Experimental Modelling and Control of Pneumatic Cylinder for Manufacturing Applications

By:

AMIRUL FAEZ BIN WAHIDON

(Matrix no.:128928)

Supervisor:
Dr. Inzarulfaisham Abd Rahim

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CHAPTER 1 DECLARATION

This work has not previously been accepted in substance for any degree and is not being concurrently submitted in candidature for any degree.

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Statement 1

This thesis is the result of my investigation, except where otherwise stated. Other sources are acknowledged by giving explicit references. Bibliography/references are appended.

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ACKNOWLEDGMENT

At the time of preparing this thesis, I am going through different books and journal which help me to get acquainted with the topics. I have gave all my effort to find related information and document. This thesis becomes a reality with the kind support and help of many individuals, therefore, I would like to extend my sincere thanks to all of them.

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CHAPTER 2 LIST ABBREVIATION

F = force

M = mass

a = accelaration

μ = coefficient cofficient

P = pressure

A = area

C = air consumption

u = Initial velocity

v = final velocity

ABSTRAK

Kuih Loyang merupakan kuih tradisional yang semakin terkenal dari semasa ke semasa kerana kerangupan dan kemanisannya. Permintaan untuk kuih loyang semakin tinggi pada hari perayaan. Pengeluaran kuih loyang yang perlahan dan terhad telah menjadi masalah utama untuk memenuhi permintaan pelanggan. Mesin separa automatik telah dicipta oleh MARDI untuk menyelesaikan masalah pengeluaran yang terhad. Bagaimanapun, mesin yang direka bentuk ini tidak dapat menghasilan kualiti dan kuantiti Kuih Loyang sebaik tenaga manusia. Untuk mencipta mesin separa automatik yang boleh berfungsi sebagai mesin tradisional, kawalan silinder pneumatik dalam kedudukan yang tepat adalah perlu untuk mewujudkan getaran yang akan melepaskan kuih loyang dari acuan. Untuk membuat getaran menggunakan silinder pneumatik, kajian dan pemahaman yang lengkap perlu dilakukan. Semua jenis komponen seperti sensor, injap solenoid, silinder pneumatik, dan alat kawalan eletronik perlu diteliti untuk memastikan silinder pneumatik bergerak mengikut kedudukan sasaran. Untuk menghasilkan getaran yang boleh menghampiri kerja manusia, omboh di silinder pneumatik perlu dikawal pada jarak yang kecil antara 5mm hingga 10mm dan bergerak berulang-ulang sebagai ulangan. Pengawalan silinder pneumatik antara 5mm hingga 10mm akan diuji di mesin Kuih Loyang. Kawalan jarak silinder pneumatik disahkan.

ABSTRACT

Kuih Loyang is getting famous from time to time for its crunch and sweetness. The demand for the biscuits is getting higher mostly during the festive day. The slow production of the biscuits has become a problem to meet the demand. A semi-automatic machine had been designed to solve the problem of late production. However, the designed machine cannot work as effective as the traditional machine. To design a semi-automatic machine that can work as effective as the traditional machine, the control of a pneumatic cylinder in an exact position is necessary to create the vibration that will shake off the cake from the mold. To create those vibration using a pneumatic cylinder a full study and understanding need to be done. All type of components such as sensor, solenoid valve, pneumatic cylinder, and microcontroller need to be scrutinized to ensure the pneumatic cylinder move according to the target position. To generate vibration that can resembles human work, the piston in the pneumatic cylinder needs to be controlled at a small distance between 5mm to 10mm and moving repeatedly as looping. The control of pneumatic cylinder distance between 5mm to 10mm will be tested at the Kuih Loyang machine. The control of pneumatic cylinder distance is verified.

CHAPTER 3 CHAPTER I : INTRODUCTION

1.1 Overview

Nowadays, the pneumatic actuator has become an important driving element that extensively used in industrial robotics and application. Due to special attributes, the pneumatic actuator has become an alternate actuator in automated material handling the task. The compressibility of air and friction in the pneumatic actuator are the main factor to nonlinearities in the system that makes the pneumatic actuator difficult to control.

An application of the pneumatic actuator was investigated for food packaging in the production line was discovered. The control strategy was applied in a combination with a modified PID controller to a pusher mechanism in the packaging of the confectionery product. Packaging operation and food processing can be more efficient with the using of robust technologies. It can give more flexibility and the ability to monitor throughout the process. In 2005, a pneumatic actuator was developed in a construction robot. The pneumatic actuator has been widely used in industry because of its low cost, compact, high rate of power or weight and reliability.

