TEMPERATURE CONTROLLER FOR AUTOMOTIVE ENGINE RESEARCH

By

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FINAL PROJECT REPORT

Submitted to the Electrical & Electronics Engineering Programme
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CERTIFICATION OF APPROVAL

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Approved:

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CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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Nor Affendi Bin Che Soh

ABSTRACT

This report basically discusses the preliminary research done and basic understanding of the chosen topic, which is **Temperature Controller for Automotive engine Research**. The research engine is known as Homogeneous Charge Compression Ignition (HCCI). HCCI engine operation is based on the compression of lean mixture of hot air with fuel. Thus the temperature of the air needs to be controlled before it mixes with the fuel. The main objective of this project is to investigate different temperature control algorithm and to implement on hardware by fabricating a controller using a temperature control IC. The controller will be tested on a gas heating chamber. Lastly, there will be a data acquisition using the labVIEW software. There are two main phases for this project. The first phase focuses on connection of all the hardware including temperature controller, Solid state relay (SSR), thermocouple and heater to the HCCI engine. While the second phase of the project is to perform data acquisitions (DAQ) of the temperature control using labVIEW software.

ACKNOWLEDGEMENTS

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LIST OF ABBREVIATIONS

e	Error
HCCI	Homogeneous Charge Compression Ignition
Kc	Controller Gain
LED	Light-emitting Diode
MV	Manipulated Variable
PID	Proportional, Integral, Derivative
PV	Process Variable
RTD	Resistance Temperature Detectors
SP	Setpoint
SSR	Solid State Relay

CHAPTER 1

INTRODUCTION

1.1   Background of Study

Nowadays, the matter of improving fuel efficiency and emission reduction is the main concern of automobile industry as the oil prices is high and the pollution problems concerning the car consumers. Hence, the introduction of Homogeneous Charge Compression Ignition (HCCI) engine is the ideal solution for the problems. HCCI relies upon a very lean and well-mixed air-fuel mixture that is compressed until it autoignites [1].

For Homogeneous Charge Compression Ignition (HCCI) engine operation, pre-heating of intake air to the engine is required. The temperature of the intake air to the engine needs to be controlled for the purpose of combustion process between airs to fuel mixture in the engine.

Thus, this project focuses on controlling the temperature of the intake air to the engine using temperature controller. Different algorithm for the temperature controller will be studied throughout the entire project including on/off, proportional and PID controller. Moreover, the controller will be tested on gas heating chamber and data acquisition of temperature of the air intake to the engine will be performed.

1.2   Problem Statement

Nowadays, instead of precise temperature control, the industrial applications also emphasize on faster warm-up phase and quicker response to disturbance with minimal overshoot and undershoot when the setpoint, SP changes [2]. For HCCI engine operation, pre-heating of intake air to the engine is required.

In order to control the temperature of the intake air to the engine, there are some conditions should be take into consideration. Firstly, the desired temperature or the SP for the intake air needs to be known first in order to control the heater. Besides, the speed of the intake air to the engine must be considered so that the calculation and controlling the heating element to get the desired temperature can be done.

1.3   Objective

The main objectives of this research are:

- To investigate different temperature control algorithm.
- To test controller on gas heating chamber.
- To perform data acquisition using LabVIEW software.

1.4   Scope of Study

A few researches and circuit design process need to be carried out in order to achieve the objectives. The resulting data need to be collect and analyzed to ensure the best circuit and heating element can be implementing to the temperature controller. A recommendation is to be made based on the findings of this study regarding the design of the temperature controller.

The scope of study will involve the installation of hardware devices (temperature controller, heater, SSR and thermocouple) and the software part on the system consists of HCCI engine and computer. The study will be in two stages, where the first stage is to study and set up all the hardware connection. The second stage is to study on experimental setup and data acquisition using LabVIEW 7.1 software.

This project is relevant to the study of Control & Instrumentation System. It is also relevant to the recent concern of improving fuel efficiency and emissions reduction.

CHAPTER 2
LITERATURE REVIEW

2.1   Selecting Controllers

A temperature control system consists of a controller, which accepts a temperature sensor such as a thermocouple as input [3]. It compares the actual temperature to the desired control temperature and provides an output to a control element.

In order to select the proper controller, the whole system should be analyzed first. Below are the items that should be considered while selecting temperature controller:

1. Type of input sensor and temperature range

2. Type of output required

3. Control algorithm needed

4. Number and type of outputs

2.2   Control Algorithm

Control algorithm is the method used in controlling the process. Basically, different control algorithm will results in different controlling process behavior. Thus, the choice of the suitable algorithm must be made correctly depending on the type of process to be controlled. There are many types of control algorithm for temperature controller as listed below:

1. On/Off control.

2. Proportional (P) control.

3. Proportional + Derivative (PD) control.

4. Proportional + Integral + Derivative (PID) control.

2.2.1   On/Off Control

An on-off controller is the simplest algorithm for the temperature control. The output is either on or off with no middle state [3]. For this type of controller, the output will be switched only when the temperature crosses the SP. For heating control, the heater is on or off when the temperature is below or above the SP respectively. Since the temperature crosses the SP to change the output state, the process temperature will be oscillatory going from below SP to above and back below.

An on-off differential or hysteresis is added to the controller operations in cases where this cycling occurs rapidly and to prevent damage to contactors and valves [4]. By adding hysteresis to the controller operations, the temperature will exceeded SP by a certain amount before the output will turn off or on again. This will prevent the output from chattering or making fast continual switches if the cycling above and below the SP occurs very rapidly.
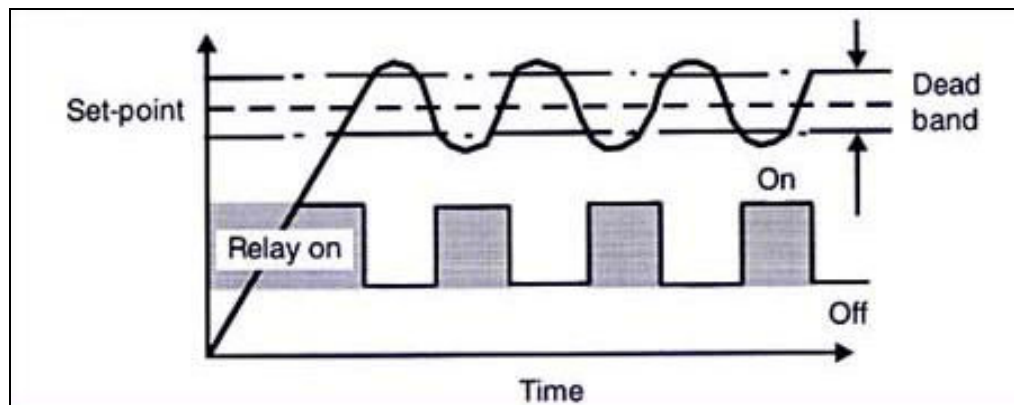
Figure 1: Graph of ON/Off Temperature Control Action with Deadband [5]

On-off control is usually used in a process which not required precise control. Figure 1 shows the graph of on-off temperature control action. From the Figure 1, it shows that the heater work in two states whether on or off depending on the temperature. When the relay is in 'On' condition, the temperature will rise until it

reaches the SP and continually increase until it exceeds the deadband. After that, the relay will quickly change to 'Off' state to bring the temperature back to the SP. This is the continuous process in On/Off control.

