DESIGN OF AUTOMATIC STAMPING MACHINE FOR DATE AND DASH CODE MARKING USING PNEUMATIC SYSTEM AND PLC CONTROLLER

Reza Alfarisi Firmansyah
003201400009

A thesis presented to the Faculty of Engineering President University in partial fulfillment of the requirements of bachelor degree in Mechanical Engineering

President University
March 2018
This thesis entitled “Design of Automatic Stamping Machine for Date and Dash Code Marking Using Pneumatic system and PLC Controller” prepared and submitted by Reza Alfarisi Firmansyah in partial fulfillment of the requirements for the degree of Bachelor Degree in Mechanical Engineering has been reviewed and found to have satisfied the requirements for a thesis fit to be examined. I therefore recommend this thesis for Oral Defense.

Cikarang, Indonesia, 9th March, 2018

Nanang Ali Sutisna M.Eng
DECLARATION OF ORIGINALITY

I declare that this thesis, entitled “Design of Automatic Stamping Machine for Date and Dash Code Marking Using Pneumatic system and PLC controller” is, to the best of my knowledge and belief, an original piece of work that has not been submitted, either in whole or in part, to another university to obtain a degree.

Cikarang, Indonesia, January 31st, 2018

Reza Alfarisi Firmansyah
DESIGN OF AUTOMATIC STAMPING MACHINE FOR DATE AND DASH CODE MARKING USING PNEUMATIC SYSTEM AND PLC CONTROLLER

By
Reza Alfarisi Firmansyah
ID No. 003201400009

Approved by

Nanang Ali Sutisna M.Eng
Thesis Advisor

Dr. Eng. Lydia Anggraini, S.T., M.Eng
Head of Industrial Engineering Study Program
ABSTRACT

In the toy manufacture company, they have some of process in producing the product, one of them is the assortment process. In assortment processes they have to giving the date and dash code marking to the master carton for the packaging the blister-pack. The problem is the target of producing marked master carton is not meet with the demands, therefore, it is needed a machine that support the production process, with the requirements which is fast, Easy to use and maintain, and also affordable in order to support the cost saving program. Then with the requirement above the researcher create the machine called as “Automatic Stamping Machine for Date and Dash code marking using Pneumatic system and PLC control”. The results are, the cycle time is below than 5 s, the shape of the design is easier to use and maintenance, and also the price for constructing the machine is affordable.

Keyword: Packaging Process, Giving Date and Dash Code, Demands, Machine, Fast, Easy to Use and Maintain, Affordable
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This final project purpose is to know about the abilities of the students in evaluating the academic process for under graduate program in majoring mechanical engineering, faculty of Engineering President University.

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The author realizes that this report is still far from the perfect of word and certainly there are still many of disadvantages therefore, criticism and constructive suggestions are very much expected by the Author.

Cikarang, 9th March 2018

Author
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<tr>
<td>$V$</td>
<td>Volume</td>
<td>$l$</td>
</tr>
<tr>
<td>$Q$</td>
<td>Air consumption for each centimeter</td>
<td>$l/cm$</td>
</tr>
<tr>
<td>$d$</td>
<td>Distance</td>
<td>$m$</td>
</tr>
<tr>
<td>$t$</td>
<td>Time</td>
<td>second</td>
</tr>
<tr>
<td>$v_a$</td>
<td>Flow rate</td>
<td>$l/s$</td>
</tr>
<tr>
<td>$\sigma_{bending}$</td>
<td>Stress Bending</td>
<td>$N/m^2$</td>
</tr>
<tr>
<td>$M$</td>
<td>Moment bending</td>
<td>$Nm$</td>
</tr>
<tr>
<td>$y$</td>
<td>Coordinate of $y$ axis</td>
<td>$m$</td>
</tr>
<tr>
<td>$I$</td>
<td>Second moment of Inertia</td>
<td>$m^4$</td>
</tr>
<tr>
<td>$b$</td>
<td>Breadth</td>
<td>$m$</td>
</tr>
<tr>
<td>$h$</td>
<td>Height</td>
<td>$m$</td>
</tr>
<tr>
<td>$F$</td>
<td>Force</td>
<td>$N$</td>
</tr>
<tr>
<td>$L$</td>
<td>Length</td>
<td>$m$</td>
</tr>
<tr>
<td>$E$</td>
<td>Modulus young</td>
<td>$N/m^2$</td>
</tr>
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CHAPTER I
INTRODUCTION

1.1 Background
PT. X is one of the biggest Toy manufacturing company in the world nowadays, in completing the needs of toys for the world PT. X produce many of varieties toys such as Fashion Dolls, Match Box, Play Board and Die Cast Car Toys with Production Plant that Planted around the world.

One branch of PT. X is located in Indonesia named as PT. X-Indonesia, PT. X-Indonesia is divided into two Plant with different production of each plant. East Plant functioned as Fashion Dolls producer and West Plant functioned as DIE-CAST Car Toy producer, at the mean time the West Plant have 2 million cars each week for the demands even though the production will be ramp up until the time being counting, in the process of assortment of product the west plant has 2 different packaging as well as usual assortment. The first packaging named as blister car pack, the function is to be the container of the DIE-CAST Car Toy and also as the commercial purpose in marketing the product to the customer, and the second named as the master carton pack the function is to be the container of 12 pack blister car pack in delivering to the market/customers. blister car packaging itself could contain until 5 cars for each blister pack carton and it has automatic processes by the Auto-Packing machine to reach the target of the demands, Auto-Packing machine works for divide the cars to each design of blister pack and giving the date code to the blister pack carton. The problem is master carton packaging is still producing by the human hands (manual processes) for forming the master carton and giving the date and dash code stamping to the master carton. Giving the date and dash code stamping is taking 8 seconds for 6 locations of stamps for each master cartons, for calculation by the theory the process of master carton packaging have to produce 3600 for each shift (8hours/shift) but in actual the operators are only able to produce 1372 master carton for each shift meanwhile the demands of the company are 2 million cars each week, in that case the company at least need to collecting 33.500 master cartons each week or 5600 master carton each shift.
Because the demand of the master carton is 5600 master cartons/shift so the company only have to choices either they have to pay more for add extra operators or pay for extra shift of work. Following that reason, the company want to save their money to gaining the profit and also to optimize the process of assortment.

This design is presented to PT. X-Indonesia in the program of cost saving and optimizing the process of assortment especially in giving the date and dash code for master carton in order to gaining the productivity and also the profit of the company. In this Thesis the authors would like to discuss the Design of “Design of Automatic Stamping Machine for Date and Dash Code Marking Using Pneumatic system and PLC Controller” this would be considered from many aspects such as optimizing the cycle time of machine from Pneumatic System and PLC Controller, then to support the machine the researcher has considered the Machine Construction, and also for support the cost saving program the researcher would to considered the Engineering Economics.

1.2 Problem Statement

- Is the use of Machine could be reach out the expected target?
- How about the Machine Construction?
- How about the comparison after improvement?

1.3 Objective

The objectives of this research are:

- Design the Automatic stamping machine for date and dash code marking starting with the shape, work system of pneumatic and also PLC as the controller based on:
  1. Align with the needs and the function of machine.
  2. Easy to Use and also easy to the maintenance.
  3. More savings and effective for the company.

1.4 Scope

- The Machine is only presented to PT. X-Indonesia (West Plant).
- All of the parameter is based on the Actual condition in PT. X-Indonesia.
1.5 Assumption

- The speed of cylinder is constant.
- Cost for maintenance and electricity is not considered.
- Flow rate from the valve is determining from the table from vendor of valve.

1.6 Research Outline

- CHAPTER I Introduction

  This chapter consist of background, problem statement that must be solved, objective as the achievement of goals in research, limitation as research, limitation as research boundaries, and assumption as an overview in the design.

- CHAPTER II Literature Study

  This chapter provides theories on how to determine the system of pneumatic, program input to PLC, the strength of the construction, and other related data from books, journals and expertise that can be used to solve problems from this design.

- CHAPTER III Research Methodology

  This chapter explains the flow of research and explanation of each step to do at this design from the initial observation to analyzing the collected data accompanied by the improvements and recommendations.

- CHAPTER IV Data Analysis

  This chapter describes the collection of data from the implementation of the system on the machine, the strength of the construction, the controller program as well as the economic benefits for the company. The point in this chapter will be supporting data to answer all problem statements.

- CHAPTER V Conclusion

  This chapter contains the result of research to answer the problem and to get the research objectives. Conclusion will consist of the function of the machine
in accordance with the needs, ease to operate and maintenance the machine, profits for the company.
CHAPTER II
LITERATURE STUDY

2.1 Engineering Design

2.1.1 Definition of Engineering Design

In a design first thing we must know is the definition of Engineering Design itself, in an Institution called ABET (Accreditation Board for Engineering and Technology) states that “engineering design is the process of devising a system, component, or process to meet desired needs”. Then in a design it is good also if we include the variety of realistic constraints that will arise such as, safety, economic, aesthetic, etc. [1]

2.1.1 Design Levels

Depth of design is also divided into several classes depending on the reasons and how to build a design. The class is divided into 3 levels namely adaptive design, development design, and new design. [1] The explanation of each level of design will described as following below:

- Adaptive Design:

This level of designer usually adapts from a state or needs without having to have special knowledge, this way in some branches of manufacturing has stopped except a little modify of the product dimension. For examples is just like the washing machine, technically and conceptually for so many years is using the same technique and concept, the designer just modify the dimensions, materials, etc. [1]

- Development Design:

This level of designer requires more scientific training and design in developing something. The designer may do the development of the existing design but in the end the result could be change drastically from the original design. Examples such as the design of the manual car gearbox developed into automatic car gearbox design, this is certainly included in the category of changes in conceptual, technical, and system work of the design itself. [1]

- New Design:
This level of design is only can be doing by a few people because in this level the designer must have special abilities, broad insight, creativity, imagination and foresight in creating new concepts. Examples such as Wright Brothers listed as the inventor of the first aircraft that successfully in the fly and controlled by humans. In this case they have to think about concepts, forms, dimensions, work system, materials, and so forth to get the desired design result.\[1\]

2.1.2 Systematic Design
The engineering students in their learning are presented by various theoretical information, but if faced in problem solving as requested to develop a product or create something new then they will fail unless they have a higher understanding. Therefore, professional designers or students can follow the existing guidelines in order to know the beginning and end of a design and also to guide them in creating creativity and solving technical problems.\[1\] In the process of systematic-design they can pay attention to 4 main aspects in design that is:

- Requirement
- Product Concept
- Embodiment of the Design
- Detailed Design

The aspects above are the core systematic contrive of a design, like what have already mention above, the most important step in designing is identifying the needs that belong to the "Requirements" aspect.\[1\]

2.1.3 Design Process
To design is to create a new product that turns into profit and benefits society in some way. The design process is a sequence of events and a set of guidelines that helps define a clear starting point that takes the designer from visualizing a product in his/her imagination to realizing it in real life in a systematic manner without hindering their creative process. The ability to design requires both science and art. The science can be learned through a systematic process (outlined in this chapter), experience, and problem-solving technique (all of which will be mastered during your college education). The art is gained by practice and a total dedication to
The design of a device or system can be done in one of two ways:

1. Evolutionary change: A product is allowed to evolve over a period of time with only slight improvement. This is done when there is no competition. The creative capabilities of the designer are limited.\[1\]

2. Innovation: Rapid scientific growth and technological discoveries as well as competition among companies for their slice of the market have placed a great deal of emphasis on new products, which draw heavily on innovation. The creative skills and analytical ability of the design engineer play an important role.\[1\]

