DESIGN AND DEVELOPMENT OF AUTOMATION SYSTEM FOR (CLOTHES FOLDING MACHINE)

BAKR SAEED RIZIQ DARAGHMEH

RESEARCH REPORT SUBMITTED TO THE FACULTY OF ENGINEERING UNIVERSITY OF MALAYA, IN PARTIAL FULFILMENT OF THE REQUIRMENTS FOR THE DEGREE OF MASTER OF ENGINEERING (MECHATRONICS)

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UNIVERSITY OF MALAYA

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ABSTRACT

Clothes folding machine is developed and designed to overcome the routine task of folding clothes, because of its highly requirement in our daily life use. The machine represented a fully automation system that combines the mechanical design with the electrical control design. the machine was developed to serve the normal people with a normal human intelligence so its design was completely representing the manual way of clothes folding, and specifically following the steps of folding the sleeves back ward then folding the lower shirt part and finally try to flip the shirt to its upper face on the way of delivering it to the operator. Shirts was taken as the first sample which the machine mechanisms designed to fold. Human intelligence was also required to overcome the obstacle of defining the clothes type and shape. So it was required by the operator to feed the clothes with a certain way, then allow the machine to fold it. Using the 3D simulation with the help of CAD engineering softwares (solidworks) boost the initial ideas to a desired point to go through the control part. PLC take a place to control the mechanisms with proper time folding and sequence. OMRON PLC CP1L model training kit hardware connected to the CX-Programmer software was the way of implementing the actual outputs for the machine parts movement before putting it in a prototype manner.

ABSTRAK

Mesin lipat pakaian dibangunkan dan direka untuk mengatasi tugas rutin mesin lipatan, dan kerana keperluan yang sangat diperlukan dalam kehidupan seharian kita. Mesin mewakili sistem automasi sepenuhnya yang menggabungkan reka bentuk mekanikal dengan reka bentuk kawalan elektrik. mesin itu dibangunkan untuk melayani orang biasa dengan kecerdasan manusia yang normal supaya reka bentuknya benar-benar mewakili cara manual pakaian lipat, dan secara khusus mengikuti langkah-langkah lipat lengan belakang lengan kemudian lipat bahagian baju yang lebih rendah dan akhirnya cuba untuk flip baju ke bahagian atasnya dalam perjalanan menyerahkannya kepada pengendali. Baju telah diambil sebagai sampel pertama yang mekanisme mesin direka untuk melipat. Kecerdasan manusia juga diperlukan untuk mengatasi halangan untuk menentukan jenis pakaian dan bentuk. Jadi ia dikehendaki oleh pengendali untuk memberi makan pakaian dengan cara tertentu, kemudian biarkan mesin melipatnya. Menggunakan simulasi 3D dengan bantuan perisian kejuruteraan CAD (solidworks) meningkatkan idea-idea awal ke titik yang dikehendaki untuk membuang bahagian kawalan. PLC mengambil tempat untuk mengawal mekanisme dengan lipat dan urutan masa yang sesuai. Perisian kit model latihan OMRON PLC CP1L yang disambungkan kepada perisian CX-Programmer adalah cara melaksanakan output sebenar untuk pergerakan bahagian mesin sebelum meletakkannya dalam prototaip.

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CHAPTER 1
INTRODUCTION

1.1 Overview

Folding your clothes is one of the most boring and routine task that you will ever do again and again. So developing a machine that overcome this boring issue was the aim of this research. Clothes are classified into many groups every group has its own specification and dimensions. These groups are (Shirts, Trousers, Shorts, Socks, Jackets, Suits and Formal Beadles). Every category of this group has also its own sub-group with different size and dimensions. So because of this wide variety of groups and sub-groups we face the first obstacle in our mission of designing the machine. Hence we decided to select one group of these groups and focus only on one sub-group of them. we go also only with one way of folding for this shape of clothes. Because of the wide difference in the clothes folding ways between cultures and even single peoples in the same society. Our selection was under shirts group and to be more specify by selecting the formal and the informal ones. Automated the manual folding steps shown in the Figure 1.1 is the goal of this research.

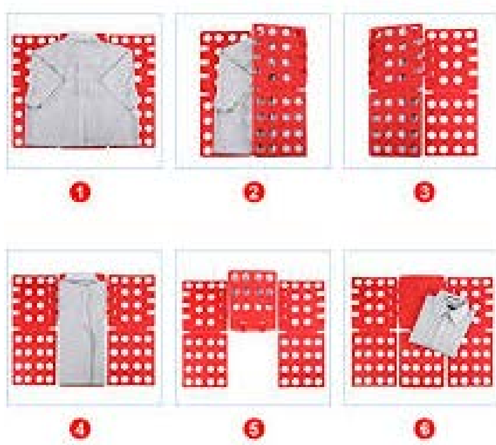


Figure 1. 1 Folding steps for clothes and desired output

1.2 Problem Statement

Since we roam with a very huge numbers of clothes groups and types, and even after we select our sub-group that we will take as an example to start our folding machine, we still face a problem of which way of folding we have to start our initial design with. To understand the different ways of clothes folding. figure 1.2 shows a different folding methods for a formal shirt, while figure1.3 shows another difference in folding the informal shirts which people use around the world.

One of the main obstacles is how the clothes will be feed to the machine? Can we just drop them inside it as in the washing machine? or we have still to use the human intelligence and feed the machine with the clothes in a proper way?

We considered here the easy way for our research, so the operator has to feed the machine with the shirts with a proper define way. Shirts has to be flipped and expanded on the machine as shown if figure 1.4. if we try to drop the clothes inside the machine and give the machine the chance to identify the type clothes or the shape. Machine has to have the ability of image processing and artificial intelligence for the processing of the shape. And this will lead our research project to deal with more complicated issue and to be more complex and advanced.

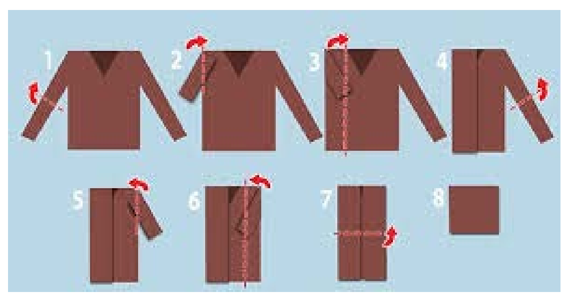


Figure 1. 2 Two different folding steps for formal clothes

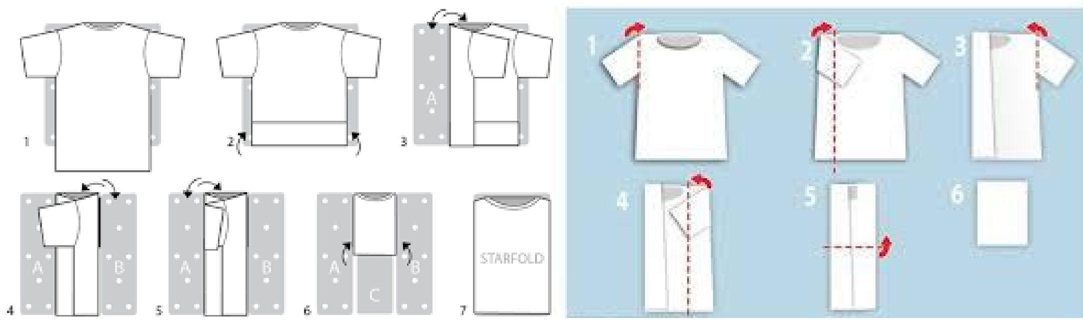


Figure 1. 3 Two different folding steps for informal clothes

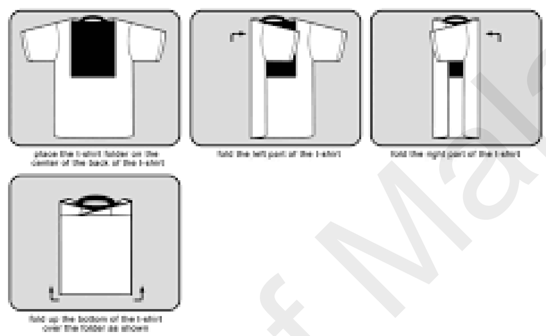


Figure 1. 4 The desired way for the operator to feed the design machine with shirts

1.3 Objectives

The goal of this research is to improve and design a complete integrated automation system of mechanical parts and assembly with a programmable logic controller (PLC), implemented in clothes folding machine. The objectives of this research are:

a. To be more familiar with automation systems by combining electrical (low voltage) system, with the mechanical system that integrates the mechanical parts to achieve the proper action.

b. Develop and design clothes folding machine with proper sequence to fulfill the client requirement, these sequences are:

   1- Define the mechanism motion with proper machinery parts.

   2- Specify the motors torque and speed.

3- Specify the Motors drivers and wiring diagram.

4- Build the sequence diagram for the motion.

5- Build the ladder diagram with a suitable software complies with the PLC.

c. Improve the skills of using the programmable logic controller and how to connect it with the stepper motors.

1.4 Scope of Study

This research is trying to build a smart automation system that uses the advanced industrial parts and engineering softwares. By using the OMRON PLC training kit and the solidworks 3D design we will build the clothes folding machine and try to simulate it for our initial prototype.

Hence The clothes folding machine represented an automation system, it has to include the machinery design and the mechanisms interface with the low voltage control units that represented by the CP1L PLC as a logic, stepper motor and dc motors as an actuator, with the proximity switch as a sensor.

So, for the machinery parts the following conditions has to be applied to achieve a proper machine motion:

a- Machine parts has to be design and build with proper dimensions. (actual logical size, weight and material type).

b- Machine parts has to interfere and connected to achieve the initial and final position without any jerk and material worn out.

c- Plc should be programmed and interface with the stepper motor driver perfectly.

d- System should be tested and stopped with a proper button accessed by the operators.

1.5 Expected Results

By completing this research, the expected goal is to build a very defined automated system that synchronize between the mechanical part and electrical one without any serious fail or damages. This machine can be carried out and be built as a prototype initially so once other problems appears we can manage and solve them or even any more special improvement can be done to achieve an excellent automation system.

1.6 Thesis Organization

In chapter 1, it presents the whole idea about starting an automating system and gives an overview for the variety of clothes that we are intending to design the machine for. Then the main objectives with the scope of work and describe shortly some obstacles that the designer had faces.

In chapter 2, here we pass through different ways of how human can automate the folding task, by using robot arms or by using mechanical interaction by using motor control. People still trying to improve the task more and more depending on other experience or initiating their own prototypes.

In chapter 3, An important skill of a design engineer is to know how to integrate systems and combine them together to ensure the full proper task with a high efficiency during operation. Here we go through the mechanical system applying the kinematic analysis and machinery design to define the initial and final position of the moving parts. Using the powerful engineering tools and software such as SOLIDWORKS and OMRON PLC programmer, the clothes folding machine will be design, simulated and tested. Since the physical model is not going to be built, the programming can be done several times so that the challenges faced with a hardware can be reduced or oven fully eliminated.

In chapter 4, results and the total system output are explained and discussed separately, starting by the machine steps, folding board's action after the motor action. Then the ladder diagram outputs in steps and how it appears after doing online simulation with the CX-program. Finally, the PLC outputs which are the led indicators in the actual relay outputs. Every led present a motor certain action.

In chapter 5, we present the research conclusion with some recommendations to improve the system, it was essential to know the weakness points of the system to avoid and overcome them while building the machine for manufacturing.

CHAPTER 2
LITERATURE REVIEW

2.1 Background

From the 20th century and beyond, machines have made human life much easier by taking over most of the tedious and repetitive tasks. Humans now have more time to attend to other pressing issues. One of the areas where machines have benefitted mankind is in the laundry services. All over the globe, different forms of sophisticated machines are available for doing the laundries. While some perform only the washing leaving the drying to human to perform manually, others are so sophisticated that they can carry out both the washing and drying. However, even with this sophistication, the laundry task is yet to be fully complete as the washed clothes need to be neatly folded before they are stored. Most of the machines are handicapped when it comes to autonomous folding of the clothes as they are only capable of washing and drying. To complete the laundry task, different approaches have been made by researchers to come up with models, designs, and machines that can perform the folding task. In this chapter, some of the works done on the clothes folding machine will be investigated. In this research project folding of clothes will be categorized into three kinds depending on the level of technology. First is the manual folding which is done by hand. It is the oldest and most efficient method till date. The second kind is the semi-manual method where the clothes are being laid on a platform and then the folding is done by the machine. So, it involves human for spreading and laying the clothes on the platform, then the motor-controlled platform then carries out the folding. The final and the third type is the fully automated kind of folding. Here the clothes are being fully folded by an intelligent folding machine. For the fully automated folding, the clothes are spread out, laid, and folded all automatically by a machine. This is mostly carried out by two-armed robot equipped with cameras or range finders for image detection and dexterous grippers for manipulations. This third kind of folding clothes is still under serious research as a total breakthrough has not been made in this regard.

2.2 Fully Autonomous Clothes Folding

It has been stated and worthy of notice that a cloth is deformable, flexible and non-rigid in shape which makes it very difficult to manipulate (Miller et al., 2015). This complexity has been the major barrier hindering the full development of the clothes folding machine. Sitting on some assumptions, (Miller et al., 2015) have come up with some cloth configurations which could be represented by some parameters that are polygonal in nature. They used a Willow Garage PR2 robot to test their model which is an algorithm that outputs the motion plans for executing a particular kind of fold. Naming it *g-folds* which stands for gravity folds, they used four categories of clothing for their model: short sleeve shirts, long sleeve shirts, pants, and towels. Each of these categories is represented by a polygon. Their work can be classified under the third kind of clothes folding method as they have tried to carry out a fully automated means of folding clothes. A similar work which is aimed at addressing clothes perception and manipulation (CloPeMa) has been conducted in (Stria et al., 2014) where a dual robot was used instead of a Willow garage PR2. Their research which also deals with a polygonal model is an extension and an improvement over previous polygonal model works. The novelty in their study is that a new garment polygonal model was developed alongside its manipulation planning algorithm. There results showed that the process of CloPeMa can be sped up by two orders of magnitude. In another article, a system which folds clothing from a random crumpled state to a fine state is presented in (Bersch, Pitzer, & Kammel, 2011). They developed an algorithm which has a novel detection and grasp strategy which is capable of suggesting grasp points from poses of the clothing. The drawback of this system is that it is limited to t-shirts alone as shown by the experiments that have been conducted in their work. They also made use of the Willow Garage PR 2 for their experiments. A set of procedure was including pick-up, perception, estimation of current grasp point, selection of next grasp point, grasp pose computation and evaluation, grasp execution, grasp verification, and finally folding (Bersch et al., 2011). The major focus of their work on the grasp points. With the use of fiducial markers, the configuration of the t-shirt need not be known, thereby making their system tolerant to all kinds of t-shirts. In a similar paper, an algorithm that can reliably detect the corners of the piece of cloth was developed (Maitin-Shepard, Cusumano-Towner, Lei, & Abbeel, 2010). They based their algorithm on geometric cues due to its robustness in texture variation. Rather than using t-shirts for their experiments, they based their experiments on a towel. However, they concluded that their algorithm can be applied to other kinds of clothing. Willow Garage PR 2 has been used in their research just like in the two previously mentioned papers. Figure 2.1 shows the process of folding using the willow garage PR 2 robot.

Figure 2. 1 Attempt to fully automate clothes folding. (source;(Hubli et al., 2017))

An all-encompassing work on autonomous folding machine has been conducted where all the process of clothes folding from the sorting of the clothes from pile of clothing to unfolding, to spreading and finally folding is taken care of (Doumanoglou et al., 2016). Capitalizing on the fact that clothes are deformable which makes perception and manipulation difficult, a two-arm robot was used in their research. All the subtasks necessary for an autonomous clothes folding has been addressed in their work making it the first of its kind. What makes their work unique is the fact that they proposed a novel method for completely unfolding a partially unfolded garment. Some garments tend to fold up at the edges after attempts have been made to spread them out, so this novel approach takes care of such problems. This was achieved by comparing the deformation of the examined garment with the template garment for a particular kind of clothing (e.g t-shirt). Another novelty in their research is the area of garment unfolding which is based on classic random forests. They called their novel method active random forests which performs a good classification and regression, thus selecting the best viewpoint. From their experiments, they have concluded that their work is not only limited to t-shirts but can also be applied to all forms or kinds of garment.

