Development of Vending Machine for Mini Components

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May, 2017

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Major Project Report

Submitted in partial fulfillment of the requirements
for the degree of
Master of Technology in Mechanical Engineering (CAD/CAM)

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May, 2017

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This is to certify that

1. The thesis comprises my original work towards the degree of Master of Technology in Mechanical Engineering **(CAD/CAM)** at Nirma University and has not been submitted elsewhere for a degree.

2. Due acknowledgment has been made in the text to all other material used.

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Undertaking for Originality of the work

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Abstract

Recent production system can be converted into profit if the subsequent assembly of the components is also automated. Automatic assembly systems are not feasible with all the industry due to high capital investment. A vending machine is proposed to make the assembly faster without miss out of any part of the assembly operator.

In this project, an effort has been made to develop a vending machine for an assembly line for toy manufacturing industry. A toy assembly consisting of 5 components is taken as a case study. The machine is programmed and controlled using 'Arduino' controller. The machine can be used to deliver the components as per requirement (pre-programmed bill of materials i.e. a number of components) in front of the assembly operator. This will fabricate to make the assembly faster, error free, and to reduce fatigue to the operator.

Keywords: Automation, Vending Machine, Part feeding

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Chapter 1

Introduction

1.1 Automation

Automation is the minimum human interference by using different control systems for using equipment such as machinery, processes in the factory, boilers and heat treating ovens, aircraft, and other application. Some process has been semi-automatic or fully automatic.

To meet the high demands, industries to have automation in production, assembly as well as dispatching sections. Automation can be achieved by integrating mechanical, hydraulic, pneumatic, electrical, electronic devices and computer systems. It leads to minimum human interference and hence helps to improve quality, accuracy and precision. However, the highly automatic industries need huge investment. Low cost automation can be thought to address production rate and quality issues for such industries.

vending machine is such an automation which caters the need for human-less dispatching systems.

Figure 1.1: Different Vending Machines[1]

1.2 Vending Machine

A vending machine delivers many items like foodstuffs such as snacks, cold drinks, alcohol, tickets and much more to customers automatically when the command is given to the machine.[2]

The Vending machine dispenses the variety of the products or services to customers. The machine sells the variety of services or products with the appropriate price. By paying the required amount, the product is delivered at the bottom of the machine by releasing it. For services when the payment is made after that the service is available to the customer[3].

In the developed countries, the Vending machine usually sells drinks like juice, soft drinks, energy drinks, and tea. Sometimes these machines also offer hot as well as cold drinks. There is much more variety of machines deliver goods such as ATM machine, Newspaper Vending Machine, Soda vending Machine[1], etc as shown in fig1.1.

There are different types of mechanism that are used in the vending machines.The main aim of the machine is deliver product/s on confirmation of payment. Vending machine include some monetary detection device like card swipes coin slots display case for displaying and product dispense area for pick up parts. Some vending machine contains unique parts like refrigeration unit for keep drinks cool heater for keep drinks hot etc.

Some products like tickets are printed or magnetized on the spot which contains printing mechanism. The coffee is freshly concocted are required to be prepared to make available. The snack machine often uses a metal coil which when ordered rotates to release the product and collected at the bottom[2].

1.3 Motivation

Automation is an essential thing in the manufacturing industry which reduce the manufacturing time of the component and the effort.In many medium and small scale industry, the assembly of a small component is done manually which takes more time with less precision. For this type of industry automatic vending machine will be helpful for reducing lead time and increase the productivity with high precision.

Looking at the acceptance and usefulness of the vending machines, it is thought to develop and implement a vending machine in an assembly line for small products like toys.This will enhance production of assembly.On pressing a button by an operator, the components will be delivered one by one in front of the operator in the sequence of assembly with due time delay.

1.4 Objectives

Based on the motivation following objectives are identified:

- To develop a conceptual design of vending machine to deliver components for small toy assembly.
- To fabricate the machine.
- To incorporate controls for the machine.
- Testing of the vending machine.

1.5 Organization of Thesis

The work done to achieve above objectives is reported and organized chapter wise in the thesis.

Chapter 1 contains the introduction of the vending machine and the objectives of the project.

Chapter 2 gives details of the literature review of different authors on different part feeding mechanisms, automation, and its costs.

Chapter 3 contains the conceptual design of the vending machine.The different parts are designed, and calculations are described in this chapter.The cad model for the automatic vending machine is illustrated.

Chapter 4 contains the overview of different controlling parts and overall controlling system.

Chapter 5 gives summary of the work done and future work is presented.

Chapter 2

Literature Survey

2.1 Review of Published work

The purpose of this literature review is to develop a base information about different dispatching machines and automation. The study is done regarding different part feeding mechanism in the dispatching machines. Many research papers have been published in the area of orienting parts or designing part feeders for handling the parts of different shapes. Methods have been investigated to feed the parts based on criteria such as orientation, mechanics of orientation, dynamics of part motion, Internal and external features of parts, space availability, and cost. Research in this direction has been reported since the early 1960s by Terborgh[4] Laktionev and Andreev[5] , Gusev[6], Boothroyd and Murch [7], and many others. A high rate of orientation has been the goal of many researchers; hence, devices such as vibratory feeders and specific feeders were the ideal choices for small and medium-sized parts.

2.2 Part feeder

Parts must be grouped before the selecting the part feeder, The grouping methodology is done by Mankame et al.[8]. The parts based on the internal as well as external features of the parts and grouped. Two stacking and orienting system of the parts based on internal features has been proposed in the research paper. 20 parts are divided with suitability according to their internal features. An inexpensive and very simple mechanism for stacking and orienting has been proposed.

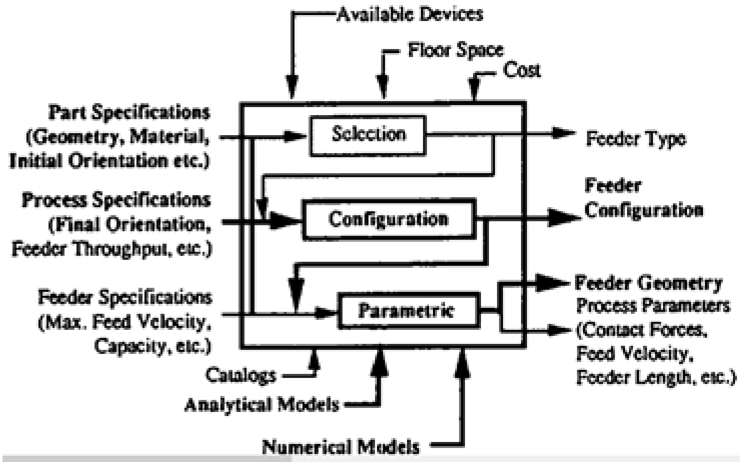

Figure 2.1: Methodology for part feeder design[9]

The Part feeder is a vital element in the vending machine.The methodology of the part feeder design is discussed in detail by Yeong and De Vries[9].The part feeder design divided into the four parts as shown in fig.2.1. The evaluation of the procedure for the designing the part feeder with the recommended shape and size has been stated in this paper. By proposing this model for design, the methodology helps the designer in understanding and solving the complicated design task into manageable tasks.