2.2.2 Proportional Control

Proportional controls are designed to eliminate the weakness of On/Off control which is the problem of continuous cycling [3]. The correction made is proportional to the error occur.

The mathematical expression of proportional mode is:

$$MV(t) = K_c E(t) + I_p$$

Where, K_c is controller gain and I_p is a constant term or bias.

The operation principle of a proportional controller is by decreasing the average power supplied to the heater as the temperature approaches SP. This principle will let the heater to slow down, so that it will not overshoot the SP, but will approach the SP and maintain a stable temperature.
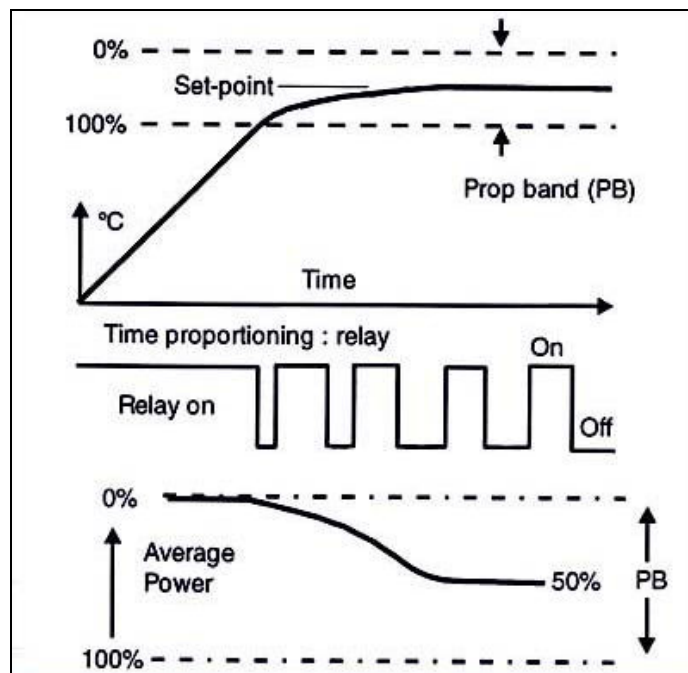
Figure 2: Graph of Proportional Control [5]

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Figure 2 shows the proportioning action diagram. Average heater power over a period of time is regulated and applied power is proportional to the error between sensor temperature and SP usually by time proportioning relay switching. The region over which power is thus varied is called the Proportional Band, PB. It is usually defined as a percentage of full scale [5]. From the diagram, it shows that proportioning action occurs within a proportional band around the SP temperature.

The advantage of proportional control is it makes the operation simple. When using proportional controller, only small adjustment required to bring the temperature to SP on initial startup.

A major disadvantage of the proportional mode is the controlled variable, CV will have a non-zero offset. Offset can be described by the steady-state deviation of the sensor temperature which is CV from the SP. This problem can be adjusted by manual reset using a potentiometer adjustment or automatically using integral action.
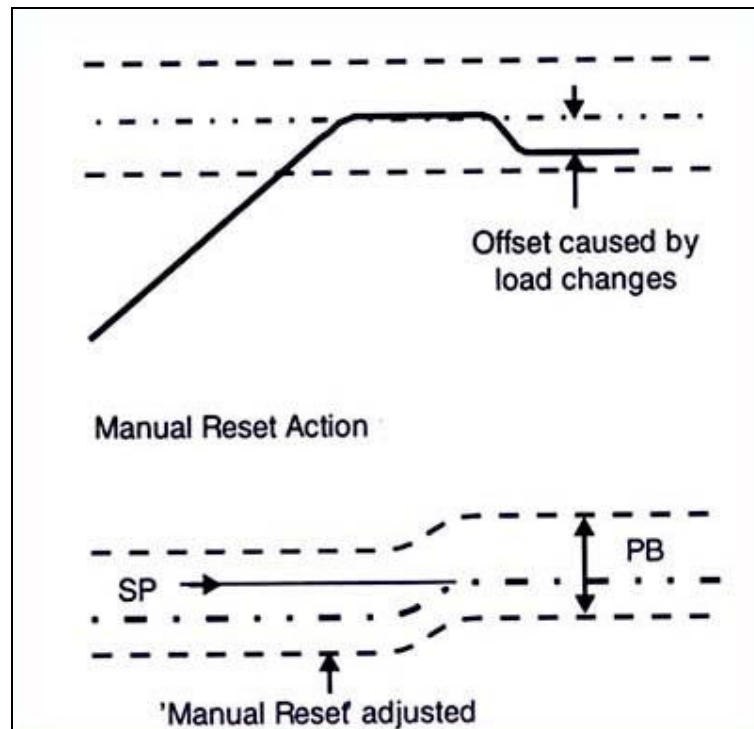
Figure 3: Offset manual reset

2.2.3   Proportional + Derivative (PD) Control [5]

The presence of derivative term in PD control is functioning to improve the control system by detecting the temperature changes and quickly make a correction. The future predict of the error is corrected by reducing the magnitude of overshoot by integral.

The mathematical expression of derivative mode is:

$$MV(t) = K_c T_D \frac{dE(t)}{dt} + I_D$$

Where, T_d is controller derivative time and I_D is a constant term or bias.
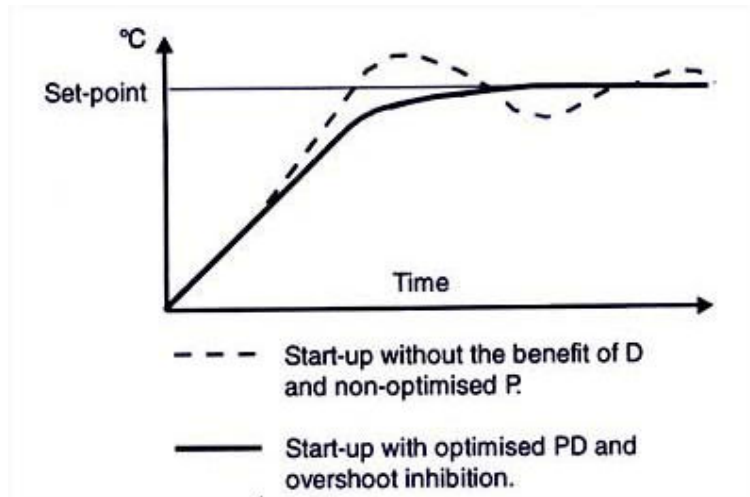
Figure 4: PD action graph [5]

2.2.4   PID Control

This type of controller consists of three modes which are proportional mode, integral mode and derivative mode. The addition of integral term is to improve the PD control by providing automatic and continuous elimination of any offset [6].

