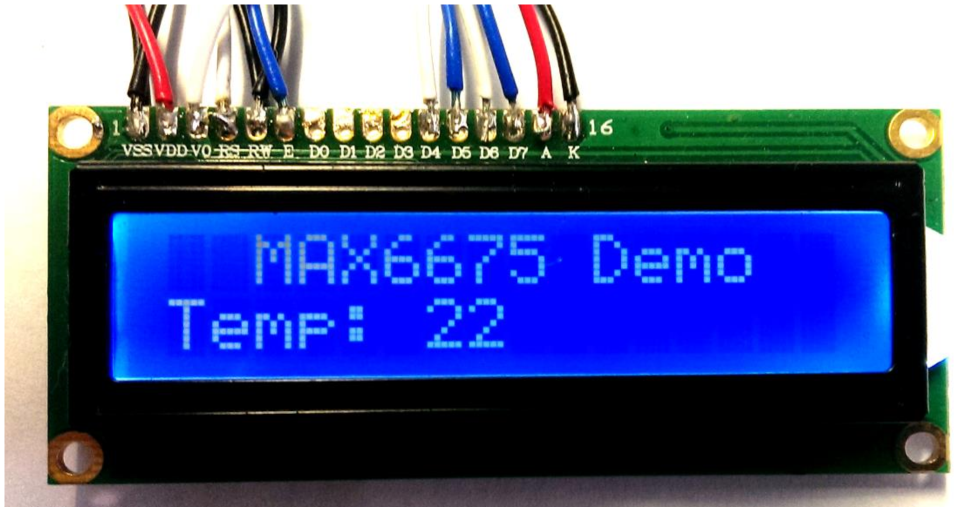


Figure 3.11. LM screen 16*2

Chapter Four

Result

This chapter focused on the both the calculated values of temprature and the expiramintal values that were taken from the thermocouple readings.

4.1 Temperature calculation

We start the calculation by calculating adiabatic temperature in order to find the gas temperature caused by the air fuel mixture combustion in the combustion chamber, then the wall temperature of the wall was calculated.

$$C_8\mathrm{H}_{18} + \mathrm{ath}(\mathrm{O}_2 + 3.76\mathrm{N}_2) \rightarrow \mathrm{x}\, H_2O + \mathrm{y}CO_2 + (3.76 \times ath\mathrm{N}_2)$$

C balance: y=8

H balance x=9

O balance: ath=12.5

ΔH product =ΔH reactant

$$\mathrm{H_P} = \sum \mathrm{N_P}\left[\overline{\mathrm{h}_f^0} + (\bar{\mathrm{h}} - \overline{\mathrm{h}^0})\right]_P , \quad = \quad \mathrm{H_R} = \sum \mathrm{N_R}\left[\overline{\mathrm{h}_f^0} + (\bar{\mathrm{h}} - \overline{\mathrm{h}^0})\right]_R$$

$$\mathrm{N}(\overline{h_f^o} + \bar{h} - \overline{h^o})\ CO_2 + \mathrm{N}(\overline{h_f^o} + \bar{h} - \overline{h^o})\ H_2O + \mathrm{N}(\overline{h_f^o} + \bar{h} - \overline{h^o})\ N_2 = \mathrm{N}(\overline{h_f^o})\ C_8H_{18}$$

Value of h_f^o and $\overline{h^o}$ from table A-26 and from tables A-18 to A-25 respectively [7].

$$9(-393520 + \bar{h} – 8669) + 8(-241820 + \bar{h} – 9,904) + 47(0+ \bar{h} – 8,669) = – 249950$$

$$– 402884 +8\ \bar{h} – 503,448+ 9\bar{h}+47\bar{h} –65,190= – 74,850$$

$$– 971,522.88 + 8\bar{h} + 9\bar{h} + 47\ \bar{h} = – 74,850$$

$$8\bar{h} + 9\bar{h} + 47\ \bar{h} = 5640521 \qquad (4.1)$$

So $\bar{h}_{\text{total}}$ = 88133 kg/kmol from tables A-18 to A-25 the value of enthalpy at adiabatic temperature equals 88133 for each composite [7].

T H_2O = 2150

T CO_2 = 1800

T N_2 = 2650

Now we take temperature at **2400 K**

h N_2 = 3728040

h CO_2 = 1001216

h H_2O = 931572

from equation 4.1

$9h\ CO_2 + 8h\ H_2O + 47\ h\ N_2 \leq 896{,}672.88$ (4.2)

Substituting the value of h in equation 4.2

$122{,}091 + 201692 + 582769.92 \leq 896{,}672.88$

$84778.5 \neq 88133$ **unacceptable**

So we take less heat value at **T = 2350 k**

h N_2 = 3642312

h CO_2 = 976725

h H_2O = 907614

We recalculate the values in equation 4.1

$5526654 \leq 88133$ **acceptable**

Now by interpolation value of T_{ad} was founded

$$\frac{2400 - T}{2400 - 2350} = \frac{5660828 - 5640521}{5660828 - 5526654}$$

$$\mathbf{T_{ad}} = \langle \mathbf{2392.5} \rangle \boldsymbol{k}$$

Then the temperature of the gas caused by air fuel combustion as is calculated as follows

Let Tg=2392.5-300 = **2092 Cº**

To calculate the value of the cylinder wall temperature, the heat transferred must be calculated by calculating the heat transfer coefficient first.

Heat transfer coefficient [6]

$$\frac{h(\underline{x},t)b}{k} = 10.4\left(\frac{U b}{\nu}\right)^{3/4} \quad \textbf{(4.2)}$$

Where :

h(x,t)= heat transfer coefficent

b = the cylinder bore

K= gas thermal conductivity (w/mK) , typical value .06

V = gas kinematic viscosity , (m^2/ s) typical value 100 x10-6

U = characteristic gas velocity (m/s)

$$\mathbf{U = 2 * \frac{rpm}{60} * stroke} \quad \textbf{(4.3)}$$

U= 2* 750\60 * 0.0605 = 1.512m\s

From equation 4.2 the heat transfer coefficient

h = 1745.56 W\m²k

$$\boldsymbol{Q = \dot{m} * cp * \Delta T} \quad \textbf{(4.4)}$$

Where:

