Palestine polytechnic University

Hebron – Palestine

College of Engineering

Mechanical Engineering Department

Design and implementation of a Petit-four machine

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By the guidance of our supervisor , and by the acceptance of all members in the testing committee, this project is delivered to Mechanical Engineering Department in the college of Engineering, to be as a partial fulfillment of the requirement of the department for the degree of B.sc .

Supervisor signature

Testing committee signature

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By

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Abstract

Most Bakeries and Pastry shops in Palestine uses the traditional way of producing the Petit-four sweets, the traditional way has many disadvantages in terms of Inconsistency of a petit-four pieces, Effort and a long time in production, in addition a unhealthy product As a result of the use of human hands in production.

This project aimed to solving this problem by design and implementation of a Petit-four machine that producing the petit-four in automatic way. The machine was desired to reduce the time and effort that need for production and to ensure the healthy of the product.

الاهداء

نهدي مشروعنا هذا الى قدوتنا ومعلمنا وقائد امتنا محمد صلى الله عليه وسلم

الى من رعونا بنور قلبهم..وحمونا بحكمتهم..وقدموا لنا حنانهم وقلبهم..إلى من سقونا وأطعمونا وربونا وأدبونا..ومنحونا الحب والحنان ..الى من فرشوا طريقنا بالورود..ورافقونا في الصعود..إلى من فتحوا أمامنا أبواب التفوق والنهوض وكسر قيود الظلام..إلى بسمة الأمل ونبع الحنان إلى من هم بلسم روحنا إلى ورود حياتنا إلى من رعونا بحنانهم ..

اليكم والدينا ..

إلى من يحملون في عيونهم ذكريات طفولتنا وشبابنا....إخوتنا وأخواتنا

إلى من ضحوا بحريتهم من أجل حرية غيرهم....الأسرى والمعتقلين

إلى من هم أكرم منا مكانة....شهداء فلسطين

إلى شمعة أحرقت نفسها لتضيء لمن هم حولها..اليك يا وردة فاح عبيرها وطاب شذاها..اليك يا وردة زاد بريقها ورونقها..ماذا بوسعنا أن نقول لقد هربت منا الكلمات وتشتت شمل العبارات..لا ندري أي الكلام يفيدك حقك..بل أي العبارات تليق بمقامك.. نديم الشكر الى مشرفنا العزيز الدكتور يوسف السويطي الذي أنار لنا الطريق ولم يبخل علينا بتوجيهاته ونصائحه والى معلمينا الذين لم يبخلوا علينا بعلمهم والذي لولا جهودهم لما وصلنا لما نحن عليه الان كما ونوجه شكر خاص الى المخرطة الهندسية الميكانيكية ممثله بمديرها المهندس صالح دويك لجهودهم معنا في خراطة اجزاء الالة الميكانيكية ، ولكل من ساهم بإنجاز عملنا هذا الذين لم يدخروا جهدا في تقديم المساعدة لنا من توفير المصادر والمراجع اللازمة وكل التقدير للذين منحونا كل التشجيع .

ولا ننسى أيضا أصدقائنا الذين وقفوا إلى جانبنا في السراء والضراء وخصوصا الذين كانوا اصدقاء أوفياء ولم يترددوا في مد يد العون لنا سائلين المولى عز وجل بأن يجمعنا بهم في جنات الخلد مع الرسل والصديقين والشهداء والأبرار حيث لا يوجد فراق

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Chapter One

Introduction to Petit-four machine

1.1 Introduction .
1.2 Project idea and importance .
1.3 Recognition of the Need .
1.4 Project Objectives .
1.5 Time schedule for the project .
1.6 Total Cost for the Project .

1.1 Introduction

Petit-Four is a French dish originally sweets, label taken from French society (Petit-Four as in figure 1.1) which Means "little oven", the Petit-Four usually eaten after meals or between as a dessert with tea or coffee. There are many types of it, There's even a salty Petit Four offers on special occasions.

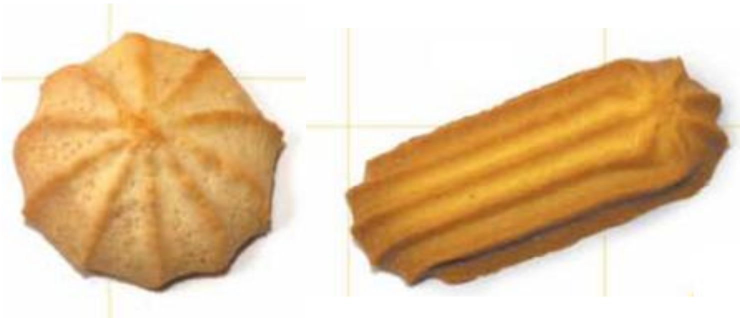

Figure 1.1: Shapes of Petit-Four.

The Petit-Four is attend from flour, butter, egg yolks, sugar, baking powder and vanilla; And added to the pieces after baked decorative materials as Jam and Cream.

In Palestinian society the Petit-Four considered essential product with some people, where we have made the study of the local market and from this study found that 40% of people consume the Petit-Four on a daily basis.

The Petit-Four was produced at the first time in the eighteenth century by the traditional way, during the process of cooling oven "made of brick" after the use of fire in order to benefit from the heat latent within these furnaces.

Types of Petit-Four :

There are three main types of the Petit-Four :-

1. Decorated or iced.

2. Salty, and is opening an appetite suppressant, so provides in concerts and buffets.

3. Dry, as Biscuit.

Nutritional value of the Petit-Four product

A piece of a Petit-Four (about 30 grams) has the following nutritional values:

1. Calories: 83
2. Fat: 5
3. Saturated fat: 3
4. Cholesterol: 14
5. Carbohydrates: 8
6. Proteins:1

1.2 Project idea and importance

The idea of the project is to design and implement a machine that makes a Petit-Four by an automatic way and is controlled by a programming PLC.

The importance of the project is summarized by the following points:-

1. Save the time needed to produce these types.
2. Reduce effort and number of workers.
3. Produce inconsistent types of petit-four that equal in weight and size.
4. Ensure you to get the health product.
5. Increase productivity and production of different types and varieties that difficult to make it by traditional methods.

1.3 Recognition of the Need.

1.3.1 A need of Petit-Four for bakery sweet use :

The research team made a questionnaire took (13) purposeful sample of bakery sweet who have Petit-Four, to decide if there is an important of the project, and if there is really a need for an automated Petit-Four machine.

The analysis of the questionnaire is attached in Appendix A. And here some of the results.

15% of the participants who have Producing more than 150 kg of Petit-Four daily, as shown in Figure 1.2 . This is a large percentage, so we decide to work with them, and solve their problem.

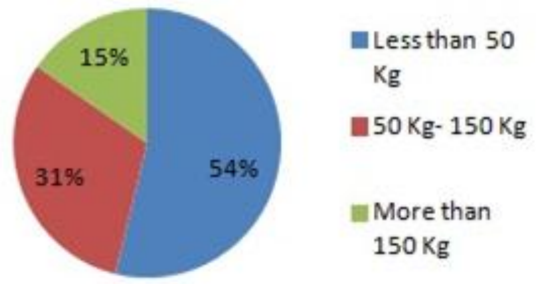

Figure 1.2. Daily production of Petit-Four.

Also according to the questioner results about 11% have 5 worker or larger, because of large quantity Figure 1.3 which the project come with the solution of it.

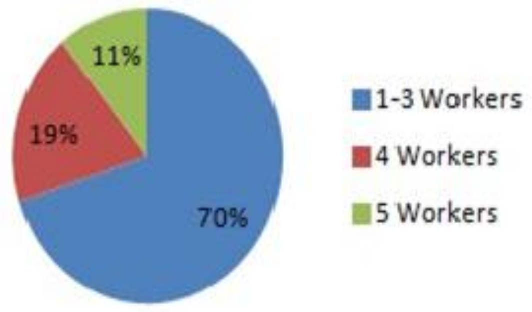

Figure 1.3. Number of workers.

As shown in Figure 1.4, 92.3% says they are ready to buy the Petit-Four machine, and the other say yes but, if the cost was good .

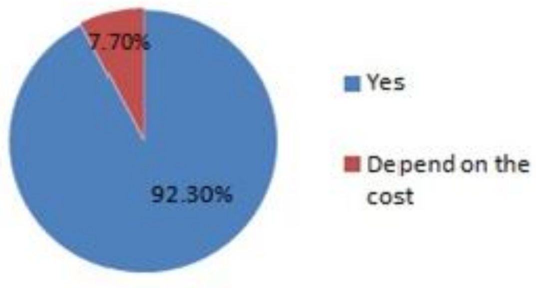

Figure 1.4.The desire to buy the machine.

1.3.2. Quality of Petit-Four

In Palestine and other Arab world countries, there's need for machine that gives a high quality of Petit-Four, our project will give higher quality than all current ways of traditional production methods, by using a modern method of production that will concerned cleanliness of the product and an elaborate form of the product.

According to the questionnaire the machine must have the following features:

1. Low noise.
2. Ease for use.
3. High safety factor, safe for worker.
4. Keeps clean & healthy.

1.4 Project Objectives

1. To build an automated machine of Petit-Four for bakery sweet.
2. To introduce modern technology for the local market.
3. To make a combination from traditional and automated methods for Petit-Four .
4. To achieve high quality Petit-Four .

1.5 Time schedule for the introduction project

Table 1.1 Time schedule for the introduction project.

Task / No. Of Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Identification Of Project Idea	■	■													
Drafting a Preliminary Project Proposal			■												
Introduction About Project (Chapter 1)				■	■										
General Description About Project (Chapter 2)						■	■	■							
Mechanical Design (Chapter 3)									■	■	■	■	■	■	■

1.6 Total Cost for the Project

Table 1.2. Total cost of the project.

Components	Price(NIS)	Quantity	Total (NIS)
Cylinder Stainless Steel	200	2	400
Standees Steel Container	300	1	300
Bearing	40	10	400
Motor's And Gears	900	3	2700
Sheets Of Stainless Steel	1000	1	1000
Profile's Of Stainless Steel	500	-	500
PLC	650	1	650
Encoder	600	1	600
Sliders	200	1	200
Micro Switches	20	5	100
Gears	300	3	900
Bolts Of Stainless Steel	150	1	150
Trays	150	2	300
Belt Drives	600	1	600
Raw Materials	2000	1	2000
Lathing	1500	1	1500
			12300

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Chapter Two

Production of a Petit-Four

2.1 Introduction .

2.2 Traditional Method Of Production .

2.3 Automated Method Of Production .

2.1 Introduction.

The production of a Petit-Four pieces has two methods, traditional method (manually) or modern method (automatically), since the Petit-Four is a foodstuff and is related to the health of the human we should follows the international standard of production, in this chapter we will show the stages of production of the Petit-Four.

2.2 Traditional Method Of Production.

Before we start explaining the automated stages of producing the Petit-Four, We have to recognize the traditional method of producing it, to evolve in our minds the principle that used for production the Petit-Four.

Petit-Four are produced in homes, bakeries and sweets shops, most of them used the traditional method of producing it by a manual way. Production of a Petit-Four by using this method passes through a multi stages :-

Step1 : Preparation of the petit-four dough as shown in figure 2.1.

Figure 2.1: Preparation of the Petit-Four dough.

Step2 :- Forming the dough by a handle dough mold as shown in figure 2.2 .

Figure 2.2: Forming the dough by handle dough mold.

Step3 :- Put the resulting pieces on the tray as shown in figure 2.3 .

Figure 2.3: Put pieces on the tray.

Step4 :- Put the tray after filling it by pieces in the oven and presented in beautiful shape after completion in the oven as shown in figure 2.4.

Figure 2.4 Petit-four presented in a beautiful shape.

Manual method in the production of Petit-Four take a long period of time and need a greater effort and human energy, also since the Petit-Four must be a healthy product and is not harmful to human health due to the pollution that results from hands and the human, we should replace this method by the automatic method (without Human intervention) that will show in the next section.

2.3 Automated Method Of Production

In our project we will show the new technology in produced of a Petit-Four using a full automated machine programmed with a PLC, which will allows the user to control the operation of the machine by an pushbutton installed on a machine body, This method of production will ensure to get healthy product and save the time and reduce the number of workers required to perform this task. The proposed machine is shown in the figure 2.5 .

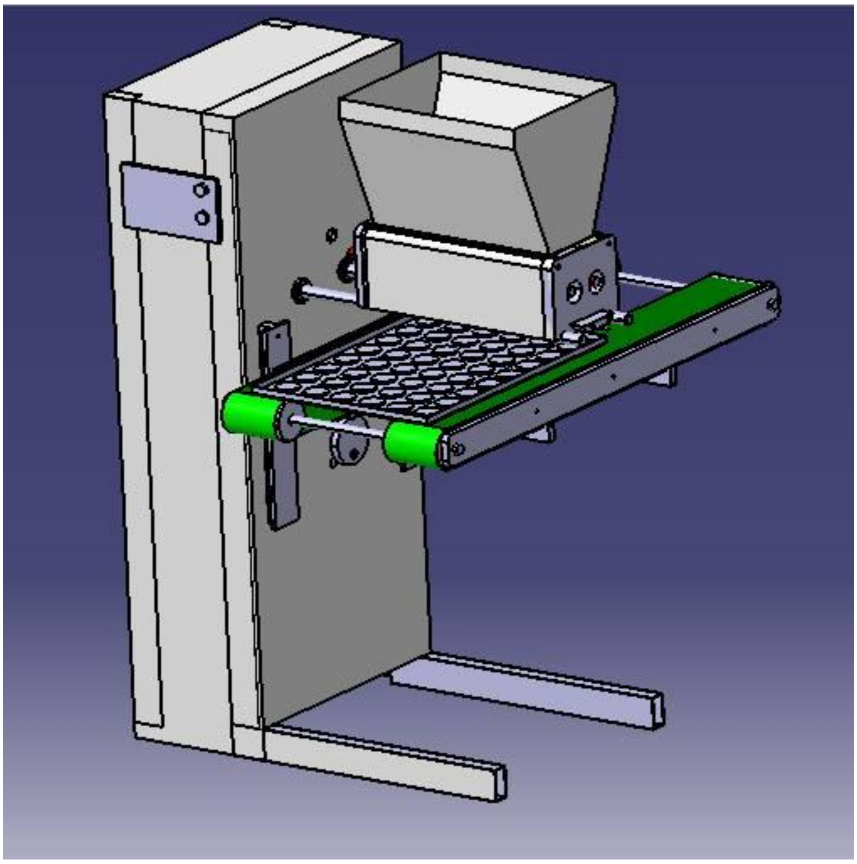


Figure 2.5 : Proposed design of the machine.

In order to take an image in our minds about how the machine works and the manufacturing stages passes through it to get the final product, we divided the stages of production into four stages as shown in figure 2.5 :-

1. Loading stage

2.Pulling and pressing stage

3. Casting stage

4. Transporting system

These four stages are integrated with each other in order to get the final product, in the coming sections each stage will be explained in full details.

2.3.1 Loading Stage:

The Loading stage starting when the user put the dough into the container manually, in this stage we will describe the container that carries the dough.

Stainless Steel Container

Because it concerns with the stuff food and in order to get a healthy product, the container material must be careful chosen, so stainless steel material's used after reviewing the specifications of this material as shown below:

1. High oxidation resistance at ambient temperature.

2. High corrosion resistance and staining.

3. High resistance attack from acids.

4. Relatively poor conductor of electricity.

5. Resistant to high temperatures.

According to these properties, the stainless steel is used as a material to make the container of the machine.

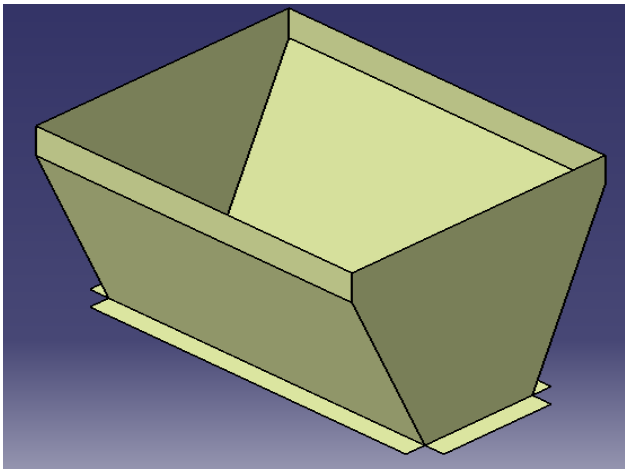


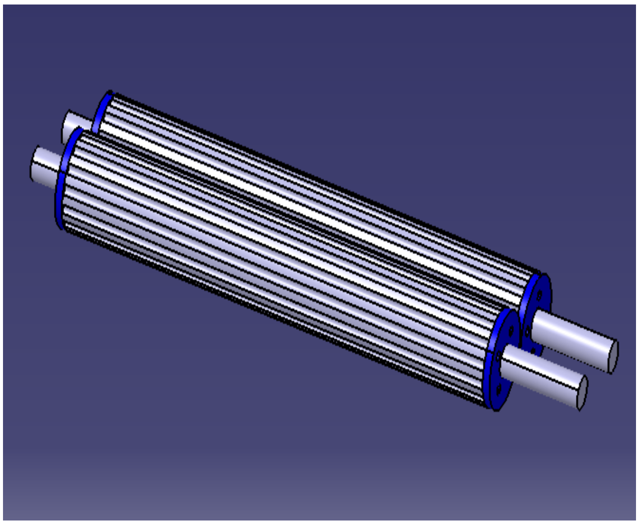
Figure 2.6: Container.

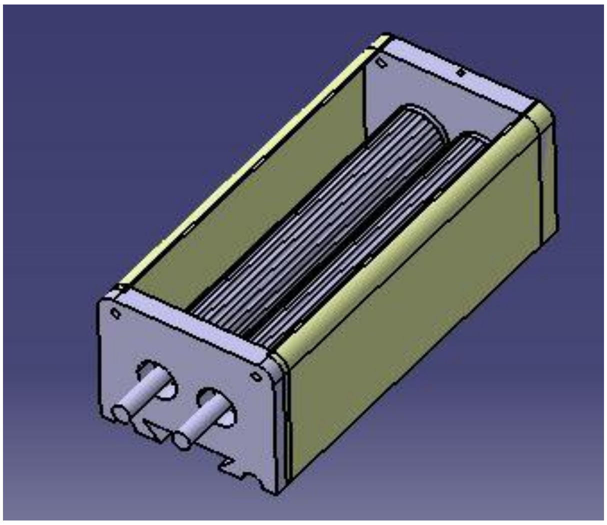
The container that shown in figure 2.6 has a volume of 52 liter and it can carries a 64 kg of dough, more details will be considered in chapter 3.

2.3.2 Pulling And Pressing Stage

After the user load the dough to the container, the two cylinder driven by a motor will pull and press the dough into the molds, the dough will flow in each hole of molds to get its final form before casting in the tray.

Pulling Cylinder :





a. Pulling cylinder. b. Pulling cylinder with housing.

Figure 2.7 Pulling cylinder.

In order to get the force that need for pull and press the dough into molds, design two toothed cylinder as shown in figure 2.7.a that moves in opposite of each other with distance to pulling the dough from container into casting molds as shown in figure 2.7.b. The two cylinder which made from delrin material [1] and the reason of chosen this material it have low density compared to steel and that give us a small weight. properties of this material can be summarized as :

1. Good dimensional stability.
2. Low moisture absorption.
3. Can operate in wet environments with little effect on performance or dimensions.
4. Excellent machinability.
5. High fatigue endurance.
6. High strength and stiffness properties.
7. Superior impact and creep resistance.
8. Chemical resistance to fuels and solvents.

1- Appendix B.

9. Good wear and abrasion properties.

Typical property values and technical product data Sheet of these material is shown in Appendix B.

2.3.3 Casting Stage

Casting Process occurs by molds as shown in figure 2.8 after the pulling cylinder pull and press the dough into the holes of molds, have a Six pieces molds in our machine that made from delrin material, these molds able to make a 5 shapes of a Petit-Four.

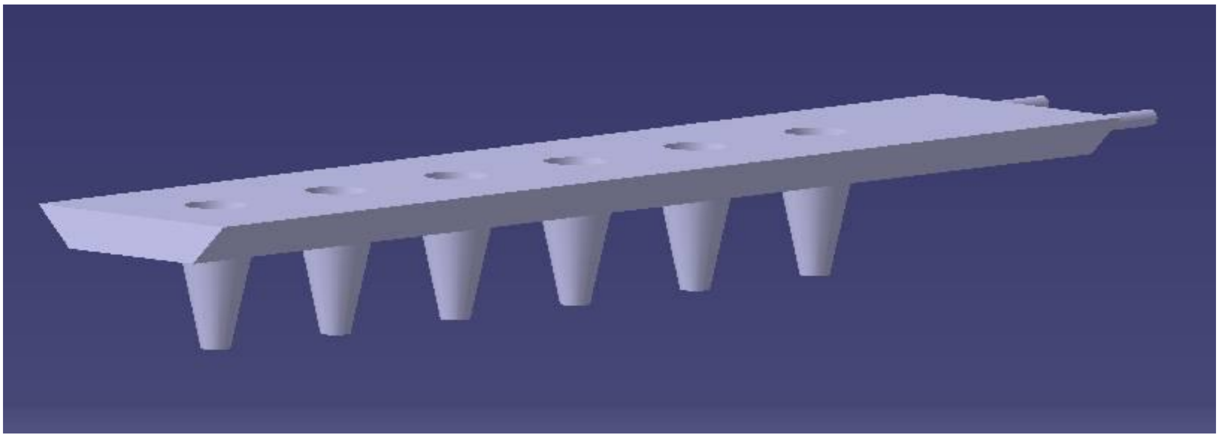


Figure 2.8 : Molds.

Through compressive strength that results from the motion of pulling cylinders in opposite direction, the mold will cast the dough into the tray. The molds will cast a Six pieces of a Petit-Four at the same time as shown in figure 2.9 and this operation will continue until filling the tray which has sequential step wise motion controlled by PLC.