Another application of pneumatic actuator was applied in Jack Hammer, power drills and blow molding process as a manufacturing application. The pneumatic system has many advantages over the conventional electro-hydraulic or electro-mechanical system. It is relatively cheap and easy to build system design is very flexible and can be ranged from lightweight, compact domestic appliances to heavy-duty industrial applications. This system also has many disadvantages mainly because it is difficult to control such a system, unlike hydraulic and electrical powered actuator which generally have a second-order dynamic pneumatic actuator. With the third even fourth order dynamic, the system tends to become unstable if PID feedback gains are high.

For this project, the pneumatic cylinder will be applied at the Kuih Loyang machine and controlled by Arduino as the microcontroller. Currently, Kuih Loyang was made using the traditional method. MARDI have take initiative to come out with semi-automatic machine yet still need human participation. As using the Arduino as a microcontroller for controlling the pneumatic cylinder, it will make the machine fully works without involving humans.

Figure 1: Kuih Loyang and its mold

A microcontroller is a compact integrated circuit to govern the specific operation. A microcontroller function is used to control the function of an embedded system in machine, vehicle, home application, motor, robots, and medical devices, and mobile radio transceivers. Usually, the microcontroller is employed in devices that need a degree of control to be applied by the user of the device. The C programming language has been a popular population as it can easily be written and understand by the user.

The pneumatic cylinder is mechanical devices that use the power of compressed gas that can produce force. Pneumatic cylinder use compressed air as a force supply to move the piston in the desired direction. The pneumatic cylinder comes from various appearances and size depending on the user. The pneumatic system consists of few components to make it works such as compressor, pressure switch, safety relief valve, and pressure regulator.

A compressor function that supplies an air tank with a sufficient amount of air is needed to perform any applicable amount of work. The working energy will be transmitted pneumatically directed and under complete control at all times. The pressure needs to be controlled as the safety of the system by controlling at the two-point which is after the compressor and after the air receiver tank. The purpose of the spring loaded system is used to sense the system pressure. When the pressure is at a low level, the spring will push the piston down. In this position, contact is made causing an electrical signal to turn on the compressor. Then, it forces the piston upward. The piston will break the electrical contact at a high level. A pressure regulator is used to portion out this stored energy to each leg of the circuit. The safety relief valve will function as a safety device when the pneumatic system does not work according to the way it is.

1.2 Project background

The process of making kuih Loyang is divided into few sections such as the dipping process in the mixture and also in the frying oil and the put into the biscuit container. For current technology, the mold is manually controlled by a skillful operator. All the entire process depending on the operator. The main problem for the traditional method which is fully depending on the operator is the production is very slow as it has to be dipped and fried one by one.

This is where the pneumatic cylinder will take place as it will be applied at the current mold frame and controlled by the microcontroller which is Arduino. Currently, the mold frame was designed (10x10) 100 pieces in a single dipping and frying process. As the pneumatic cylinder installed, it will replace operator work. The motion and vibration as the process going on need to be more efficient than the human skill and this are where the Arduino will control the movement of the pneumatic cylinder as the process going on. The benefit of using the pneumatic cylinder as it can increase the productivity of the Kuih Loyang and minimize operator involvement.

1.3 Problem statement

The vibration that creates by a human during the frying and dipping process is a vibration that results from a trained worker so proficient to create the vibration that can shake off all the cakes from the mold. However, due to the lack of skillful worker, the productivity of the cakes often do not reach the target. Efforts have been made were to overcome this problem semi-automatic machine was build. The vibration that creates from the machine to shake off all the cakes from the mold has been a major challenge where the vibration to shake off all the cakes from the mold using a machine is not the same with the vibration that creates by a human. This research focuses on the characterization and control of pneumatic cylinder to control the distance between 5mm to 10mm when installing at the machine and create the vibration that can shake off all the cakes.

1.4 Objective

The main objective of this project is to design a pneumatic cylinder that can be installed in the current Kuih Loyang machine so that it can replace the involvement of the operator, especially during their unavailability. The pneumatic cylinder movement is limiting as only two positional states which are fully retracted or fully extended. The position control of pneumatic cylinder in the small distance between 5mm to 10mm is needed to create the vibration that can shake off all the cakes from the mold Arduino will be used to provide the logic for the operation of the pneumatic cylinder.

1.5 Scope of work

To do improvement to the machine, some observation and research from the internet need to be done to get the latest or available product or extra features in the market. Moreover, the movement of the machine especially during the frying and dipping processes need to be studied as a need to make the cake shake off from the mold during the process. The movement of the mold frame needs to be inserted or program into the Arduino for controlling the pneumatic cylinder. The programming language also needs to learned and discovered before using Arduino. Some calculations of pneumatic cylinder forces, air supply needed for the pneumatic cylinder and the speed of the mold frame need to be figure out to increase the productivity of the cakes.