2.3 Vibratory Bowl Feeder

The use of vibratory bowl feeder for feeding different parts is illustrated by Gupta et al.[10]. The single vibratory bowl feeder for feeding three different parts with the pneumatic programmable system and sorting them by area detection algorithm is discussed for feeding them to develop an agile feeding and sorting system. This system eliminates the use of different bowl feeder for different parts and thus lower the total cost.

The part feeding in vibratory bowl feeder is discussed by Petrovic et al.[11]. The axiomatic design model of conventional vibratory bowl feeder is studied and presented the new functionally uncoupled design which consists of conveyors. The new design model is low in production cost and overcome many problems which are in conventional vibratory bowl feeder.

The requirements for flexible part-handling and the advantage of other strategies which are applied is discussed by Boothroyd et al.[12]. A feeding concept of a non-stable parts having adjustable tooling and a remote sensor for presentation and assembly has been presented in this paper. A low-cost hopper type belt feeder for orientation of stable parts as shown in fig.2.2 has been proposed.

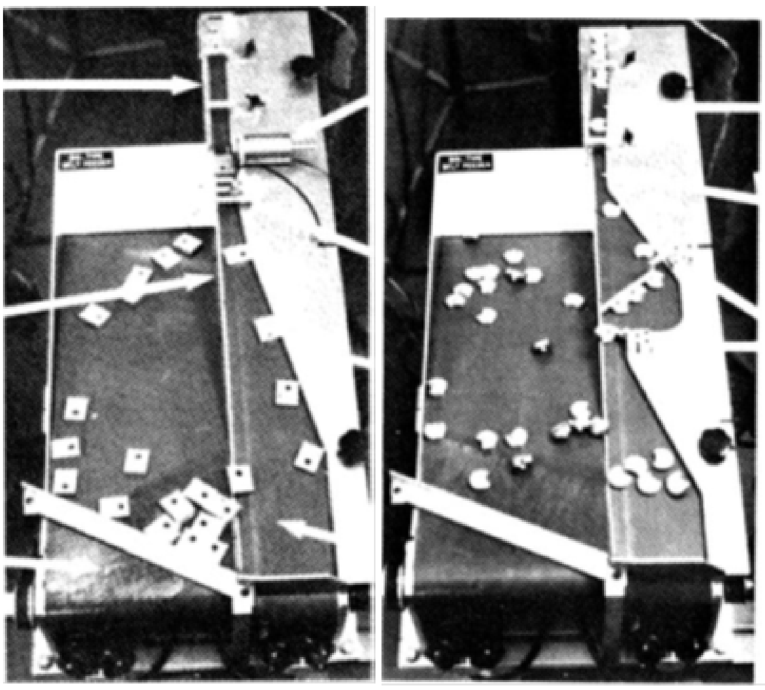

Figure 2.2: Belt feeder arrangement[12]

2.4 Conveyor Belt Drive

Chua[13] had worked on feeding cylindrical parts in shape, fragile and powdery in nature and possess asymmetrical features.The part feeding mechanism for these parts is developed which consist of linear belt drive, V-belt orientation, and unloading module. The mechanism is capable of feeding Delicate and powdery cylindrical parts (including those with asymmetrical features) with Aspect ratios having a range of 0.5 to 0.8 and 1.2 to 1.6 with high efficiency.

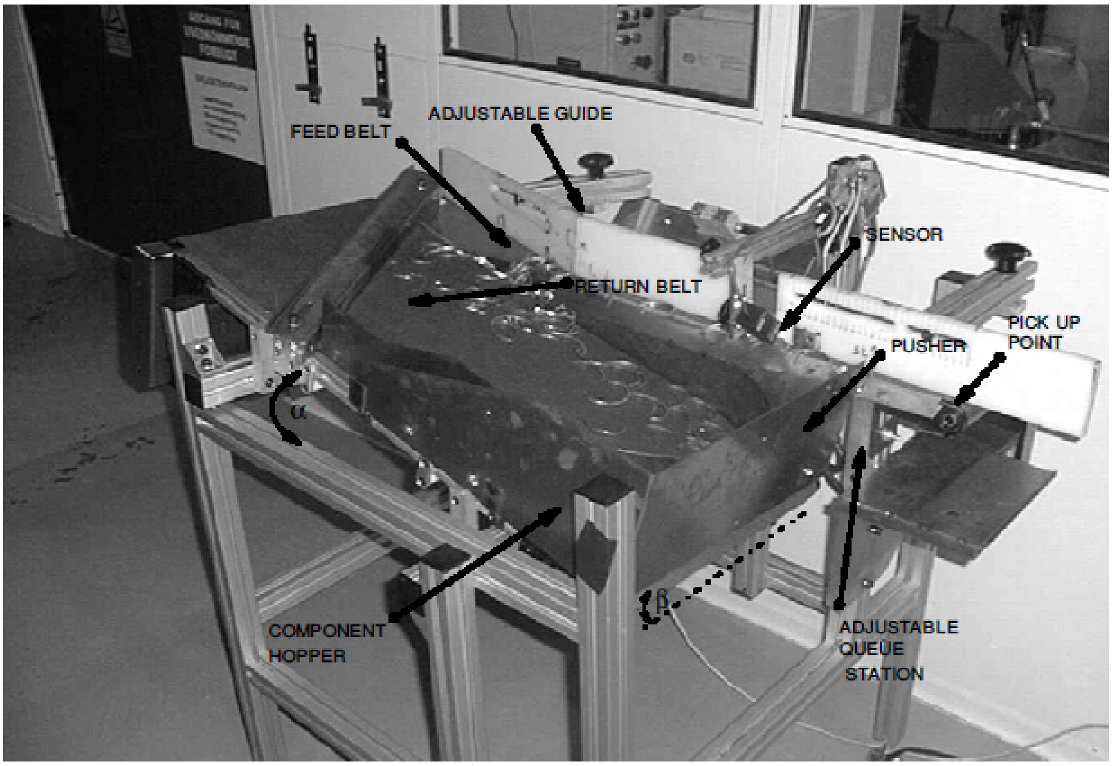

Figure 2.3: Flex feeder[14]

Edmondson and Redford[14] also worked on the feeding of cylindrical parts. A compact, low cost belt feeder prototype as shown in fig. 2.3 is developed . This system is capable of feeding complex geometries using modern sensor technology for part recognition, a conventional non-active orientation blade, and a novel method for handling cylindrical parts.The mechanism is cheaper and compact than other commercially available flexible feeding systems.