The invention of the telephone was a truly innovative design. Since its invention, many then tried to evolve and hence improve it over many decades, but very little actually changed until the next innovative and technological jump occurred, and that was the mobile phone. This created a whole new market along with new competition, and since then, this technology has been evolving once more every-verse in a while showing signs of new innovation, such as the inclusion of cameras and video-calling and the integration of pda, internet access, and mp3 facilities into one device. Proficient designers control evolution and innovation so they occur simultaneously. Although the emphasis is on innovation, designers must test their ideas against prior design. Engineers can design for the future but must base results on the past.\[1\]
2.2 Pneumatic System

2.2.1 Reason of using pneumatic

In the manufacturing department many utilities are in use such as electricity, natural gas, water, and also air, pneumatic is a system that utilizes the power carried by the air in a tool. Pneumatic system is widely used in Industrial Automation because it is quite simple and reliable, pneumatic is also often used because it quiet cheap technology in comparison with other technologies such as hydraulic or electric motor in addition to the function of moving a very light load for example it will spend much cost if use in hydraulic or electric motor. \[2\] Here is a comparative table between 3 technologies:

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Pneumatic</th>
<th>Hydraulic</th>
<th>Electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Complexity</td>
<td>Simple</td>
<td>Medium</td>
<td>Medium/High</td>
</tr>
<tr>
<td>Peak power</td>
<td>High</td>
<td>Very high</td>
<td>High</td>
</tr>
<tr>
<td>Size</td>
<td>Low size/force</td>
<td>Very low size/force</td>
<td>Medium size/force</td>
</tr>
<tr>
<td>Control</td>
<td>Simple valves</td>
<td>Simple valves</td>
<td>Electronic controller</td>
</tr>
<tr>
<td>Position accuracy</td>
<td>Good</td>
<td>Good</td>
<td>Better</td>
</tr>
<tr>
<td>Speed</td>
<td>Fast</td>
<td>Slow</td>
<td>Fast</td>
</tr>
<tr>
<td>Purchase cost</td>
<td>Low</td>
<td>High</td>
<td>High</td>
</tr>
<tr>
<td>Operating cost</td>
<td>Medium</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Maintenance cost</td>
<td>Low</td>
<td>High</td>
<td>Low</td>
</tr>
<tr>
<td>Utilities</td>
<td>Compressor/power/pipes</td>
<td>Pump/power/pipes</td>
<td>Power only</td>
</tr>
<tr>
<td>Efficiency</td>
<td>Low</td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Reliability</td>
<td>Excellent</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td>Maintenance</td>
<td>Low</td>
<td>Medium</td>
<td>Medium</td>
</tr>
</tbody>
</table>

**Figure 2.1 Comparative table of 3 technologies** \[2\]

Based on the figure above, Pneumatic is simpler if compared with hydraulic and electric system, give more profit on the capital cost and maintain. The fluid power system produces linear motion with simple pneumatic and hydraulic cylinders and actuators. Converting electricity to linear power often requires one or more mechanical devices to change motor rotation. Based on the table above, Pneumatic is simpler if compared with hydraulic and electric system, give more profit on the capital cost and maintain. The fluid power system produces linear motion with simple
pneumatic and hydraulic cylinders and actuators. Converting electricity to linear power often requires one or more mechanical devices to change motor rotation. \(^2\)

Pneumatic and hydraulic power transmission methods typically generate more power in smaller spaces, so small pneumatic cylinders can be used to provide the required high clamping or loading force required to hold the product on certain machines and other applications. \(^2\)

This power control is usually easier to do with pneumatics and hydraulics than electrical systems. Valve controls, regulators and simple flow are usually required to control the direction, speed and strength of the cylinder. Electrical actuators often require electronic controllers, multiple I / O points, communication cables, and perhaps encoder feedback, along with more complex automation system programming. \(^2\)

Pneumatic actuators typically have two highly repetitive end-time positions determined by using hard cover, bearing or shock. The electric actuators are also very repeatable and can be easily designed with some stop position. With the new advances in the field of electronics, pneumatic control of some stop positions is also possible although not as precise as electricity. Whether it's an end-of-stroke or multiple stop position, pneumatic and electric actuators can achieve the desired position at high speed. \(^2\)

The operation of the compressor may have additional costs compared to electricity, but the availability of clean dry air in most public facilities occurs. In addition, pneumatic components often have the lowest maintenance costs, such as when changing a seal, or an entire cylinder, which is often much cheaper than a service, especially changed with an electric actuator. \(^2\)

Noise becomes less apprehensive with fluid power devices. The design has improved over the years, greatly reducing ringing around the same level as the stepper-driven electric actuators. New improvements in the design and efficiency of compressors, and the use of clean dry air standards and dry distribution in manufacturing facilities, also make pneumatics a perfect choice for industrial automated machinery. \(^2\)
2.2.2 Basic Pneumatic Hardware

All pneumatic systems will have particular primary components. Which is a compressor, and a system to disseminate the clean and dry air that produced by the compressor. [2]

General pneumatic components on automated machines include:

- Air preparation system (shut-off/lock-out, combination filter/regulator, soft start valve)
- Control valves and manifolds (manual, air pilot, solenoid operated)
- Air cylinders and actuators
- Tubing and hoses
- Push-to-connect fittings
- Cylinder position sensors
- Discrete pressure switches
- Specialty components and accessories

Because most of the facilities have a plant air supply, the machine pneumatic system starts with the air preparation unit to which the plant air is connected. The air prep system must contain a shutoff valve, filter, water trap and pressure regulator which are manual and lockable. To release air during an emergency-stop, guard open or similar safety event, might also be considered by an electrically-operated soft start. The air prep system may also include a lubricator, but it’s usually not fundamental except if pneumatic rotary tools are in use. [2]

The valves or valve manifold that can include manual, air-piloted and solenoid-operated control valves to turn the air supply off and on usually bait by the air preparation system. These valves bait control air to a variety of pneumatic cylinders and actuators, the place where power transmission happens. [2]

Pneumatic cylinder position sensors and pressure switches are a general component in pneumatic systems. There are also a comprehensive variety of special pneumatic components such as flow controls, quick exhaust valves, hand valves, check valves, inline pressure regulators, gauges and indicators. [2]
2.2.3 Pneumatic circuit Symbol

Before we go too far with specifics on pneumatic system components let’s take a look at the symbols used to represent these components. Throughout the eBook we will include these circuit symbols and offer you some practical advice in how to incorporate these components into an industrial application. [2]

2.2.3.1 Valve Symbols

Directional air control valves are the building blocks of pneumatic control. Symbols representing these valves give detailed information about the valve they represent. The methods of actuation, the number of positions, the flow paths and the number of ports showed by symbols. Here is a brief explanation of how to read a symbol. Most valve symbols have three parts (see Figure 2.2) [2].

![Figure 2.2 Valve symbol](image)

The valve to shift from one position to another are caused by the mechanism of the actuators. The Position and Flow Boxes show how the valve functions. Every valve has at least two positions and each position have one or more flow paths, thus every valve symbol has at least two Flow Boxes to describe those paths. [2]

2.2.3.2 Position and Flow Boxes

The number of ‘position and flow boxes’ that compile a valve symbol indicate the number of valve positions. The arrows in each box indicates flow direction. The flow paths the valve provides when it is in each position represented by thus arrows. The Flow Box next to the ‘active’ actuator always shows the current flow path(s) of the valve. In the example above, when the lever is NOT being activated, the spring return actuator (right side) is
controlling the valve, and the box adjacent to the spring shows the flow path. When the lever IS actuated, the box next to the lever shows the flow path of

![Diagram of valve positions](image)

Figure 2. 3 Three position of valves

...the valve. A valve may only be in one position at a given time.

In Figure 2.3 the valve has both solenoids and ‘spring return’ actuators on both sides, the spring return actuators will return the valve to the center position but only IF neither of the solenoids is active: With this three-position valve, the center flow box shows the flow path when neither actuator is active and the springs are holding the valve in the center position. In this fairly common example, the center box indicates that there will be no air flow (and the associated cylinder won’t move) unless one of the two actuators is active. This type of valve can thus be used to “bump” or “inch” a cylinder incrementally along its extension or retraction stroke for various purposes.

![Diagram of valve ports](image)

Figure 2. 4 5 Ports Valve

2.2.3.3 Ports
The number of end points in a given box show the number of ports. Count only the ports in one flow box per symbol. Sometimes a port (usually an exhaust port) goes directly to atmosphere and there is no mechanical means
for attachment of silencers, flow control valves, or any other accessories. To indicate this (in some flow diagrams), ports with attachment capability will have a short line extending beyond the box (as shown on ports 1, 2, & 4), while the ports you cannot attach to will not have the external line segment (ports 3 & 5 in this example).

2.2.3.4 Port Labeling
Port labels are usually shown on a single flow box per symbol (see on figure 2.4). Different manufacturers label valve ports with different letters, but the labels at right are about standard. The pressure inlet port represented by "P", “A” and “B” are outlets (usually plumbed to the ‘extend’ and ‘retract’ ports on a cylinder), and the exhaust ports indicated by "R" and "S".

![Figure 2.5 Ports labels](image)

2.2.3.5 Port and Ways
Valves are often referred to their number of ports and also by the number of “ways” that air can enter or exit the valve. In most situations the number of ports and ways are the same for a given valve. From figure 2.5 it has five ports, but it is considered a 4-way valve because two of the ports share the same exhaust function. This is a holdover from hydraulics – where the two exhaust paths are joined (internally to the valve), so that only one return port is required, and only one return line is required to get the hydraulic oil back to the storage tank for re-use. In other words, in a pneumatic system the two exhaust ports (R and S, in Figure 2.5) are only counted as a single “way” since they both connect the valve to the same place (atmosphere). In the case of our pneumatic valve with similar functionality, the separate exhaust ports are created for mechanical simplicity (and as a cost saving measure), but they are not considered distinct “ways”. The symbols on the next page detail many of the ports, ways, and positions of common pneumatic valves. The
specification for “ways” can be somewhat tricky; analyzing the circuit symbols is a better method for verifying that a given valve offers the required functionality. [2]

2.2.3 Pneumatic Air Preparation
To protect all the pneumatic components in machines, equipment and processes and to ensure their proper operation a steady supply of clean and dry air is compulsory. Clean and dry air with enough flow to provide the required pressure must be designed into the system while controlling mechanical motion with pneumatics—such as clamping, positioning, pushing and lifting—is often the focus. [2]

2.2.3.1 Air Plant
Compressed air often flows via multiple devices, pipes and fittings that can add particulates, oil and moisture from the plant or shop compressor to the machine. The air should still be prepared at the machine before it is used even if the main plant compressor includes an air dryer, filter, water separator and regulator. If there is a far gap from the main compressor to the point of use where additional water, air preparation at the machine will be important especially if there is a far gap between them where additional water or particulates could build up. This helps assure your machine gets the best possible protection and longest possible service life. In addition to manual and electrical air dumps for safety, an air preparation system has to include regulators, filters and lubricators. [2]
2.2.3.2 Air Supply Preparation

It is not a bad thing to have an oversized air preparation system, as this can leave room for additions or unanticipated demands. The air prep system should start with a manual shutoff relief valve with lock-out to remove air for maintenance. For additional safety, OSHA also requires air to be dumped during an emergency stop or other safety event. For this purpose, an electrical soft start valve that dumps air when power is removed is recommended. The soft start valve also keeps the pneumatic equipment from banging when air is applied. [2]

