DESIGN AND DEVEPLOMENT OF MOTION AND THERMAL CONTROLLER FOR THERMAL FATIGUE MACHINE

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“In the name of Allah, the Beneficent, the Merciful”

Dedicated to my Parents.

Thank you

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ABSTRACT

This report presents the design and development of motion and a thermal controller for thermal fatigue machine. Automation system has become an important medium in manufacturing operation. The time required to perform a complete testing is depend on the performance of the machine control system. Thus, by designing a better controller in a system, it will improve the overall performance of the machine. In this project, the pneumatic system was used as a platform to the design of motion and thermal controller as the control console for the furnace. Then, the performance of motion and the thermal controller was evaluated. The pneumatic cylinder was used as mechanical devices by the power of compressed air to drive the reciprocating linear motion and rotary motion. The pneumatic control was performed automatically by OMRON's Programmable Logic Controller (PLC) based on Ladder Logic Diagram. PLC has 5v to 24v I/O voltage range which is compatible with many types of sensor and solenoid. The motion of the machine was designed based on motion sequence requirement. Cascading pneumatic circuit was used as design methods to perform the motion sequence. The furnace control console was designed to have two temperature controllers. The first controller was connected to main thermocouple which was designed to measure the temperature of heating element. While, the second controller was connected to secondary thermocouple which was design to measure the temperature of molten aluminium. This project was successfully completed with all controller was able to perform the required motion and thermal control for the thermal fatigue machine.

ABSTRAK

Laporan ini membentangkan reka bentuk dan pembangunan gerakan dan pengawal haba untuk mesin ujian kerosakan haba. Sistem automasi menjadi medium penting dalam operasi pembuatan. Masa yang diperlukan untuk menjalankan ujiian yang lengkap adalah bergantung kepada prestasi system kawalan mesin. Oleh itu, dengan mereka bentuk gerakan yang lebih baik di dalam system, ia akan meningkatkan keseluruhan prestasi mesin. Dalam projek ini, sisten pneumatik digunakan sebagai platform untuk mereka gerakan dan pengawal haba sebagai konsol kawalan untuk relau. Kemudian, prestasi gerakan dan pengawal haba dinilai. Silinder pneumatik digunakan sebagai peranti mekanikal oleh kuasa udara termampat untuk memacu gerakan salingan linear dan gerakan berputar. Kawalan pneumatik dilakukan secara automatik oleh Programmable Logic Controller OMRON (PLC) berdasarkan Rajah tangga Logik . PLC mempunyai 5v ke 24v I / O julat voltan yang sesuai dengan pelbagai jenis sensor dan solenoid. Pergerakan mesin itu direka berdasarkan urutan gerakan yang diperlukan. Cascading litar pneumatik diguna sebagai kaedah reka bentuk untuk melaksanakan urutan usul itu. Konsol kawalan relau telah direka dengan mempunyai dua pengawal suhu. Pengawal pertama telah disambungkan dengan termogandingan utama yang direka untuk mengukur suhu elemen pemanas. Walaupun, pengawal kedua berhubung dengan termogandingan kedua yang merupakan direka bentuk untuk mengukur suhu lebur aluminium. Projek ini telah berjaya siap dengan semua pengawal dapat melaksanakan apa yang diperlukan dan kawalan haba untuk mesin kerosakan haba

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LIST OF SYMBOLS

π	Pie
ρ	Density
v	Volume
p	Pressure
f	Frequency
w	Angular Velocity
V	Velocity

LIST OF ABBREVIATIONS

PLC	Programmable Logic Controller
SV	Setting Point
Al	Aluminum
PID	Proportional Integral Derivative
SSR	Solid State Relay
TRIAC	Bidirectional Triode Thyristor
I/O	Input/Output
NO	Normally Open
NC	Normally Closed
TM	Fr
IC	Internal combustion
LG	Linear generator

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

Thermal fatigue is caused by repeated process heating and cooling material can give a cyclic stress because of the differential thermal expansion (Srivastava et al., 2004). This happens when the small damage with continued cycling is possible until it develops into a big damage such as cracks that may lead to failure. This crack will affect the surface of die due to the heat check on it. This also will affect the tool life because of corrosion and erosion on the die. This think is not good for material because it will cause the material easier to damage. Based on my investigation, to know the characteristic of thermal fatigue, thermal fatigue machine testing is required to measure the thermal fatigue properties of it. There are so many models of the-the machine can use to test it and need to choose a machine with suitable automation system because of different mechanism they use. Usually, for the simpler and lighter machine like the pneumatic system, it is suitable to use in operating machine for thermal fatigue test.

The pneumatic system is usually applied to an actuator or motor through a valve (Goshorn, 13 Nov. 1984.). This actuator only will move when to have some pressure is applied to it and will move with high speed. Pneumatic system also suitable to use for this machine regarding simpler and low in cost compare to the hydraulic system but are usually not considered suitable for use in machine control due to the compressibility and cushioning effect of air as a driving medium. However, to control all operating of this machine in it cycle, it must be equipped with logic process controllers for the program all controlling the operating sequence of the machine for more efficiently in operates (Goshorn, 13 Nov. 1984.).

Programmable Logic Controller has been used in many industries today such as for industrial process in manufacturing to run the machine because it is used automation system. This is because it has a single controller which can easily run many machines at one time. Programmable controller will control all operating the machine using the sequential design

1.2 PROBLEM STATEMENT

Automation system was used widely in manufacturing operation especially for control a machine. Mostly it used application area of programmable logic controllers (PLC) are to control circuit for hydraulic or pneumatic system. PLC is a device provide with special input output units suitable to direct usage in industrial automation systems. It is designed for use in an industrial environment, which uses a programmable memory for the integral storage of user-oriented instructions for implementing specific functions such as logic, sequencing, timing, counting, and arithmetic to control through digital or analog inputs and outputs, various types of machines or processes (Bolton, Newnes, 2015.). In order to control this system, it is necessary to develop a controllable motion for pneumatic and furnace to control the process.

In thermal fatigue testing machine, the time required to perform one complete testing is depend on the performance of the machine and pneumatic control. By using a better controller in a system, it will increase the overall performance of the machine. Pneumatic and thermal control system will be evaluated for best response of the process

1.3 OBJECTIVE

i. To design thermal controller and pneumatic system for thermal fatigue machine
ii. To fabricate and evaluate the performance of the thermal controller and pneumatic

1.4 PROJECT SCOPE

i. Identify the process flow and mechanism of thermal fatigue machine
ii. Design pneumatic system and develop the Programmable Logic Controller (PLC) program to control the machine process flow
iii. Select suitable hardware and electric part to be installed at controller
iv. Program the PLC controller according to the system requirement
v. Design electrical circuit for temperature controller and PLC
vi. Fabricate the new controller for machine

CHAPTER 2

LITERATURE REVIEW

2.1 THERMAL FATIGUE TESTING METHOD

According to the A. Srivastava, the concept behind the design is to heat the specimen in molten aluminium and to cool them in water and to repeat this cycle until the test coupon cracks (Srivastava et al., 2004). The design of thermal fatigue machine consists of heating station, a cooling station, and fixtures to support the movement of specimen across the two stations. A heating station is a place for furnace containing crucible with aluminium at 1200–1400 ◦C and the cooling station is a tank with water room temperature. To move the specimen, the distance, speed and acceleration in two directions and rotation speed need to drive by motor (Srivastava et al., 2004). The schematic for this experiment shown in figure 2.1

In 2013, Dhouha Mellouli introduced a new designed which is can control using pneumatic actuator. The thermal fatigue test consists of alternately cooling and heating ledge of the specimen. While thermal cycling, the specimen is totally free to expand or to contract so that only mechanical strains resulting from the thermal gradients are seen by the specimen. Closed-loop temperature cycling was achieved using a thermocouple spot welded at the midpoint of the leading edge at 1.5 mm from the radius. The temperature cycle was obtained by setting point a temperature controller range 500 °C to 700 °C (T_{max}, T_{min},) (Mellouli et al., 2014). Heating was provided by a radiation furnace with six 1500 W light bulbs. The thin specimen edge was placed in the center of the furnace on an adjustable holder that kept the tested structure in position without additional mechanical loading. The cooling system consists of a removable nozzle that moves during the thermal cycle. The different between A, Srivastra and Dhouha Mellouli method is they use difference drivers to move the specimen.

Unfortunately, the both method by A. Srivastra and Dhouha Mellouli takes too long duration to heating up the specimen and require more electrical power consumption. Besides that, they also do not state the detailed method to control the furnace temperature. However, there has a certain concept that can be using in this project design.

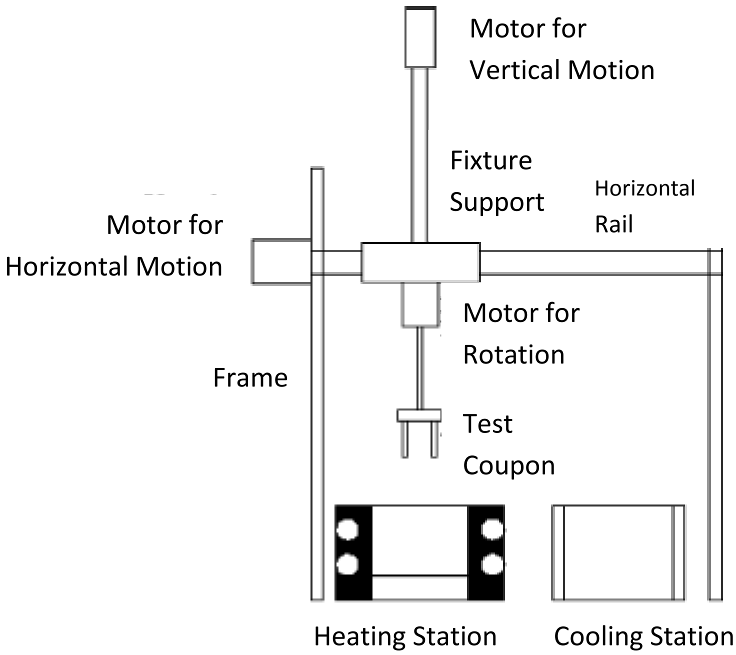


Figure. 2.1: Schematic diagram of experimental test set-up. (Srivastava et al., 2004)

2.2 PROGRAMMABLE LOGIC CONTROLLER (PLC)

A programmable logic controller (PLC) is a specialized computer used for control and automation of electromechanical processes and machines especially in the fields of factory assembly lines. Previously, PLC was also known as a programmable controller, PC. However, PC is a common abbreviation for "personal computer", so some manufacturers refer to their device as PLC. Basically, the design of most PLCs is similar to that of general purpose computers. It is designed by assembling solid-state digital logic elements to make logical decisions and provide outputs.

Initially, a single PLC was programmed to replace older automated systems which used hundreds or thousands of relays. It has been designed as an industrial computer to operate in the industrial environment and is equipped with special input/output interfaces and a control programming language. Programs are typically stored in programmable memory (non-volatile memory). Thus, a PLC is capable of performing specific applications such as logic, sequencing, timing, counting, processing of analog signals and arithmetic for the purpose of control machine and processes (Bolton, 2009). As ever-increasing of its functionality, PLC is widely used in every aspect of industry and process control to expand and increase production.

The PLC has expanded dramatically over the time. There are more capabilities of PLC have been developed other than typical relay control such as complicated motion control, process control, distributive control systems, and complex networking .(Petruzella, 2005)

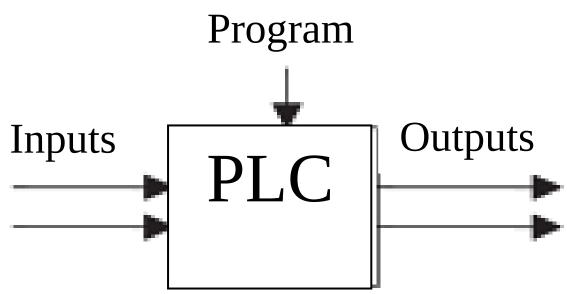


Figure 2.2: A programmable logic controller (Bolton, Newnes, 2015.)

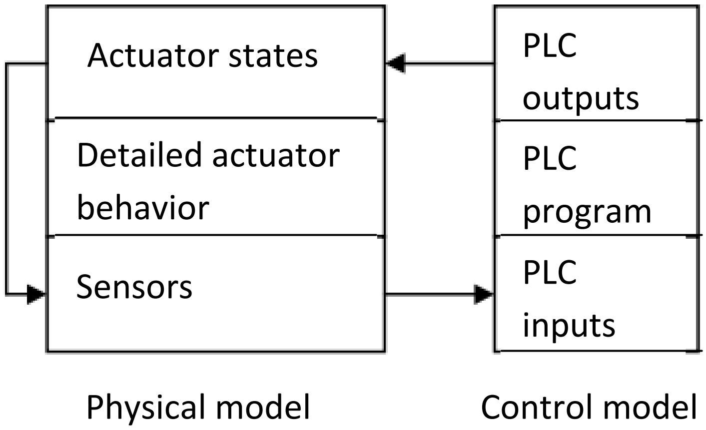


Figure 2.3: The overall model for a PLC controlled in manufacturing system (Bolton, Newnes, 2015.)

