DESIGN AND DEVELOPMENT OF AUTOMATED GLOVE FOLDING MACHINE

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Declaration

I declare that this is my own work and this thesis does not incorporate without acknowledgement any material previously submitted for a Degree or Diploma in any other University or institute of higher learning and to the best of my knowledge and belief it does not contain any material previously published or written by another person except where the acknowledgement is made in the text.

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K. R. S. Premarathne

The above candidate has carried out research for the Masters under my supervision.

Signature: …………………… Date: ……………………

Dr. A. G. B. P. Jayasekara

Abstract

Introducing any kind of automation system to manual process saves substantial time in production enabling reduction of skilled labour requirement, reduction of space, while increasing production capacity. Here automation is applied to fold gloves.

The manufactures of gloves always try to widen their glove market through their innovative products with high quality & high performance. In addition attractive packing system is playing a major role in competitive marketing.

Today, the individual glove pairs packing are mostly done using "Automatic horizontal pillow wrapping machines". Meanwhile there is a requirement to reduce the size of glove packets, as to suit for the "glove vending machines". In that case it is decided to fold a glove pair three times to be smallest in size. This glove folding process is more time & labour consumable.

The objective of this study is to identify and investigate a suitable method to fold gloves while keeping fingers of glove pair without spread fingers during its folding. Available methods which use to fold shirts are not suitable for fold gloves. Folded shirt keeps its shape as it is, but not that in gloves. Those are getting unfold. Hence, need a method for trap the shape.

Three types of conceptual manual prototype models have been tested. Only one type of the conceptual prototype among them has been succeeded. Further improvements and developments have been incorporated to fold the gloves automatically.

The machine consists of two main working stations as "glove folding with poly bag insertion station" and "glove stripping station". It is facilitated with polybag sealer near to the "striping station". This sealer is activated by a photo sensor. Conveyor chain is used to index glove between two stations. It is driven by geared induction motor with a motor driver. Folding mechanism is mainly driven by pneumatic actuators to achieve quick motions.

Maximum output of this machine is 480 pairs per hour while manual folding output is about 140 pairs per hour.

This machine can be further developed into fully automated version by introducing a system for glove placement, a system for poly bag insertion and another system for glove stripping. Hence safety precautions can be improved during placement of gloves to fold.

Dedication

To my beloved

Mother, Mrs. Leela Premarathne

Father, Mr. Piyasiri Premarathne

Wife, Lathika Rathnayake

And

Daughter, Thiseni Dahamsa

Acknowledgement

I wish to express my sincere gratitude to my supervisor, Dr. A. G. B. P. Jayasekara, Senior Lecturer, Faculty of Engineering, University of Moratuwa for his continuous supervision and guidance for me to successfully complete this research work.

Furthermore, I would like to express my special gratitude to Prof. N. Wickamarachchi, Head of the Department of Electrical Engineering, Prof. Sisil P. Kumarawadu and Dr. D. P. Chandima, Course coordinator, Senior Lecturer, Faculty of Engineering, University of Moratuwa for their Exemplary guidance, comments and encouragements throughout this research.

I would like to express my thanks to non-academic staff of Electrical Engineering Department for their support.

Also, I would like to express my heartiest thanks to Electrician, Welders and other supporters of the workshop for fabricating the machine successfully with several modifications.

Finally, I wish express my special, heartiest thanks to my wife and daughter for their encouragement, without which this research would not have been possible.

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1. INTRODUCTION

The manufactures of gloves always try to widen their glove market through their innovative products with high quality & high performance. In addition attractive packing system is playing a major role in competitive marketing.

1.1. Conventional Glove Packing

Figure 1.1: Conventional glove packets.

In the competitive glove market, we can see more colourful and attractive printed poly bags have used to pack individual glove pairs. Those glove pairs are mostly packed by using “Automatic Horizontal Pillow Wrapping Machines”.

Figure 1.2: Automatic horizontal pillow wrapping machine.

Meanwhile there is a requirement to reduce the size of glove packets, as to suit for the "glove vending machines". In that case it is decided to fold a glove pair three times to be smallest in size.

Figure 1.3: Packet of folded glove pair.

This glove folding process is more time & labour consumable.

1.2. Existing Glove Folding System

1.2.1. Step 01 – Fold left and right thumbs onto its palm

Figure 1.4: Thumbs folded onto its palm.

1.2.2. Step 02 – Place left and right palm together

Figure 1.5: Place two palms together.

1.2.3. Step 03 – Fold fingers on top of the back hand side

Figure 1.6: Fold fingers on top of the back hand side.

1.2.4. Step 04 – Fold wrist on top of the fingers

Figure 1.7: Fold wrist on top of the fingers.

1.2.5. Step 05 – Squeeze the glove pair and put into the packet

Figure 1.8: Squeezed glove pair put into the packet.

1.2.6. Step 06 – Seal the packet

Figure 1.9: Sealed glove packet.

1.3. Literature Review

1.3.1. Folded packaged gloves “in [8]…”

Many gloves are now distributed using vending machines, and indication of properties is not prominently visible on that of multi-folded gloves. The chance of user confusion is increased. That confusion may lead to wrong selection of gloves for a particular task and it may increase the likelihood of injury.

Also, gloves need to be folded and packaged efficiently, in order to utilize vending machine space efficiently, and not to jam in the vending machine, need to hold as many units as possible in correct orientation within the vending machine. Therefore packaging gloves so that, for example, a logo or a brand, as well as other identifying information, is be clearly displaced while folded represents an advance in the art.

This paper illustrates mainly two methods of glove folding systems with considering above features, but not illustrates any mechanism to fold the gloves.

1.3.2. Garment folding apparatus “in [9]…”& Apparel folding tool “in [10]…”

Above two papers disclosed garments folding apparatus which more suitable for upper-body garments, such as shirts, T-shirts and tops.

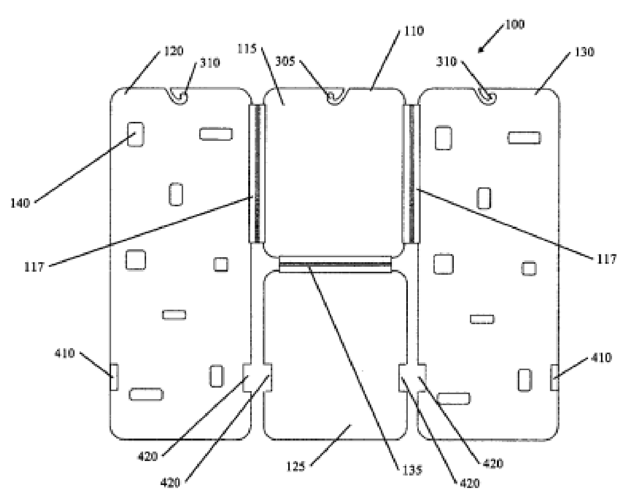


Figure 1.10: Garment folding apparatus “in [9]…”

This garments folding apparatus includes a planer center panel having a length and a width, the width being less than the length. The center panel is configured to fold in a lengthwise direction. The apparatus further includes a planer left side panel joined by a hinge to the center panel. The apparatus further includes a planer right side panel joined by a hinge to the center panel on a side opposite to the left side panel. The left side panel and the right side panel each comprise raised handle portions on an outer edge thereof. When the left side panel and right side panel are folded on to the center panel, the handle positions fit into corresponding notches formed in side edges of the second portion of the center panel and corresponding notches formed in inner side edges of the left side panel and the right side panel.

Upper-body garments, such as shirts and tops, are laid to be folded. The side panels fold over onto the center panel to accurately and consistently fold the garments.

1.3.3. Apparatus and method for high speed cross folding "in [11]…"

Apparatus and method provided in this paper for folding discrete items such as diapers at high speeds. Discrete items are conveyed in a machine direction toward a pair of vacuum drums rotating in the machine direction and first carrying a top side of a leading edge of the discrete item away from the conveyor, and then carrying a bottom side of the leading edge with a second rotational vacuum drum back towards the conveyor. A diaper fold is created at a contact point with a folding finger which travels rotationally and straight in a fixed orientation about a pair of belts, into and out of contact with the diaper.

This method is not suitable for glove folding because it is required to fold glove pair in three times and is difficult to keep pre-folded parts as it is, without unfolding.

1.3.4. Method of folding paper "in [12]…"

The invention concerns a method of folding paper with a folding machine having folding station with two feed rollers and three another rollers for folding, and a portion of a paper web supplied to it is first folded into a first stack containing continuous sheets and, after reaching a threshold value of the first stack thus created, is moved into a tray and thus remains connected to the remaining part of the paper web via a folded trailing sheet, a section of the folded trailing sheet serves as the basis for a further subsequent stack of continuous sheet to be folded thereupon.

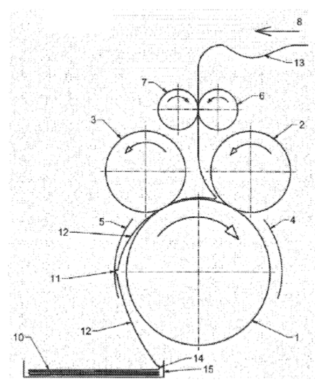


Figure 1.11: Paper folding mechanism "in [12]…"

Stack is fed alternatingly between three rollers of the folding station in to the guide plates. After reaching the threshold value, the paper web is merely folded between rollers in the next folding step, the rollers and the supply rollers are reversed after folding is completed. After the folds have left the gap between the rollers, the rollers are reversed again, while the supply rollers continue pulling the folded trailing sheet further out of the folding station. At this point the first stack is guided in to a guide plate and outward via same. The supply rollers are then reversed when the next to last fold has exited the gap between the rollers, and after the stack has left the guide plate and reached the tray. The rollers are reversed for stacking again.

This method is not suitable for glove folding because glove is the discrete article. is difficult to keep pre-folded fingers as it is, without unfolding.

1.3.5. Low cost automated machine for paper gathering and folding "in [13]…"

Friction feed method was used to feed papers for folding mechanism in this machine. Feed tray is the first part use in the paper folding process. This is where the operator stacks the sheets needed to be folded.

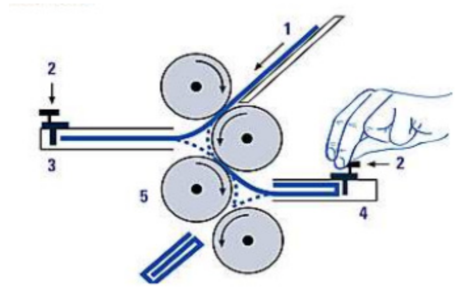


Figure 1.12: Paper folding mechanism "in [13]…"

In this folding machine, it is used feeding rollers with one rubber wheel. This rubber wheel improves the friction of the feeder than the other materials and also misaligning errors in feed engager.

This method is not suitable for glove folding because it is required to fold glove pair in three times and is difficult to keep pre-folded fingers as it is, without unfolding.

1.3.6. Method of making disposable pants having underwear-like waistbands, and pant made thereby "in [14]…"

This paper illustrates a method of manufacturing disposable absorbent garments and a garment made thereby.

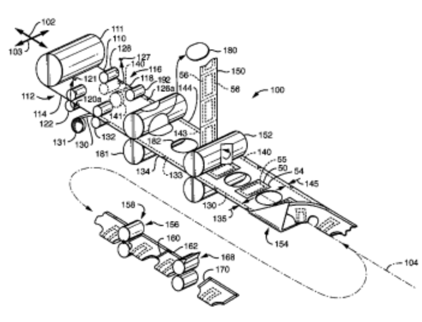


Figure 1.13: Method of manufacturing disposable pants "in [14]…"

In particular embodiments, the method comprises removing notches or holes of a garment web or webs adjacent to front and back waist edges to define a series of spaced apart front and back waist edge openings. The method includes providing front and back elastic waistband webs, and positioning the respective waistband webs to overlay at least a portion of each opening and bonding the waistband webs to each other. The garment includes first and second waist cutouts, wherein two side seams extend from the waist edge cutouts to respective leg openings. The garment further includes front and back elastic waistbands attached to each other at first and second waistband side seams.

Among all of the mechanisms and methods disclosed in this paper, my concern only for the folding mechanism used. Here the folding mechanism is a guide plate.

It is required to perform a trial to check the suitability of this folding mechanism to fold the gloves.

1.3.7. Apparatus and method for folding "in [15]…"

The invention disclosed herein relates to apparatus and methods for folding pieces travelling on a production line. Here the description provided relates to diaper manufacturing.

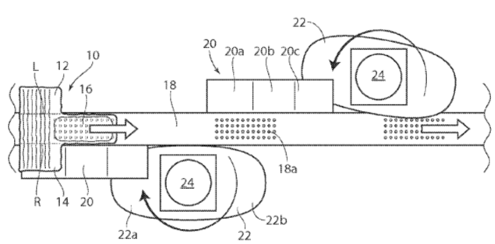


Figure 1.14: Web folding system for diapers "in [15]…"

Here the items are conveyed by a vacuum conveyor, in a machine direction toward a pair of rotating blades. A first intended target of folding, for instance a right portion of front and back panels of a diaper. Travels up ramp, raising the level of the intended target. A rotating blade passes under the intended target of folding, and folds the right portion of front and back panels of a diaper over. If desired a second intended target of folding, for instance a left portion of front and back panels of a diaper, travels up a second ramp, raising the level of intended target. A rotating blade passes under the second intended target of folding, and folds the left portion of front and back panels of a diaper over. The folded diaper then exits the folding system and travels downstream for further processing.

This method is not suitable for glove folding because it is required to fold glove pair in three times and is difficult to keep pre-folded fingers as it is, without unfolding.

1.3.8. Fabric article folding machine and method "in [16]…"

This invention folds fabric articles automatically. Articles include shirts, sweaters, pants, and towels, in a wide range of fabric types and sizes.

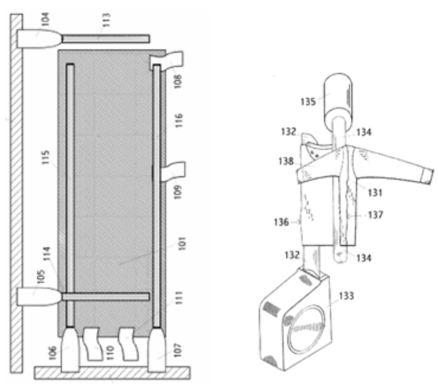


Figure 1.15: Fabric folding platform and method "in [16]…"

A rotating rod in combination with a retractable concave/convex tape creates pairs of folds on a fabric article on a horizontal platform. The article to be folded generally placed on a horizontal platform. The rotatable rods are above the platform and below the article. The tape extends outward and downward to hold the article at a first fold location, while the rotating rod moves from below, then over and across the tape, pulling the fabric with it to create a second fold at the farthest motion of the rod.

These motions are typically repeated on the other side of the article, then at right angles, created a finished, folded article of a generally rectangular shape.

This method is not suitable for glove folding because it is difficult to keep pre-folded fingers as it is, without unfolding.