Lynch [15] derived the mechanical conditions for toppling. The conveyor feeding method with 1 JOC (Joint Over Conveyor) robot is used in this research paper. Toppling and settling of the parts are discussed and also the mathematical model is given. Two approaches regarding toppling and settling of parts in conveyor based system is suggested.

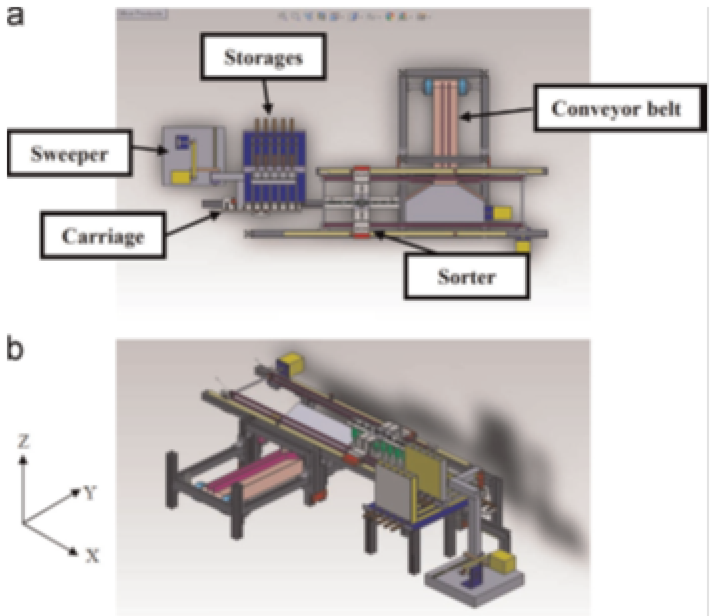

Figure 2.4: Tiling automation system[16]

Phooripoom and Koomsap[16] developed a tiling automation to support custom mosaic design from uniform size square tiles. As shown in fig 2.4, the system follows a product flow concept. In this concept the sorting of the tesserae is done to form a row and then being assembled to a mosaic by moving on a conveyor. It permits a simple point-to-point movement for assembly.

The product dispensing machine mechanism is discussed by Katsuhiko et al.[17]. It can provide sufficient drive energy at a low voltage by utilizing the configuration which is a combination of DC gear motor and a cam-linkage mechanism for the drive source used in the product dispensing mechanism.

2.5 Part Feeding Mechanisms

In the automatic and semi automatic assembly line the most difficult task is material handling. In many situation the feasibility of the system is limited because of the material handling. The material handling contains necessary provide desire amount of parts aligned and precisely positioned on pick up location at the right time. This task may be divided into four sub tasks : 1) storing, 2) feeding, 3) clamping and 4) inspection. Because of the problems of jamming, telescoping,orienting, and entangling of the part, the feeding task is the most challenging task. Different part feeding mechanisms are studied and presented in following section.

2.5.1 Vibratory Bowl Feeder

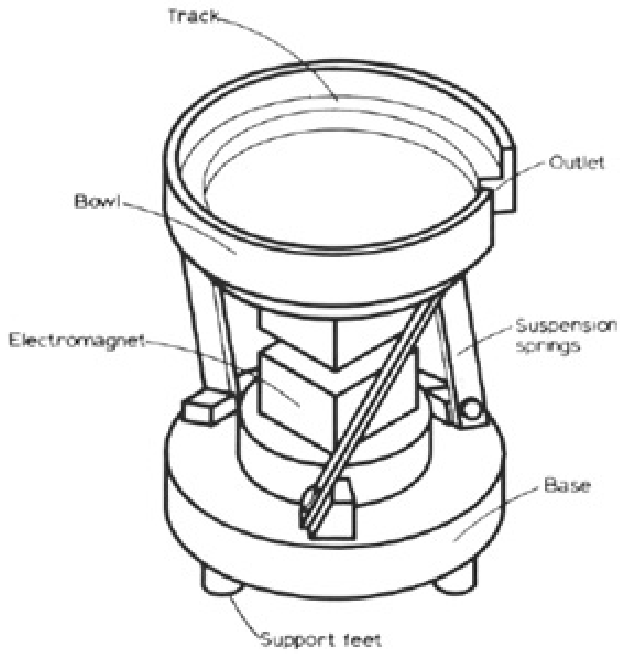

Figure 2.5: Vibratory Bowl Feeder[18]

Vibratory bowl feeders as shown in fig.2.5 are used to feed and orient in proper direction of parts into a production line. 3 or 4 leaf springs are used to support the bowl.These restrain the bowl's movement such that only vertical movement is possible. The bowl feeder has a magnetic coil. The coil is magnetized by the external power supply, and thus the electromagnetic vibrations are generated. This in turn produces mechanical vibrations which causes the movement of components on the tracks provided in the bowl and feed them to the production line[18].

2.5.2 Reciprocating tube hopper feeder

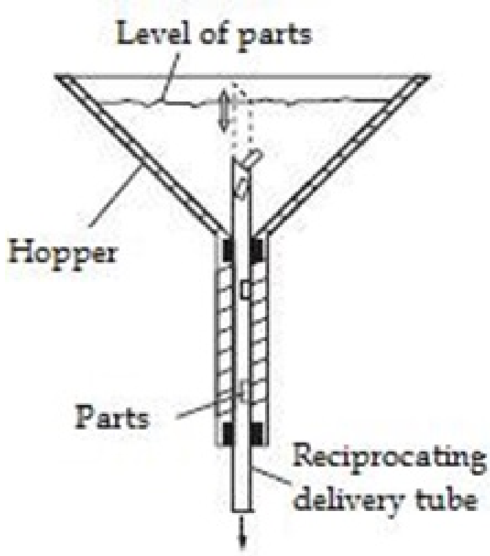

Figure 2.6: Reciprocating tube hopper feeder[20]

The reciprocating tube hopper feeder contains a conical hopper. There is a hole in the center through which the delivery tube passes.With the help of reciprocation of either the tube or the hopper, Relative vertical movement between the hopper and the tube is generated. When the top of the tube comes under the level of parts, some parts will fall into the reciprocating delivery chute[19].The reciprocating tube hopper is shown in fig. 2.6.