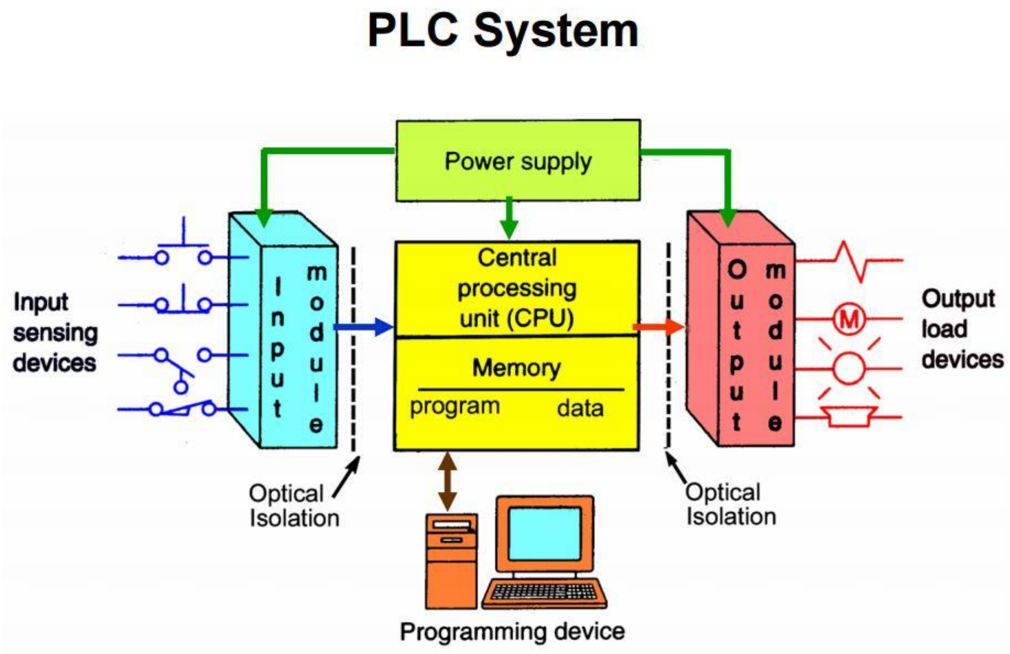


Figure 2.4: The Block Diagram of Typical Component of a PLC (Hashim, 2013)

2.2.1 Ladder diagram

In 1994, the International Electrotechnical Commission (IEC) stated IEC 1131-3 as the standard specific to programmable controllers. The five international standard programming languages for PLC are Ladder Diagram (LD), Sequential Function Charts (SFC), Function Block Diagram (FBD), Structured Text (ST) and Instruction List (IL) (Maslar).

The most popular used language for PLC is ladder diagram. LD is a graphical description of the process with rungs of logic. It designed to copy the relay ladder logic scheme that was replaced by PLCs. This gives convenience for those engineers who do not have great knowledge in programming. The main functions of LD program are to control outputs based on input conditions. A LD basically consists of two vertical rails and horizontal rungs. A rung consists of a set of symbolic instructions such as contacts, relays, functions and logical operations. Each symbol is referenced with an address number for identification purpose in controlling and evaluating. The process of scanning LD is in left-to-right and top-to-bottom sequences. For an output to be energized, there must have logic continuity, means that left-to-right path of input instructions must be closed (Fischer-Cripps, 2002).

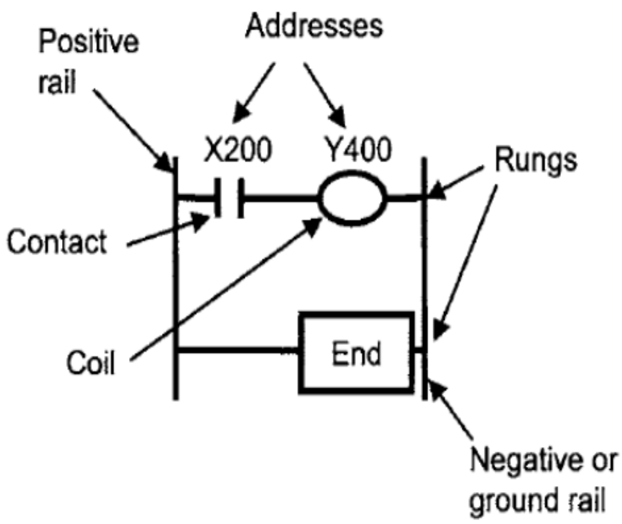


Figure 2.5: Ladder logic diagram (Fischer-Cripps, 2002)

2.2.2 PID CONTROLLER

PID controller or conventional proportional integral derivative is widely used in many industrial applications due to ease of design [15]. Software PID controllers have become a standard component of automation with Programmable Logic Controllers and work together with classical sequential function charts in the same processing units . The temperature controller is independent control of each furnace zone is provided by type K sensing thermocouple located in the furnace. PID temperature controller was used to control the behavior of the furnace zone heating element in the system. The controller’s closed loop temperature control system uses K-type thermocouple feedback .

The PID models are independently optimized to provide the best performance for furnace for operating range furnace temperature 100-1000C. The zone controllers automatically select the PID control model closed to the target set point.

2.3 PNEUMATIC SYSTEM

Pneumatics is the technology used to controlling the mechanical movement using air pressure (Parr, June 21-22, 2011).Pneumatics system basically used in two main applications which are for automatic manufacturing system and conveying system. Basically, pneumatic working in the industry used compressed air as its application .Air compressed at high pressure contains pneumatics power and compressor used to compress pneumatics power. Besides that, pneumatics system contained four section devices such as compression section devices, air quality control devices, control devices, and drive devices

The first section is compression section devices. At this section device, it generates compressed air and stores the air by using two main components which are a compressor and air tank. The Filter-Regulator-Lubricator (FRL) functions are to filtering and air servicing from dust and water before the air move to control devices. At control devices section, it contained directional control valve and velocity control valve for drive pneumatics actuator. The function of the valve is to OFF and ON the air supply through actuators.

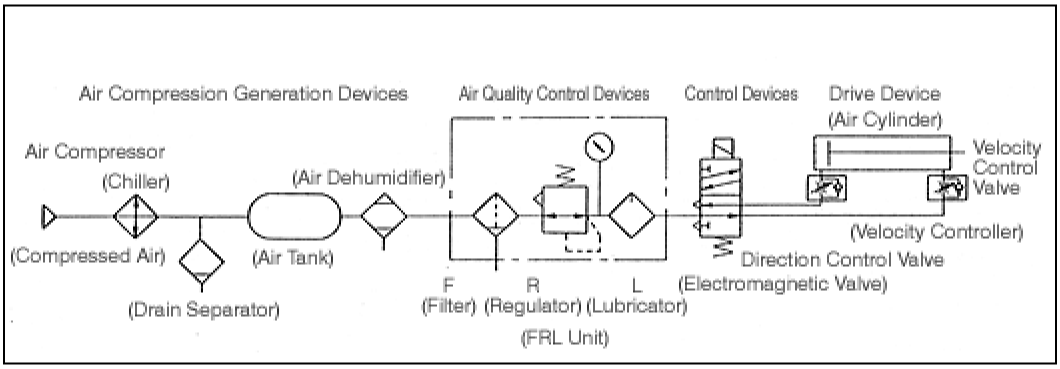


Figure 2.6: Pneumatic system

2.3.1 Advantages and Disadvantages

By comparing pneumatic actuator and hydraulic actuator, although hydraulic actuator offers a higher better precision motion transmission compare to a pneumatic actuator, but pneumatic actuator has more advantages compared to the hydraulic actuator. The pneumatic actuator is suitable to use in varies type of environment because of the medium used in the pneumatic cylinder are air instead of fluid. It is no significant effect for pneumatic actuation system while it exposes to ambient temperature change. Table 2.1 below show other advantages and disadvantages of pneumatics system.

Table 2.1: advantages and disadvantages of pneumatics system

ADVANTAGES	DISADVANTAGES
• Can used air anytime and everywhere in unlimited quantities • Air can transport easily using pipelines for large distances • In under extreme condition, compressed air is nearly insensitive to temperature fluctuations and this will ensure it operation will reliable. • Can store and removed compressed air in reservoir • More safety compared with electromotive system because it does not cause fire or explosion without using a component that can cause flammable	• Can only working in normal pressure of 600 to 700 kPa (6 to 7 bar) and dependent on the travel and speed • Produce a noise from the compressed air when pneumatic was released.

2.3.2 Pneumatic cylinder

The pneumatic cylinder is mechanical devices which use the power of compressed air to produce a force in a reciprocating linear motion. According to A. Srivastava, V. Joshi, R. Shivpuri, the distance, speed and acceleration in two directions and rotation speed can be controlled by a computer through motor drives (Srivastava et al., 2004). For this project, actuator cylinder and rotary cylinder was uses to produces mechanical motion. There are two types of the cylinder that will use such as single-acting cylinders and double-acting cylinders. A single-acting cylinder requires only one air supply. A double-acting cylinder has no spring inside to return it to its original position. It needs two air supplies, one to outstroke the piston and the other to in stroke the piston

2.4 ELECTRICAL COMPONENT

2.4.1 Temperature Controller

Temperature controller was used in wide variety of industries, especially for control temperature. The function of this controller is for controlling the temperature to get the accurate temperature as condition needed. Temperature controller gets their inputs from a thermocouple located inside the furnace and displays the temperature on the screen. This temperature controller can control for a variety of application because can provide accurate temperature management and offer quick setup. The figure 2.7 shown the temperature controller

Figure 2.7: Temperature Controller

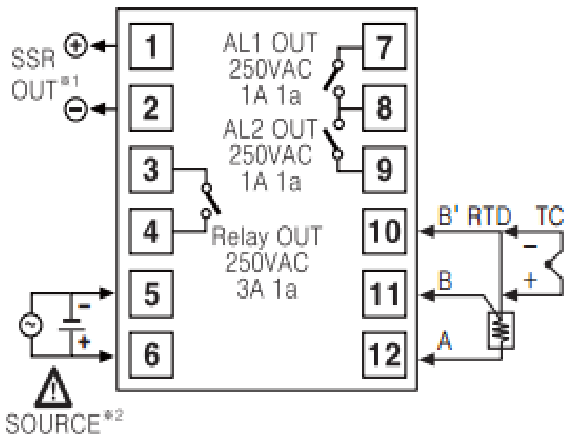


Figure 2.8: Temperature Controller connection [14]

Table 2.2: Temperature controller specification

Features	TCN4S	TCN4M
Power supply	100-240VAC 50/60Hz	
Control output	Relay 250VAC 3A/Solid state relay (SSR) 12VDC±2V 20mA Max	
Alarm output	AL1, AL2 Relay: 250VAC 1A 1a	
Control method	ON/OFF control, P, PI, PD, PID control	
Input type	Thermocouple K(CA), J(IC), L(IC), T(CC), R(PR), S(PR)	
Dimensions	48mm × 48mm	72mm × 72mm

2.4.2 Solid State Relay (SSR)

Relay is one such type of protective device for circuit and as a switch that works on the principle of electromagnetic induction. The switching between the OFF and ON position is work with the help of an electromagnet. Besides that, relay also can be used to control device that draws much power like isolator and circuit breaker and it can be operated with a small amount of power. A relay is like a remote control switch and has many applications because of its long life, high accuracy, relative simplicity and proven high reliability (Nidhi Verma, 2015).In industries, a wide variety of application requires the use of a relay. Relays are used in a lot of home appliances as well, such as dish washers, washing machines and refrigerators along with air condition or heating controls (Nidhi Verma, 2015). Figure 2.9 shown below shows how do relay work.

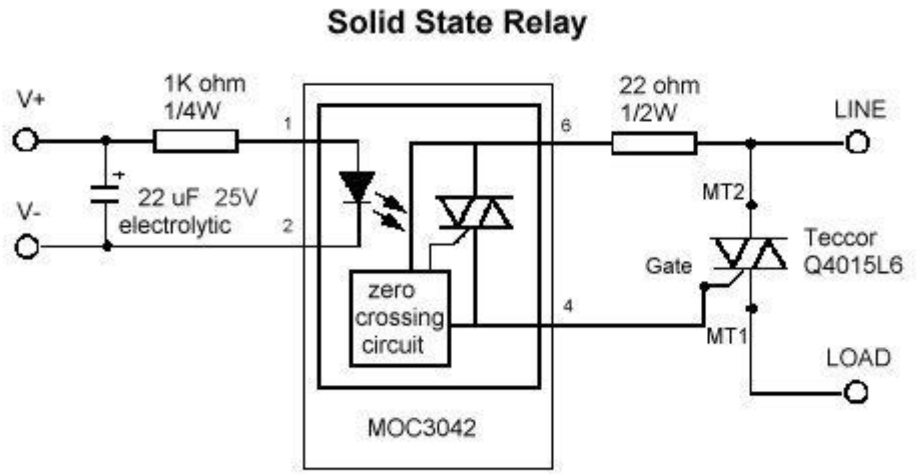


Figure 2.9: Relay operation circuit (Nidhi Verma, 2015)

There are three types of relay which are a static relay (solid state relay), electromechanical relay, and numerical relay. For solid state relay, it is the type of relay of the magnetic coil or mechanical components that create the relay characteristic and the incoming current or voltage waveform using analog electronic devices and monitored by an analog circuit. The SSR have a function like semiconductor devices to conduct load current and to protect the circuit under control for the introduction of electrical noises.

Photo-coupled SSR is one of the types of SSR. In this type of relay, an indicator or infrared source is provided with the control signal. The output will generate when a photo sensitive semi-conductor device detects the radiation from the source. Then, the output from triggers the TRIAC was used to switch the load current. SSR has gained favor in various regions that were earlier the domain of electromechanical relay or contactor. These are increasingly used in transformers, lamps, temperature control, solenoids, motors, and valve. (Nidhi Verma, 2015).Figure 2.10 shown the photo-coupled SSR.