1.3.9. Development of system to fold T-shirt in the state of hanging “in [17]…”

This paper discussed an automatic T-shirt folding device. After take a T-shirt out of the washing machine and put it on a specially developed hanger to dry, this device folds the T-shirt in a completely automatic way. Steps as follows,

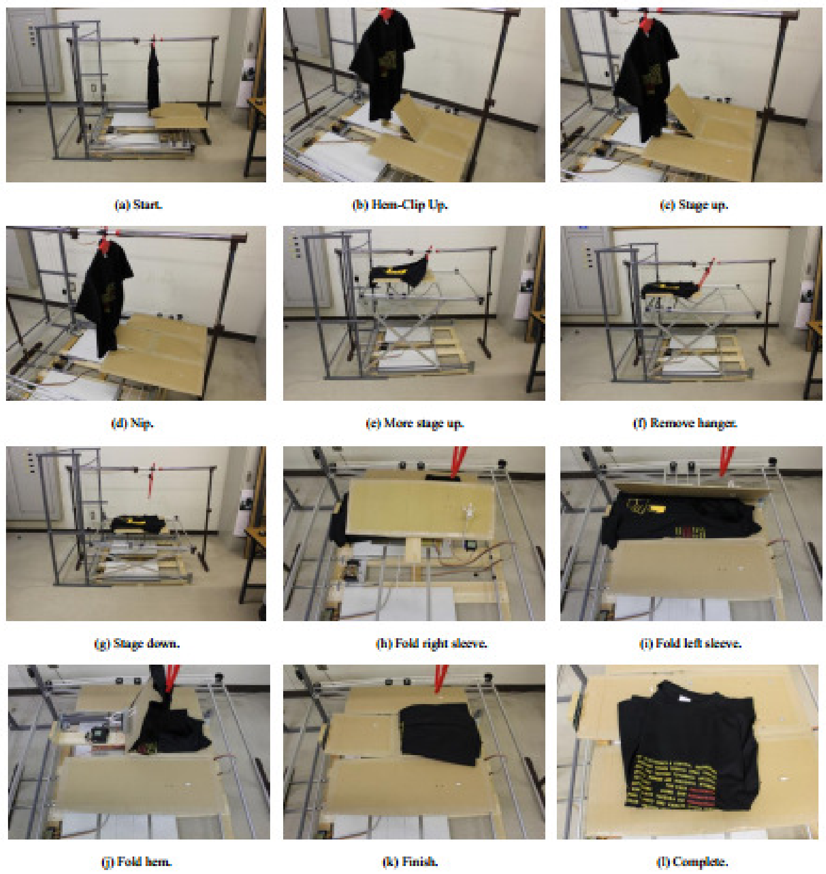


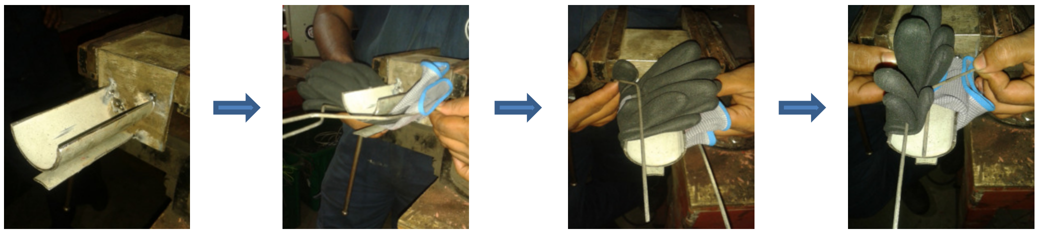
Figure 1.16: Movements of the folding system “in [17]…”

This system is most suitable to fold T-shits like articles and not for gloves, because it is difficult to keep pre-folded fingers as it is, without unfolding.

1.4. Trials Performed

Considering the existing folding system and referring all above research papers, three trials are performed to find a suitable method to fold gloves automatically.

1.4.1. Trial – 1: Fold gloves using former and guide rods



(a) (b) (c) (d)

Figure 1.17: Steps of the folding system using former and guide rods

Trial - 1 is failed due to,

- Fingers are not controllable during folding.
- Unable to insert polybag.

1.4.2. Trial – 2: Fold gloves using foldable plates

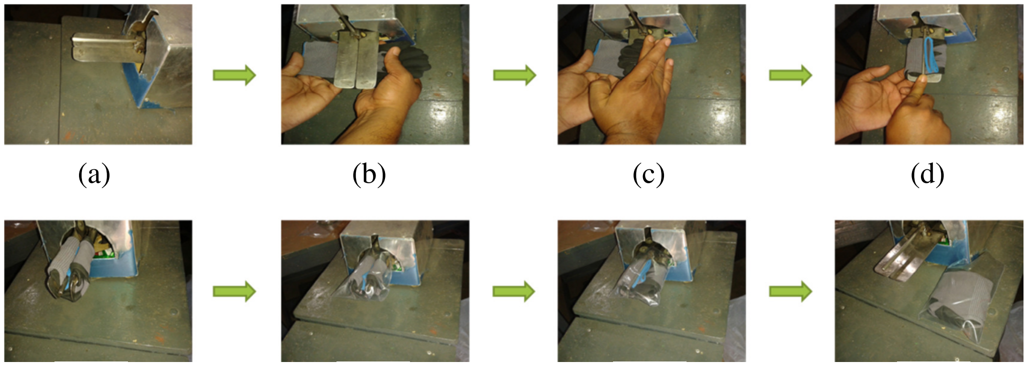
(a) (b) (c)

Figure 1.18: Steps of the folding system using foldable plates

Trial - 2 is failed due to,

- Fingers try to spread during folding.
- Unable to insert polybag.
- Finishing is not satisfactory.

1.4.3. Trial – 3: Fold gloves using duple plates with lock



(a) (b) (c) (d)

(e) (f) (g) (h)

Figure 1.19: Steps of the folding system using duple plates with lock

Trial - 3 is successful,

- Fingers are controllable.
- Easy to insert polybag.
- Finishing is satisfactory.
- Can fold gloves in uniform manner.

1.5. Problem Statement

- To reduce the labour requirement for manual glove folding arrangement.
- To fold the gloves in uniform manner.
- To stable the output efficiency. (In manual folding system, the output efficiency depends on the experience of the labour allocated.)
- There are no machines available in the market to fulfill the customer's glove folding requirement.

1.6. Aim and Objectives

The objective of this study is to identify and investigate a suitable method to fold gloves while keeping fingers of glove pair without spread fingers during its folding. Available methods which use to fold shirts are not suitable for fold gloves. Because folded shirt keeps its shape as it is, but not that in gloves. Those are getting unfold. Hence, need a method for trap the shape.

My approach in this regard to develop a machine which it can fold gloves in uniform manner and with higher efficiency. This research is mainly developed by using "Mitsubishi Alpha" logic controller with pneumatic actuators & mechanical arrangements. Mechanical arrangements & mechanisms are mainly developed by trial & error method.

2. CONCEPTUAL PROCESS DESIGN

2.1. Methodology

The machine consists of two main working stations as “glove folding with poly bag insertion station” and “glove stripping station”. It is facilitated with polybag sealer near to the “striping station”. This sealer is activated by a photo sensor. Conveyor chain is used to index glove between two stations. It is driven by geared induction motor with a motor driver. Folding mechanism is mainly driven by pneumatic actuators to achieve quick motions.

2.2. Sequence of Operation

2.2.1. Glove pair to be packed

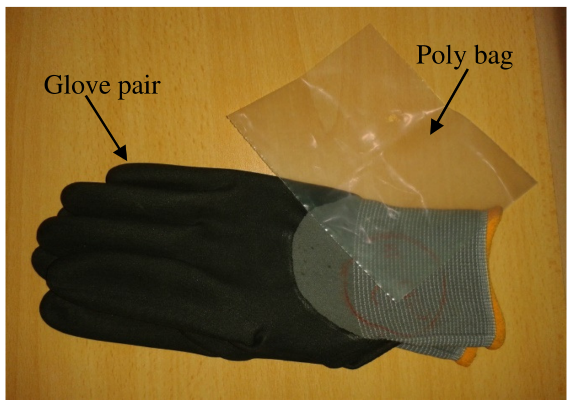


Figure 2.1: Glove pair and poly bag.

2.2.2. Initial position of the machine

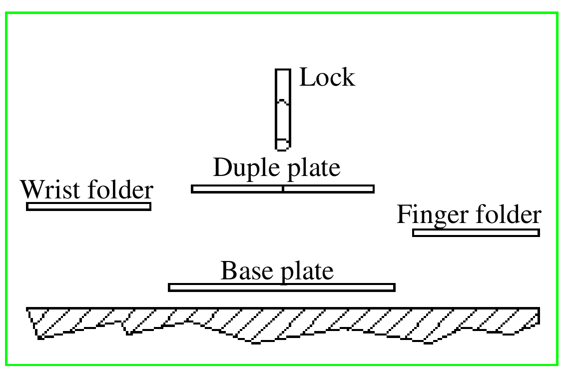


Figure 2.2: Initial position of the machine.

2.2.3. Step 01 – Lock release

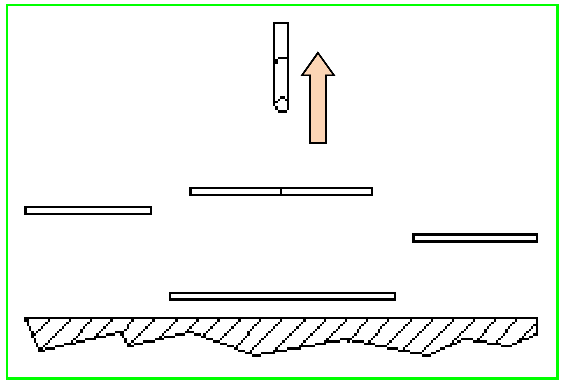


Figure 2.3: Lock pulls up.

2.2.4. Step 02 – Fold duple plates up

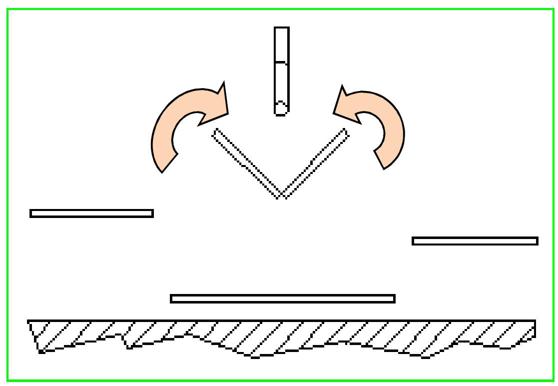


Figure 2.4: Fold the duple plates up.

2.2.5. Step 03 – Place a glove pair on base plate

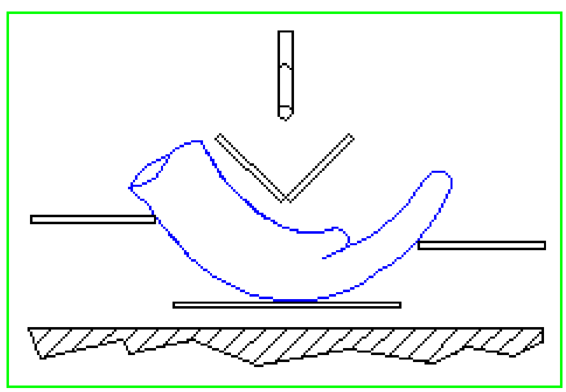


Figure 2.5: Place a glove pair on base plate.

2.2.6. Step 04 – Release duple plates down

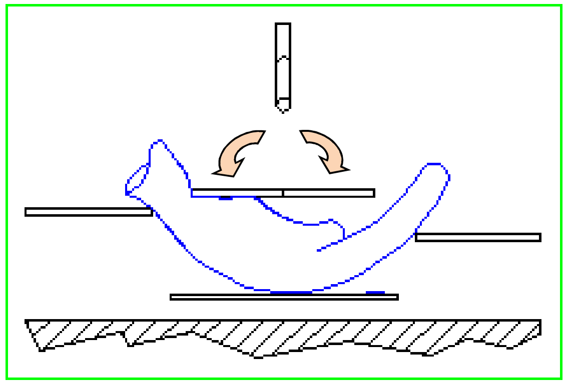


Figure 2.6: Release duple plates down.

2.2.7. Step 05 – Base plate moves up

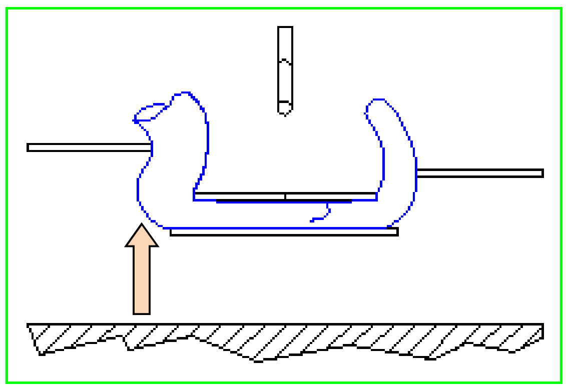


Figure 2.7: Base plate moves up.

2.2.8. Step 06 – Finger folder moves forward

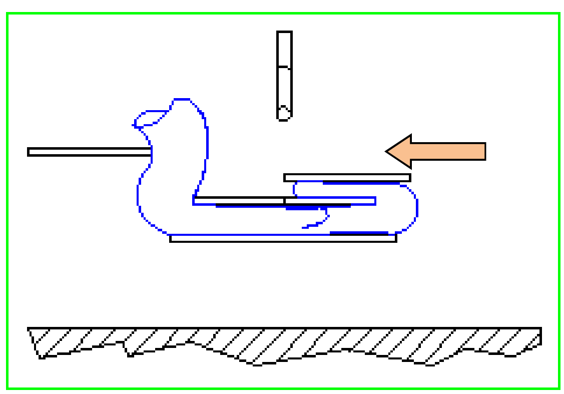


Figure 2.8: Finger folder moves forward.

2.2.9. Step 07 – Wrist folder moves forward

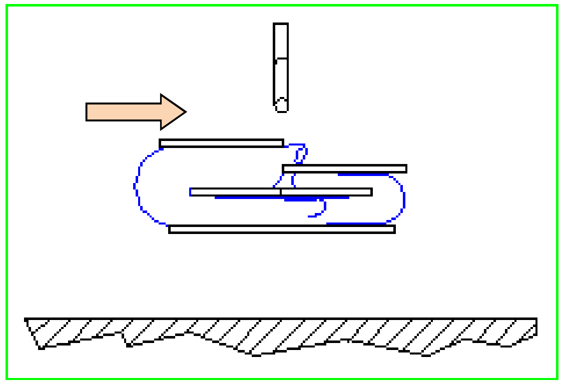


Figure 2.9: Wrist folder moves forward.

2.2.10. Step 08 – Lock release down

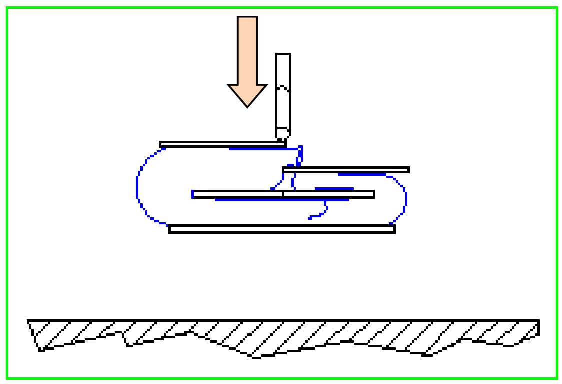


Figure 2.10: Lock release.

2.2.11. Step 09 – Wrist folder reverse

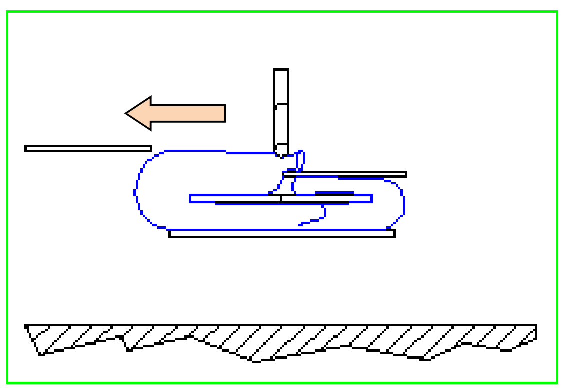


Figure 2.11: Wrist folder reverse.

2.2.12. Step 10 – Finger folder reverse

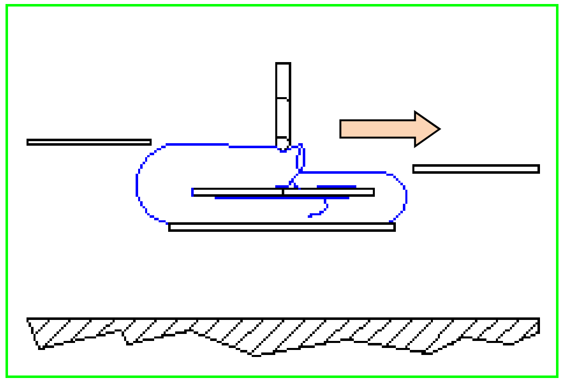


Figure 2.12: Finger folder reverse.