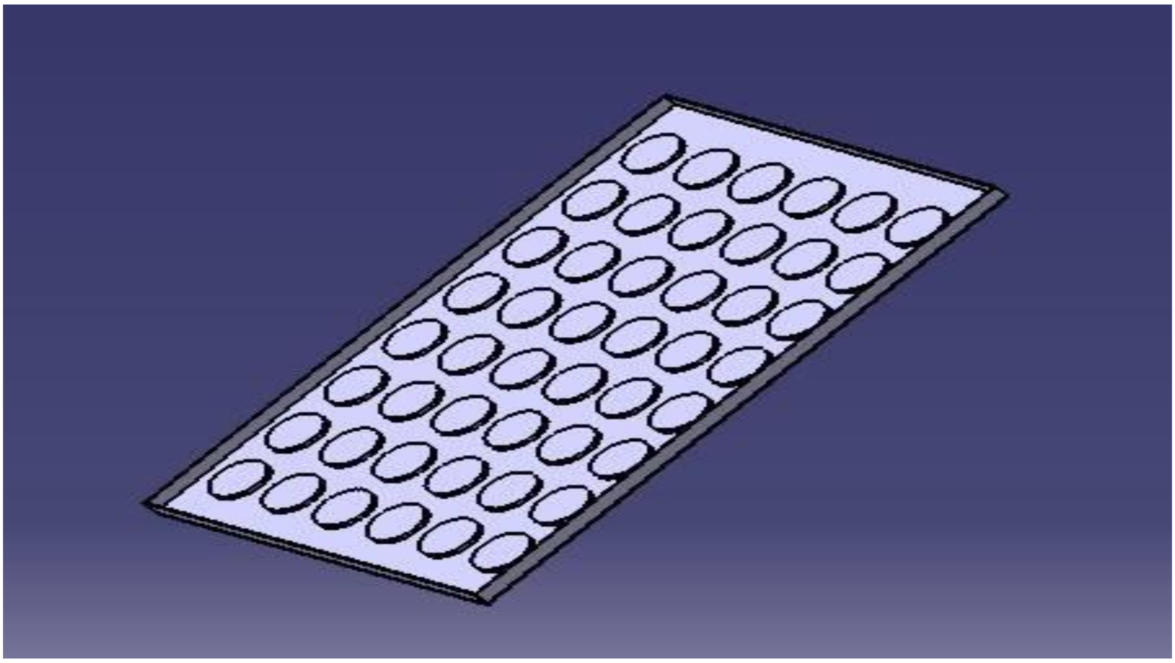


Figure 2.9: Cast pieces on the tray.

2.3.4 Transporting Stage

To transport the tray to fill it with a Petit-Four pieces that pouring from casting molds, we need a conveyor (Transporting System) driven by a motor as shown in figure 2.10

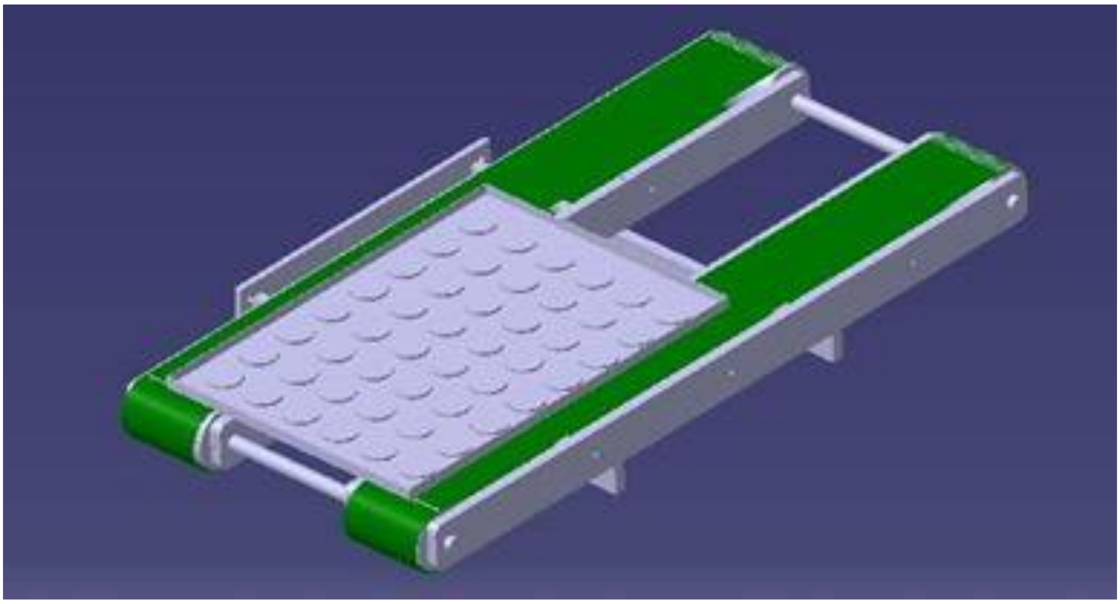


Figure 2.10: Conveyor system.

The conveyor system consist of two shafts, belt, and roller tube, one of the two shafts is driven by a motor and the other is follower.

The conveyor is moving up, down, right, and left to transport the tray and to complete the operation of filling the tray with the different shapes of Petit-Four pieces; This process is done by a cam follower mechanism that connected with a linear bearing to hold the base of conveyor and push up and down or left and right as commanded by the user of machine (shown in figure 2.11).The shafts and roller tube is made of stainless steel, and the belt is made from rubber metal.

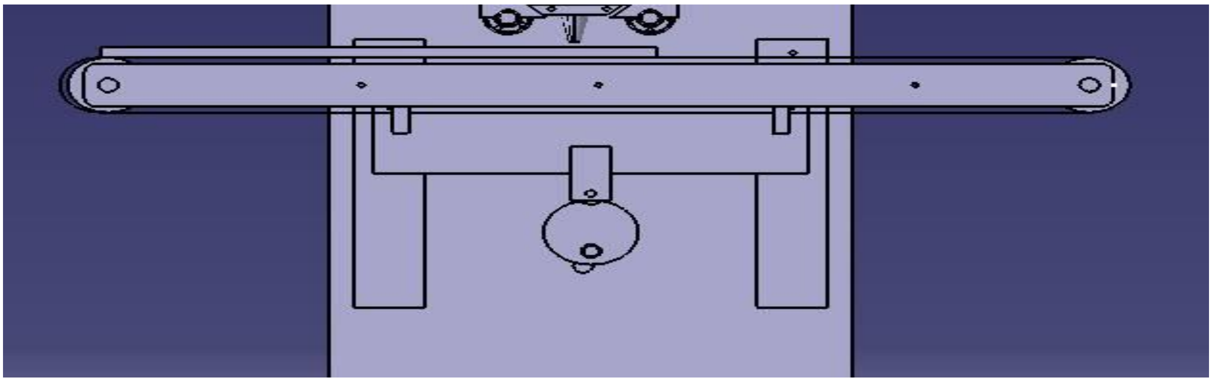


Figure 2.11: Cam follower mechanism.

3

Chapter Three

Mechanical Design

3.1 Proposal System Description And Specifications.

The first step in mechanical design is to know the hole operation of the system and to know how the machine is bind as shown in figure 3.1 and figure 3.2.

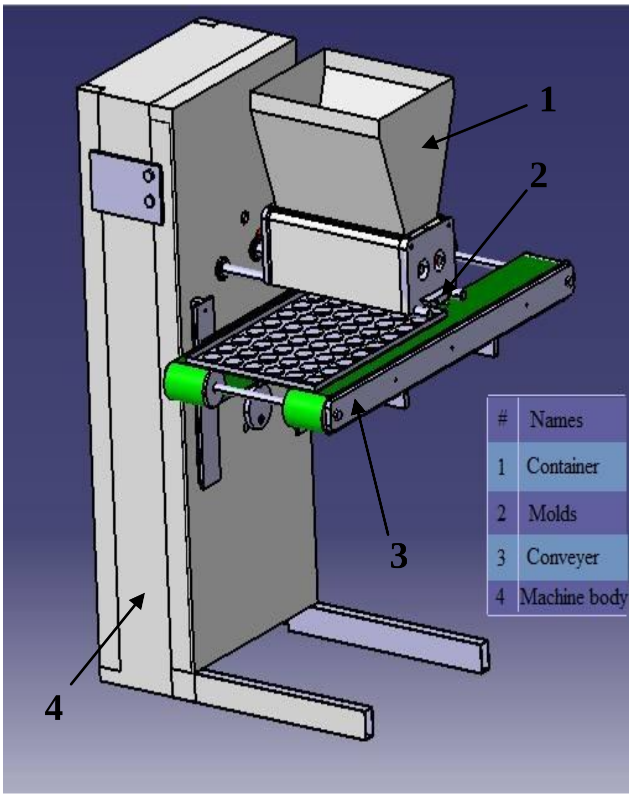


Figure 3.1: The machine in 3D.

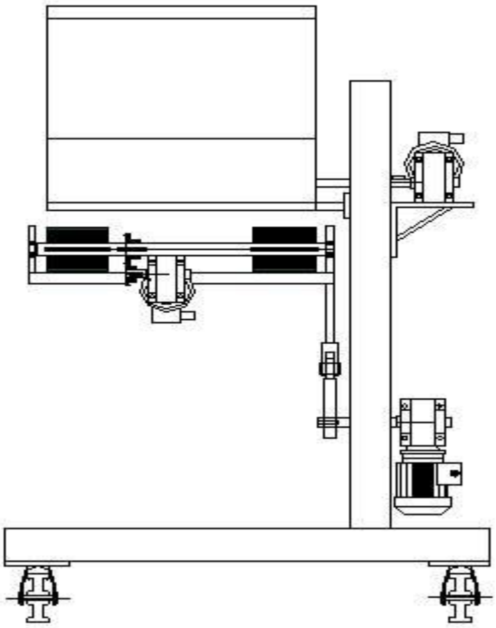


Figure 3.2 : The machine in 2D.

In the next sections the parts of the machine will be describe in full details .

3.2 Introduction

As explained before, the production of Petit-Four passes through four stages (prepare the dough, load the dough to container, pull the dough into molds, loaded the formed dough by molds into tray).

The dough is prepared and loaded to the container manually, but the process of pulling the dough into the molds is done by two cylinders are moving contrary to each other, and moving them is done by an electric motor through a gearbox to get the opposite rotational movement to be pulling the dough inside the container to the casting molds.

After pulling the dough into casting molds, the dough is loaded to tray by the molds, this process is done through the pressure force that result from the weight of the dough and from the pulling force of the rotating pulling cylinder.

In this design the machine, is divided it into five parts, which are connected to each other to cover all stages needed, these parts are:-

1. Container.

2. Cylinders.

3. Conveyer.

4. Molds.

5. Machine body.

Since the machine is used for production of a foodstuff and in order to get a healthy and clean product, most of the machine parts are made of stainless steel that has resistance to corrosion and prevent food poisoning; And in order to obtain a good and simple design a set of parameters must be considered, these parameters are related to the machine itself such as: safety, portability, cost, design simplicity, availability, work space, easy to move, volume occupied by the machine. On the other hand, the design must be able to produce a high quality Petit-Four related into the international standard.

3.3 Conceptual Design

It is desired to design and produce a Petit-Four machine fully automated and controlled. The process starts when the user puts the Petit-Four dough in the container and press the start button, the dough will be transferred to the two cylinder which applying pressure to the dough and pulling it to the casting molds, then the molds loading the dough into the tray, we have a six casting molds which will produce a six pieces of Petit-Four at the same time, the process will repeated until the tray is filled.

The machines divided into four subsystems:-

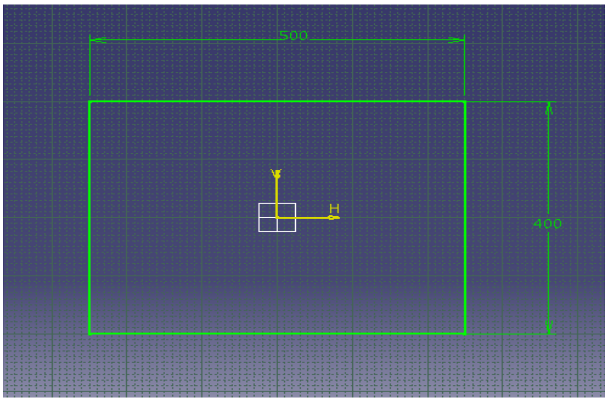
1. loading system.
2. Pulling system.
3. Casting system.
4. Transporting system.

3.4 Mechanical Design

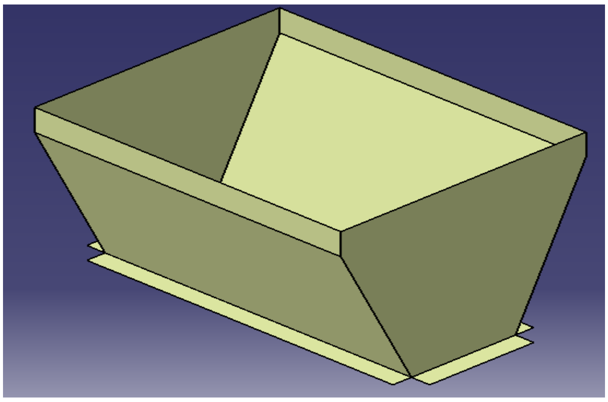
In this section each block will be explained in details, the used material for most parts in this machine is stainless steel (304L) suitable for food uses.

3.4.1 The Container

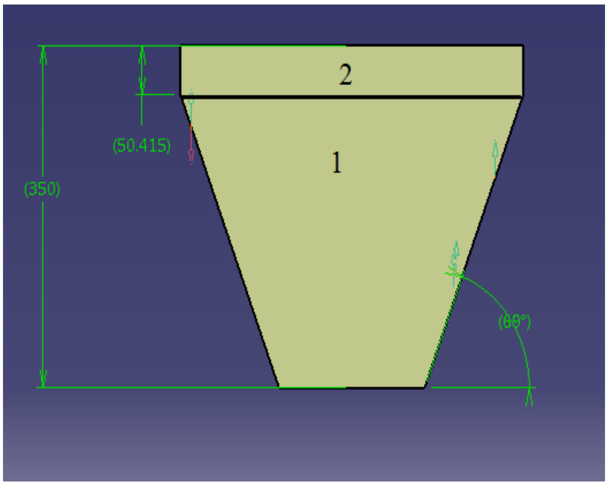
The first step in the whole operation start in the container as shown in figure 3.2 which designed to hold (64kg) of Petit-Four dough.



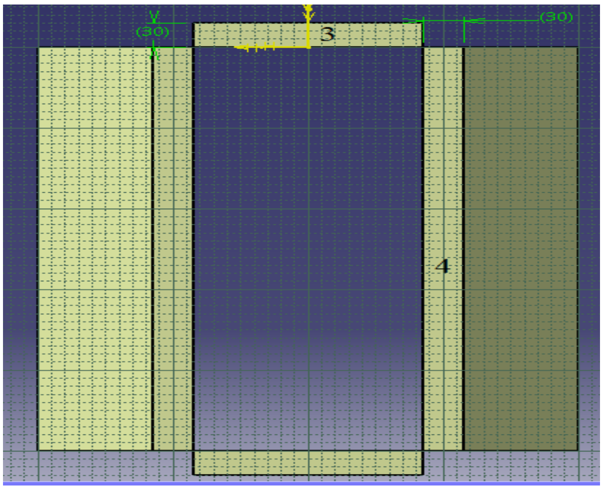
a. Top view



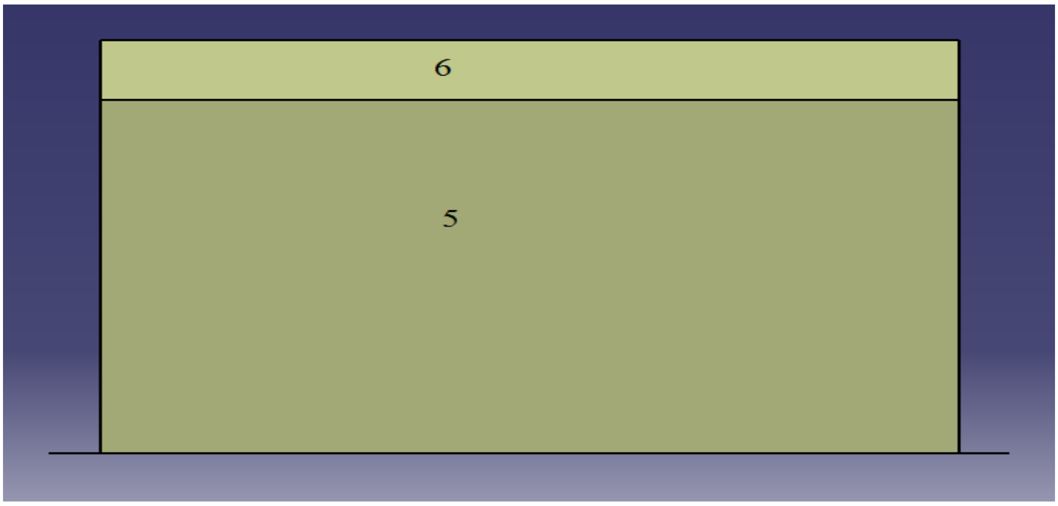
b. Overall view



c. Side View



d. Bottom View



f. Front view

Figure 3.3:Dough container [mm].

Need find the area of stainless steel that used for make the container, disassemble the container into multi section or parts needed, the parts shown at Figure 3.3.

First at figure 3.3(c) the area of this section divided to two part:

First rectangular area(A_1) :

$A_1 = t_1 * \text{W}$ (3.1)

$= 5.0415*40 = 201.66\ cm^2$

Second trapezoidal (A_2):

$A_2 = \frac{H(b1+b2)}{2}$ (3.2)

$= \frac{29.9585(40+17)}{2} = 853.81725\ cm^2$

A=A_1+A_2 (3.3)

By substitution Eq (3.1) and Eq (3.2) in Eq (3.3) can find the area of first rectangular :

A = 201.66+853.81725= 1055.47 cm^2

t_1:Width of rectangular at figure 3.3.c (cm).

b1:Length of larger base of trapezoidal(cm).

b2:Length small base trapezoidal (cm).

H:Hight of container (cm).

Second at figure 3.3(d) the area of this section divided to two part

Rectangular area(A_3) :

A_3 = t_2 * l (3.4)

=3*17 =51 cm^2

Rectangular area(A_4) :

A_4=t_2 *L (3.5)

=3*50 =150 cm^2

t_2:Width of rectangular at figure 3.3.d (cm).

L: Length of container (cm).

l: Length of rectangular 3 at figure 3.3.d (cm).

Third at figure 3.3(f) the area of this section divided to two part

Rectangular area(A_5) :

A_5 = t_3 * L (3.6)

=32.09*50 =1604.5 cm^2

Rectangular area(A_6) :

A_6=t_1 *L (3.7)

=5.0415*50 =252.075 cm^2

t_3: Width of rectangular at figure 3.3.f (cm).

To find the area of stainless steel that need to make the container, should found the total area of the upper parts:-

Total area =2*(A+A_3+A_4+A_5+A_6)

=2*(1055.47+51+150+1604.5+252.075)

= 0.623 m^2

In order to find the mass Petit-Four dough contains in the container first have to find the volume of container and the density of Petit-Four dough and for this we made an experiment by taking a Petit-Four dough and filling out in a can with a mass and volume known and find the density of the Petit-Four dough.

The volume of container :

V = A*L (3.8)

=1055.47*50 =52.77*10^3 cm^3

The mass of Petit-Four dough:

M = V*ρ (3.9)

= 0.05277*1200 ≈ 64 Kg

L: Length of container (cm).

W:Width of container (cm).

ρ: Density of petit-four dough (Kg/m^3).

A: The side area of the container.

3.4.2 Pulling Cylinder System

The design of this stage must be suitable and able to break the Petit-Four dough including the slot, and produce a force that pull the dough into the molds. in order to determine the required force to pull the dough and design the cylinders. It is desirable to make an experiment on bread dough machine with different forces.

In order to find the force required to pulling the dough into molds, we make an experiment on the bread dough machine and we applied a different force from frequency inverter (device used for control of induction motor) to show at what value of force the cylinder starting to move and pulling the dough, first we applied a 75 N force but the cylinders still not move at this value, then we increase the force to 125 but the cylinder also still no move, and we increase the force until the cylinder is moving and pulling the dough into molds and this occurred at force 180 N.

From this experiment, the selected force for this stage to pull the whole Petit-Four dough including the slot was 180 N. The design chosen was two contacted cylinders rotated opposite to each other as shown in Figure 3-4.

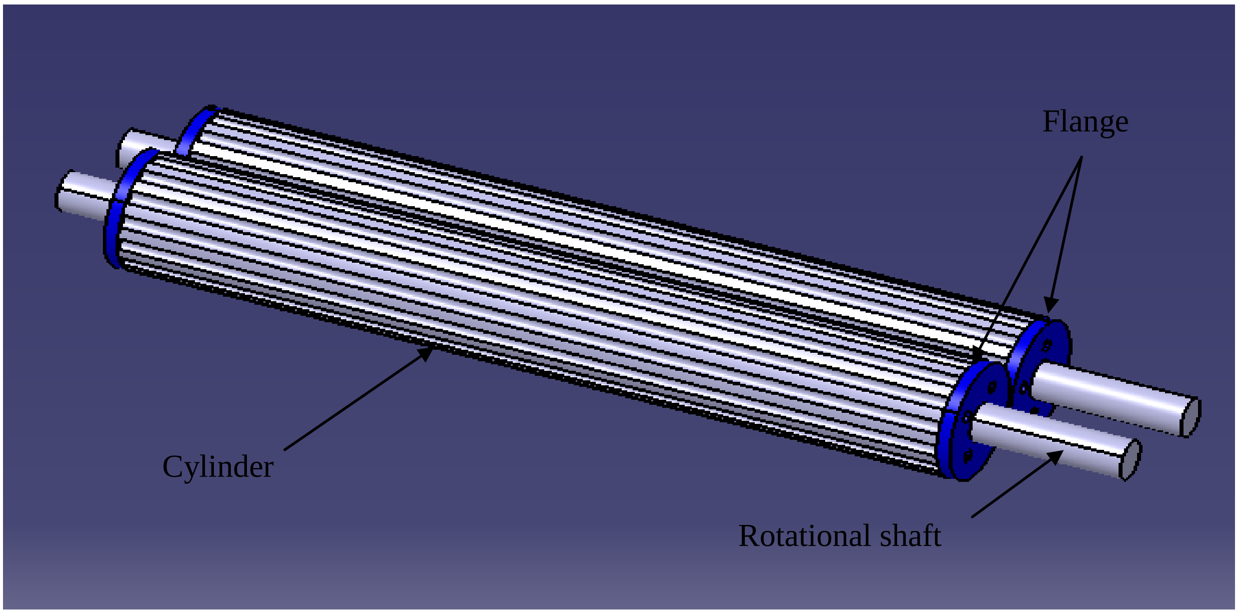


Figure 3.4 Pulling Cylinder.