The filter, regulator and lubricator (FRL) is installed just downstream of the manual shutoff relief valve. The air filter provides particulate removal and moisture separation filters in a wide range of port sizes, typically from 1/8” to 1”. Standard filters remove particulate to around 40 µm, while fine filters are available to remove particulates down to 5 µm or less. [2]

These filters are necessary to reduce contaminates and moisture in the compressed air at the machine. All pneumatic components benefit from this, but keep in mind that a filter that is too fine for the application can become blocked quickly. While a 40 µm filter works well to protect valves and cylinders, process instrumentation or high speed pneumatic tools will benefit from a finer particle filtration. Special, finer filters may also be needed for

Figure 2. 6 Filter regulator and lubricator (FRL) [2]
food, pharmaceutical and paint shop applications, and specify coalescing filters if oil vapors or aerosols need to be removed from the air stream.\[2\]

The air filter bowls often include manual, semi-automatic or automatic drains to remove trapped liquid that has been separated from the air. The manual drain is just a valve. The semi-auto drain is similar to a check valve; it is closed when pressure is applied and opens when pressure is removed. The auto drain automatically opens when the liquid in the bowl reaches a certain level. These removable bowls also allow easy replacement of the filters. A variety of accessories are available to mount these combined filter/separators individually, or to a downstream regulator.\[2\]

2.2.3.3 Pressure Adjustment

The regulator used to suit the port size of the upstream filter. The regulator fit the pressure of the filtered air between a typical in range of 20-130 psi, with lower pressure ranges usually available for applications needing more accuracy. Most piloted valves require 30 psi to operate. When press down, the knob locks in the pressure. And pulling the knob up and rotating it will changes the air pressure. The design of the equipment usually determines the operating pressure that required. A minimum operating pressure should be maintained, by a pressure switch to alert an operator with values below this level sensed. Even though higher pressure than required may make the machine run faster, it can cause excess wear and tear due to the banging caused by fast cylinder motion. While more than 100 psi may be supplied to a machine, operating at 60 - 80 psi is usually a good design goal. Features of note in a regulator are a pressure relieving design and a built-in, integral pressure gauge. If the set point is reduced or if a downstream condition boosts the pressure, the pressure relieving design will relieve pressure. There is only one way to bring down the pressure in a non-relieving design, which is to cycle the downstream equipment. An integral pressure gauge is always a good idea to give a quick indication of system air pressure, and to help when setting the regulated pressure. The pressure gauge indicates the regulated downstream pressure, not the incoming/upstream pressure. The combination filter regulator air prep units are also available. These units that described above combined into a single unit and they have all the capabilities of the
separate filters and regulators. If a single air pressure works for the application, this design will save necessary pneumatic panel space and it also save more money. \textsuperscript{[2]}

2.2.4 Pneumatic Actuator

There are thousands of industrial applications that require a linear motion during their operation sequence. One of the simplest and most cost-effective ways to accomplish this is with a pneumatic actuator. Pneumatic actuators are also very clean operating because the operating fluid is a gas, which prevents leakage from dripping and contaminating the surroundings. \textsuperscript{[2]}

This section will discuss the basic construction and function of a pneumatic actuator, the relationship with a fluid power system and the selection guidelines for pneumatic actuators or air cylinders. \textsuperscript{[2]}

Pneumatic actuators convert compressed air into rotary or linear motion. There are many styles of pneumatic actuators: diaphragm cylinders, rod-less cylinders, telescoping cylinders and through-rod cylinders. \textsuperscript{[2]}

![Figure 2. 7 Styles of pneumatic actuator \textsuperscript{[2]}](image)

The most popular style of pneumatic actuator consists of a piston and rod moving inside a closed cylinder. Even so, there is a large variety of construction techniques and materials to fit a wide range of applications and user preferences. Body materials can be aluminum, steel, stainless steel and even certain polymers. Construction can be either non-repairable or repairable. This actuator style can be sub-divided into two types based on the operating principle: single acting and double acting. Single-acting cylinders have a single port to allow compressed air to enter the cylinder to move the piston to the desired position. They use an internal spring or
sometimes simply gravity to return the piston to the “home” position when the air pressure is removed. Single-acting cylinders are a good choice when work is done only in one direction such as lifting an object or pressing an object into another object. [2]

Pressure and flow requirements of the actuators in a system must be taken into account when selecting these upstream system components to ensure the desired performance. Undersized upstream components can cause a pneumatic actuator to perform poorly or even make it unable to move its load at all. [2]

The final bit of basic selection criteria is the cylinder mounting arrangement.

There are many different configurations available from various manufacturers. The more common ones include rigid nose or tail mount, trunnion mount, rear pivot mount and foot mount. A study of the machine motion required usually will show which mounting configuration is the best choice. [2]

Once the basic actuator size and configuration is known, other options such as end-of-stroke cushions, magnetic piston (for position detection switches) or special seals should be considered when making the final selection. [2]

Cushions do an excellent job of preventing a piston from banging into the end caps at the end of stroke. Flow control valves can prevent banging also, but at the expense of a slow travel speed. Cushions only slow the travel for about the last half inch of
stroke. A cushion is very useful when the design requires a higher cycle rate or speed and also smooth starting and stopping. [2]

Magnetic pistons allow simple magnetic proximity sensors to be mounted on a cylinder which can allow a control system to get feedback on the position of a cylinder. Since most cylinders are either extended or retracted, two proximity switches can monitor the operation of a cylinder. This can be very beneficial for machines that require a sequence of operations. Due to the nature of compressed air systems, the exact speed of a cylinder may vary slightly due to a number of factors outside of the control of the machine’s control system such as supply pressure variations, moisture content in the air or ambient temperature. Therefore, a control sequence that begins Step 2 once Step 1 is confirmed complete and so on is a much more robust design. [2]

2.2.5 Valves for Pneumatic Cylinders
In the pneumatic world, valves are the equivalent of relays controlling the flow of electricity in automation systems. Instead of distributing electric power to motors, drives and other devices, pneumatic valves distribute air to cylinders, actuators and nozzles. [2]

2.2.5.1 Valve Activation
Pneumatic valves, also called directional control valves, are activated in a variety of ways including manually, solenoid operated and air piloted. In their simplest form, 2-way and 3-way valves can be normally open (NO) or normally closed (NC), terms that refer to their normal states without power applied. Another very common valve is a 4-way valve which switches supply and exhaust between two outlet ports. Manually activated valves are typically switched open and closed by a foot pedal, toggle actuator, handle, knob or push button. An operator controls the activated position of the valve, and a spring or the operator returns the valve to its home position. Solenoid

Figure 2. 9 Valves [2]
operated valves use an electrical coil to control the position of a poppet, plunger or spool to open or close a valve. Typical solenoid control voltages are 12VDC, 24 VAC/DC, 120VAC or 240VAC. Air piloted valves are operated by an external air source such as a solenoid operated valve in a remote location. The valve can also be internally air piloted, enabling use of a smaller integrated electric solenoid to provide an air pilot signal to control the larger valve spool. [2]

2.2.5.2 Valve Type
With pneumatic valves, the configuration or valve type indicates how air is connected to the device and switched through the valve. This configuration has a strong influence on the device the valve is controlling and understanding this is critical for specifying the proper valve for the application. The Pneumatic Circuit Symbols Explained section has the information needed to understand valve configurations, but these symbols must be interpreted. The pneumatic symbol for a valve has three parts: actuation (how the valve is actuated), position (the number of positions and ports) and flow (how the air flows through the device). The actuation methods are on the left and right of the symbol and can be thought of as pushing the boxes left or right. The number of boxes indicates the number of positions, typically two or three. Flow of supply air or exhaust, for each position, is defined by the information in each box. Each valve position has one or more flow paths, and the arrows in each box represent flow of air and exhaust. The point where each path touches a box is called a port, and to determine the number of ports, one must count a single box of the symbol. The flow path can also be blocked, indicated by a “T” symbol. [2]

2.2.5.3 Valve Port and Position Types
The number of ports and positions define the type of work a valve is designed for, so selecting these options is a critical design decision. A 2-port or 2-way, 2-position valve has one inlet port and one outlet port. This type of valve is on or off, with no way to vent air pressure, unless that is its only function. The number of different pathways for air to travel in or out of the valve are referred to as “ways” while the different available states are called “positions”. Valves commonly used in industrial applications are
either a 2-, 3- or 4-way configuration, 2- and 3-way valves have 2 positions while 4-way valves can be either 2- or 3-position. Below are the commons pneumatic valve types [2]:

1. 2-port (2-way), 2-position

![Figure 2. 10 2port-2way-2position](image)

2. 3-port (3-way), 2-position

![Figure 2. 11 3port-3way-2position](image)

3. 5-port (4-way), 2-position

![Figure 2. 12 5port-4way-2position](image)

4. 5-port (4-way), 3-position

![Figure 2. 13 5port-4way-3position](image)

By adding a third port, the 3-port or 3-way, 2-position valve can both supply and exhaust pressure. The three ports are air in, air out and exhaust. While exhausting pressure is important for cylinder movement, this type of valve only works well in applications such as single-acting cylinders with a spring return, or in air blow off applications such as blowing chips in a machining
process. Adding two more ports turns the valve into a 5-port (4-way), 2-position valve. A 5-port valve is technically a 4-way valve since there are two ports open to ‘Exhaust’. This is mainly done to simplify valve construction. This is the most popular directional control valve because it can extend and retract double-acting cylinders, providing a wide range of control capabilities. This type of valve includes an inlet port, two outlet ports and two exhaust ports. In a 2-position configuration, one output is flowing air from the inlet and the other is flowing air to an exhaust port. When the valve is switched, the two outputs are in opposite modes. This is the most common way to extend and retract a double-acting pneumatic actuator, pressurizing one side of the cylinder while exhausting the other.\[^{2}\]

Keep in mind that 2-position, single solenoid valves have a spring return. With an energized valve, if the double-acting cylinder it’s connected to is extending, that cylinder will retract if electrical power is lost (such as when an emergency stop is pressed) but air remains on. If the emergency stop also dumps air pressure in the system, as recommended, the cylinder will retract once pressure is restored unless the valve is re-energized. If a 2-position, double solenoid valve has a detents feature, the valve spool is held at whichever position it was at the moment the emergency stop was pressed. If the cylinder was at mid-stroke when the emergency stop was pressed, when air is reapplied, the valve will command the cylinder to continue motion to the original energized position, even with both solenoids on the valve de-energized. This motion, due to the maintained valve position, can cause issues. For example, unintended cylinder motion after an emergency stop can damage tooling and should be examined during design.\[^{2}\]

2.2.5.4 3 Position Valve

The 5-port or 4-way, 3-position valve offers a center position that can be specified to either exhaust or block pressure when neither valve solenoid is actuated. These valves are typically used in applications where it is a requirement to stop a cylinder in mid stroke. They are also used to inch or jog a cylinder, or when air must exhaust during an emergency stop and no cylinder movement is allowed after air is reapplied until a reset button or start button is pressed.\[^{2}\]
Caution is required when using these valves as there is additional control complexity. Center block 3-position valves can trap air and cause unexpected movement under emergency stop conditions, especially if tooling is jammed. To deal with this condition, all energy including trapped air should be removed when an emergency stop is pressed. Air can also leak out, causing the cylinder to drift or drop.  

A 3-position center exhaust valve will dump all pressure to a cylinder under emergency stop conditions or when both solenoids are de-energized. During startup, there will be no air to control air flow to the cylinder, causing very fast and possibly damaging cylinder speeds during the first machine cycle. To prevent this condition, both sides of the cylinder must be charged with air pressure at startup.  