The following formula represents the integral action.

$$MV(t) = \frac{K_c}{T_I} \int_0^\infty E(t')dt' + I_I$$

Where, T_i is controller integral time and I_i is a constant term or bias.

Integral action operates in the steady state condition by shifting the Proportional Band upscale or downscale until the system temperature and SP coincide.

All the mode need to be combined to formulate the PID controller. First step is to obtain the error (*e*). The PID controller compares the SP to the process variable (PV) to obtain the error (*e*) [7].

$$e = SP\text{-}PV$$

Then the PID controller calculates the controller action, *MV (t)*, where *Kc* is controller gain.

$$MV(t) = K_c \left[E(t) + \frac{1}{T_I} \int_0^{\bar{t}} E(t')dt' - T_D \frac{dCV(t)}{dt} \right] + I$$

Ti is the integral time in minutes, also called reset time, and *Td* is the derivative time in minutes, also called the rate time. Controller output is the summation of the proportional, integral and derivative action.
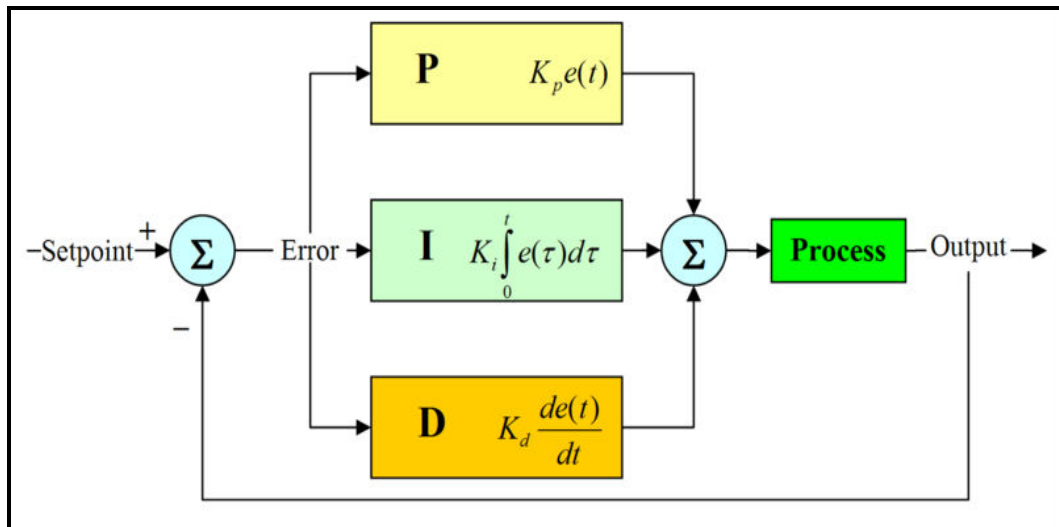
Figure 5: Block Diagram of PID controller [6]

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2.3   Tuning Method

Tuning is the process of calibrating the controller so that it will function precisely and avoid the controllers from function too aggressive or too sluggish. Tuning method consist of manual and autotuning.

2.3.1   Manual Tuning

In manual tuning, the tuning procedures are based on the work of Ziegler and Nichols. Under this tuning method, there are two main tuning approaches which are Open-Loop (Step Test) tuning procedure and Closed-Loop (Ultimate Gain) tuning procedure [8].

a) Open-Loop (Step Test) tuning procedure

The open-loop tuning procedure is using process reaction curve in order to determine the value of the parameters involved. It is quicker and more reliable for many processes. The following steps need to be completed to perform the open-loop tuning procedure [9].

1. The controller is put in the manual mode, the output is set to a nominal operating value and the PV is allowed to settle completely. The PV and output values are then recorded.

2. The step change is made in the output. The new output value is then recorded.

3. The values from the process reaction curve are determined after the PV is settled. The variables represent the following values;

   - Td – Deadtime (minutes)

   - T – Time constant (minutes)

   - K – Process gain = change in output/change in PV

Figure 6: Process Reaction Curve [9]

4. The measures values are multiplied by the factors in Table 1 and the new tuning parameters are entered into the controller. The table provides the proper value for a quarter-decay ratio. The value of the gain, K_c is controlled depending on the overshoot required. Higher K_c is for higher overshoot.

Table 1: Tuning formula for Open-Loop tuning procedure [9]

Controller	PB (percent)	Reset (minutes)	Rate (minutes)
P	$100\dfrac{KT_d}{T}$	—	—
PI	$110\dfrac{KT_d}{T}$	$3.33T_d$	—
PID	$80\dfrac{KT_d}{T}$	$2.00T_d$	$0.50T_d$

b) Closed-Loop (Ultimate Gain) tuning procedure

This tuning procedure is very accurate. The process must be put in steady-state oscillation in order to use this method. This method requires less analysis than the open-loop tuning procedure. The following steps need to be completed to perform closed-loop tuning procedure [8]:

1. Both derivative time and integral time on PID controller are set to 0.

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2. The proportional gain, K_c is increased in small increments with the controller is set in automatic mode. After each increment, the small change in SP is made to disturb the loop. As the value of K_c is increases, the PV value should start to oscillate. The changes are continuously made until the oscillation is sustained, neither growing nor decaying over time.

3. The controller proportional band is recorded as a percent with $PB_u = 100/K_c$.

4. The period of oscillation (T_u) is recorded in minutes.
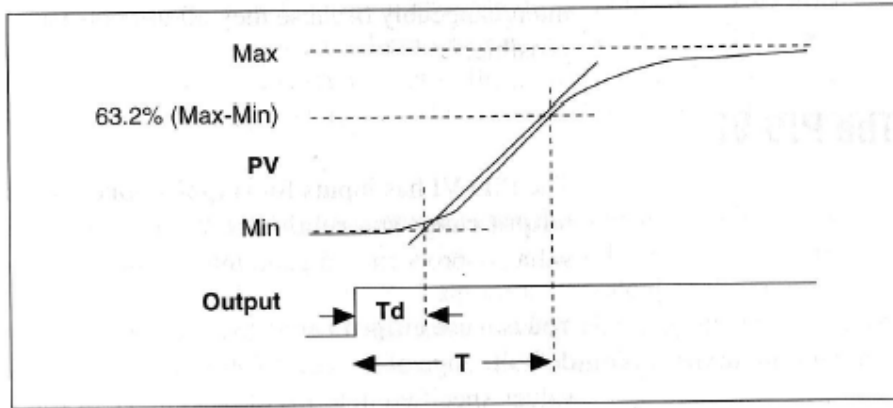
5. The measures values are multiplied by the factors in Table 2 and the new tuning parameters are entered into the controller. The table provides the proper value for a quarter-decay ratio. The value of the gain, K_c is controlled depending on the overshoot required. Higher K_c is for lower overshoot.