The length of the cylinders equal 50 cm, and the total length of cylinder including the set shaft of bearing and gearbox is equal to 65.9 cm as shown in figure 3.5.

The pulling operation start when the start switch is pressed and the optical sensor give a signal to the controller that there is an Petit-Four dough in the container.

In order to select the suitable motor to drive the system with suitable gear box some calculations was made:-

Figure 3.5 Cylinder section

The weight of cylinder :

Part one" cylinder" :

$A = \pi r^2$ (3.10)

$= \pi * 0.0375^2 \ = 0.00415\ m^2$

V= A*L (3.11)

=0.00415*0.5

=0.0022m^3

M =V*ρ (3.12)

= 0.0022*1419.9 =2.83kg

The cylinder section is shown un figure 3.5 .

V: Volume (m^3).

L:Length (m)

A:Area(m^2).)

M:mass (kg)

ρ: Density of Delrin material as shown in Table 3.1(Kg/m^3).

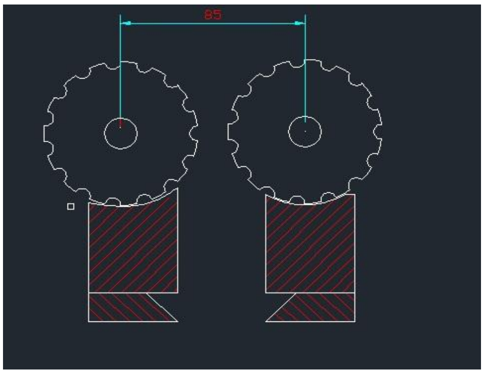


Figure 3.6:Cylinder section

Part two flange stainless steel:

Area of flange =Area of cylinder =0.00415 m^2

V=A*L (3.13)

= 0.00415*0.008 = 0.000033 m^3

M=V*ρ (3.14)

= 0.000033*7500 = 0.2475 kg

Have two flange 2*0.2475 = 0.495kg . As shown in figure 3.4.

ρ: Density of stainless steel (Kg/m^3).

Part three stainless steel rod:

$A = \pi r^2$ (3.15)

$= \pi * 0.015^2$

= 0.000706 m^2

V = A*L (3.16)

=0.000706*0.659

=0.0004652 m^3

M=V* ρ (3.17)

=0.0004652*7500

=3.489kg

ρ: density of stainless steel (Kg/m^3).

The total mass of three part =2.83+0.465+3.489 = 6.784 Kg.
The system mass is equal to 66 Kg as mentioned above and the force produced from this mass is equal to 647.5 N .
Mass of tank = Area of tank * thickness * density of stainless steel (3.18)

= 0.623 *1.5 *10^{-3} *7500 = 7.1 Kg

Mass of cylinder housing equal 3Kg , mass of Petit-Four dough equal 64 Kg from section 3.4.1 ,mass of Pulling Cylinder equal 13.6 kg from section 3.4.2 ,mass of dough mold equal 4 Kg and mass of gears equal 6 Kg.

Total mass = 7.1+3 +64+13.6+4+6 = 97.7 Kg .

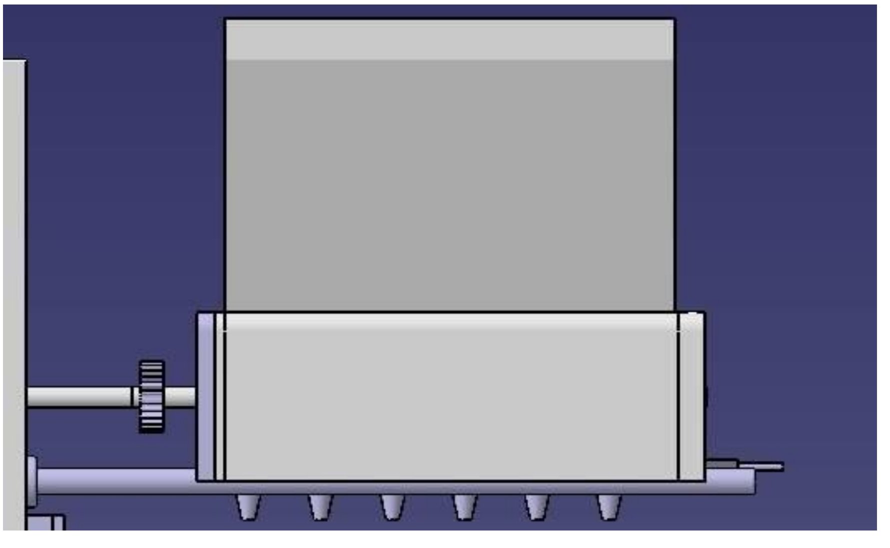


Figure3.7. Container position.

The chosen total mass above the beam equal100Kg include as shown in figure 3.7

Table 3.1 Properties of delrin material:

Property	Astm test method	Units	Delrin
Density	D792	Lbs/in^3	0.0513
Tensile strength	D638	Psi	9000
Water absorption	D570	%	0.25
Heat deflection temperature	D648	F	336
Rock well hardness	D758	M ® scale	M 94(120)
Wear Factor Against Steel, 40 psi, 50 FPM	D3702	in3 x 1/ hr PV	55 x 10-10

The required force to pull the dough into the molds equal 90N ,n=30rev/min.
Now, referring to figure 3.8 the calculation will be:

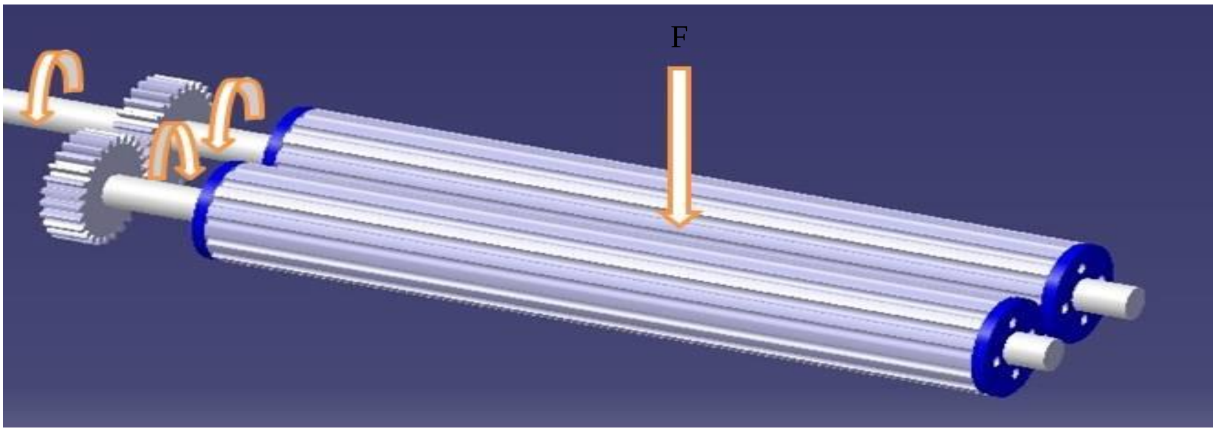


Figure 3.8.Power transition for pulling motor.

$\Sigma M_o = J_o \ddot{\theta}$ (3.19)

$T - F.r - C_t \dot{\theta} = J_o \ddot{\theta}$

$T = J_o \ddot{\theta} + C_t \dot{\theta} + F.r$

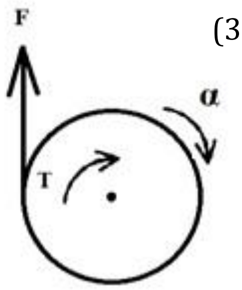
$\alpha = \ddot{\theta}$, $J_o = \frac{1}{2} mr^2$ (3.20)

$T = \frac{1}{2} mr^2 \alpha + C_t \omega + F.r$

$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$

$\omega_2 = \frac{2\pi n}{60} = \frac{2.\pi.30}{60} = 3.14$ rad/s (3.21)

$t_2 = 0.5$ sec



Free body diagram of cylinder

$\alpha = 6.28$ rad/s^2

$T = 2*(\frac{1}{2}*6.78*0.035^2*6.28) + 4*(1.5*10^{-3}*3.14) + (90*2*0.085)$

= 0.0522 +0.019 + 7.625 ≈ 15.37 N.m

The value of the bearing fraction(C_t) is taken from the Table 3.2

Table 3.2: Bearing coefficient factor (C_t)

Bearing type	Friction factor $\mu \times 10^{-3}$
Deep groove ball bearings	1.0~1.5
Angular contact ball bearings	1.2~1.8
Self-aligning ball bearings	0.8~1.2
Cylindrical roller bearings	1.0~1.5
Needle roller bearings	2.0~3.0
Tapered roller bearings	1.7~2.5
Self-aligning roller bearings	2.0~2.5
Thrust ball bearings	1.0~1.5
Thrust roller bearings	2.0~3.0

The chosen gear box has a reduction ratio equal to (1:30)has these specification

Name Product :NMRV050 Speed Reducer Model
Size: NMRV50
Speed Ratio: 1/30
Color: Blue or silver

$W_{motor}= \frac{W_{gear}}{1/30}$ (3.22)

$= 3.14 * 30 = 94.2$ rad/s

$n_{motor} = 94.2 * \frac{60}{2*\pi} = 900$ rpm (3.23)

$T_{motor} = \frac{W_{gear}}{30}$ (3.24)

$= 0.512$ N.m

P $= T_{motor}$*W (3.25)

= 0.512*94.2= 48.3 Watt

P'= 48.3/746

= 0.065 hp

P_{motor} = F.s * P' (3.26)

= 6 * 0.0324 = 0.4hp

So the chosen motor will be a 0.5 hp because there is no motor with 0.4 hp

The motor with this characteristic has been chosen to fit the calculation of the pulling system.

Table 3.3 Pulling motor characteristic :

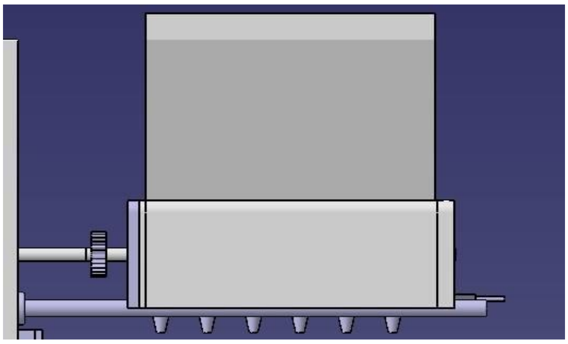
Output		Frame	Type	Speed	Current	Torque	Efficiency %			Power Factor			STA	STT	POT	GD²	Wt.
KW	HP	Size	Designation	(rpm)	(A)	(kgm)	FL	3/4L	1/2L	FL	3/4L	1/2L				(kgm²)	(kg)
0.37	0.50	80	2HS2 080-06	915	1.02	0.39	69.4	69.4	65.0	0.73	0.62	0.50	5.0	2.0	2.3	0.0049	15

3.4.3 Container Rod

In this section we will show the calculation of the rod that carry the container with the cylinder .

The calculation include reaction , dimension and deflection :

Stress analysis :



The force produced from the container has a shear effect on the rod that carry the container and to find it we make the following calculation :

ΣF_y=0 (3.27)

R_A - 875.9*0.56 =0

R_A = 490.5 N

ΣM_A=0 (3.28)

M_A+ 875.9*0.38*0.56 =0

M_A =-186.4 N.m

Shear diagram from Figure 3.9 can find V_A , V_C:

V_A = R_A= 490.5 N

V_C = V_A -875.9*0.56 =0

Area of shear diagram :

$A_{\text{A-B}}$ = 0.1*490.5

= 49.05 N.m

$A_{\text{B-C}}$ = 0.5*0.56*490.5

=137.35 N.m

Bending moment from Figure 3.9 can find M_A , M_B :

M_A =-186.4 N.m

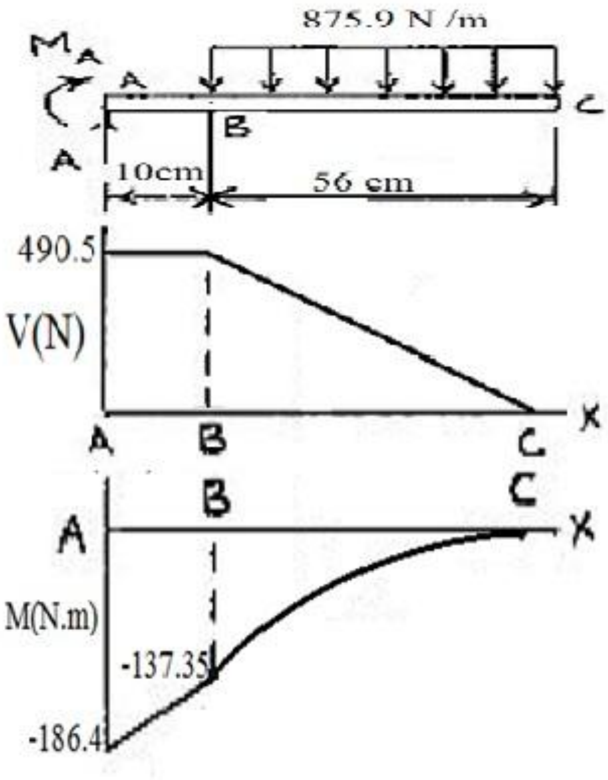


Figure 3.9 : Shear and Bending moment

$M_B = M_A + A_{\mathrm{A-B}}$
$= -186.4 + 49.05 = -137.35$ N.m

$M_c = M_B + A_{\mathrm{B-C}}$
$= -137.35 + 137.35 = 0$

To find the diameter make the following calculation :

$|M_{max}| = M_A = 186.4$ N.m

$$\sigma_{req} = \frac{M_{max}.C}{I} \quad (3.29)$$

$$I = \frac{\pi D^4}{64} \quad (3.30)$$

$$C = \frac{D}{2} \quad (3.31)$$

The chosen safety factor equal 2 and the chosen material of beam it a Chromium it has allowable stress [1] equal 689 MPa.

$$n_f = \frac{\sigma_{all}}{\sigma_{req}} \quad (3.32)$$

$$\sigma_{req} = \frac{\sigma_{all}}{n_f} \quad (3.33)$$

$$= \frac{689}{2} = 344.5 \text{ MPa}$$

Now by substitution Eq (3.30) , Eq (3.31) and Eq (3.33) in Eq (3.29) we can found the required diameter of the rod.

$$\sigma_{req} = \frac{186.4 * \frac{D}{2}}{\frac{\pi D^4}{64}}$$

D ≈18 mm

Deflection analysis :

Using a superposition the given loading can be obtained by superposition the loading shown in the following picture equation figure 3.10.

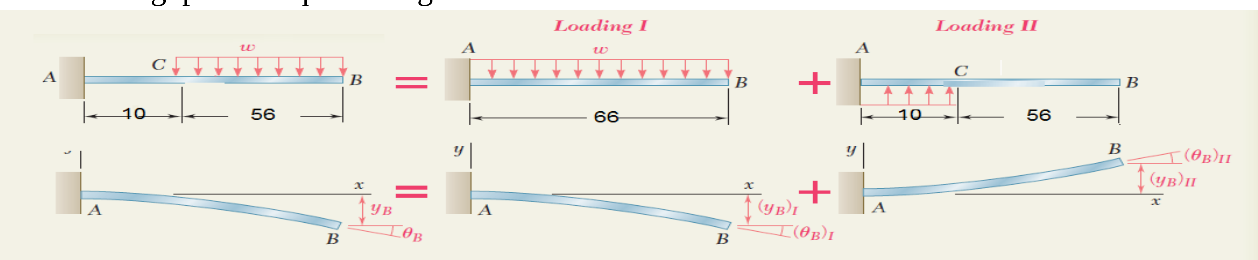


Figure 3.10. Deflection of container beam.

[1]- Appendix B

For each of the loading | and ‖ we now determine deflection at B.

Loading | :

$$(y_B)_{|} = -\frac{wL^4}{8EI} \tag{3.34}$$

Loading ‖ :

$$(\Theta_c)_{\|} = +\frac{w(L-0.56)^3}{6EI} \tag{3.35}$$

$$(y_C)_{\|} = +\frac{w(L-0.56)^4}{8EI} \tag{3.36}$$

In portion CB ,the bending moment for loading ‖ is zero and thus the elastic carve is a straight line .

$$(y_B)_{\|} = (y_C)_{\|} + (\Theta_C)_{\|} \,.\, (L-0.56) \tag{3.37}$$

Deflection at B

$$y_B = (y_B)_{|} + (y_B)_{\|} \tag{3.38}$$

$$= -\frac{wL^4}{8EI} + (y_C)_{\|} + (\Theta_c)_{\|} \,.\, (L-0.56)$$

$$= -\frac{wL^4}{8EI} + \frac{w(L-0.56)^4}{8EI} + \left(\frac{w(L-0.56)^3}{6EI}\right).\,(L-0.56)$$

Now we substitute w = 875.9 N/m , L =0.66 m and modules of elasticity (E) =294 GPa .

$$y_B = -\frac{875.9(0.66)^4}{8*294*10^9*I} + \frac{875.9(0.66-0.56)^4}{8*294*10^9*I} + \left(\frac{8759(0.66-0.56)^3}{6*294*10^9*I}\right).\,(0.66-0.56)$$

$$y_B = -\frac{7*10^{-11}}{I}$$

The acceptable deflection for our part is 1 mm as maximum .

$$\mathrm{I} = \frac{\pi D^4}{64} = \frac{-7*10^{-11}}{-1*10^{-3}} \tag{3.39}$$

D=34.56 mm

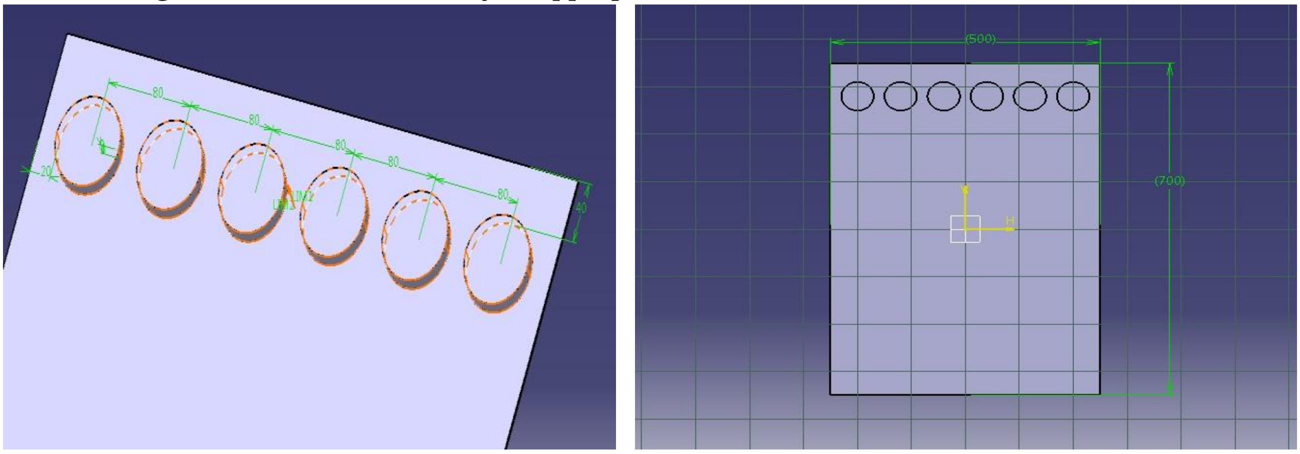
By stress analyses gave a beam diameter equal 18 mm and from deflection analyses have a rod diameter equal 34.56 mm there for we will choose the biggest one .

Rod diameter ≈ 35 mm

3.4.4 The conveyer

3.4.4.a Tray

We found that the used tray in the bakery has a fixed dimension (50x70) as shown in figure 3.11 and 5.25 kg so we will used this tray to appropriate the market demand.



a b

Figure 3.11.Tray dimension .

As talk in perverse chapter the number of the shape mold is six and the number of units produce in the tray is 48 units with a 50 g for each units .

Mass of petit-four units = Number of units * Mass of each units (3.40)

= 48*50 = 2.4kg

Mass 1 = Mass of tray + Mass of petite four units =5.25+2.4 = 7.65 kg.

3.4.4.b Belt

From the above section the tray must choose suitable belt to appropriate the tray with the conveyer so we use a belt with the following dimensions in figure 3.14 and properties as in table 3.4 .