$\dot{m}$ is the mass flow for C_8H_{18} and equals 0.002kg\s

Cp is the specific heat capacity for C_8H_{18} and equals 2.22 kJ\g

ΔT is the temperature mean differance and equals 2092 C^O

From equation (4.3)... Q = 0.002*2.22*2092 = **9288.48 W**

$Q_{out} = Q_{in}$ * efficiency

= 9288.48* 76% = **7059.24 W**

To calculate temperature of cylinder wall :

$$Q = hA\Delta T \qquad \textbf{(4.5)}$$

$7039.24 = 1745.60 * 0.0025* (2092-T_w)$

Tw = 201.39

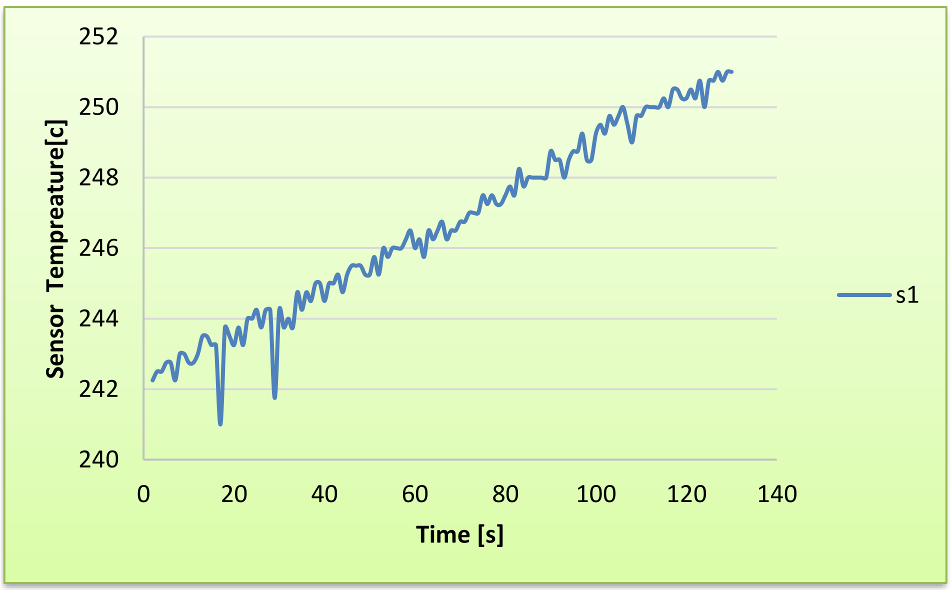
4.2 Temperature measurment

After starting the engine and raising the engine temperature to operating temperatures the temperature from the four sensor at idel load, part load , and full load were taken.

4.2.1 Measuring temperature at ideal load

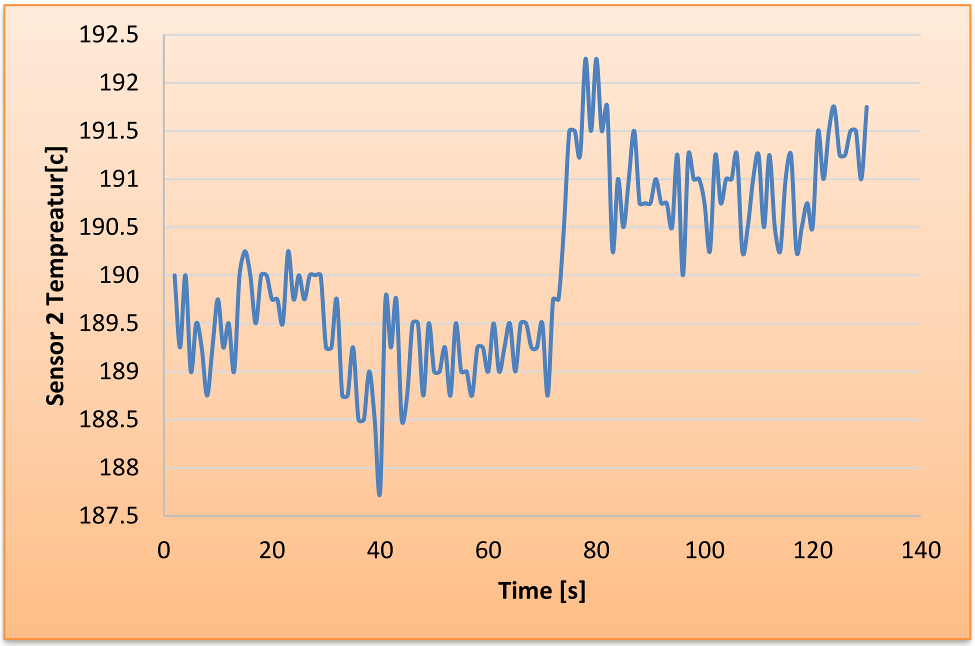
This reading was taken at idel speed @750 RPM for four sensor that was planted in engine .

4.2.1.1 Measuring sensor that located at cylinder head of engine



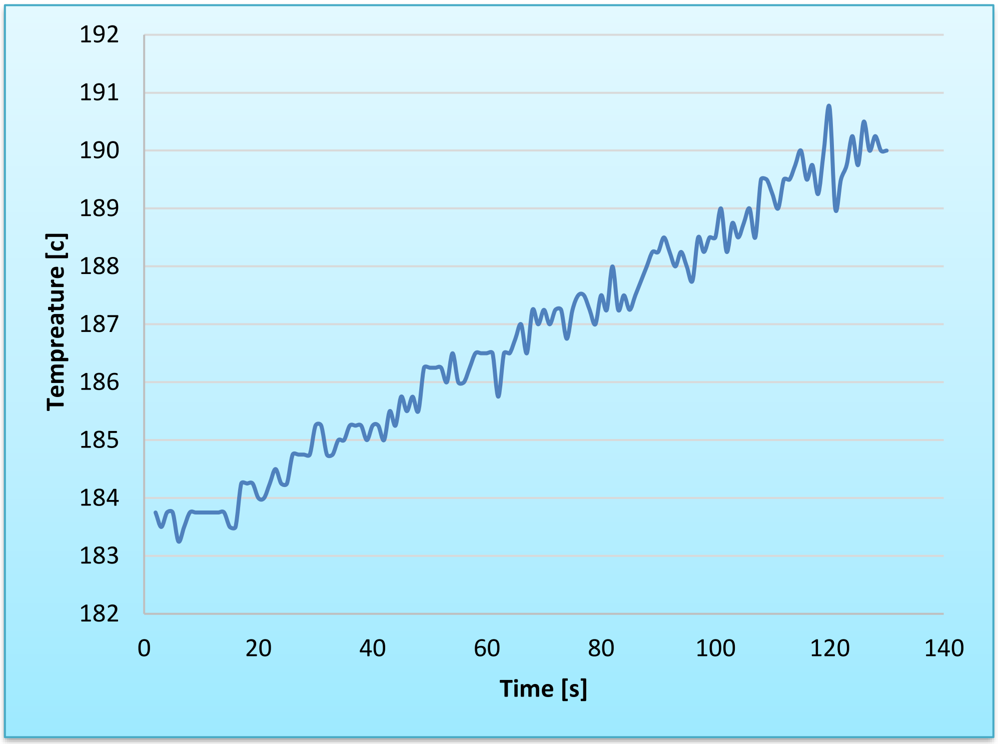
Graph 4. 1: Measuring temperature of cylinder head (sensor 1) at ideal speed