Table 2: Tuning formula for Closed-Loop tuning procedure [8]

Controller	PB (percent)	Reset (minutes)	Rate (minutes)
P	$2.00PB_u$	—	—
PI	$2.22PB_u$	$0.83T_u$	—
PID	$1.67PB_u$	$0.50TT_u$	$0.125T_u$

For this method, K_c is related to PB as $K_c = PB/100$

2.3.2 Autotuning Method

Autotuning is used to improve performance of the controller. PID controllers are difficult to tune when the process dynamics or disturbances is unknown. In this case, autotuning is use. Before autotuning is started, a stable controller must be established.

Figure 3 illustrates the autotuning procedure, which connects relay and an extra feedback signal with the SP.

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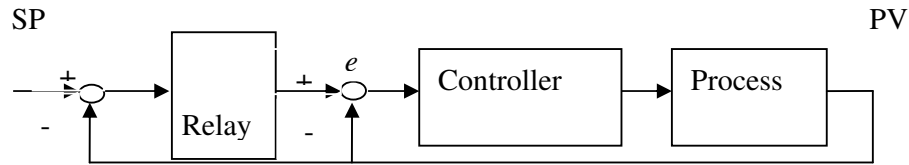
Figure 7: Autotuning procedure diagram with relay [11]

The basic idea is the observations that many processes have limit cycle oscillations under relay feedback. From this, the autotuning algorithm identifies the relevant information needed for PID tuning. If the existing controller is proportional only, the ultimate gain K_u and ultimate period T_u can be identifies. If the existing model is PI or PID, the autotuning algorithm identifies the dead time and time constant T_p.

In this project, the LabVIEW 7.1 software tuning formulas is used. This package used Ziegler and Nichols' heuristic methods for determining the parameters of a PID controller [13]. When autotune, one of the following three types of loop performance can be select:

i)   Fast (¼ damping ratio)

ii)   Normal (some overshoot)

iii)   Slow (little overshoot)

Below are the tuning formula tables for each type of loop performance. All tables are taken from [12].

Table 3: Tuning formula under P-only control (fast)

Controller	K_c	T_i	T_d
P	$0.2K_u$	—	—
PI	$0.18K_u$	$0.8T_u$	—
PID	$0.25K_u$	$0.5T_u$	$0.12T_u$

Table 4: Tuning formula under P-only control (Normal)

Controller	K_c	T_i	T_d
P	$0.5K_u$	—	—
PI	$0.4K_u$	$0.8T_u$	—
PID	$0.6K_u$	$0.5T_u$	$0.12T_u$

Table 5: Tuning formula under P-only control (Slow)

Controller	K_c	T_i	T_d
P	$0.13K_u$	—	—
PI	$0.13K_u$	$0.8T_u$	—
PID	$0.15K_u$	$0.5T_u$	$0.12T_u$

Table 6: Tuning formula under PI or PID Control (fast)

Controller	K_c	T_i	T_d
P	T_p/τ	—	—
PI	$0.9T_p/\tau$	3.33τ	—
PID	$1.1T_p/\tau$	2.0τ	0.5τ

Table 7: Tuning formula under PI or PID Control (normal)

Controller	K_c	T_i	T_d
P	$0.44T_p/\tau$	—	—
PI	$0.4T_p/\tau$	5.33τ	—
PID	$0.53T_p/\tau$	4.0τ	0.8τ

Table 8: Tuning formula under PI or PID Control (slow)

Controller	K_c	T_i	T_d
P	$0.26T_p/\tau$	—	—
PI	$0.24T_p/\tau$	5.33τ	—
PID	$0.32T_p/\tau$	4.0τ	0.8τ

2.4   HCCI engine

For this project, HCCI engine is used. HCCI engine operation involves compressing the well-mixed air-fuel mixture until it autoignites [13]. It is flameless and does not involve the use of spark plug as used by other engines.
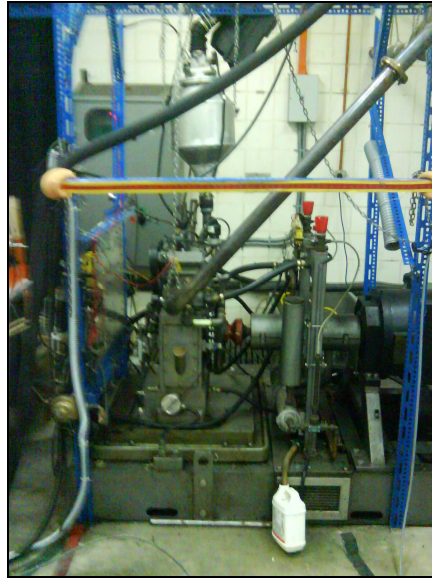
Figure 8: HCCI engine.
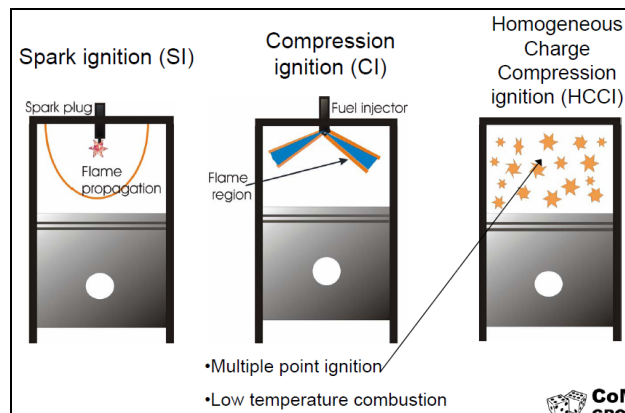
Figure 9: Characteristics of HCCI engine

The characteristics used in HCCI engine are homogeneous charge spark ignition (gasoline engines) and stratified charge compression ignition (diesel engines) which normally being used in IC engine [14]. The combination of these two designs will results in diesel-like high efficiency without the difficult and expensive to deal with Nitrogen Oxide, NO and particulate matter emissions. This will leads to a low fuel usage and low emissions. Besides, there are many other advantages of HCCI engine as being listed below [16].

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- Compatible with gasoline as well as E85 (ethanol) fuel.

- Fuel is burned quicker and at lower temperatures, reducing heat energy loss compared to a conventional spark engine.

- Throttleless induction system eliminates frictional pumping losses incurred in traditional (throttle body) spark engines.

Due to the fact that this engine is in development phase, thus there are many challenges exist. One of the challenges is on controlling the combustion process. With spark ignition, the timing of the combustion can be easily adjusted by controlling of the spark event. However, it is not possible for HCCI engine due to flameless combustion[14].

Thus, the mixture composition and temperature must be controlled precisely and accurately to achieve comparable performance of spark-ignition engines in the wide range of operating conditions. For my project, I will only focusing on controlling the temperature of the intake air that will mix with the fuel inside the engine [14].