To fully automate the laundry process, classification is a key property that a system should have as that will enable the system to autonomously perform washing, drying, and folding. (Willimon, Birchfield, & Walker, 2011) worked on classification of clothing using an interactive perception technique. Two tasks are involved in this technique, the first being the isolation of clothing from a pile one after another, and the second task being classification of the sorted clothing into pre-specified categories (short sleeves, long sleeves, pants, shorts, and underwear) using the information form the visual based shape and appearance.

It has been stated that clothes are generally difficult to handle due to their flexibility, but linen is even more difficult to handle. So, for proper and efficient handling at a linen supply industry, (Hata, Hojoh, Toda, & Hamada, 2011) developed a system that can autonomously input washed clothes (linen based) into washing and folding machines. Also using towels for testing their algorithm, they have agreed with those who believe that the most essential part to handle a rectangular piece of clothing is at the edges. The number of steps in the algorithm of (Hata et al., 2011) is five (5) which is contrary to the number of steps in (Willimon et al., 2011).

Utilizing small mobile robots and a normal table, (Watanabe, Kawamura, Iizuka, & Suzuki, 2107) proposed a system which is capable of folding clothes. Although they were faced with limited work space, they were able to implement their algorithm. The mobile robots are equipped with markers which are used to obtain coordinates and also manipulate the clothes while an external camera is mounted above the robots to fetch RGB images files for the PC. Their system uses a path planning algorithm to trace the coordinates needed to fold the clothes. In another study (Yang et al., 2017), a humanoid robot is programmed using deep learning to perform the herculean task of folding a soft object. Cotton material was used as the training and testing data set.

An attempt at attaining a full autonomous clothes folding has been made in the work of (Hubli et al., 2017) where a three stage procedure is used to get a clothes from a pile transformed into a neat uniform folds. A gripper capable of sliding was employed in separating each clothe from the pile of clothes. With the aid of fans and moveable grippers, the second step of unfurling the clothes is achieved thereby spreading the clothes over the platform for folding. An orientation algorithm which is angular-based is used to compare the actual orientation with that of the template in order to achieve the best orientation of the unfurled clothes. (Hubli et al., 2017) concluded that although their model is not void of some inaccuracies, they have been able to automate the clothes folding process. Not precise form of measurement was seen present in their work. So, further investigation is needed to optimize their work. In a similar study, (Hamada, Hata, Hojoh, Kobayashi, & Fukumoto, 2009) made use of two robot arms to perform the folding task on linen. Although they didn't develop any serious algorithm, trial and error method was adopted by them to perform several hundreds of experiments. They also divided the task into three stages as described previously. (Hamada et al., 2009) relied on images obtained from the cameras mounted on robots and made their robot perform grasping of corners and edges for the manipulation and eventually folding.

Figure 2. 2 Attempt to fully automate clothes folding. (source;(Hubli et al., 2017))

By generating a folding path, a single arm robot was used to perform garment folding in the work of (Petrík, Smutný, Krsek, & Hlavác, 2017). Their research was based on the static equilibrium of forces and a two-dimensional shape were used to model the garment as an elastic shell. This makes the work an upgraded version of a previous similar one-dimensional path generation technique. Their model has the advantage of preventing slippage of the garment while it is being folded on a surface with low friction. One of the limitations in (Petrík et al., 2017) is the fact that material properties detection is somewhat left for the operator to be manually done. By making use of some complex algorithms which collects data form 3D images and then converting them into grayscale image, (Estevez, Victores, Morante, & Balaguer, 2016) investigated how clothes can be unfolded. In their model, height of contours are used to generate a height profile which the systems records as folded or unfolded part. For contours that are high, the model takes them a critically folded part, while for low contours the model takes them as unfolded parts.

2.3 Semi-Manual Clothes Folding

For the semi-manual kind of clothes folding method, the work of (Mahajan, Prasad, Binnar, & Tambe, 2017) has shown some advancement in this regard. A motor driven clothes folding machine was developed in their project. They aimed at reducing the time consumed during the house chores (laundry in particular) thereby saving time for other chores. The project consisting of folding trays, folding flaps, and flips was focused on folding only t-shirts. Just like in the work of (Bersch et al., 2011), the shortcoming of this project is the fact that it cannot accommodate all types of garments as all the system is limited to t-shirts only. It is believed that if applied in the Indian textile industry, it will save plenty of time and minimize errors in sorting of textiles. Figure 2.2 shows the work of (Bersch et al., 2011).

Figure 2. 3 Semi-manual folding machine (source; (Mahajan et al., 2017))

In an effort to eliminate the manual laying of the clothes on the semi-manual folding machine, (Miyamotoa, Mub, & Kitazono, 2014) developed a clothes folding machine which is an enhancement of the previous work of (Mahajan et al., 2017). This is because their folding machine is able to fold clothes (t-shirt) from the state of hanging. The machine is also equipped with sensors which detects whether or not the clothes are wet before folding, and a special kind of hanger which folds up during the clothes folding process. Inexpensive materials were used in the work of (Miyamotoa et al., 2014) as the folding board is made of cardboard, while the frames are made of aluminum. The motors used to control the folding motion are off-the-shelf (OTS) servo motors.

Figure 2. 4 Folding of clothes from hanging (source; (Miyamotoa et al., 2014))

While most of the articles used in this project did their works on clothes folding, the article of (Triantafyllou, Mariolis, Kargakos, Malassiotis, & Aspragathos, 2016) rather focuses on unfolding of clothes. Relying on some heuristic approaches, (Triantafyllou et al., 2016) also adopted the detection and manipulation method to determine two arbitrary grasping points on a garment where when held, the clothe unfolds using gravity. A two-arm robot equipped with range sensors for image detection was used in their work. They concluded that the geometric approach they have used in their method is more advantageous than the machine learning method based on some reasons.

In summary, different articles on clothes folding have been reviewed. While some of the researches are working on full automation of the clothes folding, others have attempted a semi-automatic folding. In all of the researches, emphases were made on the usage of robots to accomplish the folding task. Most of them involved algorithms that are used for the detection and manipulation of the clothes. However, little or no effort has been made to utilize a PLC for the programming aspect of the clothes folding. So, in this research project, a PLC based kind of programming will be used in controlling the clothes folding machine. The research project is limited to the folding of the clothe only. The detection and spreading of the clothes is not treated in this project.

CHAPTER 3
METHODOLOGY

Herein we are going to explain all the steps and the methodologies we used to establish and improve our prototype simulation for the Clothes Folding Machine using the engineering software's (Solidworks and OMRON PLC).

3.1 Introduction

In this chapter, the steps and the methodologies that were used to establish and improve the prototype are discussed. The simulation and analysis of the Clothes Folding Machine were achieved using the engineering software Solidworks for the design and OMRON Programmable Logic Controller (PLC) for the simulation.

The first step in conducting this project was to put down the sketches of the initial ideas of the machine prototype on paper. Upon satisfactory sketches, 3D design is performed using a CAD software, SOLIDWORKS was used in this regard. All these steps and more are represented in the flow chart of the research methodology given in Figure 3.1.

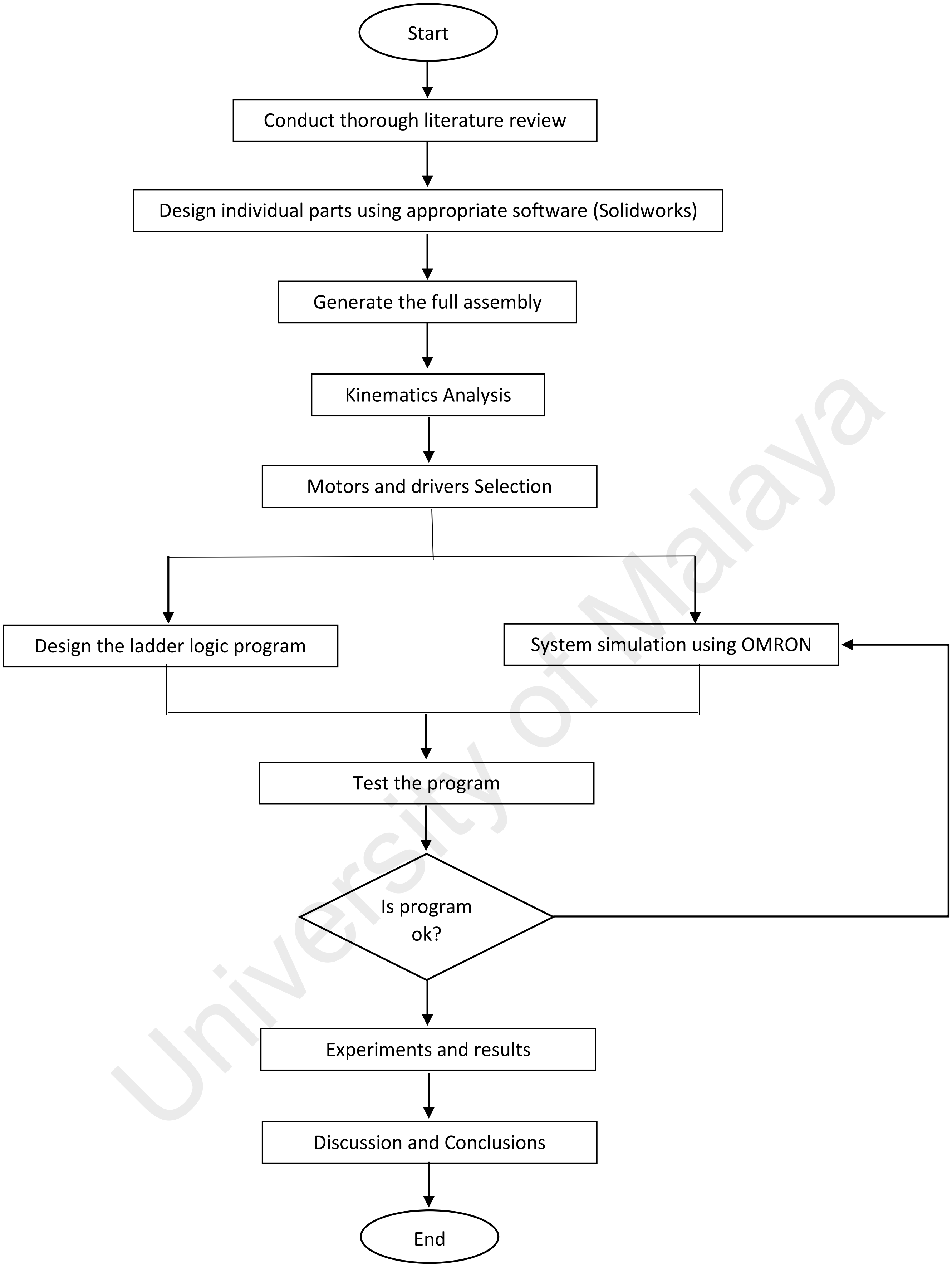


Figure 3. 1 Research methodology flow chart

3.2 Material

3.2.1 Solidworks Software

Solidworks is one of the powerful softwares that helps the engineers to imagine and visualize their designs and ideas in a powerful manner. It gives the designer the ability to present his ideas in a 3D model and in assemblies. By using SOLIDWORKS, a designer is able to mate different parts together and create sub-assemblies. These sub-assemblies are assembled together to generate a full assembly of the machine parts.

Running the software will be by clicking the main icons of mechanical desing in the computer system. Figure 3.2 below shows the main software icons that engineers can use.

Figure 3. 2 Main Solidworks Icons

3.2.2 OMRON Programmable Logic Contoller CP1L

OMRON Corpration manufacture provides Programmable Logic Controller with different kit specifications, here we are using the training kit model CP1L that has built in pulse, serial communications and digital input/output.

The kit has the ability to contorl small and medium machine size, this CP1L has an embedded ether net port that gives more flexibility in funcitioning, logging and monitoring. Since we are dealling with stepper motor in our desgin also the CP1L has a high-precision position contol. Figure 3.3 shows the physical shape of the OMRON PLC CP1L.

Figure 3. 3 OMRON Kit dimensions and shape

Using the PLC in a proper way will be by having all the information about its spcifications and charachteristics, for OMRON PLC Training Kit table 3.1 shows the specifications.

Table 3. 1 Specification of OMRON PLC (CP1L)

Type	AC power supply models
Model	CP1L
Power Supply	100 to 240 VAC 50/60 Hz
Operating voltage range	85 to 264 VAC
Power consumption	30 VA max
Inrush current	100 to 120 VAC inputs: 20 A max. (at room Temerature),8 ms max. 200 to 240 VAC inputs: 40 A max. (at room temperature), 8 ms max.
External power supply	2000 mA at 24 VDC
Insulation resistance	20 MΩ min. (at 500 VDC) between the external AC terminals and GR terminals.
Dielectric strength	2.300 VAC at 50/60 Hz for 1 min between the external AC and GR terminals, Leakage current: 5 mA max.
Noise immunity	Confirms to IEC 61000-4-4.2 KV (power supply line).
Vibration resistance	Conforms to JIS C60068-2-6. 10 to 57 Hz,0.075-mm amplitude, 57 to 150 Hz, acceleration: 9.8 $^{m}/_{s^2}$ in X,Y and Z directions for 80 minutes each.
Shock resistance	Conforms to JIS C60068-2-27. 147 $^{m}/_{s^2}$ three times each in X,Y and Z direction.
Ambient operating termprature	$0^o$to 55^o C
Ambient humidity	10% to 90% (no condensation)
Ambient operating environment	No corrosive gas
Ambient storage temperature	-20% - 75^o C (excluding battery).
Power holding time	10 ms min.

3.2.3 CX-Programmer Software

CX-programmer which main icon is shown in figure 3.4 is a software used to constuct the logic program for the OMRON PLC. This software is one of the software included in the CX-ONE package provided by the manufacturer togither with OMRON PLC.

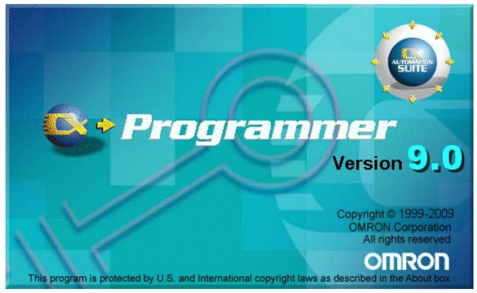


Figure 3. 4 CX-Programmer

CX-Programmer software uses ladder logic program to communicate the information to PLC. The users can choose the OMRON PLC mode (programming, running, online runinig) to design their program and check it, even OMRON PLC give the chance to the designer to simulate the program using online simulator provided in the sofware. This is to ensure that the program functions according to requirement before it is uploaded to real PLC.

The first window that you see when starting CX-Programmer is the main application window. This window is the launching point for you to access other CX-Programmer views and functions. The screen will be blank until you open or create a project. When a project has been opened or created, you will see two main working spaces and additional menu options appear:

- Project (Information) Workspace

  Located on the left for accessing the information about the PLCs and programs used in the project.

- Ladder/Programming Workspace

Located on the right for creating the PLC programs.

Figure 3.5 shows the main working space for the CX-Program.