4.2.1.2 Measuring sensor that located at Top dead center



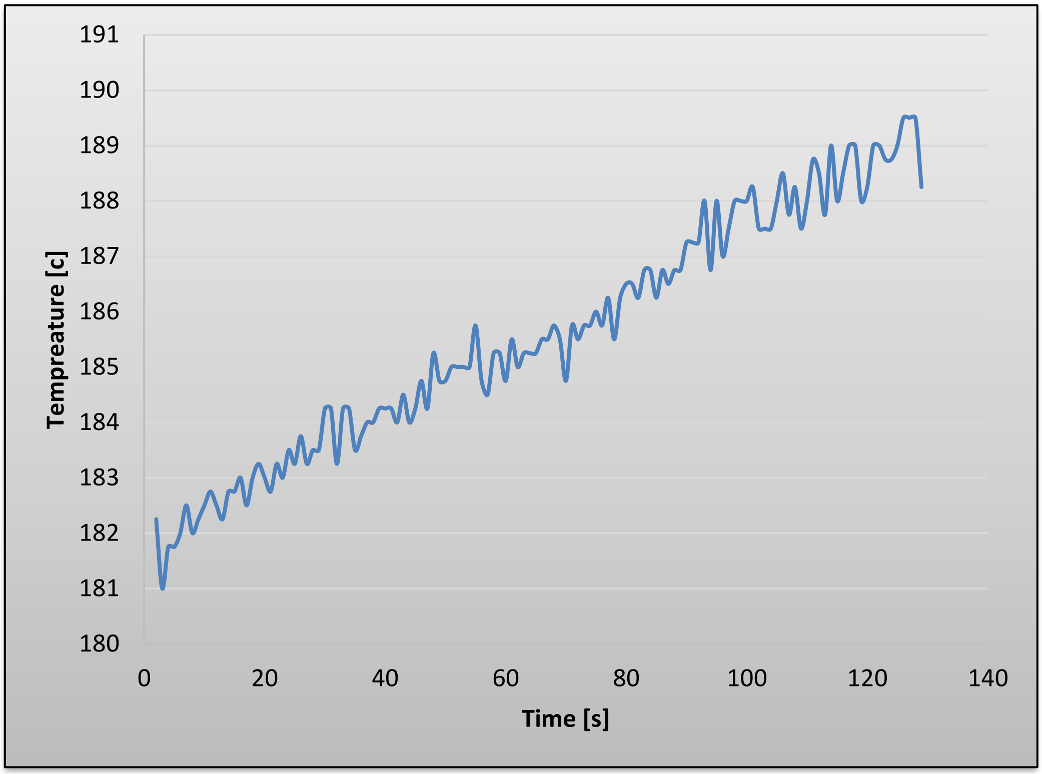
Graph 4. 2: Measuring temperature of Top dead center (sensor 2) at ideal speed

4.2.1.3 Measuring sensor that located at mid dead center



Graph 4. 3: Measuring temperature of mid dead center (sensor 3) at ideal speed

4.2.1.4 Measuring sensor that located at bottom dead center

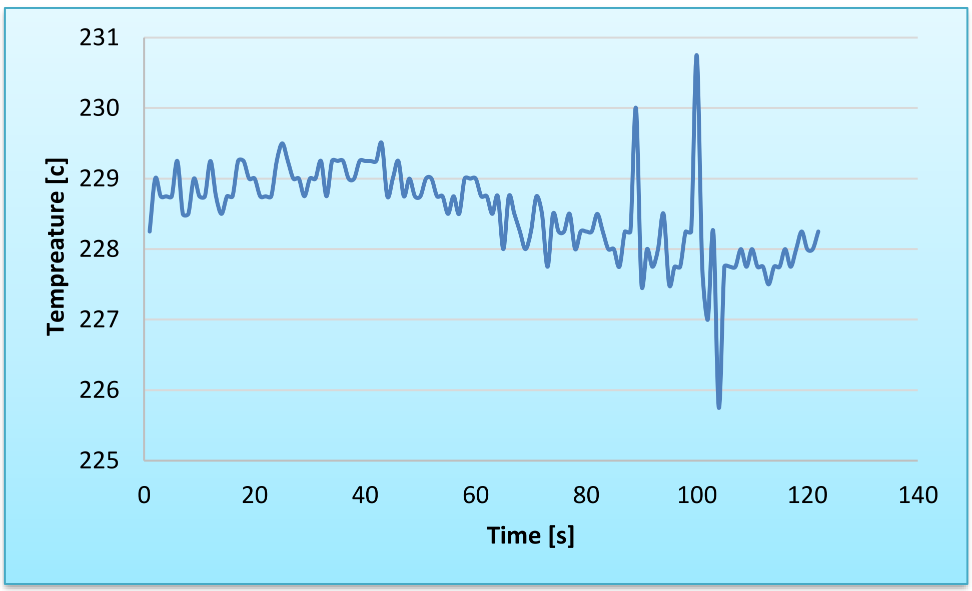


Graph 4. 4: Measuring temperature of bottom dead center (sensor 4) at ideal speed