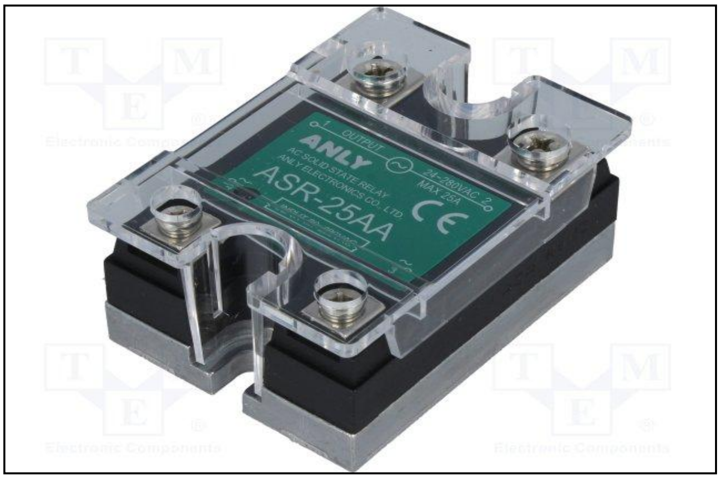


Figure 2.10: Photo-coupled SSR

2.4.3 Heating Element

The heating element is an electrical device that converts electric current to heat. There are two main types of heating elements or electrical resistance alloys. First is Nickel-chromium (e.g. 80 Ni, 20 Cr) or called NIKROTHAL was developed around the beginning of the 20th century and was soon used as heating element material in industrial furnaces as well as in electric household appliances (Kanthal). Then, Kanthal introduced a new resistance heating alloy (called KANTHAL) which is longer life and a higher maximum operating temperature than nickel-chromium (Kanthal). So, Kanthal manufactures both types of alloys under the names KANTHAL (iron-chromium-aluminium) and NIKROTHAL (nickel-chromium).

These two types of alloy have their own specific properties with advantages and disadvantages and can get in many different forms and grades. In general KANTHAL type alloy is superior to NIKROTHAL due to performance and life. The NIKROTHAL alloy also may have special advantages because it is a heating element having very good mechanical properties in the hot state compare to KANTHAL. However, KANTHAL APM has creep strength at elevated temperatures in the same levels as NIKROTHAL

For use heating element in the furnace, KANTHAL types are most suitable heating element because of lower price and a longer life. Tables 2.3 show a comparison between KANTHAL and NIKROTHAL.

Table2.3: comparison between KANTHAL and NIKROTHAL (Kanthal).

Element Data	NIKROTHAL	KANTHAL
Furnace temperature, ◦C	1000	1000
Element temperature, °C	1068	1106
Hot resistance, R_w	3.61	3.61
Temperature factor, C_t	1.05	1.06
Cold resistance, R_{20}	3.44	3.41
Wire diameter, mm	5.5	5.5
Surface load, W/cm^2	3.09	3.98
Wire length, m, 3 elements	224.9	174.6
Wire weight, kg, 3 elements	44.4	29.6

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION.

This chapter will cover all activities and research in order to get the results. In this chapter, the material, components, software and journal about machine system controller will be searched. The methodology‘s framework consists of the step need to do as drawn in figure 3.1. After getting some information about how the machine operation, the project was started with designing a circuit for the controller. Then, the ladder diagram was constructed and tested in the machine to ensure the pneumatic movement is same with the pneumatic system requirement. Next stage, is listed the part component for the pneumatic and furnace system that require for controller design.

After finalizing the concept, the electrical and electronic for PLC, pneumatic, and the furnace was wiring. Then execute the ladder diagram into the program and setting the temperature controller before test it with a real experiment. At this stage, all the data was recorded and the result was validated before including in the report. Finally, the discussion and conclusion will write. To improve the project in future, some suggestion and limitation will be discussed.

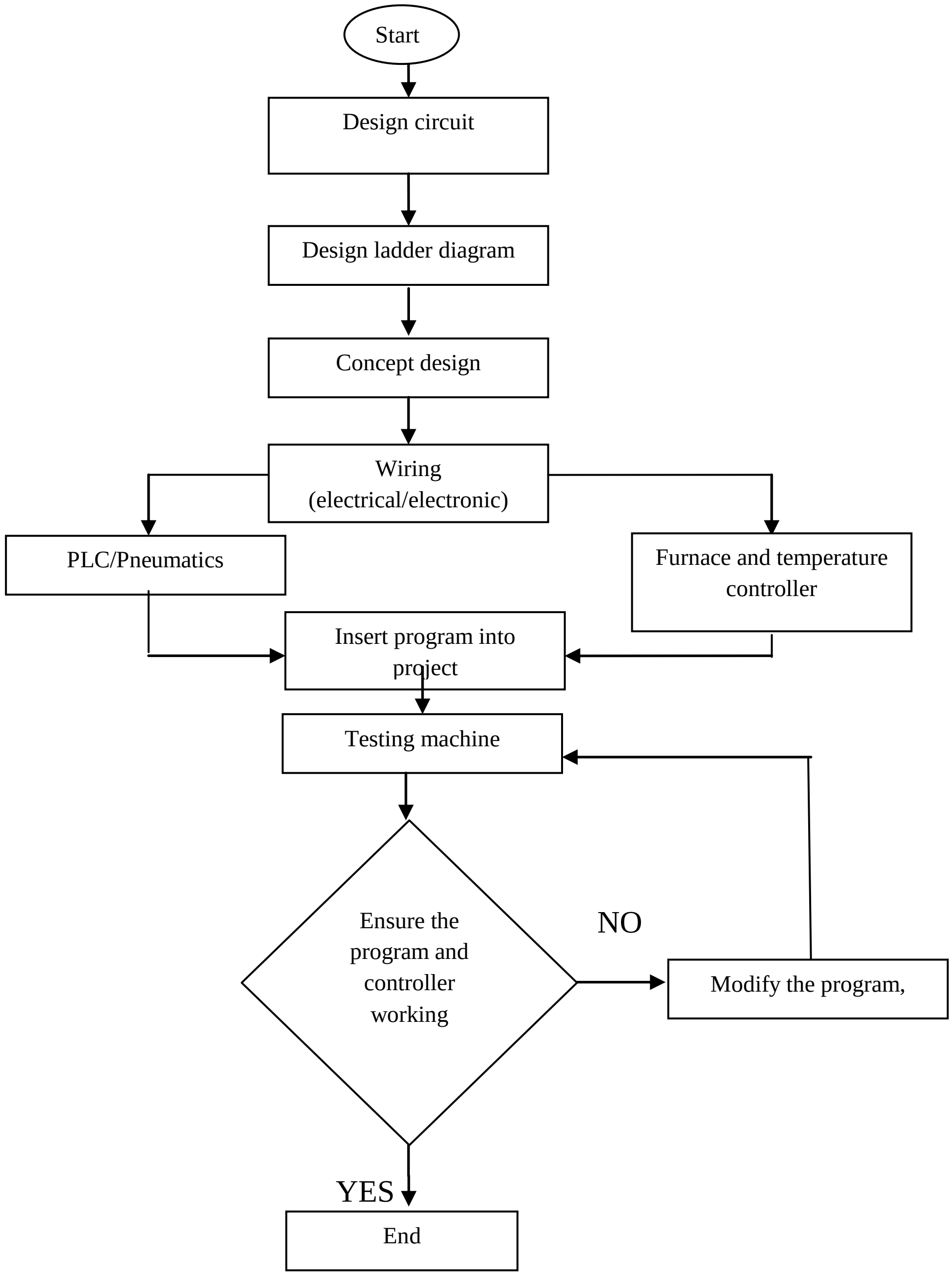


Figure: 3.1: Research Methodology Flow Chart

3.2 SYSTEM REQUIREMENT ANALYSIS METHOD

By referring the previous thermal fatigue experiment, the system parameters can determine. For this project, the main purpose is to control the time cycles for better by avoiding the time error. The time error will result in inconsistent data when to conduct the thermal fatigue experiment (Amiruddin, 2015). The cylinder and rotary actuators are the two types of pneumatics actuator that related to the time control. Table 3.1 below shows the systems parameter before develops machine controller.

Table 3.1: Systems Parameters for Thermal Fatigue Testing Machine (Amiruddin, 2015).

Pneumatic Actuator			
Cylinder		**Rotary**	
Process	**Time (s)**	**Process**	**Time (s)**
Rapid Cooling	2	Rotate Left	2
Dipping in Molten Aluminum	4	Rotate Right	2
Total Process Time	6	**Total Process Time**	4

3.3 DESIGN THERMAL CONTROLLER AND PNEUMATIC SYSTEM

3.3.1 Pneumatics system design

The pneumatic system is designed by referring pneumatics sequence requirement. CASCADE methods are used to determined the system as shown in figure 3.2. The process or sequences start when rotary actuator move to homing position and the movement of this actuator will be detected by a sensor (A1). After two second the cylinder will extend for four seconds in the furnace and then retract back. Then the process will continue with rotary actuator was rotate anti-clockwise and move back into the tap water for cooling process (Amiruddin, 2015). This process will continuously until the user pushes the stop button and PLC will stop it.

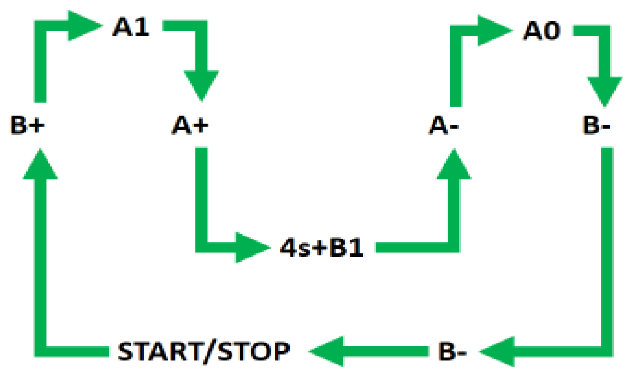


Figure 3.2: Cascade Method (Amiruddin, 2015)

Next, the process for pneumatics design is a create and design ladder diagram. In the previous study have been discussing ladder diagram. PLC is suitable to use ladder diagram because ladder diagram is created specific for PLC. The Automation Studio also was used to writing the program and easy to troubleshoot because the program and the pneumatic circuit contain in one window form and able to simulate on time as shown in figure 3.3 below (Amiruddin, 2015)

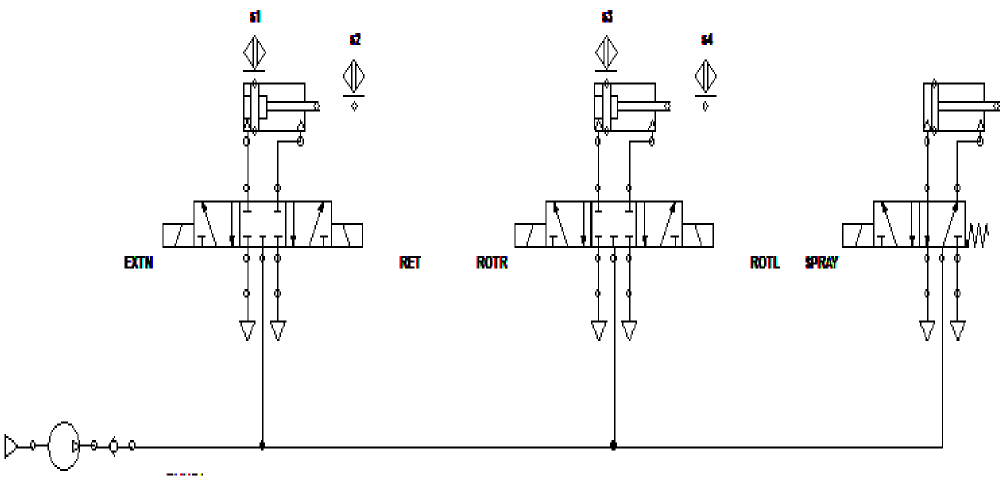


Figure 3.3: Pneumatic Circuit(Amiruddin, 2015)

The input and output devices connection can represent in the pneumatic electrical circuit in figure 3.4 below. The circuit produces two differences of the power source which are 5v for the input and 24v for the output devices.

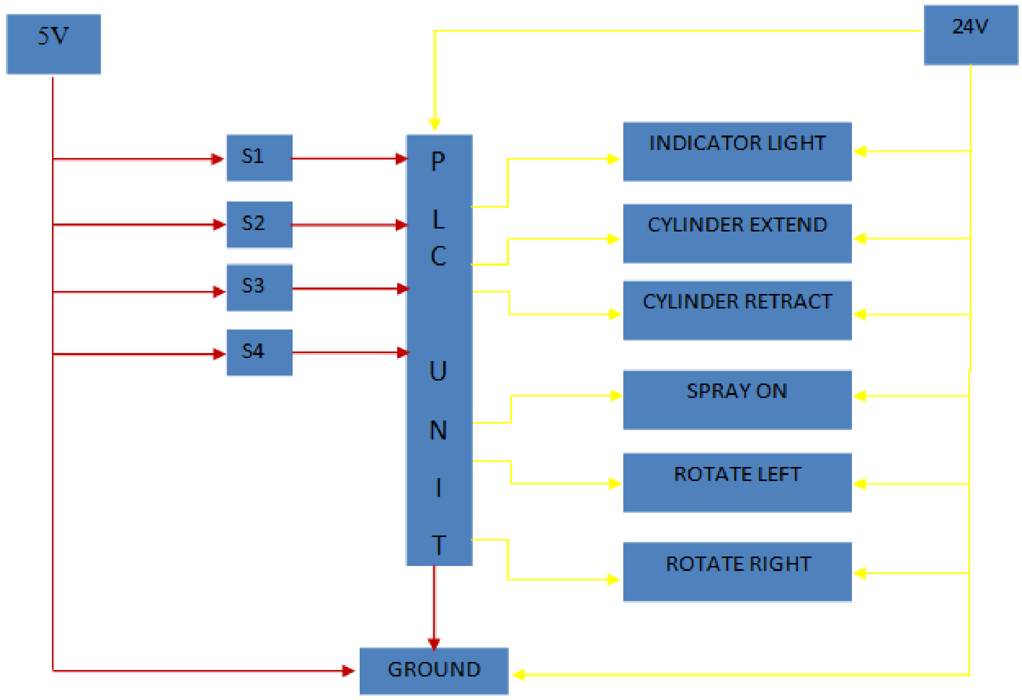


Figure 3.4: Electrical block diagram for pneumatics system(Amiruddin, 2015).