CHAPTER 3

METHODOLOGY

3.1   Procedure Identification

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                    │  Start  │
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        ┌────────────────────────────────┐
        │  Research and data gathering   │
        └────────────────┬───────────────┘
                         │
                         ▼
        ┌────────────────────────────────┐
        │  Study on the temperature      │
        │  control algorithm             │
        └────────────────┬───────────────┘
                         │
                         ▼
        ┌────────────────────────────────┐
        │  Perform hardware connection   │
        └────────────────┬───────────────┘
                         │
                         ▼
        ┌────────────────────────────────┐
        │  Test controller on gas heating│
        │  chamber                       │
        └────────────────┬───────────────┘
                         │
                         ▼
        ┌────────────────────────────────┐
        │  Perform data acquisition      │
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                    │   End   │
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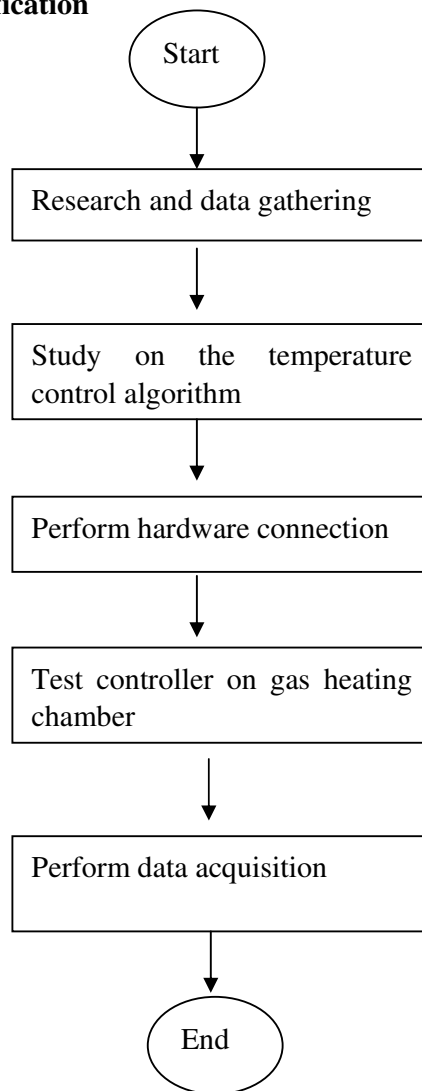
Figure 10: General project procedure

1. Research and data gathering

As soon as the project is given, the research and data gathering process is the first step taken. This research and data gathering mostly used the book, journal and internet. For my project, the research and data gathering process are focused on the control algorithm of the temperature controller, HCCI engine operation, hardware connection and software installation and connection.

2. Study on the temperature control algorithm

The study of temperature control algorithm is essential because this is the basic thing before the implementation of temperature controller can be done.

3. Perform hardware connection

The project consists of many hardware including temperature controller, solid state relay, thermocouple and heater. As soon as the research on temperature control algorithm is done, the hardware connection takes place.

4. Test controller on gas heating chamber

After the connection is complete, the controller will be test on gas heating chamber.

5. Perform data acquisition

Data acquisition of the temperature control is performed using LabVIEW software. This process will show the result of the project.
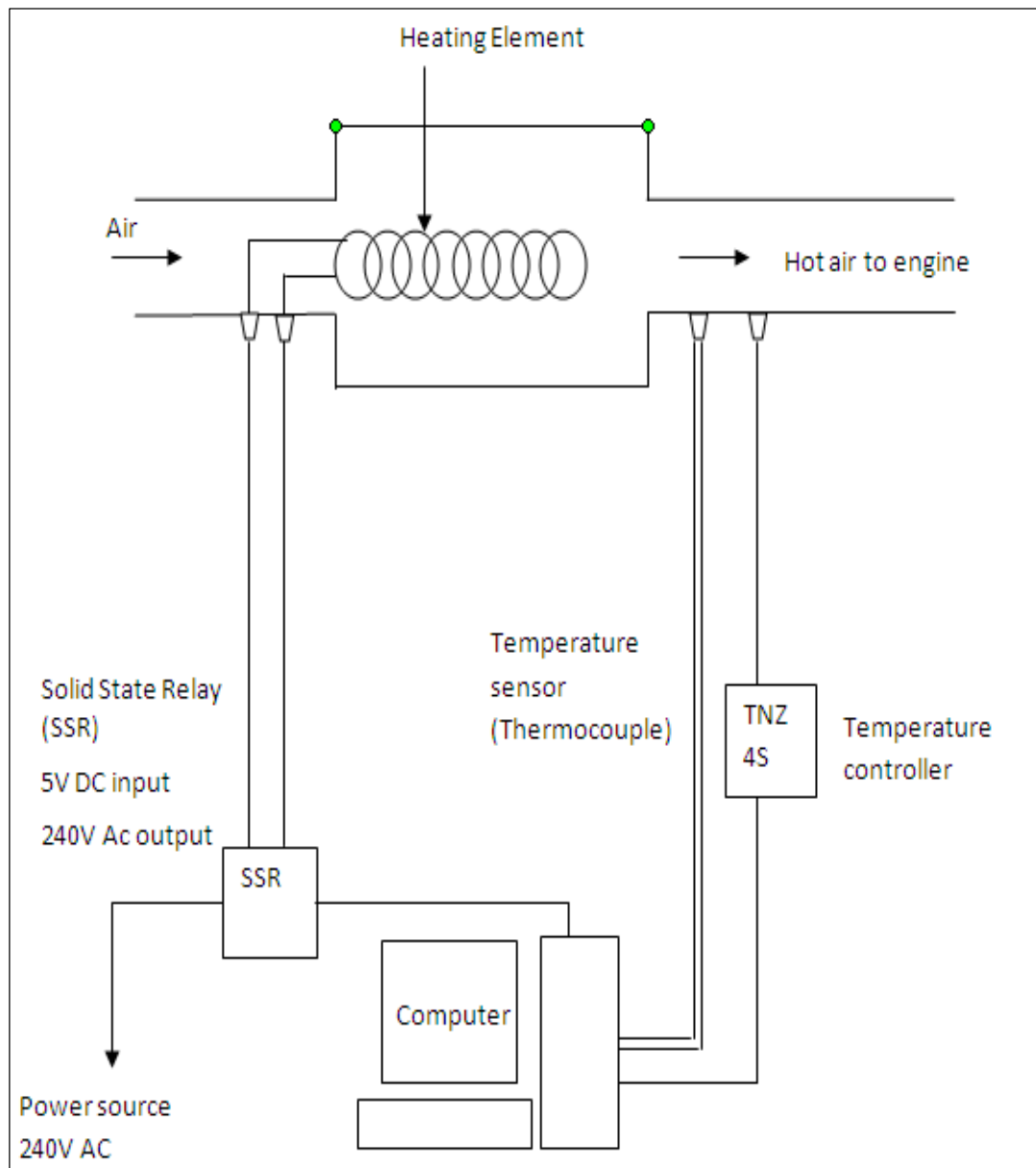
3.2 Project Design

Figure 11: Project design

Figure 11 shows the design of my temperature controller system of air intake to the HCCI engine. It consists of a heating element connected to the solid state relay with 5V DC input, 240V AC output. One pole of SSR connects to the 240 AC source while the other pole connect to the computer. At the other end of the chamber there is temperature sensor which is thermocouple and temperature controller connects to the computer.