2.2.13. Step 11 – Base plate moves down

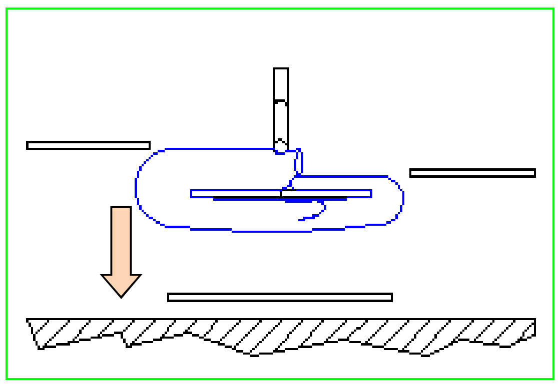


Figure 2.13: Base plate moves down.

2.2.14. Step 12 – Squeeze the gloves

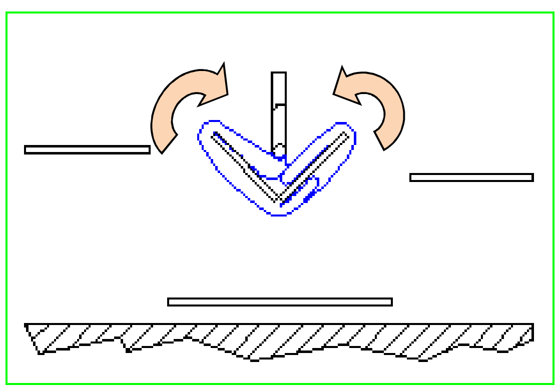


Figure 2.14: Fold the duple plates up to squeeze the gloves.

2.2.15. Step 13 – Dress a poly bag to squeezed glove pair manually

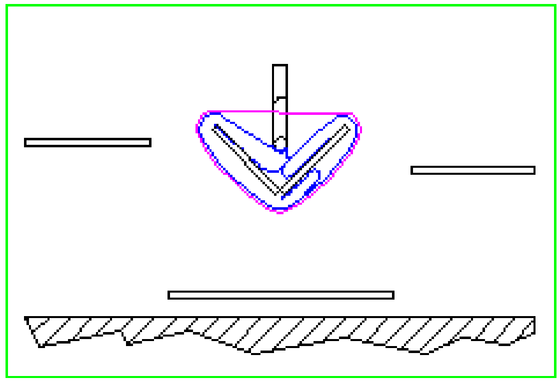


Figure 2.15: Dress a poly bag manually.

2.2.16. Step 14 – Release duple plates down

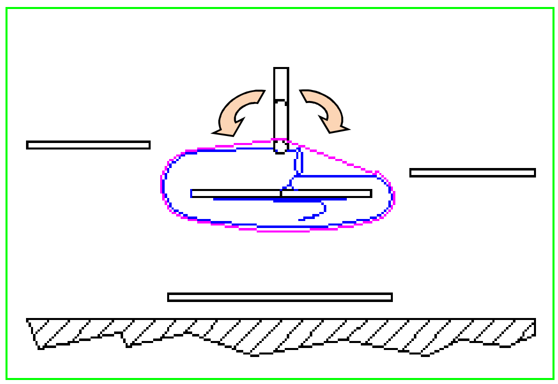


Figure 2.16: Release duple plates down.

2.2.17. Step 15 – Move duple plates to "glove stripping station"

Now the duple plates are wrapped with glove pair and poly bag which inserted on it. Then conveyor chain is activated and move duple plated to "glove stripping station". At the glove stripping station, lock is slightly released to strip off the glove pair from duple plates.

2.2.18. Step 16 – Poly bag sealing

This machine is facilitated with polybag sealer near to the "striping station". This sealer is activated by a photo sensor. Glove inserted poly bag is sealed by using this sealer manually.

3. MACHINE DESIGN

3.1. Selection of Pneumatic Cylinder to Lift the Base Plate

Diameter of cylinder	$= d$
Working pressure (P)	$= 5$ bar
	$= 4.90\times10^{5}$Pa
Load to be lift with base plate	$= 10.5 \times 9.8$ N
	$= 102.9$ N
Force exerted by the cylinder	$\geq$ Required force $\times$ Safety factor
$P(\frac{\pi d^2}{4})$	$\geq 102.9 \times 1.5$
$4.9 \times 10^5 \times (\frac{\pi d^2}{4})$	$\geq 102.9 \times 1.5$
d	≥ 20.03 mm
Diameter of cylinder taken as	$= 25$ mm

- ✓ Select Mindman MCGJ-12-25-40 pneumatic cylinder due to,
  - In built front mount of cylinder facilitate to mount Base plate easily.
  - Cylinder facilitate with two guide rods.
  - Compact in size.

3.2. Design of Duple Plates

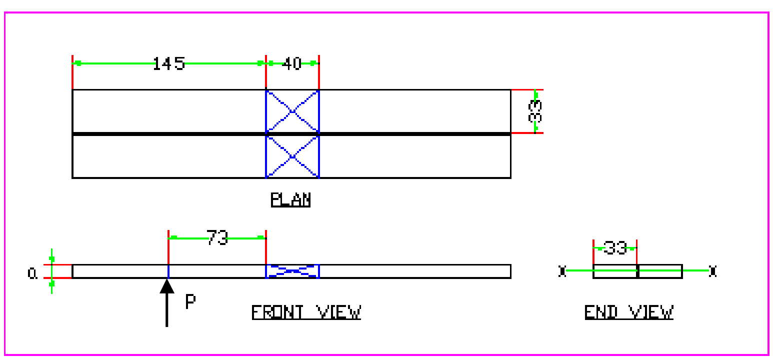


Figure 3.1: Elevations of duple plates.

3.2.1. Calculation of plate thickness of Duple plates

From trial,

- Material : Stainless Steel
- Max. Stroke required for base plate $= 40\text{mm}$
- Dimensions of a duple plate $= 33 \times 330\text{mm}$
- Load to be lift with base plate $= 10.5 \times 9.8\ N$

$= 102.9\ N$

Ultimate tensile strength of Stainless Steel $= 760$ MPa

Thickness of a duple plate $= a$

Max. Force exerted by the cylinder $= 4.9 \times 10^5 \times \frac{\pi \times (25\times10^{-3})^2}{4}$

$= 240.52\text{N}$

Force applied to one duple plate $= \frac{240.52}{2}\text{N}$

$= 120.26\text{N}$

3.2.1.1. Calculation – Avoid from shear failure at mounting

$$Design\ stress \geq Direct\ stress$$

$$\frac{Ultimate\ shear\ stress}{Safety\ factor} \geq \frac{Force\ applied}{Effective\ area}$$

$$\frac{760\times10^6\times0.75}{2} \geq \frac{120.26}{33\times10^{-3}\times a}$$

$$a \geq 1.28 \times 10^{-5}\text{m} \text{ ------------}(1)$$

3.2.1.2. Calculation – Avoid from bending failure due to base plate up

Moment of inertia about x-x axis, $I_{xx} = \frac{33\times10^{-3}\times a^3}{12}$

$= (2.75 \times 10^{-3} \times a^3\ )\text{m}^4$

Bending moment, $M_b = 120.26 \times 73 \times 10^{-3}\text{Nm}$

$= 8.78\text{Nm}$

Bending stress, $\sigma_b = \frac{M_b y}{I_{xx}}$

$$= \frac{8.78 \times \frac{a}{2}}{2.75 \times 10^{-3} \times a^3}$$

$$= \left(\frac{1596.36}{a^2}\right) \text{Nm}^{-2}$$

$$\textit{Design stress} \geq \textit{Direct stress}$$

$$\frac{\textit{Ultimate bending stress}}{\textit{Safety factor}} \geq \textit{Bending stress}$$

$$\frac{760 \times 10^6}{2} \geq \frac{1596.36}{a^2}$$

$$a \geq 2.04 \times 10^{-3}\text{m} \text{ ------------}(2)$$

Considering (1) & (2),

Thickness of a duple plate taken as (a) = 2 mm

3.3. Design of Actuator for Duple Plates

From trial,

Material: Stainless Steel

Top horizontal length of squeezed duple plates = 48 mm

Stroke required to move the duple plates up = 30 mm

Diameter of the rod = 6 mm

Size & shape of the actuator designed as follows,

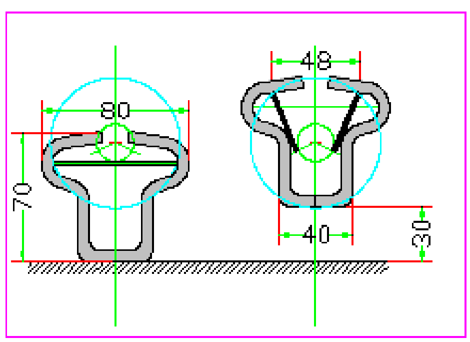


Figure 3.2: Actuator of duple plates.

3.4. Design of Base Plate

Since exerted force is same as on duple plates and bending moment acting on the base plate is lesser than that of duple plates, it is decided to take same plate thickness for the base plate.

- Thickness of base plate = 2 mm

Other dimensions of the base plate are determined,

- According to the trials done.
- According to the size of glove packet.
- Considering the weld joints.

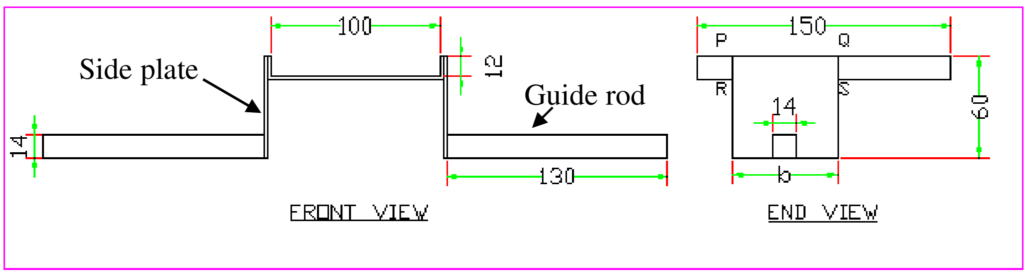


Figure 3.3: Elevations of base plate.

3.4.1. Calculation of width (b) of side plates

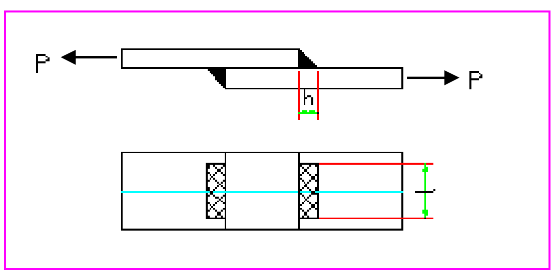


Figure 3.4: Double transverse fillet weld for side plates.

3.4.1.1. Calculation – Avoid from welding failure at PQ and RS (figure 3.3)

Consider double transverse fillet weld,

Material: Stainless Steel

P = Tensile force (7N from trial)

h = Leg of the weld (Plate thickness 2 mm)

l = Length of the weld

σ_t = Maximum tensile stress for the weld metal

$$P = 1.414hl\sigma_t$$

$$7 = 1.414 \times 2.0 \times 10^{-3} \times l \times 580 \times 10^{6}$$

$$l = 4.3 \times 10^{-3}\text{mm}$$

Adding15mm length for starting and stopping of the weld

$$l = 15.0043 \text{ mm}$$

Considering the other mounting purposes,

- Width of the side plate selected as (b) = 60mm

3.4.2. Calculation of suitable leg of the weld (h) for square guide rod

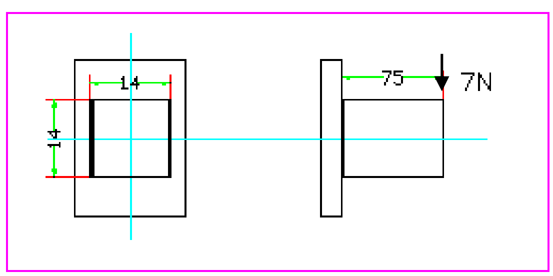


Figure 3.5: Weld joint subjected to bending moment.

3.4.2.1. Calculation – Avoid welding failure of guide rod

Consider weld joint subjected to bending moment,

Material: Stainless Steel

σ_b = Bending stress

M_b = Bending moment

h = Leg of the weld

t = Throat thickness

P = Force (7N from trial)

I_{xx} = Moment of inertia of all welds based on the throat area about x-x axis

y = Distance of the point in weld from the neutral axis

τ = Maximum principal shear stress in the weld

τ_1 = Primary shear stress

A = Throat area of all welds

$$A = 2(14 \times 10^{-3} t)$$
$$= 28 \times 10^{-3} t$$

$$\tau_1 = \frac{P}{A}$$
$$= \frac{7}{28 \times 10^{-3} t}$$
$$= \frac{250}{t}$$

$$I_{xx} = 2\left(\frac{t(14 \times 10^{-3})^3}{12}\right)$$
$$= 4.573 \times 10^{-7} t$$

$$\sigma_b = \frac{M_b y}{I_{xx}}$$
$$= \frac{7 \times 75 \times 10^{-3} \times 7 \times 10^{-3}}{4.573 \times 10^{-7} t}$$
$$= \frac{8036.3}{t}$$

$$\tau = \sqrt{[\left(\frac{\sigma_b}{2}\right)^2 + (\tau_1)^2]}$$

$$0.3 \times 580 \times 10^6 = \sqrt{[\left(\frac{8036.3}{2t}\right)^2 + \left(\frac{250}{t}\right)^2]}$$

$$174 \times 10^6 = \frac{4025.9}{t}$$

$$t = 0.023 \text{ mm}$$

$$h = \frac{t}{0.707}$$

$$h = \frac{0.023}{0.707}$$

$$h = 0.033 \text{ mm}$$

- Leg of the weld is selected as $h = 2$ mm

3.5. Design of Finger Folder and Wrist Folder

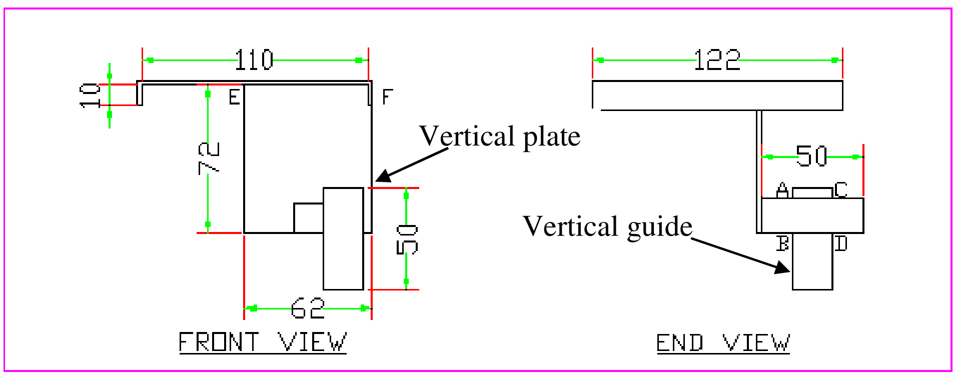


Figure 3.6: Elevations of finger / wrist folder.

3.5.1. Selection of pneumatic cylinder to move finger / wrist folder

Diameter of cylinder	$= d$
Working pressure (P)	= 5 bar
	$= 4.90\times10^5$ Pa
Stroke required	= 75 mm
Force required	$= 16 \times 9.8$ N
	= 156.8 N

Force exerted by the cylinder $\geq$ Required force $\times$ Safety factor

$$P(\frac{\pi d^2}{4}) \geq 156.8 \times 1.5$$

$$4.9 \times 10^5 \times (\frac{\pi d^2}{4}) \geq 156.8 \times 1.5$$

$$d \geq 24.72 \text{ mm}$$

Diameter of cylinder taken as = 32 mm

✓ Select Mindman MCQI2-11-32-75M pneumatic cylinder.

Other dimensions of the wrist / finger folder are determined,

- According to the trials done.
- According to the size of glove packet.
- Considering the weld joints.