1.6 Thesis outline

For writing a thesis with the title controlling pneumatic cylinder, a fully understanding is needed. This thesis divided into five section which is introduction, literature review, methodology, results and discussion, and conclusion and future work. Introduction section is describing what is this thesis generally all about and what is the purpose of doing this research. Further understanding can be obtained from the literature review part. This section is where journals, website, and other research need to be scrutinized one by one to get idea and guides for this research. Methodology is explaining how this research is done. All the equipment and set up needed are explained in this section. In results and discussion sections, all the result are explained here. All the reasons and discussion are needed to support the result obtained. Conclusion, is generally what can be concluded from this experiment and a few suggestios can be suggested for improving this research in the future.

CHAPTER II : LITERATURE REVIEW

This chapter will discuss the traditional method of Kuih Loyang production and the motion involved during the process. The movement produced by the pneumatic cylinder during the whole process in the exact position will be elaborated more in this chapter. Beside that, this chapter will also discuss the suitability of Arduino as a microcontroller for this project

2.1 The development of semi-auto and automatic machine by MARDI

Mardi have taken an initiative to help local Kuih Loyang producer by building a machine that can increase the production of cakes as shown in figure 2.1. The mechanical system was developed to process Kuih Loyang using an automatic forming and frying technique consisting of 18-25 molds attached to the machine. By this method, 1200-1500 pieces per hour of the product can be produced by a single operator. The forming process took only 20-30 seconds where all molds are simultaneously dipped into the batter. The frying process is carried out in 180 degrees Celcius oil for 2 minutes. The most suitable size of the mold is 60mm in diameter, but other sizes also applicable that suits the need of user[1].

Figure 2.1: Kuih Loyang machine by MARDI

2.2 Arduino uses for laboratory experiment of automatic control

The researcher has conducted a few experiments such as 3D printer hot end using PID, Cartesian robot, Humanoid robot programming, and follower robot programming. The purpose of this experiment is to know how well the student can adapt with the suing of Arduino to the system even they have never been used before. From the experiment and survey that have been done it proven that the Arduino platform has been relative. From their experience of using Arduino, the development and programming of a control algorithm that makes the robot or machine work with the given specification. Their several available laboratory types of equipment but it did not have a good use, after replacing the control electronics by Arduino achieved to take advantage of that equipment [2].

2.3 Control of Industrial Pneumatic system using serial communication

2.3.1 Arduino microcontroller

Figure 2.2 shows Arduino which is a device that makes the computer to sense and controls the physical movement of an object. It's an open-source physical computing platform based on a simple microcontroller board[3]. In this research, Arduino is used as a tool for the designer and has been a major choice for the popularity in using it. It helps the designer to develop controlling a variety of lights, motors, and other physical output and taking inputs from a variety of switches or sensors.

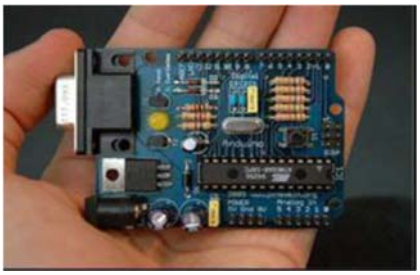

Figure 2.2: Arduino Uno

2.3.2 Serial communication

Means ‘one after another'. Serial communication is when we transfer data on the bit at a time, one right after the other. Information is passed back & forth between the computer and the Arduino.

2.3.3 Serial communication between Arduino

We have to connect the Arduino board to the PC. Each port in the serial was label. The Arduino will be given a COM port number. The first serial port object has to be created. The serial port object is just a name given to that serial port so that can be used in later commands.

2.3.4 Pneumatic circuit

Electropneumatic circuit diagram developed in Automatism Studio Software. In the circuit, two cylinders are there among which one is double acting and another is a single acting spring return. Valve also used to control them.

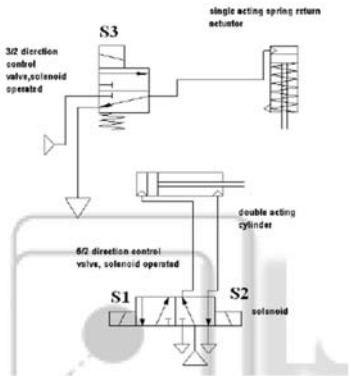

Figure 2.3.: Pneumatic circuit

2.4 Application of pneumatic cylinder

Energy optimization of a pneumatic actuator system in manufacturing is to improve the energy efficiency of the pneumatic actuator system is automated production machinery, the alternative energy design, and control of the pneumatic actuator system are necessary. To increase industrial adoption, important to simplify the implementation of energy efficient pneumatic circuits through the provision of automatic selection and design software[4].