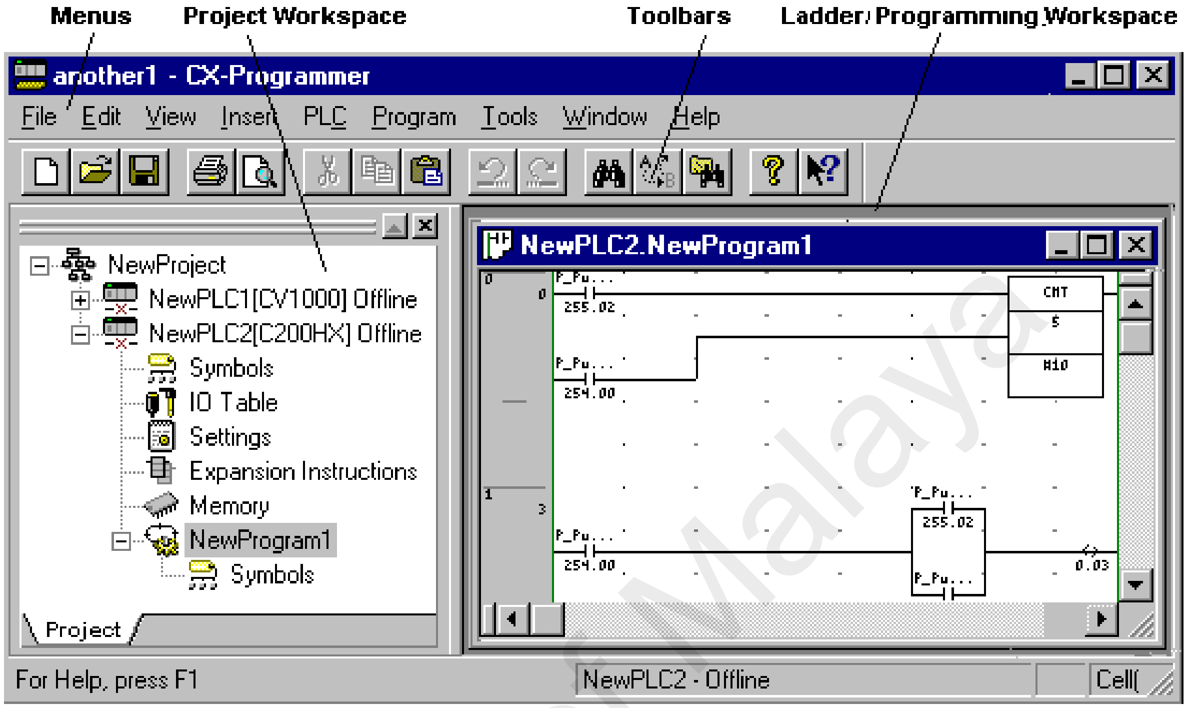


Figure 3. 5 CX-Programmer Main working spaces

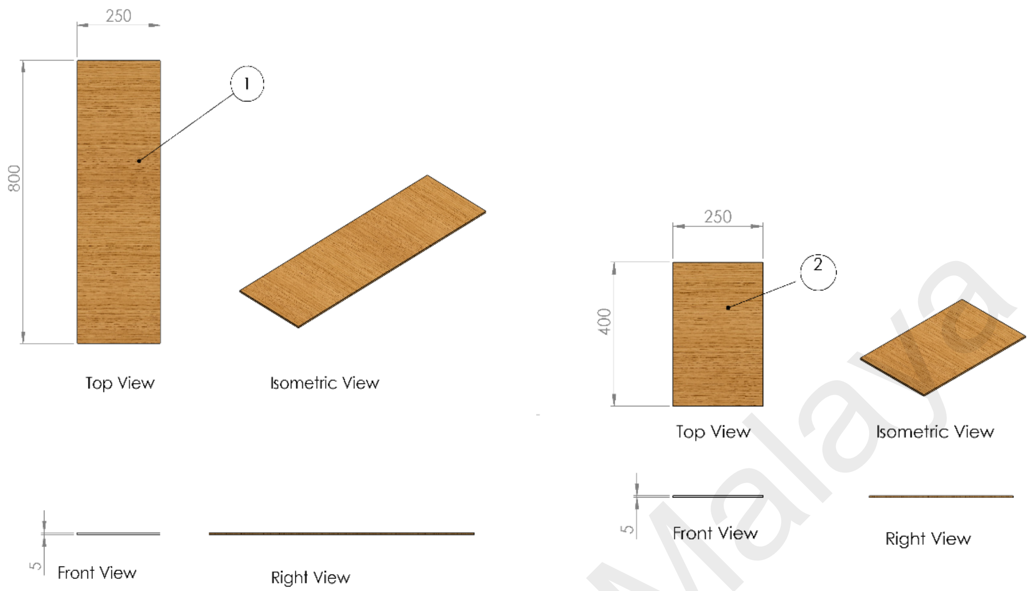
3.3 Machine Design

Since our goal is to find a machine that is capable to fold the clothes, it was necessary to go through the major steps of designing (Sketching, Improving the drawing to 3D, Doing the motion study (simulating), analyzing, and building the initial prototype). In the following sub-section we will explain these steps.

3.3.1. Major Parts

In this section we are going to show the major parts dimensions and specification individually before we create our assembly .

3.3.1.1. Main folding boards

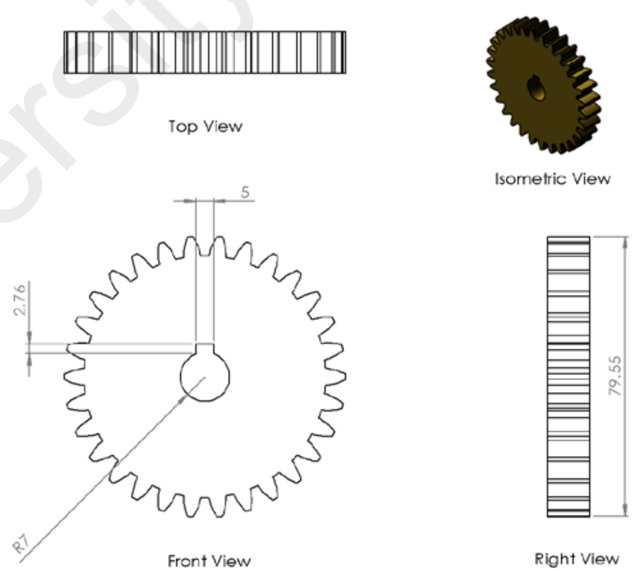


ITEM NO.	PART NUMBER	DESCRIPTION	Mass KG
1	Folding board	800 x 250 (mm) Wooden board	0.560

ITEM NO.	PART NUMBER	DESCRIPTION	Mass KG
2	Folding board	400 x 250 (mm) Wooden board	0.280

Figure 3. 6 Main Folding Boards

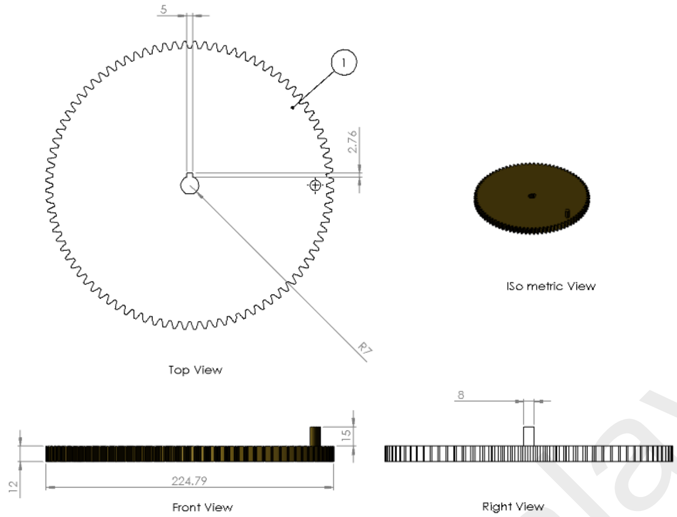
3.3.1.2 Drive Gear



ITEM NO.	PART NUMBER	DESCRIPTION	Mass /KG
1	Metric - Spur gear 2.5M 30T 20PA 12FW --S30N75H50L14S1	Drive Gear /Brass	0.425

Figure 3. 7 Drive Gear

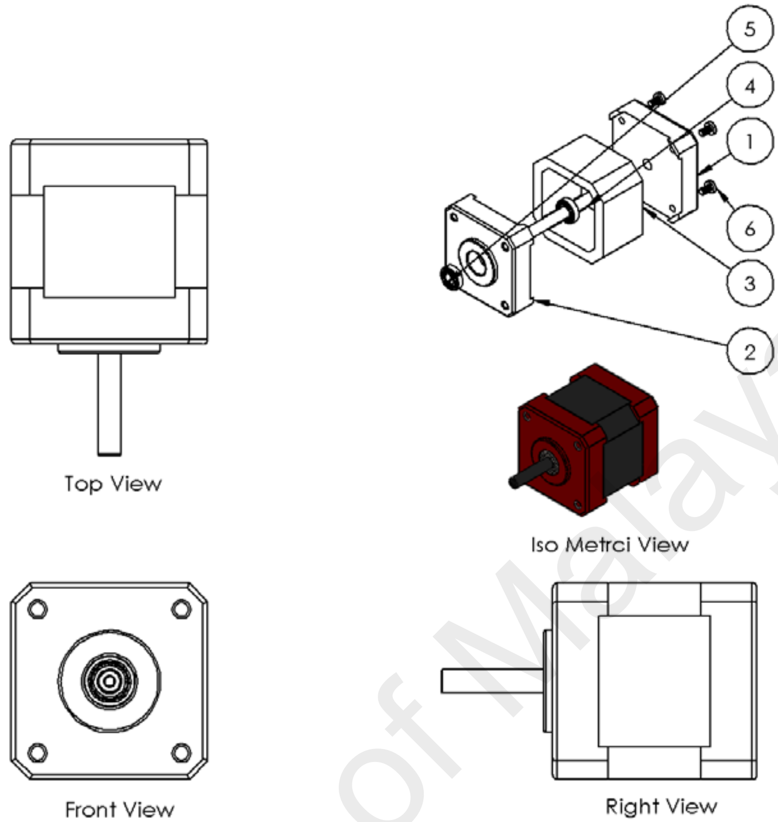
3.3.1.3 Driven Gear



ITEM NO.	PART NUMBER	DESCRIPTION	Mass/ KG
1	Metric - Spur gear 2.5M 88T 20PA 12FW ---S88N75H50L14S1	Driven Gear / Brass	3.84

Figure 3. 8 Driven Gear

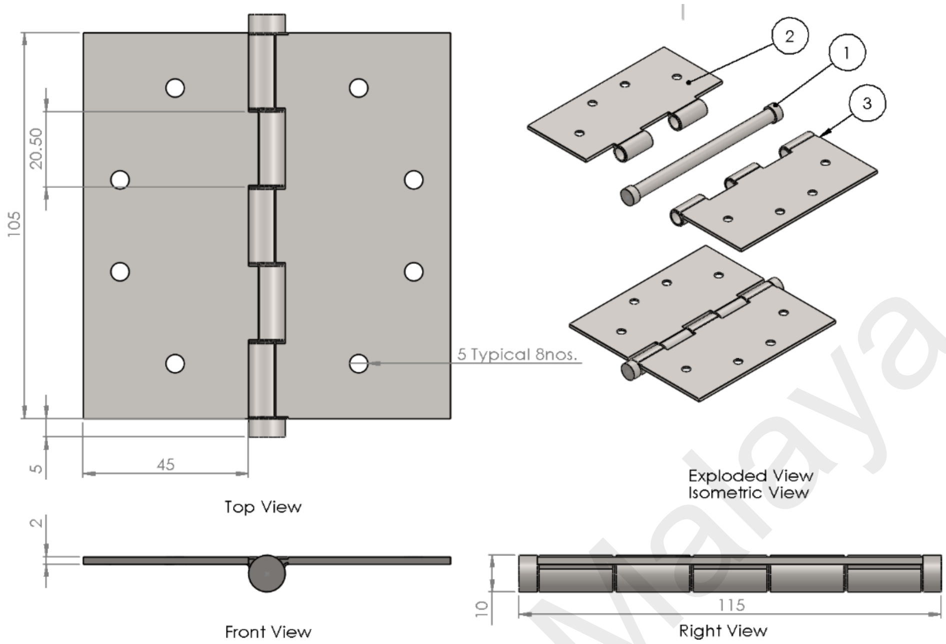
3.3.1.4 Stepper motor



ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Base		1
2	Back Plate		1
3	Body		1
4	Axial Rod		1
5	AFBMA 12.1.4.1 - 0050-11 - 10,DE,AC,10_68		2
6	B18.6.7M - M3 x 0.5 x 5 Type I Cross Recessed PHMS --5S		4

Figure 3. 9 Stepper motor assembly

3.3.1.5 Hinge



f	PART NUMBER	DESCRIPTION	QTY.
1	Central Pin	Axial Pin Fixing the Hinges Parts	1
2	Hinge B	Aluminum Hinged	1
3	Hinge A	Aluminum Hinged	1