4.2.2 Measuring temperature at part load

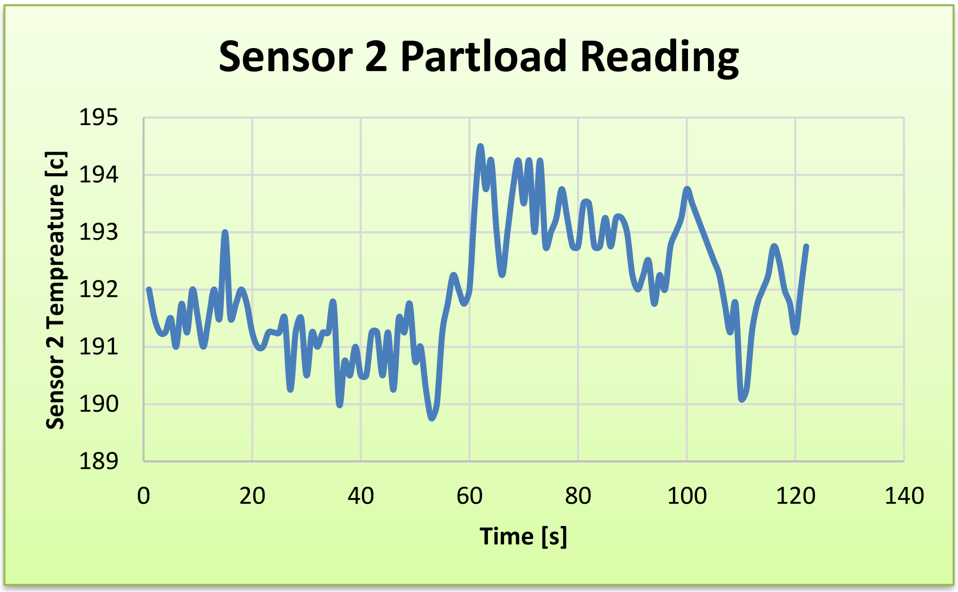
This reading was taken at part speed @1500 RPM for four sensor that was planted in engine.

4.2.2.1 Measuring sensor that located at cylinder head of engine



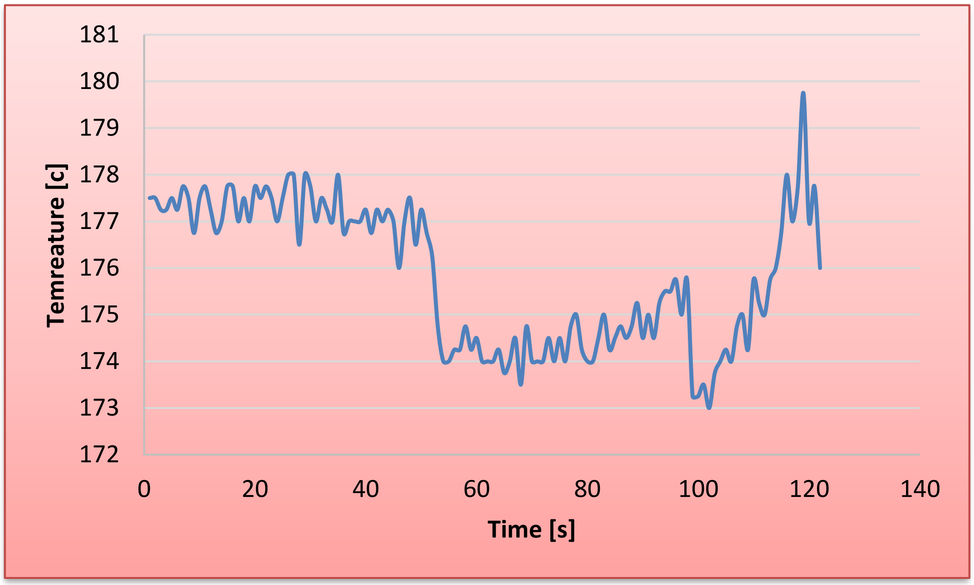
Graph 4. 5: Measuring temperature of cylinder head (sensor 1) at part speed

4.2.2.2 Measuring sensor that located at Top dead center



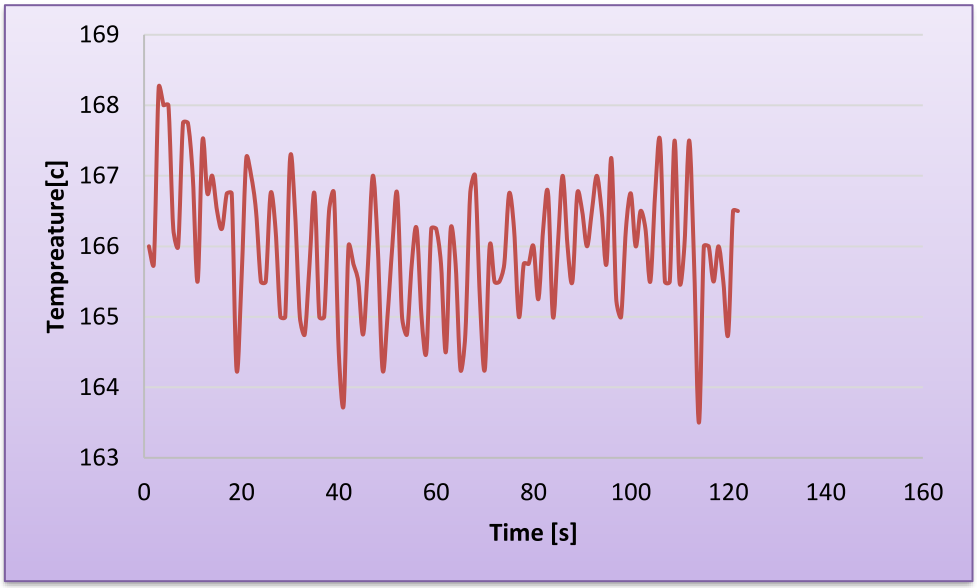
Graph 4. 6: Measuring temperature of Top dead center (sensor 2) at part speed