2.2.5.5 Valve Form Factor  
The form factor of the valve is often driven by its use. This includes both internal configuration and external design. Common internal configurations include poppet, diaphragm and spool. Poppet valves are usually direct solenoid operated, similar to a gate valve in a 2-way, 2-position application, the details can be seen on figure 2.14. A pilot piston, accessed from a pilot port, moves the valve stem opening the valve. Diaphragm valves work similar to a poppet valve but physically isolate the operator solenoid from the valve and the working fluid by use of the diaphragm. Spool valves, either direct or pilot actuated, are often used on 4-way, 2- and 3-position body ported valves. These spool valves are pistons with seals that when shifted move along a bore opening or closing ports depending on the position. They provide a simplified way to change flow paths, are easy to actuate and are not affected by pressure.  

The external form factor of many valves makes them stackable, allowing more valves to fit into a smaller area. Some valves are easier than others to

![Figure 2.14 4-way valve often used to control a double-acting cylinder](image-url)
mount individually, and some can be specified to mount either individually or as part of a manifold. Designers may wish to consider compact, modular, manifold-mounted valves in applications with high pneumatic valve counts. [2]

2.2.5.6 Connecting the Valves

Valves have three primary electrical connection methods: hard wired, modular wired or digital communication. Many valves have a connector built in with removable flying leads, or a DIN style wiring connector. Modular wiring is typically used with manifold mounted valve configurations. This wiring usually consists of a D-sub connector embedded in the manifold base. This provides an efficient and clean integration option for large pneumatic systems. Ether-Net/IP and other digital communication protocols are becoming a popular way to replace individual discrete wires with a single cable. This is particularly effective when a large number of valves in a small space require activation. This can also reduce cost on the controller side of the system by using a single communication port instead of multiple output modules. A variety of threaded ports or push-to-connect fittings are also available to attach pneumatic tubing to the valves. A 5-port (4-way), 2-position valve type is often the best choice for a pneumatic directional control application. Adding a manual operator feature and an indicator light on the electrical connection make maintenance easier, so these options should be considered. Figure 5H to below is a 2-way media separated diaphragm style valve for use with gases or fluids where the metal working components of the valves do not come into contact with the working fluid. The valve symbol is the same whether it is a poppet, diaphragm or spool valve. [2]

2.3 Programmable Logic Control

2.3.1 Controller

*What type of task might have a control system?* It might be required to control sequence of events or maintain some variable constant or follow some prescribed change. Then *what form might a controller have?* For the automatic drilling machine, we could wire up electrical circuits in which the closing or opening of switches would result in motors being switched on or valves being actuated. Then we might have the
closing of a switch activating a relay which, in turn, switches on the current to a motor and causes the drill to rotate. [3]

2.3.1.1 Microprocessor controlled system
Instead of hardwiring each control circuit for each control situation we can use the same basic system for all situations if we use a microprocessor-based system and write a program to instruct the microprocessor how to react to each input signal from, say, switches and give the required outputs to, say, motors and valves. [3] Then we might have a program of the form:

- If switch A close, Output to motor circuit
- If switch B close, Output to valve circuit

By changing the instructions at the program, we can use the same microprocessor system to control a wide variety of situations.

2.3.1.2 The programmable logic controller
A programmable logic controller (PLC) is a special form of microprocessor-based controller that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting and arithmetic in order to control machines and processes (Figure 2. 15) and are designed to be operated by engineers with perhaps a limited knowledge of computers and computing languages. They are not designed so that only computer programmers can set up or change the programs. Thus, the designer of the PLC has pre-programmed it so that the control program can be entered using a simple, rather intuitive, form of language. The term logic is used because programming is primarily concerned with implementing logic and switching operations. [3]

![Figure 2. 15 A programmable logic controller](image)

PLC’s have the great advantages that the same basic controller can be used with a wide range of control systems. To modify a control system and the rules that are to be used, all that is necessary is for an operator to key in a
different set of instructions. There is no need to rewire. The result is a flexible, cost effective, system which can be used with control systems which vary quite widely in their nature and complexity. [3]

PLCs are similar to computers but whereas computers are optimized for calculation and display tasks, PLC are optimized for control tasks and the industrial environment. Since the PLCs are:

1. Rugged and designed to withstand vibrations, temperature, humidity and noise.
2. Have interfacing for inputs and outputs already inside the controller.
3. Are easily programmed and have an easily understood programming language which is primarily concerned with logic and switching operations.

2.3.2 Ladder and functional block programming

Programs for microprocessor-based systems have to be loaded into them in machine code, this being a sequence of binary code numbers to represent the program instructions. However, assembly language based on the use of mnemonics can be used, e.g. LD is used to indicate the operation required to load the data that follows the LD, and a computer program called an assembler is used to translate the mnemonics into machine code. Programming can be made even easier by the use of the so-called high-level languages, e.g. C, BASIC, PASCAL, FORTRAN, COBOL. These use pre-packaged functions, represented by simple words or symbols descriptive of the function concerned. For example, with C language the symbol & is used for the logic AND operation. However, the use of these methods to write programs requires some skill in programming and PLCs are intended to be used by engineers without any great knowledge of programming. As a consequence, ladder programming was developed. This is a means of writing programs which can then be converted into machine code by some software for use by the PLC microprocessor. [3]

This method of writing programs became adopted by most PLC manufacturers, however each tended to have developed their own versions and so an international standard has been adopted for ladder programming and indeed all the methods used for programming PLCs. The standard, published in 1993, is IEC 1131-3 (International Electrotechnical Commission). The IEC 1131-3 programming
languages are ladder diagrams (LAD), instruction list (IL), sequential function charts (SFC), structured text (ST), and function block diagrams (FBD). [3]

In purpose to introducing to the programming of PLC using ladder diagrams and functional block diagrams. Here we are concerned with the basic techniques involved in developing ladder and function block programs to represent basic switching operations, involving the logic functions of AND, OR, Exclusive OR, NAND and NOR, and latching. [3]

2.3.2.1 PLC Ladder programming

A very commonly used method of programming PLCs is based on the use of ladder diagrams. Writing a program is then equivalent to drawing a switching circuit. The ladder diagram consists of two vertical lines representing the power rails. Circuits are connected as horizontal lines, i.e. the rungs of the ladder, between these two verticals. [3]

In drawing a ladder diagram, certain conventions are adopted:

1. The vertical lines of the diagram represent the power rails between which circuits are concerned. The power flow is taken to be from the left-hand vertical across a rung.
2. Each rung on the ladder defines one operation on the control process.
3. A ladder diagram is read from left to right and from top to bottom, (figure 2 (16)) showing the scanning motion employed by the PLC. The top rung is read from left to right. Then the second rung down is read from the left to right and so on. When the PLC is in its run mode, it goes through the entire ladder program to the end, the end rung of the program being clearly denoted, and then promptly resumes at the start. This procedure of going through all the rungs of the program is termed a cycle. The end rung might be indicated by a block with the word END or RET for return, since the program promptly returns to its beginning.
4. Each Rung must start with an input or inputs and must be ended with at least one output.

![Ladder Diagram](image)

**Figure 2. 16 Scanning the ladder program**

5. Electrical devices are shown in their normal condition, so a switch which is normally open until some object closes it, is shown as open on the ladder diagram. A switch that is normally closed is shown closed at the ladder diagram.

6. A particular device can appear in more than one rung of a ladder. For example, we might have a relay which switches on one or more devices. The same letters and/or numbers are used to label the device in each situation.

7. The inputs and outputs are all identified by their address, the notation used depends on the PLC manufacturer.
Figure 2. 17 shows standard IEC 1131-3 symbols that are used for input and output devices. Some slight variations occur between the symbols when used in semi-graphic form and when in full graphic. Note that inputs are represented by different symbols representing normally open or normally closed contacts. The action of the input is equivalent to opening or closing a switch. Output coils are represented by just one form of symbol. [3]

![Figure 2. 17 Basic symbols](image)

To illustrate the drawing of the rung of a ladder diagram, consider a situation where the energizing of an output device, e.g. a motor, depends on a normally open start switch being activated by being closed. The input is thus the switch and the output the motor. Figure 5.5 shows the ladder diagram. [3]

![Figure 2. 18 Ladder diagram](image)

2.3.2.2 Logic Functions

There are many control situations requiring actions to be initiated when a certain combination of conditions is realized. For e.g. the drilling machine
might have some condition that need a combination of inputs or outputs so it will need an AND logic function, condition A and condition B having both to be realized for an output to occur. [3] This section is a consideration of such logic functions, below are types of the logic function:

1. **AND**

![AND gate diagram]

Figure 2. 19 AND gate with a ladder diagram rung. [3]

Figure 2. 19 Shows an AND gate system on a ladder diagram. AND gate is an interlock control system for a machine tool, so that it can only be operated when the safety guard is in position and the power switched on. [3]

2. **OR**

![OR gate diagram]

Figure 2. 20 OR gate [3]

Figure 2 (20) Shows an example of OR gate control system of a conveyor belt transporting bottled products to packaging where a deflector plate is activated to deflect bottles into a reject bin is either the weight is not within certain tolerances or there is no cap on the bottle. [3]

3. **NOT**

![NOT circuit diagram]

Figure 2. 21(a) NOT circuit, (b) NOT logic with a ladder rung, (c) high output when no input to A [3]
Figure 2 (21) (a) Shows an Electrical circuit controlled by a switch that normally closed, Figure 2 (21) (b) shows a NOT gate system on a ladder diagram. The input A contacts are shown as being normally closed. This is in series with the output ( ). With no input to input A, the contacts are closed so there is an output. When there is an input to input A, it opens and there is no output. An example of a NOT gate control system is a light that comes on when it becomes dark, i.e. when there is no light input to the light sensor there is an output. \[3\]

4. NAND

![NAND gate](image)

Figure 2. 22 NAND gate \[3\]

Suppose we follow an AND gate with a NOT gate, the consequence of having the NOT gate is to invert all the outputs from the AND gate. An alternative, which gives exactly the same results to put NOT gate on each input and then follow with OR gate. An example of a NAND gate control system is a warning light that comes on if, with a machine tool, the safety guard switch has not been activated and the limit switch signaling the presence of the workpiece has not been activated. \[3\]

5. NOR

![NOR gate](image)

Figure 2. 23 NOR gate \[3\]

The combination of OR and NOT gate is termed a NOR gate, there is an output when neither input A or input B is 1. \[3\]
6. **Exclusive OR (XOR)**

![XOR gate diagram]

When input A and input B are not activated then there is 0 output. [3]

7. **Latching**

There are often situations where it is necessary to hold an output energized, even when the input ceases. A simple example of such a situation is a motor which is started by pressing a push button switch. Though the switch contacts do not remain closed, the motor is required to continue running until a stop push button switch is pressed. The term latch circuit is used for the circuit used to carry out such an operation. It is a self-maintaining circuit in that, after being energized, it maintains that state until another input is received. [3] An example of latch is shown in figure below:

![Latched circuit diagram]

2.3.3 Entering Program

Each horizontal rung on the ladder represents an instruction in the program to be used by the PLC. The entire ladder gives the complete program, there are several methods that can be used for key-in the program into a programming terminal. Whatever method is used to enter the program into a programming terminal or computer, the output to the memory of the PLC has to be in a form that can be handled by the microprocessor. This is termed *machine language* and the language is binary code, e.g. 001010001110001. [3]
2.3.3.1 Ladder Symbols