Figure 3. 10 Hinge

3.3.2 Full Machine Assembly

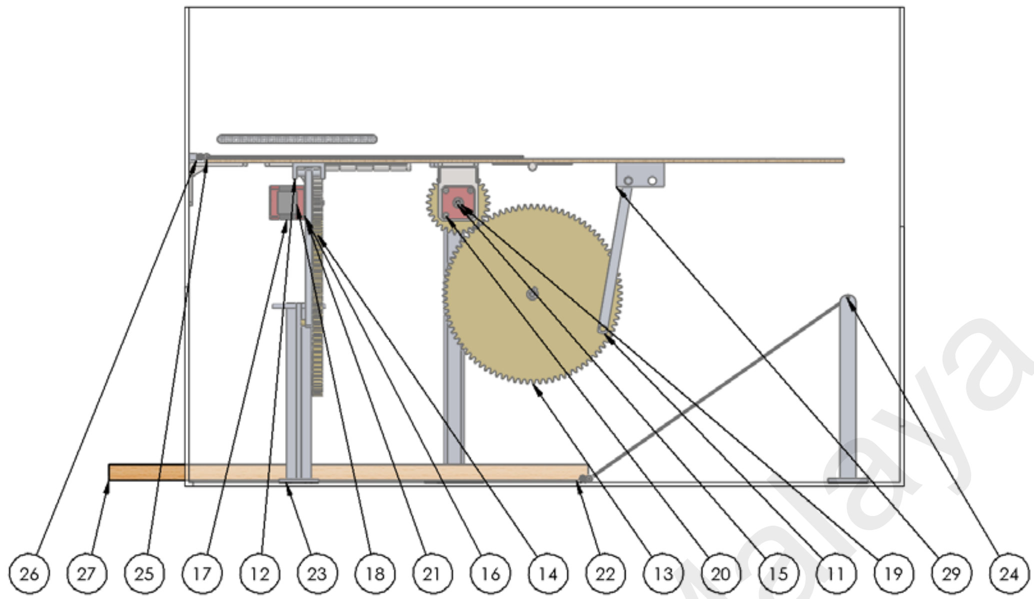


Figure 3. 11 Left View

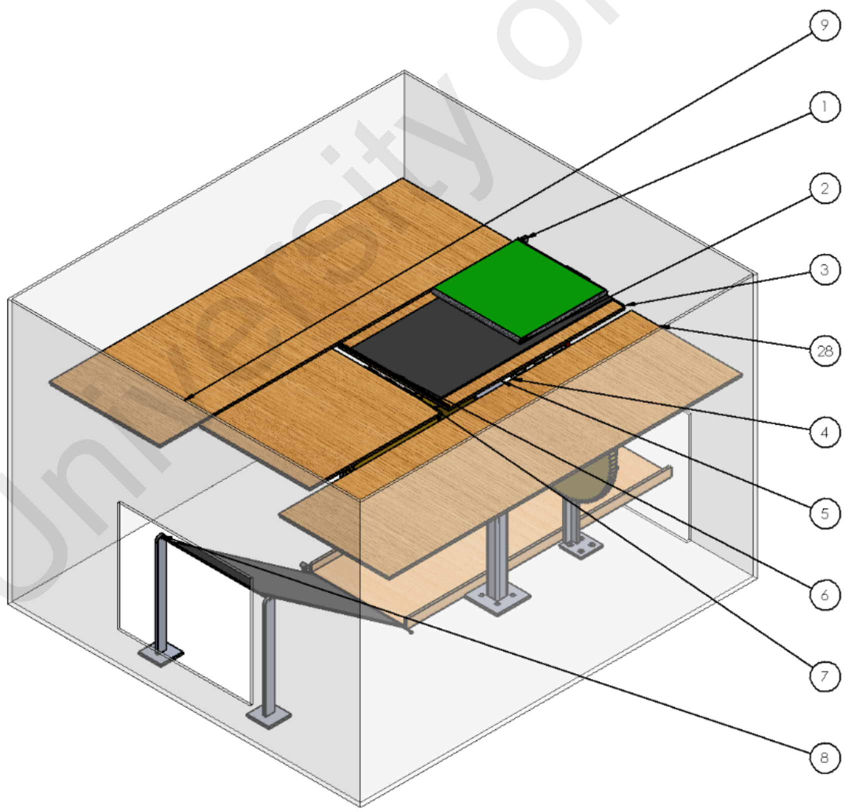


Figure 3. 12 Isometric View

Table 3. 2 Bill of Material for the machine

Folding Machine Bill of Material Table			
ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Dc motor billow		1
2	Clothes Representation		1
3	1 belt Drive		4
4	Central Pin	Axial Pin Fixing the Hinges Parts	3
5	Main Board Support		1
6	Belt1-3^1 belt drive		2
7	Hinge B	Aluminum Hinged	3
8	conveyor support		2
9	Machine frame		1
10	Hinge A	Aluminum Hinged	3
11	Pushing Arm		3
12	Pushing Hinge		2
13	Metric - Spur gear 2.5M 88T 20PA 12FW --- S88N75H50L14S1	Stepper Motor Driven Gear / Brass	3
14	Metric - Spur gear 2.5M 30T 20PA 12FW --- S30N75H50L14S1	Drive Gear /Brass	3
15	Base	Stepper Motor Assembly	3
16	Back Plate	Stepper Motor Assembly	3
17	Body	Stepper Motor Assembly	3
18	Axial Rod	Stepper Motor Assembly	3
19	AFBMA 12.1.4.1 - 0050-11 - 10,DE,AC,10_68		6
20	B18.6.7M - M3 x 0.5 x 5 Type I Cross Recessed PHMS --5S		12
21	Stepper Motor Mount NEMA_17 Sized		4
22	1 belt drive hanger		7
23	Driven Gear Support		2
24	AFBMA 20.1 - 17-2 - 12,SI,NC,12_68	Bully	5
25	Metric - Spur gear 0.5M 16T 20PA 2FW --- S16N75H50L1N		4
26	Motor		2
27	Wodden Rack		1
28	Folding Board	400 x 250 (mm) Wooden board	4
29	Pushing Hinge		1

3.3.2.1 Position view

Figure 3.13 shows the mechanism move for the clothes folding machine, we can see the implementation for each part mentioned before as a line and the points of connection between these linkages.

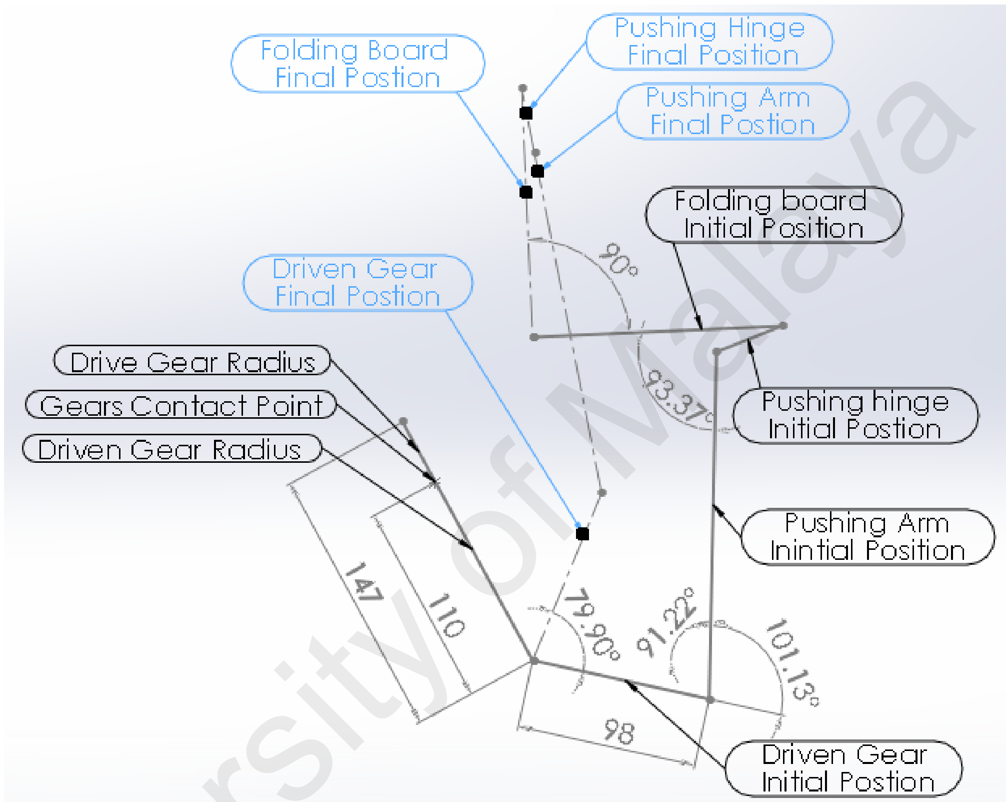


Figure 3. 13 First and Final Mechanism Position

3.3.3 Motor Selection:

To specify the accurate engineering data for the motor, we have to define the characteristics for the motor (Torque, Pulses / revolution, rising and falling time). All of these characteristics can be calculated as per motion requirement and system mechanism movement.

3.3.3.1 Stepper motor:

Stepper motor is one of the most popular motors used to achieve an exact position with a high resolution and precision.in this section we will find the characteristics (Torque, Pulses/revolution, rising and falling time) of the stepper motor that we used to actuate our mechanical mechanisms.

3.3.3.1.1 Finding the Motor Torque:

The stepper motor torque is divided into two types of torque, the acceleration torque, and the running torque. The acceleration torque is related to the system inertia and system acceleration, the running torque is due to friction and oppose forces need to overcome them.

$$T = T_{acc} + T_{run} \quad (3.1)$$

$$T_{acc} = J * \alpha \quad (3.2)$$

$$T_{run} = F * d \quad (3.3)$$

$$J = J_{drive} + J_{driven} + (J_{link} + J_{holder} + J_{wooden\ plate}) \quad (3.4)$$

Table 3. 3 Machine mechanism parts (Mass, Moment of Inertia)

Item #	Part Description	Material/Mass (grams)	J (moment of inertia around output axis) gram.mm^2	J (moment of inertia around moving axis) gram.mm^2
1	Drive Gear	Brass/425	173929.7	173929.7
2	Driven Gear	Brass/3840	11773104.3	11773104.3
3	Linkage	Alloy 1060/55	1757444.3	14086574.5
4	Holing pad	Alloy 1060/52	34995.4	
5	Wooden board	Oak wood/560	12505000.0	
	Total Moment of inertia			43252615.8

Since we are designing the system, We assumed the acceleration to be $\frac{\pi}{2}\ {rad}/{s^2}$. This assumption was concluded as we required the wooden board to travel from its initial position the final one by 1 second.

Recall equation (2) and substitute the values of J mentioned in table 3.3 and the assumed α we can get the following torque value in N.M

$$T_{acc} = 43252615.8 * \frac{\pi}{2}\left(gram.mm^2 * {rad}/{s^2}\right)$$

$$T_{acc} = 67906606.8 * 10^{-9}\left(kg.m^2 * {rad}/{s^2}\right)$$

$$\boldsymbol{T_{acc} = 0.068\ N.M}$$

For the running torque we are required to find the effected forces for the system that acts on point B for the Driven Gear. Figure 3.14 shows the full mechanism parts, (a) shows the dimensions between the contact point of the parts. (b) the mechanism real shape.

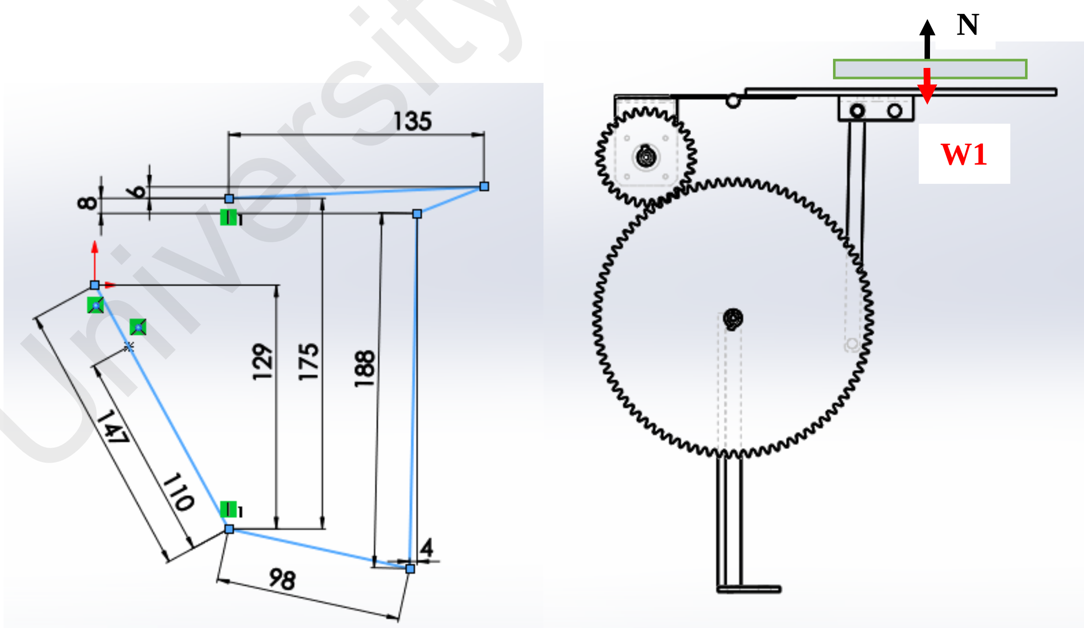


Figure 3. 14 Machine mechanism (a) shows the dimensions between the contact point of the parts. (b) the mechanism real shape.

Recalling the equation (3)

$T_{run} = F * d$

Using Newton's Second Law (NSL)

Cloth = 300 N

$\sum F_y = 0$

$N - W1 = 0$

where N is the normal force from the plate and

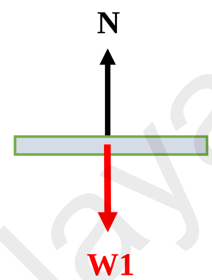
$W1$ is the cloth's weight, accordingly:

$N = 2.943\ Newton$

Wooden plate = 560 N

$\sum F_y = 0$

$R + F1 - N - W2 = 0$



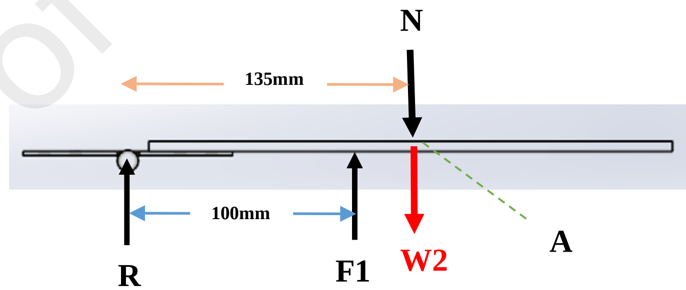


Figure 3. 15 Force analysis for the moving mechanism

where R is the reaction force on the hinge

$F1$ Normal force from the Pushing hinge and

$W2$ is the plate's weight, accordingly:

$R + F1 = 8.4366$

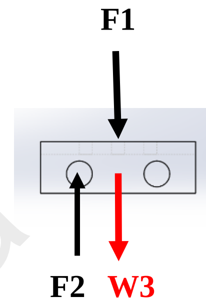
$\sum M_A = 0$

$0.035 * F1 + 0.135 * R = 0$

Solving the previous two equations lead to:

$R = -2.95281\ Newton, F1 = 11.38941\ Newton$

Pushing hinge = 54 N



$\sum F_y = 0$

$F2 - W3 - F1 = 0$

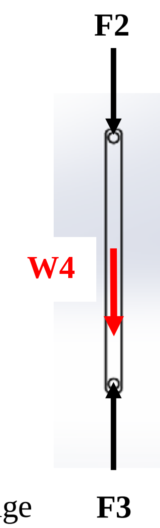
where $F2$ is the reaction force from the link,

$W3$ is the Pushing hinge weight and

$F1$ is the resultant force from plate and cloth, then:

$F2 = 11.91915\ Newton$

Linkage Arm = 52 N



$\sum F_y = 0$

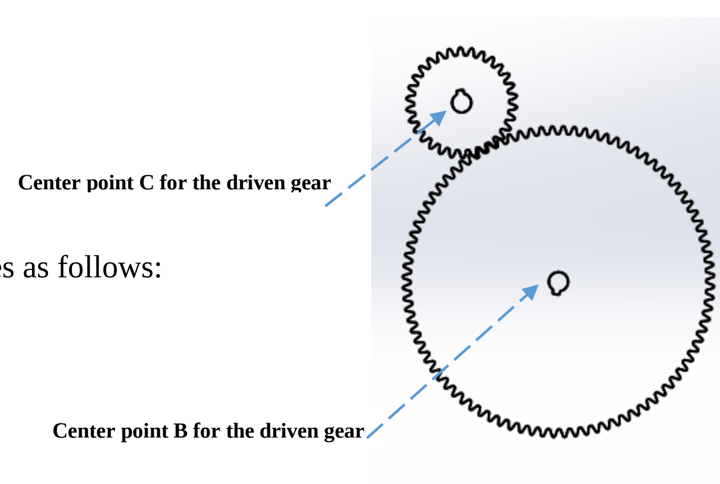
$F3 - W4 - F2 = 0$

where $F2$ is the resultant force from upper parts i.e. Cloth, plate and Pushing hinge

$W4$ is the link's weight and

$F3$ is the reaction force from the gear, then:

$F3 = 12.42927\ Newton$



For the gears meshing, we finalize the forces as follows:

$\sum M_B = 0$

$0.098 * F3 - 0.11 * F_t = 0$

where, $F3$ is the resultant force from upper parts

F_t, F_r are the tangential and redial forces, respectively.

Solving this equation lead to:

$F_t = 11.07334964\ Newton$

$\sum M_c = 0$

$T - 0.037 * F_t = 0$

Solving this equation lead to:

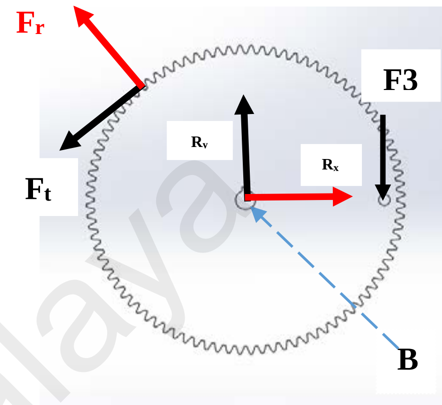
$T = 0.4097139\ N.m$

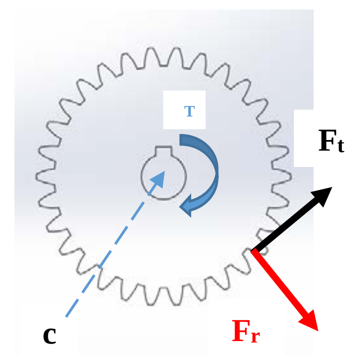
So now by adding the two torques together

we will get the total motor torque

$T = T_{acc} + T_{run}$

$T = 0.068 + 0.41 = 0.48\ N.M$





3.3.3.1.2. Find the Pulses for the Motor per one Full Move .

To calculate the minimum pulses for the motor to get the desired output, we have to analyze the mechanism machinary and to define the angle required by the drive motor, in addtion to the pulses of the rising and falling time.