For this project, 5/3 ways valve have been deciding to use for the rotary due to 5/3-way valve consists three switching positions and five working ports. The double-acting cylinder also can be stopped with the stroke range if used this valve. This means cylinder piston under pressure in mid position is briefly clamped in the normally closed position and in the normally open position because the piston can be moved without more pressured. The valve also will still in spring-centered in mid position if no signals are applied at either of two ports. Figure 3.5 show the 5/3 way valve in normally closed.

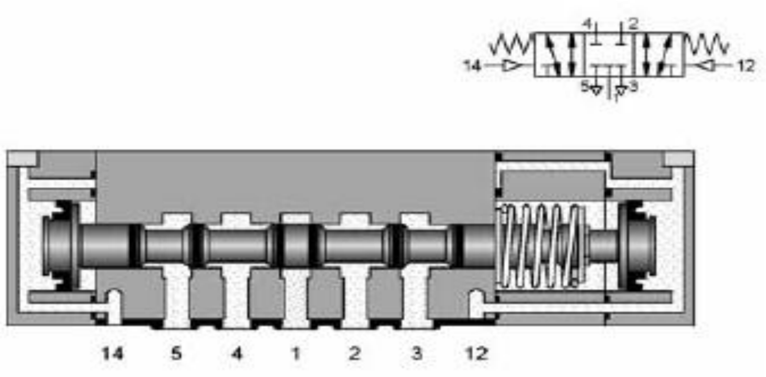


Figure 3.5: 5/3 way valve in normally closed (P. Croser, 2002)

3.3.1.1 Linking pneumatics system to the PLC

All of the solenoid valves for pneumatic cylinder will connect to the PLC output. The function of this linking is to provide regulated power supply, to receive the correct level of the signal from PLC, and to convert the PLC output signals to the correct level in order to drive the pneumatic cylinder. Figure 3.6 below show wiring solenoid valve to PLC.

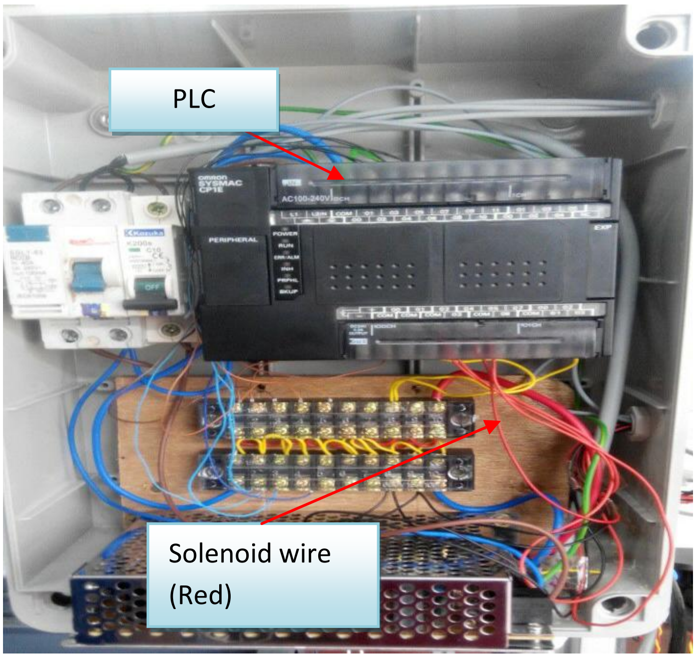


Figure 3.6: Solenoid valve connection to PLC

3.3.1.2 CX-Programmer

CX-Programmer is programming software to create, manage and debug programs. It is a software product special for all OMRON’s PLC series, i.e. SYSMAC CS/CJ/NSJ-series, C-series and CVM1/C-series CPU units . It provides an automatic connection to serial, USB and EthernetIP devices. Thus, the onsite startup and debugging time have been significantly reduced. The program is able to do the calculation, read analog data, monitor memory data in the storage continuously while the process running and also observe the processes through the computer.

In this project, CX-Programmer is a platform used to develop a program using ladder diagram graphic technique. The complete ladder diagram is included in next chapter.

3.3.2 Thermal Controller Design

In this project, it will consist two difference state of operation which is first in the manual mode and second is automatic mode. In manual mode, the user needs to press (switch on) in every state condition to start the process and complete the operation. However, in automation mode, all the operation will start automatically after the users pressed one switch simultaneously. For this system, all state operation has its own switch.

Interface with the furnace with Control console is designed to control the process of the machine. The control console is divided into some part. Some of the parts are controlling the pushbutton with indicators. For example, when pressing the green button it will make the machine ready to start the process until the green lamp of indicator lighting. Then, pressing the red button to stop the process. This Control Console is used to communicate with the programmable logic controller (PLC) that control the machine operation (Clark, 2004).

3.3.2.1 Lamps pushbuttons with indicators

Switches power is used in this project to select heating element and control the process. These buttons work only when a controls indicator is on. For example pressing the green button when the green lamp is lighting because the aluminum in the furnace is already heated and the red lamps will switch on when the red button is pressing to stop the process.

3.3.2.2 Ready lamp

Indicates the furnace is ready to process the experiment when aluminum is melting. The temperature controller also heated to their SV set point values and controllers have reported all PV process temperatures as within proving ready limits for 2 minutes. Then, the process was ready (light green) on the box will on.

3.3.2.3 Buzzer

Audible warning, to produce warning of any alert alarm condition

3.3.2.4 Switch for silence buzzer with red lamp

This button will turn the silence the buzzer. This will also turn the silence red lamp ON as a reminder to the operator that the buzzer is disabled.

3.4 FURNACE TEMPERATURE CONTROL

The furnaces are controlled by temperature controllers. The temperature gets their inputs from a thermocouple located inside the furnace and sends necessary control action to the solid state relay to maintain the process set point.

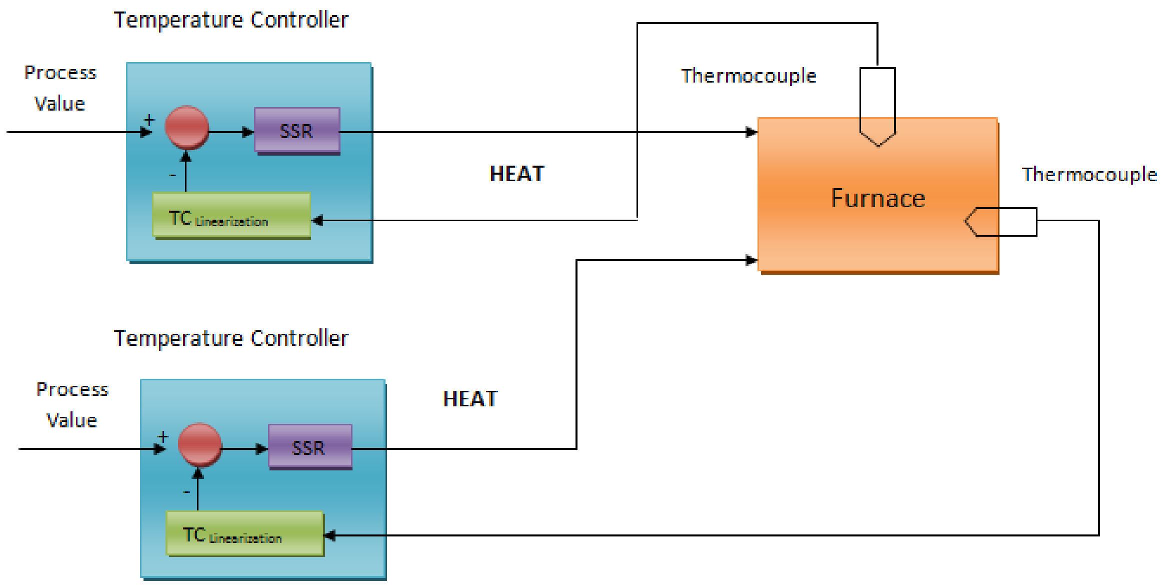


Figure 3.7: Schematic temperature controller to furnace

The control action for the temperature control can be either on/off. On/off control is simple to understand. For example during the heating process, if the measured process temperature is below the control set point, solid state relay continuously supplies power to the heating element. If the measured value exceeds the control set point, the controller shuts give control signals to the solid state relay and stop supply power to the heating element. Switching the heat on and off takes place at set point. This type of control causes the process value to oscillate around the control set point.

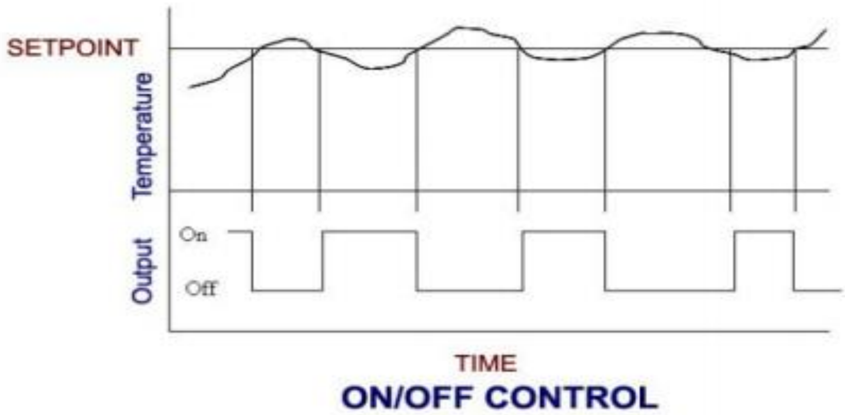


Figure 3.8: On/Off controllers commonly used in furnace (Purushothaman, 2008)

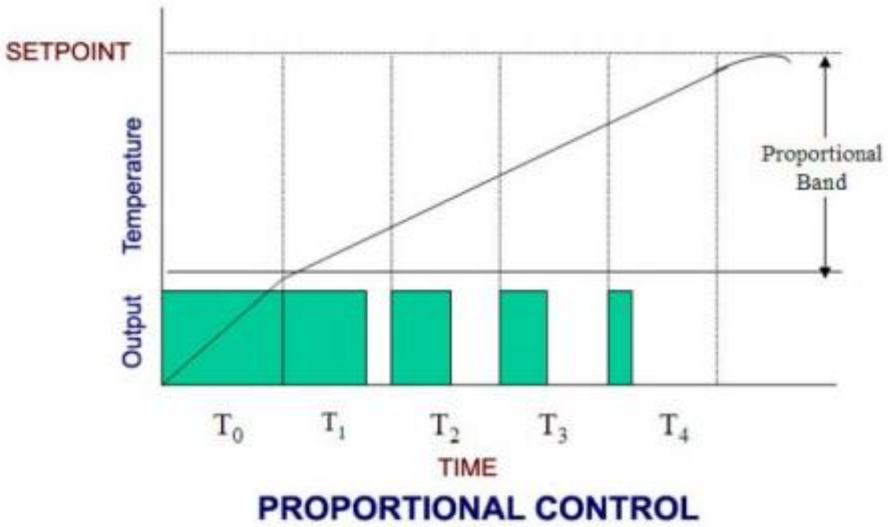


Figure 3.9: Proportional controllers commonly used in furnace (Purushothaman, 2008)

3.4.1 Implementation of two solid state relay (SSR)

Solid state relay function in this project is a switching to control heating process in the furnace. All detailed about solid sate relay already discuss in the previous chapter. The reason for used two temperature controller and two solid state relay in this furnace is to prevent overheat from occurring. From the previous testing, the problems are identified and need a solution to avoid this problem. Another method is by using thermal overload relay .This is because the thermal overload relay is used to sense the overload current. Thermal overload relay is recommended which provides an accurate tripping of the circuit preventing the overheating (Badrinarayanan Rajagopalan, 2011).

3.5 EVALUATE OF THERMAL FATIGUE TESTING MACHINE

A testing machine with actual experiment is a process to evaluating either the machine working or not. This method will allow people to test and adjusting the precision and accuracy of measurement parameter require for the machine. For this project, the testing will perform on the furnace and pneumatic system. The purpose of this testing is to recorded time for furnace and coil increase from room temperature to the molten temperature either the furnace can heat with optimum performance or not. Besides that, the time for experiment complete in 4000cycles also will be recorded to see the motion performance.This will be discussed more detailed in Chapter 4 Result and Discussion.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss design analysis of the system and the results from the testing with a real experiment. Besides that, this project also will discuss the new system for the furnace and the methods are used to avoid the problem. So, the position the coil, the diameter and length need to calculate to know the current density and prevent the coil from overheating due to the both aspects. Lastly, the experiment of thermal fatigue will be calibration and all the machine performance and performance for the pneumatics and thermal control will be recorded for analysis. The time required for the furnace to achieved maximum temperature, the size of the coil and the actual parameter will be discussed detailed in order achieve optimization.

4.2 HARDWARE

4.2.1 Pneumatic system

According to the methodology in chapter three, there were used two types of the pneumatic actuator to move the sample inside the furnace. The pneumatic actuator was used 5/3 ways and 4/3 ways solenoid valve as a drive and it requires maximum 10 bars working pressure. The solenoid valve 4/3 ways was used to drive expand and retract for actuator cylinder while 5/3 ways valve was used to control the rotation of the rotary cylinder. Based on the previous chapter, the 5/3 ways valve was used to control the rotary cylinder because 5/3-way valve consists three switching positions and five working ports. The rotary cylinder also can be stopped with the stroke range if used this valve. Figure 4.1 show the position o the valve, sensor, and solenoid for solenoid valve and it motion and figure 4.2 show the solenoid valve to control the motion of actuator.