Next,the purpose of modelling and testing of automatic pneumatic sliding door using sensor and controller research is using IR proximity sensors and applied them into the door so that it can be automatically controlled. The door is to open automatically upon detecting a person standing in front of it, and after the person has passed through, it should close automatically. The door opens only after the person is present for a stipulated amount of time. If, after detecting a person in front of it, the person does not cross the door and goes in some other direction, then the door should close after a preset'timeout' limit. The researcher is using microcontroller/ Arduino to provide the logic for the operation of the door. One of the advantages of using the microcontroller or Arduino is that it can use the same door for different applications just by altering the programming logic without any change in the hardware. In this project, a prototype of the automatic pneumatic sliding door needs to be designed which can be modified for various industrial and commercial purposes [5].Figure 2.4 shows the schematic diagram depicting the logic of program.

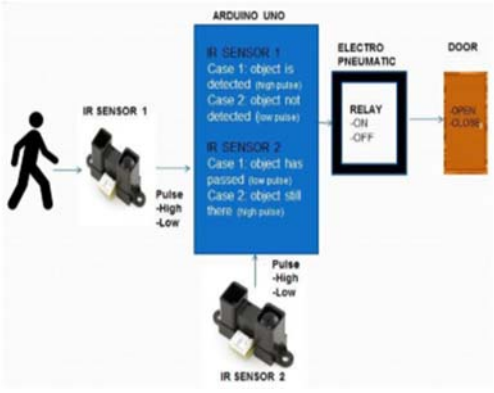

Figure 2.4: Schematic diagram depicting the logic of program

Furthermore, the development of pneumatically drive cell for low cost automation is also one of applications. The rise of industrial automation seeks to optimize the production process to raise the quality of manufacture, decrease production time, and minimize risks of accidents and ergonomics. The reason why this paper has been released is to help in developing a manufacturing prototype for low-cost automation. The mechatronic system can contribute to future applications that will increase productivity, workplace safety and reducing cost. Moreover, the pneumatically manufactured manufacturing cell can be easily integrated into robotic cells and its programming can be synchronized with planning, modeling, and control of robotic manipulators. Through the development of an automated pneumatic system, beginning by the expository way presented for the logical formula of the problem, and posteriorly creating a pneumatic system aided by ISO 1219-1 and 1219-2 standards, it was possible to properly control each other[6]. Figure 2.5 shows driven cell manufacturing for low cost applications.

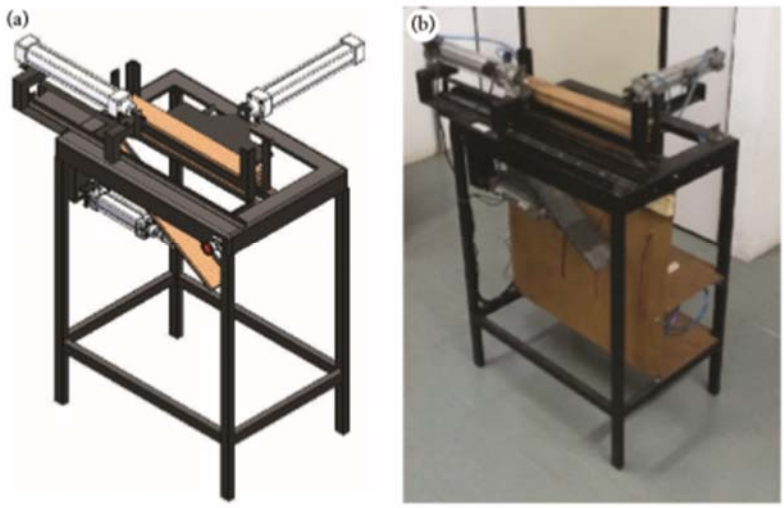

Figure 2.5: Pneumatically driven cell manufacturing cell for low-cost applications (a)design, (b)prototype

Other application that can be used is contactless position sensing and control of pneumatic cylinders using a hall effect sensor array.This paper overviews an accurate sensing system for pneumatic cylinders using an array of sensors that can be mounted to the external casing of a cylinder, with no modification required provided a magnet is present inside the cylinder. As shown in figure 2.6 the hall effect sensor used to enable high frequency and accurate sampling of the flux field produced by the magnet moving on linear axis The contactless sensing ability of the sensors allow the system to experience no physical wear or tear, as no sensor touches a moving surface[7]. As a result increasing the usability of a pneumatic cylinder to applications that require accurate control such as robotic arms, actuators for humanoid robots, factory automation and any other applications that require a fast linear rate of positional change and high energy density in a small and lightweight package.