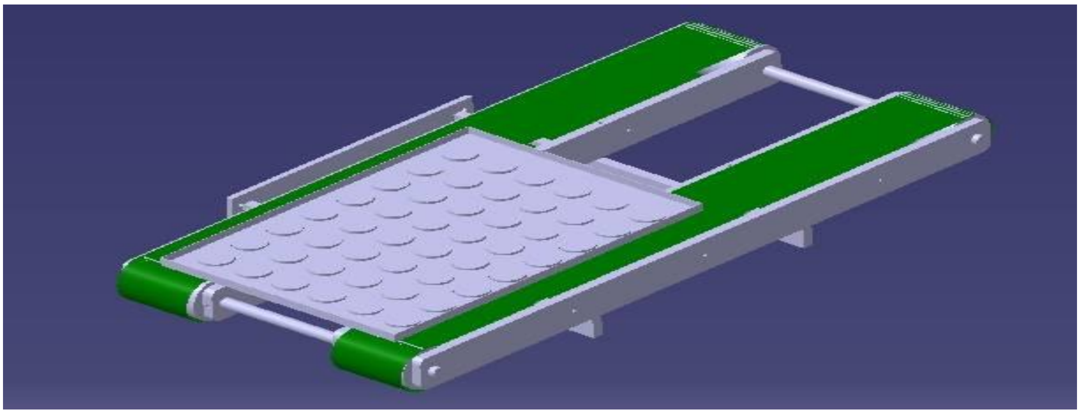


Figure 3.12. Belt in 3D.

Table 3.4 Properties of belt [2] :

Properties	Value
Material conveying side	Polyvinylchloride (PVC)
Colour conveying side	Green
Total thickness	2,5 mm (+/- 0,1 mm)
Belt weight	2,8 kg/m²
Maximum tensile force	120 N/mm
Standard production width	2.000 mm
Friction coefficient on slider bed of steel	0.35

From the table 3.4 the weight factor is equal 2.8 kg/m² . the belt is shown in the figure 3.14

The area of one belt = L*W (3.41)

$= 15*10^{-2} *270*10^{-2}$

$= 0.405\ m^2$

The weight of one belt = Weight factor * Area (3.42)

=2.8*0.405 = 1.134 kg

For two belt the total weight is:

Mass * 2 = 2.268 kg

The total mass(M) = Mass1 + Mass 2

= 7.65 + 2.268 =9.92 kg

The force produce from this mass = M*g (3.43)

= 9.92*9.81 = 97.3 N

Use a motor with a speed of 1400 rpm and to have a low speed equal 14 rpm we choose a gear box is 1:100 to reduce the speed, and the reason of not choose a motor with a speed of 900 rpm is there is no gear box ratio gave me 14 rpm.

The chosen gear box has a reduction ratio equal to (1:100)has these specification

Name Product :NMRV050 Speed Reducer Model
Size: NMRV50
Speed Ratio: 1/100
Color: Blue or silver

2- Appendix B

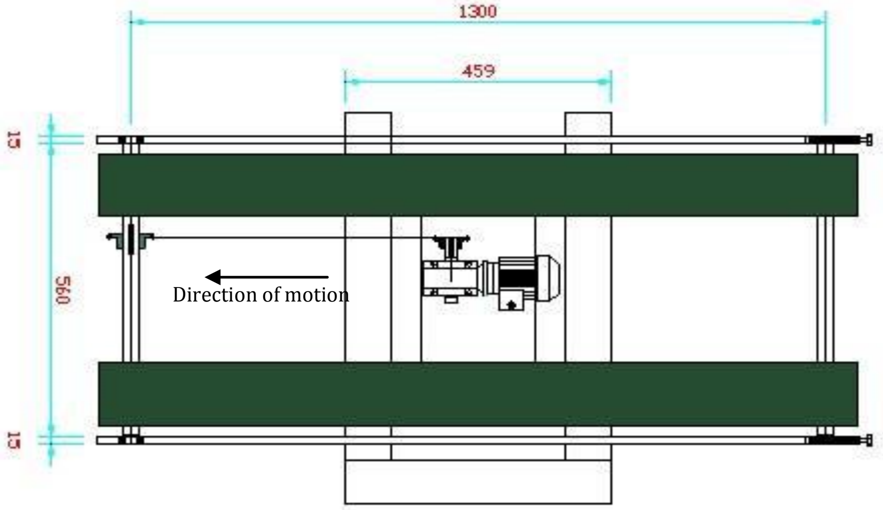


Figure 3.13. Double Conveyor in 2D .

In the figure 3.13 its show how the system work and in the figure 3.14 its show the free body diagram of the force that the motor is effect by.

By substitution in Eq(3.19) the belt motor torque found:

$\Sigma M_o = J_o \ddot{\theta}$

$T - F.r - C_t \dot{\theta} = J_o \ddot{\theta}$

$T = J_o \ddot{\theta} + C_t \dot{\theta} + F.r$

$\alpha = \ddot{\theta}$, $J_o = \frac{1}{2} m r^2$

$T = \frac{1}{2} m r^2 \alpha + C_t \omega + F.r$

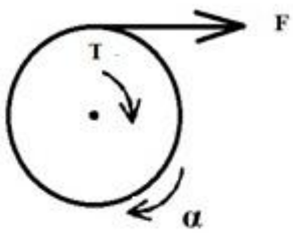


Figure 3.14. Free body diagram of belt

By substitution in Eq(3.20) the acceleration and speed found:

$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$

$\omega_2 = \frac{2\pi n}{60} = \frac{2.\pi.14}{60} = 1.46$ rad/s

$t_2 = 0.5$ sec

$\alpha = 2.92$ rad/s^2

By substitution in Eq(3.21) the polar inertia found:

$J_o = \frac{1}{2} m r^2$

To find the mass of roller tube

$m = \rho * V$ (3.44)

$V = A * l$ (3.45)

$$A = \frac{\pi\ (D_o - D_i)^2}{4} \quad (3.46)$$

$$= \frac{\pi\ (0.102 - 0.08)^2}{4}$$

$$= 3.8 * 10^{-4}\ m^2$$

length(l) =0.15m

$V = 3.8 * 10^{-4} * 0.15$

$= 5.7 * 10^{-5}\ m^3$

$m = 8000 * 5.7 * 10^{-5}$

≈ 0.5 kg

Have two roller tube then the mass is 1kg

$J_o = \frac{1}{2} * 1 * 0.51^2$

$= 0.13$ kg. m^2

From the table 3.3 friction coefficient on slider bed of steel is 0.35,then the fraction force between belt and conveyor frame.

$F_{fraction}$ = Force * Fraction coefficient (3.47)

= 97.3 * 0.35 =34 N

$T = (0.13*2.92) + 4*(1.5 * 10^{-9} * 1.46) + (34*0.51)$

$= 0.38 + 8.7*10^{-9} + 17.3 \approx 17.7$ N.m

$T_{motor} = \frac{T_{gear}}{100}$ (3.48)

$= \frac{17.7}{100} = 0.177$ N.m

$W_{motor} = \frac{1.46}{1/100} = 146$ rad/s (3.49)

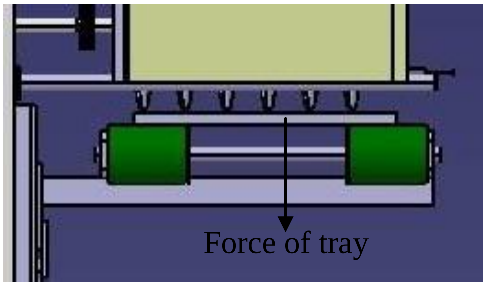


Figure 3.15: Fraction between belt and conveyor frame.

$n_{motor} = 146 * \frac{60}{2*\pi} = 1396$ rpm (3.50)

$P = T_{motor} * W$ (3.51)

= 0.177*146= 25.8 Watt

P = 25.8/746 = 0.0346hp

The chosen power factor is 3 so the motor power will be 0.10 hp because there is no motor with 0.10 hp. The motor has some characteristic in the table 3.5

Table 3.5 Conveyor motor characteristic :

Frame size	Power (KW)	Current (A)			Current (A)			Current (A)			rpm. (r/min)	Eff. (%)	Power factor (Cosφ)	Cs/ Cn	Cmax/ Cn	Cn (Nm)	Is/In	dB(A)	Weight (Kg)
		220V	380V	660V	230V	400V	690V	240V	415V	720V									
MS 562-4	0.09	0.82	0.47	0.27	0.78	0.45	0.26	0.75	0.43	0.25	1360	52	0.59	2.3	2.4		4	50	3.20

3.4.4.C Mass Of Conveyor

Need to calculate the total mass of conveyer, to determine the force that effect on the cam, the conveyer shown in the figure 3.1 .

Conveyer part:

Mass of conveyer frame :

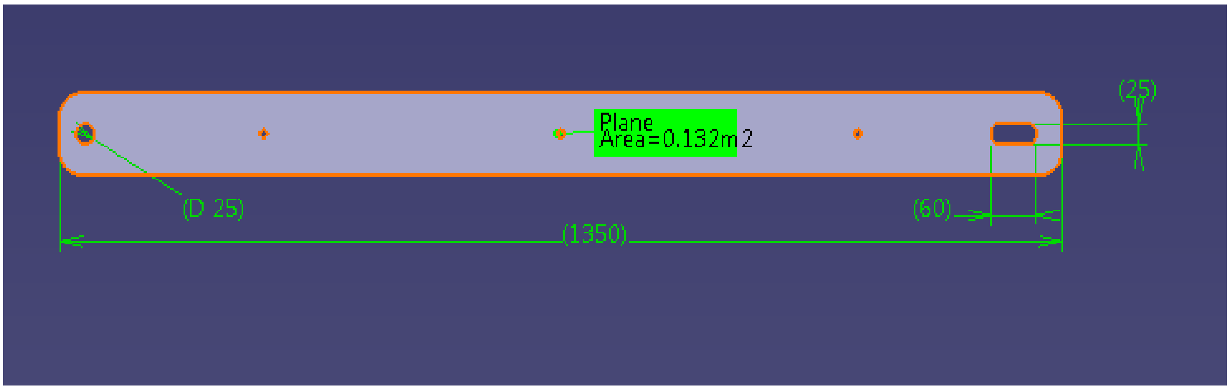


Figure 3.16: Conveyor frame dimension[mm]and area.

Mass of conveyer frame = Volume of conveyer frame *Density of aluminum (3.52)

Volume of conveyer frame = Area* Thickness (3.53)

$= 0.132 * 0.02 = 2.64*10^{-3}\ m^3$

Density for aluminum = 2700 Kg/m^3

Mass of conveyer frame = $2.64*10^{-3} * 2700 = 7.13$ Kg

We have 4 conveyer frame as in the figure 3.16 then the mass will be 7.13 * 4 = 28.52 Kg

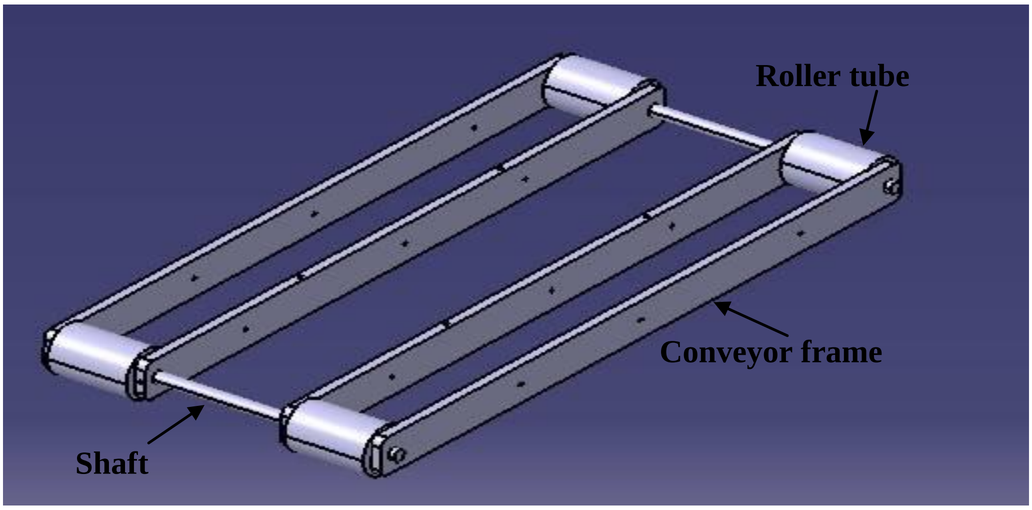


Figure 3.17: Conveyor frame with Rolling tube .

Mass of roller tube in figure 3.17 :

Mass of Roller tube = Volume of Roller tube * Density for Steel (3.54)

Area of Roller tube = $\frac{\pi}{4}(D_o - D_i)^2$ (3.55)

$= \frac{\pi}{4}(0.102 - 0.08)^2$

$= 3.8 * 10^{-4}\ m^2$

The Length of roller tube is 0.15 m

D_o: Outer dimension [mm] in figure 3.18.
D_i: Inner dimension [mm] in figure 3.18.

Volume of roller tube = Area of roller tube * Length (3.56)

$= 3.8 * 10^{-4}$ *0.15

$= 5.7 * 10^{-5}\ m^3$

Density for Steel = 8000 Kg/m^3

Mass of Roller tube = $5.7 * 10^{-5}$ * 8000
= 0.456 Kg

Have Four Roller then the mass will be 1.85 Kg .

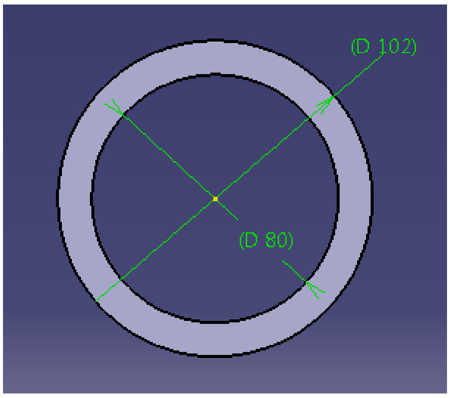


Figure3.18.Rollering tube section

Mass of the Shaft in figure 3.17 :

Mass of Shaft = Volume of Shaft * ρ_{steel} (3.57)

Volume of Shaft = Area of Shaft * length (3.58)

$= \frac{\pi}{4} D^2 * \text{L}$

$= \frac{\pi}{4} .025^2 * 0.65$

$=3.19*10^{-4}\ m^3$

D: Diameter [mm] in figure 3.19.

Mass of Shaft = $3.19*10^{-4} * 8000$

= 2.5 Kg

Have two shaft so the mass will be 5Kg.

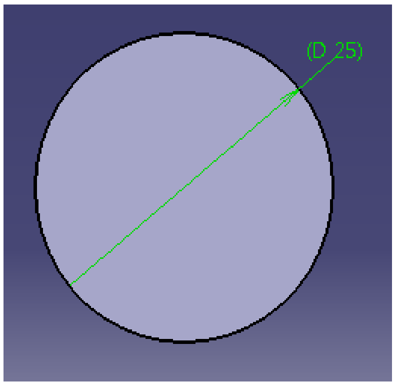


Figure 3.19. Shaft section.

Mass of motor and gear box :

From the data sheet of motor and gear box we find the mass of motor is 6.2 and mass of gear box is 3.8 , the total mass will be 10 Kg.

Mass of the conveyer belt and Tray :

From the section 3.4.4.b the mass of belt equal to 2.268 Kg and From the section 3.4.4.a the mass of Tray equal to 7.65 kg.

Total Mass Of Conveyer Equal :

Mass = 28.25 + 1.85 + 5 + 10 + 2.268 + 7.65

= 55 Kg

3.4.5 Sliding System

In this section will discuss the force that effect on beam that carrying the conveyer and will calculate the motor needs for carry the hole system rise and decline.

3.4.5.A Beam Design

The function of the beam as shown in figure 3.20 is to carry the conveyer system and the dimension of the beam that have a chosen dimension (20mm x 40 mm) so there is must to cheek the maximum deflection according to this dimension and disease if allowable or not.

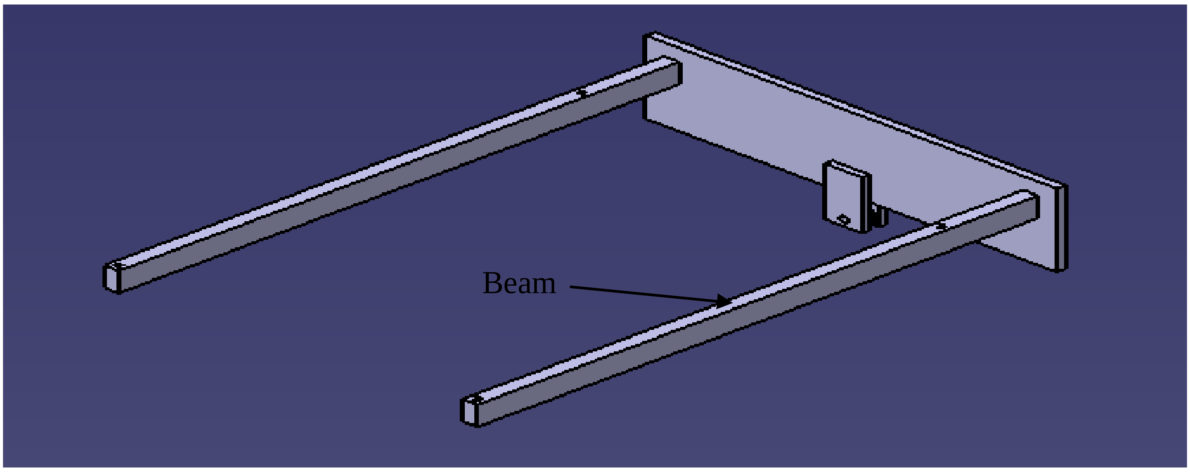


Figure 3.20: Conveyer beam.

The maximum deflection [3] from figure 3.22 :

$$y_{max} = \frac{Fa^2}{6EI}(a-3L) \quad (3.59)$$

$$F = \frac{\text{mass of conveyer} * 9.81\ m/s^2}{2} \quad (3.60)$$

$$= \frac{55*9.81}{2} = 270\ N$$

a =41mm from figure 3.22

L = 75 mm from figure 3.22.

E=207 GPa (modules of elasticity)

$$I = \frac{0.04^3*0.02}{12} \quad (3.61)$$

$$= 1.07*10^{-7}\ m^4$$

I: Moment of inertia in figure 3.21

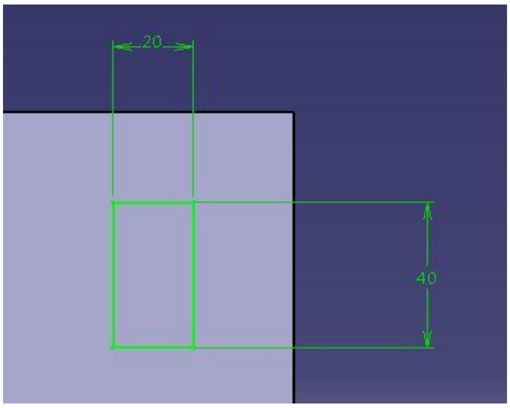


Figure 3.21. Beam dimension

$$y_{max} = \frac{270*0.41^2}{6*270*10^9*1.07*10^{-7}}(0.41-3*0.75)$$

$$= - \frac{\mathbf{83.512}}{173340}$$ `= 0.5 mm

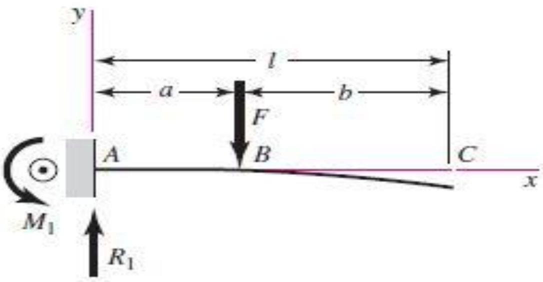


Figure 3.22: Beam deflection

3.4.5.B Cam Motor Calculation

3- Appendix B

The motor are affected by the force produced from the hole system mass, so must choose a motor meat this effect as in figure 3.23.

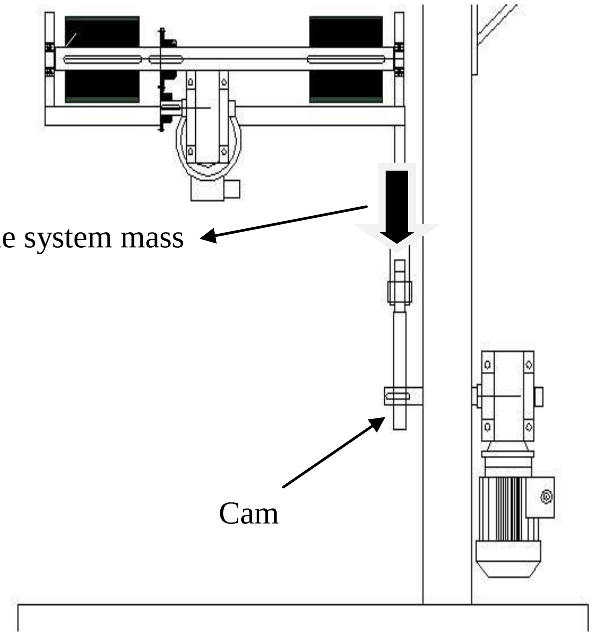


Figure 3.23.Cam system.

The system mass is equal to 66 Kg as we mentioned in section 3.4.5.a and the force produced from this mass is equal to 647.5 N. with velocity 1400 rpm and gear box with ratio of 1:50 .