3.5.1.1. Calculation – Avoid from welding failure at AB and CD (figure 3.6)

Consider double transverse fillet weld,

Material: Stainless Steel

P = Tensile force (394 N from trial)

h = Leg of the weld (2 mm)

$$P = 1.414 h l \sigma_t$$

$$394 = 1.414 \times 2.0 \times 10^{-3} \times l \times 580 \times 10^6$$

Length of the weld, $l = 0.24 \times 10^{-3}\text{m}$

Adding15mm length for starting and stopping of the weld

$$l = 15.24 \text{ mm}$$

Considering the other mounting purposes,

- Weld length for AB and CD selected as = 20mm

3.5.1.2. Calculation – Avoid from bending failure of vertical plate of finger folder/wrist folder

Max. Force exerted by the cylinder $= 4.90 \times 105 \times \frac{\pi \times (32\times10^{-3})^2}{4}$

$= 394$ N

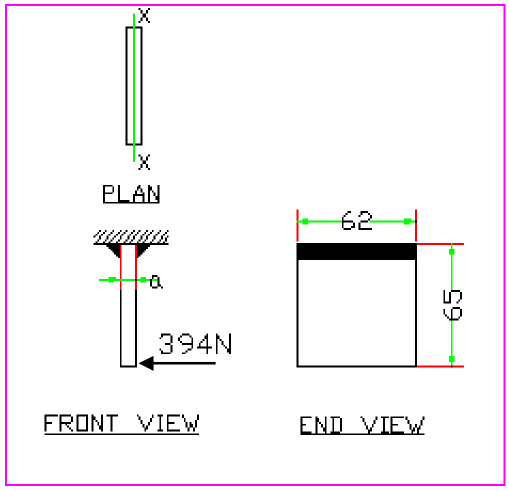


Figure 3.7: Force applied on vertical plate.

Thickness of the vertical plate $= a$

$$I_{xx} = \frac{62\times10^{-3}\times a^3}{12}$$

$$= (5.17 \times 10^{-3} \times a^3)\text{m}^4$$

$$M_b = 394 \times 65 \times 10^{-3}\text{Nm}$$

$$= 25.61 Nm$$

$$\sigma_b = \frac{M_b y}{I_{xx}}$$

$$= \frac{25.61\times\frac{a}{2}}{5.17\times10^{-3}\times a^3}$$

$$= (\frac{2476.79}{a^2})\ \text{Nm}^{-2}$$

$$\textit{Design stress} \geq \textit{Direct stress}$$

$$\frac{\textit{Ultimate bending stress}}{\textit{Safety factor}} \geq \textit{Bending stress}$$

$$\frac{760\times10^{6}}{2} \geq \frac{2476.79}{a^{2}}$$

$$a \geq 2.55 \times 10^{-3}\text{m} \text{ ------------}(3)$$

- Thickness of the vertical plate taken as (a) = 3 mm

3.5.1.3. Calculation – Avoid from welding failure at EF (figure 3.6)

Consider welded joints subjected to bending moment,

Material: Stainless Steel

$$\text{A} = 2(62 \times 10^{-3}t)$$
$$= 124 \times 10^{-3}t$$

$$\tau_1 = \frac{P}{A}$$
$$= \frac{394}{124\times10^{-3}t}$$
$$= \frac{3177.42}{t}$$

$$I_{xx} = 2[\frac{62\times10^{-3}t^{3}}{12} + 62 \times 10^{-3}t \times (1.5 \times 10^{-3})^{2}]$$
$$= [10.3 \times 10^{-3}t^{3} + 2.8 \times 10^{-7}t]$$

$$\sigma_b = \frac{M_b y}{I_{xx}}$$
$$= \frac{25.61\times1.5\times10^{-3}}{[10.3\times10^{-3}t^{3}+2.8\times10^{-7}t]}$$
$$= \frac{38.415}{[10.3t^{3}+2.8\times10^{-4}t]}$$

$$\tau = \sqrt{[\left(\frac{\sigma_b}{2}\right)^2 + (\tau_1)^2]}$$

$$0.3 \times 580 \times 10^6 = \sqrt{[\left(\frac{38.415}{2[10.3t^3+2.8\times10^{-4}t]}\right)^2 + \left(\frac{3177.42}{t}\right)^2]}$$

$$t^2 = 9.01534 \times 10^{-6}\text{m, Others are complex roots}$$

$$t^2 = 9.01534 \times 10^{-8}\text{m}$$

$$t = 0.3 \text{ mm}$$

$$h = \frac{t}{0.707}$$

$$h = \frac{0.3}{0.707}$$

$$h = 0.42 \text{ mm}$$

- Leg of the weld is selected as (h) = 2 mm

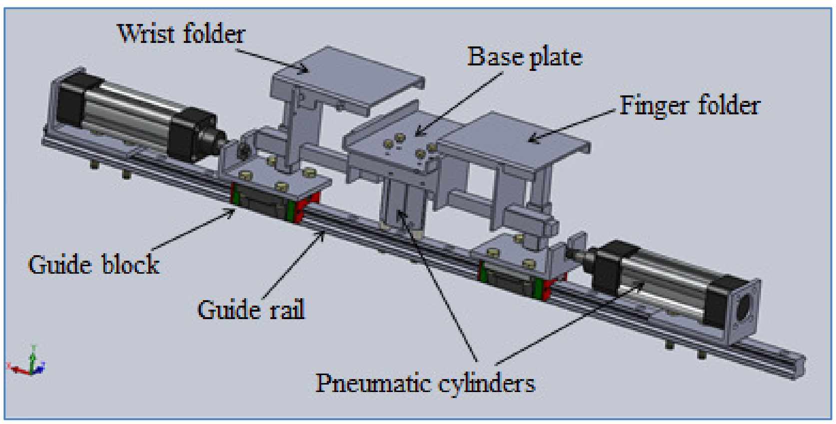


Figure 3.8: SolidWorks model of folder

3.6. Design of Mounts for Duple Plates

Material: Mild Steel

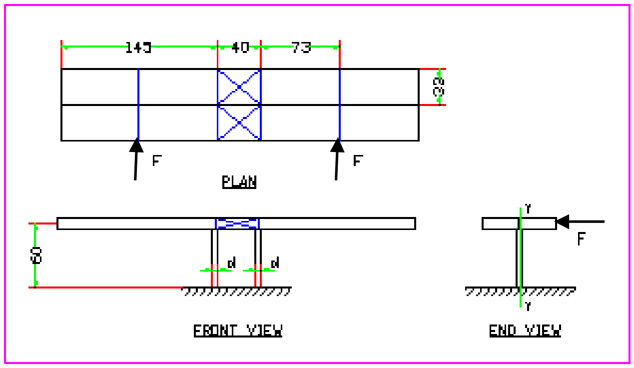


Figure 3.9: Elevations of duple plates mounts.

Diameter of rod	= d
Max. Force exerted by the cylinder	= 394 N
Ultimate tensile strength of M/S	= 430 MPa

3.6.1. Calculation – Avoid from shear failure at mounting

$$Design\ stress \geq Direct\ stress$$

$$\frac{Ultimate\ shear\ stress}{Safety\ factor} \geq \frac{Force\ applied}{Effective\ area}$$

$$\frac{430 \times 10^6 \times 0.75}{2} \geq \frac{394 \times 2}{\frac{2 \times \pi d^2}{4}}$$

$$d \geq 1.76\ \text{mm} \text{ ------------}(4)$$

3.6.2. Calculation – Avoid from bending failure at mounting

$$I_{yy} = \frac{\pi d^4}{64}$$

$$M_b = 2 \times 394 \times 60 \times 10^{-3}\text{Nm}$$

$$= 47.28\ \text{Nm}$$

$$\sigma_b = \frac{M_b y}{I_{yy}}$$

$$= \frac{47.28 \times \frac{d}{2}}{2 \times \frac{\pi d^4}{64}}$$

$$= \left(\frac{240.8}{d^3}\right) \text{Nm}^{-2}$$

$$\textit{Design stress} \geq \textit{Direct stress}$$

$$\frac{\textit{Ultimate bending stress}}{\textit{Safety factor}} \geq \textit{Bending stress}$$

$$\frac{430 \times 10^6}{2} \geq \frac{240.8}{d^3}$$

$$d \geq 10.4 \text{ mm} \text{ ------------}(5)$$

Considering (4) & (5),

- Diameter of a duple plate mount (d) = 12 mm

3.7. Design of Locking System

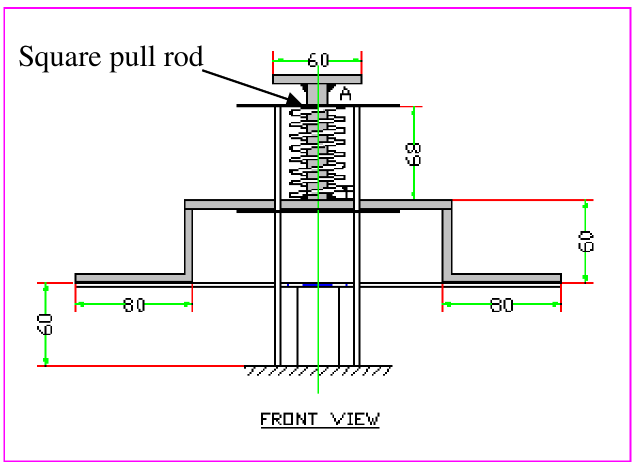


Figure 3.10: Arrangement of lock.

From trial,

Material: Stainless Steel

Max. Stroke required for unlocking = 40 mm

Min. force required to hold gloves = 5 N

3.7.1. Selection of spring

According to the spring manufacture's data sheet (see Appendix – A),

Outer diameter of spring = 34.93 mm

Rate of the spring = 4.8 N/mm

3.7.2. Selection of pneumatic cylinder for lock

Force required to compress spring by 40mm $= 4.8 \times 40$ N

$= 192$ N

- Select Mindman MCGJ-12-25-40 pneumatic cylinder to pull the lock up

Max. Force exerted by the cylinder = 240.52 N

3.7.3. Calculation of leg length of weld for square pull rod

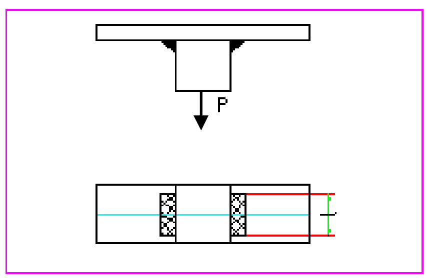


Figure 3.11: Force acting on pull rod.

3.7.3.1. Calculation – Avoid from welding failure at A and B (Figure 3.10)

Consider double transverse fillet weld under perpendicular load,

Material: Stainless Steel

P = Tensile force (192 N from trial)

h = Leg of the weld (2 mm)

$$P = 1.6568 h l \sigma_t$$

$$P = 1.6568 hl\sigma_t$$

$$192 = 1.6568 \times 2.0 \times 10^{-3} \times l \times 0.3 \times 580 \times 10^{6}$$

Length of the weld, $l = 0.33 \times 10^{-3}\text{m}$

Adding10 mm length for starting and stopping of the weld

$$l = 10.33 \text{ mm}$$

- Leg length of square pull rod taken as 12 mm

3.8. Design of Chain Drive System

Conveyor chain is used to index glove from folding station to stripping station. It is driven by geared induction motor with a motor driver.

3.8.1. Selection of Chain

Facts that considered to select conveyor chain,

- Need conveyor chain to guide the path without sagging. It is required to have R-type rollers to guide the path.
- Facilitate to mount the attachments.

According to the chain manufacture's data sheet (see Appendix – B),

- Select C2062H chain

3.8.2. Selection of Sprockets

The main fact considered to select sprockets is the gap between two rows of chain

- Required minimum gap between two rows of chain = 180 mm

According to the sprockets manufacture's data sheet (see Appendix – C),

- Number of teeth = 16
- Pitch circle diameter = 195.29mm

- Select 2062B-16 Sprocket

3.8.3. Selection of Motor and Gear box

From trial,

Force required to pull the chain $= 21 \times 9.8$ N

$= 205.8$ N

Minimum torque required to drive the unit $= 205.8 \times \frac{195.29}{2} \times 10^{-3}$ Nm

$= 20.1$ Nm

$$Design\ torque = S.F \times Minimum\ torque\ required$$

$= 3 \times 20.1$ Nm

$= 60.3$ Nm

According to the motor & gear box catalogues (see Appendix – D and E),

- Selection,
  - 3phase, 4 pole, 0.37 kW, 400 V, 50 Hz induction motor
  - BSM 60 R30 gear box

3.8.4. Calculation of key way length for drive shaft

According to the gear box manufacture's data sheet (see Appendix – E),

Output shaft diameter $= 22$ mm

Dimensions of key way $= 7 \times 4$ mm

According to the motor manufacture's data sheet (see Appendix – D),

Max. Torque exerted by motor $= 2.55 \times 2.05$ Nm

$= 5.23$ Nm

Max. Output torque of gear box $= 5.23 \times 30$ Nm

$= 156.9$ Nm

Force transferred to shaft by key $= \frac{156.9}{11 \times 10^{-3}}$ N

$= 14263.6$ N

3.8.4.1. Calculation – Avoid from bending failure of key way

Material: Mild Steel

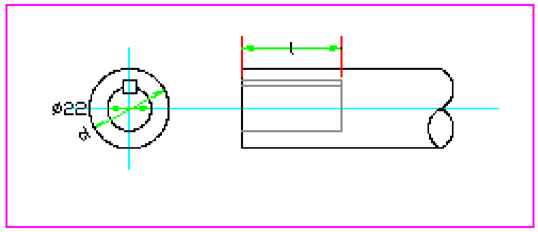


Figure 3.12: Drive shaft

$$\frac{Ultimate\ bearing\ stress}{Safety\ factor} \geq \frac{Holding\ force}{Affective\ area}$$

$$\frac{430\times{}^{5}/_{3}\times10^{6}}{5} \geq \frac{14263.6}{3\times10^{-3}\times l}$$

$$l \geq 33.2 \text{ mm}$$

- Length of key way is selected as $l = 50$ mm

3.8.5. Calculation of drive shaft diameter

3.8.5.1. Calculation – Avoid from torsional shear failures at hollow section

τ - Torsional shear stress

r - Radius of the shaft

T - Torque

J - Polar moment of inertia

$$J = \frac{\pi[d^4-(22\times10^{-3})^4]}{32}$$

$$\tau = \frac{Tr}{J}$$

$$\tau = \frac{156.9\times\frac{d}{2}\times32}{\pi[d^4-(22\times10^{-3})^4]}$$

$$\frac{Ultimate\ shear\ stress}{Safety\ factor} \geq Torsional\ stress$$

$$\frac{430\times0.75\times10^6}{12} \geq \frac{156.9\times\frac{d}{2}\times32}{\pi[d^4-(22\times10^{-3})^4]}$$

$$33632.2 \geq \frac{d}{[d^4-(22\times10^{-3})^4]}$$

$$33632.2d^4 - d - 7.88\times10^{-3} \geq 0$$

$$d \geq 0.0332 \text{ or}$$

$$d \geq -0.0077 \text{ or}$$

$$d \geq (-0.0127+0.0273i) \text{ or}$$

$$d \geq (-0.0127-0.0273i)$$

Considering real positive roots, $d \geq 0.0332$ m

$d \geq 33.2$ mm

- Drive shaft diameter is selected as $d = 40$ mm

3.8.6. Calculation of key length(l) for sprockets

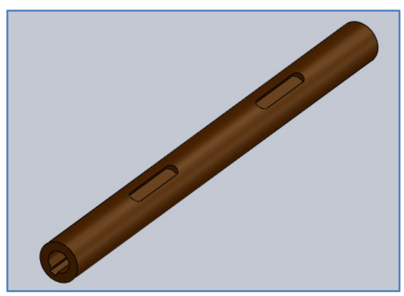


Figure 3.13: SolidWorks model of drive shaft

Considering shaft size and according to the proportions of standard parallel keys (see Appendix – F),