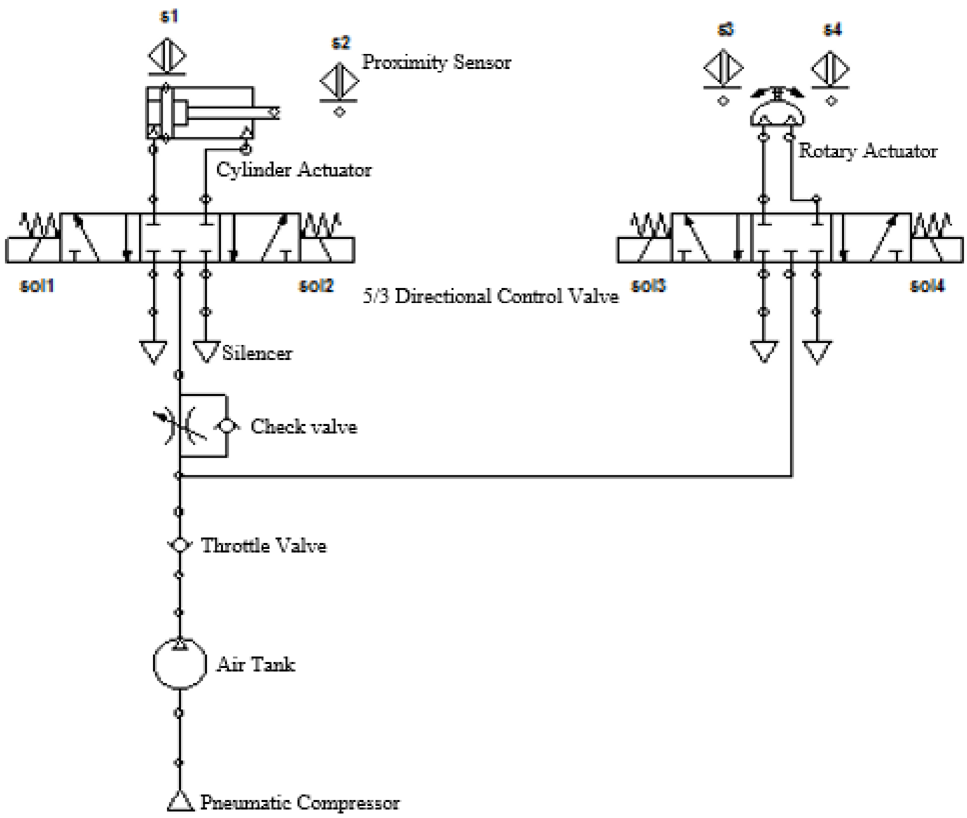


Figure 4.1: Pneumatic Circuit (Amiruddin, 2015)

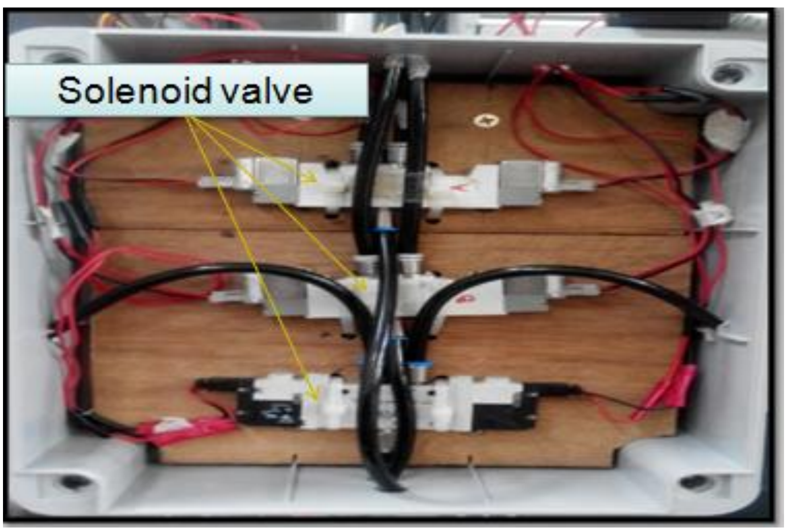


Figure 4.2: Solenoid valve

4.2.2 Furnace design

The furnace for thermal fatigue test was designed with three layers. The first layer is an outside body or cover made from mild steel because steel can be held in high-temperature condition. The second layer for the furnace is cover by a ceramic blanket made from high-temperature fiberglass as an insulating material. The ceramic blanket is made from high resistive material and suitably used in the high-temperature application regarding it properties can prevent heat leakage and fire hazard

In the second layer, the important parameter of the thickness ceramic blankets needs to consider before to put around the wall. This is because when the parameter, it will affect the temperature in the furnace and the reading of thermal controller also will affect because the heat loss around the furnace. So to minimize the heat loss, the ceramic blanket must put with a higher thickness in every area in the wall.

The third layer for the furnace was ceramic brick. This brick will cut in shape require as that of the furnace and are joined with slot thread along the side of the brick.The main function of this ceramic brick is a place to put the heating element and also a place to put the crucible. The three layer for the furnace was shown in figure 4.3 below.

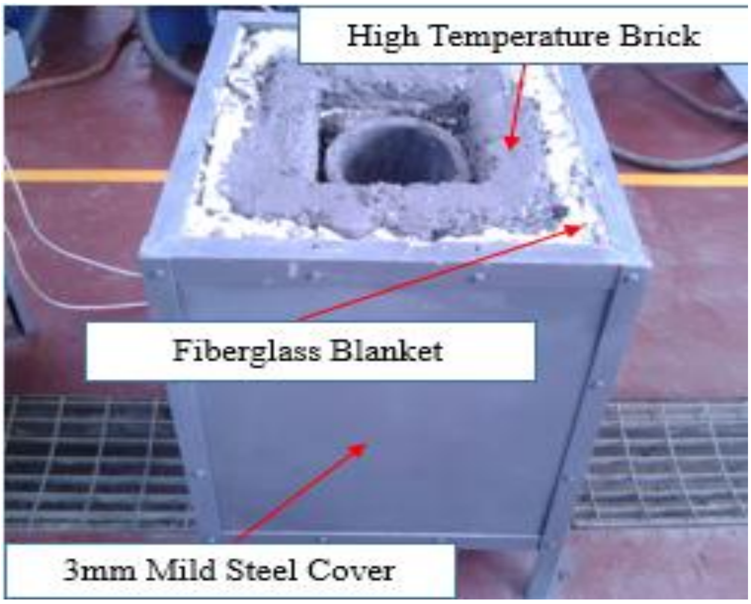


Figure 4.3: Furnace design (Amiruddin, 2015)

4.2.3 Heating element

The heating element use in the furnace was from Kanthal AF with 2mm diameter and 79.812m long. The power used for this furnace was 1000watt for one phase power direct from the power supply. The thermocouple K-typed Nickel chrome-Nickel was used to measure the temperature of the coil to prevent over heat. Thus, this furnace will work with 1000watt, 240 volts and has the capacity to raise heat to 700°C. Detail about heating element specification as shown in the table 4.1.

Table 4.1: Kanthal AF specification

DESCRIPTION	PARAMETER
Wire diameter (mm)	2.0
Coil OD (mm)	14
Lead length (mm)	1500
Exit length (mm)	1500
Coil length (mm)	10455
Pitch (mm)	6
Total wire length inc lead and exit (mm)	79812

4.2.4 Furnace Control Design

The main purpose of the furnace control design is to control and maintain the conditions inside the furnace with maximum efficiency

4.2.4.1 Temperature control

The temperature is the most important instrument in the furnace control design. This controller will measure and displays the temperature in the furnace through the thermocouple sensor placed inside the crucible and coil. The temperature controller will control the temperature for aluminium and coil by regulates current flow to maintain the set temperature and hence avoids overheating. For this thermal fatigue machine, two temperature controller already used to maintain the temperature of aluminium and coil from overheating. When the temperature inside the aluminium rises above from set value the temperature controller will stop sent control signal to solid state relay (SSR) input and this relay will cut the circuit and when temperature falls below the set temperature the control signal will be sent back signal to the input to produce back output for the furnace to start heating. So, the temperature for aluminium and coil is maintained.

Figure 4.4: Furnace Controller Box

4.2.4.2 Furnace circuit

The complete furnace circuit is shown in Figure 4.5. Two solid state relay was used to receive input control signal from temperature controller and gives and output or load to the heating element. In solid state relay, a light is provided with a control signal. To generate an output, photo-sensitive semiconductor devices such as diode and transistor will detect the radiation from the sources. The load current will switch when the output triggers were used. The circuit breaker was used in this circuit to prevent the overload source and short the circuit. For this circuit, two circuit breakers were used to protect the circuit from the main source and another one to protect solid state relay. Another component for this circuit is NO and NC relay. The relay function is a switch to connect with a push button to control start and stop heating the furnace.

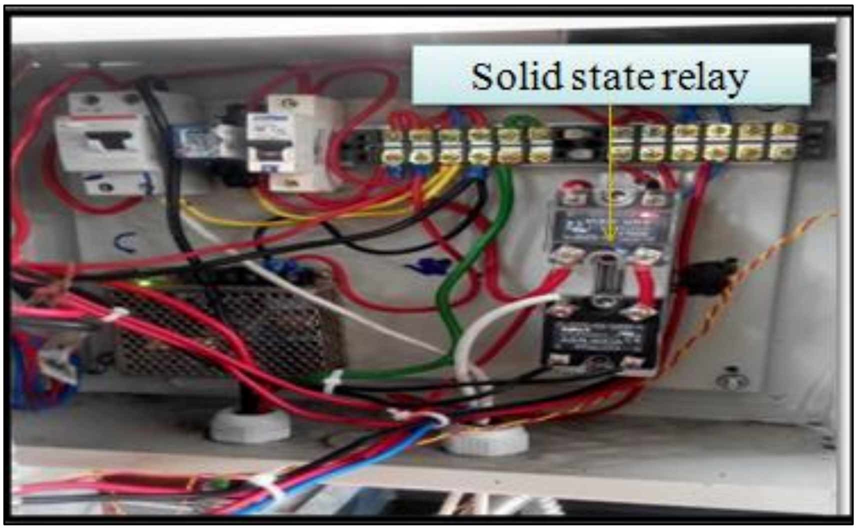


Figure 4.5: Furnace circuit

4.2.5 Omron PLC

The wiring connection between thermal fatigue testing machine and PLC I/O are listed in the table 4.2 and 4.3 below.

Table 4.2: List of input

Input	Type	Address
Start	Push button	0.00
Stop	Push button	0.01
Down sensor	Sensor	0.02
Up sensor	Sensor	0.03
Middle sensor	Sensor	0.04
Turn sensor	Sensor	0.05
U-turn sensor	Sensor	0.06

Table 4.3: List of output

Output	Type	Address
Solenoid turn clockwise	Rotary cylinder	100.02
Solenoid turn counter clockwise	Rotary cylinder	100.03
Solenoid for water left	Water spray	100.00
Solenoid for water right	Water spray	100.01
Solenoid A12	Actuator cylinder	100.04
Solenoid A14	Actuator cylinder	100.05
Solenoid C14 slow turn	Rotary cylinder	100.06
Solenoid C12 fast turn	Rotary cylinder	100.07
Green	Indicator light	101.00
Red	Indicator light	101.02

4.3 SOFTWARE

4.3.1 CX-Programmer

The CX-Programmer v9.03 was installed in the PC where it was then connected to the OMRON's CP1E via a USB cable. In this project, two programs (1 and 2) have been designed for a PLC using Ladder programming languages. Ladder diagram 1 is an old ladder and ladder diagram 2 is a new program

For program 2, the sequences start when push button with input 0.00 was push and this input is switched to normally close. The output for indicator 101.00 and relay 2.00 was energized. Then, sensor 0.05 will energize the output relay, 2.01 for cylinder extend until it reaches sensor 0.02. From this input sensor 0.02, it will cause the timer (TM) for 7 second delay. The stroke will retract back and cause input sensor 0.03. Then, the rotary actuator will rotate clockwise at this stage. The sequence will continue until stop button was a push. When the stop button 0.01 normally closed, the red indicator light up and the whole program will be reset and program stops running. Figure 4.6 below show PLC ladder diagram use for the machine.