4.2.2.3 Measuring sensor that located at mid dead center



Graph 4. 7: Measuring temperature of mid dead center (sensor 3) at part speed

4.2.2.4 Measuring sensor that located at bottom dead center

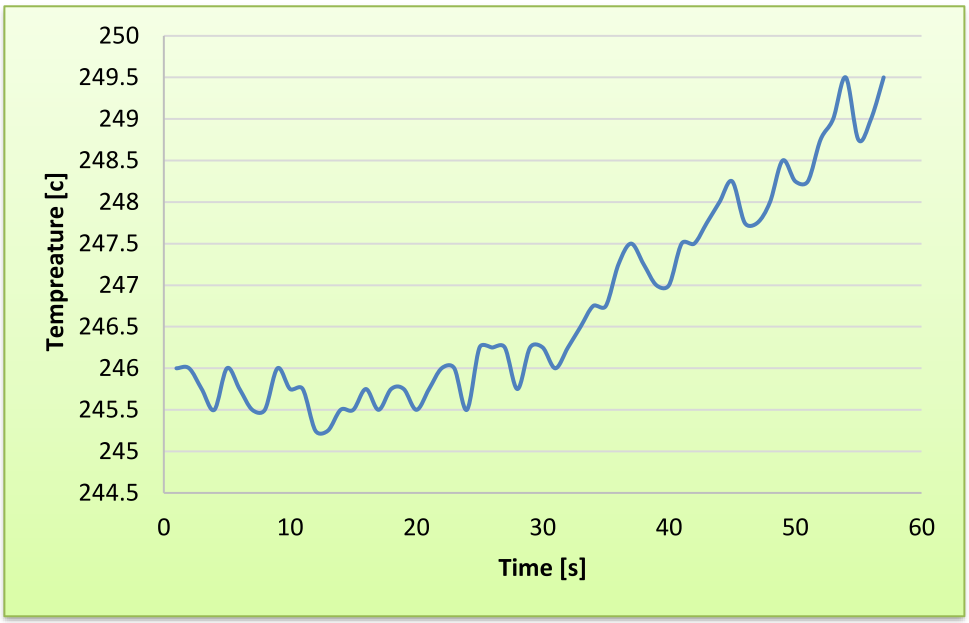


Graph 4. 8: Measuring temperature of bottom dead center (sensor 4) at part speed

4.2.3 Measuring temperature at full load

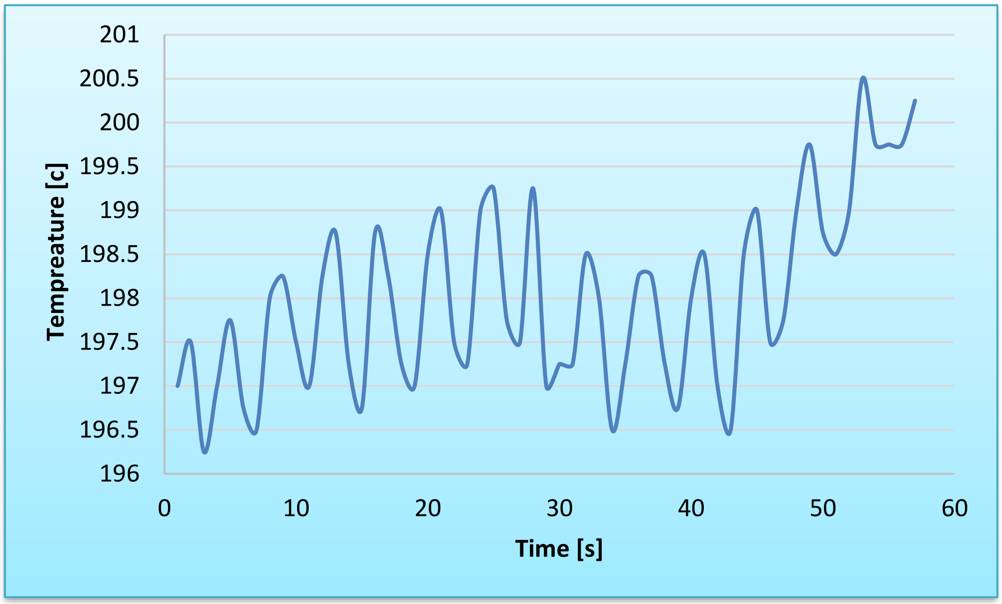
This reading was taken at part speed @2400 RPM for four sensor that was planted in engine.

4.2.3.1 Measuring sensor that located at cylinder head of engine



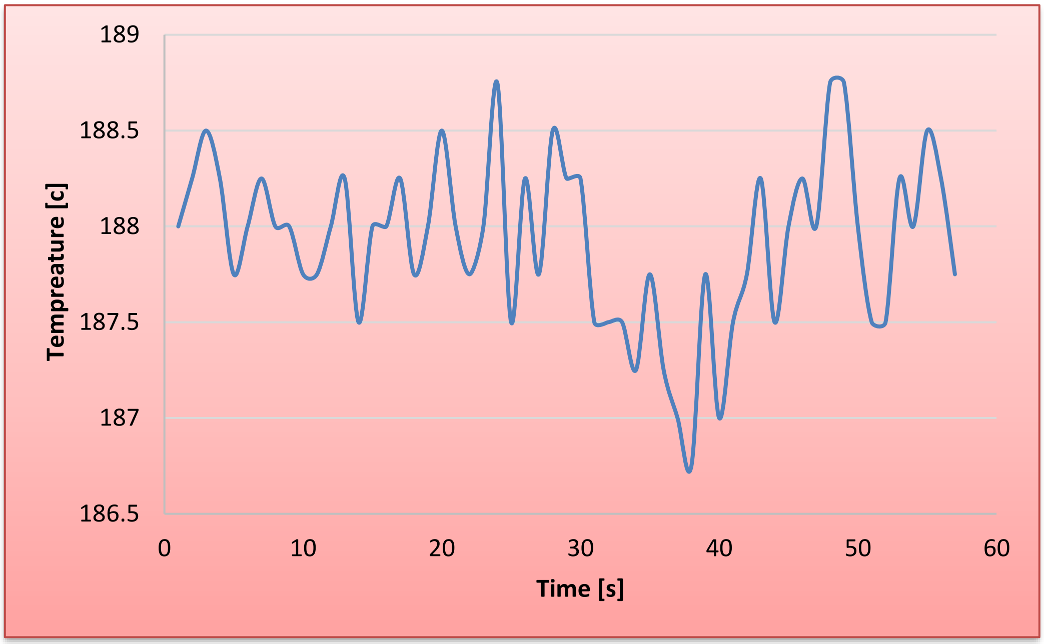
Graph 4. 9: Measuring temperature of cylinder head (sensor 1) at full speed