The process begin when the air from outside enter the chamber. The air will be heat by heating element until it reaches SP. The temperature of the hot air at the end of chamber will be detected by thermocouple. If the temperature is exceed or below the SP, temperature controller will operate in order to ensure the temperature reach SP.

3.3   Experimental Procedure

The experiment will be performed using either Method 1 or Method 2.

Method 1: Using Open–Loop (Step Test) tuning procedure

1. Temperature controller is tune using Open–Loop (Step Test) tuning procedure (Refer to literature review part 2.4).

2. Process Reaction Curve, PRC is obtained from the tuning procedure.
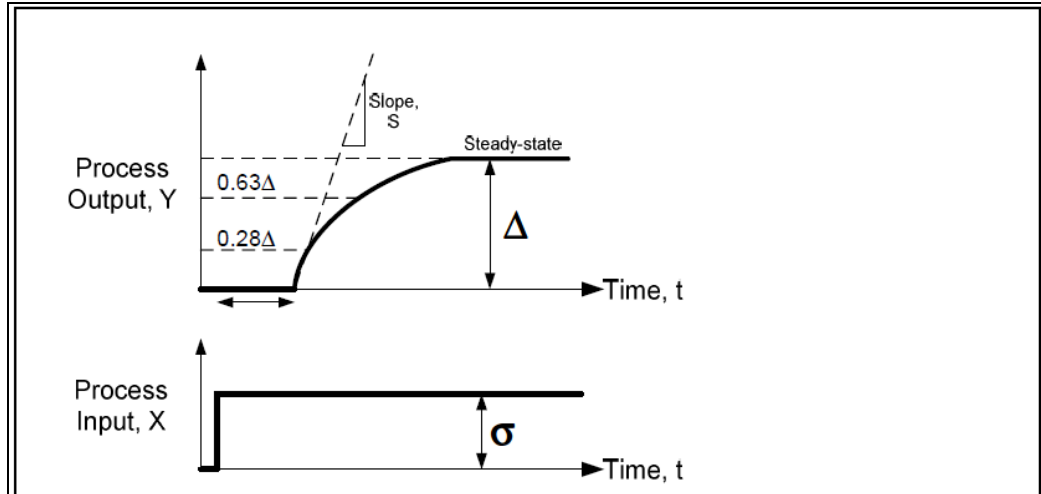

Figure 12: Process Reaction Curve

3. From the PRC, the parameters involved are measured and calculated by referred to the table below:

Table 9: Results of Process Reaction Curve

Measurement	Value
Change in perturbation / MV, σ	
Change in output / PV, Δ	
Maximum slope, S	
Apparent dead time, T_d	
Calculations	Value
Steady State Process Gain, $K_P = \Delta/\sigma$	
Apparent time constant, $\tau = \Delta/S$ or $\tau = 1.5(t_{0.63\Delta} - t_{0.28\Delta})$	
*Fraction dead time, $R = \theta/\tau$	

4. The measures values are multiplied by the factors in Table 1 and the new tuning parameters can be determined. The table provides the proper value for a quarter-decay ratio. The value of the gain, K_c is controlled depending on the overshoot required. Higher K_c is for higher overshoot.

5. The controller is set it in manual mode. Sp is set at 250°C. Tuning parameters obtained from step 4 is keyed in one at a time. For this time, the parameter of P-only control is keyed in.

6. MV is adjusted until PV is close to its SP.

7. The controller is set to Auto mode.

8. The controller SP is change to 300°C.

9. PV curve is observed in trend window on the labVIEW software. The typical response characteristics are observed.

10. Steps 5 to 9 are repeated for PI mode and PID mode.

Method 2: Using Closed-Loop (Ultimate Gain) tuning procedure

1. Temperature control is tuned using Closed-Loop (Ultimate Gain) tuning procedure (Refer to literature review part 2.4).

2. The measures values are multiplied by the factors in Table 2 and the new tuning parameters can be determined. The table provides the proper value for a quarter-decay ratio. The value of the gain, K_c is controlled depending on the overshoot required. Higher K_c is for higher overshoot.

3. Steps 5 to 9 of Method 1 are repeated for PI mode and PID mode.

3.3   Equipments

The project consists of several equipments.

3.3.1   *Temperature Controller Model TNZ4S*

This controller has many features including dual PID auto tuning function. There are high speed response and low speed response mode in dual PID function. When the desired value need to reach fast, high speed (PIDF mode) should be use and when overshoot need to minimize even though response is a little bit slower, low speed response should be use. Besides the controller provide high display accuracy which is $\pm0.3\%$. It also contains 13 kinds of multi-input selection function such as temperature sensor, voltage and current selection function. Other function include various sub output function such as 7kinds of alarm output,4 kinds of alarm option function, built in PV value transmission output (4-20mADC), RS485 communicate output.

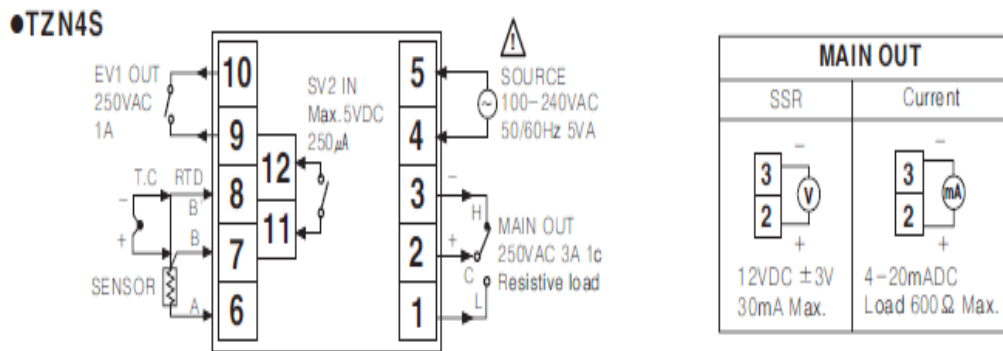Figure 13 shows the connection of temperature controller Model TNZ4S.

Figure 13: Temperature controller connection

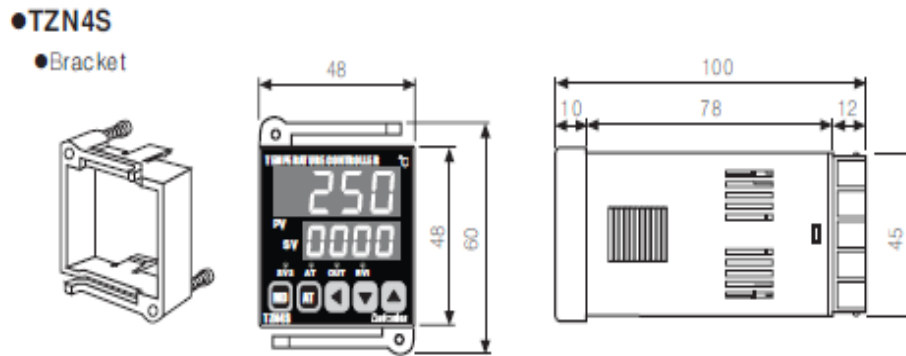Figure 14 shows the dimension of temperature controller Model TNZ4S.