Cross section of selected Key $= 12\times8$ mm

Torque affected to one drive sprocket $= \frac{156.9}{2}$ Nm

$= 78.45$ Nm

Force transferred to sprocket by key $= \frac{78.45}{20\times10^{-3}}$ N

$= 3922.5$ N

3.8.6.1. Calculation – Avoid from shear failure of key

$$\frac{Ultimate\ shear\ stress}{Safety\ factor} \geq \frac{Holding\ force}{Affective\ area}$$

$$\frac{430\times0.75\times10^{6}}{10} \geq \frac{3922.5}{(12\times10^{-3})\times l}$$

$$l \geq 10.1mm \text{------------}(6)$$

3.8.6.2. Calculation – Avoid from bearing failure of key

$$\frac{Ultimate\ bearing\ stress}{Safety\ factor} \geq \frac{Holding\ force}{Affective\ area}$$

$$\frac{430\times{}^{5}/_{3}\times10^{6}}{10} \geq \frac{3922.5}{(4\times10^{-3})\times l}$$

$$l \geq 13.7mm \text{------------}(7)$$

Since width of the boss of sprocket is 45mm & considering above (6), (7)

- key length for sprockets is taken as l = 60mm

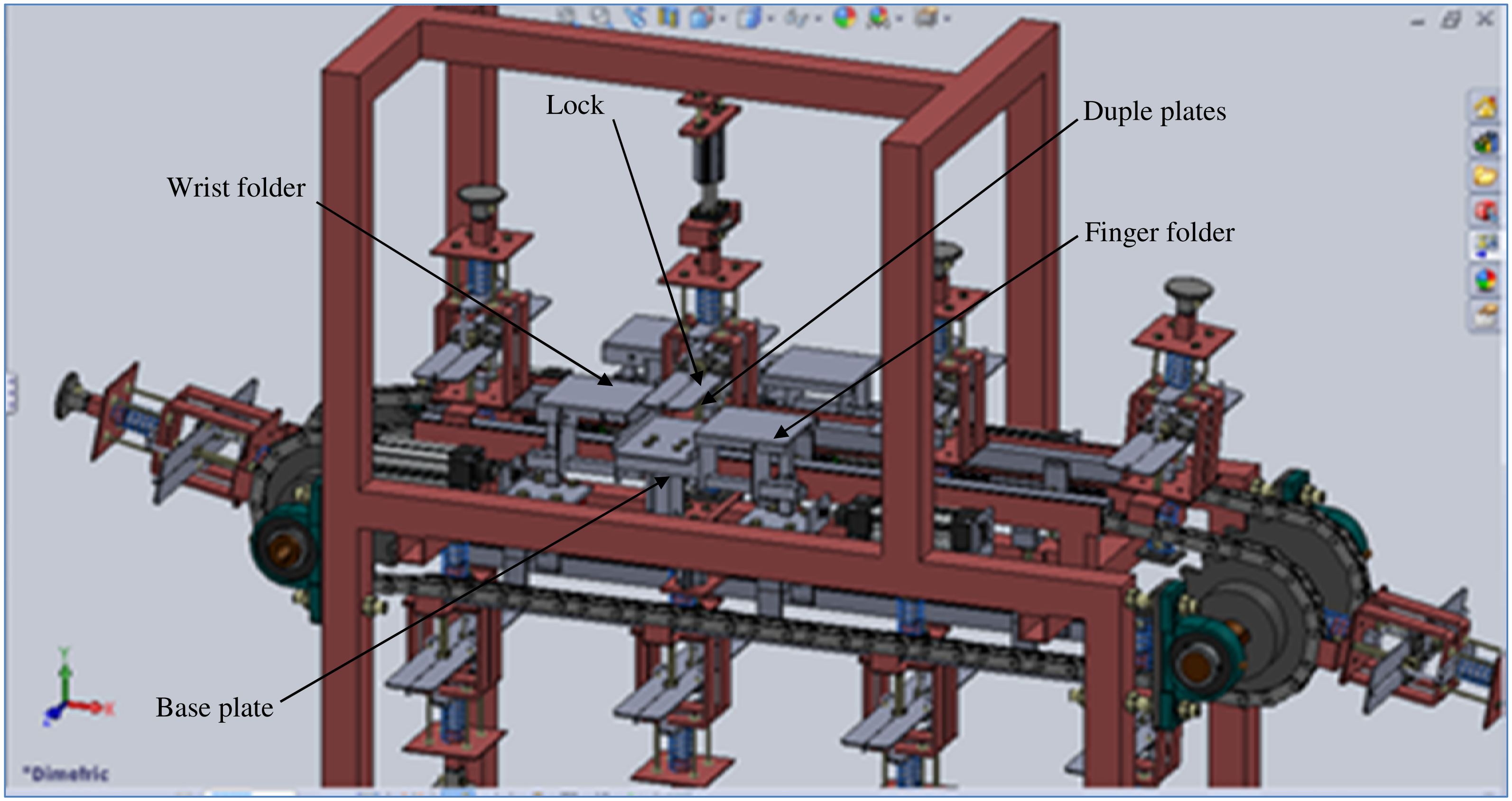


Figure 3.14: SolidWorks model of machine

4. MACHINE AUTOMATION

4.1. Control Panel Wiring Diagrams

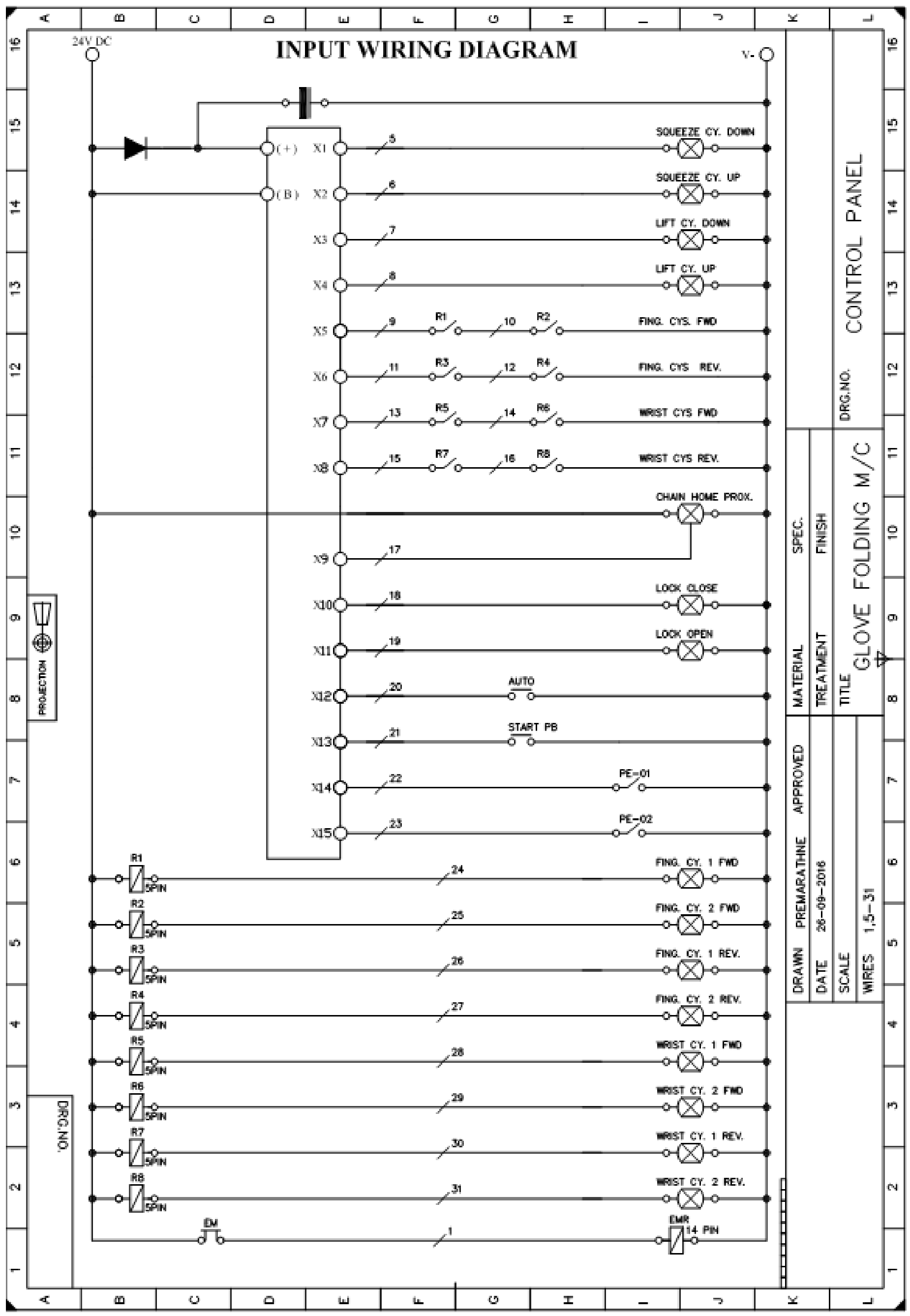


Figure 4.1: Input wiring diagram

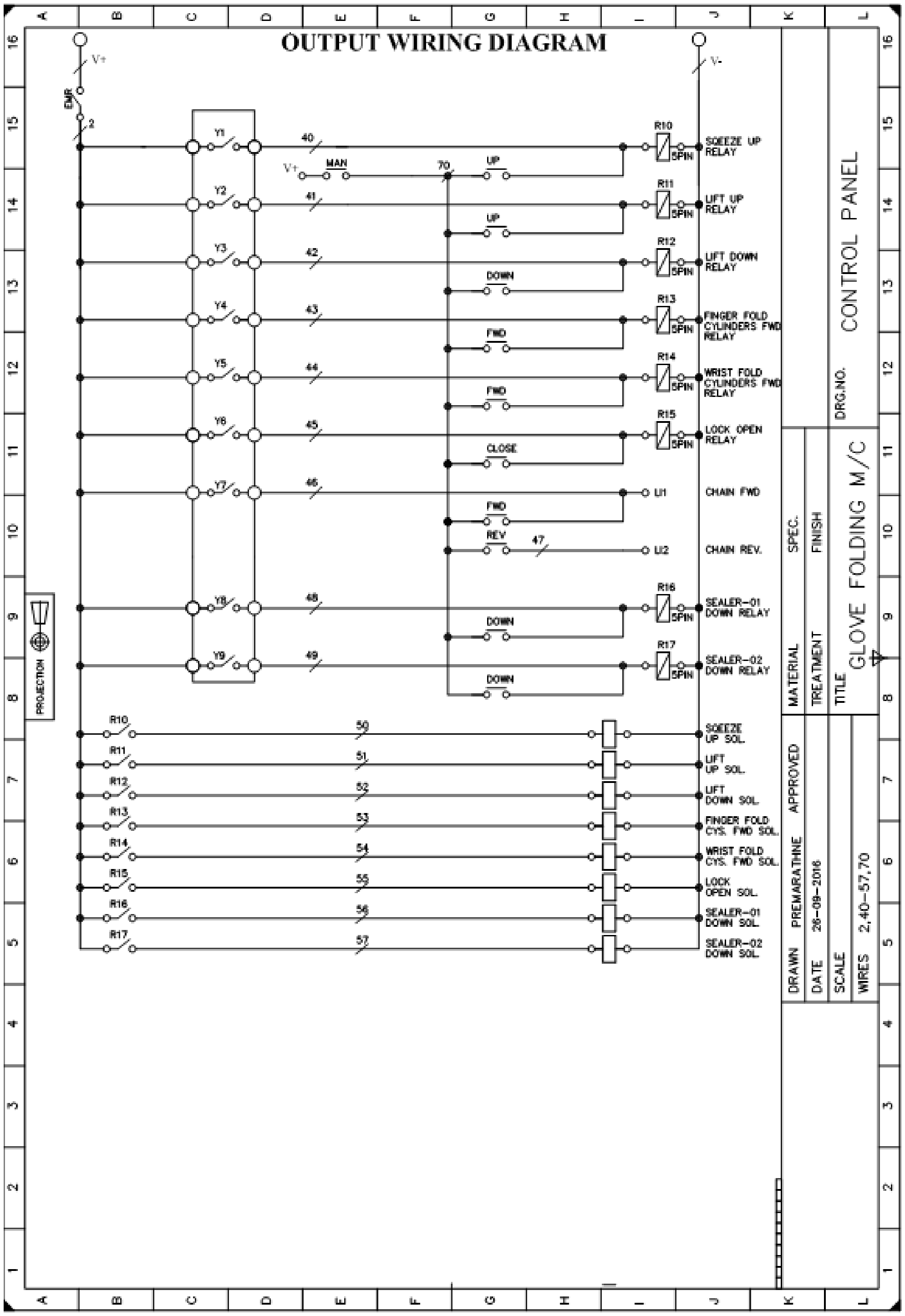


Figure 4.2: Output wiring diagram-1

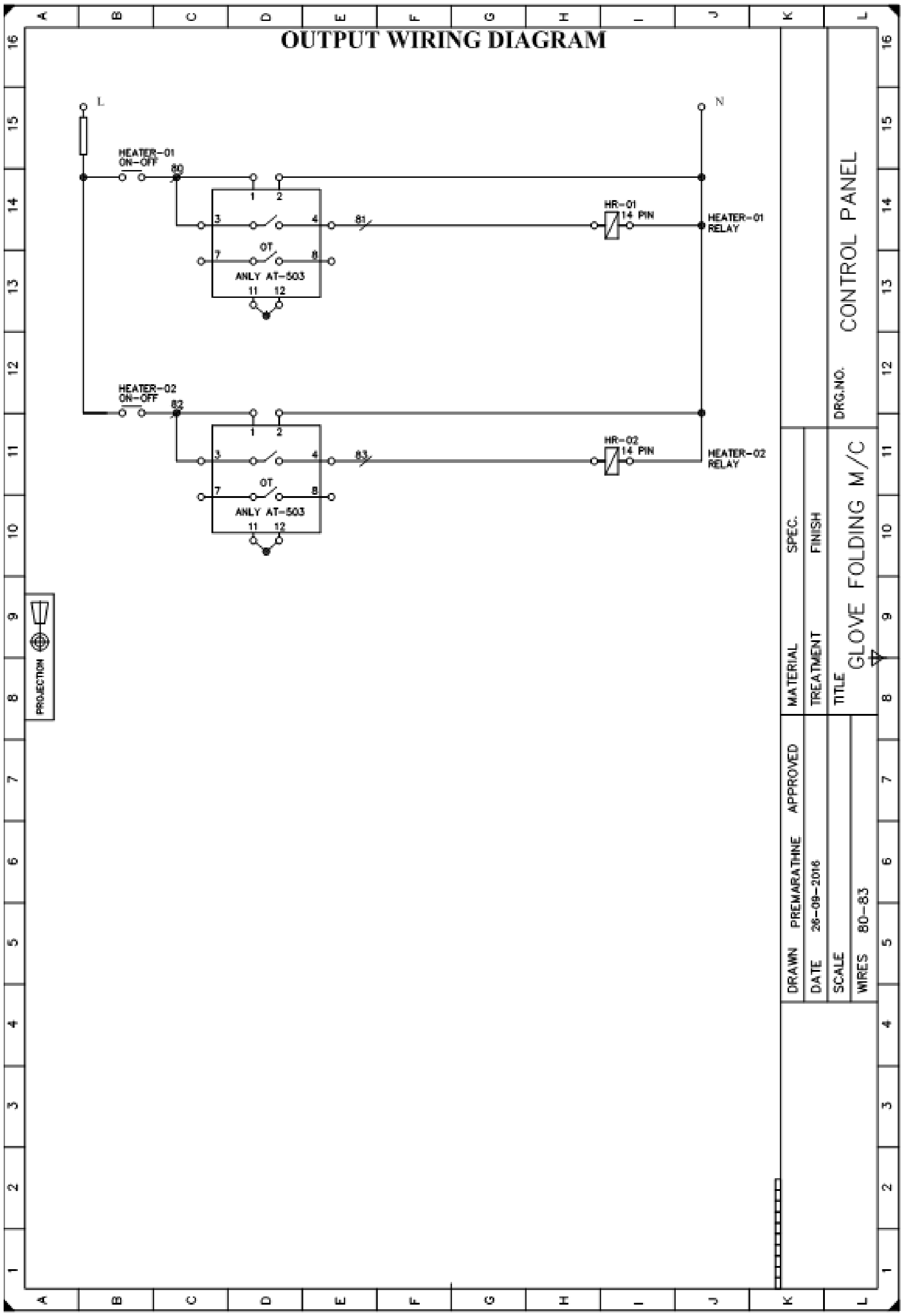


Figure 4.3: Output wiring diagram-2

4.2. Pneumatic Circuit Diagram

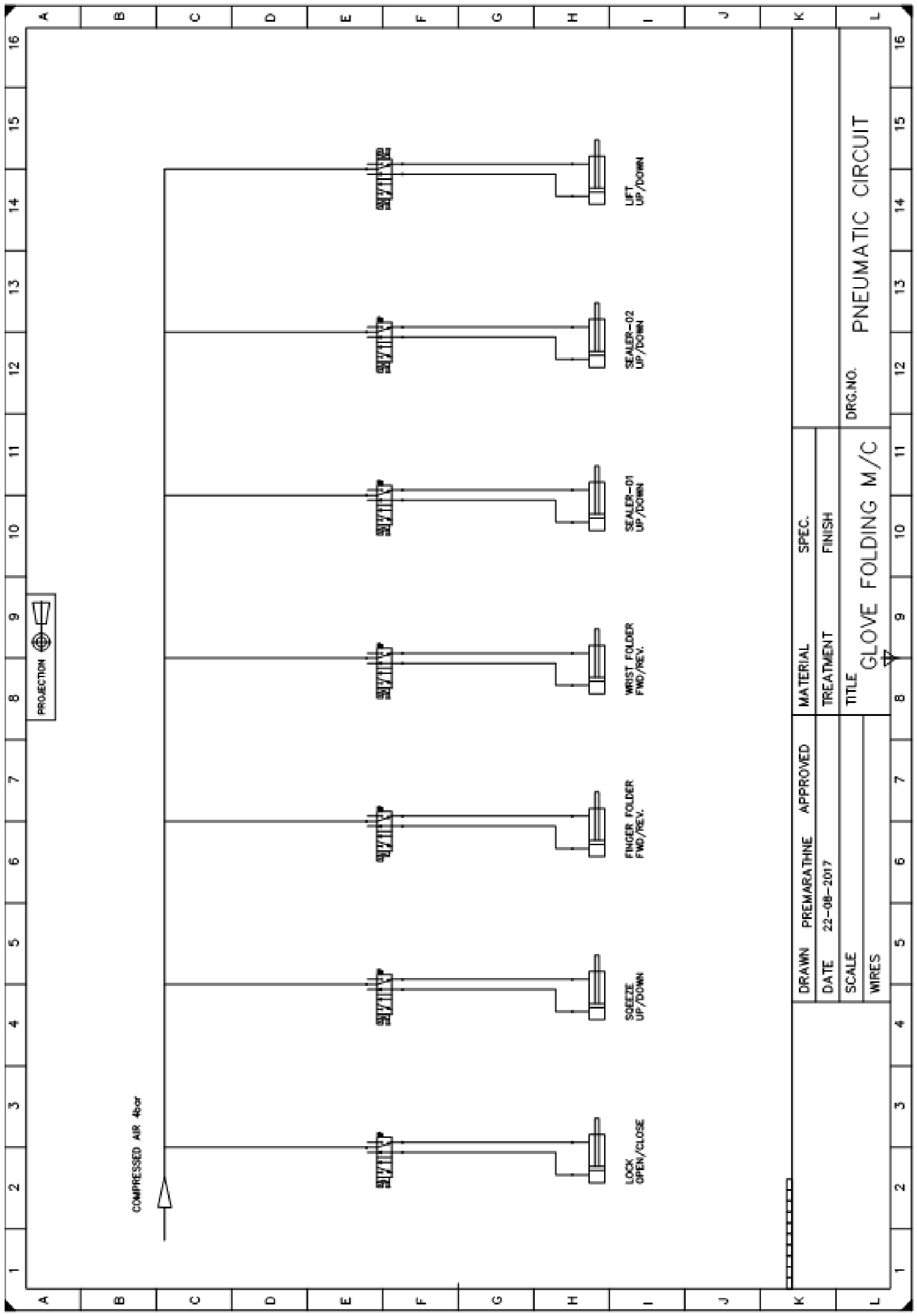


Figure 4.4: Pneumatic circuit diagram

4.3. Programing

4.3.1. Program flow chart

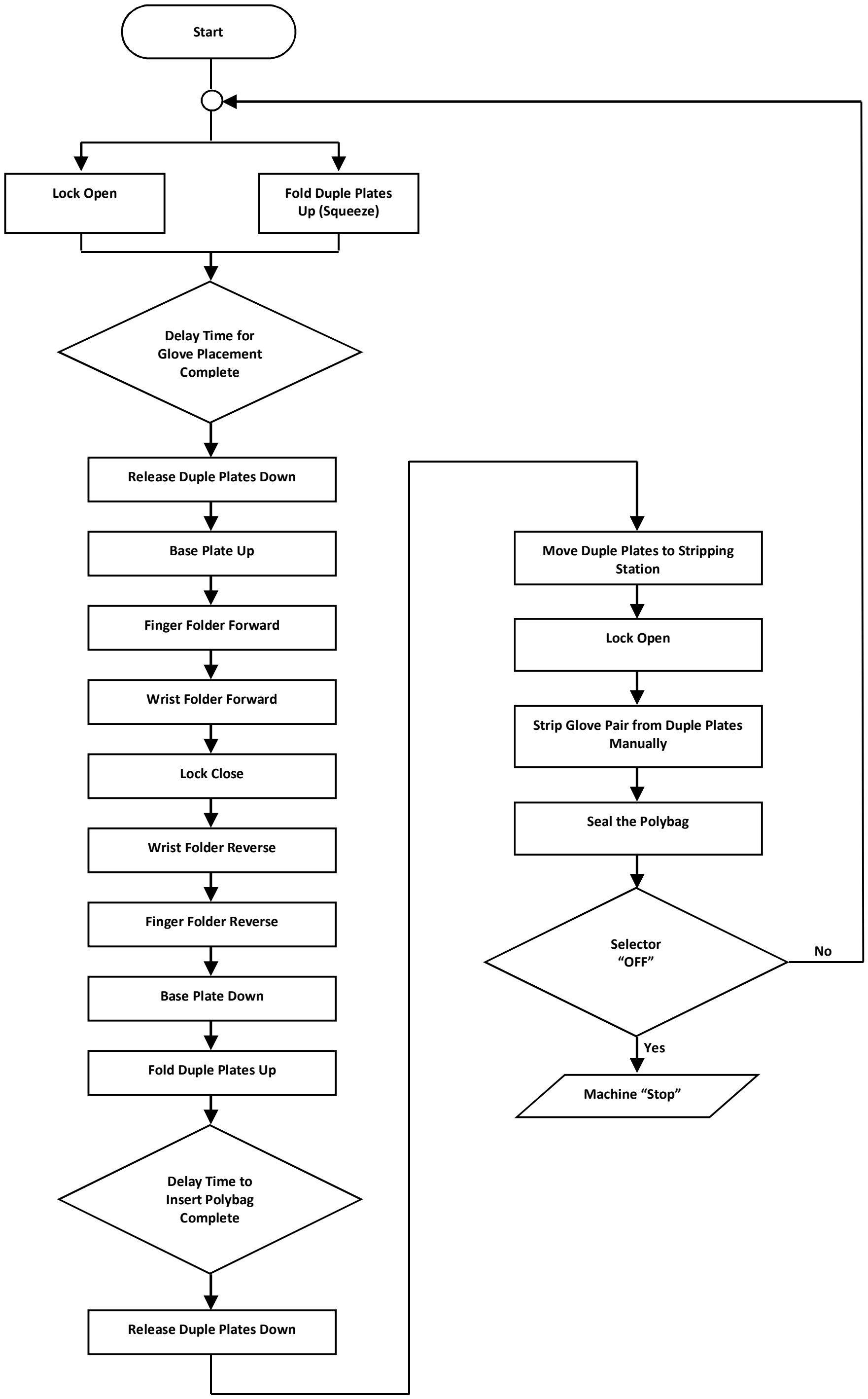