4.2.3.2 Measuring sensor that located at Top dead center



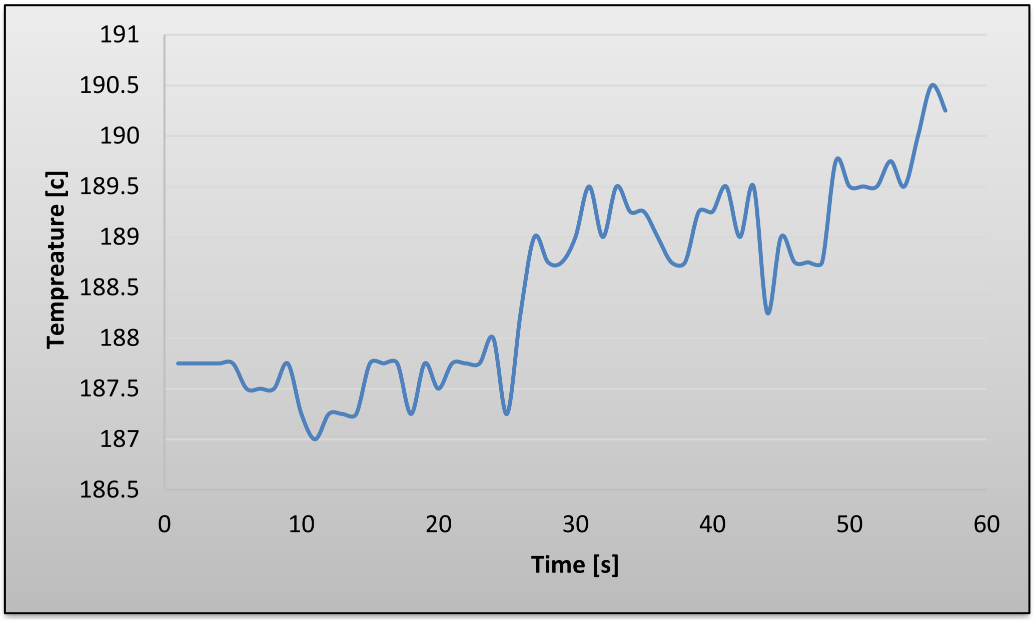
Graph 4. 10: Measuring temperature of Top dead center (sensor 2) at full speed

4.2.3.3 Measuring sensor that located at mid dead center



Graph 4. 11: Measuring temperature of mid dead center (sensor 3) at full speed

4.2.3.4 Measuring sensor that located at bottom dead center

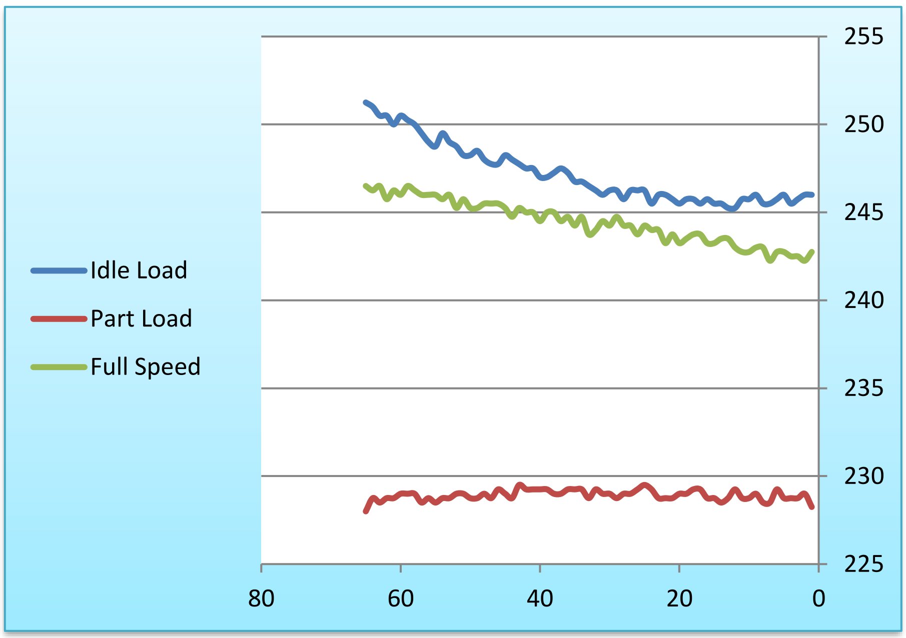


Graph 4. 12: Measuring temperature of bottom dead center (sensor 4) at full speed

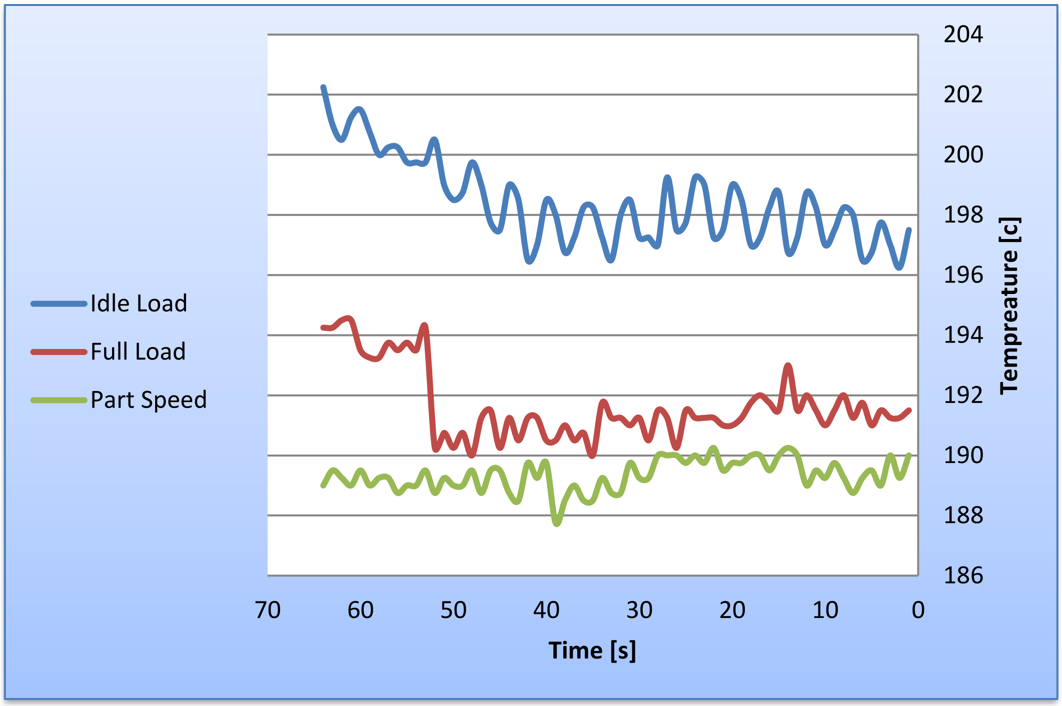
At the idle speed, the temperature is the highest value because the engine is close to the complete combustion, but at part speed the temperature is reduced because in this case the combustion is close to the incomplete combustion, that occur because of increases amount of air charged, but at full speed, the temperature high but less than the temperature in idle speed, the reason for this because we have to advan of spark , the combustion becomes almost complete and the amount of fuel increase and the engine is fast there so no time for the heat exchange.