$\Sigma M_o = J_o\ddot{\theta}$ (3.62)

$T - F.r - C_t\dot{\theta} = J_o\ddot{\theta}$

$T = J_o\ddot{\theta} + C_t\dot{\theta} + F.r$

$\alpha = \ddot{\theta}$, $J_o = \frac{1}{2} mr^2$

$T = \frac{1}{2} mr^2\ \alpha + C_t\omega + F.r$

$\alpha = \frac{\Delta\omega}{\Delta t} = \frac{\omega_2 - \omega_1}{t_2 - t_1}$ (3.63)

$\omega_2 = \frac{2.\pi.28}{60} = 2.93$ rad/s

$t_2 = 0.5$ sec

$\alpha = 5.86$ rad/s^2

Area of cam $= \frac{\pi D^2}{4}$ (3.64)

$= \frac{\pi * 0.12^2}{4} = 0.011\ m^2$

Volume of cam = Area of cam * Thickness of cam (3.65)

$= 0.011 * 0.02 = 2.2 * 10^{-4}\ m^3$

Mass of cam = Volume of cam * Density of steel (3.66)

$= 2.2 * 10^{-4} * 8000 = 1.76$ Kg

$J_o = \frac{1}{2} mr^2$ (3.67)

$= \frac{1}{2} * 1.76 * 0.06^2 = 3.168 * 10^{-3}$ Kg.m^2

T= $3.168 * 10^{-3} * 5.86 + 1.5 * 10^{-3} * 2.93 + 640.8 * 0.0475$

= 0.018+ 0.0043 + 30.72 = 30.7 N.m

The chosen gear box has a reduction ratio equal to (1:50) has these specification

Name Product :NMRV050 Speed Reducer Model
Size: NMRV50
Speed Ratio: 1/50
Color: Blue or silver

$W_{befor} = \frac{W_{after}}{1/_{50}}$ (3.68)

= 2.93* 50 = 146.5 rad/s

n_{befor} = 146.5 * $\frac{60}{2*\pi}$ = 1400 rpm (3.69)

$T_{befor} = \frac{T_{after}}{50} = 0.614$ N.m (3.70)

P = T_{motor}*W (3.71)

= 0.614*146.5= 89.9 Watt

P = 263.7/746

=0 .354hp
Safety factor equal to 2.5
p = p*6
=0.354 *2.5 = 0.88 hp .

So the chosen motor will be a 1hp because there is no motor with 0.88 hp

The motor with this characteristic has been chosen to fit the calculation of the Cam system.

Table 3.6 Cam Motor characteristic :

Frame size	Power (KW)	Current (A)			Current (A)			Current (A)			rpm. (r/min)	Eff. (%)	Power factor (Cosφ)	Cs/ Cn	Cmax/ Cn	Cn (Nm)	Is/In	dB(A)	Weight (Kg)
		220V	380V	660V	230V	400V	690V	240V	415V	720V									
MS 802-4	0.75	3.50	2.03	1.17	6.34	02.33.00	1.11	3.21	1.86	1.07	1380	72	0.78	2.2	2.4	5.27	6	58	9.10

3.4.6 Machine Body

To know if the machine support will be able to carry the weight of the machine frame, so there must be some calculation to verify that the support can carry. the support are describe in figure 3.24.

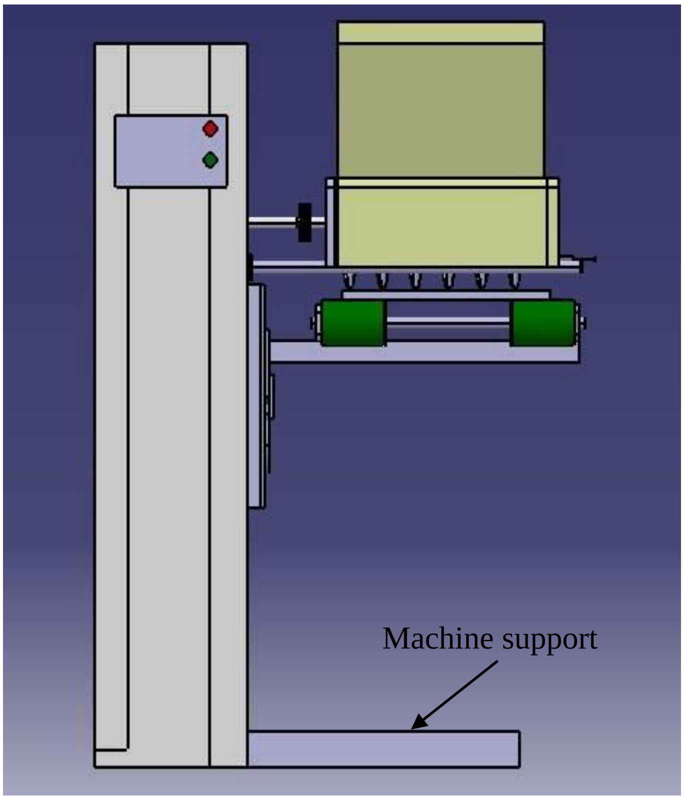


Figure 3.24 : Machine body.

Now the resultant force of each part in the machine body was calculate in the previous sections and this force are describe in the Figure 3.25 .

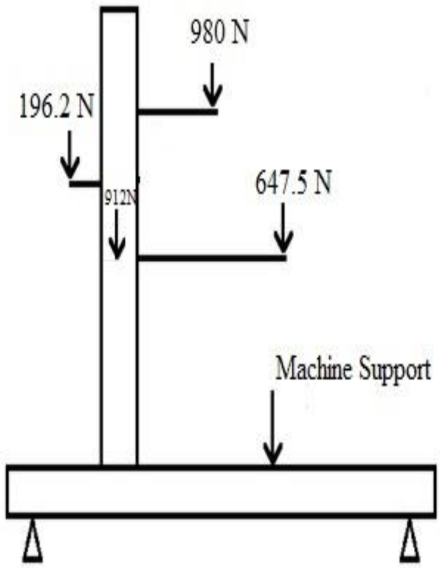


Figure 3.25 : Free body diagram of machine body.

The resultant force as shown in figure 3.26, are equal to the force from the weight of container and pulling system. weight of conveyer, weight of back side of machine and weight of steel pleat.

R= 980 +647.5+196.2+912 = 2735.7 N. (3.72)

M_o=F*R (3.73)

M_o=980*0.38+647.5*0.41+196.2*0.1
=372.4+265.5+19.62 = 657.52 N.m

The machine have two support so the moment must be divided by tow.

R*d=M_o (3.74)
2735.7*d=657.52
d= 0.24m= 240 mm

$\sum M_b = 0$ (3.75)
1.030*Ra - $\frac{R}{2}$ *0.520= 0
Ra =690.56 N

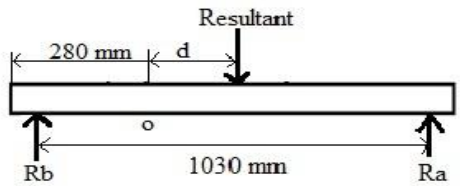


Figure 3.26:Free body diagram for machine support.

By cutting the beam at point o as shown in figure 3.27 :

$\sum M_o = 0$ (3.76)
M_c + 0.750*Ra - R*0.24 = 0
M_c + 0.750*690.56 - $\frac{2735.7}{2}$ *0.24 =0
M_c = 189.64N.m

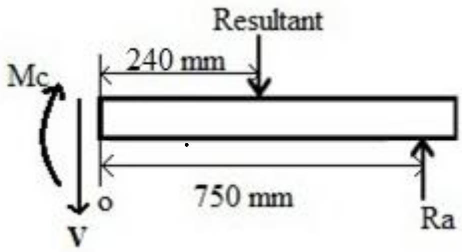


Figure 3.27:Free body diagram for cutting beam.

Calculate safety factor

$\sigma_{req} = \frac{M_c.C}{I}$ (3.77)

$I = \frac{1}{12}(0.080)(0.040)^3 - \frac{1}{12}(0.076)(0.036)^3$ (3.78)

$= 1.4 * 10^{-7}$

I: Moment inertia of figure 3.28.

$C = \frac{80}{2} = 40$ mm. (3.79)

$\sigma_{req} = \frac{189.64 * .040}{1.4 * 10^{-7}}$

$= 54.2 * 10^6$

=54.2 MPa

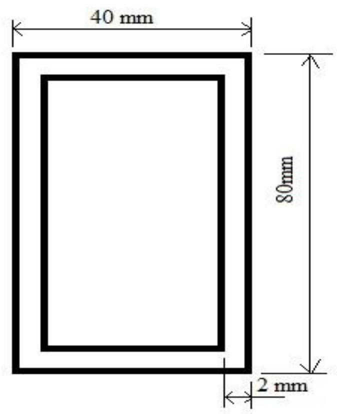


Figure 3.28: Beam section.

The chosen material of beam is steel and it has allowable stress equal 380 MPa

$n_f = \frac{\sigma_{all}}{\sigma_{req}}$ (3.80)

$= \frac{380 * 10^6}{54.2 * 10^6} = 7$

So can use this standard of beam to carry the machine body.

3.5 The Welding Design

The welding is needed to connect the conveyer beam with the sliding system. Figure 3.29 shows the welding joints. Filler metal rods and wires are designated by a system established by the American Welding Society (AWS). AWS designation is E60XX .

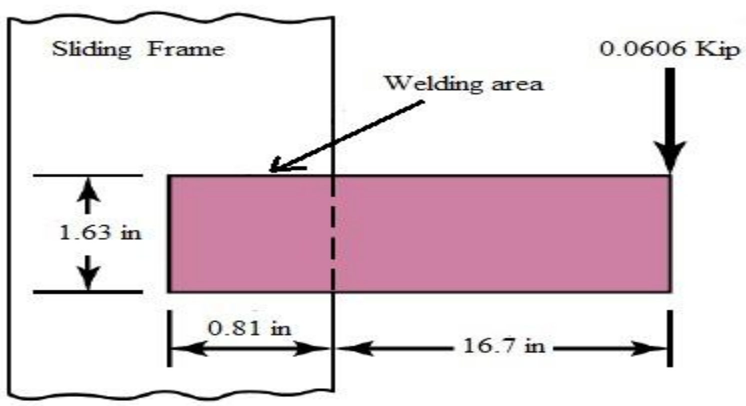


Figure 3.29 : Welding joint.

From the weld design tables the area of welding is :

A= 1.414hd (3.81)

=1414*h*0.81 = 1.1455 h

M = F* L (3.82)

Where ,

h: Height of welding as in Figure 3.30.

d: Length of the part that the welding is on .

F: Force effect on the beam as in figure 3.30.

L: Length of the beam .

M= 16.7 * 0.0606 =1.012 Kip.in.

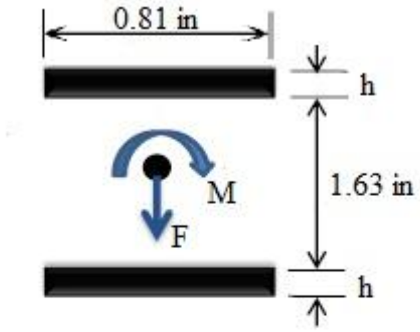


Figure 3.30.Weld pattern.

The polar moment of area of the weld group per throat length (J_u) is selected from the weld design tables.

$$J_u = \frac{d(3\,b^2 + d^2)}{6} \tag{3.83}$$

$$= \frac{0.81(3\;1.63^2 + 0.81^2)}{6} = 1.1646$$

This value needs to represent the value of (J) in the equation (3.84)

$$J = 0.707\,J_u \tag{3.84}$$

The leg weld (h) needs to be designed.

The primary shear is :

$$\tau^{`} = \frac{F}{A} \tag{3.85}$$

$$= \frac{0.0606}{1.145h} = \frac{0.052}{h}$$

The second shear is :

$$\tau^{``}_{x} = \frac{Mr_y}{J} \tag{3.86}$$

$$= \frac{(1.012)(0.815)}{0.82\,h} = \frac{1}{h}$$

$$\tau^{``}_{y} = \frac{Mr_x}{J} \tag{3.87}$$

$$= \frac{(1.012)(0.405)}{0.82\,h} = \frac{0.49}{h}$$

$$\tau = \sqrt{\tau^{``}_{x} + \tau^{``}_{y}}$$

$$= \sqrt{(1/h^2 + (\,0.49)/h)^2} = \frac{1.7}{h}\text{ Kpsi}$$

Member: structured steel ; A.36 → $s_y = 36\;Kips$

Attachment: AISI 1018 HR steel → $s_y = 32\ Kips$

Allowable stress: Attachment : $\tau_{all\ =\ 0.4}\ s_y$ = 0.4(32) = 12.8 Kips (3.88)

Member : $\tau_{all\ =\ 0.4}\ s_y$ = 0.4(36) = 14.4 Kips (3.89)

Note that the Attachment is weaker than the member . It is the critical part. therefore, select an electrode not weaker than the attachment and the chosen electrode is E60XX .

$\tau_{all,electode}$= 0.3S_{ut} = 0.3* 60 = 18 Kips which is greater than 12.8 Kips (3.90)

$\tau_{all} = Min(12.8\ ,14.4\ ,18.0) = 12.8\ Kips$

Setting τ_{max}= τ_{all} , the value of the leg length (h) is considered 3 mm with two lines where the total length for each line is 20 mm .

4

Chapter Four

PLC Programming

4.1 Introduction

As it has been mentioned before the pitit-fore machine is fully automated and the process is performed sequentially, this can be perform by using PLC (programmable logic controller). This made adding automation capability and safety precautions possible , which is explained through this chapter.

The PLC is chosen to be used on the machine rather than the microcontroller because of its ability to operate with the voltage used at workshop (220v) without the need of other component, where the microcontroller can operate only with 5v and needs other component which has a high cost, A comparison between PLC and microcontroller is made in the table - 4.1 .

	PLC	Microcontroller
Less Initial Cost		✓
Ease In Programming	✓	
Work At 220V	✓	
Build In Modules	✓	
Faster Response		✓
Less Total Cost	✓	

Table 4.1 : PLC VS Microcontroller

4.2 PLC Characteristic

Programmable Logic Controller (PLC) is a digital computer used for automation of electromechanical process, such as control of machinery on factory assembly lines, PLCs are used in many industries and machine. Unlike general-purpose computers, the PLC is designed for multiple inputs and output arrangements, extended temperature ranges, immunity to electrical noise, and resistance to vibration and impact. programs to control machine operation are typically stored in battery backed-up or non- volatile memory .

A PLC is an example of a hard real time system since output results must be produced in response to input conditions within a limited time otherwise unintended operation will result. In our controlling design it is desirable to use a PLC with 13 input and 6 outputs mention in the table 4.2 below, It must be compatible to use with 220 volt .

The PLC connection are shown in the figure 4.1.

Table 4.2 : logic allocation

Input	Symbol	Logic allocation	address
Start(NO)	START	START = 1, Operation is run. /CAM motor is run on manual.	I0.0
Stop(NC)	STOP	STOP = 0, Operation is stop.	I0.1
Encoder	ENCODER	Cont pulse at Rising edge.	I0.2
Emergency switch(NC)	EMG	Turn off all process.	I0.3
Limit switch 1	CAM_UP	CAM_UP = 1, Conveyer is ready for casting.	I0.4
Limit switch 2	CAM_DOWN	CAM_Down = 1, Conveyer is ready for moving the tray.	I0.5
Limit switch 3	TRAY_READY	TRAY_READY = 1, The tray is on the casting position.	I0.6
Push bottom 1(NO)	TYPE1	TYPE1 = 1, Shape one is selected /Cylinder motor is run in manual.	I0.7
Push bottom 2(NO)	TYPE2	TYPE2 = 1, Shape second is selected / conveyer motor is run in manual.	I0.8
Select switch	AUTOMATIC	If the select switch in the right position the operation mode is automatic.	I0.9
Select switch	MANUAL	If the select switch in the left position the operation mode is manual.	I0.10

Output	Symbol	Logic allocation	address
Cam Motor	CAM_MOTOR_M1	CAM_MOTOR_M1=1, The cam motor is run.	Q0.0
	CAM_MOTOR_M4	CAM_MOTOR_M4=1, The output frequency from the inverter is 25 Hz.	Q0.1
	CAM_MOTOR_M5	CAM_MOTOR_M5=1, The output frequency from the inverter is 35 Hz.	Q0.2
Conveyer Motor	CONVEYER_MOTOR	CONVEYER_MOTOR=1, The conveyer motor is run.	Q0.3
Cylinder Motor	CYLINDER_MOTOR	CYLINDER_MOTOR=1, The cylinder motor is run.	Q0.4
Red Led	STOP_LED	STOP_LED=1, The red led is light.	Q0.5
Green Led	START_LED	START_LED=1, The green led is light.	Q0.6

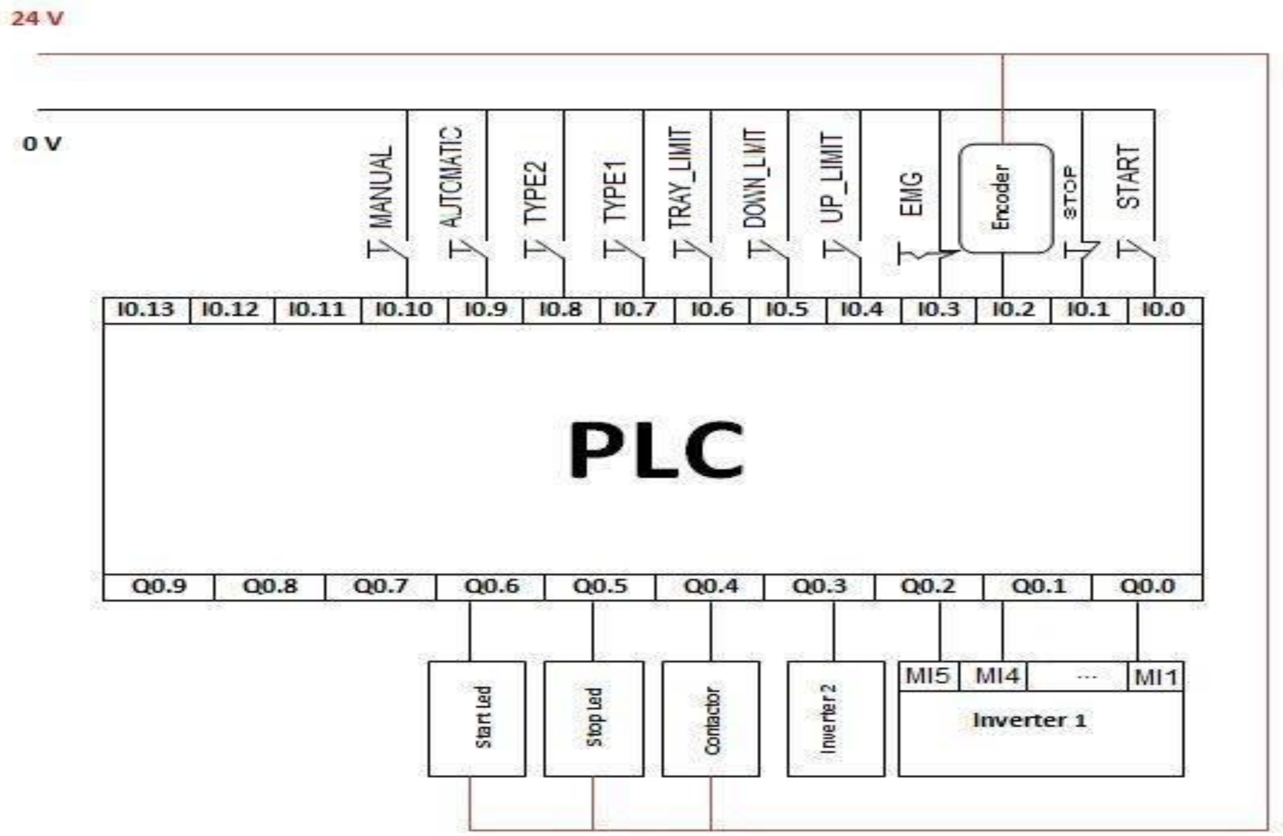


Figure 4.1 : PLC Connection.

The used PLC is Schneider TWDLCAA24DRF as shown in figure 4.2 ,with 14 inputs and 10 outputs and the data sheet is shown in the appendix

Figure 4.2 : PLC Schneider TWDLCAA24DRF.

The software for TWDLCAA24DRF is the program TwidoSuite micro/win64 as shown in the figure 4.3 .

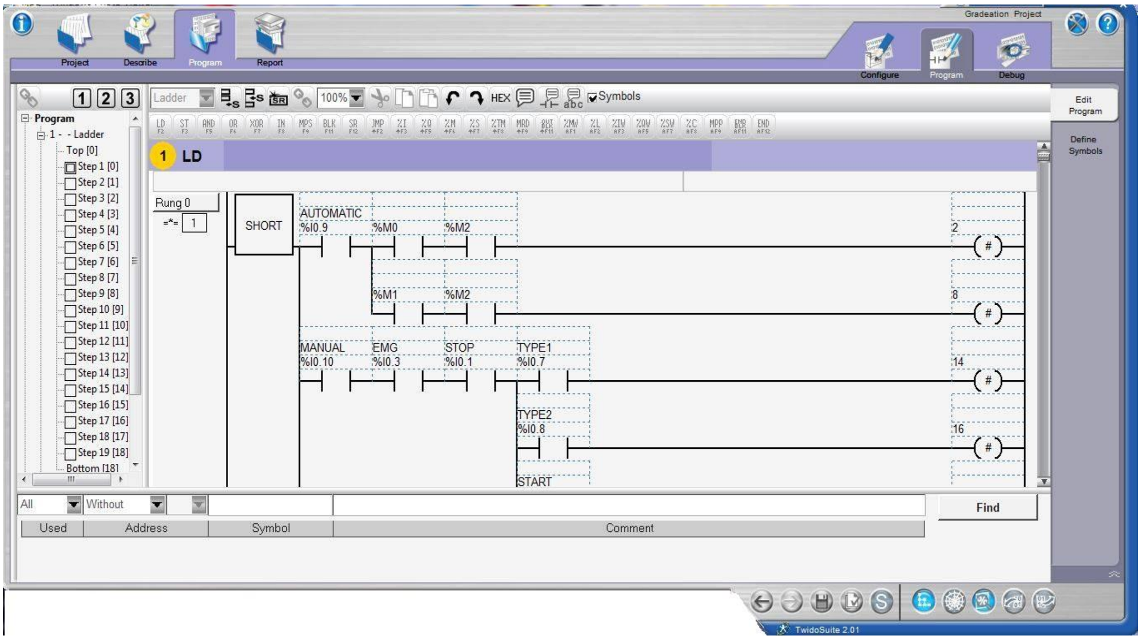


Figure 4.3: TwidoSuite micro/win64 program .