One method of entering the program into the programming terminal, it involves a keypad that have keys with symbols depicting the various elements of the ladder diagram and then key-in them into the ladder diagram appears on the screen of the programming terminal. Below are the examples of symbols of the key marked for ladder diagram:

1. Pair of Contacts

![Pair of Contacts](#)

**Figure 2.26 Pair contacts ladder symbol**

2. Output

![Output](#)

**Figure 2.27 Output ladder symbols**

3. Start Junction symbol

![Start Junction](#)

**Figure 2.28 Start junction symbol**

4. End Junction symbol

![End Junction](#)

**Figure 2.29 End junction symbols**

5. Horizontal circuit links

![Horizontal Circuit Links](#)

**Figure 2.30 Horizontal circuit links symbol**

Computers can be used to draw up a ladder program. These involve loading the computer with the relevant software, e.g. RS-Logix from Rockwell Automation Inc. for Allen-Bradley PLCs, MELSOFT-GX Developer for Mitsubishi PLCs, STEP7-Micro/WIN V4 for Siemens PLCs. The software operates on the Windows operating system and involves selecting items, in
the usual Windows operating system and involves selecting items, in the usual Windows manner, from pull-down menus on the screen. [3]

2.3.3.2 Function Blocks

The term function block diagram (FBD) is used for PLC programs described in terms of graphical blocks. It is described as being a graphical language for depicting signal and data flows through blocks, these being reusable software elements. A function block is a program instruction unit which is when it executed, yields one or more output values. These a block is represented in the manner shown in Figure 2(15) with the function name written in the box. [3]

![Function block](image)

**Figure 2. 31 Function block** [3]

The IEC 113-3 standard for drawing such blocks is shown in figure 2. 32, a function block is depicted as a rectangular block with inputs entering from the left and outputs emerging from the right. The function block type name is shown in the block, e.g. AND, with the name of the function block in the system shown above it, Timer1. Names of function block inputs are shown within the block at the appropriate input and output points. Cross diagram connectors are used to indicate where graphical lines would be difficult to draw without cluttering up or complicating a diagram and show where an output at one point is used as an input at another. [3]
2.4 Cycle time

In designing the machine using the pneumatic system the first thing should to determine is the pressure supply to lift the load, basically the force of the actuator should be higher than the Load. Usually the vendor of the actuator will give the graph of Force and the air consumption but the calculation of Force from the pressure is determined by pressure and the Area. Then to calculate the cycle time of machine it will uses the velocity for every movement. It should be noted that the fluid pressure has no effect to the cylinder speed, the speed is determined from the Area of the piston and the flowrate so the total time would be the volume of the air consumption at distance that would be reach divided by the flow rate, below is the step to find cycle time \([4]\):

---

\[\text{Cycle time} = \frac{\text{Volume of air consumption at distance}}{\text{Flow rate}}\]

---

**Figure 2. 32 Function block diagram representations** \([3]\)
1. Find the Volume from the air consumption

\[ V = Q \times d \]  
(2.1)

Where:
- \( V \): The volume of air consumption (\( l \))
- \( Q \): The air consumption for each cm (\( l/cm \))
- \( d \): The distance of the stroke moves (\( cm \))

2. Find the cycle time

\[ t = \frac{V}{v_a} \]  
(2.2)

Where:
- \( t \): The time (\( s \))
- \( V \): The volume (\( l \))
- \( v_a \): The flowrate (\( l/s \))

2.5 Calculation of Construction

To calculating the construction of machine, it will consider about the stress of the material in which shape. Then at this design the critical point will be in the bending stress, the bending moment \( M \) along the length of the beam can be determined from the moment diagram. Below is the formula of stress bending \(^{[5]}\):

\[ \sigma_{bending} = \frac{My}{I} \]  
(2.3)

Where:
- \( \sigma_{bending} \) is stress bending (\( MPa \))
- \( M \) is Moment (\( Nmm \))
- \( y \) is width (\( mm \))
- \( I \) is Area of inertia (\( mm^4 \))

The bending moment at any locations along the beam can be used to calculate the bending stress over the beam’s cross section at that location. The bending moment varies over the height of the cross section according the formula below \(^{[5]}\):
Where:

- $M_x$ the Moment along the beam ($Nm$)
- $-F$ the Force that distributed to the beam ($N$)
- $L_y$ the Length of the force distributed ($mm$)

The Area moment of the inertia is a property of two-dimensional plane shape which characterizes its deflection under loading. It is also known as the second moment of area or second moment of inertia. The area moment of inertia has dimensions of length to the fourth power, to determine the moment are of inertia is depends on the shape of the area, for the rectangular area will use the formula below $^{[5]}$:

$$I = \frac{1}{12} bh^3$$

Where:

- $I$ is Area of inertia ($mm^4$)
- $b$ is breadth ($mm$)
- $h$ is the height ($mm$)

Comparing bending stress with the stress allowable

$$allowable\ bending = \frac{yield}{safety\ factor}$$

(2.6)
Deflection from moment bending

\[
Deflection = \frac{Fx(L^3)}{3EI}
\]  

(2.7)

Allowable Deflection

\[
allowable\ deflection = coefficient\ deflection \times Length
\]

(2.8)

Comparison between the deflection and allowable deflection, the allowable deflection must be greater than the deflection.

\[
allowable\ deflection > deflection
\]

2.6 Break event point

Break-even point is to give an answer to the business such as “how much sales be decreased and the company still continues to be profitable”. Break-even analysis is extremely important before starting a new product or new decision in investing a tool or machine. Break-even analysis based on categorizing production costs between those which are variable and those which are fixed. Below is the formula to calculate the break-even point \[6\]:

\[
BEP = \frac{FC}{CS-VC}
\]

(2.9)

Where :

- \(BEP\) is Break-even point
- \(FC\) is Fixed cost
- \(CS\) is the profit
- \(VC\) is the variable cost
CHAPTER III
RESEARCH METHODOLOGY

In this chapter all the process in conducting the research will be explained in the form of steps framework that are done during the research. The types of step framework will be divided into 2 parts, the first is Theoretical Framework and the second is Research Framework. Inside the Framework is a sequence of flowcharts to help the researcher to simplify and determine the steps taken in the research, this chapter also will be a guidance for the researcher in determining the starting line and also the finish line, as well as the goals to be achieved in this research.

3.1 Theoretical Framework
Theoretically, the step description to be performed as shown in figure 3.1 (1).

![Figure 3.1 Theoretical Framework](image.png)
1. Initial Observation
   Assortment process is a packing process that is needed by every product. In this case, the assortment of products in PT. X is done by packing a blister-pack into master carton that has been stamped with Date and Dash code. In order to optimize the process of giving Date and Dash code, the company needs innovation in this process.

2. Problem Identification
   Identification of problems in giving Date and Dash code at assortment process are:
   
   - No machine used in giving Date and Dash code process.
   - In giving Date and Dash code process, the cycle time is relatively long, it is about 8 seconds for each master carton.
   - The process of giving Date and Dash code is tedious, therefore the consistency of the cycle time cannot be maintained due to the Tiredness of the workers.
   - Master cartons does not achieve the targeted number of 33500 master carton per week.

   Based on the problems above it can be concluded that the process of giving Date and Dash code requires a machine to overcome.

3. Literature Study
   To overcome all of the problems above the researcher tries to do a research in “Design of Automatic Stamping Machine for Date and Dash Code Marking Using Pneumatic System and PLC Controller”. For the design of the machine the researcher requires to study the related resources such as books, journals, web, and other sources to support the research processes. Here is a list of Literature that is used for this research:

   - Engineering Design
   - Pneumatic System
   - Programmable Logic Control
   - Bending and Deflection
   - Break-even point
4. Data Collection and Analysis

At this step the researcher will need all related data based on facts in the field, and the researcher has determined the conceptual design for the working mechanism of the machine to be analyzed about how reliable the machine is. Here are the related data and working mechanisms to be analyzed:

- The need of cycle-time to achieve the production target.
- Pneumatic work mechanism influenced by kinematics and Dynamics.
- Pneumatic Sequences and Ladder PLC controller
- Break-even point on Initial Investment.

5. Conclusion and Suggestion

In this step the researcher concludes the results of the research, in this case the conclusion will be produced in the form of the specification of the machine. Furthermore, the result is also evaluated for further research.
3.2 Research Framework

Process Observation

Current Methods & Problem

DEVELOP AUTOMATIC STAMPING

DETERMINE THE DESIRED NEEDS

DETERMINE THE MECHANISM OF THE MACHINE

DETERMINE THE LITERATURE STUDY THAT RELATED TO THE RESEARCH

DRAWING THE CONCEPTUAL DESIGN USING CATIA

START ANALYZE

NO

YES

DETERMINE THE USE OF PNEUMATIC SYSTEM

ANALYZE THE KINEMATICS AND DYNAMICS CONDITION

MAKE THE SCHEMATIC LADDER OF PLC AS THE CONTROLLER

ANALYZE THE RETURN OF INVESTMENT IN INITIAL INVESTMENT AND THE PROFIT EVERY YEAR

CONCLUSION AND ANALYSIS

INOVATION

Research for Automatic Stamping machine

Figure 3.2 Research Framework
CHAPTER IV
DATA COLLECTION AND ANALYSIS

In this chapter the researcher will analyze the design concept that has been made. Step will be divided into 5 parts of discussion, parts are:

1. Data Collection based on Conceptual Design.
2. Analyzing the Kinematics of pneumatic system of the Machine.
3. Analyzing the Machine Construction.
4. Program input.
5. Engineering economics.

4.1 Data Collection

4.1.1 Requirements

In choosing the type of Work system of the machine, it needs working sequences that have been made based on the requirements. Therefore, this step will be very important on the next analysis that will be performed. below are the requirements of the company:

<table>
<thead>
<tr>
<th>No</th>
<th>Description</th>
<th>Specific Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Need a Machine that could give the Date and Dash code on Carton</td>
<td>Machine</td>
</tr>
<tr>
<td>2</td>
<td>Could Reach the production target around 5300 master cartons/shift.</td>
<td>Fast (5s/carton.)</td>
</tr>
<tr>
<td>3</td>
<td>Easy to Use and Maintain</td>
<td>Easily operable and Maintainable</td>
</tr>
<tr>
<td>4</td>
<td>Applying the cost saving program</td>
<td>Affordable</td>
</tr>
</tbody>
</table>

The requirements above is used by the researcher to create the next step of solving the problems.

4.1.2 Detailed Design

From the Table 4 (1), the researcher know that the company needs a machine that could work fast, easy to maintain, and also affordable. Then in order to meet the desired needs, the researcher develop the conceptual design of the machine to become the detailed design using CATIA V5R21 software to realize the imagination into a
computer aided design (CAD). In conceptual design the researcher already determined the shape of the machine, working sequences, and other mechanisms that will be needed for the analysis. The detail of design is shown in figure below:

The researcher calls this machine as “Automatic Stamping machine for Date and Dash Code marking using Pneumatic system and PLC control” this design is one type of the development design from the stamping machine. At this design the concept of the stamping machine applied to stamp the master carton of the company, hopefully this machine could solve the issues on the assortment processes. From the figure 4.1 the researcher also would to describe the ease of operating and maintaining the machine.

4.1.2.1 Operating the machine
To increase the cycle time efficiency, the researcher has designed the machine as easily as possible for the operator of the machine. The researcher would to describe the reason of why the design is easily to operate. The reason will show below:
1. Panel Button

The position of the panel button is not blocking the sitting position of the operator, then the panel button has designed 30 degrees tilt from the working beds that aims not to block the loading process.