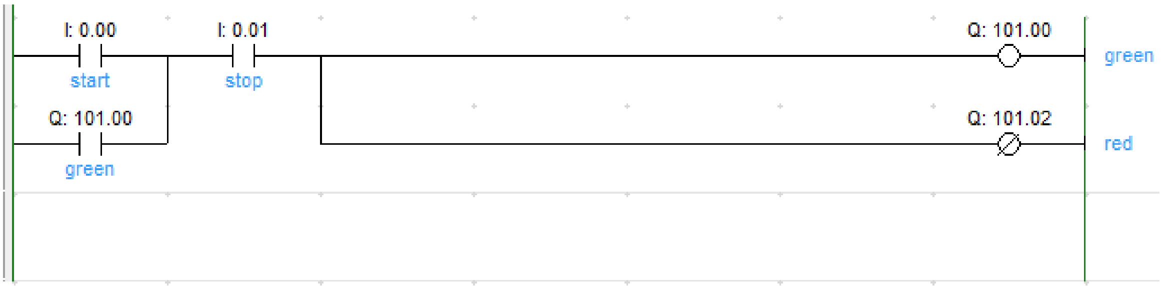


Figure 4.6 PLC ladder diagram

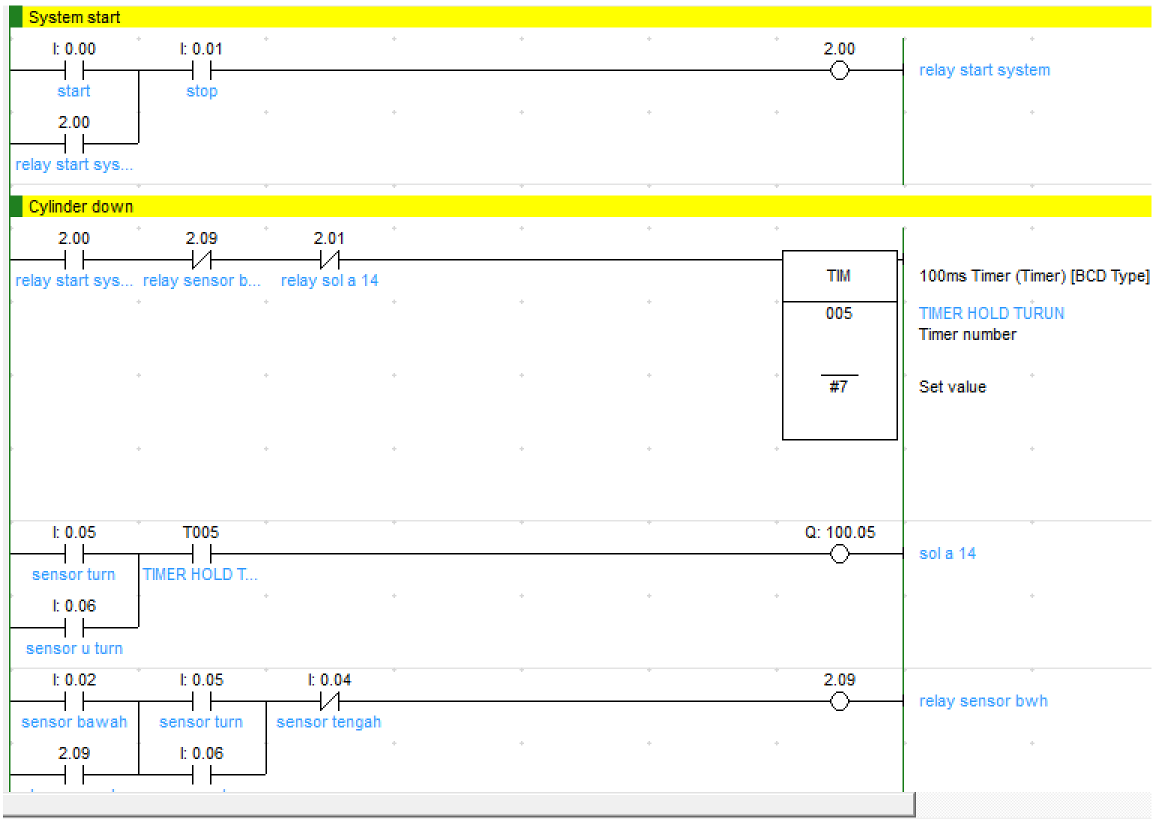
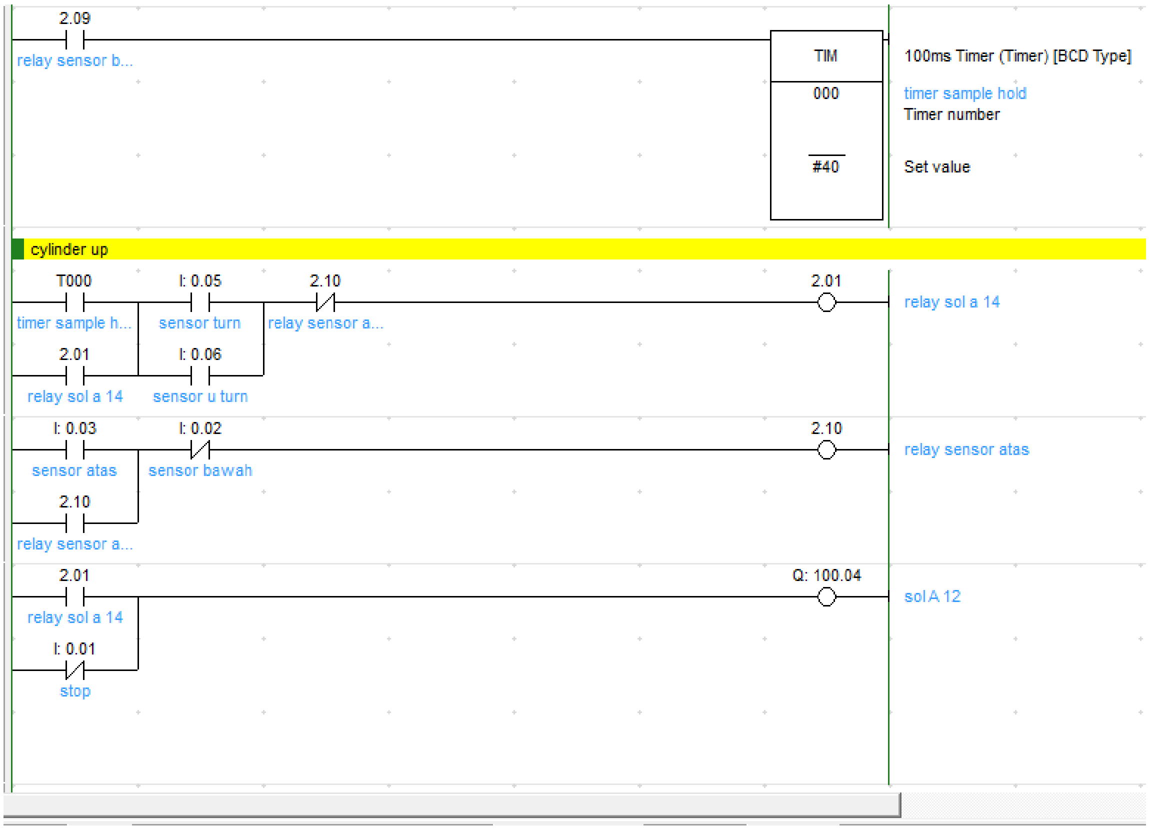


Figure 4.6: Continued



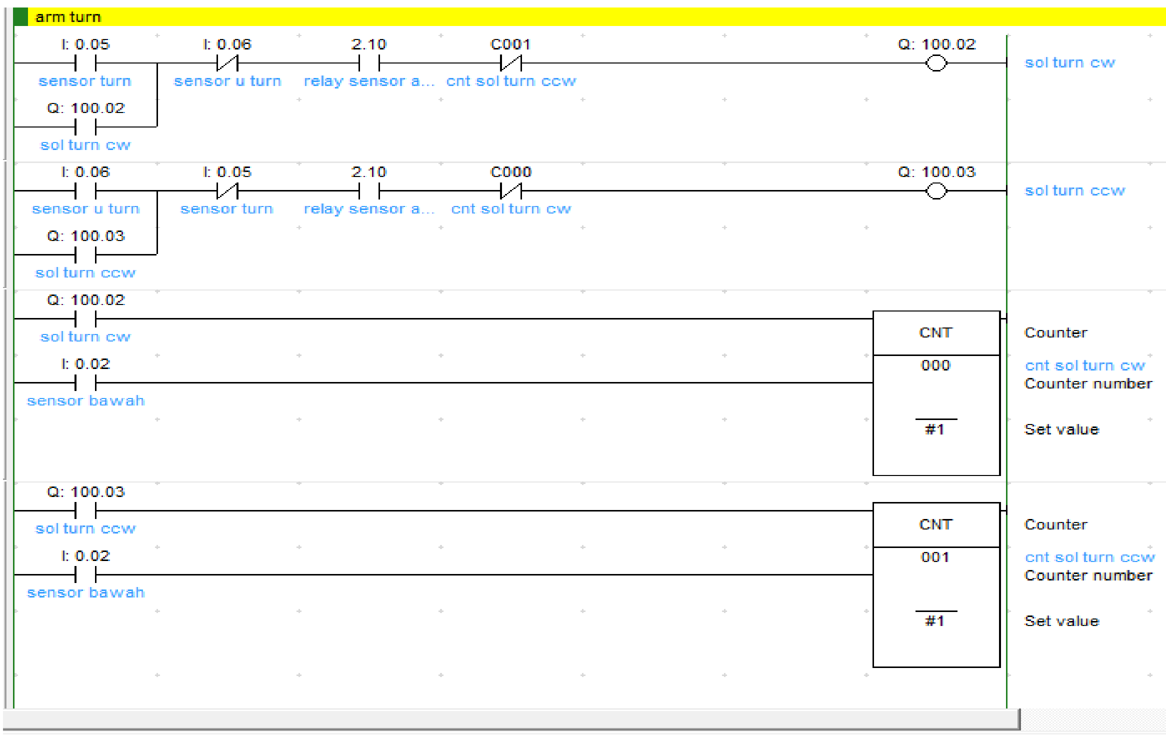


Figure 4.6: Continued

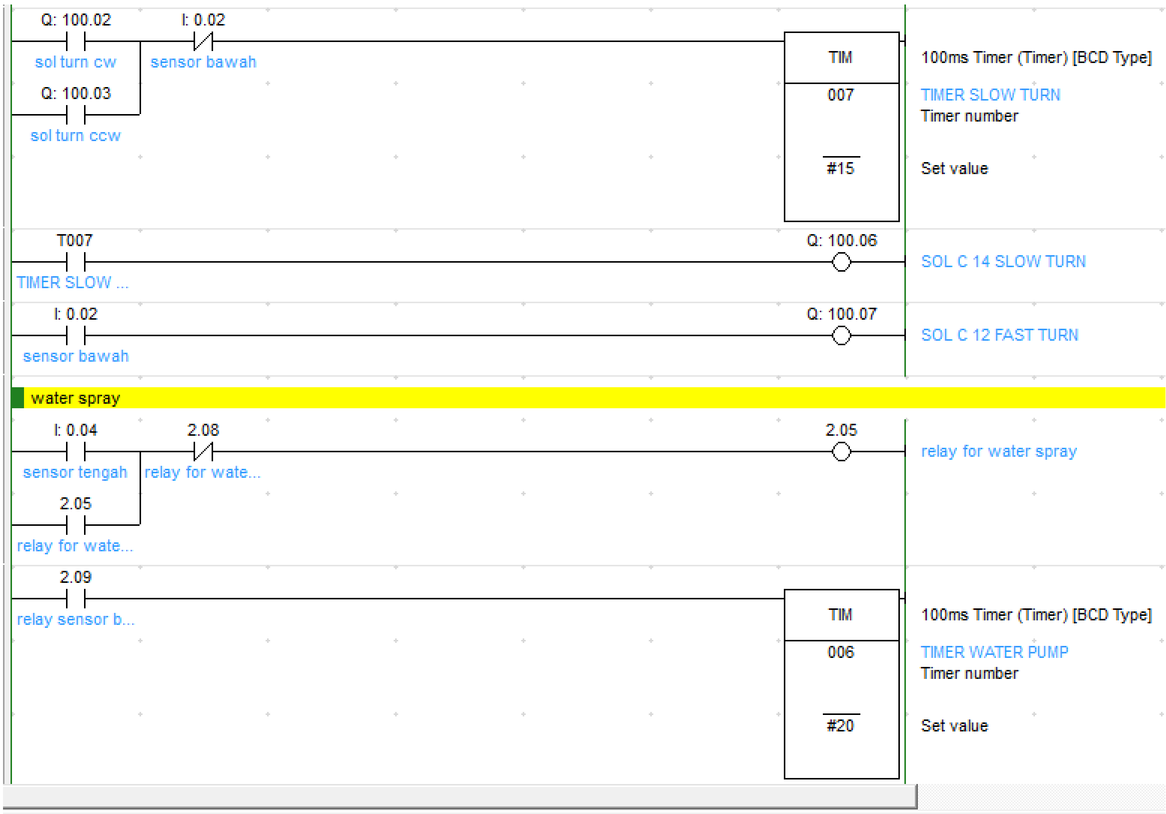


Figure 4.6: Continued

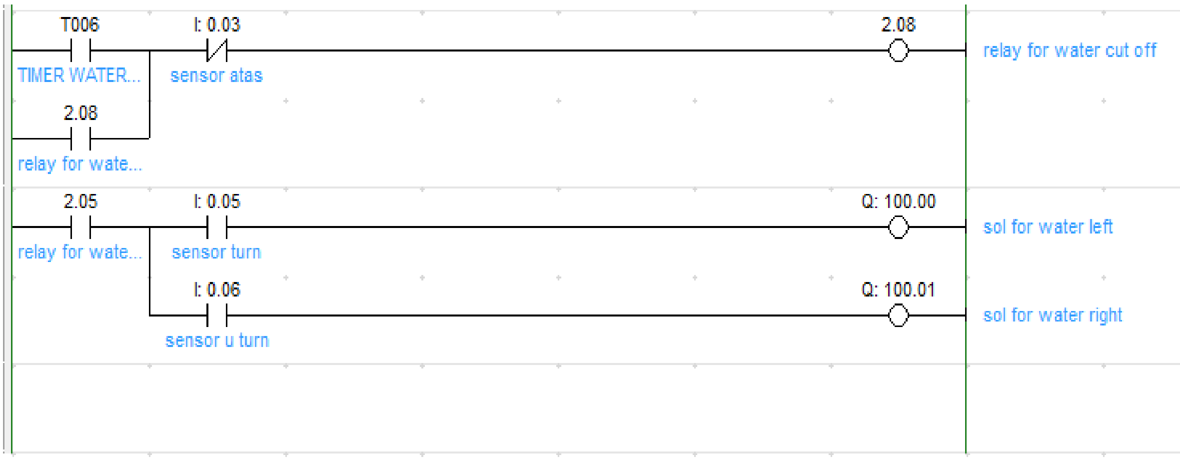


Figure 4.6: Continued

4.4 Determination of Furnace Power

The calculation of heating element is to make sure the power is suitable for the coil. The one phase power is = 1000 Watt. From the table in Kanthal handbook, C_t for Kanthal AF typed of wire in 700°C is 1.04. Total resistance for this furnace can be expressed as

$$\text{Total resistance (Rt)} = \frac{V^2}{P} \tag{1}$$

$$= 57.6\Omega$$

$$= \frac{240^2}{1000}$$

Then, after calculating the total resistance for one phase, next is to calculation the resistance at 20°C (R_{20}) where the total resistance is R_t in (ohm) is divided with C_t.

$$(R20) = Rt/Ct \tag{2}$$

$$= 55.38\Omega$$

$$= \frac{57.6}{1.04}$$

The length requires by one phase furnace and it required the weight of wire for one phase can calculate when Resistance Ω/m 20°C = 0.442 and weight = 22.5 g/m for 2.0 mm diameter wire by using Kanthal handbook . So, the calculation is

$$\text{Required length of wire for 1 phase (L)} = 1 \times \frac{R}{0.442} = 1 \times \frac{55.38}{0.442} \tag{3}$$

$$= 24.48 \text{ m}$$

$$\text{Required weight of wire for one phase (G)} = 24.48 \times 22.5 \tag{4}$$

$$= 550.8 \text{ g}$$

From this calculation, the ideal length and weight required by using Kanthal AF wire with diameter 2.0 mm at working temperature 700°C were 24.48m and 550.8g. Other than that, the optimization for furnace heating element cannot be achieved.