Spheres, cylinders with L/D less than 4, discs with L/D less than 7, Prism of square cross section with L/D less than three may be fed. The delicate parts is not suitable for this feeding mechanism[20].

2.5.3 Rotary Disk Feeder

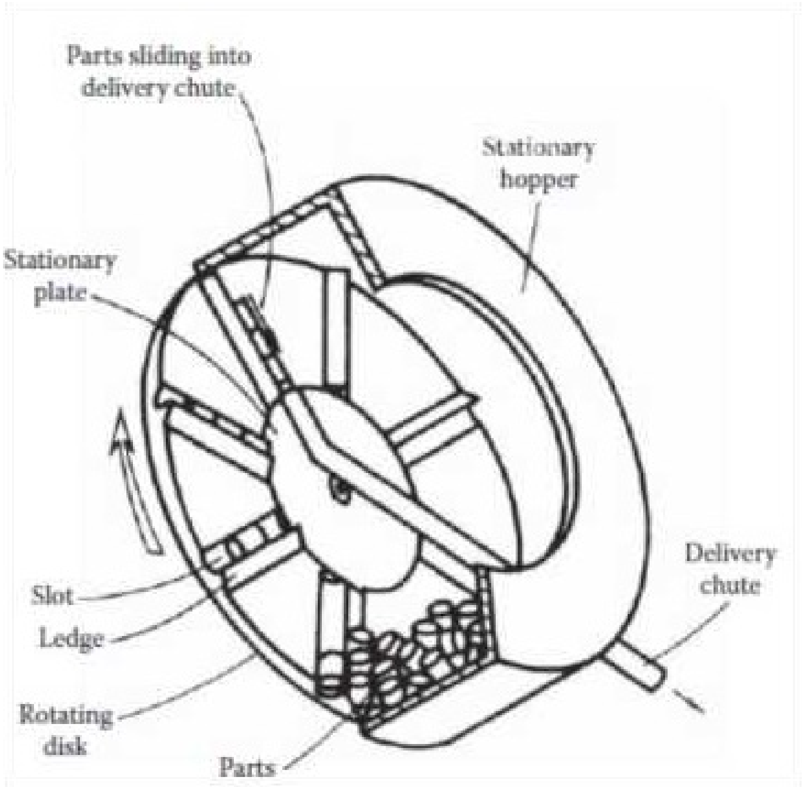

Figure 2.7: Rotary Disk Feeder[20]

Rotary disk feeders have a cylindrical bowl that rotates and centrifugal forces acted on the parts as shown in fig.2.7. Due to this force, the parts move outside of the bowl.There is a hole on its periphery through which the parts move to the receivers when they are align with the delivery chute. Centrifugal feeders are usually less noisy than vibratory feeders and faster in operation [21]. Cylindrical parts, spherical parts, disc-shaped parts such as a nut, washer, etc. can be fed. The driving mechanism can be a continuous or indexing drive.

2.5.4 Rotary Hopper Feeder

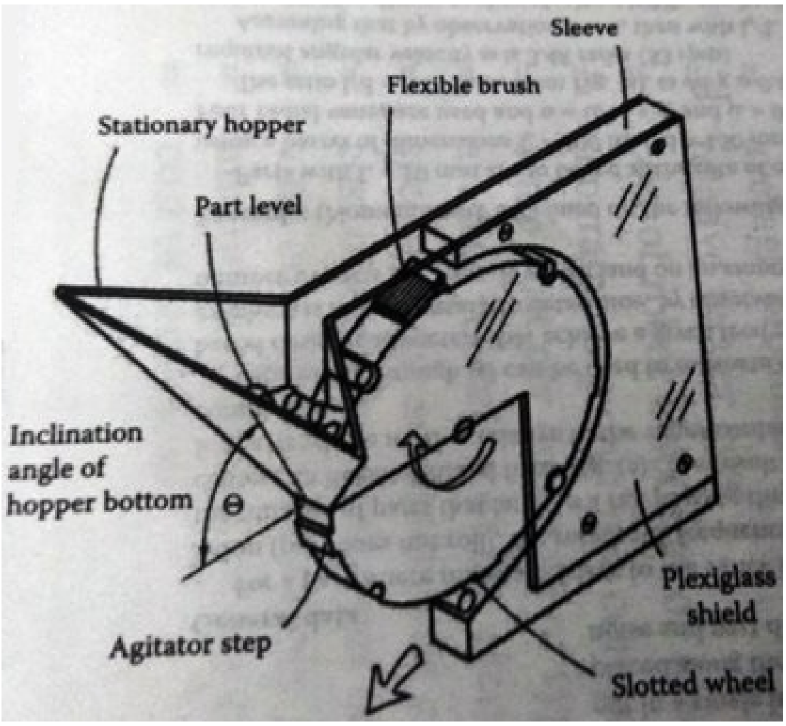

Figure 2.8: Rotary Hopper Feeder[20]

Rotary hopper feeder consist of the rotating wheel, with a machined slot in its periphery as shown in fig.2.8, which turns through a stationary hopper so that parts tend to fall into the slots. The brush is provided at the top of feeder which removes incorrectly oriented parts or excessive parts. Correctly oriented parts are engaged in the slot by a sleeve. The part fell down from the delivery chute, when sleeve reach the delivery chute at the bottom of the device[20]. Long slender parts which have an end to end symmetry such as cylinder parts are suitable for this mechanism.