2. Loading-Unloading

The position of loading-unloading has designed to make the operator stay safe on their work. The position of loading is wide enough to load the carton into the machine because the researcher gives a space
around 130mm to load, then the Unloading process also could be faster because the operator does not need to take the carton for unloading, they just need to reload the carton to push the marked carton.

3. Refilling the ink

![Refilling the ink position](image)

Figure 4. 4 Refilling the ink position

Refilling the ink is much easier because the batch marker is accessible and the door is easy to pull, also the door will not bother the working process because the researcher gives the magnet to lock the door keep in its positions.

4. Allows to sit in work

Enable the operator use the chair so the operator did not feel exhausted.

![Sitting position](image)

Figure 4. 5 Sitting position
4.1.2.2 Maintenance

In designing the machine, the researcher also thinks about the way to maintenance process so the design is enable the mechanic to do the maintenance processes. The researcher would to describe the reason of why the design is easily to maintain. The reason will show below:

1. Assemble and Disassemble the bolt on Cover of Marking actuator

   Mechanics is easy to repair the marking actuator by opening the cover from the bottom so they don’t need to open other part, then if the repair is done please to assemble the bolts align with the direction as shown in the figure 4.6.

2. Assemble and Disassemble the bolt on the flange mounting

   Mechanics is easy to repair the marking actuator by opening the cover then disassemble the bolts on flange mounting from the bottom so they don’t need to open other part, then if the repair is done please to plug in the direction of the bolts as shown the figure 4.7.
3. Not to open all of the acrylic cover

The mechanics is possible to open one side of the acrylic cover when the trouble is on the working bed, you can open the front cover, back cover, right cover, or left cover because the researcher give the screw on every side of the cover.

From those explanation the researcher could say that this machine is easy to use and also easy to maintain. Then from the conceptual design we also could determine the used system for the machine, in manufacturing industry there are 3 types of systems that many in use by the company because it is supported by the existing utilities such as electric usage, air pressure, and also fluid flow, in Chapter 2 has been informed that 3 of them are Pneumatic, Hydraulic, Electric (motor). In each system it has
advantages of each, but it could be adjusted with the desired needs that have been determined. In order to meet the desired needs that listed in Table 4.1 *Requirements*, the researcher will choose the pneumatic system because it could operate quickly, affordable, and also easy to maintain.

4.1.3 Working Sequences of Machine
The researcher could determine the working sequence using the pneumatic for designing a machine and also meet the desired needs. From the table 4 (2), we could choose the tools for the movement system of the machines. It requires 1 kinds of pneumatic with different distance of retract for 2 system of movement purposes there is Linear Actuator. For specified the kinds of Pneumatics that used at this machine the researcher shown in the figure 4.9.

![Figure 4.9 Place of actuator](image_url)
### Table 4.2 Working sequence

<table>
<thead>
<tr>
<th>No</th>
<th>Type of Work</th>
<th>Description</th>
<th>Tools</th>
<th>Distance of Movement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marking</td>
<td>At this step it needs a linear movement to marking the stamp to the stamping machine</td>
<td>Double Acting Cylinder</td>
<td>250mm from initial position</td>
</tr>
<tr>
<td>2</td>
<td>Un-marking</td>
<td>At this step it needs a linear movement to bring back the marker batch to initial position</td>
<td>Double Acting Cylinder</td>
<td>250mm from Marking position</td>
</tr>
<tr>
<td>3</td>
<td>Stamping</td>
<td>At this step it needs a linear movement to stamp the carton</td>
<td>Double Acting Cylinder</td>
<td>70mm from initial position</td>
</tr>
<tr>
<td>4</td>
<td>Un-stamping</td>
<td>At this step it needs a linear movement to bring back the stamping to initial position</td>
<td>Double Acting Cylinder</td>
<td>70mm from Stamping position</td>
</tr>
</tbody>
</table>

4.1.4 Specification of Basic spare-part used for pneumatic system

After the kinds of pneumatic is known, now is the step for choosing the type of that kinds, especially in choosing the Double Acting cylinder the researcher should be adjusted with the design concept. There is so many type of Double Acting cylinder such as Round type, tie rod Cylinder type, and many more, but for this machine the researcher will choose DSBG Double-Acting Cylinder from FESTO. Below are the specifications of the spare-part:
1. DSBG-32-250-PPSA-N3 for Marking Actuator

Figure 4. 10 Marking actuator (DSBG-32-250-PPSA-N3) \(^7\)
2. DSBG-32-80-PPSA-N3 for Stamping Actuator

![Stamping Actuator (DSBG-32-80-PPSA-N3)](image)

### Data sheet

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping date</td>
<td>View</td>
</tr>
<tr>
<td>Stroke</td>
<td>80 mm</td>
</tr>
<tr>
<td>Piston diameter</td>
<td>22 mm</td>
</tr>
<tr>
<td>Piston rod thread</td>
<td>M10 x 1.25</td>
</tr>
<tr>
<td>Cushioning</td>
<td>PPS: Self-adjusting pneumatic end-position cushioning</td>
</tr>
<tr>
<td>Assembly position</td>
<td>Any</td>
</tr>
<tr>
<td>Conforms to standard</td>
<td>ISO 1552</td>
</tr>
<tr>
<td>Piston-rod end</td>
<td>Male thread</td>
</tr>
<tr>
<td>Design structure</td>
<td>Piston, Piston rod, Tie rod, Cylinder barrel</td>
</tr>
<tr>
<td>Position detection</td>
<td>For proximity sensor</td>
</tr>
<tr>
<td>Variants</td>
<td>Single-ended piston rod</td>
</tr>
<tr>
<td>Working pressure</td>
<td>0.6...12 bar</td>
</tr>
<tr>
<td>Mode of operation</td>
<td>Double-acting</td>
</tr>
<tr>
<td>Operating medium</td>
<td>Compressed air in accordance with ISO5573-1:2010 (7.4.4)</td>
</tr>
<tr>
<td>Note on operating and pilot medium</td>
<td>Lubricated operation possible (subsequently required for further operation)</td>
</tr>
<tr>
<td>Corrosion resistance classification CRC</td>
<td>2 - Moderate corrosion stress</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-30...80 °C</td>
</tr>
<tr>
<td>Impact energy in end positions</td>
<td>0.4 J</td>
</tr>
<tr>
<td>Cushioning length</td>
<td>17 mm</td>
</tr>
<tr>
<td>Theoretical force at 6 bar, return stroke</td>
<td>415 N</td>
</tr>
<tr>
<td>Theoretical force at 6 bar, advance stroke</td>
<td>415...483 N</td>
</tr>
<tr>
<td>Moving mass with 0 mm stroke</td>
<td>110 g</td>
</tr>
<tr>
<td>Additional weight per 10 mm stroke</td>
<td>25 g</td>
</tr>
<tr>
<td>Basic weight for 0 mm stroke</td>
<td>465 g</td>
</tr>
<tr>
<td>Additional mass factor per 10 mm of stroke</td>
<td>9 g</td>
</tr>
<tr>
<td>Mounting type</td>
<td>Optional with internal (female) thread with accessories</td>
</tr>
<tr>
<td>Pneumatic connection</td>
<td>G1/B</td>
</tr>
<tr>
<td>Materials note</td>
<td>Conforms to RoHS</td>
</tr>
<tr>
<td>Material cover</td>
<td>Aluminum die cast coated</td>
</tr>
<tr>
<td>Material seals</td>
<td>TPE-U(PU)</td>
</tr>
<tr>
<td>Material piston rod</td>
<td>High alloy steel</td>
</tr>
<tr>
<td>Material cylinder barrel</td>
<td>Wrought aluminium alloy Smooth anodized</td>
</tr>
</tbody>
</table>

Figure 4. 11 Stamping Actuator (DSBG-32-80-PPSA-N3) [8]
3. CPE10-M1CH-5J-M7 for 5/2 valve in every actuator

![Data sheet](image)

**Data sheet**

<table>
<thead>
<tr>
<th>Feature</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shipping data</td>
<td>View</td>
</tr>
<tr>
<td>Valve function</td>
<td>5/2 bistable</td>
</tr>
<tr>
<td>Type of actuation</td>
<td>electrical</td>
</tr>
<tr>
<td>Width</td>
<td>10 mm</td>
</tr>
<tr>
<td>Standard nominal flow rate</td>
<td>350 l/min</td>
</tr>
<tr>
<td>Working pressure</td>
<td>2.5 – 8 bar</td>
</tr>
<tr>
<td>Design structure</td>
<td>Piston slide</td>
</tr>
<tr>
<td>Protection class</td>
<td>IP66/IP67</td>
</tr>
<tr>
<td></td>
<td>to IEC 60529</td>
</tr>
<tr>
<td></td>
<td>with plug socket</td>
</tr>
<tr>
<td>Maritime classification</td>
<td>see certificate</td>
</tr>
<tr>
<td>Nominal size</td>
<td>4 mm</td>
</tr>
<tr>
<td>Exhaust-air function</td>
<td>throttleable</td>
</tr>
<tr>
<td>Sealing principle</td>
<td>soft</td>
</tr>
<tr>
<td>Assembly position</td>
<td>Any</td>
</tr>
<tr>
<td>Manual override</td>
<td>with accessories, detenting</td>
</tr>
<tr>
<td></td>
<td>Pushing</td>
</tr>
<tr>
<td>Type of ploting</td>
<td>Pivoted</td>
</tr>
<tr>
<td>Pilot air supply</td>
<td>Internal</td>
</tr>
<tr>
<td>Flow direction</td>
<td>iron reversible</td>
</tr>
<tr>
<td>Valve position identification</td>
<td>Label holder</td>
</tr>
<tr>
<td>Freedom from overlap</td>
<td>Yes</td>
</tr>
<tr>
<td>Switching time reversal</td>
<td>8 ms</td>
</tr>
<tr>
<td>Duty cycle</td>
<td>100%</td>
</tr>
<tr>
<td>Max. positive test pulse with</td>
<td>1.200 µs</td>
</tr>
<tr>
<td>logic 0</td>
<td></td>
</tr>
<tr>
<td>Max. negative test pulse with</td>
<td>600 µs</td>
</tr>
<tr>
<td>logic 1</td>
<td></td>
</tr>
<tr>
<td>Characteristic coil data</td>
<td>24 V DC: 1.28 W</td>
</tr>
<tr>
<td>Permissible voltage fluctuation</td>
<td>-15% / +10%</td>
</tr>
<tr>
<td>Operating medium</td>
<td>Compressed air in accordance with ISO 9573-1:2010 (7.4.4)</td>
</tr>
<tr>
<td>Note on operating and pilot medium</td>
<td>Lubricated operation possible (subsequently required for further operation)</td>
</tr>
</tbody>
</table>

**Figure 4. 12 5/2 solenoid valve (CPE10-M1CH-5J-M7)** [9]
4.2 Analysis

At the analysis, the researcher has to proving the conceptual design by the theory that has been mentioned in the discussion of CHAPTER II. All of the data that has been collected will help the calculation in proving of the mathematical way.