So by looking to the side view of the system we find that the diven Gear (88 teeth) is travilling a 80^0 angle to reach the desired output postion. By converting this angle to a travilling distance on the parameter of the driven gear and reflected it to the drive Gear (30 teeth) we can find the travilling angle for the motor shaft and then calculate the pulses required.

$$\frac{\Theta_1}{\Theta_2} = \frac{r_2}{r_1}$$

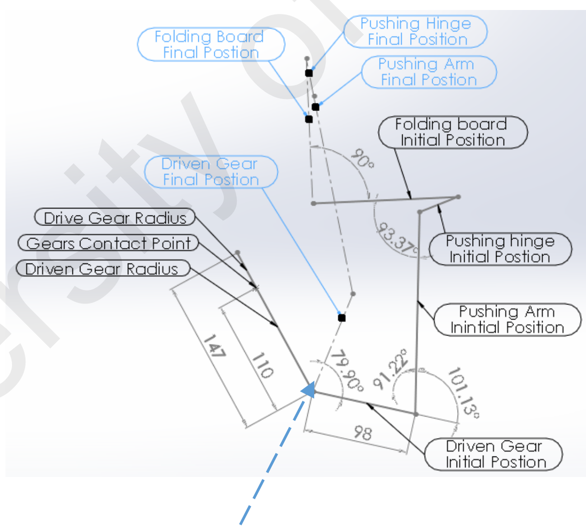
$$\Theta_1 = \frac{r_2}{r_1} * \Theta_2$$

$$\Theta_1 = \frac{0.11_{mm}}{0.037_{mm}} * 1.4_{rad}$$

$$\Theta_1 = 4.16\,rad \longrightarrow 238.5\,degree$$

Where

$r_2, r_1, \Theta_2, \Theta_1$ are driven gear raduis, drive gear raduis, driven gear travilling angle , drive gear travilling angle respectively



Θ_2 *Driven gear travilling angle* 80 *degree*

Figure 3. 16 Initial and Final positions

By selecting a 1.8^{o} stepper motor, and with 239 steps required to reach the desired position, we can calculate the required pulses needed by the motor to complete the rotation. For one pulse we get 1.8^{o} rotation and for 239 degree we will require a $133 \frac{\text{pulses}}{\text{second}}$.

ifwe consider a 0.1ms for rising time and the same for the falling time so the total pulses for the motor for one move will be as $\text{Total pulses} = 133 + (2 * 13.3) = 159.6$

$$= 160 \text{ pulses for one move}$$

To complete one revolution the motor required $\frac{239}{360} = 0.66$ present the relative value ro the action move to the full rotaion. so 242 pulses is required To complete one rotation.

3.3.3.2 DC motor

For the conveyor system that do the task of transferring the clothes to the delivery area we can use the normal DC motor, with the precise specifications of (Torque, Revelations). How to select the proper motor depending on the torque and rotation speed will be explained next?

3.3.3.2.1 Calculating the DC motor torque.

The torque of the motors is divided into running torque and the acceleration torque. Here because of the small size of the motor moment of inertia that will reduce the acceleration torque to be approximately neglected comparing to the running torque that is created by analyzing the system kinetics (recall equations (3.1,3.2,3.3)). we will only consider the running toque in our calculation to select the proper motor size. Because the accelerating torque will be too small and nearly zero.

$$T = T_{acc} + T_{run}$$

$T_{acc} = J * \alpha$

$T_{run} = \frac{1}{2} D(F + \mu mg)$

$T_{acc} = J_{drive} * \alpha$

J_{drive}= $1.2 * 10^{-9}\ KG.M^2$

α=$\pi/_2\ ^{rad}/_{s^2}$

$T_{acc} = 1.2 * 10^{-9} * \ ^{\pi}/_2$

$T_{acc} = 1.2 * 10^{-9} * \ ^{\pi}/_2$

$T_{acc} = 1.9 * 10^{-9}\ N.M\ which\ is\ nearly\ zero$.

For the running Torque we can use the following formula for a moving load on a conveyor

$T_{run} = \frac{1}{2} D(F + \mu mg)$ ……………………………………………………..….(3.5)

Where T,D,m,g,µ,F are Torque(N.M),Roller diameter(M),Mass of Load(KG),Gravity acceleration($^m/_{s^2}$) ,Friction coefficient, External force (N) respectively .

From the design the inputs data are:

D = 2 mm , F = 0 N, m = 0.8 KG, g=9.81 $^m/_{s^2}$, µ = 0.3 assumed as the belt made of rubber.

$T_{run} = \frac{1}{2} D(F + \mu mg)$

$T_{run} = \frac{1}{2} * 2 * 10^{-3}(0 + 0.3 * 0.8 * 9.81)$

$T_{run} = 2.354 * 10^{-3}\ N.M$

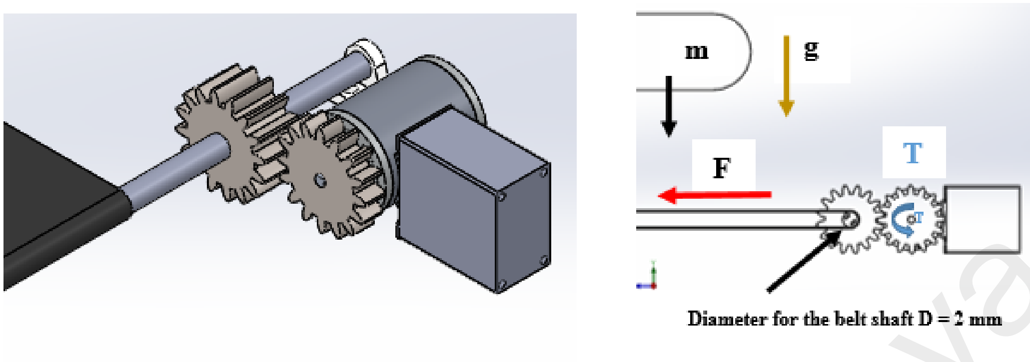


Figure 3. 17 Kinetics analysis for the DC motor

3.3.3.2.2 Calcualating the motor speed (revelution per minute)

The need of transfering the cloth for 400 mm lead us to search for a way of doing it. By using a simple DC motor we can fulfil the task. To identify the motor speed we will calcualate it as the total travelling distance for the cloth is 400 mm withen 1 seconed , so the speed will equal to 400 $^{mm}/_{s}$ converting this value to RPM, it will equal to 24000 $^{mm}/_{min.}$. to make it revolution per minute we require to transfer the linear distance to rotational move for the driven/drive gear. Knowing that the raduis of the gears are 4.5 mm we can just devide the 24000 by the raduis to get the rotation angle, then devide the value by 2π we will get the speed for the motor per minute.

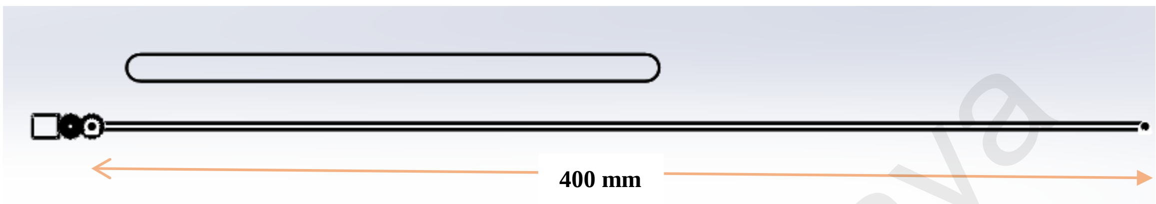
By equations

$$400\,\frac{\mathrm{mm}}{\mathrm{s}} * \frac{60\mathrm{s}}{\mathrm{min.}} = 24000\,\frac{\mathrm{mm}}{\mathrm{min.}}$$

$$\text{rotation angle} * \text{raduis} = \text{total travelling distance} = 24000\,\frac{\mathrm{mm}}{\mathrm{min.}}$$

$$\text{rotation angle} = \frac{\text{total travelling distance}}{\text{raduis}} = \frac{24000\ \text{mm}}{4.5\ \text{mm}} = 5334\ \text{rad}\ .$$

$$\text{Motor revolution} = \frac{\text{total degrees}}{2\pi} = \frac{5334\ \text{mm}}{2\pi} = 850\ \text{rev/min.}$$



3.3.4 Machine Control Design

Explaining the control side of the designed machine will take place in the following sections. These sections will include the sequence diagram, Boolean equations, ladder logic, and circuit diagram.

3.3.4.1 Boolean equations

the Boolean equations represent the relations between the output variable (Virtual and Actual) and the programmable instructions logic. Every variable has to has a set value and reset value, so it can be correctly programmed and inserted to PLC. Table 3.4 shows the Boolean equations for our project.

Table 3. 4 Boolean equation for the Machine logic

RUNG #	Variable	SET	RESET
0	HRT00M1F	PB+S1	TIM 01
1	TIM 00	HRT00M1F	
2	M1F	HRT00M1F	TIM 00
3	HRT01M1BW	TIM 00	TIM 01
4	TIM 01	HRT01M1BW	
5	M1BW	HRT01M1BW	TIM 01
6	HRT02M2F	TIM 01	TIM 03
7	TIM 02	HRT02M2F	
8	M2F	HRT02M2F	TIM 02
9	HRT03M2BW	TIM 02	TIM 03
10	TIM 03	HRT03M2BW	
11	M2BW	HRT03M2BW	TIM 03
12	HRT04M3F	TIM 03	TIM 05
13	TIM 04	HRT04M3F	
14	M3F	HRT04M3F	TIM 04
15	HRT05M3BW	TIM 04	TIM 05
16	TIM 05	HRT05M3BW	
17	M3BW	HRT05M3BW	TIM 05
18	HRT06DCM1	TIM 05	TIM 06
19	TIM 06	HRT06DCM1	
20	M1DC Running	HRT06DCM1	TIM 06
21	HRT07DCM2	TIM 06	TIM 07
22	TIM 07	HRT07DCM2	
23	M2DC Running	HRT07DCM2	TIM 07

3.3.4.2 Sequence diagram

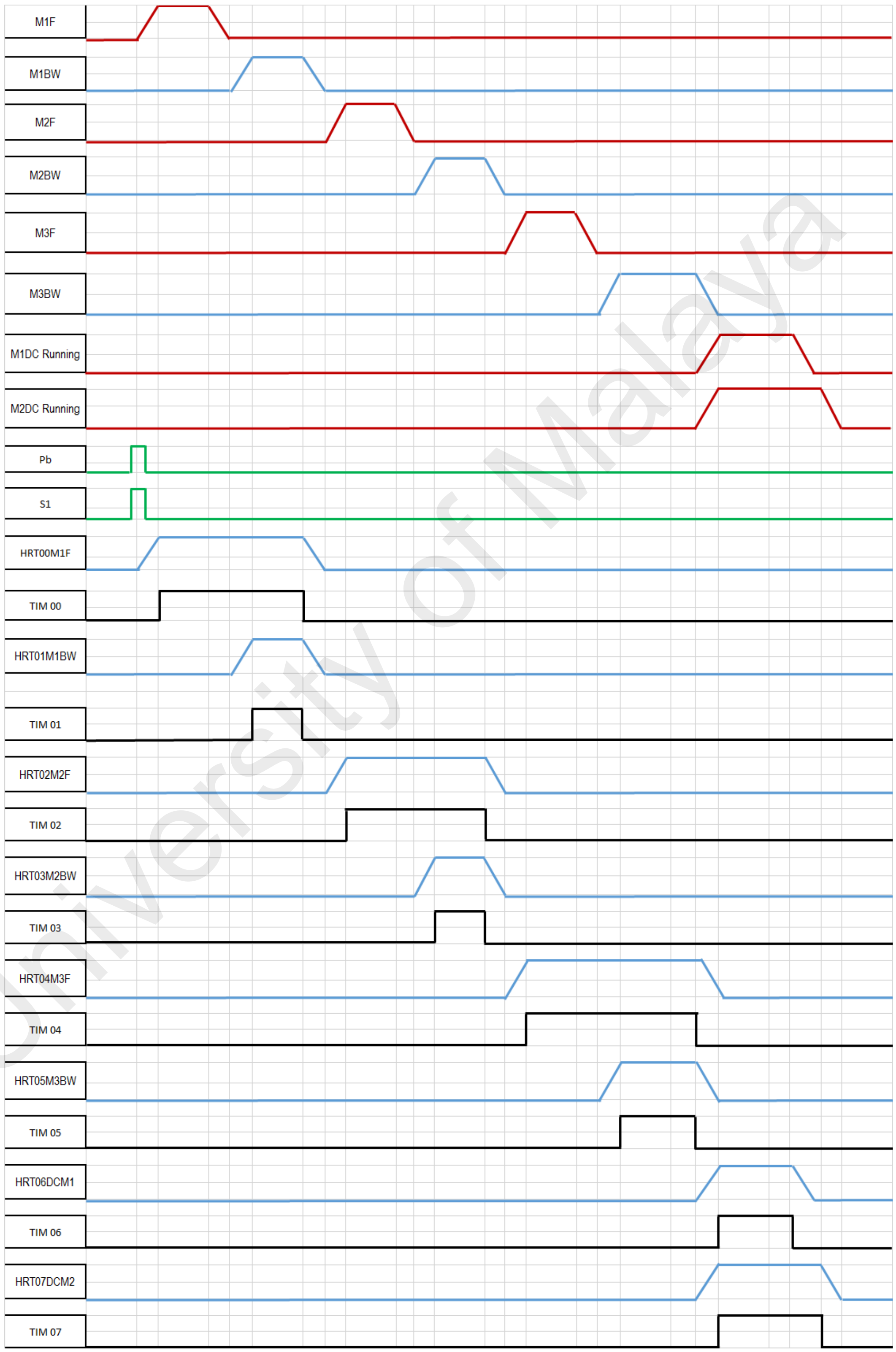


Figure 3. 18 Sequence diagram for the machine logic

The sequence diagram describes the sequence of the desired logic intended to be done by the engineer or the designer. Figure3.18 Shows the sequence diagram for the clothes folding machine.

3.3.4.3 Ladder Logic

Ladder logic it is the way which the engineer transfers the data and the logic to the PLC. Ladder logics always done by a proper software that can be interface with the PLC without any problems and interruptions because it is the final step of programming to be done before transfer the data to the PLC. Figure 3.19 Shows the ladder logic diagram for the Clothes Folding Machine.