2.5.5 Elevating Hopper Feeder

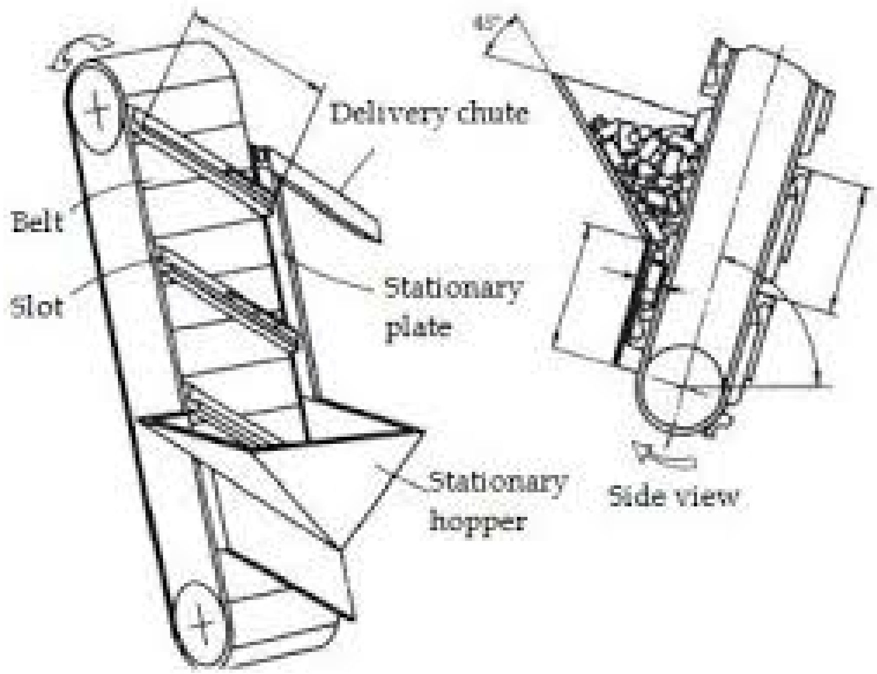

Figure 2.9: Elevating Hopper Feeder[20]

A elevating hopper feeder is consist of flexible belt on the elevator which has a series of slots as shown in fig.2.9. The slots turn through the hopper due to that the part slide to fall on the belt. A stationary plate is provided for preventing the part to slide out of the slot until the part reach to the delivery chute. This feeder has a stationary hopper with inclines sides. An unsettling device is fitted so that the parts tends to slide to the lowest point of hopper. The slots are designed in such a way that only desire oriented parts can be engaged in conveyor belt. The elevating hopper feeder is suited for cylindrical as well as circular parts[20].

2.6 Summary

- The conventional vibratory bowl feeder is not economical for a batch production and for feeding different parts because of a high cost of bowl and capability of feeding only one type of part.

- The flexible part feeder with vision system has a good accuracy, but the cost of the system is high due to a high-resolution camera and control.
- The most economical part feeder is the conveyor belt type which has very low cost as compared to other feeding systems and simple in design.

Chapter 3

Conceptual Design of a Vending Machine

A conceptual design for vending machine for assistance in assembly process of a toy car has been presented in this chapter. The main purpose of the proposed vending machine is to deliver the varieties of parts in front of the assembly operator. The vending machine contains the part feeding mechanism that must feed the parts at the right time. and different types of small components of this assembly need to be fed for the assembly process from the vending machine. According to size and shape of the parts, the concept of the part feeding mechanism is developed, and the design of the vending machine has been done.

The elevating hopper feeder mechanism is used in this design. This mechanism consists of the belt conveyor,motor,controller and hopper for part feeding.The advantage of elevating hopper feeder are as follows:

- Less space is required.
- Flexibility is high
- Operating cost is low than vibratory bowl feeder.
- less maintenance cost.

- Time for feeding the part is low compared to other mechanisms.

3.1 Sub assembly of a toy car

The toy car assembly is shown in fig 3.1 which is going to assemble by collecting parts from the vending machine.

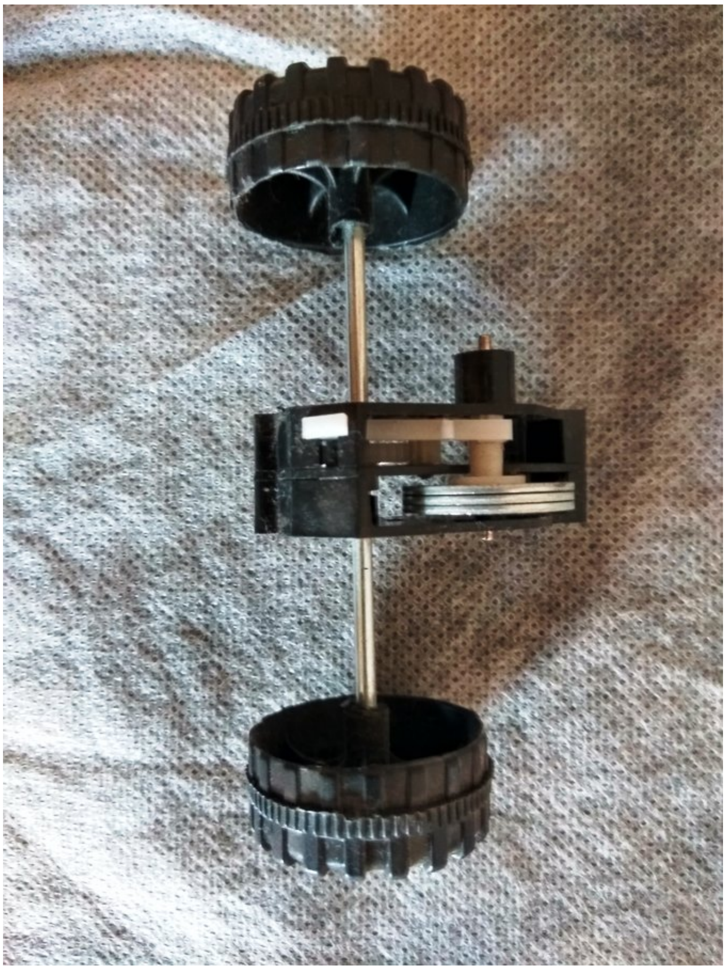

Figure 3.1: Toy car assembly

3.1.1 Parts in sub assembly

The different parts that need to be feed by vending machine are shown with details in table 3.1 .