4.3 PLC Graph

The machine will has two operation mode manual mode and automatic mode. The manual mode is added for increasing the safety of the machine with the addition of the emergency switch and to allow the user to clean the machine. the selection between two modes can be made by using the switch, the transformation between the two modes can be implemented at any stage if an errors are happened. The state graph shown in figure 4.4 " Automatic mode " and figure 4.5 " Manual Mode ".

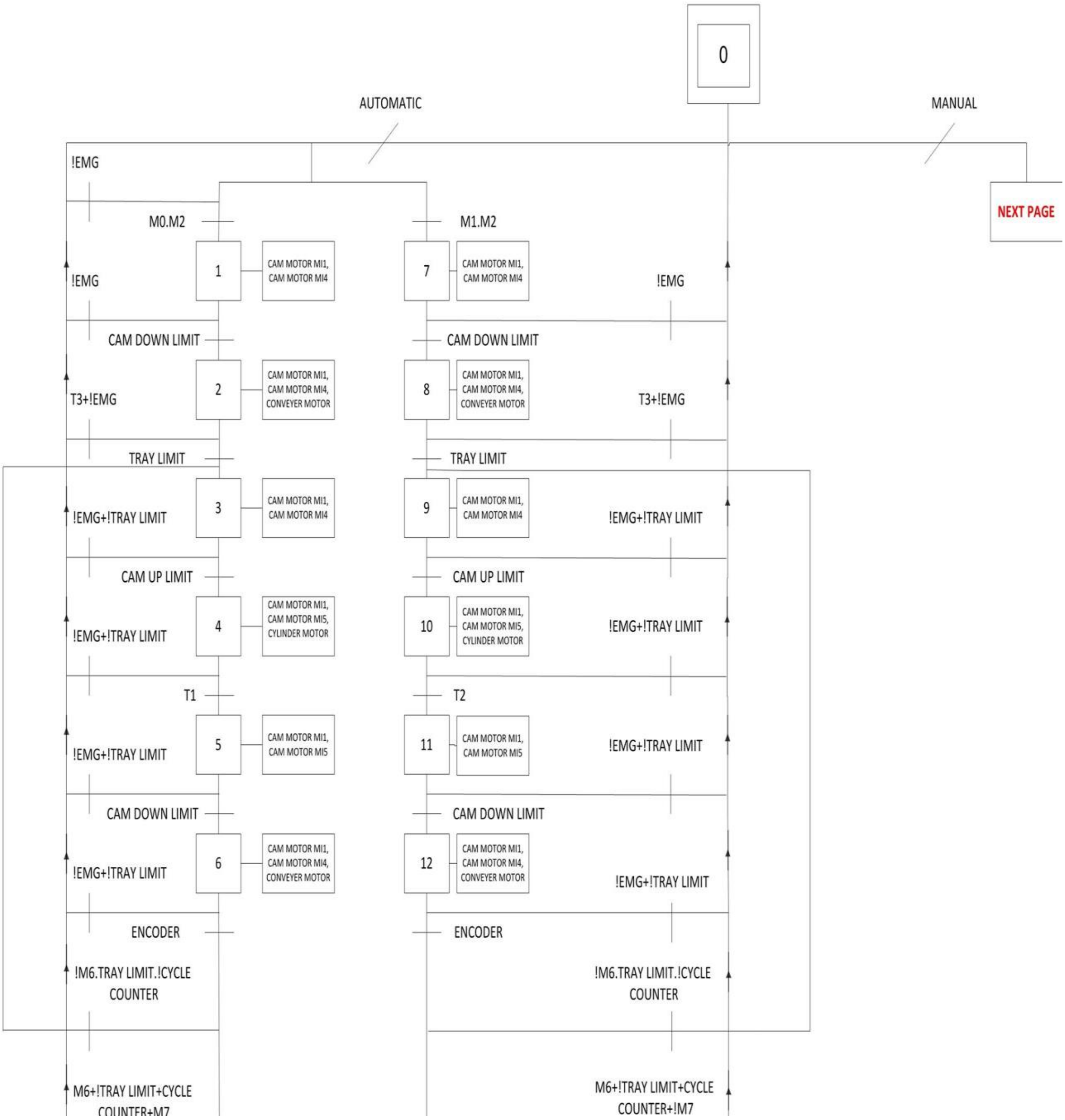


Figure 4.4 : The state graph" Automatic Mode ".

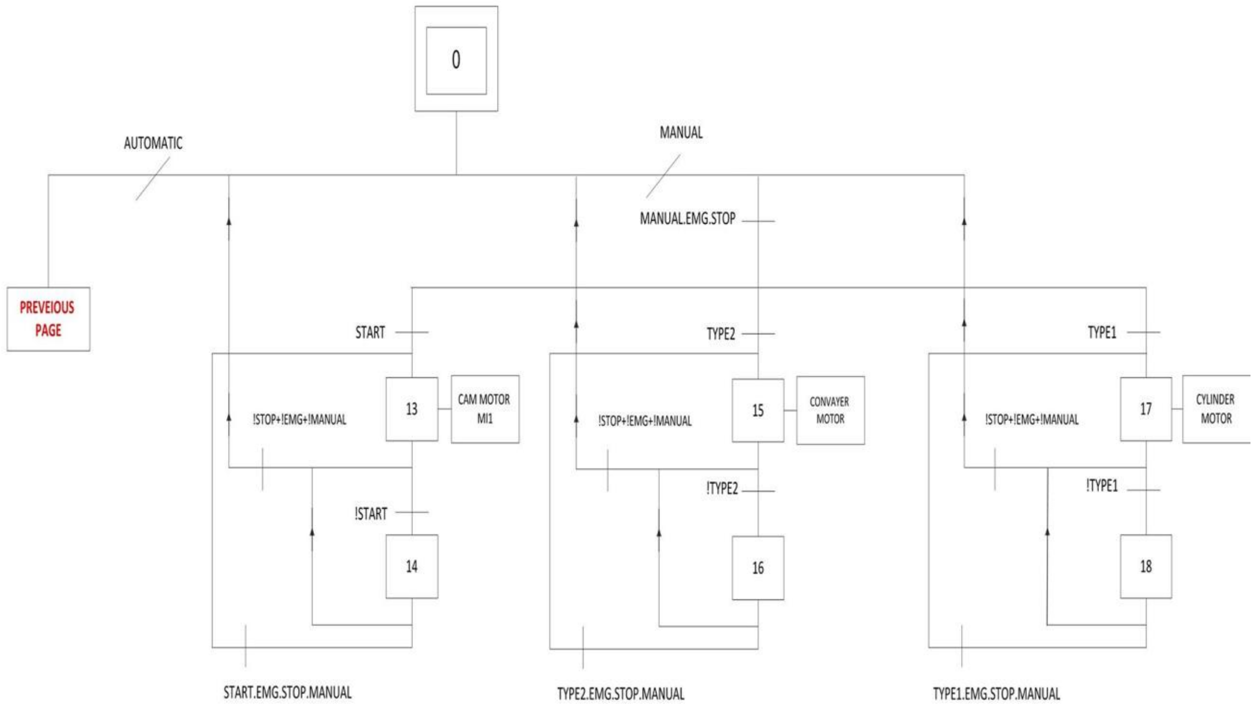


Figure 4.5 : The state graph" Manual Mode ".

The ladder code [1] is obtained from the state graph .

[1] -Appendix C

5

Chapter Five

Electrical Design & Protection

5.1 Introduction.

5.2 Motors.

5.3 Voltage Frequency Driver.

5.4 Sensors.

5.5 (Power & Control) Circuit.

5.6 Electrical Panel & Protection**.**

5.1 Introduction

This chapter contain the electrical component specifications (motor, inverters, sensor, overload, ... etc) , power & control circuit, and protection.

5.2 Motors:

In this project there are three AC motors (CAM Motor, Conveyer Motor, Casting Motor).

5.2.1 CAM motor

Three phase AC motor(to control it using inverter) (1HP:0.75KW) , REM Germany Electric Machine Co.

Frame size	Power (KW)	Current (A)			Current (A)			Current (A)			rpm. (r/min)	Eff. (%)	Power factor (Cosφ)	Cs/ Cn	Cmax/ Cn	Cn (Nm)	Is/In	dB(A)	Weight (Kg)
		220V	380V	660V	230V	400V	690V	240V	415V	720V									
MS 802-4	0.75	3.50	2.03	1.17	6.34	02.33.00	1.11	3.21	1.86	1.07	1380	72	0.78	2.2	2.4	5.27	6	58	9.10

5.2.2 Conveyer motor

Three phase AC motor(to control it using inverter) (0.12HP:0.09KW) ,REM Germany Electric Machine Co.

Frame size	Power (KW)	Current (A)			Current (A)			Current (A)			rpm. (r/min)	Eff. (%)	Power factor (Cosφ)	Cs/ Cn	Cmax/ Cn	Cn (Nm)	Is/In	dB(A)	Weight (Kg)
		220V	380V	660V	230V	400V	690V	240V	415V	720V									
MS 562-4	0.09	0.82	0.47	0.27	0.78	0.45	0.26	0.75	0.43	0.25	1360	52	0.59	2.3	2.4		4	50	3.20

5.2.3 Pulling motor

Single phase AC motor(230V,50Hz) (0.5HP:0.37KW) ,REM Germany Electric Machine Co.

Model	Power (KW)	Speed (r/min)	Eff. (%)	Power Factor (CosΦ)	Current (A)			T_{st}/T_n (Times)	T_{max}/T_n (Times)	T_{min}/T_n (Times)	I_{st}/I_n (Times)	Noise dB(A)
					230V	400V	690V					
MSBCCL712-4	0.37	1370	65	0.74	1.92	1.11	0.64	2.2	2.4	1.7	6	55

5.3 Voltage Frequency Driver

5.3.1 CAM motor voltage frequency driver

The purpose of using the voltage frequency driver is to control the speed of CAM motor by using multifunction speed, the type of CAM Motor driver is Delta model VFD015EL21A shown in figure 5.1

The VFD-EL series is multiple function new generation micro type AC drive, high precision current detection, overload protection, and a built in keypad.

Specifications

Nominal Input VAC: 208;240 Volts AC

Input Range VAC: 200 to 240 Volts AC

Input Phase: 1

HP (CT): 2 Horsepower

Amps (CT): 7.5 Amps

Max. Frequency: 600 Hertz

Figure 5.1: CAM motor inverter.

5.3.2 Conveyer motor voltage frequency driver

The purpose of using the voltage frequency driver is to control the speed of conveyer motor by using multifunction speed, the type of conveyer Motor driver is Delta model VFD007L21A shown in figure 5.2

Specifications

Input :1PH/9.7A 3PH/5.1A 200-240A 50-60HZ

Output:3PH 0-240V 4.2A 1.6kVA 1HP

Input Phase: 1

HP (CT): 1 Horsepower

Max. Frequency: 600 Hertz

Figure 5.2: Conveyer motor inverter.

5.4 Sensor

Limit switch is a switch operated by the motion of a machine part or presence of an object. They are used for control of a machine.

In this project there is 3 limit switches, 2 to check the position of cam during machine running and the other one is to check the presence of tray on the conveyer.

The limit switches used in this project has a model number Z-15GW2-B shown in figure 5.3.

Figure 5.3: Limit Switch.

5.5 (Power & Control) Circuit

The shown in figure 5.4 an it is contain:

Figure 5.4: Electrical Panel.

5.5 (Power & Control) Circuit

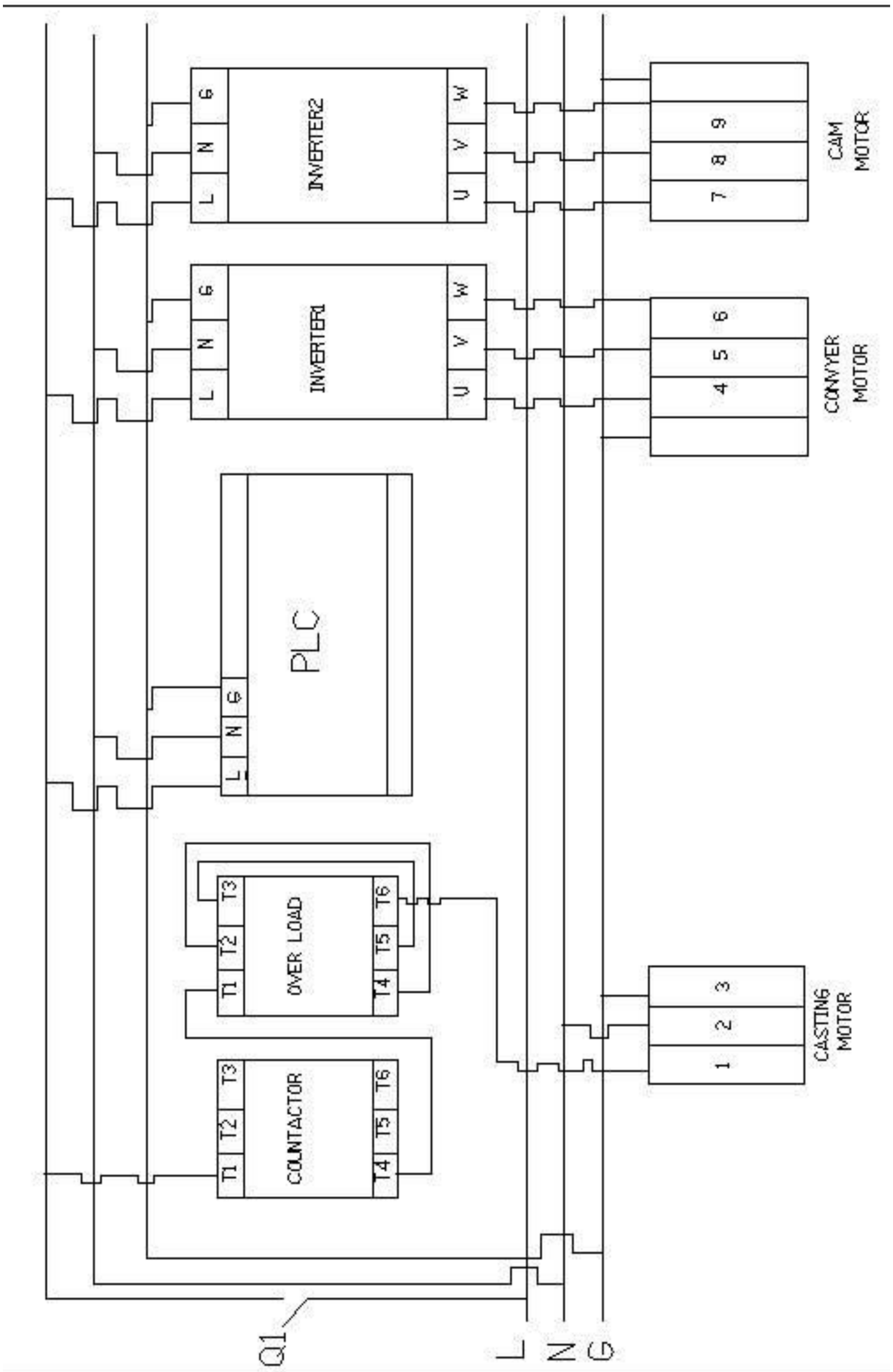


Figure 5.5 Power Circuit.

5.6 Electrical Panel & Protection

5.6.1 Motor Overload

Overload relays are intended to protect motors against excessive heating due to prolonged motor over currents up to and including locked motor currents. Protection of the motor due to short circuits or grounds, is a function of circuit breakers, or motor short-circuit protectors.

The motor overload used for cylinder motor, and in this project used a META-MEC Series MMS-32S (2.5A) overload as shown in figure 5.6.

Figure 5.6: Motor overload

5.6.2 Contactors

A contactor is an eclectically controlled switch used for switching a power circuit, similar to a relay except with higher current ratings.

A contactor is controlled by a circuit which has a much lower power level than the switched circuit.

Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contactor is not intended to interrupt a short circuit current. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand to large devices approximately a meter (yard) on a side. Contactors are used to control electric motors, lighting, heating, capacitor banks, thermal evaporators, and other electrical loads.

In this project used a one contactors for a cylinder motor and the contactor shown in figure 5.7.

Figure5.7:contactor.

5.6.3 Switches

The emergence switch are used to stop the machine immediately when something wrong happened with the machine as shown in the figure 5.8.a. The pushbutton are used to select the betit-fore type as shown in the figure 5.8.b .The selector switch used to select automatic or manual as shown in the figure 5.8.c .

A. Emergence Switch

B. Pushbutton

C. Selector Switch

Figure 5.8: Emergence, Pushbutton, and select switch.

5.6.4 Klements

Used to connect wires and a rang the connections as shown in figure 5.9.

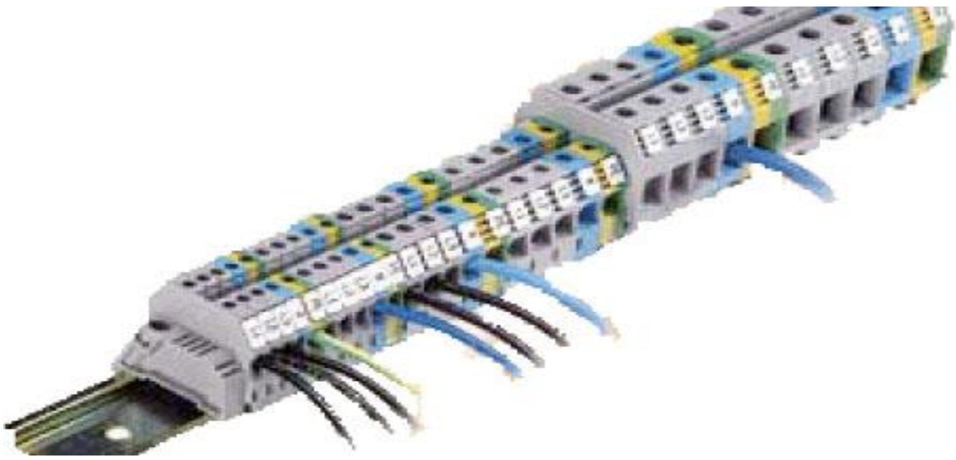


Figure 5.9: Klements.

5.6.5 LED

The led as shown in figure 5.10 are singed the machine operation mode .

Figure 5.10: LED.

6

Chapter Six

Experimental Result & Recommendations

6.1 Introduction

6.2 Experimental Result

6.3 Recommendations

6.4 Future Work

6.1 Introduction

This chapter provides experimental result and some recommendations from the work learn for this project. In this chapter we are listing some goals hope to be accomplished or _at least_ under attention .

6.2 Experimental Result

We made some experiments on parts of our project and these are some of results :

1. Transporting system: before get the dough from molds, tried to check the operation of conveyer, so putting the tray on the conveyer unit and it run successfully and moving the tray under casting molds to starting the casting operation.

2. Cylinder and molds system: put a small quantity of a petit-four dough on the container (2 kg) and the dough is passing through the cylinder into the molds, so the cylinder and molds system work successfully.

3. Cam system: the conveyer unit goes up or down when the cam motor run, so the cam motor run successfully.

At the first experiment we note that the final product of petit-fore has a large size so we reduce the casting time to make to achieve the desired size of petit-fore piece as shown in figure 6.1.

Figure 6.1: petit-Fore Sizes.

The experiment as shown in figure 6.2.

Figure 6.2: The Final Machine.

6.3 Recommendations

These recommendations are recorded to people who can create opportunities for student to make something new and useful, in order to make difference in our country Palestine:

1. Such projects should be handled among different departments according to the project nature (we had lots of electrical problems that might solve without having enough previous knowledge) .

2. Once the university administration financially supported graduation projects, this support must be provided at the beginning of the project work, to enable students to do their projects according to the time plan, and to test them at the proper time.

3. The university should provide the proper toolsets , which enable the student to assemble his project and to test it the university campus, so he could get benefit of experiences in the university.

6.4 Future Work

The following tasks are suggested as future works:

1. Testing and evaluating the machine with different types of dough.
2. Compare the improvement of our product with other product by public bakery

Appendix A

Questionnaire Analysis

A.1.1. The amount of daily production.

A.1.2. Number of the worker.

A.1.3. Number of work hours.

A.1.4. Number of shapes.

A.1.5. Buy the machine.

A.1.6. Price of the machine.

This questionnaire took (13) bakery that production Petit-Fore.

The results of the questionnaire :

-Q1: Do produce the petit-fore in your bakery?

All of the bakeries are produce a Petit-Fore in their shops.

-Q2:What is the method that you are us in your bakery?

All of the bakeries are produce a Petit-Fore in the traditional method that depends on labor.

-Q3: What is the size of the daily consumption of the product?

About %54 of bakeries are sell about 50Kg of Petit-Fore, and the others are sell less as shown in the figure A.1.1

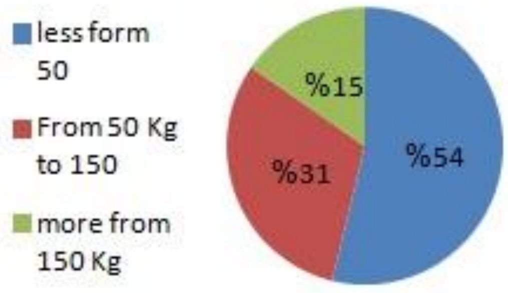


Figure A.1.1:The amount of daily production .

-Q4:How many workers does it take to production this product?

About %70 of bakeries are use 3 or less worker to produce this product, and the other are more than that as shown in figure A.1.2.

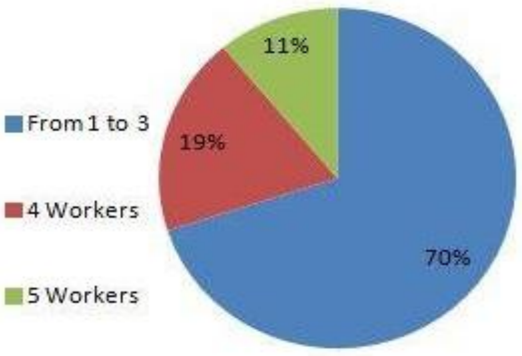


Figure A.1.2:Number of the worker.

-Q5: How much time needs of production this product?