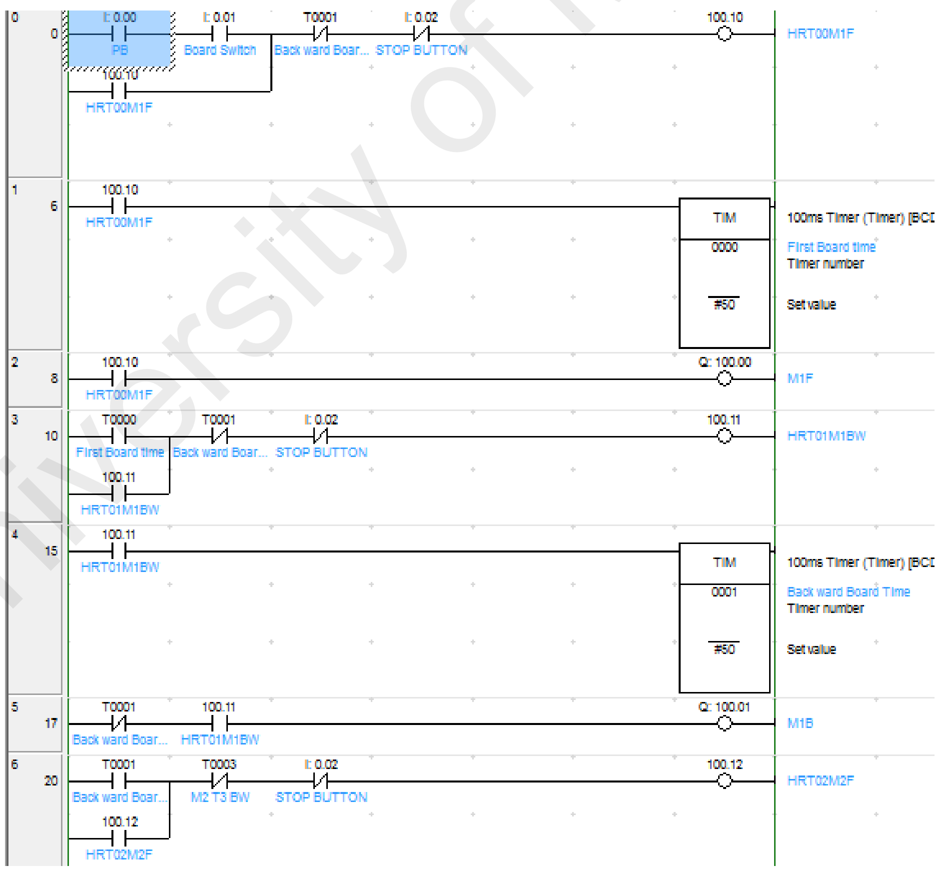
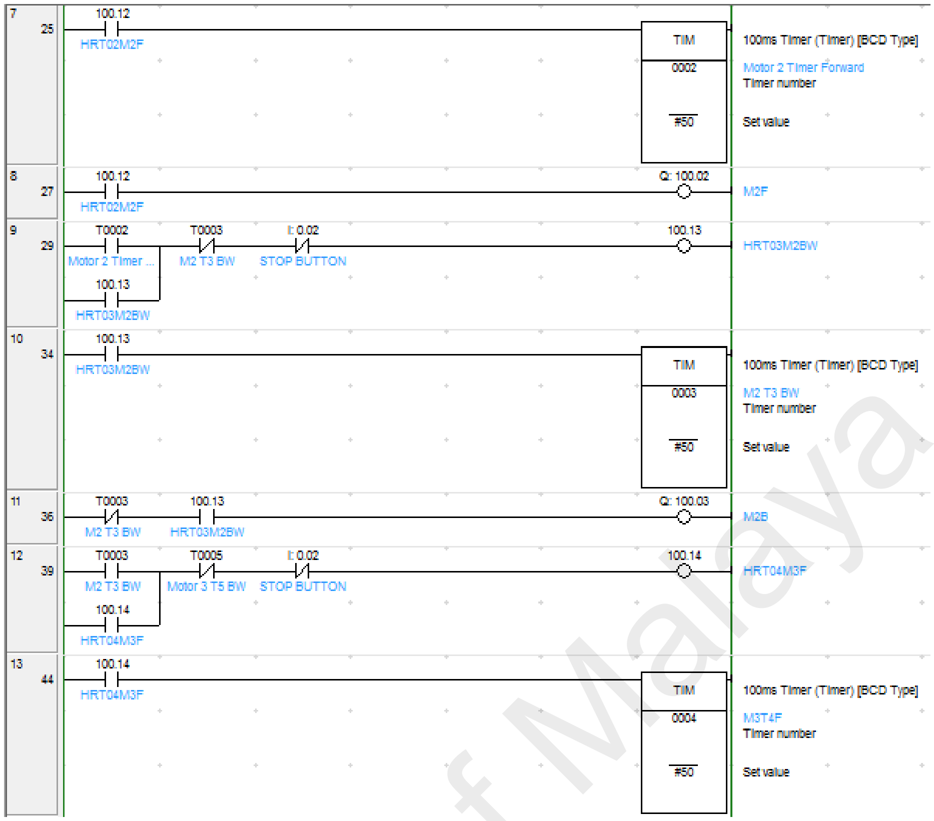


Figure 3. 19 ladder logic diagram for the machine logic



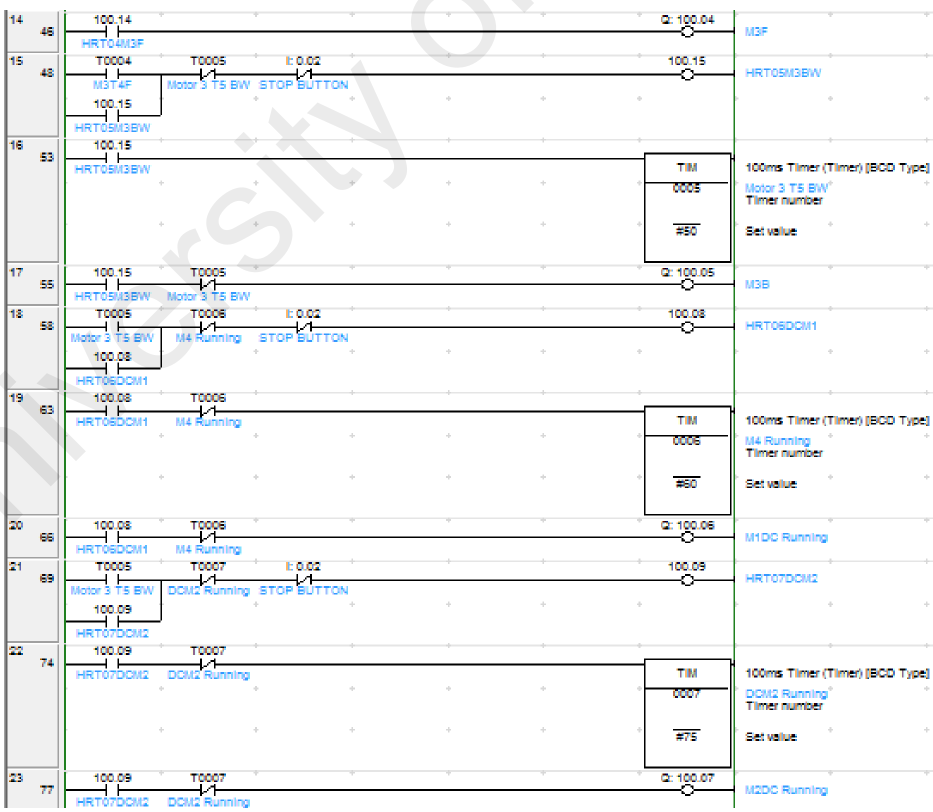


Figure 3.19 Ladder logic diagram for the machine logic (continued)

3.3.5 Stepper motor driver

After the selection of the stepper motor of a 1.8^{o} step, torque (4.8 N.M) , and 160 pulses. We can go and select the proper stepper motor driver to do the task for providing the accurate pulses to the motor to rotate. Because our torque and rotations are not that big values we are not going to face any serious issue to pick a random driver with two direction rotations that complies with the PLC and stepper motor current and voltage. Figure 3.20 present three different types of stepper motor drivers that do the same task of driving the motor but from different manufactures (STP-DRV-DL050, M542, AND TB6600). Figure 3.21 shows an implementation of wiring connection to drive the stepper motor, we can easily see that the input for the drivers are the Vcc and the signals from the PLC which are the (-Pulse) and the (-DIR). Here we explain the driver model (STP-DRV-DLO5) from sure step automation company. This driver is compatible to be used by PLC signal or even by microchips pulses. Figure 3.22 represent the wiring diagram for the driver with the PLC and Motor to introduce a proper understanding of our system. After complete the full Vdcc connection to the motor and the PLC, you can find the signal output Y0 (-step), Y1(-dir) from the PLC going to the drivers these two signals control the motor rotation CW, CCW. As per the PLC program. Table 3.5 introduce the functions of activating Y0, Y1.

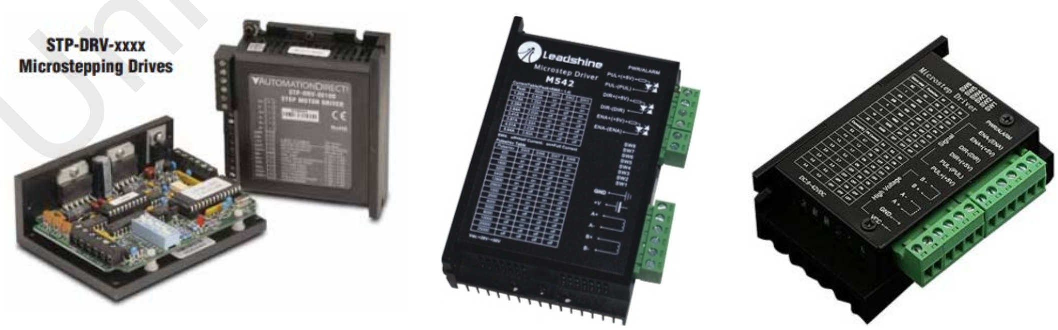


Figure 3. 20 Stepper motor drivers a) STP-DRV-DLO5. b) M542. c) TB6600.

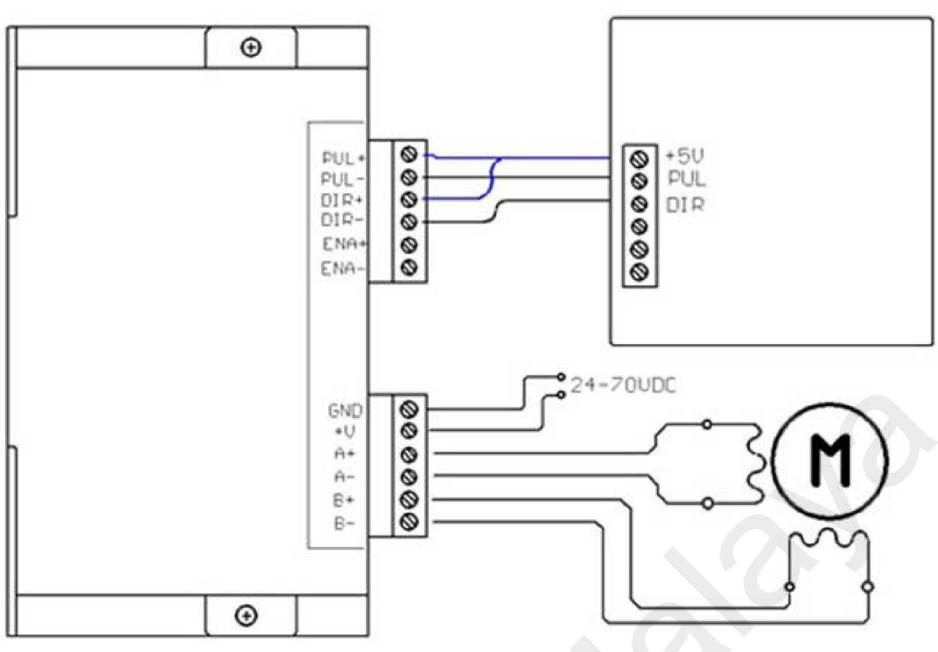


Figure 3. 21 Implementation of drivers wiring

Table 3. 5 Connection configuration for the Stepper motor driver

Pin Function	Details
PUL+(+5V) PUL-(PUL)	Pulse signal: In single pulse (pulse/direction) mode, this input represents pulse signal, active at each rising or falling edge (set by inside jumper J1); 4-5V when PUL-HIGH, 0-0.5V when PUL-LOW. In double pulse mode (pulse/pulse) , this input represents clockwise (CW) pulse， active at high level or low level (set by inside jumper J1). For reliable response, pulse width should be longer than 1.5μs. Series connect resistors for current-limiting when +12V or +24V used.
DIR+(+5V) DIR-(DIR)	DIR signal: In single-pulse mode, this signal has low/high voltage levels, representing two directions of motor rotation; in double-pulse mode (set by inside jumper J3), this signal is counter-clock (CCW) pulse， active at high level or low level (set by inside jumper J1). For reliable motion response, DIR signal should be ahead of PUL signal by 5μs at least. 4-5V when DIR-HIGH, 0-0.5V when DIR-LOW.
ENA+(+5V) ENA-(ENA)	Enable signal: This signal is used for enabling/disabling the driver. High level (NPN control signal, PNP and Differential control signals are on the contrary, namely Low level for enabling.) for enabling the driver and low level for disabling the driver. Usually left **UNCONNECTED (ENABLED)**.

Table 3. 6 Stepper motor driver electrical specification

Parameters	M542			
	Min	Typical	Max	Unit
Output current	1.0	-	4.2 (3.0A RMS)	A
Supply voltage	20	36	50	VDC
Logic signal current	7	10	16	mA
Pulse input frequency	0	-	300	KHz
Isolation resistance	500			MΩ

Table 3. 7 Stepper motor driver signals activation table

Stages	Step-/Pul-	Dir-	ENA -	Motor Action
1	0	0	0	Driver is off/ motor off
2	1	0	0	Rotate CW
3	1	1	0	Rotate CCW
4	1	1	1	Stop running

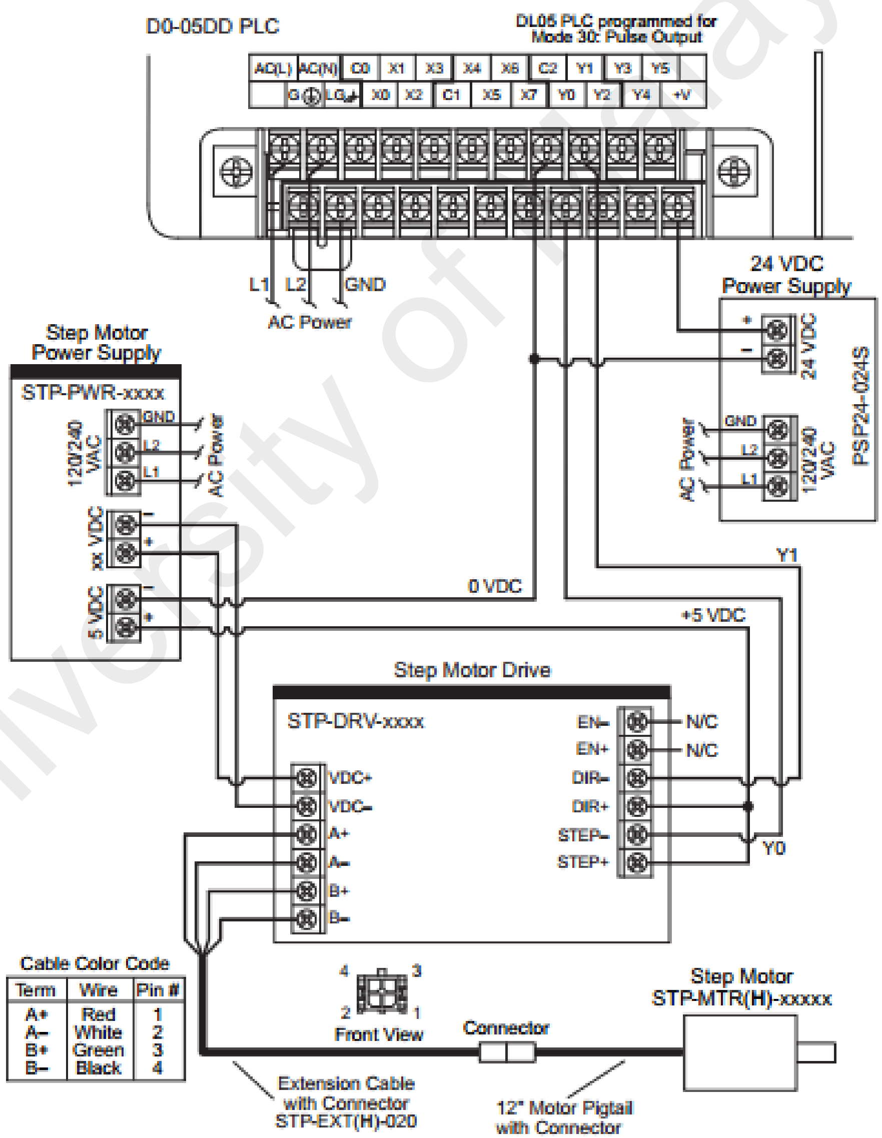


Figure 3. 212 Typical connection for the driver STP-DRV-DLO5 with the PLC

CHAPTER 4

RESULTS AND DISCUSSION

In this chapter we overview all the results and output data we found in the methodology of chapter 3. These results will be divided in three manners. The machine hardware design and assembly, the ladder logic outputs, and the actual simulation for the PLC.