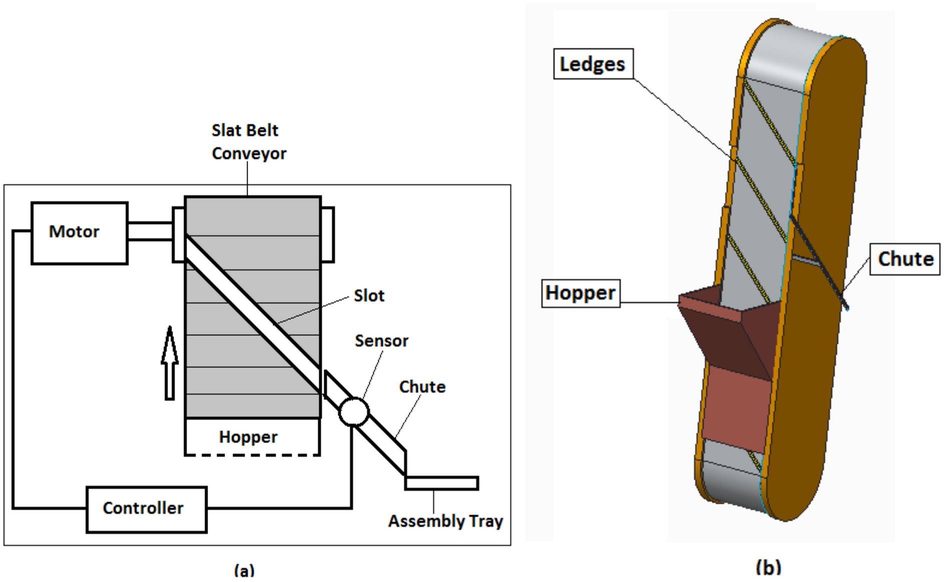

Figure 3.2: a) Schematic diagram of Assembly Vending Machine b) Elevating hopper feeder for wheel shaft

Parts	Dimension	Weight (gram)	Volume (mm^3)
Wheel Shaft	Diameter=ø2mm Length=75mm	1.72	223.84
Shaft Flywheel	Diameter=ø1mm Length=25mm	0.25	249.41
Flywheel	Outside Diameter=ø10mm Inside Diameter=ø1mm Thickness=3mm	0.39	384.20
Gear Flywheel	Outside diameter=ø14mm Length=6mm	0.15	19.63
Gear	Outside Diameter=ø14mm Thickness=3mm	1.81	235.17

Table 3.1: Parts in Assembly

3.2 Conceptual Design

The parts are placed in the hopper which is located near slat belt conveyor. By pushing a button, the slat belt conveyor moves upward with the slot attached on it. The slot passes through the hopper and the part engages in the slot. When The slot reaches near the chute the part slides down to the chute and with the help of sensor the signal is given to the motor to stop. Thus, with the help of controller and sensor, only one part can be fed at a time. There are five elevating hopper feeder used and all are connected with the controller in the vending machine. They all are operated with fixed delay time after pushing the button.

3.3 Design of Elevating hopper feeder

3.3.1 Selection of the belt

Usually, the slat conveyor belt is used for the elevating hopper feeder[19]. It consists of slats on an endless chain as shown in fig.3.3. The slots are divided and mounted on this slats, and the whole belt is driven by a motor with the sprocket. The belt size, mainly width, is selected based on maximum length of the component to be fed. The size of the components in the toy car sub assembly varies from 14 mm to 75 mm. Hence, considering maximum length to be handled and interchangeability of the belt following belt size and sprocket size have been identified from the manufacturers catalog[22].

Belt type : Slat top-820 [22]

Belt width : 90 mm

Belt material : Polyoxymethylene

For slat top-820 belt Multi hub-820 sprocket is used as shown in fig.3.4 and the dimension of the sprockets are as follows.

pitch diameter of sprocket,

Figure 3.3: slat top-820 belt[22]

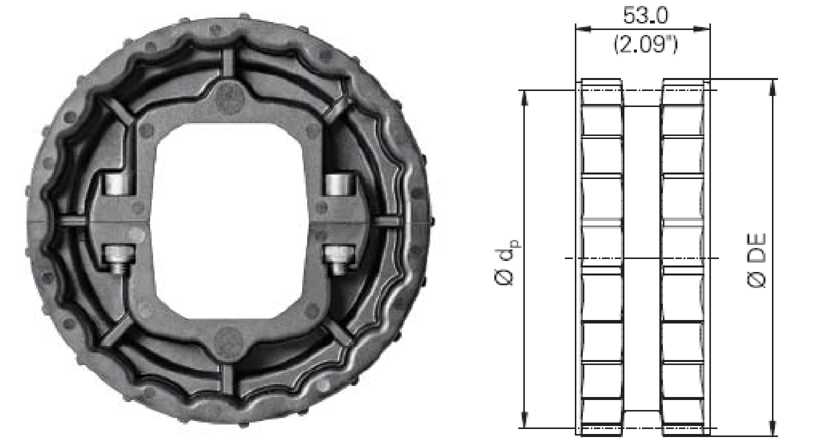

Figure 3.4: Multi-Hub-820 sprocket[22]

$$\phi d_p = 114.3\,mm$$

Outside diameter of sprocket,

$$\phi DE = 117\,mm \tag{3.1}$$

3.3.2 Slot design and angle of repose

The design of slot is made for the cylindrical component as shown in fig.3.5 and for disk component as shown in fig.3.6 such that it picks the part every time passes through from hopper. The slot inclination is also determined in such a way that the part slides to the delivery chute due to its gravitational force only. Friction is considered between the part material and slot material and to overcome this friction appropriate inclination angle is evaluated.