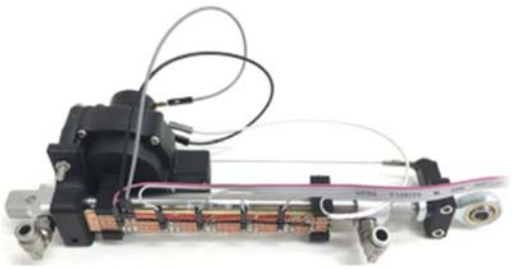

Figure 2.6: String transducer and hall effect sensor array mounted onto a pneumatic cylinder, for gathering data and piston control

Forced and position control based method has many advantages in legend robotics. Some of these have been recognized by researchers and investigated theoretically. Forced based stability margins are promising because the stability criterion directly uses environmental data already found which is accurate and complete, without using a system or environmental model. Stability margin result can also be directly mapped to the control being used, meaning the stability margin goes from merely observing system status to influencing system control. Forced based method shows great promise in the real application for legged robotics because they are suited to the over-constrained system[9]. Environmental data in the form of reaction force is accurate, complete and able to be used in several algorithms with a minimum further processing.

2.5 Development of design pneumatic circuits using arduino microcontroller

The pneumatic sequential logic circuits were designed for industrial automation are presented and implemented with a fabricated kit. The basic of the Arduino controller is briefly described in this circuit design. These programming codes are to be followed in developing these logical sequences of cylinder movement are then presented[8].

2.6 A comparative study on the position control method of DC servo motor with position feedback by using Arduino

The use of rotation servo with position feedback is important in any closed loop electronic system. Angular position can be controlled wisely is not only the primary advantage but the system can easily give feedback to the actual positions. The potentiometer is accurate enough to give voltage feedback as it represents the actual angular position of the motor. Moreover, introducing the position feedback features with the presented three methods will improve the control method of servo motor from open loop to closed loop system[10]. The three methods used which are Arduino IDE, support target for Simulink and Arduino IO package were compared in terms of the suitability and performance for future applications in a more complex closed-loop system.

CHAPTER 4 CHAPTER III: METHODOLOGY

From the knowledge gained from the literature review study, the idea to start the methodology for the pneumatic cylinder position control can be obtained. The study of position control of the pneumatic cylinder can be applied to the Kuih Loyang mold frame so that the vibration creates can shake off all the cakes from the mold. All the components to control the pneumatic cylinder must be study and compared to get the best fit when installed to the Kuih Loyang machine

3.1 Introduction to the electro-pneumatic system

Pneumatic actuators have various types of size and form depending on the purpose of the project such as automation, suspension, and robotics. The reason why pneumatic cylinder always been chosen because of inexpensive, safe, and have a high power ratio making them very attractive to the industry. The standard use of pneumatic is control these actuator using solenoid valve by controlling the on or off switching. This method leads to limiting the movement of a pneumatic cylinder in two positional states either fully retracted or fully extended especially stroke that less than 200mm [1]. It is difficult to control the exact position of the piston when retracted or extended in these cylinders because of the limited control by the solenoid valve. This type of sensing the position of the pneumatic cylinder is still not available as currently only, discrete, digital, sensors can be used.

Electro-pneumatic is defined as the combination of electro which refers to electrical and pneumatic means air pressure. For the common system, a relay has been used as switches that open and close circuits electromechanically or electronically [2]. The relay will control one electrical circuit by opening and closing contacts in another circuit. The difference between these systems is that controller such as programmable logic controller known as (PLC), Arduino, raspberry pi replaced relay as switches for more flexible automation depending on how the system designed [2].

The basic control system is divided into four sections which are the input element, processing element, final control element, and power component. For the first section, components such as push button, control switches, limit switches, reed switches, proximity sensors act as an electrical signal section that will send the signal input. These devices are used as feedback elements. The second section which is processing elements that involve components such as relays, contractors, and microcontrollers such as programmable logic gate (PLC) process the signal received from the signal input. The directional control valve forms the interface between the signal control section (electrical) and the pneumatic section. The third section is the final control element which electro-pneumatically operated directional control valves acting as signal output. The last section is power components involving components such as cylinder, swivel cylinder, pneumatic motor, and the optical display will receive the command execution.

A microcontroller can be conveniently used to obtain the output that required time delay, distance, and sequence operation. The output signal is supplied to the microcontroller and activating the solenoids which control the movement of the cylinder. The advantage of using electro pneumatics is it can combine a variation type of sensor and microcontroller while the effectiveness in the system still can be maintained. Tube used in pneumatic circuit system also can be replaced to electrical wire in electro-pneumatic which leads reduce working space as fewer parts are used.

3.2 Devices uses on electro pneumatic system

3.2.1 Arduino

A microcontroller is made up of an inbuilt processor, memory, timer, and counter. This device is used to be the brain of the embedded systems that can control the action of the pneumatic cylinder. This device allows choosing the input and output when operates the pneumatic cylinder. Figure 3.1 show Arduino act as a data acquisition device to become a medium for input or output of the system [3].