4.1 Machine Hardware

The figures below will show us the full assembly of the clothes folding machine with the exploded view. In addition of its steps after each signal from the PLC.

4.1.1 Machine full assembly

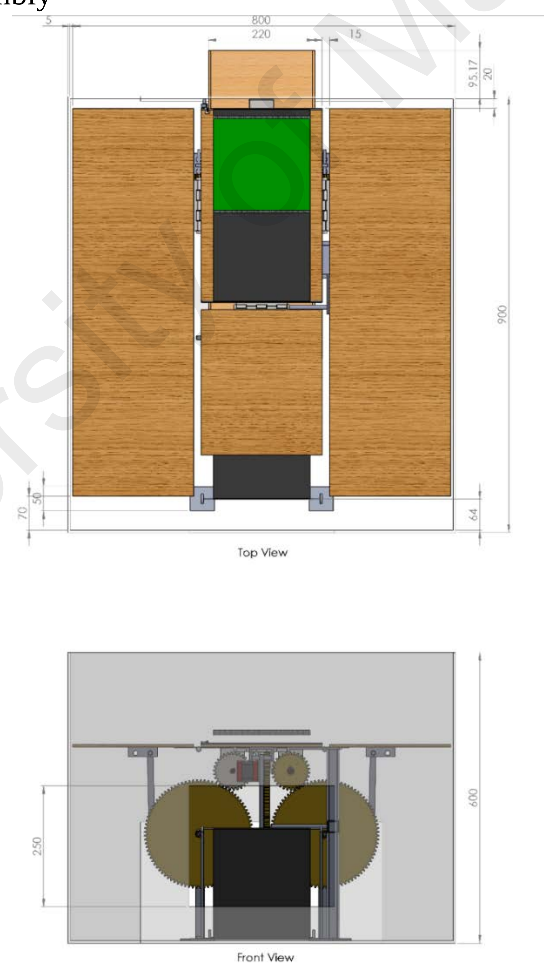


Figure 4. 1 Top and Front View for the machine with some dimensions

Figure 4.1 shows the top and front view of the final machine design including the main out dimensions, height (600 mm), width (800mm), and the depth (900mm). while the figure 4.2 shows the right view in addition with the isometric one. Note here that the right view is done to show the hidden lines and make them visible view so we can see the internal integrated parts of the machine.

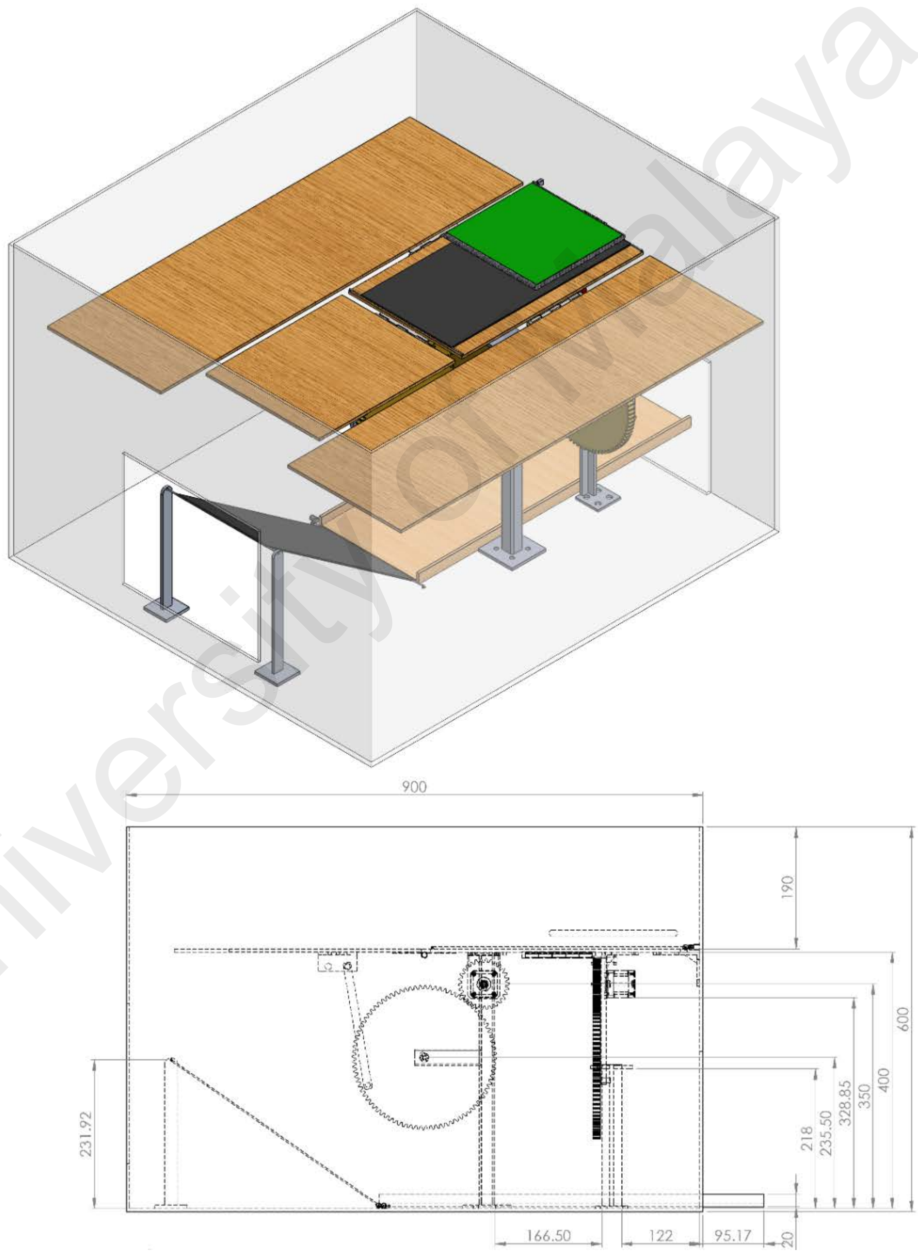


Figure 4. 2 Isometric view with the right view shows hidden line.

4.1.2 Exploded View

Figure 4.3 displays the exploded view for the clothes folding machine, with annotations that described in table 4.1.

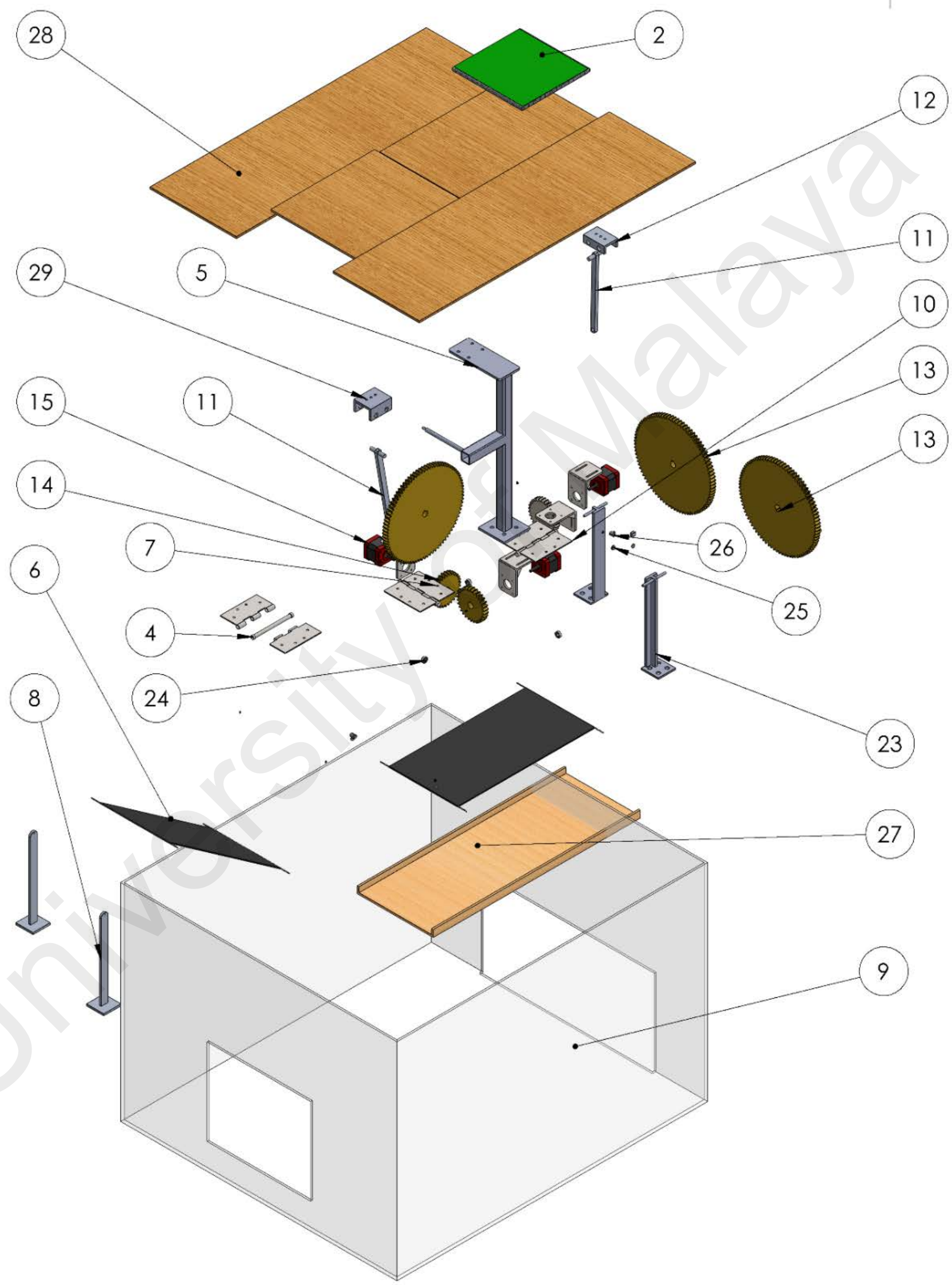


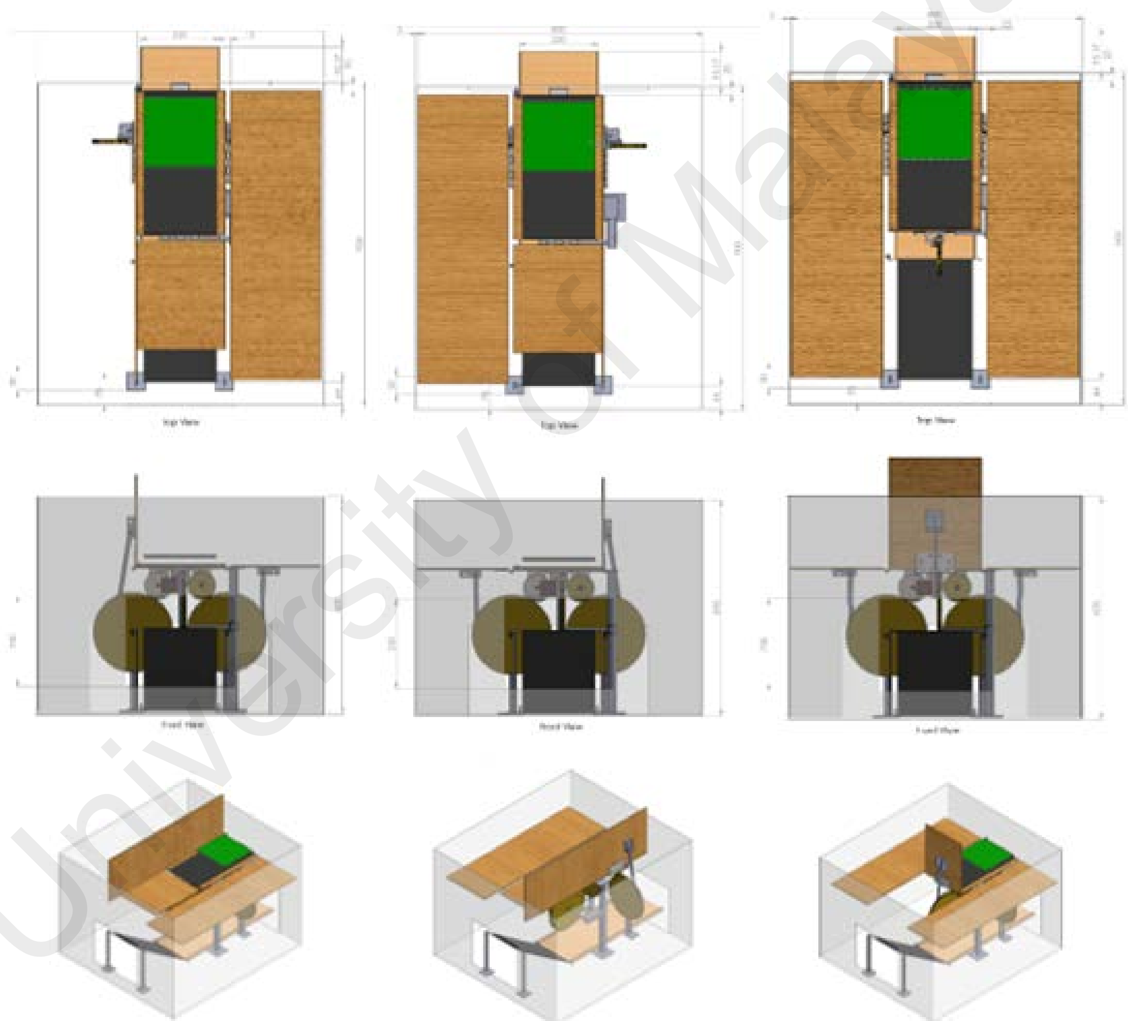
Figure 4. 3 Exploded view for clothes folding machine with annotations.

Table 4. 1 Folding machine parts with ref. annotation number to the exploded view in figure 4.3

ITEM NO.	PART NUMBER	DESCRIPTION	QTY.
1	Folding Board	Oak Wooden Board	2
2	Hinge A	Aluminum Hinged	3
3	Hinge B	Aluminum Hinged	3
4	Central Pin	Axial Pin Fixing the Hinges Parts	3
5	Pushing Arm		3
6	Pushing Hinge		3
7	Metric - Spur gear 2.5M 88T 20PA 12FW ---S88N75H50L14S1	Driven Gear / Brass	3
8	Metric - Spur gear 2.5M 30T 20PA 12FW ---S30N75H50L10S1	Drive gear	1
9	Base	Stepper Motor Assembly	3
10	Back Plate		3
11	Body		3
12	Axial Rod		3
13	AFBMA 12.1.4.1 - 0050-11 - 10,DE,AC,10_68		6
14	B18.6.7M - M3 x 0.5 x 5 Type I Cross Recessed PHMS --5S		12
15	Stepper Motor Mount NEMA_17 Sized		4
16	1 belt drive hanger		7
17	Machine frame		1
18	Clothes Representation		1
19	Driven Gear Support		2
20	AFBMA 20.1 - 10-5 - 8,SI,NC,8_68		3
21	Main Board Support		1
22	Metric - Spur gear 0.5M 16T 20PA 4FW ---S16N75H50L2N		1
23	Motor		2
24	Dc motor billow		1
25	1 belt Drive		4
26	Belt1-3^1 belt drive		2
27	rack		1
28	conveyor support		2
29	board	400 x 250 (mm) Wooden board	2
30	Metric - Spur gear 2.5M 30T 20PA 12FW ---S30N75H50L14S1	Drive Gear /Brass	2
31	Metric - Spur gear 0.5M 16T 20PA 2FW ---S16N75H50L1N		2
32	Metric - Spur gear 0.5M 16T 20PA 2FW ---S16N75H50L2N		1
33	AFBMA 20.1 - 17-2 - 12,SI,NC,12_68		2

4.1.3 Machine steps

After loading the proper ladder diagram to the PLC the simulated steps will be as the shown in figure 4.4. we can easlily see when the motors are in action for the foldig steps. Figure 4.4a is explains the first step of moving the left board for its final position. Figure 4.4b also shows the right board in action. Figure 4.4c is the middle board in action. In addition to the siometric views for every step.



a) b) c)

Figure 4. 4 Folding machine in action (a) left board in action. (b) right board in action. (c) middle board in action.