Figure 4.5: Program flow chart

4.3.2. Step 1 - Linguistic model

1. Put "MACHINE" selector switch into "AUTO" position and press "START" push button.
2. When "START" push button pressed, lock open and fold duple plates up (Squeeze cylinder up)
3. Time delay to place glove pair on base plate.
4. Release duple plates down while keep open the lock.
5. Base plate lift up towards duple plates.
6. Finger folder moves forward.
7. Wrist folder moves forward.
8. Lock close.
9. Wrist folder reverse while keep closing the lock.
10. Finger folder reverse while keep closing the lock.
11. Base plate moves down while keep closing the lock.
12. Fold duple plates up again while keep closing the lock and squeeze the glove pair to facilitate to insert a polybag.
13. Time delay to insert polybag.
14. Release duple plates down again while keep closing the lock.
15. Move duple plates towards the stripping station.

4.3.3. Step 2 - State transition diagram

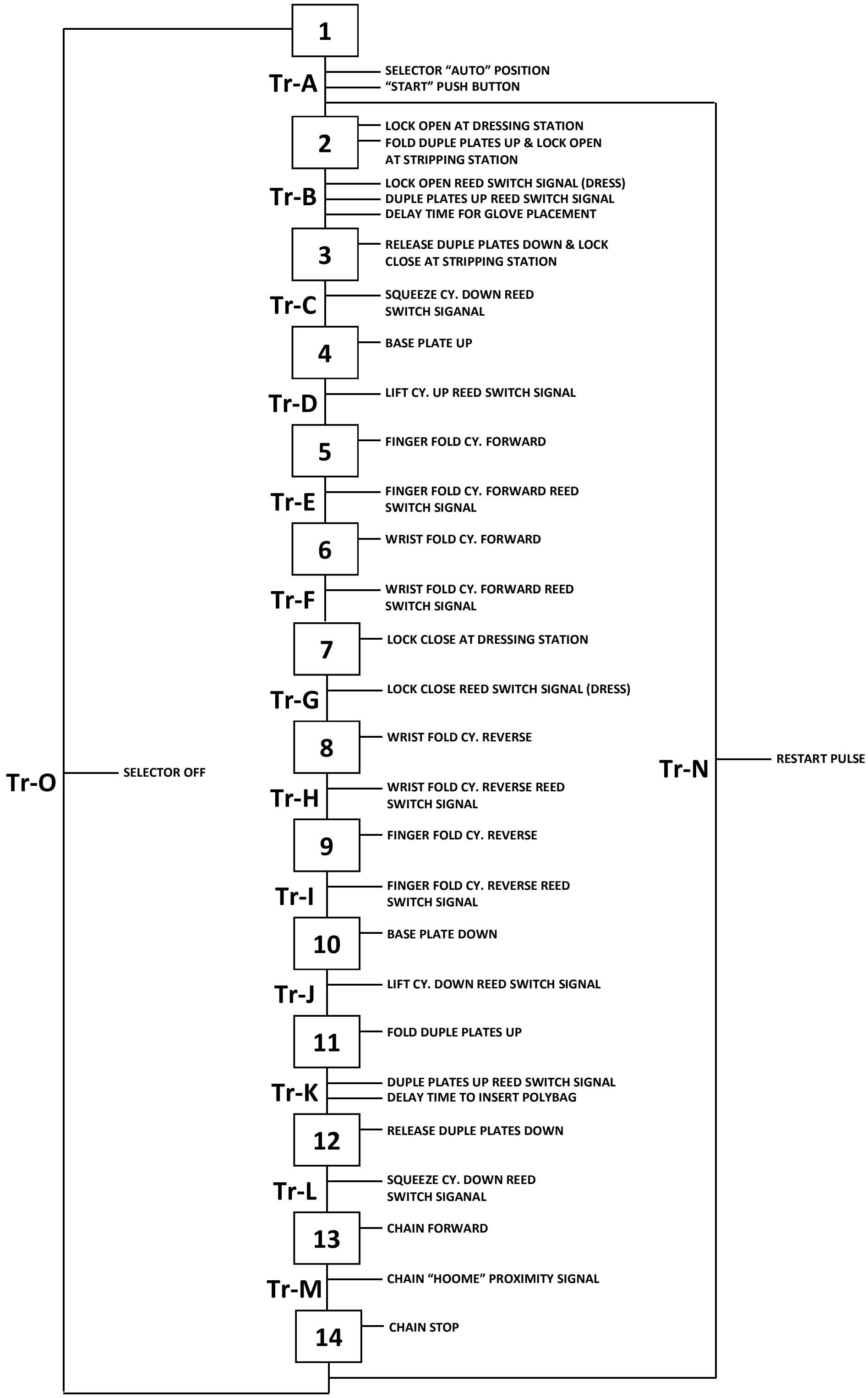


Figure 4.6: State transition diagram

4.3.4. Step 3 - State to output relationship

Table 4.1: State to output relationship

States \ Outputs	Squeeze cylinder up	Lift cylinder up	Lift cylinder down	Finger fold cylinder forward	Wrist fold cylinder forward	Lock open	Chain forward
1	0	0	0	0	0	0	0
2	1	0	0	0	0	1	0
3	0	0	0	0	0	1	0
4	0	1	0	0	0	1	0
5	0	1	0	1	0	1	0
6	0	1	0	1	1	1	0
7	0	1	0	1	1	0	0
8	0	1	0	1	0	0	0
9	0	1	0	0	0	0	0
10	0	0	1	0	0	0	0
11	1	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	1
14	0	0	0	0	0	0	0