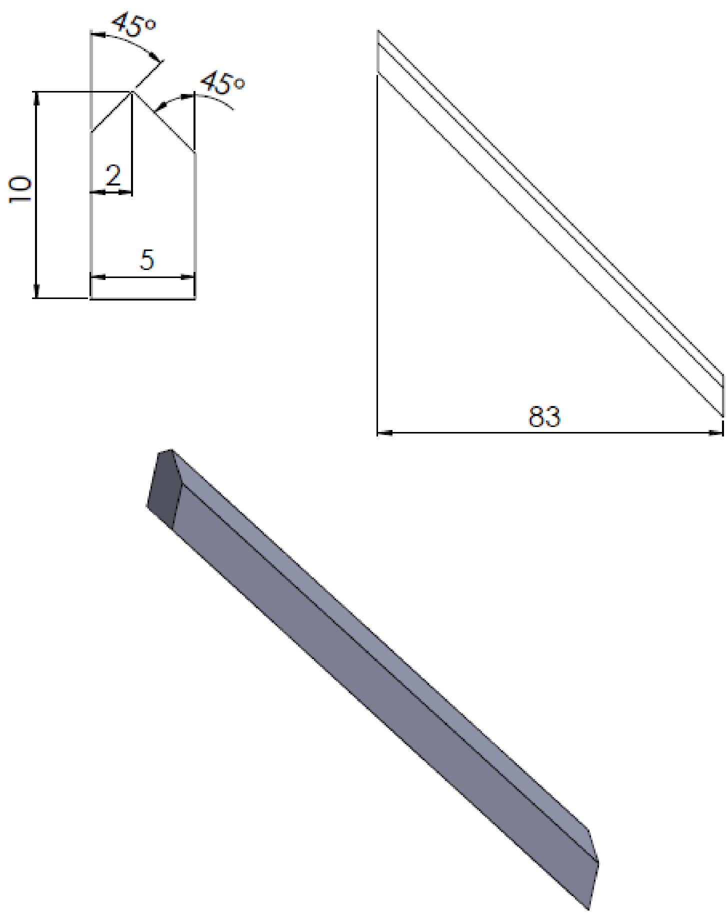

Figure 3.5: Slot for cylindrical component

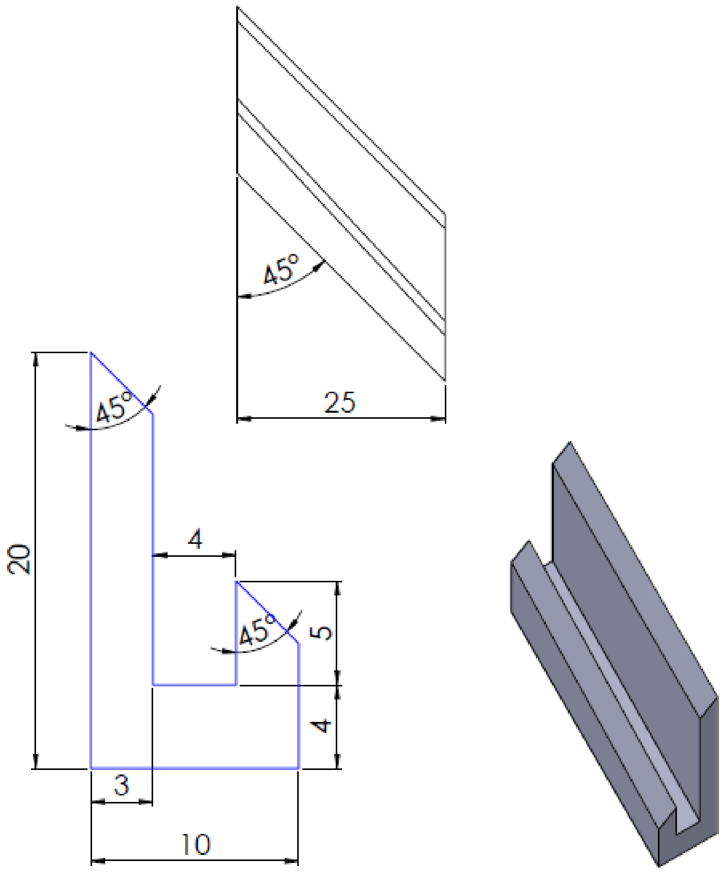

Figure 3.6: Slot for Disk Component

Now, for a wheel shaft angle of repose(α),

$$angle\,of\ repose\ \ (\alpha) = tan^{-1}\,(\upsilon)$$

Where = Coefficient of friction between slot material and part material

For a wheel shaft = 0.4 [23]

$$\alpha = tan^{-1}\,(0.4)$$

$$\alpha = 21.80^{o}$$

For the different material the angle of repose is different. For the different parts the angle of repose is illustrated in table 3.2 .

Parts	material	Coefficient of friction (υ)	Angle of repose (α)
Wheel Shaft	Steel	0.4	21.80°
Shaft Flywheel	Steel	0.4	21.80°
Flywheel	Cast iron	0.25	14.04°
Gear Flywheel	Plastic	0.5	26.57°
Gear	Plastic	0.5	26.57°

Table 3.2: Angle of repose

The slot inclination should be higher than the angle of repose of the different parts. For the flexibility and interchangeability, the hopper inclination is selected as 45°.

3.3.2.1 Time require for part to slide to chute

The part is engaged in the slot and when the slot reaches to the delivery chute, the part is slide down from slot to the delivery chute. The velocity of the belt is kept in such a way that the part should slide down to delivery chute in time. The time required for the part to slide to chute is determined as follows.

Mass of the part(m) = $1.81*10^{-3}$kg

Inclination angle = 45°

coefficient of friction υ =0.4[23]

From the design data book[23]

$$\text{Friction Force } (F_r) = \upsilon * m * g * cos\,(\Theta)$$

$$F_r = 0.4 * 1.81 * 10^{-3} * 9.81 * cos\,(45^o)$$

$$F_r = 5.022 * 10^{-3}\, N \tag{3.2}$$

$$F_r = m * a$$

$$a = \frac{F_r}{m}$$

$$a = \frac{5.022 * 10^{-3}}{1.81 * 10^{-3}}$$

$$a = 2.77\, m/s^2 \tag{3.3}$$

Now,

$$v_f - v_i = a * t$$

here v_i= 0 and a = 2.77 $m/s^2$from 3.3,

$$v_f = 2.77 * t \tag{3.4}$$

but,

$$final\, velocity\, v_f = \frac{d}{t}$$

$$v_f = \frac{117.38 * 10^{-3}}{t} \tag{3.5}$$

From 3.4 and 3.5,

$$2.77 * t = \frac{113.14 * 10^{-3}}{t}$$

$$t^2 = \frac{113.14 * 10^{-3}}{2.77}$$

$$\mathbf{t = 0.2059\,s} \tag{3.6}$$

Thus part is feed to chute in **0.2059 s** from the slot.

3.3.2.2 Selection of Sprocket revolution

For the sprocket revolution the belt velocity is needed.

For Wheel shaft

The time(t) required to feed the part to chute is 0.2021s from 3.6 and the available distance(d) for feed the part is 50 mm.

So,

$$belt\ velocity(v) = \frac{Distance(d)}{Time\ required\ to\ feed\ the\ part\ (t)}$$

$$v = \frac{50}{0.2059}$$

$$v = 247.4022\,mm/s$$

$$v = 0.2474\,m/s \tag{3.7}$$

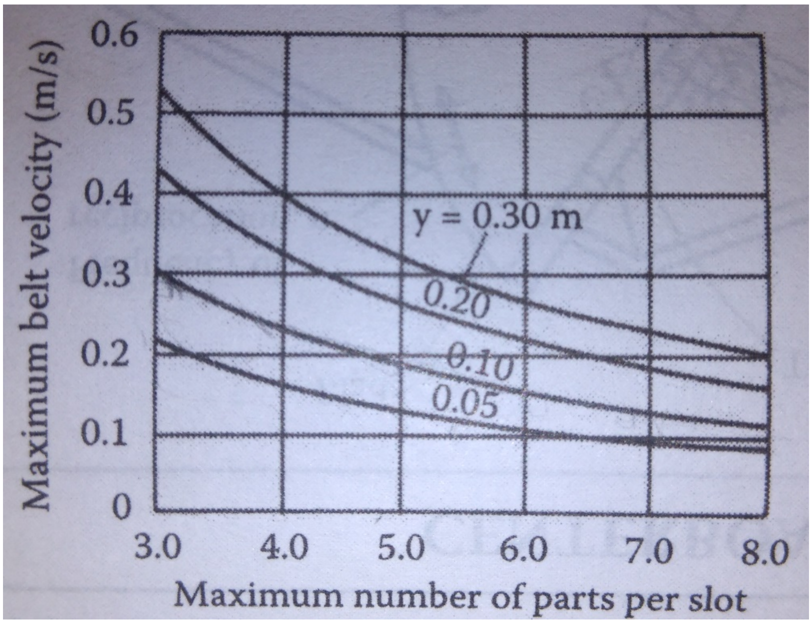

Figure 3.7: Characteristics of conveyor belt feeder[20]