About %68 of bakeries that produce 50Kg it take 3-4 hour to produce that amount and the other amounts are shown in figure A.1.3.

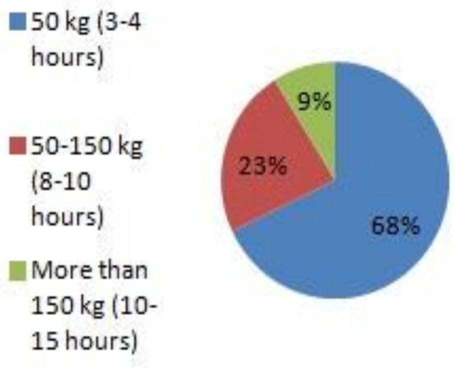


Figure A.1.3: Number of work hours .

-Q6: The number of shapes that can be produced in the traditional way?

According to figure A.1.4 more than the half of bakeries are produce between 11-20 shape of the petit-fore .

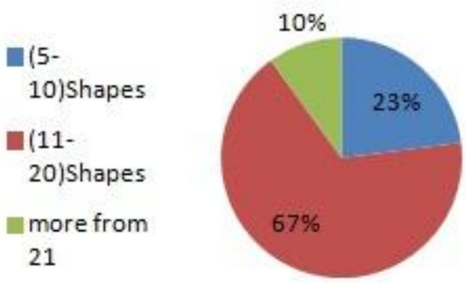


Figure A.1.4: Number of shapes.

-Q7: If you have been offered to you a machine industry Petit-Fore in automatic way are you going to buy it?

Most of the bakeries are said yes if the cost was acceptable according to figure A.1.5.

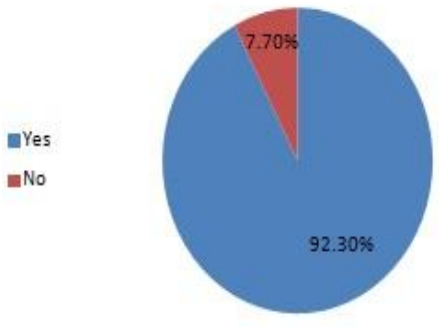


Figure A.1.5: Buy the machine.

-Q8: What is the expected price that will you pay for this machine?

About %80 of them were expected to pay around 10,000 $ as you see in figure A.1.6.

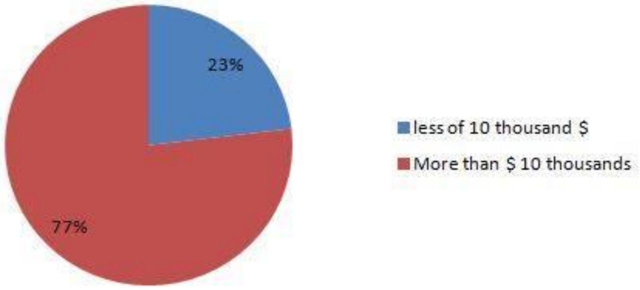


Figure A.1.6: Price of the machine.

-Q9: Is the manual " traditional " production covers the need of the market?

Almost agree that the traditional not cover the need of the market.

-Q10: How important is the machine for you, and whether you expect it would be economically?

Some of them are excited to this machine and expect that will be economically.

كلية الهندسة والتكنولوجيا
دائرة الهندسة الميكانيكية
مشروع الة صنع البيتيفور

التاريخ :   /   /
اسم المحل : ....
العنوان : ....

ورقة استبيان

١. هل تقوم بإنتاج البيتيفور في محلك ؟

أ. نعم   ب. لا

٢. ما هي الطريقة التي تستخدمها في انتاج البيتيفور ؟

....

٣. ما هو حجم الاستهلاك اليومي من منتج البيتيفور ؟

....

٤. كم هو عدد العمال الذي يتطلبه انتاج هذا الصنف ؟

....

٥. كم يحتاج من الوقت انتاج هذا الصنف ؟

....

٦. عدد الاشكال التي يمكن انتاجها بالطريقة اليدوية ؟

....

٧. اذا عرضت عليك ماكنة تقوم بصناعة البيتيفور بشكل الي وبدون الحاجة الى عمال هل ستقوم بشرائها ؟

....

٨. ما هو السعر المتوقع والمقبول والذي من الممكن ان تدفعه لشراء مثل هذه الالة ؟

....

٩. هل الانتاج اليدوي يغطي حاجة السوق

....

١٠. ما مدى اهمية الماكنة بالنسبة لك وهل ستتوقع انها ستكون ذات جدوى اقتصادية ؟

....

Appendix B

B.1 Delrin Properties.

B.2 Belt Properties.

B.3 Mechanical Properties of stainless steel.

B.4 Mechanical Properties of steel 1020.

B.1 Delrin Properties:

ENSINGER-HYDE
ASK. THINK. SUCCEED.

DELRIN®

DELRIN®
(Acetal Homopolymer)

DELRIN® is a crystalline plastic which offers an excellent balance of properties that bridge the gap between metals and plastics. DELRIN® possesses high tensile strength, creep resistance and toughness. It also exhibits low moisture absorption. It is chemically resistant to hydrocarbons, solvents and neutral chemicals. These properties along with its fatigue endurance make DELRIN® ideal for many industrial applications.

- **Good dimensional stability**
- **Low moisture absorption**
  DELRIN® can operate in wet environments with little effect on performance or dimensions.
- **Excellent machinability**
- **High fatigue endurance**
- **High strength and stiffness properties**
- **Superior impact and creep resistance**
- **Chemical resistance to fuels and solvents**
- **Natural grade is FDA, NSF and USDA compliant**
- **Good wear and abrasion properties**
  With its low coefficient of friction and hard and resilient surface, DELRIN® is the material of choice in many wear applications.

DELRIN®s overall combination of physical, tribological and environmental properties make it ideal for many industrial wear and mechanical applications. Parts exposed to a moist or wet environment, such as pump and valve components, are especially appropriate. Other common uses for DELRIN® include gears, bearings, bushings, rollers, fittings and electrical insulator parts.

TYPICAL PROPERTY VALUES

	PROPERTIES	ASTM Test Method	Units	Delrin® 150
PHYSICAL	Density	D792	lbs/in³	0.0513
	Specific Gravity	D792	g/cc	1.42
	Water Absorption, @24 hours, 73°F	D570	%	0.25
	@Saturation, 73°F	D570	%	0.9
MECHANICAL	Tensile Strength @ Yield, 73°F	D638	psi	9,000
	Tensile Modulus	D639	psi	350,000
	Elongation @ Break, 73°F	D638	%	25
	Flexural Strength, 73°F	D790	psi	11,500
	Flexural Modulus, 73°F	D790	psi	420,000
	Compressive Strength	D695	psi	5,200
	Izod Impact Strength, 73°F	D256	ft-lbs/in	1.5
	Rockwell Hardness, 73°F	D785	M (R) Scale	M 94 (120)
	Shure Hardness	-	D Scale	-
	Wear Factor Against Steel, 40 psi, 50 fpm	D3702	$\frac{in^3}{hr} \times \frac{1}{PV}$	55×10^{-10}
		-		-
	Static Coefficient of Friction	D3702		-
	Dynamic Coefficient of Friction, 40 psi, 50 fpm	D3702		0.2
THERMAL	Heat Deflection Temperature @ 66 psi	D648	°F	336
	@264 psi	D648	°F	257
	Coefficient of Linear Thermal Expansion	D696	in/in/°F	6.8×10^{-5}
	Maximum Servicing Temperature, Intermittent	-	°F	300
	Long Term	UL746B	°F	185
	Specific Heat	-	BTU/lb-°F	0.35
	Thermal Conductivity	-	-	-
	Vicate Softening Point	-	°F	-
	Melting Point	D2133	°F	347
	Flammability	UL94		HB (1.47)
ELECTRICAL	Surface Resistivity	D257	ohm/square	-
	Volume Resistivity	D257	ohm-cm	10^{15}
	Dielectric Strength	D149	V/mil	500
	Dielectric Constant, @ 60 Hz, 73°F, 50% RH	D150		3.7
	@ 1 MHz	D150		3.7
	@ 20 GHz	D150		-
	@ 30 GHz	D150		-
	Dissipation Factor, @ 60 HZ, 73°F	D150		0.005

This information is only to assist and advise you on current technical knowledge and is given without obligation or liability.
 Data obtained from extruded shapes material.

MATERIAL AVAILABILITY

Rods: Diameters: 4 3/4", 10' length
Length: 5" and greater diameter, 5' length

Plates: 1/4" to 2" thickness inclusive are 2' x 4', 4' x 8', 4' x 10'
2-1/4" to 4" thickness inclusive are 2' x 4'

Primary Specification (Resin) (Typical)
ASTM-D-4181 POM110B34330

Shapes Specification (Typical)
ASTM-D-6100 S-POM0111

Profiles, tubes, and special sizes are custom-produced on request.

B.2 Belt Properties :

Technical Product Data Sheet

Product identification	S 8/2 E V05A/V05NP	21108009

Product group	Standard conveyor belt
Mode of transport	Sloping and horizontal running with support roller
Application	Harvest machines, sorting belts, transport of unit loads
Industry	Agriculture, machine and plant construction, wood industry

Product construction

Material conveying side	Polyvinylchloride (PVC)
Characteristics conveying side	smooth, adhesive
Colour conveying side	green
Cover thickness conveying side	0,5 mm
Shore hardness A°	70
Material traction layer	Polyester fabric
Number of fabrics	2
Material running side	Polyvinylchloride (PVC)
Characteristics running side	negative pyramide (NP)
Colour running side	green
Cover thickness running side	0,5 mm

Product characteristics

Total thickness	2,5 mm (+/- 0,1 mm)	
Belt weight	2,8 kg/m²	
Standard production width	2.000 mm	special widths on request
Maximum tensile force	120 N/mm	
- at 1% elongation	8 N/mm	
Minimum pulley diameter	60 mm	
Knife edge suitable	no	
Operation temperatures	-10…+70°C	
Permanently antistatic DIN EN 20284	yes	
Flammability DIN EN 20340	no	
Chemical resistance	limited oil and grease resistant - see list of resistance	
FDA Food suitability	no	
EU Food suitability	no	

Installation terms

Slider bed suitable	no
Carrying rollers suitable	yes
Low noise application	no
Accumulation mode	no
Inclined transportation	yes
Buckling conveyor	no
Curved installation	no
Friction coefficient on slider bed of steel	0,35
Friction coefficient on slider bed with friction cover	0,4
Troughed installation	no
Cross rigidity	yes

- specifications subject to change without notice -

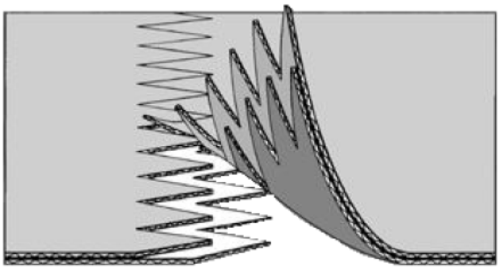
phone: +49 (0)37468 666 0 fax: +49 (0)37468 666 29 web: www.visgmbh.eu email: info@visgmbh.eu

Joining Instruction

Product identification | **S 8/2 E V05A/V05NP** | **21108009**

Endless Joining

Recommended joining	double finger joining
Joining addition	105 mm



Joining material

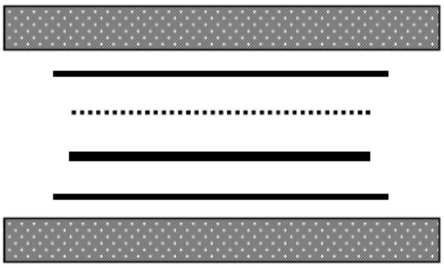
Joining material conveying side	Silicone paper glossy
Joining material running side	Silicone pad NP
Joining material inside	PVC foil
Additional material	no

Joining parameters

Heating temperature (top/bottom)	165°C
Heating time	5 minutes
Pressure	2 bar
Remarks	use same material for edge demarcation

Alternative joining methods

Step joining	yes
Wedge joining	yes
Mechanical joining	yes G002 Alligator RS62



Heating plate top
Silicone paper glossy
PVC foil
Conveyor belt (Conveying side up)
Silicone pad NP
Heating plate bottom

Technical status: 03/2012

VIS GmbH

Bahnstrasse 1-3
D-08233 Treuen/Vogtland
GERMANY

- specifications subject to change without notice -

phone: +49 (0)37468 666 0 fax: +49 (0)37468 666 29 web: www.visgmbh.eu email: info@visgmbh.eu

B.3 Mechanical Properties of Stainless steel :

† Often preferred.

Table A–5

Physical Constants of Materials

Material	Modulus of Elasticity E		Modulus of Rigidity G		Poisson's Ratio ν	Unit Weight w		
	Mpsi	GPa	Mpsi	GPa		lbf/in³	lbf/ft³	kN/m³
Aluminum (all alloys)	10.4	71.7	3.9	26.9	0.333	0.098	169	26.6
Beryllium copper	18.0	124.0	7.0	48.3	0.285	0.297	513	80.6
Brass	15.4	106.0	5.82	40.1	0.324	0.309	534	83.8
Carbon steel	30.0	207.0	11.5	79.3	0.292	0.282	487	76.5
Cast iron (gray)	14.5	100.0	6.0	41.4	0.211	0.260	450	70.6
Copper	17.2	119.0	6.49	44.7	0.326	0.322	556	87.3
Douglas fir	1.6	11.0	0.6	4.1	0.33	0.016	28	4.3
Glass	6.7	46.2	2.7	18.6	0.245	0.094	162	25.4
Inconel	31.0	214.0	11.0	75.8	0.290	0.307	530	83.3
Lead	5.3	36.5	1.9	13.1	0.425	0.411	710	111.5
Magnesium	6.5	44.8	2.4	16.5	0.350	0.065	112	17.6
Molybdenum	48.0	331.0	17.0	117.0	0.307	0.368	636	100.0
Monel metal	26.0	179.0	9.5	65.5	0.320	0.319	551	86.6
Nickel silver	18.5	127.0	7.0	48.3	0.322	0.316	546	85.8
Nickel steel	30.0	207.0	11.5	79.3	0.291	0.280	484	76.0
Phosphor bronze	16.1	111.0	6.0	41.4	0.349	0.295	510	80.1
Stainless steel (18-8)	27.6	190.0	10.6	73.1	0.305	0.280	484	76.0
Titanium alloys	16.5	114.0	6.2	42.4	0.340	0.160	276	43.4

B.4 Mechanical properties of Steel 1020 :

Table A–20

Deterministic ASTM Minimum Tensile and Yield Strengths for Some Hot-Rolled (HR) and Cold-Drawn (CD) Steels [The strengths listed are estimated ASTM minimum values in the size range 18 to 32 mm ($\frac{3}{4}$ to $1\frac{1}{4}$ in). These strengths are suitable for use with the design factor defined in Sec. 1–10, provided the materials conform to ASTM A6 or A568 requirements or are required in the purchase specifications. Remember that a numbering system is not a specification.] *Source:* 1986 SAE Handbook, p. 2.15.

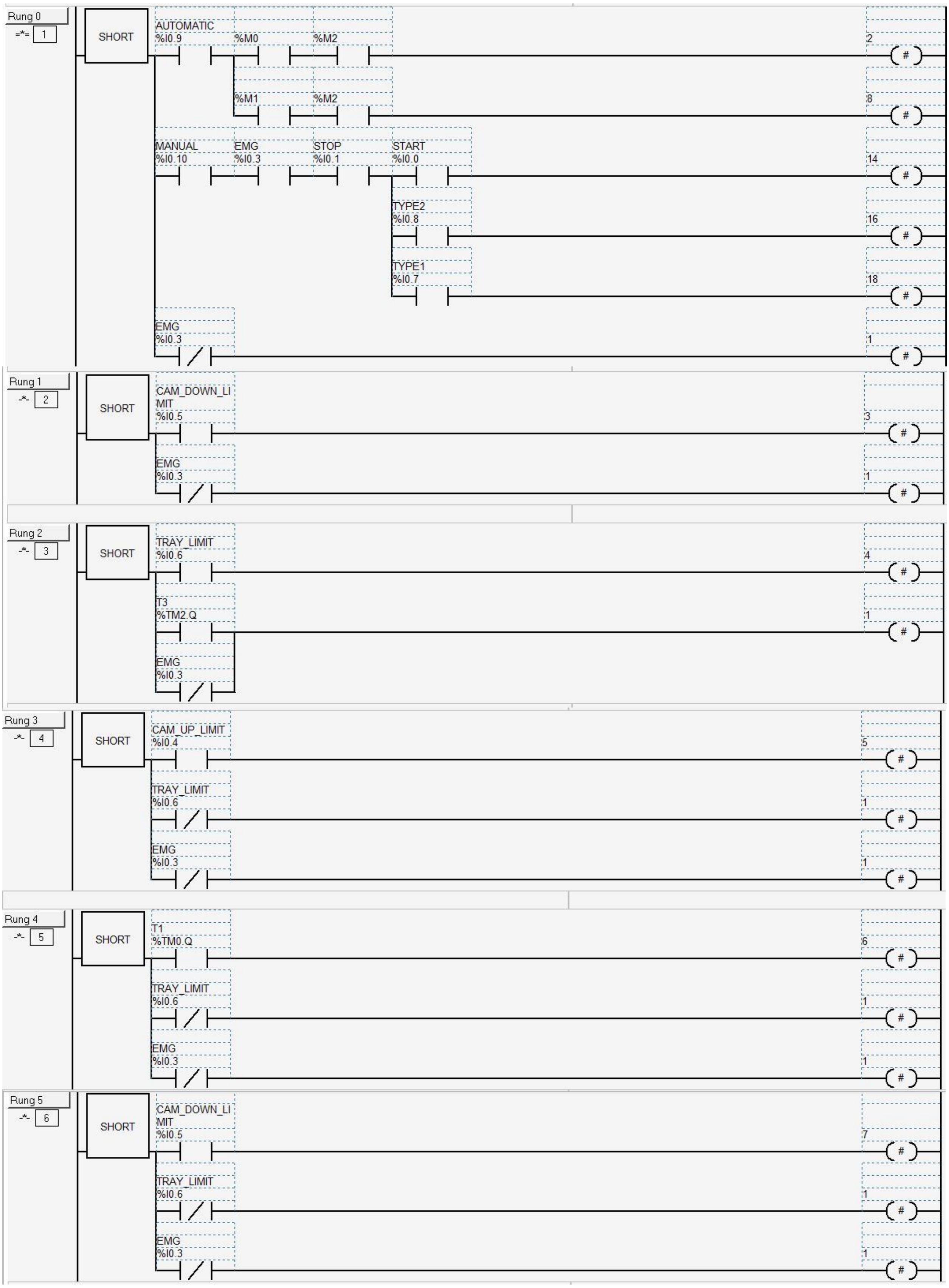
1 UNS No.	2 SAE and/or AISI No.	3 Processing	4 Tensile Strength, MPa (kpsi)	5 Yield Strength, MPa (kpsi)	6 Elongation in 2 in, %	7 Reduction in Area, %	8 Brinell Hardness
G10060	1006	HR	300 (43)	170 (24)	30	55	86
		CD	330 (48)	280 (41)	20	45	95
G10100	1010	HR	320 (47)	180 (26)	28	50	95
		CD	370 (53)	300 (44)	20	40	105
G10150	1015	HR	340 (50)	190 (27.5)	28	50	101
		CD	390 (56)	320 (47)	18	40	111
G10180	1018	HR	400 (58)	220 (32)	25	50	116
		CD	440 (64)	370 (54)	15	40	126
G10200	1020	HR	380 (55)	210 (30)	25	50	111
		CD	470 (68)	390 (57)	15	40	131
G10300	1030	HR	470 (68)	260 (37.5)	20	42	137
		CD	520 (76)	440 (64)	12	35	149
G10350	1035	HR	500 (72)	270 (39.5)	18	40	143
		CD	550 (80)	460 (67)	12	35	163
G10400	1040	HR	520 (76)	290 (42)	18	40	149
		CD	590 (85)	490 (71)	12	35	170
G10450	1045	HR	570 (82)	310 (45)	16	40	163
		CD	630 (91)	530 (77)	12	35	179
G10500	1050	HR	620 (90)	340 (49.5)	15	35	179
		CD	690 (100)	580 (84)	10	30	197
G10600	1060	HR	680 (98)	370 (54)	12	30	201
G10800	1080	HR	770 (112)	420 (61.5)	10	25	229
G10950	1095	HR	830 (120)	460 (66)	10	25	248