Figure 14: Temperature controller dimension

In this project, the temperature controller model TNZ4S is connected near the entrance of air intake to the engine. The temperature of the air intake to the engine will be controlled by this temperature controller.

Figure 15: Temperature controller

3.3.2 Solid State Relay (SSR)

A solid state relay (SSR) is an electronic switch that contains no moving parts.

Figure 16: Solid State Relay

The SSR with 5V DC input, 240V AC output is connected to the heating element inside the gas heating chamber and the computer for the data acquisition using Labview 7.1 sotware. The SSR will supply the power to the heater for the heating purpose.

3.3.3 Thermocouple type K

A thermocouple is a junction between two different metals that produces a voltage related to a temperature difference.

K type thermocouple.

Figure 17: Thermocouple type K

Thermocouple type K is connected from the end of the gas heating chamber to the National Instruments SCXI-1112 located at the computer. This is for observation of the air intake temperature to the engine.

3.3.4 Heating element

Heating element is installed in the gas heating chamber to heat the air before it flow into the engine.
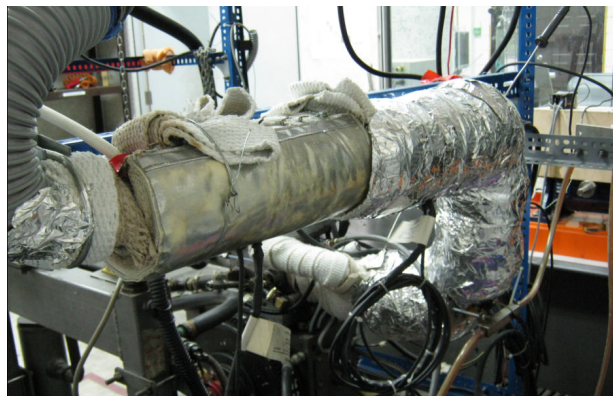

Figure 18: Chamber with heating element inside

3.3.5   LabVIEW 7.1

LabVIEW programs are virtual instruments or VIs because their appearance and operation imitate physical instruments such as oscilloscopes and multimeters. LabVIEW contains a comprehensive set of tools for acquiring, analyzing, displaying and storing data, besides as tools to help in troubleshooting the code. The LabVIEW 7.1 programs can run the PID Control Toolset which contains function that can use to develop LabVIEW control application.

CHAPTER 4

RESULTS AND DISCUSSIONS

4.1 Results

4.1.1 Typical Graphs of PID Controller

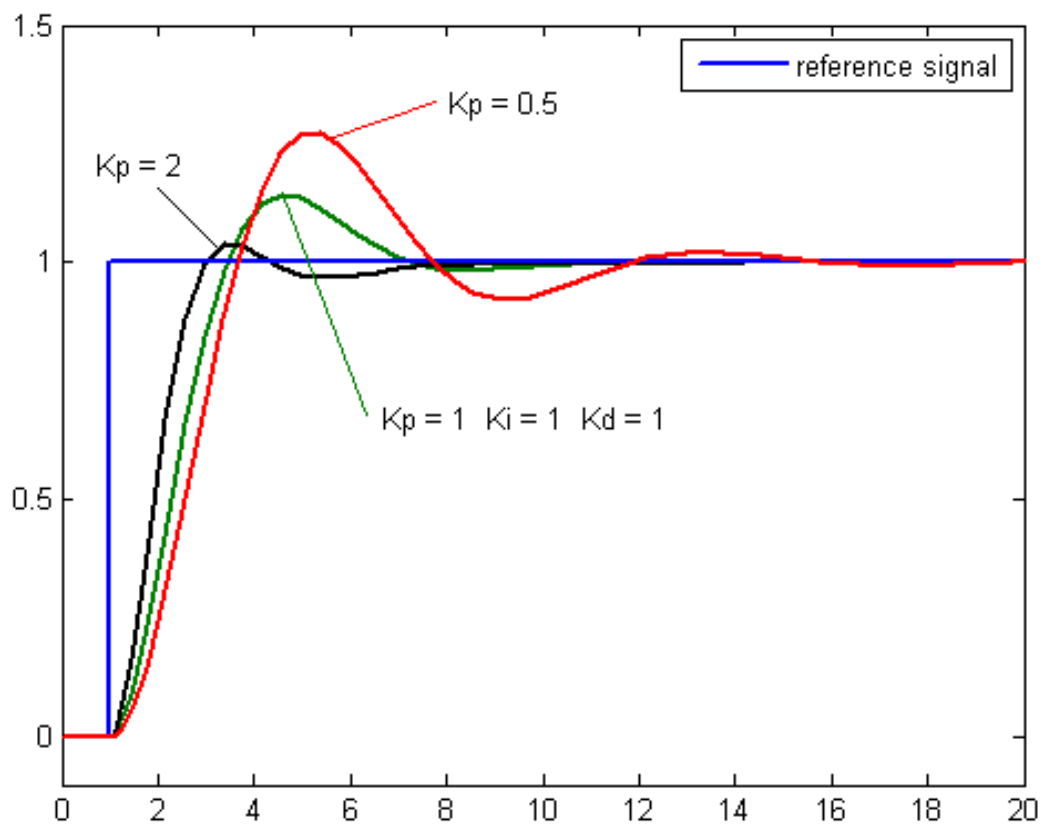Below are typical graphs expected that shows the desired response for the certain value of K_p, K_d and K_i.