4.3.4.1. Transition logic block

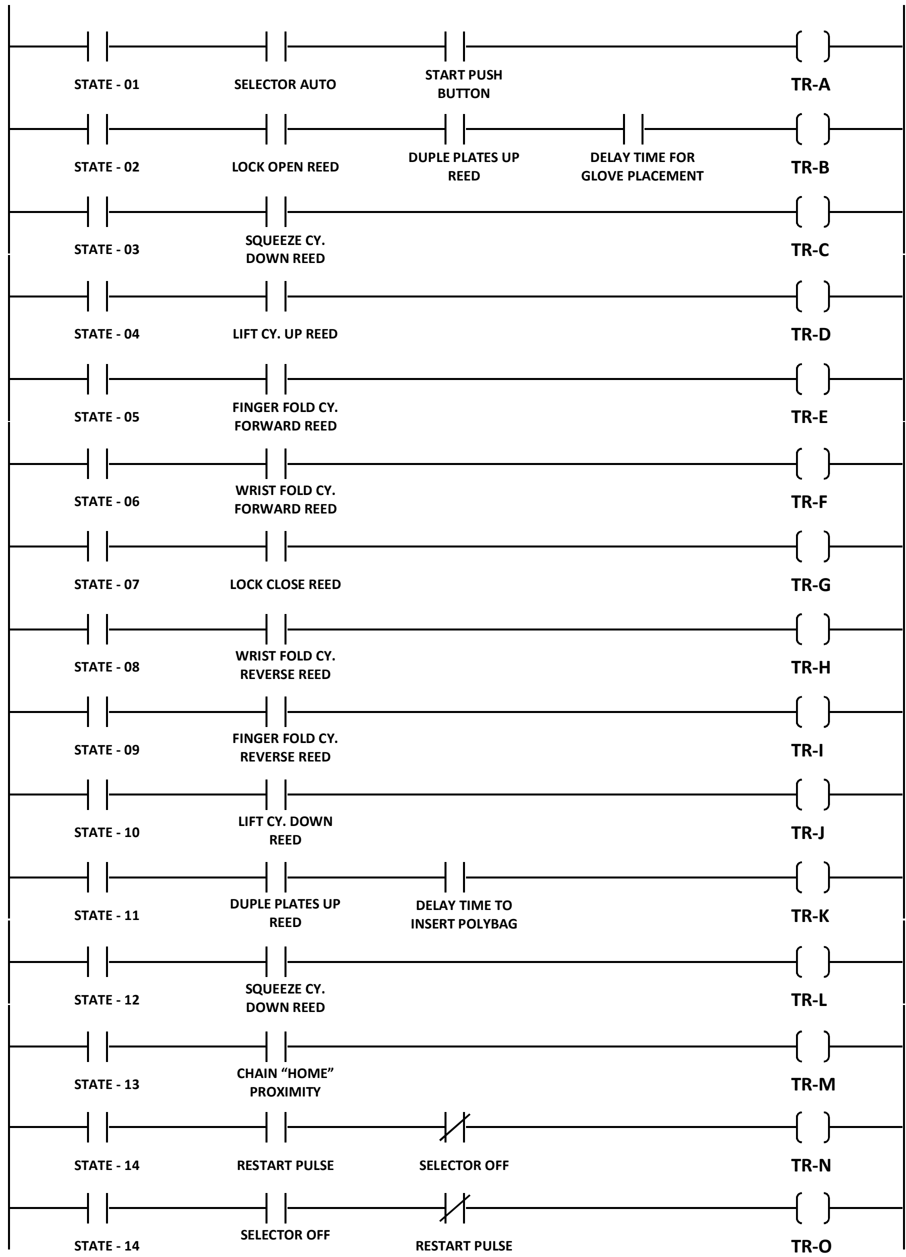
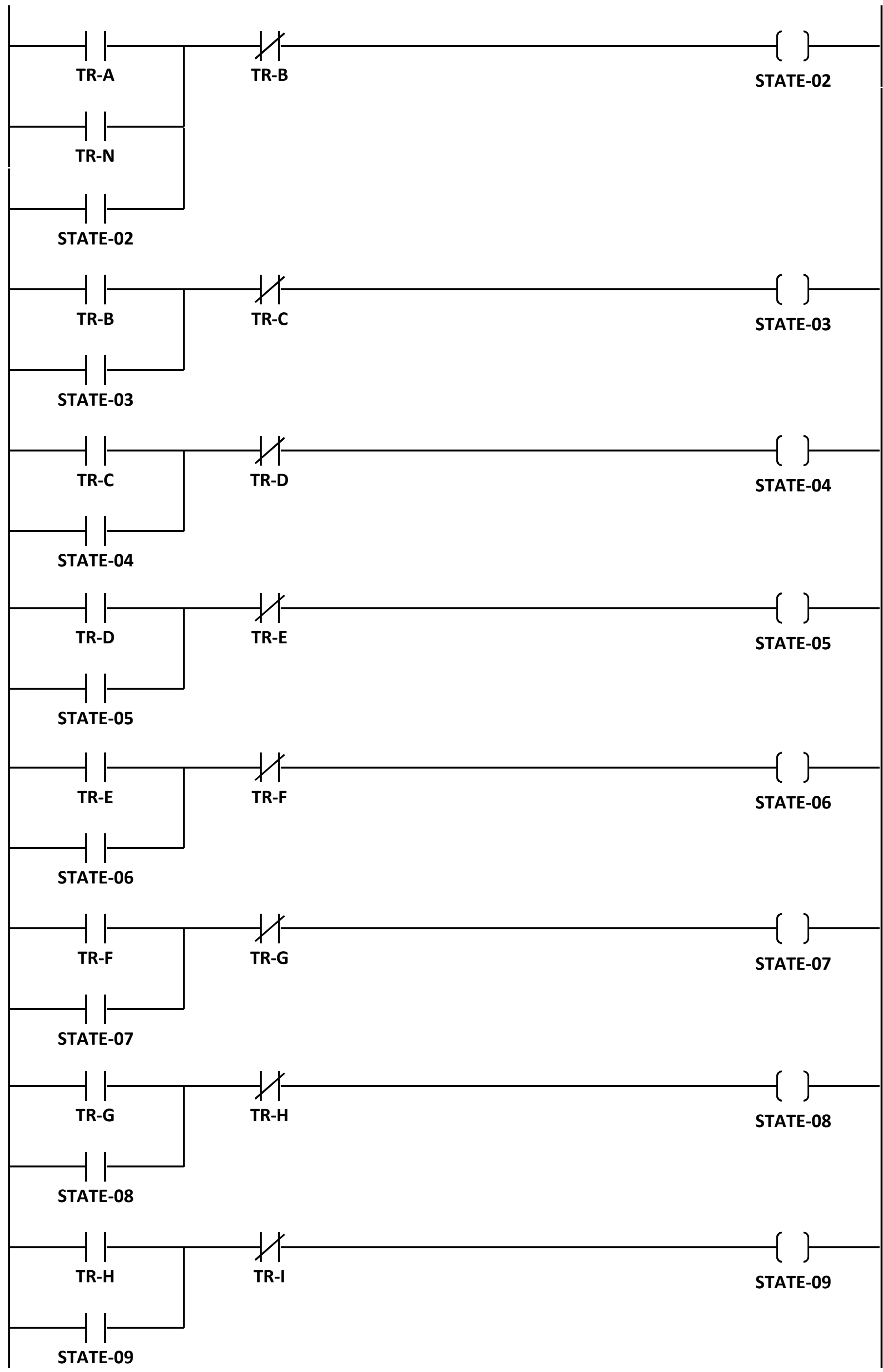


Figure 4.7: Transition logic block

4.3.4.2. State logic block



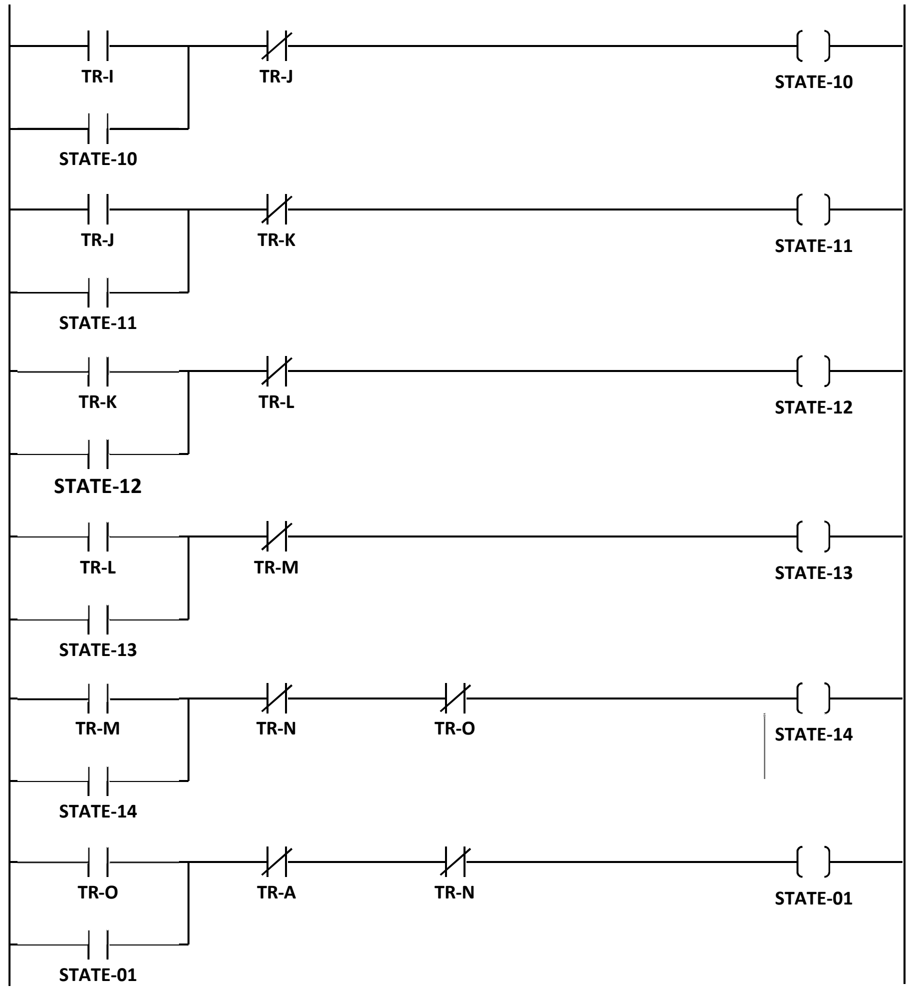


Figure 4.8: State logic block

4.3.4.3. Output logic block

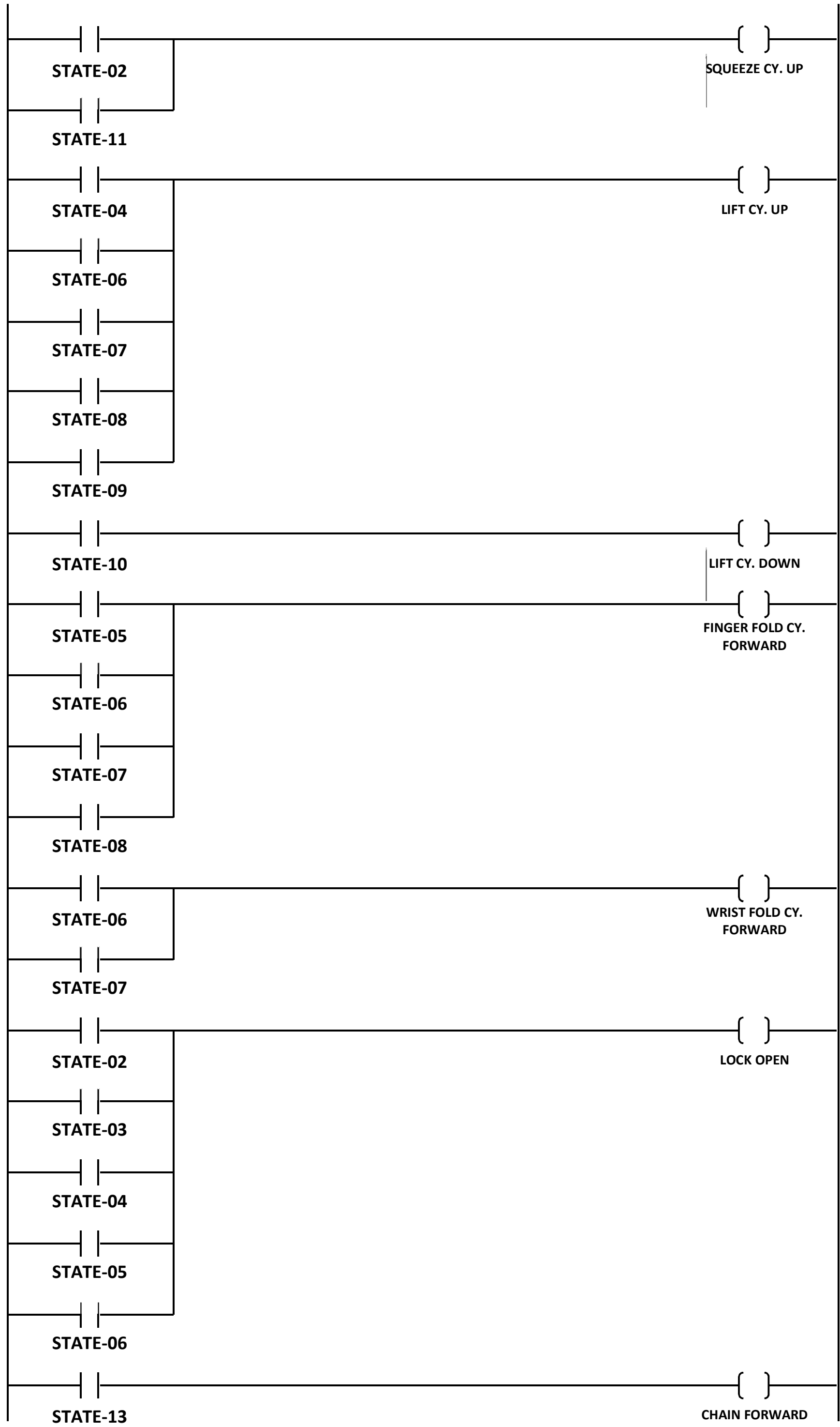


Figure 4.9: Output logic block

5. RESULTS

5.1. Operation Procedure of Machine

Figure 5.1: Control panel of the machine

Please refer figure 3.14 and figure 5.1 to identify the components of the machine.

1. Connect the machine to 230V, 50Hz power supply and 5bar compressed air supply. Switch "ON" the sector switch of the control panel.
2. Check whether the machine is on its initial position.
    - Chain "Home" Proximity switch - ON
    - Squeeze Cylinder "Down" Reed - ON
    - Lift Cylinder "Down" Reed - ON
    - Squeeze Cylinder "Down" Reed - ON

- Finger fold Cylinder “Rev” Reed - ON
- Wrist fold Cylinder “Rev” Reed - ON
- Lock Cylinder “Close” Reed - ON

3. If anyone of above components is not in initial position, put the selector switch named as “MACHINE” into “MAN” position and correct the relevant component by using manual switches accordingly.
4. Switch “ON” the selector switches of “HEATER-01 & HEATER – 02”. Adjust the temperature level which suit to seal polybags.
5. Put all the selector switches into “AUTO” position.
6. Press “START” push button.
7. Machine will start, fold the duple plates up (squeeze) and open the lock simultaneously to facilitate to place the glove pair on base plate.
8. Place the glove pair on base plate.

Figure 5.2: Place glove pair on base plate

9. After 5 seconds machine releases duple plates down while keep open the lock.

Figure 5.3: Machine releases duple plates down

10. Base plate lift up towards duple plates and finger folder moves forward to fold fingers of glove pair

Figure 5.4: Finger folder moves forward

11. Wrist folder moves forward to fold wrists of glove pair and lock comes down

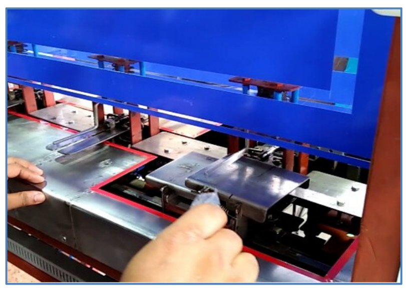


Figure 5.5: Wrist folder moves forward

12. Both wrists folder and finger folder reverse then base plate moves down

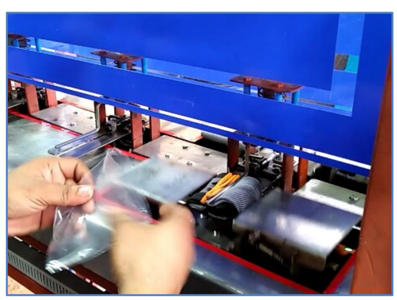


Figure 5.6: Both wrists folder and finger folder reverse

13. Duple plates move up and squeeze glove pair as facilitate to insert poly bag

Figure 5.7: Squeeze the glove pair

14. Inset polybag manually

Figure 5.8: Inset polybag manually

15. After 5 seconds machine releases duple plates down and glove pair moves to stripping station

Figure 5.9: Duple plates down and glove pair moves to stripping station

16. Lock open slightly as facilitate to strip glove pair from duple plates at glove stripping station

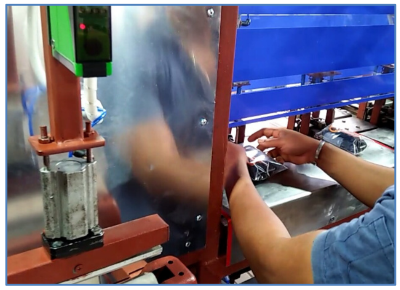


Figure 5.10: Strip glove pair from duple plates

17. Seal the poly bag using auto sealer

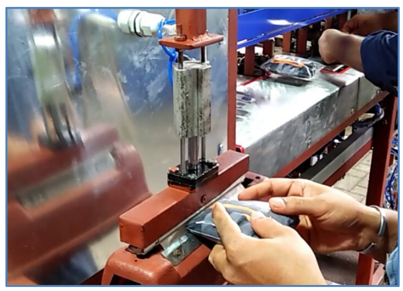


Figure 5.11: Seal the poly bag using auto sealer

5.2. Comparison of Machine Output

- Manual output = 140 packets per hour
- Expected output = 200^+ packets per hour
- Machine maximum output = 480 packets per hour

6. CONCLUSION

Three types of conceptual manual prototype models have been tested. Among them only one type of the conceptual prototype has been succeeded. Further improvements and developments have been incorporated to fold the gloves automatically.