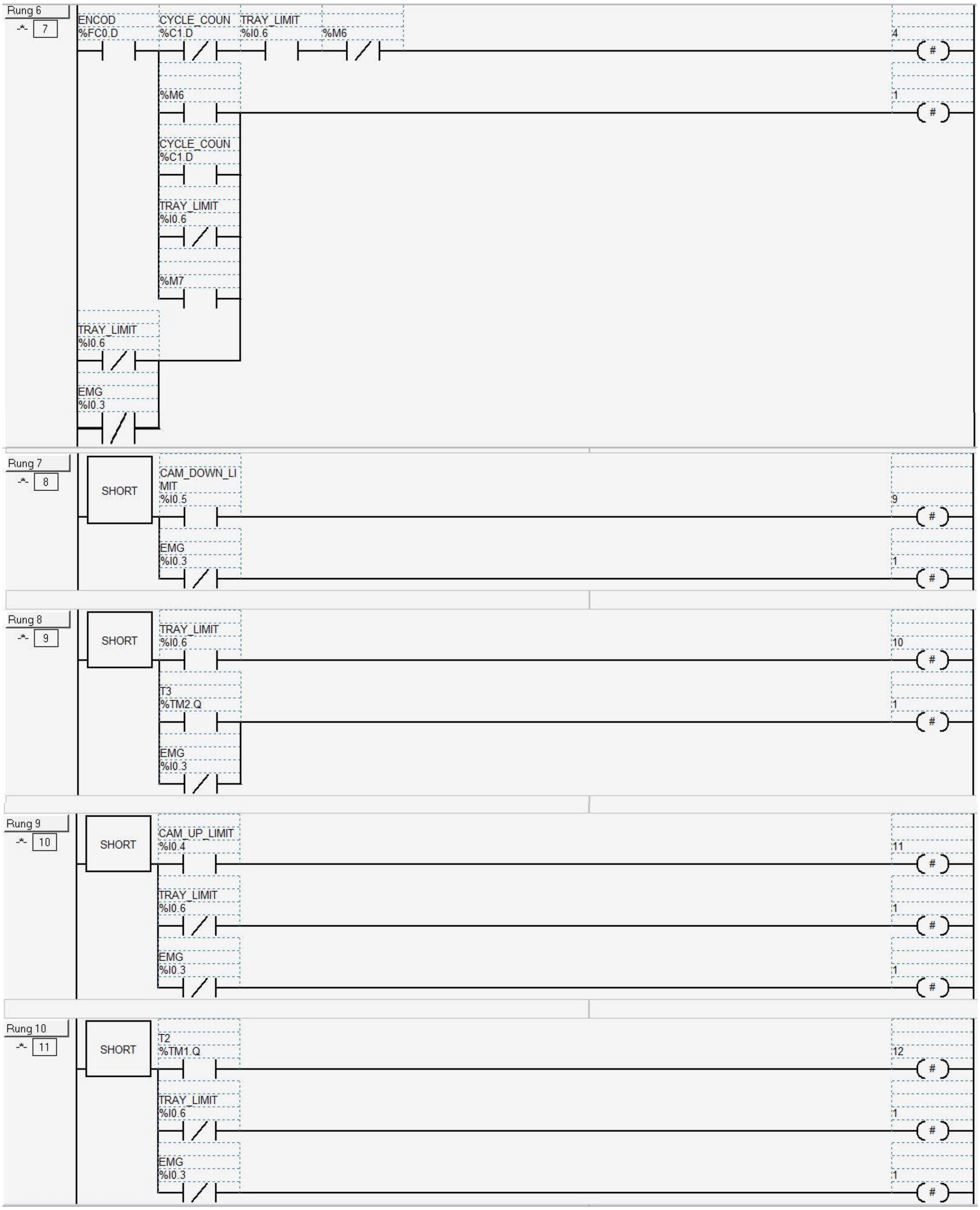
Appendix C

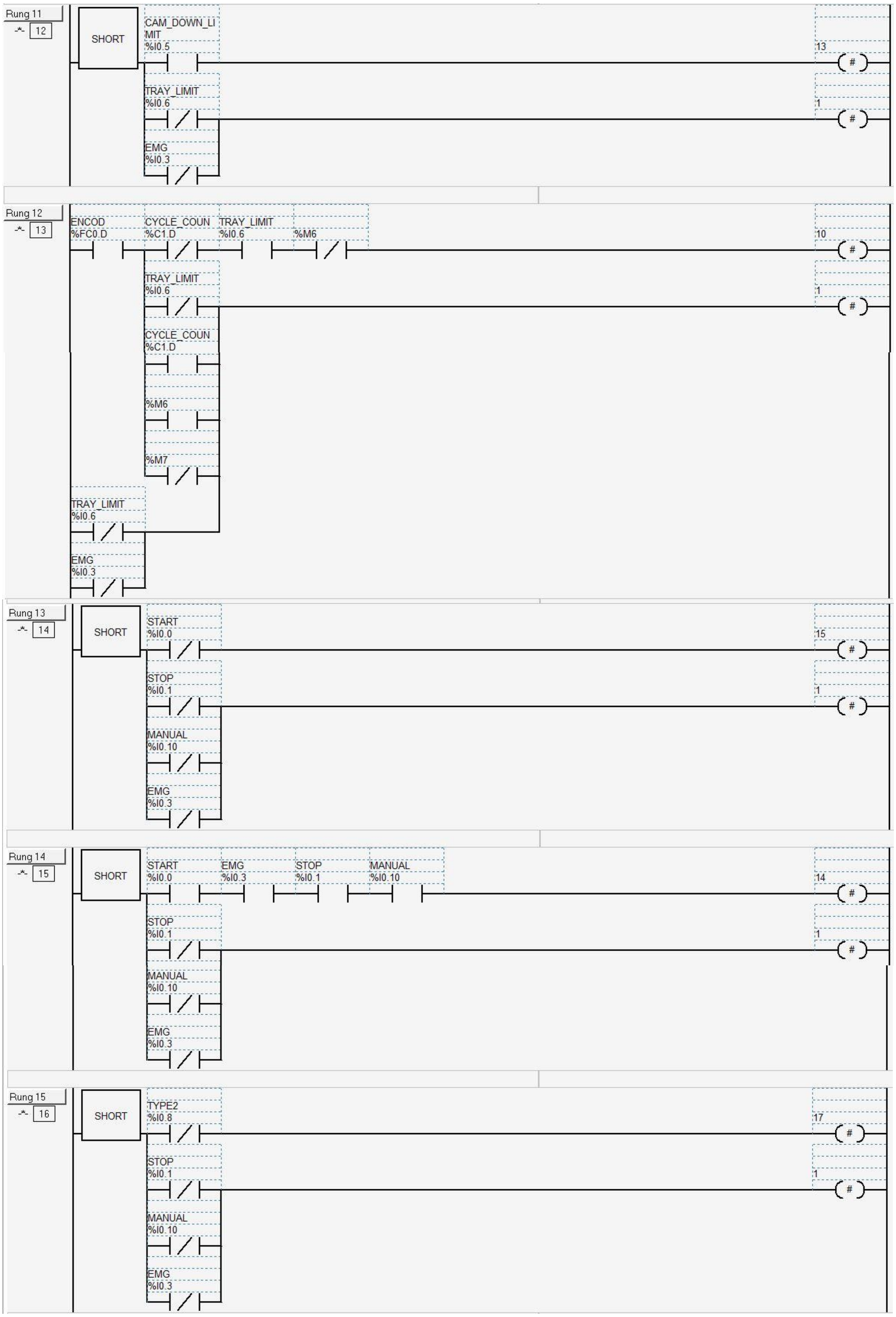
Programming Code

C.1 Ladder Code.

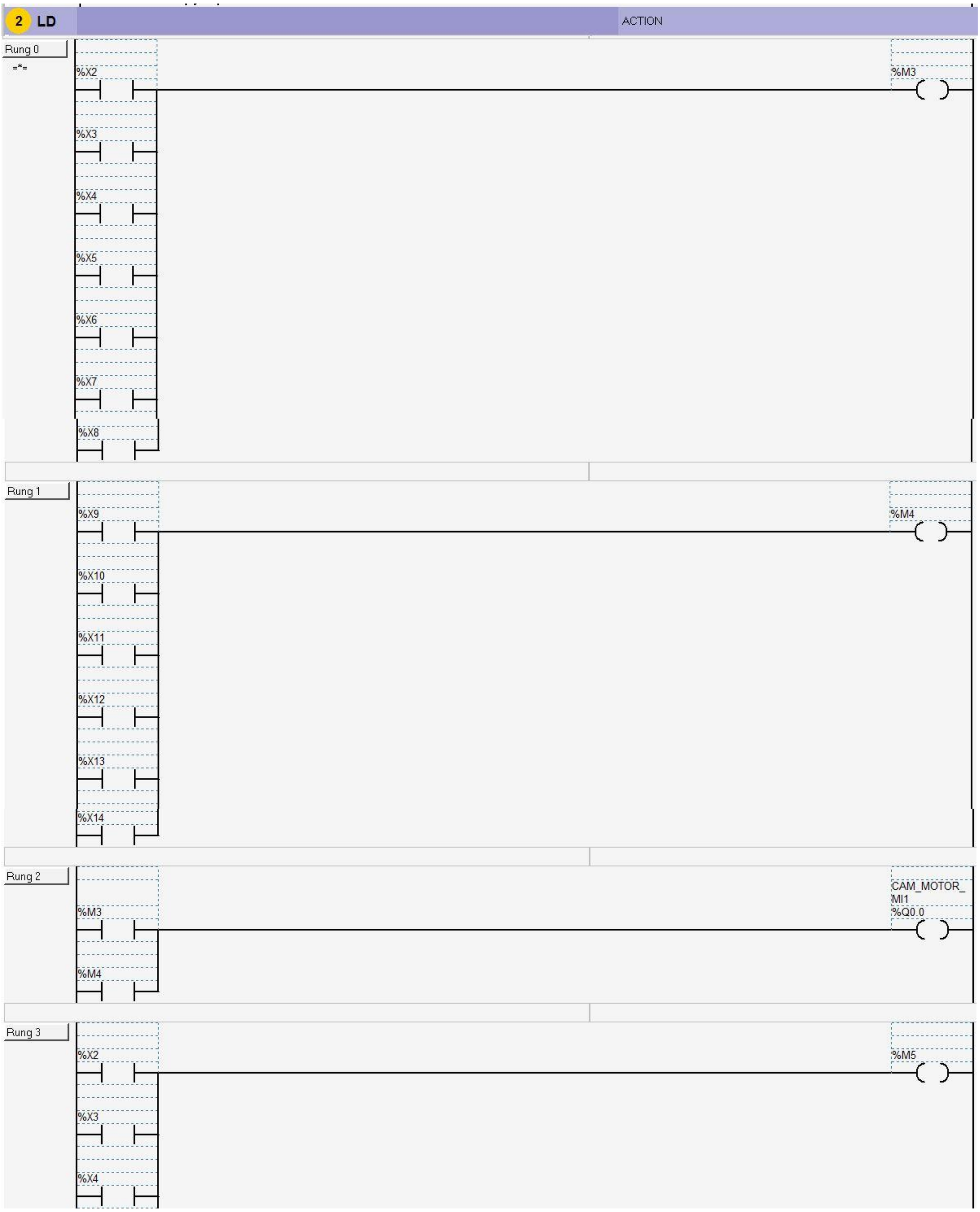
C.1 Ladder Code :




Rung 6
7
ENCOD
%FC0.D
CYCLE_COUN
%C1.D
TRAY_LIMIT
%I0.6
%M6
4
%M6
1
CYCLE_COUN
%C1.D
TRAY_LIMIT
%I0.6
%M7
TRAY_LIMIT
%I0.6
EMG
%I0.3
Rung 7
8
SHORT
CAM_DOWN_LI
MIT
%I0.5
9
EMG
%I0.3
1
Rung 8
9
SHORT
TRAY_LIMIT
%I0.6
10
T3
%TM2.Q
1
EMG
%I0.3
Rung 9
10
SHORT
CAM_UP_LIMIT
%I0.4
11
TRAY_LIMIT
%I0.6
1
EMG
%I0.3
1
Rung 10
11
SHORT
T2
%TM1.Q
12
TRAY_LIMIT
%I0.6
1
EMG
%I0.3
1


Rung 11
12
SHORT
CAM_DOWN_LIMIT
%I0.5
13
TRAY_LIMIT
%I0.6
1
EMG
%I0.3
Rung 12
13
ENCOD
%FC0.D
CYCLE_COUN
%C1.D
TRAY_LIMIT
%I0.6
%M6
10
TRAY_LIMIT
%I0.6
1
CYCLE_COUN
%C1.D
%M6
%M7
TRAY_LIMIT
%I0.6
EMG
%I0.3
Rung 13
14
SHORT
START
%I0.0
15
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3
Rung 14
15
SHORT
START
%I0.0
EMG
%I0.3
STOP
%I0.1
MANUAL
%I0.10
14
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3
Rung 15
16
SHORT
TYPE2
%I0.8
17
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3


Rung 16
17
SHORT
TYPE2
%I0.8
EMG
%I0.3
STOP
%I0.1
MANUAL
%I0.10
16
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3
Rung 17
18
SHORT
TYPE1
%I0.7
19
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3
Rung 18
19
SHORT
TYPE1
%I0.7
EMG
%I0.3
STOP
%I0.1
MANUAL
%I0.10
18
STOP
%I0.1
1
MANUAL
%I0.10
EMG
%I0.3


2 LD
ACTION
Rung 0
%X2
%X3
%X4
%X5
%X6
%X7
%X8
%M3
Rung 1
%X9
%X10
%X11
%X12
%X13
%X14
%M4
Rung 2
%M3
%M4
CAM_MOTOR_
MI1
%Q0.0
Rung 3
%X2
%X3
%X4
%M5


%X7
%X8
%X9
%X10
Rung 4
%X13
%M5
CAM_MOTOR_MI4
%Q0.1
Rung 5
%X5
%X6
%X11
%X12
CAM_MOTOR_MI5
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Rung 6
%X3
%X7
%X9
%X11
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%X16
CONVAYER_MOTOR
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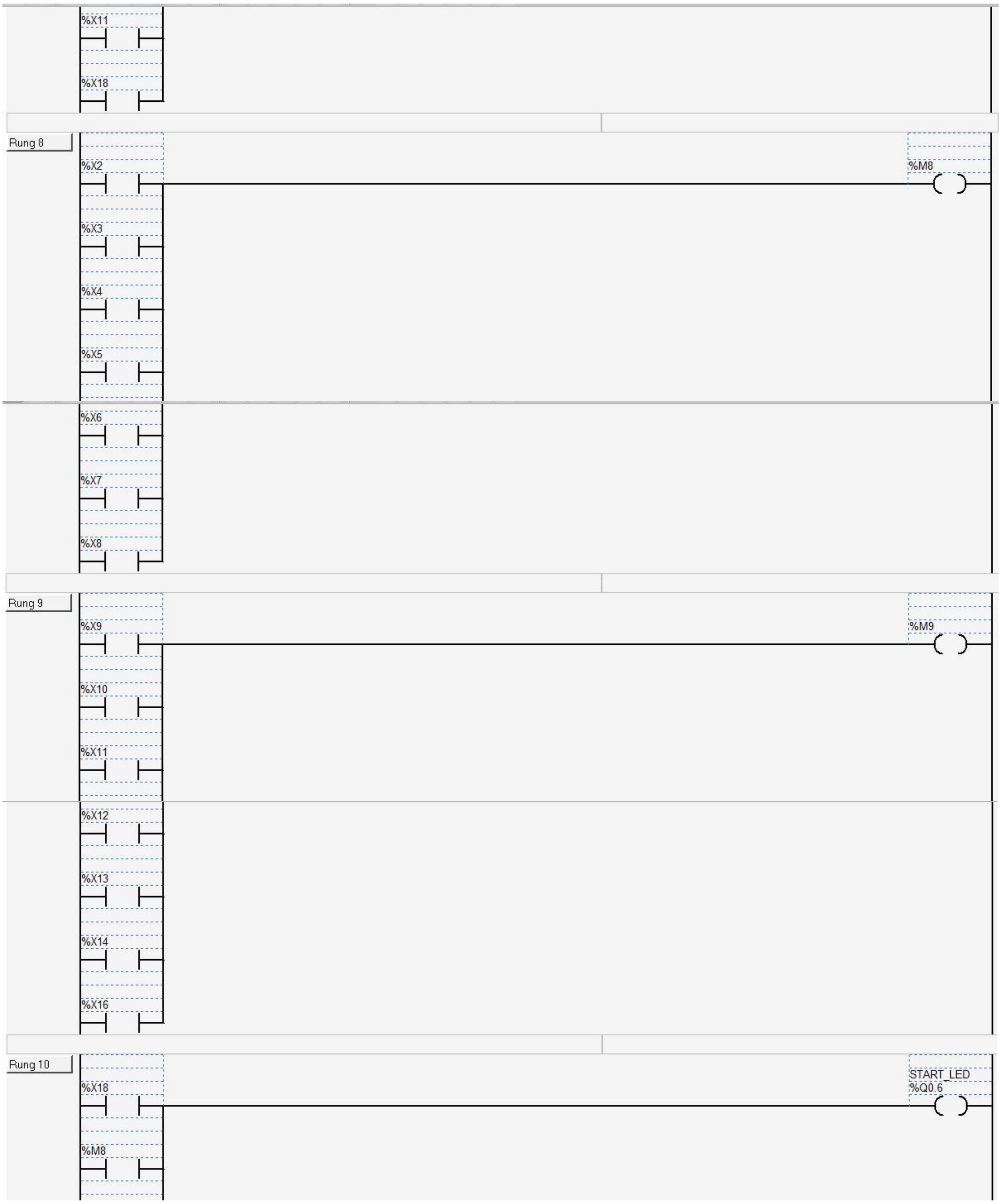
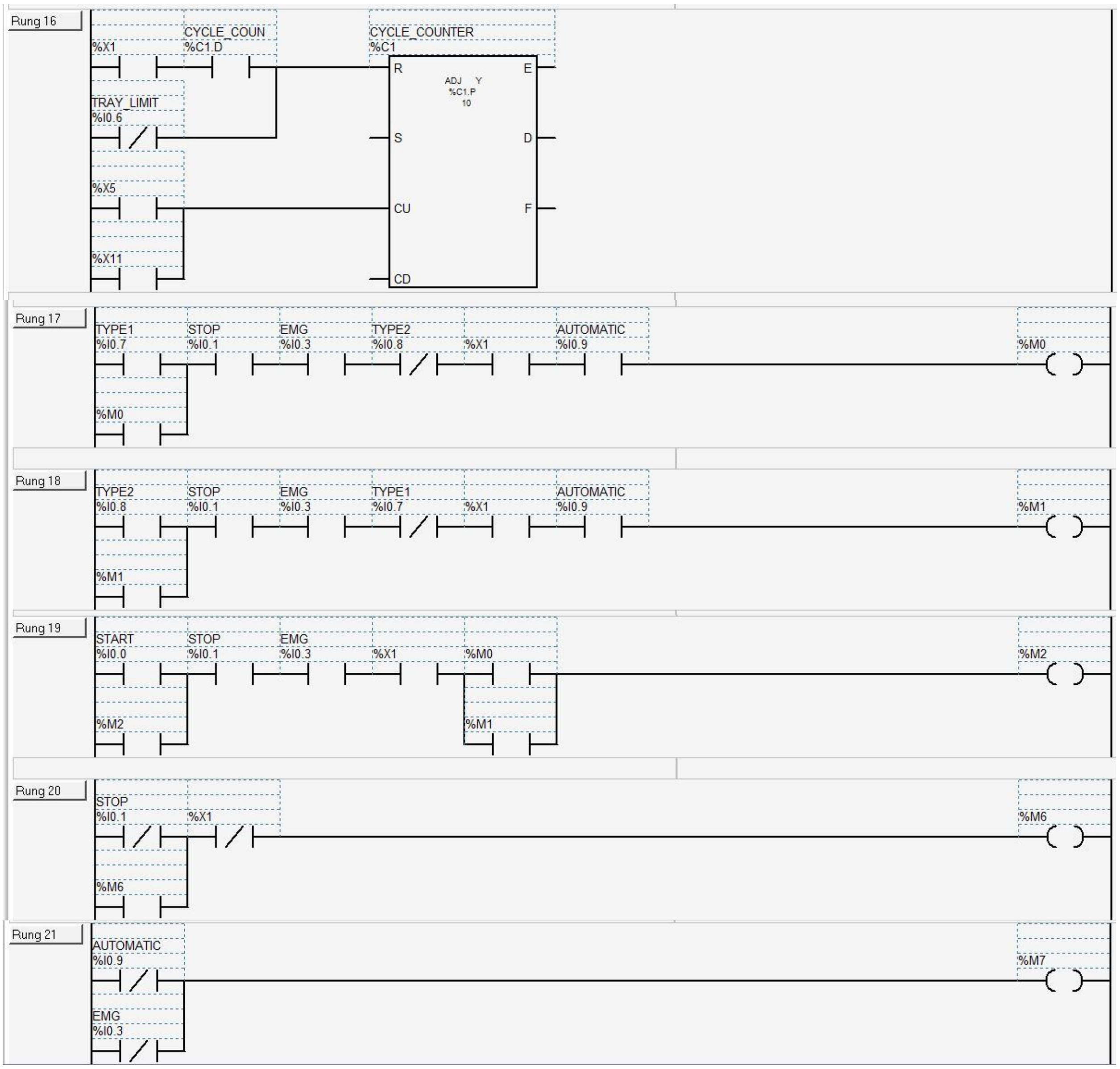
Rung 7
%X5
CYLINDER_MOTOR
%Q0.4


%X11
%X18
Rung 8
%X2
%X3
%X4
%X5
%X6
%X7
%X8
%M8
Rung 9
%X9
%X10
%X11
%X12
%X13
%X14
%X16
%M9
Rung 10
%X18
%M8
START_LED
%Q0.6


%M9
Rung 11
%X1
STOP_LED
%Q0.5
%X15
%X17
%X19
Rung 12
TIMER1
%TM0
%X5
IN
Q
TYPE TON
TB 1 sec
ADJ Y
%TM0.P
2
Rung 13
TIMER2
%TM1
%X11
IN
Q
TYPE TON
TB 1 sec
ADJ Y
%TM1.P
2
Rung 14
TIMER3
%TM2
%X3
%X9
IN
Q
TYPE TON
TB 1 sec
ADJ Y
%TM2.P
10
Rung 15
%FC0
IN
D
TYPE UP
SINGLE
ADJ Y
%FC0.P
125
%X6
R
%X12


Rung 16
%X1
CYCLE_COUN
%C1.D
CYCLE_COUNTER
%C1
R
E
ADJ Y
%C1.P
10
TRAY_LIMIT
%I0.6
S
D
%X5
CU
F
%X11
CD
Rung 17
TYPE1
%I0.7
STOP
%I0.1
EMG
%I0.3
TYPE2
%I0.8
%X1
AUTOMATIC
%I0.9
%M0
%M0
Rung 18
TYPE2
%I0.8
STOP
%I0.1
EMG
%I0.3
TYPE1
%I0.7
%X1
AUTOMATIC
%I0.9
%M1
%M1
Rung 19
START
%I0.0
STOP
%I0.1
EMG
%I0.3
%X1
%M0
%M2
%M2
%M1
Rung 20
STOP
%I0.1
%X1
%M6
%M6
Rung 21
AUTOMATIC
%I0.9
%M7
EMG
%I0.3

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