4.2.4 Measurement for each sensor at different loads

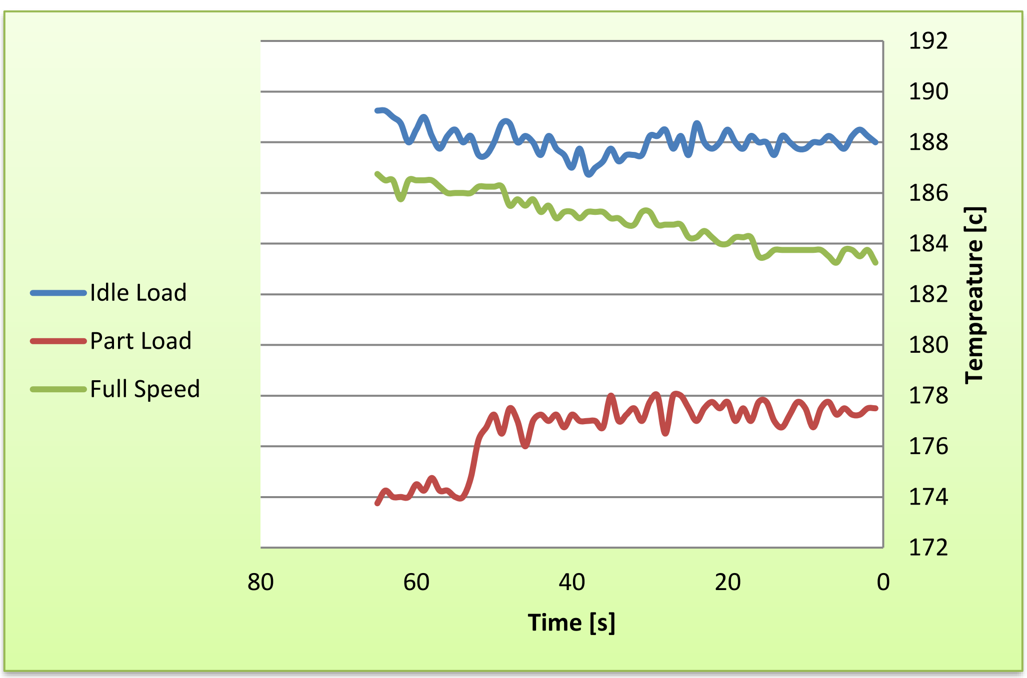
In this section the readings of each sensor at different loads were combined to see the difference in temperature value according to the load (idle load, part load, and full load).



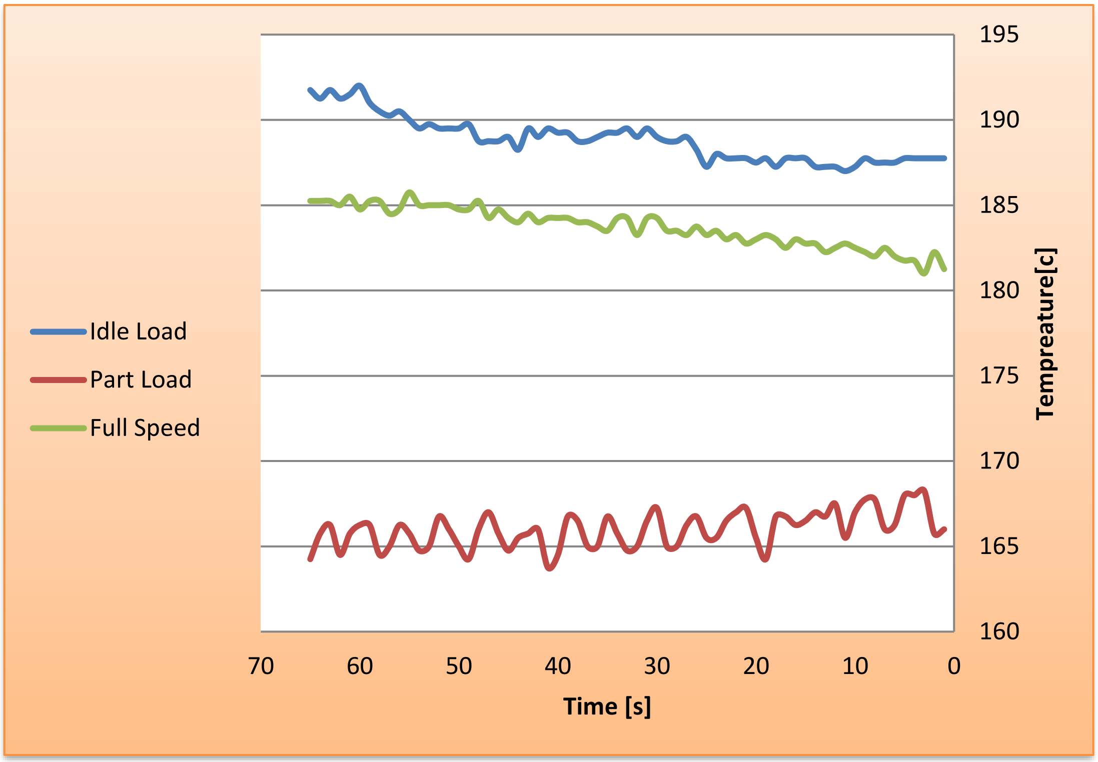
Graph 4. 13: Measuring temperature of cylinder head (sensor 1)



Graph 4. 14: Measuring temperature of Top dead center (sensor 2)



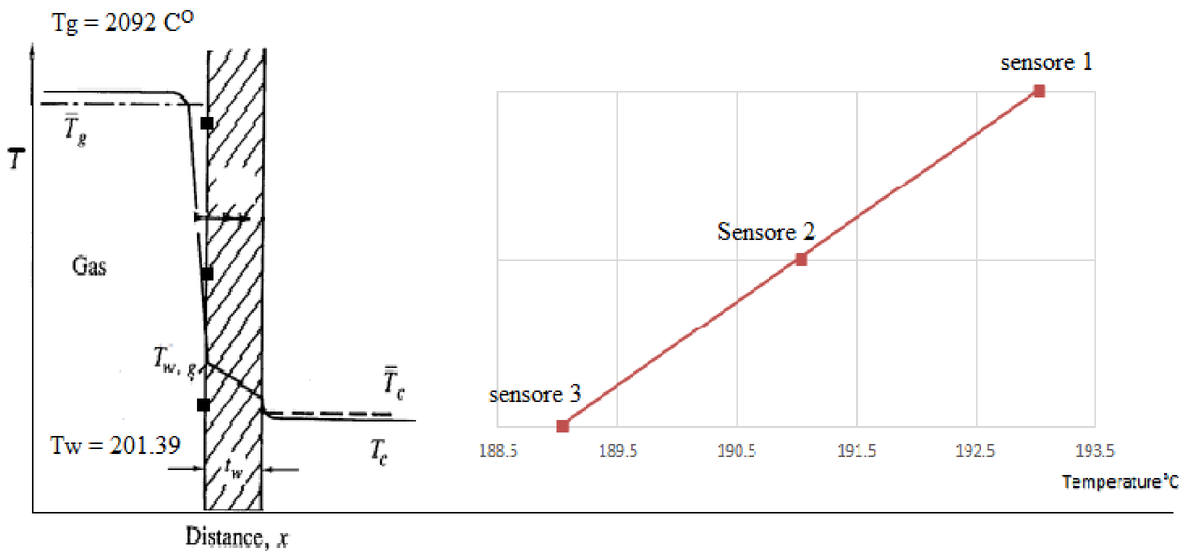
Graph 4. 15: Measuring temperature of mid dead center (sensor 3)