Mechanism of the glove folding process has been successfully completed in this research and it can be applied for use in the glove manufacturing industry. Though the main concern of this research is to design and development of glove folding system, it has also introduced a semi-automated glove packet sealing system as an attachment.

Maximum output of this machine is 480 pairs per hour while manual folding output is about 140 pairs per hour.

This machine can be further developed into fully automated version by introducing a system for glove placement, a system for poly bag insertion and another system for glove stripping. Hence safety precautions can be improved during placement of gloves to fold.

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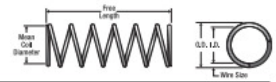
[Appendix – A: Data sheet for Compression springs]

1-800-237-5225
1-213-749-1466
Fax (213)749-3802
www.centuryspring.com



O.D.		CENTURY STOCK NUMBER	FREE LENGTH		I.D.		RATE		SUGG. MAX. DEFL.		SUGG. MAX. LOAD		SOLID LENGTH		WIRE DIA.		TOTAL COILS	MAT'L	ENDS	FINISH
Inches	mm		Inches	mm	Inches	mm	Lbs./In.	N/mm	Inches	mm	Lbs.	N	Inches	mm	Inches	mm				
1.375	34.93	S-1087	1.63	41.3	1.135	28.8	48	8.4	.77	19	37	163	.57	14.5	0.120	3.0	4.75	SST	CG	N
1.375	34.93	11628	1.63	41.3	1.123	28.5	41	7.2	.81	20	33	148	.82	20.8	0.126	3.2	6.50	SPR	CG	Z
1.375	34.93	S-326	1.69	42.8	1.105	28.1	63	11	.78	20	50	221	.74	18.9	0.135	3.4	5.50	SST	CG	N
1.375	34.93	3560	1.75	44.5	.991	25.2	393	69	.37	9.3	144	641	.96	24.4	0.192	4.9	5.00	SPR	CG	Z
1.375	34.93	10401	1.97	50.0	1.063	27.0	104	18	.79	20	82	366	1.01	25.8	0.156	4.0	6.50	SPR	CG	Z
1.375	34.93	12610	2.00	50.8	1.041	26.4	141	25	.71	18	100	447	1.09	27.6	0.167	4.2	6.50	SPR	CG	Z
1.375	34.93	10299	2.13	54.0	1.193	30.3	13	2.3	1.4	35	18	81	.50	12.7	0.091	2.3	5.50	SPR	CG	Z
1.375	34.93	11671	2.13	54.0	1.041	26.4	141	25	.71	18	100	447	1.09	27.6	0.167	4.2	6.50	SPR	CG	Z
1.375	34.93	12779	2.19	55.6	1.079	27.4	79	14	.92	23	72	321	1.00	25.4	0.148	3.8	6.75	HD	CG	Z
1.375	34.93	4400	2.22	56.4	1.179	29.9	15	2.6	1.5	39	23	101	.61	15.6	0.098	2.5	6.25	SPR	CG	Z
1.375	34.93	4343	2.25	57.2	1.193	30.3	10	1.8	1.7	42	17	76	.59	15.0	0.091	2.3	6.50	SPR	CG	Z
1.375	34.93	S-1388	2.31	58.7	1.191	30.3	6.8	1.2	1.6	39	11	47	.76	19.3	0.092	2.3	8.25	SST	CG	N
1.375	34.93	11839	2.34	59.5	1.187	30.1	7.6	1.3	1.6	40	12	53	.78	19.7	0.094	2.4	8.25	SST	CG	N
1.375	34.93	S-450	2.44	61.9	1.191	30.3	7.1	1.2	1.7	43	12	54	.74	18.7	0.092	2.3	8.00	SST	CG	N
1.375	34.93	10309	2.44	61.9	1.021	25.9	164	29	.73	18	119	530	1.24	31.5	0.177	4.5	7.00	SPR	CG	Z
1.375	34.93	10348	2.50	63.5	1.193	30.3	8.5	1.5	1.8	46	15	68	.68	17.3	0.091	2.3	7.50	SPR	CG	Z
1.375	34.93	12092	2.50	63.5	1.167	29.6	18	3.2	1.4	35	25	112	.73	18.5	0.104	2.6	6.00	SST	C	N
1.375	34.93	73	2.50	63.5	1.105	28.1	48	8.4	1.2	29	55	245	.98	24.9	0.135	3.4	7.25	HD	CG	Z
1.375	34.93	S-347	2.50	63.5	1.105	28.1	46	8.0	1.1	28	50	221	.91	23.1	0.135	3.4	6.75	SST	CG	N
1.375	34.93	12420	2.75	69.9	1.277	32.4	.89	16	2.4	61	2.1	9.5	.34	8.7	0.049	1.2	6.00	SPR	C	Z
1.375	34.93	269	2.75	69.9	1.135	28.8	27	4.8	1.5	37	40	178	1.02	25.9	0.120	3.0	7.50	HD	C	Z
1.375	34.93	3464	2.75	69.9	1.105	28.1	31	5.5	1.3	32	40	176	1.49	37.7	0.135	3.4	10.0	HD	C	Z
1.375	34.93	54	2.75	69.9	1.021	25.9	122	21	.98	25	119	530	1.55	39.3	0.177	4.5	8.75	HD	CG	Z
1.375	34.93	10742	2.88	73.0	1.215	30.9	5.4	.95	2.3	59	13	56	.56	14.2	0.080	2.0	7.00	SPR	CG	Z
1.375	34.93	4355	2.94	74.6	1.205	30.6	4.0	.70	2.0	51	8.1	36	.91	23.2	0.085	2.2	10.8	SPR	CG	Z
1.375	34.93	S-1209	3.00	76.2	1.135	28.8	20	3.5	1.8	46	37	163	1.02	25.9	0.120	3.0	8.50	SST	CG	N

Source: Compression Spring Catalogue "Century Spring Corp." p-201.

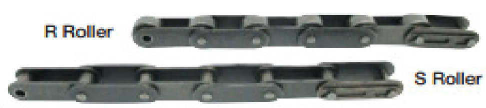
[Appendix – B: Catalog for double pitch roller chains]

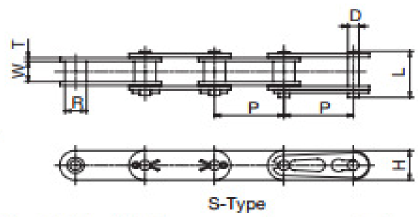
Double Pitch Roller Chains

● **Order No. Example**

C2040 **120 Links**
10ft
3m

Chain No. — Unit





Double pitch roller chains are roller chains for transmission with a double pitch. They are small conveyor chains, each part of which is the same as roller chains and which are excellent in rupture strength and wear resistance. The R-type and S-type are available for rollers and the A1/2, K1/2, SA1/2 and SK1/2 types for chains with attachments. See P86 to P87 for chains with attachments.

Chain No.		Pitch	Roller	Inner Link	Link Plate		Pin		Average	Maximum
Type	Roller Shape	P	Outer Diameter R	Inner Width W	Thickness T	Width H	Outer Diameter D	Length L	Tensile Strength kN (kgf)	Allowable Tension kN (kgf)
C2040 C2042	S R	25.40	7.92 15.88	7.95	1.5	11.7	3.97	17.55	17.2 (1,750)	2.65 (270)
C2050 C2052	S R	31.75	10.16 19.05	9.53	2.0	14.6	5.09	21.75	27.9 (2,850)	4.31 (440)
C2060H C2062H	S R	38.10	11.91 22.23	12.70	3.2	17.5	5.96	30.00	39.5 (4,000)	6.28 (640)
C2080H C2082H	S R	50.80	15.87 28.58	15.88	4.0	23.0	7.94	38.50	68.6 (7,000)	10.69 (1,090)
C2100H	S	63.50	19.05	19.05	4.8	28.9	9.54	46.40	106.9 (10,900)	17.06 (1,740)

Source: "RoHS" Double Pitched Roller Chains Catalogue, p-82

[Appendix – C: [Catalog for double pitch sprockets]

2062B Standard Double Pitch Sprocket for R Rollers B-type

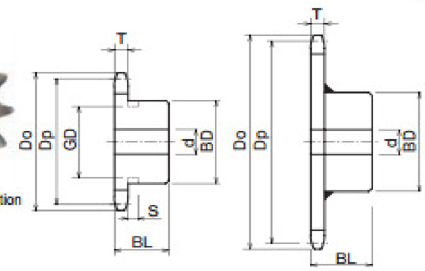
Order No. Example

2062B 20

Type — No. of Active Teeth

Sprocket No.

Ground Specification Welded Specification



Ground Specification Welded Specification

- Chain ········· No.C2062H
- Chain Pitch ········· (P)38.10mm
- Roller Link Inner Width ······ (W)12.70mm
- Roller Outside Diameter ······ (Dr)22.23mm
- Tooth Width ········· (T)11.7 mm

Type	Action No. of Teeth	Outer Diameter Do	Pitch Diameter Dp	Shaft Hole Diameter d: Prepared hole	Shaft Hole Diameter d: Minimum	Shaft Hole Diameter d: Maximum	Boss Diameter BD	Boss Length BL	Shape	Material	Weight kg	¥	Semi-F ¥
2062B	7	102	87.81	18	19	40	★60	40	Ground Specification	Carbon Structural Steel	0.97		
	8	115	99.56	18	19	50	★75	40			1.44		
	9	128	111.40	18	19	50	80	40			1.80		
	10	140	123.29	18	19	55	80	45			2.50		
	11	153	135.23	18	19	55	83	45			2.60		
	12	165	147.21	18	19	55	83	45			2.80		
	13	177	159.20	25	26	55	83	45	Welded Specification	Common Steel	3.10		
	14	190	171.22	25	26	55	83	45			3.60		
	15	202	183.25	25	26	55	83	45			3.90		
	16	214	195.29	25	26	55	83	45			4.20		
	17	227	207.35	25	26	63	93	45			4.60		
	18	239	219.41	25	26	63	93	45			5.00		
	19	251	231.48	25	26	63	93	45			5.50		
	20	263	243.55	25	26	63	93	45			6.00		
	21	276	255.63	25	26	63	93	45			5.89		
	22	288	267.72	26	27	63	93	45			6.34		
	24	312	291.90	26	27	63	93	45			7.28		

Source: "RoHS" Standard Double Pitch Sprockets Catalogue, p-309

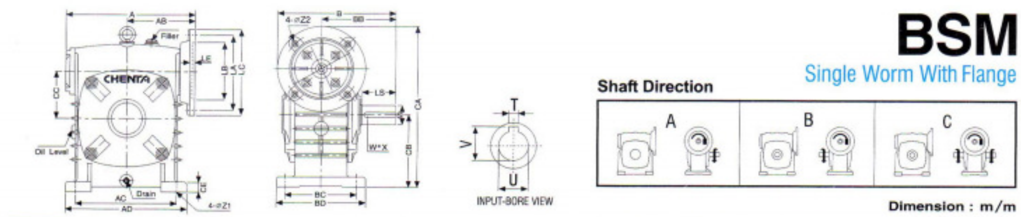
TECO e-motion **Technical data**

4-pole

Power rating	Nominal speed	Frame size Type code ALAA...	Nominal current	Locked rotor current (multiple of nominal current)	Efficiency at load points				Power factor at load points				Nominal torque	Locked rotor torque (multiple of nominal torque)	Pull up torque (multiple of nominal torque)	Break down torque (multiple of nominal torque)	Moment of Inertia	Total mass (B3 version; approx.)	Sound pressure; Noise level
P_N	n_n		I_N	I_l/I_N	η				cos φ				T_N	T_l/T_N	T_p/T_N	T_b/T_N	J	m	dB (A)
[kW]	[rpm]		[A]		[%]								[Nm]				kgm²	[kg]	
					Full load	3/4 load	2/4 load	1/4 load	Full load	3/4 load	2/4 load	1/4 load							
0,18	1375	0063M1	0,54	3,90	65,0	63,8	58,2	43,6	0,75	0,64	0,50	0,35	1,25	2,00	1,80	2,00	$0{,}43 \times 10^{-3}$	6,0	42
0,25	1380	0071M0	0,67	4,20	69,5	70,1	66,2	51,8	0,77	0,67	0,52	0,35	1,73	2,00	1,75	2,00	$0{,}67 \times 10^{-3}$	8,0	46
0,37	1385	0071M1	1,02	4,20	69,5	69,9	66,3	52,2	0,75	0,65	0,50	0,33	2,55	2,05	1,80	2,05	$0{,}8 \times 10^{-3}$	9,0	46
0,55	1435	0080M0	1,34	6,60	78,1	78,1	75,2	63,6	0,76	0,69	0,56	0,37	3,66	2,55	2,20	2,80	$2{,}6 \times 10^{-3}$	13,0	48

Source: "TECO e-motion" Technical Catalogue 2014, p-61

[Appendix – E: Technical data sheet of Gear box]



Size	Ratio	A	AB	AC	AD	B	BB	BC	BD	CA	CB	CC	CE	Z1	Input Bore U	Input Bore T	Input Bore V	Output Shaft LS	Output Shaft S	Output Shaft W * X	Flange LA	Flange LB	Flange LC	Flange LE	Flange Z2	OIL (l)	Weight (Kg)
50		174	97	110	140	175	95	95	120	210	80	50	18	11	11 14	4 5	12.8 16	40	17	5 * 3	115	95	140	4	M8	0.22	7.2
60		177	97	120	150	190	110	105	130	230	90	60	20	11	11 14	4 5	12.8 16	50	22	7 * 4	130	110	160	4	M8	0.32	10
70	1/10	213 215	118 120	150	190	210 230	130	115	150	255 275	105	70	22	15	14 19	5 6	16 21.8	60	28	7 * 4	130 165	110 130	160 200	4 5	M8 M10	0.55	15
80		234	130	180	220	240	140	135	170	300	120	80	20	15	19 24	6 8	21.8 27.3	65	32	10 * 4.5	165	130	200	4	M10	0.77	20.2
100	|	273 278	140 142	220	270	270 295	170	155	190	350 375	150	100	25	15	24 28	8 8	27.3 31.3	75	38	10 * 4.5	165 215	130 180	200 250	5 5	M10 M12	1.53	39.5
120		339	180	260	320	315	190	180	230	425	180	120	30	18	28	8	31.3	85	45	12 * 4.5	215	180	250	5	M10	2.4	65
135		370 390	195 218	290	350	335 360	210	200	250	475 500	215	135	30	18	28 38	8 10	31.3 41.3	95	55	15 * 5	215 265	180 230	250 300	5 4.5	M12 15	3.25	85.2
155	1/60	405.5 430	213.15 236. 5	320	380	367 392	242	220	280	530 540	235	155	32	20	28 38	8 10	31.3 41.3	100	60	15 * 5	215 265	180 230	250 300	5 4.5	M12 M12	7.4	116
175		420 465	212. 5 255	350	410	398 423	248	250	310	585 610	260	175	35	20	38 42	10 12	41.3 45.3	110	65	18 * 6	265 300	230 250	300 350	5 6	M12 19	11.5	162

Source: "CHENTA Brand Speed Reducer 02.08" Technical Catalogue, p-03

[Appendix – F: Proportions of standard parallel keys]

Shaft diameter (mm) upto and including	*Key cross-section*		*Shaft diameter (mm) upto and including*	*Key cross-section*	
	Width (mm)	*Thickness (mm)*		*Width (mm)*	*Thickness (mm)*
6	2	2	85	25	14
8	3	3	95	28	16
10	4	4	110	32	18
12	5	5	130	36	20
17	6	6	150	40	22
22	8	7	170	45	25
30	10	8	200	50	28
38	12	8	230	56	32
44	14	9	260	63	32
50	16	10	290	70	36
58	18	11	330	80	40
65	20	12	380	90	45
75	22	14	440	100	50

Source: “in [2]…”p 472.