4.2 Ladder Diagram

The ladder logic program was developed and tested using the CX-Program,then loaded to the PLC. In the following series of figures, we will comment the figures and explain them briefly for every activated rung in the ladder diagram, showing the inputs, the outputs and their addresses .

Figure 4.5 shows the system condition before simulation started. then Figure 4.6 (a) and (b) presents the first step of the program, we can see that the open contactor dresses by 0.00 stands for the Push Button which is connected in series with the input switch 0.01 which stands for the board sensor that defines if the cloth exists on the board or not. Then timer T0001 is the one for reseting the output for the rung which is the vertual Holding relay adressed 100.10 to run the first motor forward by activating the T0000. We can see also that all the contactors are all high in the first rung in figure 4.5a, while the sensor is already off in figure 4.5b. even though the output still high because of the latch connection 100.10. we can also see that the 2nd rung is taking the responsibilty to activate the physical output (represented by a led in the PLC) addressed by 100.00. which stands that the siganl is sending to the motor driver while the timer T0000 is on. Keep in mind that these steps are typically done for all the motors in the machine to be forward drive.

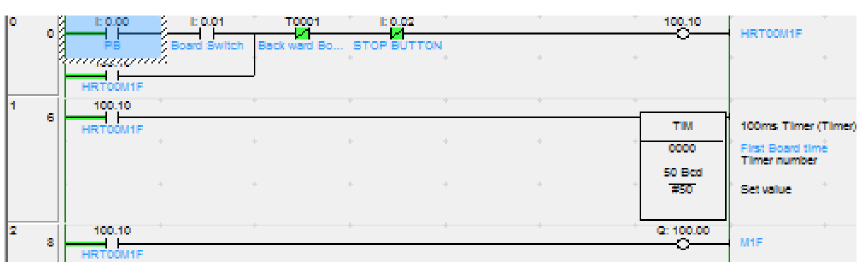
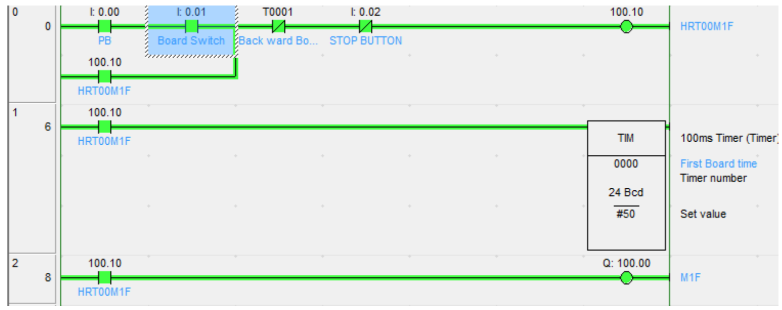
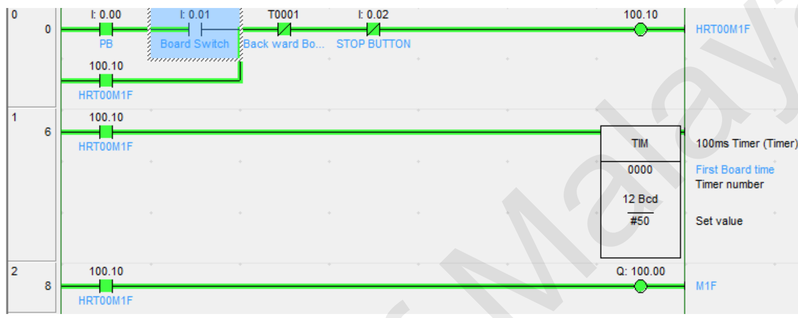


Figure 4. 5 Condition of OMRON PLC before simulation started



a)



b)

Figure 4. 6 Ladder logic diagram activation (a) physical inputs responsible for high output (b) latch 100.10 is keeping the output high.

figure 4.7 shows how the backward rotation for the motors are controlled. In rung 3 in the ladder diagram the timer T000 is latched by the output 100.11 which present the vertual holding relay for the backward Timer on rotation. The timer T0001 is set on by 100.11 and reseted by the same holding relay after T0001 time is finish. Rung 5 explains the physical output for the ladder logic in the PLC addressed by 100.01 which is shown as a led. You have to note that both outputs are high for rotating the motor in the back ward side as per the driver STP-DL05 specs requires (Y0,Y1).

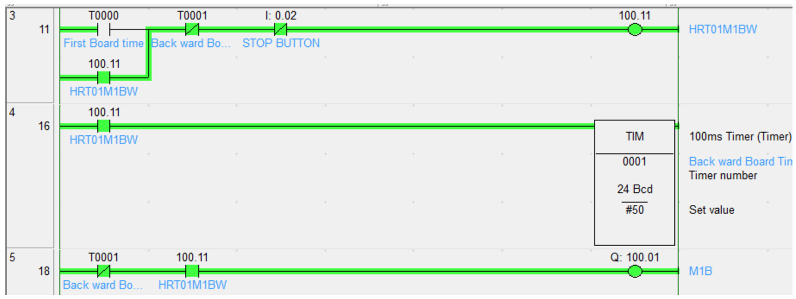


Figure 4. 7 The logic sequence of backward rotation for motor 1

Figure 4.8 shows the forward sequence for the second motor. Virtual relay setted by the timer T001 and reseted by the Timer T0002 that activate the forward motor by keeping the relay 100.12 on.

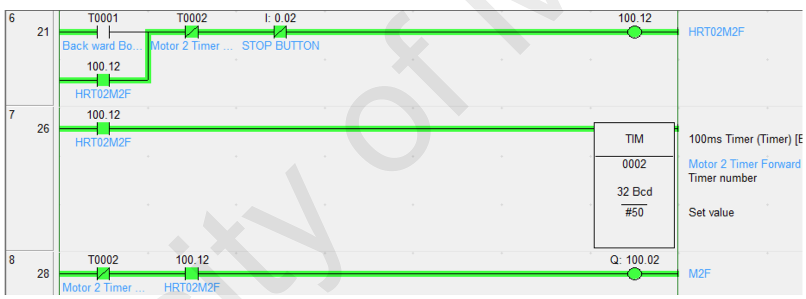


Figure 4. 8 The logic sequence of forward rotation for motor 2

Figure 4.9 shows the backward sequence for the second motor. Virtual relay 100.13 setted by the timer T0002 and reseted by the Timer T0003 that activate the forward motor by keeping the relay 100.13 on.

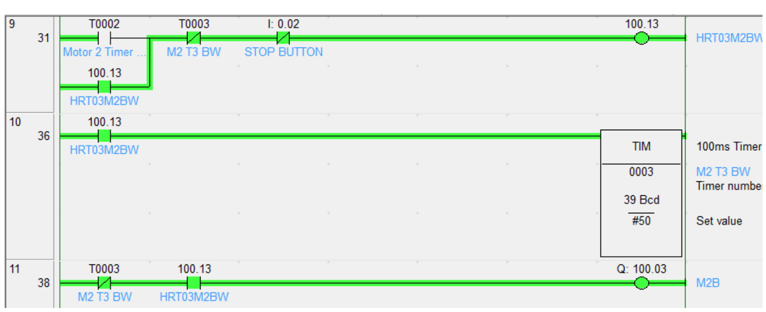


Figure 4. 9 The logic sequence of backward rotation for motor 2

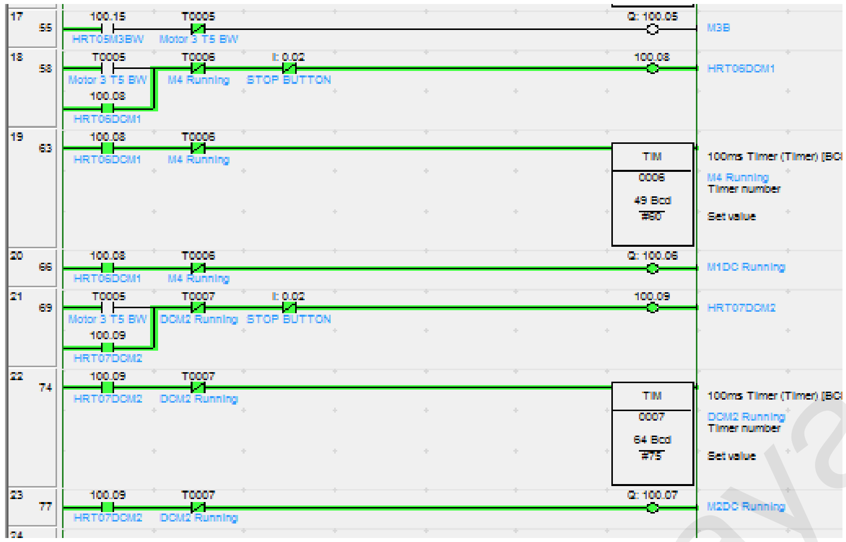


Figure 4. 10 Ladder diagram while activating the conveyor DC motors

Figure 4.10 shows the DC motors activated in the rung 20 and 23 under the addresses of Q100.06, Q100.07.

4.3 Simulation Using OMRON PLC Training Kit

Having an over view of the system simulation by the PLC we be discussed in this sub-chapter. Figure 4.11 represent the condition of the OMRON PLC before the program been in action. We can clearly see the inputs switches (PB,S1,S2) and the outputs (Y0,Y1,Y2,Y3,Y4,Y5,Y6,Y7).

S0 S1 S2

Figure 4. 11 Omron PLC on standby condition

Once we activate the system by the Push Button (S0) and with the cloth reading sensor (S1) that fixed on the main wood boards, the system starts to run. The first step of the system is implemented by the figure 4.12 where we can see that the output Y0 is high and the led number 0 is on. This activation means that the first stepper motor is running forward by receiving this signal.

Figure 4. 12 The first motor receives the signal and running

Changing the status of the switches (S0, S1) from active to Off will not stop the system, since, the system is already latched by the virtual holding relay 100.10. this can be seen by figure 4.13.

Figure 4. 13 Holding relay latch keeps the system ON

In Figure 4.14 we can see that the both outputs Y0, Y1 are high and the led numbers (0,1) are on, indicating that the stepper motor is running backward as per the motor driver specifications that when the both (Pulse-/step-) and the Dir- are high the motor will change his way of rotation.

Figure 4. 14 The first motor receives the signal and running

Figure 4.15 shows the motor 2 in action for the second folding step by the second wooden board. The output Y2 are high and the led 2 are on. Indicating that the second motor is running forward.

Figure 4. 15 The second motor receives the signal and running forward

Figure 4.16 represent the backward movement for the second motor when the both outputs are high Y2, Y3 and the leds 2,3 are on. Here the driver of the stepper motor receives the signal from the PLC to reverse the forward rotation and make it backward.

Figure 4. 16 The second motor receives the signal and running backward

The third action of the machine is impelemented by figure 4.17 for the third stepper motor, the led 4 are on means that the output Y4 is high, and the driver is receiving the signal to run the motor forward.

Figure 4. 17 The third motor receives the signal and running forward

Moving the third wooden board back to its desired postion is done impemented by the figure 4.18 where we can see the leds 4,5 are on and the outputs Y4,Y5 are high to ignite the motor driver to run back the motor. If you follow the ladder diagram rung number 19 you will see that this leds will be on more time than the others. Because the board has to move backward more than the forward angle position.

Figure 4. 18 The third motor receives the signal and running backward

Running the DC motors with the PLC signal is presented in the figure 4.19 where we can see that led 6,7 are on and the outputs Y6, Y7 are high. These motors are responsible to deliver the cloth to its desired final position to be delivered to the operator.

Figure 4. 19 Indicators are on as DC motors are in action

in figure 4.20 we can see that if we activate the stop button switch S2, the program will be interrupted and the machine will stop running since all the input signals has been stopped.

Figure 4. 20 Switch 2 activated to stop the system from running

Once the PLC activated and the DC motors are running we can note that the second DC motors still running (led 7 is on) while the first one is off (led 6) in figure 4.21 and this is represets the ladder logic timer time, since we keep it on for more seconds than the first motor.

Figure 4. 21 Second DC motor still on while the first one is off.

figure 4.22 shows the final shape of the cloth after finishing the task. In this shape the clothes will be delivered to the operator by the machine.

Figure 4. 22 Final shape of folded cloth, delivered by the machine.

CHAPTER 5
DISCUSSION AND RECOMMENDATION

Our goal in this research was trying to introduce a fully automation system, that identifies how the integrity of a pure mechanical with a control system can be smoothly go to achieve the desired aims.

5.1 Conclusion

Designing the clothes folding machine was an improvement of the manual steps where normal humans used to fold their clothes, and make it fully automatic. Fully automatic mean you just drop your piece of cloth inside the machine and it will deliver it to you folded within a short time. But facing obstacles as the difference in clothes shapes and categories forced us to choose just one type of these clothes and simulate our machine to fold it. This shape was the T-shirts, where we try folding it within six series steps. Shown in figure 5.1

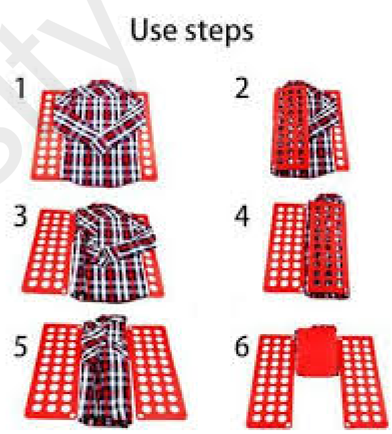


Figure5. 1 Final shape of folded cloth, delivered by the machine.

After reaching to the suitable design through many drafts and sketches, engineers software takes a place to develop the machine assembly and control. Using solidworks was a wise decision to complete the task of drawings, and parts assembly even to animate the machine. Then heading to CX-Program that can interface easily with the PLC OMRON which we use to simulate the machine movements by. It was essential for the designer to build the ladder logic diagram for testing the system and simulate it with the CX-program before transferring it to the PLC where he can put his design in action.

Using the human intelligence in the process was one of weak point of this machine. Operator still has to feed the cloth with a proper way, so the machine can fold it easily. From here we can see that the machine was designed to do only a few certain simple steps to fold the cloth, not to make it complex and more intelligent.

5.2 Recommendations

For future work, and after building the first prototype of the machine and test it, it is necessary to integrate this machine with others, to make it more easy for the operator to deal with it. These integrated machine could be like design a way to feed the machine with clothes as hanging the clothes form the shoulders and feed them to the core of the machine, or even improve it more like adding a box where the machine can decide the shape of the clothed by itself using advance image processing and artificial intelligence science. This step surely need a high precise cameras and huge data collection to do the image processing for the feed cloth.

5.3 What we gain by going through this machine design?

Programming the control is surely depending on the controller type itself. Here we use the PLC to simulate the task, if PLC is not available or expensive. Still you can find your controller by using the Arduino kit, where it can easily interface with the stepper and DC motors in the machine using a proper driver. All of these electronic devices has to be technically applicable for interfacing each other. Specifically, the current value that present the key of running the electronic devices.

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