Figure 3.1 : Arduino Uno

3.2.2 Pneumatic cylinder

Pneumatic cylinder as in figure 3.2. is mechanical devices that use the power of compressed air to produce a force in linear motion. The pneumatic cylinder has two separate compartments, air flow into one side, the other is bled as a result the inside piston change in position. The speed of the pneumatic cylinder can be controlled by controlled the air pressure applied from the external forces. The other method that can be used is by adjusting the flow control valves which used to reduce the flow rate from a pneumatic actuator as shown in figure 3.3 and quick exhaust valve in figure 3.4. The specification model of the pneumatic cylinder that will be used as in table 3.2.2

Table 3.1 : Pneumatic cylinder specification (Model:MAL16X100-CA)

Material	Aluminum
Size	Blueprint
Inner diameter	16mm
The standard stroke	100mm
Working medium	Air
Action type	Double action
Working pressure	0.1-1 Mpa (14-145 Psi)
Magnet	No
Application	Pneumatic component

Figure 3.2: Pneumatic cylinder

Figure 3.3: Flow control valve

Figure 3.4: Quick exhaust valve

3.2.3 Electro pneumatic valve

A system that based on this technology relies on precision valves to control flow and distance, in turn, move the actuator to a required location. Pneumatic also is efficient in terms of energy efficiency. When design uses a pneumatic flow control, a valve in the center position blocks airflow in either direction and the cylinder automatically stays put. The model that will be used for the experiment is model: 4V210-08. Figure 3.5 is a 5 ported 4-way directional valve used to move cylinder or actuator. The pressure will be supplied at the center port. The outlet port on the opposite side is connected to each side of a cylinder or actuator. When one side of the cylinder is exhausted, the other side of the cylinder will hold by the pressure. .When voltage is applied to the solenoid end of the valve, the valve spool will shift causing air to go to the opposite side of the cylinder while exhausting the pressurized side. This causes the cylinder to shift or extend. When the voltage is removed, a spring with an air assist will return the cylinder to it is at rest position.

Table 3.2 : Specification of pneumatic valve

• Media-Air (Minimum 40 micron filtration)
• No of position and port- 2 position, 5 ports
• Flow Cv=78, equivalent orifice area = 14mm^2, (36.6 cubic feet per minute at 80 PSI)
• Port size- IN OUT = $\frac{1}{4}$ BSP, exhaust = $\frac{1}{8}$ BSP
• Voltage range – plus or minus 10%
• Pressure range – 24PSI min to 100 PSI maximum
• Wire insulation – Class F
• Weight = 48 Ibs

Figure 3.5 : Electro pneumatic valve (Model: 4V210-08)

3.2.4 Power amplifier

The solenoid works anywhere between 21.6V-26.4V which is too high for Arduino to use with Arduino 5V. The power amplifier as shown in figure 3.6 will be used as an external power supply to the solenoid while Arduino built in voltage regulator will turn that extra power into the 5V that it needs to operate.

Figure 3.6: External power supply

3.2.5 Laser displacement sensor

Keyence LK-G152 laser displacement sensor used to detect the amount of displacement when the pneumatic cylinder moves between the retract and extend position. By detecting the amount of displacement allows measuring the height and thickness of the object. The display panel as shown in figure 3.7 and separate controller is connected to the laser displacement sensor as shown in figure 3.8 to get the result after the measure was taken at the stroke.

Figure 3.7: A Display panel

Figure 3.8 :Laser displacement sensor

3.3 System overview

The control techniques used to control the piston position is difficult due to non-linear properties by the system. The compressibility of air, system compliance, air leakage, varying air pressure, airflow through the valve and end of stroke inactive volume due to cushioning contribute to the linear system [7]. The accurate controller needs to model these factors, to work efficiently. However, if a strong feedback loop is present these non-linear factors can be accounted for the next time step.

Position control rather than force control was chosen due to the prevalence of electric motor. The reason why electric actuator is commonly have been choose because of their low weight, size and cost, high power and ease of integration. However, the electric actuator is not recommended when using it in force control because of their high stiction and reflected inertia. The pneumatic cylinder is cheap, light, have a compact footprint and are naturally compliant but their natural compliance makes position control difficult. A pneumatic cylinder with a 100mm stroke was chosen in this research as this length is commonly used in industrial automation and has recently been researched. The inner diameter of the cylinder is 16mm and due to cylinder pressure ratings, the working pressure is between 0.1-1 Mpa (14-145) Psi.

Several micro-controller have emerged to perform a wide variety of functions at very low upfront hardware and software costs. A large number of boards, including micro-controller, field-programmable gate arrays (FPGAs) and single board computers, have emerged. Arduino and Raspberry Pi are two leading microcontrollers which become a popular choice. Arduino is a collection of three things. There is hardware prototype platform which is the pneumatic cylinder that attaches to Kuih Loyang machine, Arduino language and IDE & libraries where all the programming idea of movement pneumatic cylinder will be written to run the pneumatic cylinder. The main purpose of the Arduino board is to interface with the solenoid valve and pneumatic cylinder, so the suitability is great for responding of the solenoid valve when the pneumatic cylinder moves and manual input to the system. It has an 8-bit AVR microcontroller and hardware support for SPI,12C and serial.