4.2.2 Finding the cycle time of process

From the chapter 2 the researcher has discussed about the calculation of the cycle time in every movement, the movement means the sequence of pneumatic system, so from the discussion the researcher would to calculate the total cycle time from every sequence and cycle time of the operator to become the total cycle time of process, the total cycle time would be:

$$\Sigma t = t_{Machine} + t_{Operator}$$

$$t_{Machine} = t_{Marking} + t_{Unmarking} + t_{Stamping} + t_{Unstamping}$$

From the equation of $\Sigma t$ above the researcher should to find cycle time of machine and operator. The cycle time of operator has been simulated by the researcher for loading-unloading then press the push button and the result is about 2.5 s, then the table of the total cycle time of machine will be shown in the bale below:

<table>
<thead>
<tr>
<th>Movement</th>
<th>Distance (d)</th>
<th>Unit</th>
<th>Air consumption for full stroke (V)</th>
<th>Unit</th>
<th>Cycle Time (s)</th>
<th>Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marking</td>
<td>25 cm</td>
<td>l</td>
<td>0.675</td>
<td>l</td>
<td>0.436</td>
<td>s</td>
</tr>
<tr>
<td>Un-Marking</td>
<td>25 cm</td>
<td>l</td>
<td>0.425</td>
<td>l</td>
<td>0.274</td>
<td>s</td>
</tr>
<tr>
<td>Stamping</td>
<td>7 cm</td>
<td>l</td>
<td>0.189</td>
<td>l</td>
<td>0.122</td>
<td>s</td>
</tr>
<tr>
<td>Un-Stamping</td>
<td>7 cm</td>
<td>l</td>
<td>0.119</td>
<td>l</td>
<td>0.076</td>
<td>s</td>
</tr>
</tbody>
</table>

| Total cycle time | 0.9 s |

$$\Sigma t = t_{Machine} + t_{Operator}$$

$$\Sigma t = 0.9 s + 2.5 s$$

$$\Sigma t = 3.4 s \approx 4 \text{ second}$$
From the table above there are four sequences of the machine which are Marking, Un-Marking, Stamping, Un-Stamping. Each of the sequences will have their own cycle time. To calculate the cycle time there are some required data that will be need. The data are pressure, flow rate from the valve, area of every sequences. The details of data required will be listed below:

- **Pressure** \( (P) \) : 4 bars
- **Flow Rate** \( (v_a) \) from valve : 310 l/min
  \[ = 5.16 \text{ l/s} \]

Example of finding cycle time

Marker sequence is using Double acting cylinder to carrying the marker batch until 250mm from initial position, so the calculation would be shown below:

- **Distance** \( (s) \) = 25 cm`
- **Mass** \( (m) \) = 0.81 kg
- **Diameter of Bore** \( (D) \) = 0.032 m
- **Area** \( (A) \) = 0.000804 m\(^2\)
The table shows that at the diameter of 32 the Force is about 320 N.
The table shows that the Force is about 321.6 N.
The table shows that the air consumption per centimeter is about 0.027 l/cm.

Figure 4. 14 Air consumption graph \cite{10}
The solution would be:

From the figure 4.14 (b) the researchers know that there is acceleration at this system from the static condition into steady. But usually the acceleration has the small value so it will not consider to this calculation indeed there is acceleration. The calculation when the flow is steady would be:

1. Find the Volume from the air consumption

   \[ V = Q \times d \]

   \[ V = 0.027 \frac{l}{cm} \times 25cm \]

   \[ V = 0.675 l \]

2. Find the cycle time of movement

   \( v_a \) is the flow of air from the valve, in this calculation the flow would be controlled by the tool called as “flow control” then it would be open the until 30% aperture, as we know from the given condition the flow of air

---

**Figure 4.15 Free body diagram and graph of Marking sequence**

(a) Simple system of marking sequence (b) Graph for \( P_1 \) is \( P_\text{in} \), \( P_2 \) is \( P_\text{out} \), and speed \(^{[4]}\)

From the figure 4.14 (b) the researchers know that there is acceleration at this system from the static condition into steady. But usually the acceleration has the small value so it will not consider to this calculation indeed there is acceleration. The calculation when the flow is steady would be:

1. Find the Volume from the air consumption

   \[ V = Q \times d \]

   \[ V = 0.027 \frac{l}{cm} \times 25cm \]

   \[ V = 0.675 l \]

2. Find the cycle time of movement

   \( v_a \) is the flow of air from the valve, in this calculation the flow would be controlled by the tool called as “flow control” then it would be open the until 30% aperture, as we know from the given condition the flow of air
from the valve is 5.16 l/s so the flow after controlled by flow control with 30% aperture would be 1.16 l/s. then the calculation for the cycle time would be:

\[
t = \frac{V}{v_a}
\]

\[
t = \frac{0.675 \text{ l}}{5.16 \text{ l/s} \times 0.30}
\]

\[
t = 0.436 \text{ s}
\]

4.2.3 Bending Stress affecting the foot of buffer stamping actuator

For calculating the construction of machine, the researcher has chosen the most critical part that happens by force of the stamping-un-stamping actuator. See the figure 4.17 to shows the distributed force and other condition.

![Figure 4. 16 Visualization of force direction](image)

**Figure 4. 16 Visualization of force direction**
From the figure above the force that caused by the stamping actuator will affecting the buffer foot of the actuator. Then to simplify the cases the researcher would be shown in the figure 4.17.

![Free body diagram of buffer actuator](image)

**Figure 4.17 Free body diagram of buffer actuator**

From the figure above the case is seems with the cantilever, the force distributed into 4 foots. The calculation would be:

Given:

- Length = 220 mm
- Thickness (b) = 10 mm
- Width (h) = 30 mm
- F = 80.4 N
- Yield \(^{[11]}\) = 215Mpa
- Safety factor \(^{[12]}\) = 8
- Coefficient of deflection \(^{[13]}\) = 0.0005

1. Find Bending Stress
   - Moment bending
\[ M_x = -FLy \]
\[ M_x = -80.4 \times 220 \]
\[ M_x = -17688 \text{ Nmm} \]

Negative means the direction

- Area of Inertia

\[ I = \frac{1}{12} bh^3 \]
\[ I = \frac{1}{12} \times (10) \times (30)^3 \]
\[ I = \frac{1}{12} \times (10) \times 27000 \]
\[ I = \frac{1}{12} \times 270000 \]
\[ I = 22500 \text{ mm}^4 \]

- Stress bending

\[ \sigma_{bending} = \frac{My}{I} \]
\[ \sigma_{bending} = \frac{17688 \text{ Nmm} \times 30 \text{ mm}}{22500 \text{ mm}^4} \]
\[ \sigma_{bending} = 23.584 \text{ N/mm}^2 \]

Compared with the yield in tensile strength, the amount of yield for SS304 is 215 MPa.

\[ yield > Stress \ bending \]
\[ 215 > 23.584 \]

2. Comparing bending stress with the stress allowable

\[ allowable \ \sigma_{bending} = \frac{\text{yield}}{\text{safety factor}} \]
Safety factor chosen from the characteristic of the condition, this machine is one type of live load condition, then the amount of safety factor for live load is 8.

\[
\text{allowable } \sigma_{\text{bending}} = \frac{215}{8} \\
\text{allowable } \sigma_{\text{bending}} = 26.875
\]

\[
\text{allowable } \sigma_{\text{bending}} > \sigma_{\text{bending}}
\]

\[
26.875 > 23.584
\]

3. Deflection from moment bending

\[
\text{Deflection} = \frac{F \times (L^3)}{3 \times E \times I}
\]

\[
\text{Deflection} = \frac{80.4 \text{ N} \times (220 \text{ mm})^3}{3 \times 193000 \text{ MPa} \times 22500 \text{ mm}^4}
\]

\[
\text{Deflection} = 0.065 \text{ mm}
\]

4. Allowable Deflection

\[
\text{allowable deflection} = \text{coefficient deflection} \times \text{Length}
\]

Coefficient deflection is taken from the deflection limits for general machine in the books that has been discussed in the chapter II. The amount of the coefficient is 0.0005 in/in.

\[
\text{allowable deflection} = 0.0005 \times 220 \text{ mm}
\]

\[
\text{allowable deflection} = 0.11 \text{ mm}
\]

5. Comparison between the deflection and allowable deflection

The allowable deflection must be greater than the deflection.

\[
\text{allowable deflection} > \text{deflection}
\]

\[
0.11 \text{ mm} > 0.065 \text{ mm}
\]

4.2.4 Input Program to PLC

From the Data collection the researcher could create the program to run the pneumatic system as the expected working sequences of the machine. The researcher has decided to using the Programmable Logic Control (PLC) to controlling the working sequences, PLC itself is a special form of microprocessor-based controller.
that uses a programmable memory to store instructions and to implement functions such as logic, sequencing, timing, counting, etc.

The language of the machine is using binary code signal, binary code uses to give the signals to the output memory of the PLC. To realize that binary code, the PLC has 2 packages of the methods to inputting the program easier than inputting the binary code. Below are the methods that will be uses to create the program into the PLC:

1. LADDER DIAGRAM
2. BLOCK FUNCTION DIAGRAM

Before the researcher creating the program input, the researcher has to determine the pneumatic system of the machine. Below is the figure of pneumatic system in this machine.

Figure 4 (18) shows the pneumatic system of Automatic Stamping machine for Date and Dash Code using marking with Pneumatic system and PLC controller, from the figure above the researcher would to create the explanation of the system by separating into 2 unit, first is Stamping Unit and the second is Marking unit. The explanation would be described as the table below:
1. Stamping Unit

Table 4. 4 The components of pneumatic system of stamping-un-stamping

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stamping DAC</td>
<td>As a Linear Actuator to stamp the carton</td>
</tr>
<tr>
<td>2</td>
<td>Stamping DAC</td>
<td>As a Linear Actuator to stamp the carton</td>
</tr>
<tr>
<td>S3</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Un-stamping position(Initial) for Pneumatic Actuator 1</td>
</tr>
<tr>
<td>S4</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Stamping position for Pneumatic Actuator 1</td>
</tr>
<tr>
<td>S7</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Un-stamping position(Initial) for Pneumatic Actuator 2</td>
</tr>
<tr>
<td>S8</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Stamping position for Pneumatic Actuator 2</td>
</tr>
<tr>
<td>Y3</td>
<td>Solenoid Valve</td>
<td>To be a gate of pressure air supply for Stamping air supply</td>
</tr>
<tr>
<td>Y4</td>
<td>Solenoid Valve</td>
<td>To be a gate of pressure air supply for Un-stamping air supply</td>
</tr>
<tr>
<td>Valve</td>
<td>5/2 Way Valve</td>
<td>Circulated system of Air supply (Terminal Air supply to Actuating the Actuator)</td>
</tr>
</tbody>
</table>

2. Marker Unit

Table 4. 5 The components of pneumatic system of marking-unmarking unit

<table>
<thead>
<tr>
<th>Symbols</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Stamping DAC</td>
<td>As a Linear Actuator to Mark the stamp</td>
</tr>
<tr>
<td>2</td>
<td>Stamping DAC</td>
<td>As a Linear Actuator to Mark the stamp</td>
</tr>
<tr>
<td>S1</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Un-Marking position(Initial) for Pneumatic Actuator 1</td>
</tr>
<tr>
<td>S2</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Marking position for Pneumatic Actuator 1</td>
</tr>
<tr>
<td>S5</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Un-Marking position(Initial) for Pneumatic Actuator 2</td>
</tr>
<tr>
<td>S6</td>
<td>Magnetic Sensor</td>
<td>To indicate the Piston into Marking position for Pneumatic Actuator 2</td>
</tr>
<tr>
<td>Y1</td>
<td>Solenoid Valve</td>
<td>To be a gate of pressure air supply for Stamping air supply</td>
</tr>
<tr>
<td>Y2</td>
<td>Solenoid Valve</td>
<td>To be a gate of pressure air supply for Un-Stamping air supply</td>
</tr>
<tr>
<td>Valve</td>
<td>5/2 Way Valve</td>
<td>Circulated system of Air supply (Terminal Air supply to Actuating the Actuator)</td>
</tr>
</tbody>
</table>
From those, the researcher will create Block Function methods for choosing the way to inputting the program methods by using FESTO Fluid simulator. Since the figure 4 (13) is the function block diagram for this machine. The researcher would describe the steps and the reason of why using the program like the figure 4 (13), so to describe the function block diagram a lot of easier when we separated the function based on the Output, below is the separation:

1. Output 1 (Functioned as Marking)
From the figure 4. 13, the Function block of Output 1 is functioned to make the actuator marking retracted it means all of the requirements for AND function must be active, the requirements are \( I_1, I_8, Hi, I_1 \) active=1, \( I_2 \) active=1, Hi=1, so the output will be 1.