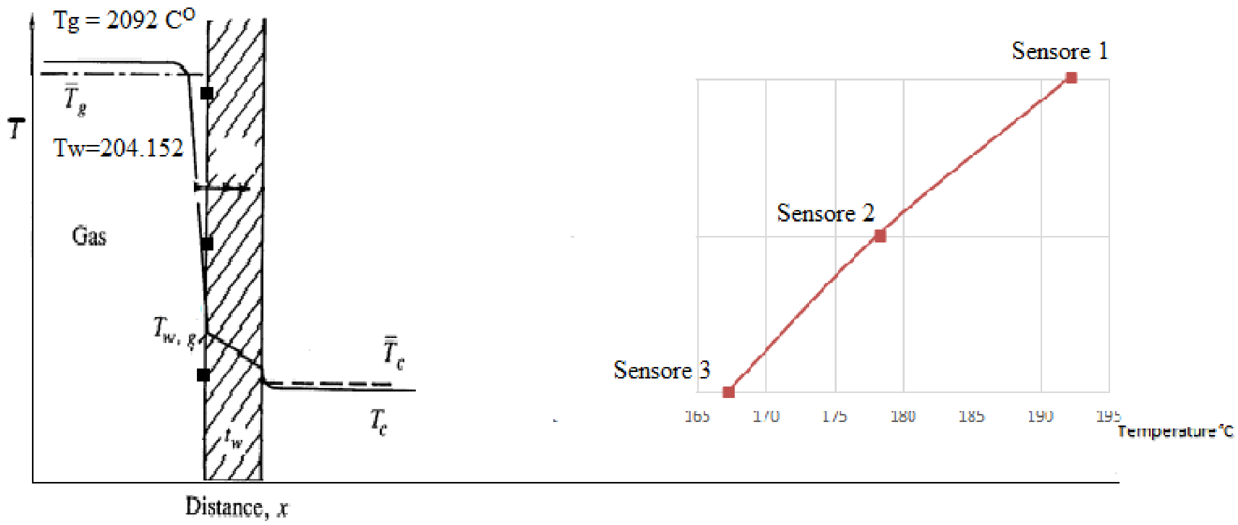
Graph 4. 16: Measuring temperature of bottom dead center (sensor 4)

4.3 Claculated and measured temperature comparisson

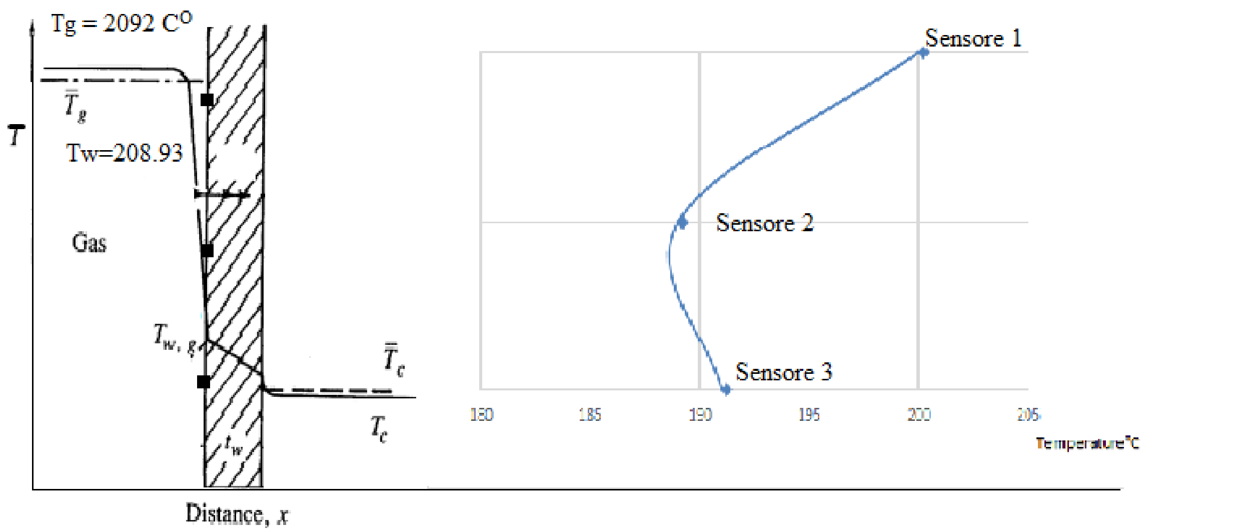
The following graphs shows the comparison of the calculated and the measured temperature at ideal load (750 RPM), part load (1500 RPM) and full load (2400 RPM).



Graph 4. 17: Calculated and measured temperature comparison at ideal load



Graph 4. 18: Calculated and measured temperature comparison at part load



Graph 4. 19: Calculated and measured temperature comparison at full lo

Conclusion

Methods of heat transfer in the gasoline engine and measure the temperature of the cylinder wall produced by the compustion of fuel and air was studed in this project, this project results that the maximun temperature for cylinder head is at ideal load (251**ºC**) then it decreases at part load (230**ºC**) then it increases again at full load (248**ºC**), the maximum temperature for the top dead center is at full load (199**ºC**) then it decreases at both ideal and part loads (192**ºC**), then the maximum temperature for the middle of the cylinder at ideal load (189**ºC**), then it sligtly decreases at full load (188**ºC**) and significantly decreases at part load (177**ºC**), then the maximum temperature for the bottom dead center is at ideal and full loads (188**ºC**), then it decreases at part load (188**ºC**),also it was found that the calculated temperature value of the cylinder wall is about **10**^{o}C higher than the maximum measured value**.**

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