The laser displacement sensor is used to get the displacement when the stroke is extracted and retract. Figure 3.9 shows the set-up of how the pneumatic cylinder stroke displacement was taken when the pneumatic cylinder was moving. The pneumatic cylinder was clamped to avoid it from moving when the vibration occurs. The starting point was taken when the pneumatic cylinder is fully retracted.

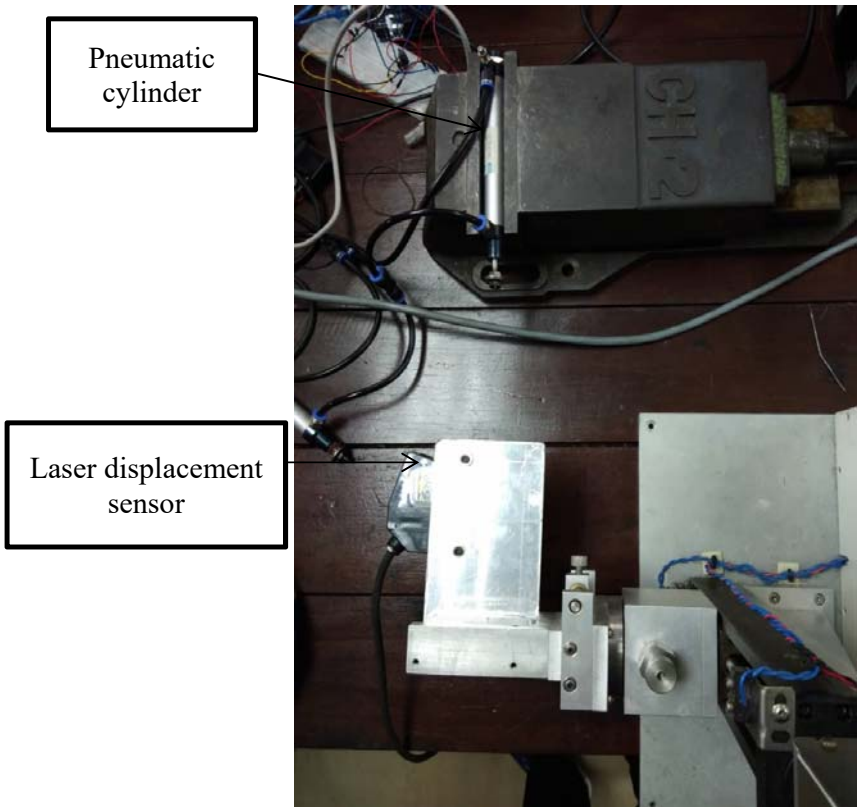

Figure 3.9: Laser displacement set-up

After getting the displacement result for each time delay different, installed a pneumatic cylinder into the Kuih Loyang machine. Each time delay also was tested at the pneumatic cylinder when attaching to the mold frame. The cakes which the appearance is in good condition require the pneumatic cylinder to create the vibration that suits to shake off all the cakes.

3.4 Electrical connection design

This is the component required for running the Arduino:

I. Solenoid valve
II. Arduino Uno
III. Solderless breadboard
IV. TIP120 Darlington transistor
V. 1K Ohm resistor
VI. 1N4001 diode
VII. Jumper Wire
VIII. External power supply