4.5 Pneumatic cylinder calculated value

4.5.1 Actuator cylinder

The cylinder actuator should be extended downward and retracted upward when the machine was running. The gravity force will be included in the calculation because of the actuator in a vertical position as well as the mass of specimen holder (1Kg). The table 4.4 below show the parameter for actuator cylinder.

Table 4.4: Actuator cylinder specification

DESCRIPTION	PARAMETER
Stroke Diameter (mm)	32
Stroke Length (mm)	400
Pressure (KPa)	
Maximum:	1.0MPa
Minimum:	0.05MPa
Theoretical Force	483 N

The actuator cylinder was placed in vertical position. The 1 bar equal to 100Kpa and the weight of specimen and stiff load frame was assumed to equal to 1.5Kg

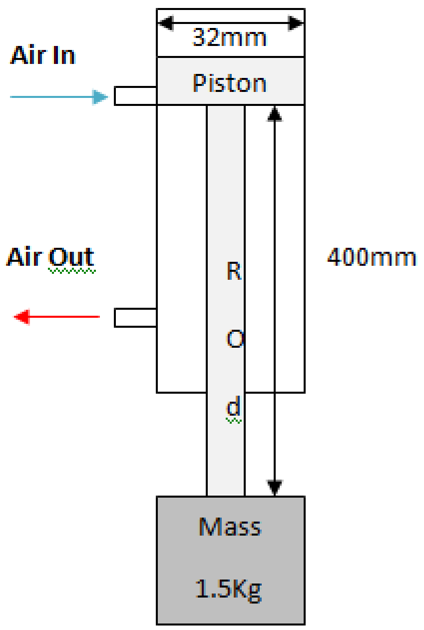


Figure 4.7: Cylinder Actuator Schematic

The calculations for area of the piston need to calculate. The diameter of stroke D needs to convert from 32 mm to 0.032 m. The calculation for area is

$$Area, A = \frac{\pi\ (D)^2}{4} (\mathrm{m}^2 \tag{5}$$

$$= \frac{\pi(0.032)^2}{4}$$

$$= 0.8 \text{ x } 10^{-3}\ \mathrm{m}^2$$

The retract pressure p can be calculated by total force divided with the area. The gravity force is 9.81m/s^2

$$F_{mass} = 1Kg(9.81) = 9.81N$$

$$F_{total} = 483N + 9.81N = 492.81N$$

$$Pressure, p = \frac{F}{A} (Pa) \tag{6}$$

$$= \frac{492.81N}{0.8 \times 10^{-3} m}$$

$$= 0.61MPa$$

The extended pressure can determine by using same formula:

$$F_{total} = 483N - 9.81N = 473.19N$$

$$Pressure, p = \frac{F}{A} (Pa)$$

$$= \frac{473.19N}{0.8 \times 10^{-3} m}$$

$$= 0.59MPa$$

The velocity for extending and retract the stroke can determine by calculated the volumetric displacement *VD*. Then, the flow-rate Q can be found by divided by the time taken to reach full extends *t*.

$$VD = A \times S \ (m)^3 \tag{7}$$

$$= (0.8x10^{-3}m^2) \times (0.4m)$$

$$Q = \frac{VD}{t} \left(\frac{m^3}{s}\right) \tag{8}$$

$$= \frac{0.32 \times 10^{-3} m^3}{2s}$$

$$= 0.16 \times 10^{-3} m^3/s$$

The velocity for extend and retract can calculate by

$$Velocity, V = \frac{Q}{A}\left(\frac{m}{s}\right) \tag{9}$$

$$= \frac{0.16 \times 10^{-3}\ m^3/s}{0.8x10^{-3}m^2}$$

$$= 0.2m/s$$

The system for a complete cycle for extending and retract is in 4 seconds with maintaining 0.61 Mpa at the inlet and 0.59 Mpa at the air outlet. The velocity for cylinder actuator also will maintain constant because the pressure for extending and retract movement has been determining in the equation above. The time requires for extend and retract stroke is fulfilling the design requirement.

4.5.2 Rotary cylinder

For a rotary cylinder, the purpose of the calculation is to calculate the moment inertia and velocity for rotary motion. The calculation will assume the weight of specimen holder and the shaft is 1.5Kg. Thus, moment inertia can be determined from rotary shaft point to the specimen holder. Figure 4.8 below show the rotary cylinder and table 4.5 show the specification of the rotary actuator.

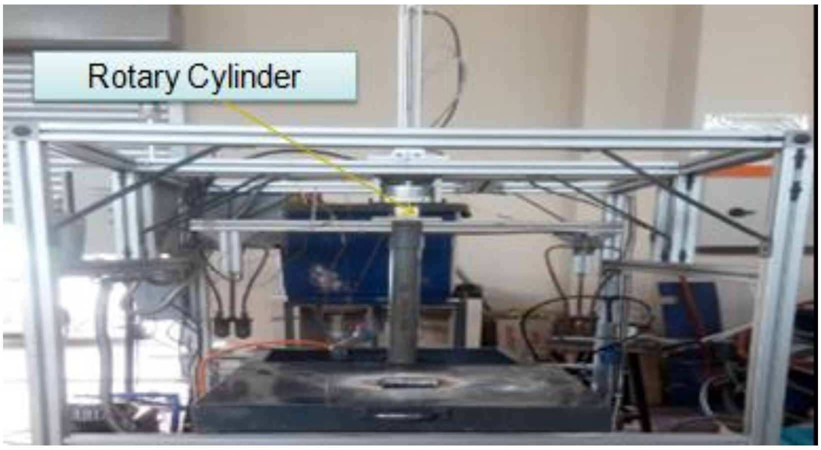


Figure 4.8: Rotary cylinder

Table 4.5: Rotary Actuator Specification

DESCRIPTION	PARAMETER
Swivel Angle (°)	180
Torque (Nm)	0.85
Pressure (KPa)	
Maximum:	1.0MPa
Minimum:	0.5MPa

The calculation below is to determine the velocity of the rotary actuator when it rotates right and left. The frequency of 20 second *f* need to find before can calculate the angular frequency *w* for rotation.

$$\text{Frequency}, f = \frac{1}{t} \tag{10}$$

$$= \frac{1}{\ }$$

$$= 0.05 \text{ Hz}$$

$$\text{Angular Velocity}, w = 2\pi f \tag{11}$$

$$= 2 \times \pi \times 0.05$$

$$= 0.314 \text{ r/s}$$

$$\text{Velocity} = w \times L \tag{12}$$

$$= 0.16 m/s$$

The calculation for moment inertia can be expressed by mass of the stiff load frame m, moment inertia *m*, width and thickness the stiff load frame *a* and *b*.

$$\text{Moment Inertia}, I = \text{m}\frac{\text{a}^2 + \text{b}^2}{12} \tag{13}$$

$$= (1.5\text{Kg})\frac{(1\text{m})^2 + (0.03\text{m})^2}{12}$$

$$= 0.123\text{Kg.m}^2$$

4.6 PERFORMANCE EVALUATION FOR THERMAL FATIGUE TESTING MACHINE

4.6.1 Testing machine with real experiment

The testing is performed to measure the furnace temperature and coil temperature rising in order to see the optimization of the heating element. For the furnace, there have two types of measured temperature which is aluminium temperature and coil temperature. The scrap metals of aluminium were placed carefully into crucibles. The furnace was turn on and was fully covered to avoid heat loss. Two thermocouples were used to obtain the temperature of aluminium and coil in the combustion chamber of the furnace through the opening on the cover of the furnace. The temperature for molten aluminium and coil was recorded at a time interval of 60 minutes. The result is shown in table 4.6

Table 4.6: Comparison of Furnace and coil temperature Controller Reading

TEMPERATURE CONTROLLER TIME (min)	FURNACE TEMPERATURE CONTROLLER READING (°C)	COIL TEMPERATURE CONTROLLER READING (°C)
0	32	32
60	316	350
120	430	437
180	511	513
240	559	569
300	581	600
360	606	621
420	637	661
480	668	693
540	696	718
600	700	732

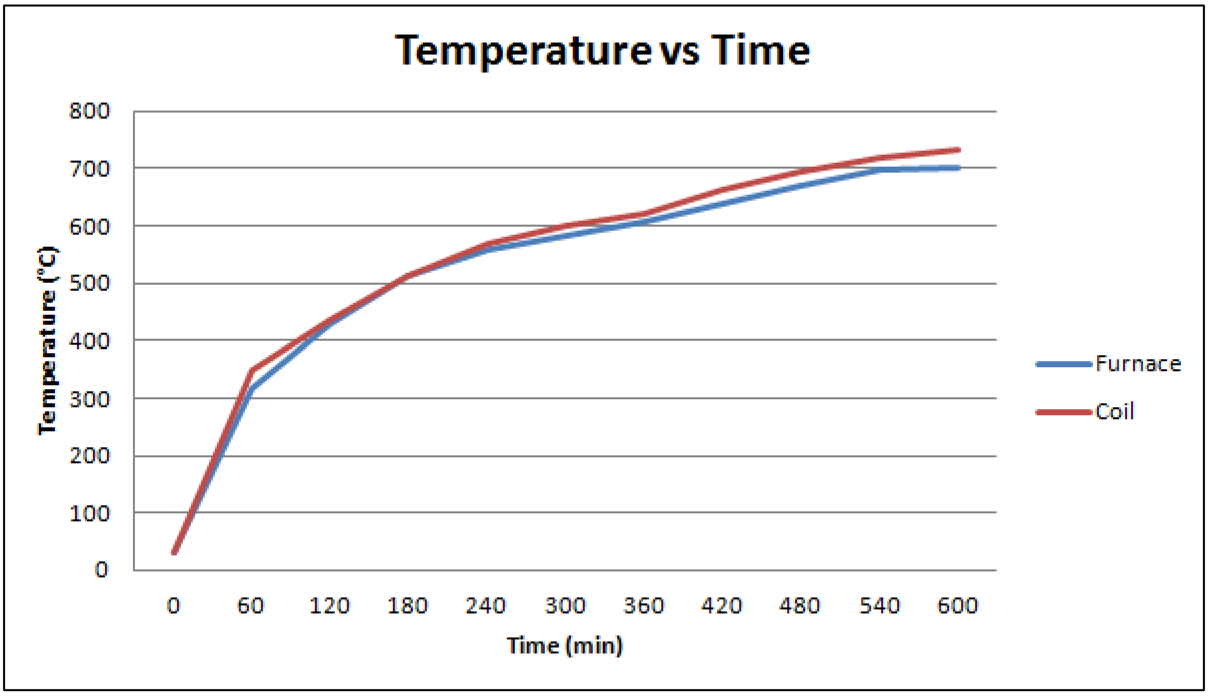


Figure 4.9: Furnace and coil characteristic of heating

Table 4.6 shows the value of the temperature for furnace and coil. Based on the table above, the temperature was increased slowly. Figure 4.9 clearly show the trending of the temperature increase slowly without consistent value until the setting point. The temperature for coil and furnace was increased with the small difference value of temperature. From the analysis, the temperatures increase slowly because the power supply is not enough to heating the coil. This is because the power requirements do not meet the wire length. So, the time for heating the wire also increases. Another reason is because the fiberglass was used is not enough to prevent heat loss. Fiberglass is a high heat resistive material used in high temperature application to avoid heat leakage and fire hazard. Thus, the critical thickness of fiberglass is the minimum thickness that must be provided, so that the heat loss could be minimized and can avoid temperature drop.

Besides that, from the calculation of one phase power supply, the length require for use one phase power supply is not more than 24.8m. Other than that, the wire will not receive enough power and will affect the time when the furnace was running. Based on heating element specification in table 4.1, the wire total length was 79.812 m and more than wire length in the calculation for one phase power. Hence, it was clearly seen why the temperature has a problem to increase.

4.6.2 Pneumatic system testing

The real experiment is performed to measure the machine performance and also a pneumatic system in order to fulfill the system requirements. For this machine, there have two of measured performance for two ladder diagram. The ladder diagram one is an actual program for the machine and the second ladder diagram is a program after controller for pneumatic and component was changed. The purpose of this two types ladder diagram is to compare the and evaluate the best performance of the machine after the controller was design
.