2. Output 2 (Functioned Unmarking)

![Output 2 Function block diagram](image)

Figure 4. 21 Output 2 Function block diagram

From the figure 4. 14, the Function block of Output 2 is functioned to return the marking actuator, it means all of the requirements for RS function must be active, the requirements are \( I_2 \) and \( I_4 \).

3. Output 3 (Functioned Stamping)

![Output 3 Function block diagram](image)

Figure 4. 22 Output 3 Function block diagram

From the figure 4. 14, the Function block of Output 3 is functioned to retracted the stamping actuator, it means all of the requirements for RS function must be active, the requirements are \( I_1 \) and \( O_2 \).
4. Output 4 (Functioned Un-stamping)

From the figure 4. 14, the Function block of Output 4 is functioned to retracted the stamping actuator, it means all of the requirements for AND function must be active, the requirements are O₃ and I₄.

4.2.5 Cost Analysis

At this analysis the researcher would to analyze the cost when the company use the current process and the improvement process, after that it would compared to get the break event point when the company investing the machine.

4.2.6.1 Current process

At the current process, the company using the manual operation to giving date and dash code to the master carton. The value of production in this process is 1372 pieces per shift, meanwhile the target of producing the master carton is about 5600 pieces per shift. Then to meet the target of demands, the company need to add some operator, below is the calculation of the new total operator needed and the expense cost to meet the demands:

1. Number of operator when using manual operation

\[ Person = \frac{Target \ of \ Production}{Value \ of \ Production} \]

\[ Person = \frac{5600 \ pcs/shift}{1372 \ pcs/shift} \]

\[ Person = 4.08 \approx 5 \ persons \]

2. Expense of current process cost

Given :

Salary of operator \( = IDR \ 4,000,000 \ (R_p) \)
4.2.6.2 Improvement process

In the purpose of cost saving program, innovating or improving is one of the consideration in every process of production. Then to implementing the cost saving program, the company will improve the process of assortment especially for master carton packaging in giving the date and dash code to the master carton. The improvement process will be using the machine called as “Automatic Stamping Machine for Date and Dash Code marking using Pneumatic System and PLC Controller”, the total cycle time when using this machine is 4 seconds per master carton. Below is the calculation of total production when using the machine and the expense cost to meet the demands:

1. Total production when using the machine

\[
Total \ Production = \frac{t_{\text{work}}}{\Sigma t_{\text{machine}}} \]

\[
Total \ Production = \frac{8 \ hours \times 3600 \ seconds}{4 \ seconds} \]

\[
Total \ Production = 7200 \ pcs/\text{shift} \]

2. Number of Operator when using the machine

\[
Person = \frac{\text{Target of Production}}{\text{Value of Production}} \]

\[
Person = \frac{5600}{7200} \approx 0.77 \approx 1 \ person \]

3. Expense of improvement process cost

\[
Cost_{\text{improvement}} = R_p \times Person \]

\[
Cost_{\text{improvement}} = IDR \ 4,000,000 \times 1 \ person \]

\[
Cost_{\text{improvement}} = IDR \ 4,000,000 \]
At the improvement process the company need to create the machine with the same specification of this design, below is the table lists of prices of the spare part:

**Table 4.6 Initial investment cost**

<table>
<thead>
<tr>
<th>No</th>
<th>Description</th>
<th>Specifications/Part Number</th>
<th>Vendor</th>
<th>Price per pcs (IDR)</th>
<th>Total pcs</th>
<th>Price of total pcs (IDR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Marker Actuator</td>
<td>DSBG-32-250-PPSA-N3</td>
<td>FESTO</td>
<td>2,312,102.2</td>
<td>2</td>
<td>4,624,204.40</td>
</tr>
<tr>
<td>2</td>
<td>Stamping Actuator</td>
<td>DSBG-32-80-PPSA-N3</td>
<td>FESTO</td>
<td>2,155,028.48</td>
<td>2</td>
<td>4,310,056.96</td>
</tr>
<tr>
<td>3</td>
<td>Flange Mounting</td>
<td>FNC-32</td>
<td>FESTO</td>
<td>331,366.24</td>
<td>2</td>
<td>662,732.48</td>
</tr>
<tr>
<td>4</td>
<td>Foot Mounting</td>
<td>CRHNC-32</td>
<td>FESTO</td>
<td>733,903.52</td>
<td>2</td>
<td>1,467,807.04</td>
</tr>
<tr>
<td>5</td>
<td>Directional Control Valves</td>
<td>CPE10-M1CH-5J-M7</td>
<td>FESTO</td>
<td>2,165,359.76</td>
<td>2</td>
<td>1,330,719.52</td>
</tr>
<tr>
<td>6</td>
<td>Proximity Sensor</td>
<td>SMT-8M-A-PS-24V-E-0.3-M8D</td>
<td>FESTO</td>
<td>631,356</td>
<td>8</td>
<td>5,050,848.00</td>
</tr>
<tr>
<td>7</td>
<td>PLC</td>
<td>CPX-CEC-M1-V3</td>
<td>FESTO</td>
<td>4,500,000</td>
<td>1</td>
<td>4,500,000.00</td>
</tr>
<tr>
<td>8</td>
<td>Lever Switch</td>
<td></td>
<td></td>
<td>56,000</td>
<td>1</td>
<td>56,000.00</td>
</tr>
<tr>
<td>9</td>
<td>Push Button</td>
<td></td>
<td></td>
<td>2,000</td>
<td>1</td>
<td>2,000.00</td>
</tr>
<tr>
<td>10</td>
<td>Panel box</td>
<td></td>
<td></td>
<td>600,593</td>
<td>1</td>
<td>600,593.00</td>
</tr>
<tr>
<td>11</td>
<td>Stainless-steel Square hollow</td>
<td>SS304/ D1”xL15m</td>
<td></td>
<td>149,378.19</td>
<td>15</td>
<td>2,240,672.85</td>
</tr>
<tr>
<td>12</td>
<td>Aluminum plate</td>
<td>5083/ Thick 10mmxL1mxW1m</td>
<td></td>
<td>454,390.21</td>
<td>2</td>
<td>908,780.42</td>
</tr>
<tr>
<td>13</td>
<td>Stainless steel Plate</td>
<td>SS304/ Thick 5mmxL1mxW1m</td>
<td></td>
<td>811,000</td>
<td>1</td>
<td>811,000.00</td>
</tr>
<tr>
<td>14</td>
<td>Nylon</td>
<td>Nylong/ Thick 20mmxL1mxW1.2m</td>
<td></td>
<td>7,183,920</td>
<td>1</td>
<td>7,183,920.00</td>
</tr>
<tr>
<td>15</td>
<td>Acrylic</td>
<td>Acrylic 5 mm, L (122cm x 244cm)</td>
<td></td>
<td>932,000</td>
<td>3</td>
<td>2,796,000.00</td>
</tr>
<tr>
<td>16</td>
<td>Tubing</td>
<td>OD(6mm)-ID(4mm)</td>
<td></td>
<td>151,689.48</td>
<td>1</td>
<td>151,689.48</td>
</tr>
<tr>
<td>17</td>
<td>Socket Head Cap Screw</td>
<td>M5x10 / SHCS</td>
<td>MISUMI</td>
<td>5,000</td>
<td>20</td>
<td>100,000.00</td>
</tr>
<tr>
<td>18</td>
<td>Flat Heat Cap Screw</td>
<td>M3x10 / FHCS</td>
<td>MISUMI</td>
<td>5,000</td>
<td>28</td>
<td>140,000.00</td>
</tr>
<tr>
<td>19</td>
<td>Bolt</td>
<td>M8x20</td>
<td>MISUMI</td>
<td>7,500</td>
<td>15</td>
<td>112,500.00</td>
</tr>
<tr>
<td>20</td>
<td>Bolt</td>
<td>M8x40</td>
<td>MISUMI</td>
<td>10,000</td>
<td>8</td>
<td>80,000.00</td>
</tr>
<tr>
<td>21</td>
<td>Bolt</td>
<td>M8x15</td>
<td>MISUMI</td>
<td>7,000</td>
<td>6</td>
<td>42,000.00</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td><strong>Total (IDR) 39,797,024.15</strong></td>
</tr>
</tbody>
</table>
4.2.6.3 Comparison between current and improvement processes

The comparison here is to calculate the cost saving after using the improvement process. At this calculation also consist of the break event point after investing the machine cost, the fix cost here means the cost of investing the machine, the variable cost here is 0, and the profit here is from the value of cost saving below is the calculation:

1. Cost saving

\[ \text{Cost Saving} = \text{Cost}_{\text{current}} - \text{Cost}_{\text{improvement}} \]

\[ \text{Cost Saving} = \text{IDR} 20,000,000 - \text{IDR} 4,000,000 \]

\[ \text{Cost Saving} = \text{IDR} 16,000,000/\text{month} \]

2. Break Event Point

\[ \text{BEP} = \frac{\text{FC}}{\text{CS} - \text{VC}} \]

\[ \text{BEP} = \frac{\text{IDR } 39,797,024.15}{\text{IDR } 16,000,000} \]

\[ \text{BEP} = 2.49 \text{ Months} \]

3. Graph of Break Event Point

From the graph we know that the company will save until IDR 152,202,975.85 in the first year.

Figure 4. 24 Graph of break event point
CHAPTER V
CONCLUSION AND SUGGESTION

After the research has done, then the researcher concludes the research about “Design of Automatic Stamping Date and Dash code marking using Pneumatic system and PLC control”, as follows:

1. The function of the machine is met with the desired needs.

   From the research we know that the company need a machine that could work fast, easy to use and maintain, also affordable. To meet all of the desired needs the researcher has designed the machine called as “Automatic Stamping Date and Dash code marking using the Pneumatic system and PLC control”. The machine could work fast because the machine uses pneumatic system, in addition the use of the pneumatic is also cheap for maintenance cost. The reason for using pneumatic refers to figure 2 (1).

2. Easy to Use and Maintenance

   The design is easy to use because the researcher has think that the operator must enjoy to operates the machine as we discuss before, the position of the stamp also could be adjusted with your needs so it can be used for any company with A4 standard master carton, then the machine also easy to maintain because the researcher has designed the machine that easy to assemble and disassemble.

3. Money saving and effective

   To help the program of cost saving at the company the researcher has analyze all of the profit of improvement, the profit is depending on the cycle time of the processes, so the researcher wants to say that much faster of the cycle time will increase the profit. From the analyzing we get 4 second for the cycle-time of the Date and Dash code marking, so for 1 shift the operator can produce 7200pcs of marked master carton. Then at the analysis also calculating the cost savings when using the improvement process, the company will save IDR 16,000,000 per month also 2.5 months of break event point after using the machine.

   Then the suggestion for this research is the design should be constructed in the real life to prove the calculation of the theory of the analyzes.
REFERENCE