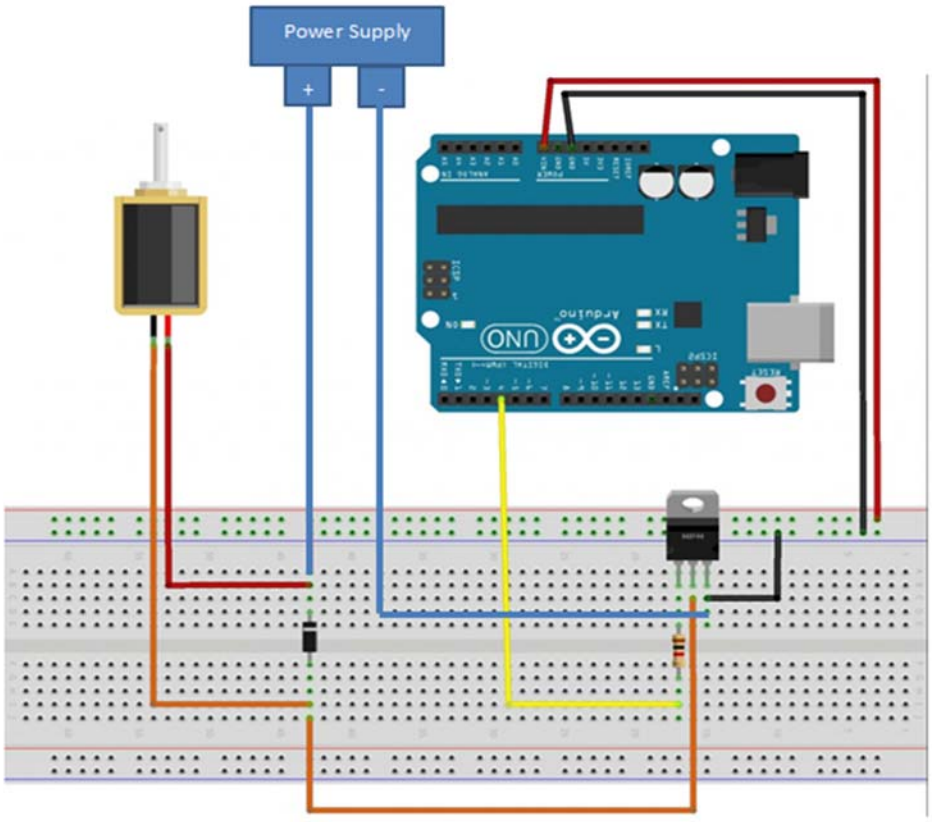

Figure 3.10: Circuit connection

3.5 Coding

After finished with the hookup, the code needed to write for running the Arduino. The basic setup for the programming consists of a magnetic sensor mounted on the cylinder. The function of the transistor is to do all the heavy lifting in this circuit so that there is no need to do much in terms of coding. The moment pin 4 in Arduino is set to high this will connect the transistor collector to the transistor emitter, which will activate the solenoid. An accurate feedback loop must, therefore, be present to allow accurate positional control of the piston to move in small distance within 5mm-10mm.

When the pneumatic cylinder is fully extracted by 100mm, the delay was set at 5000 milliseconds. The use of delay is to define the intervals between the pneumatic cylinder retracted or extended. The important of delay is to block any function in a program from doing anything else until the pneumatic cylinder is fully extended. When the stroke is in a fully extended state, the delay was set at 5000 milliseconds and to create the small distance the delay was set at 50 milliseconds and before the stroke was full retracted the time delay was set back to 50 milliseconds. This resulting in the pneumatic cylinder will move in the small distance and create vibration when attaching the pneumatic cylinder to the mold frame. the sensor will detect the initial position of the stroke then it responds by retracted but delays in 100ms. There are four types of delay of time that will be testing which is 45,48,50 and 52 milliseconds. Figure 3.11 shows one of the time delay used in the comamand coding.

Figure 3.11: Coding for Arduino

3.6 Design calculation

3.6.1 Cylinder sizing

A pneumatic cylinder with a 100mm stroke was used in this experiment as this range of length is commonly used in industrial automation and has been researched[7]. The pneumatic cylinder that can provide an extra 33-100% of the calculated force is more suitable as it needs to overcome the internal friction from seals, bearings, guides, and other external forces. For cylinder to move the load at high speed, a force that exceeds the load by 50% or more is required to reliably move the load at high speeds.

Let the force be 50% more than the load

From the equation,

$$\text{Thrust} = \text{Pressure} \times \text{Area} \times \text{Efficiency}$$

Assume the efficiency of the cylinder is 93%, the operating pressure is 0.6Mpa, by using two cylinders with each cylinder is lifting an average of 6.5kg of load

$$6.5 + (6.5 \times 50\%) = 6.5 \times \frac{\pi D^2}{4} \times 0.93$$

$$D = 1.433\text{cm}$$

For a round cylinder, the size that approaches a diameter of 1.433cm is 16mm.

Recalculate the thrust,

$$\text{Thrust} = 6.5 \times \frac{\pi 16mm^2}{4} \times 0.93$$

$$= 12.15\ \text{kg}$$

The exceed force is $\frac{12.154-6.5}{6.5}$ x 100% = 86.98 %

The exceed force is suitable as it is between the range of 33-100%. The pneumatic cylinder of a 16mm diameter is suitable to apply at the Kuih Loyang machine.

3.6.2 Cylinder speed calculation

To create a good vibration that can shake off all the cakes from the mold, the mold must move with a certain speed. The upward force of the pneumatic cylinder retraction has to be greater than the frictional force to shake off all the cakes. Hence, using the formula, take 0.5 as coefficient friction of steel[11].

By using formula F=ma,

$$F = ma$$

$$\mu mg = ma$$

$$\mu g = a$$

$$a = 0.45\ x\ 9.81 = 4.905\frac{m}{s^2}$$

Acceleration required to shake off the cakes from the mold 4.90 (Friction and coefficient friction)5 m/s^2