Table 4.7: Comparison between two ladder diagrams

Cycles	**Time Process Cycle (s)**	
	Ladder 1	**Ladder 2**
Stage 1	12012	10015
Stage 2	24030	20050
Stage 3	36075	30120
Stage 4	48180	40220
Stage 5	60725	50325
Stage 6	72480	60030
Stage 7	84770	70105
Stage 8	97000	80160

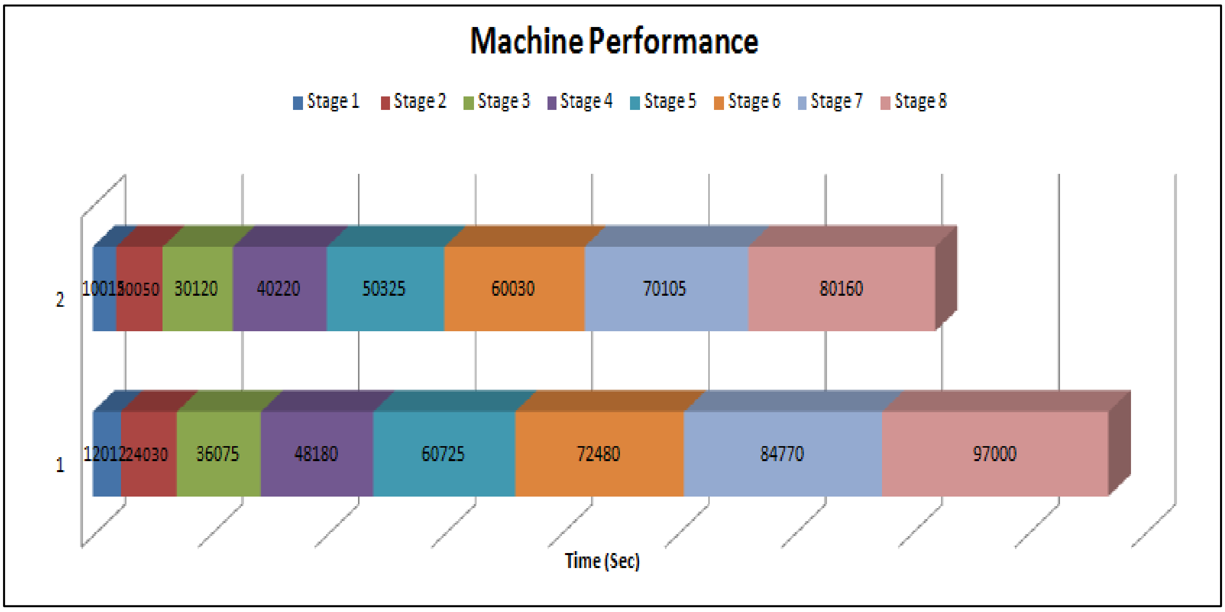


Figure 4.10: Machine performance result

In figure 4.10, an experiment consisting eight stages. One stage for this experiment is for 500cycles. To complete experiment for one sample the 4000cycles are required or eight stage running. The time for one stage was recorded when digital counter display the cycles. The result shows when used the first ladder diagram, it will take 97000 second or 26.94 hours to complete one sample. This mean for one cycle it will take average 24.25 seconds. The second ladder diagram takes 80160 seconds or 22.27 hours to complete one sample and average 20 seconds for one cycle.

Based on this data, the comparison between this ladder diagram can be analysis. The time difference between first and second ladder diagram is 16840 seconds or 4.47 hours. This time, the parameter can be reduced from the actual performance because, in pneumatics system, there have several things that need to give attention. The air input to actuators or pressure regulator needs to be adjusted slowly in order to get the best frequency in the machine. At the same time, the solenoid valve as a controller for the actuator and rotary cylinder also need to change in order to get a better movement.

From the bar chart above, the time cycle for the machine was reduced due to pneumatic valve controller design. However, the process cycle time still not constant and have a bias due to the leak from air pressure.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion.

The conclusion of the first objective of this project to design a thermal and pneumatic controller for thermal fatigue machine.The two main parts were focused in this project, furnace and pneumatics system. The furnace controller was designed using two temperature controls switching by solid state relay. The pneumatic system was designed using three solenoid valve, pneumatic cylinder and controls by PLC.

The conclusion of the second objective was to fabricate and evaluate the performance of the thermal and pneumatic controller. The furnace electrical circuit is designed to receive 32A current directly from 240VAC single phase supply and using a 79.812m length of wire. The pneumatic controller was designed to reduce the time cycle of the machine using three solenoid valves.

Unfortunately during the testing for the furnace, the furnace unable to heated with a constant time. The furnace takes two hours to heat from room temperature to 400°C. From this point temperature, it takes another eight hours to reach 700°C. The situations happen due to single-phase power supply is not suitable for the wire length. This requires more power and current to give more resistance to heating up coil. Thus, all the calculation needs to do first before choosing the heating element as the requirement for single phase supply.

The function of the pneumatic system in this project is to move the pneumatic cylinder for a process such as rapid cooling and dipping in the molten aluminium. The process requires a minimum time to complete one cycle because to avoid heat convection at atmosphere. The rotation of rotary cylinder also showed smooth movement when it rotates clockwise and anticlockwise. This rotation will avoid the vibration for testing rig which can make a failure if run in a long time.

The testing for pneumatic and a thermal controller for thermal fatigue machine is achieved after have been tested its function. For the furnace controller, the time for heating up to 700°C is not quite optimum and need to change the heating element.

Based on the project title "Design and Development of Motion and Thermal Control for Thermal Fatigue Machine", the design two part was mentioned here is considered done and the data for evaluation also already recorded.

5.2 Recommendation.

From this research, there are several recommendations can be improved for future studies. Based on the studies that have been conducted, there are many factors can develop to achieve the best optimization.

To ensure the furnace reach the setting temperature with minimum time, the phase power supply need to increase. This method will produce more power supply to the heating element and will reduce time heating up the furnace.

Direct resistance heating is another specialty heating technique that can be used for elevated temperature fatigue test. This technique will make specimen itself as the heating element. Although a specimen have a low electrical resistance, passing a very high current directly through the specimen will produce heat. But it also has the disadvantage of direct current include safety concern because large current and the potential for a short circuit that could produce instant molten metal.

Another recommendation, the position of the coil from around the brick can be change to the ceramic rod and put around the crucible like a cage concept. Based on this method, the coil can implement with simpler if to compare with the previous method

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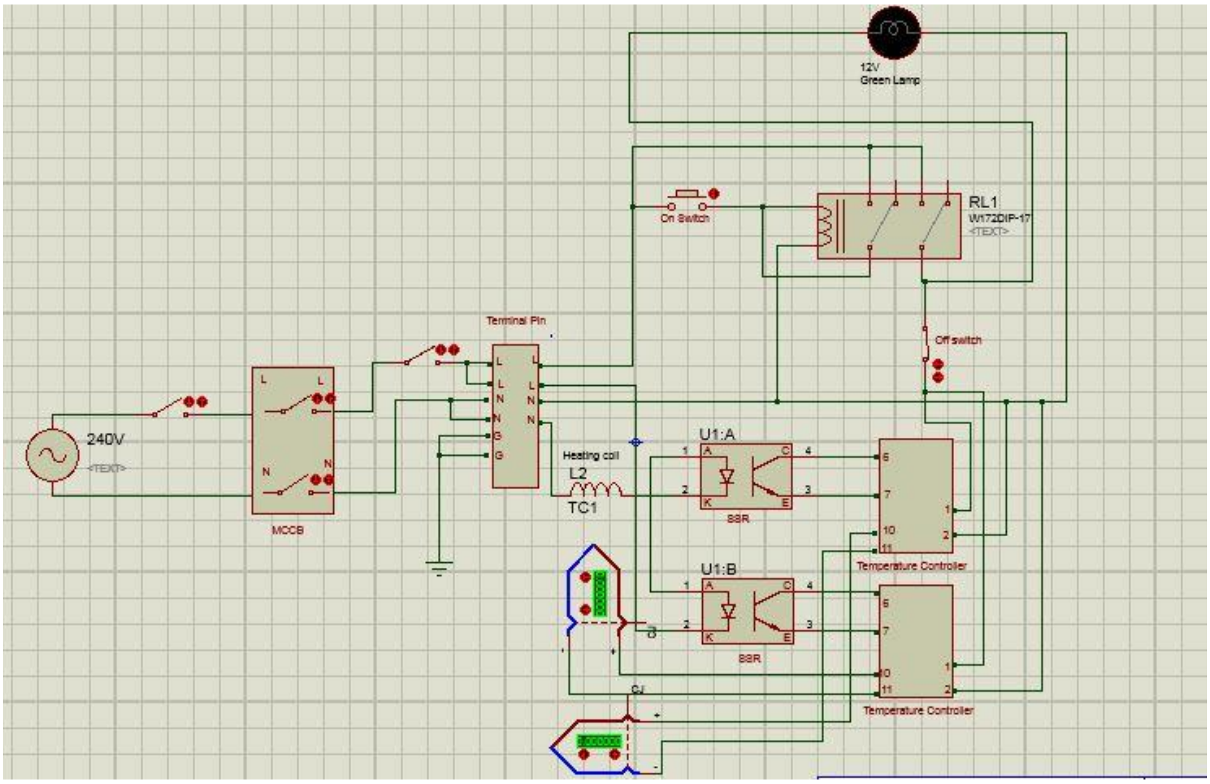
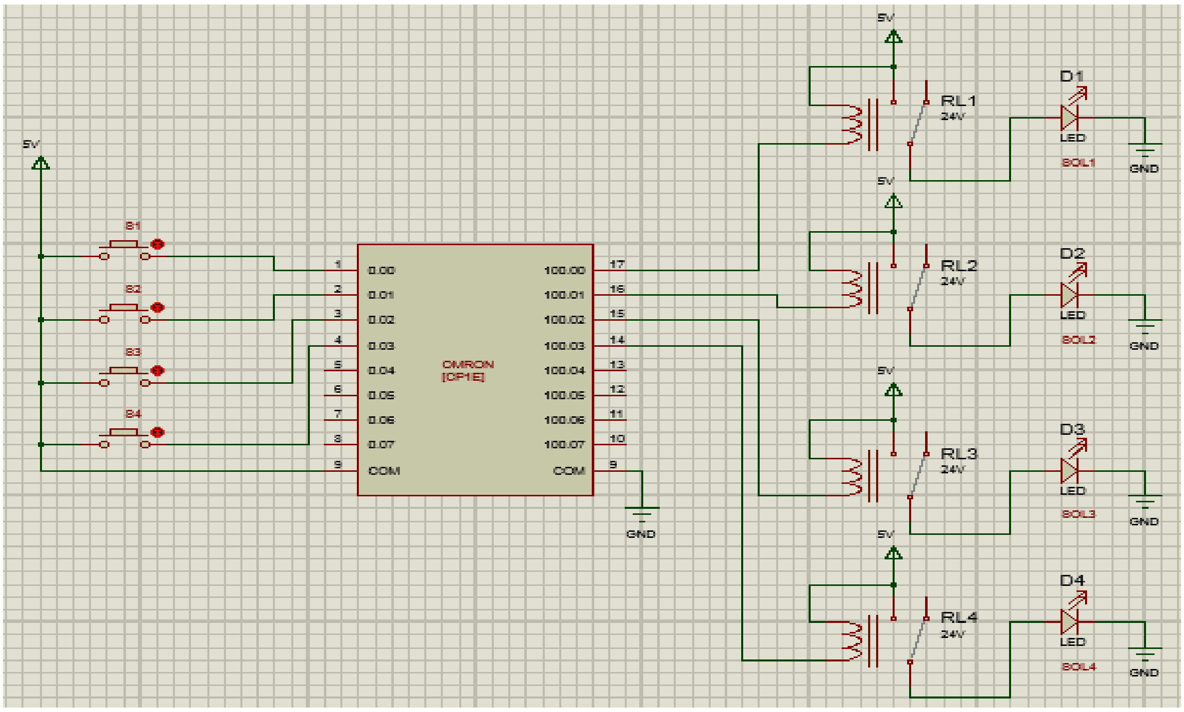
APPENDIX A

Appendix A.1 : Furnace circuit



Appendix A.2: PLC Circuit



APPENDIX B.1: Machine Standard Operating Procedure

Standard Operating Procedure for Thermal Fatigue Testing Machine

I. Safety and Precautions

1. Do not unplug the furnace when operating.
2. Do not move the furnace.
3. Do not touches the insulator on the inside chamber walls.
4. Get Supervisor approval before add or putting material in furnace.
5. Do not touch the furnace walls when operating at high temperature.
6. Use crucible tong, safety gloves and face shield to handle the material when the furnace is hot.
7. Turn off the furnace, compressor, PLC and water cooling completely when not in use.
8. Do not changes setting of the controller other than actual setting unless get approval from Supervisor.
9. Do not open the controller box when operating.

II. Turning on the Furnace

1. Turn on the furnace by means of the MAIN POWER SWITCH (figure). After a few seconds, the PV displays (red, upper display) on both controllers show molten aluminium temperature and another controller show coil temperature. The SV display (green, lower display) on controller shows the set point temperature.
2. Green indicator light at furnace box will on to show furnace is ready to heating.
3. Set the temperature for furnace by increase SV temperature

III. Setting Temperature Controller

1. The temperature to control can be set by press mode button and press up down left arrow button.
2. Press any key among mode, up, and down key in RUN mode, the right digit at SV display flashes and it enters to SV setting group
3. Press left arrow key to move the desired digit.

4. Press up and down key to move the desired number (1-5)
5. Press mode key to save the value and it controls with this set value (Even thought there is no key input for over 3 sec, it saves automatically)

IV. Turning on Programmable Logic Controller (PLC)

1. Turn on the switch for PLC and compressor when to start operating.
2. Wait until the pressure regulator show 4bar.
3. Press the red button from PLC box to ensure pneumatic cylinder places at homing position and red indicator will on.
4. Press the green button when the furnace was ready to running the experiment and green indicator will be on.

APPENDIX C.1

GANT CHART FYP 1

PROJECT ACTIVITIES		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Verify the project objective and	P														
problem statement	A														
Literature search (book/journal)	P														
	A														
Refining chapter 1	P														
	A														
Submit draft chapter 1	P														
	A														
Redefined chapter 1	P														
	A														
Submit draft chapter 2	P														
	A														
Redefined chapter 2	P														
	A														
Submit draft chapter 3	P														
	A														
Submit milestone 1	P														
	A														
Presentation of final year project	P														
	A														
Redefined chapter 1, 2, 3	P														
	A														
Submission of final year project report 1	P														
	A														

APPENDIX C.2

GANT CHART FYP 2

PROJECT ACTIVITIES		W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Hardware implementation	P	■	■	■	■										
	A														
Software implementation	P			■	■	■	■	■	■						
	A														
Testing the product	P								■	■	■				
	A														
Discussion	P									■	■				
	A														
Submit draft chapter 4	P									■	■				
	A														
Redefined chapter 4	P										■				
	A														
Conclusion and recommendation	P										■	■			
	A														
Suggestion for further work	P											■			
	A														
Submit draft chapter 5	P											■	■		
	A														
Redefined chapter 1, 2, 3, 4, and 5	P												■	■	
	A														
Submission of final year project report	P														■
	A														
FYP 2 presentation	P														■
	A														