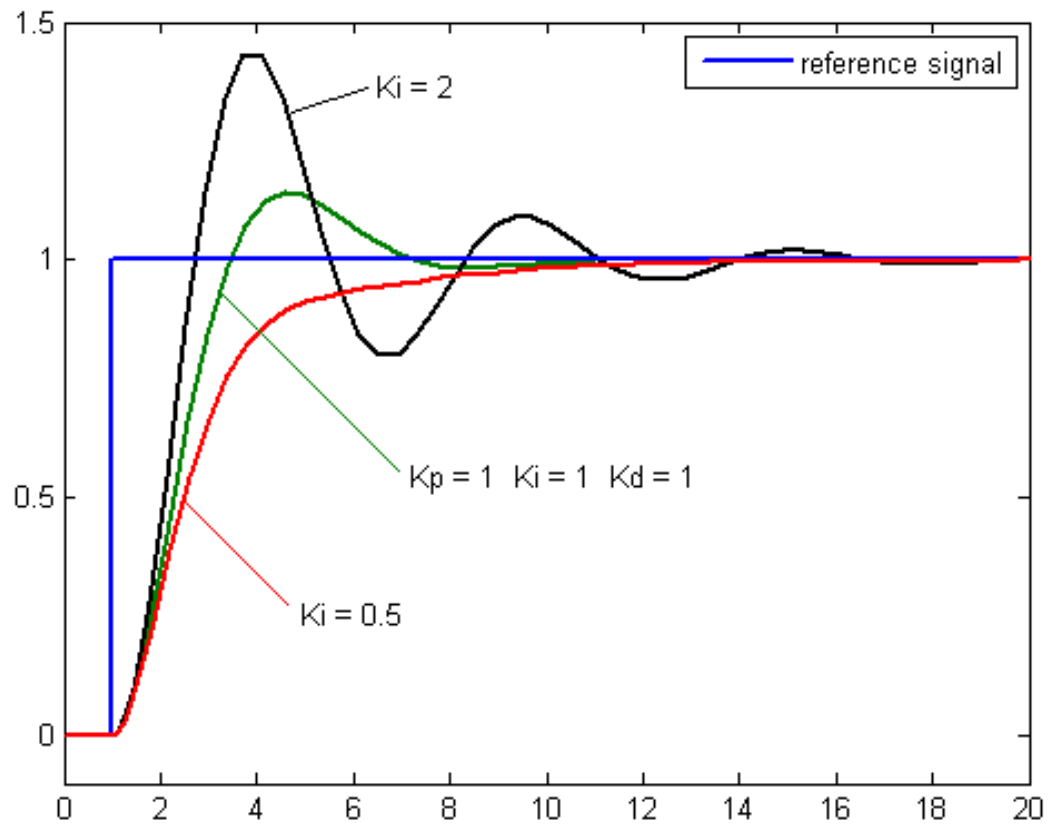Figure 19: Plot of PV Vs Time for 3 values of Kp (Ki and Kd held constant)

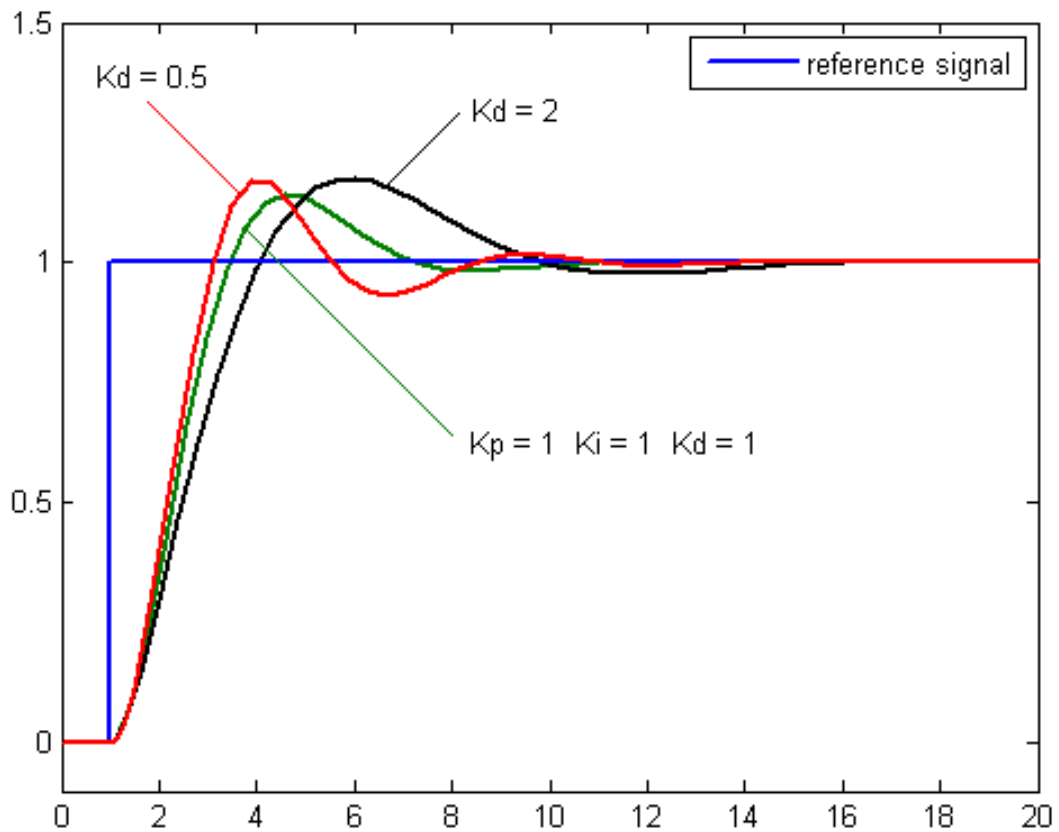Figure 20: Plot of PV Vs Time for 3 values of Ki (Kp and Kd held constant)

Figure 21: Plot of PV Vs Time for 3 values of Kd (Kp and Ki held constant)

The first stage of the project which is set up all the hardware connections is already complete. However, the second stage which is to perform experiment and data acquisition cannot be done yet because the engine facing a problem. From my conversation with one of master student who also doing a research using the same engine, he say that the engine cannot be start due to the leaking oil. Thus the experiment will be held after the problem regarding the engine is solved.

4.2   Discussions

As soon as the problem regarding the engine is solved, the experiment will be held using the different mode of the temperature controller including proportional (P) mode, proportional Integral mode (PI) and Proportional, Integral and Derivative mode (PID) in order to get the temperature variation data. Besides, labVIEW 7.1 software will be use for the data acquisition of the temperature variation. Lastly, the software will be programmed to control the temperature controller using the computer so that the system will become more sophisticated.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

5.1   Conclusion

To achieve the objectives of the project, more reading and research on the temperature control algorithm need to be done. Besides, an experiment and data acquisition on temperature of air intake to the engine needs to be performed. For a conclusion, the temperature controller for the air intake to the HCCI engine is essential for the development of the HCCI engine.

5.2   Recommendations

It is recommended that for future work of the project, some modification will be made to obtain different result. First is to conduct more research on the temperature required for an ideal combustion between hot air and fuel to happen. Besides, the position of the air heating chamber should be change to a spot where the heat from the engine is released. Thus less energy can be use to heat the air because the air at that spot is already hot before entering the chamber.

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APPENDIX A

PROJECT MILESTONE

No.	Detail/ Week	1	2	3	4	5	6	7		8	9	10	11	12	13	14
1	Project work continues	■	■	■	■	■	■	■								
2	Submission of Progress Report 2									■						
3	Seminar (compulsory)										■	■	■			
4	Project work continue										■	■	■	■		
5	Poster Exhibition											■				
6	Submission of Dissertation (Soft bound)													■		
7	Oral Presentation														■	
8	Submission of Project Dissertation (Hard															■

■   Suggested milestone

■   Process

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