From the figure 3.7 for y=0.1 and one part per slot, maximum belt velocity(v) is 0.5 m/s. For the flexibility and the interchangeability of the sub assembly parts the calculated belt velocity v = 0.2474 m/s is suitable, which is lower than 0.5 m/s.

Thus,

Sprocket Diameter (D) = 0.117 m from 3.1

Sprocket Speed (N),

$$N = \frac{60 * v}{\pi * D}$$

$$N = \frac{60 * 0.2474}{\pi * 0.117}$$

$$\mathbf{N = 40.4054\,rpm} \tag{3.8}$$

3.3.2.3 Distance between two slots (z)

The distance require for part to slide the chute s=v*t

$$s = 0.5 * 0.2021$$

$$s = 0.05\,m$$

$$s = 50\,mm \tag{3.9}$$

The distance between two slot y must be greater than the require distance for the part to slide to the chute.

$$\mathbf{z = 80\,mm} \tag{3.10}$$

Likewise, for other parts, the value of y is illustrated in table 3.4.

3.3.2.4 Hopper Design

Hopper is designed for 1000 parts to be accommodated.

For Wheel shaft

Volume of one part = 223.84mm^2

Volume of 1000 parts = 223840 mm^2

Hopper volume must be greater than the volume of 1000 parts. The capacity of hopper is 356112.17 mm^2which is greater than that of required for 1000 parts. The orthographic view of the hopper is presented in fig. 3.8.

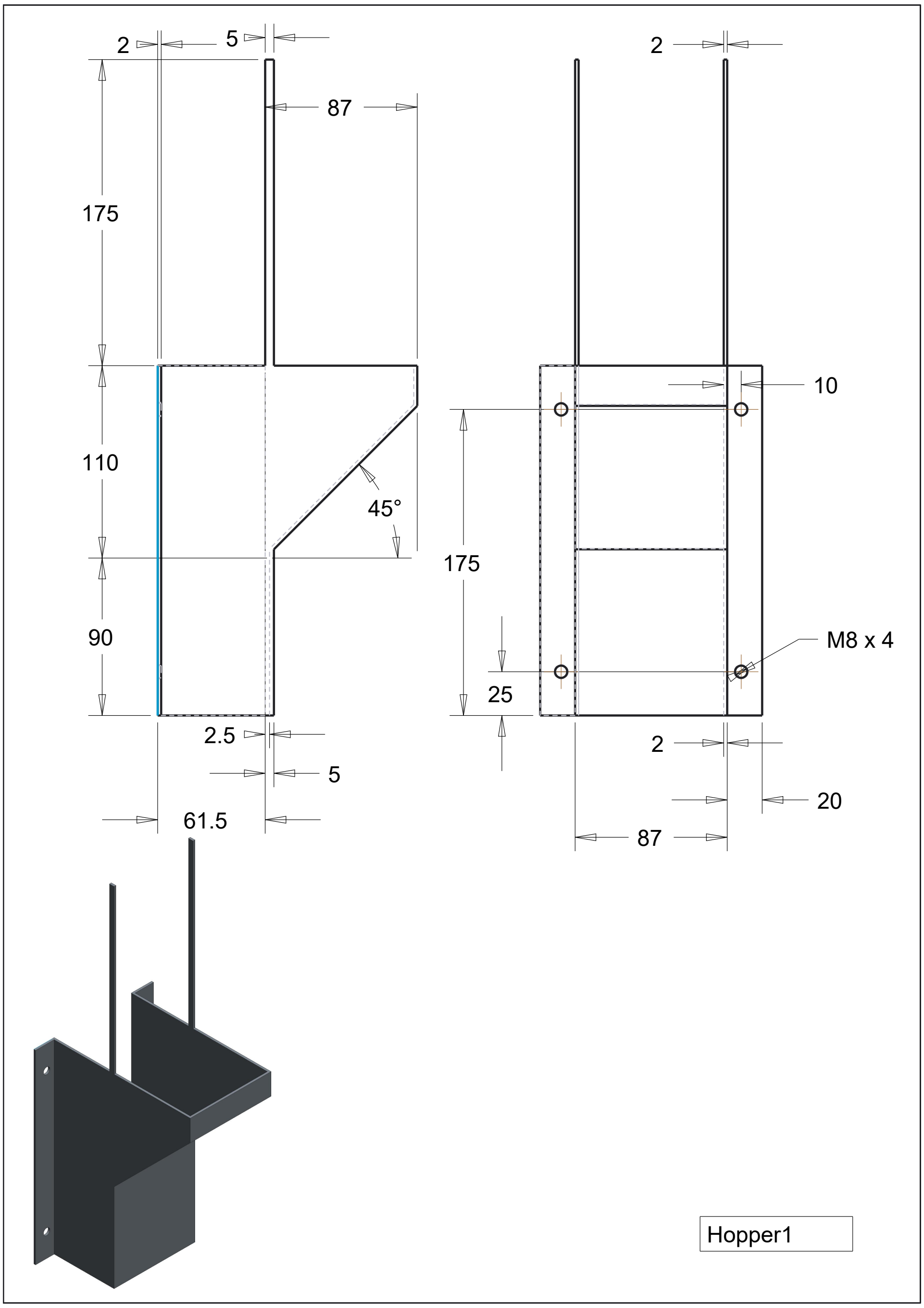

Figure 3.8: Hopper for Wheel Shaft

Likewise, for other part, Hopper is designed and orthographic view is presented as shown in fig. 3.9. The lower width of the hopper is changed based on the slot size for the different small parts which is given in the table 3.3.

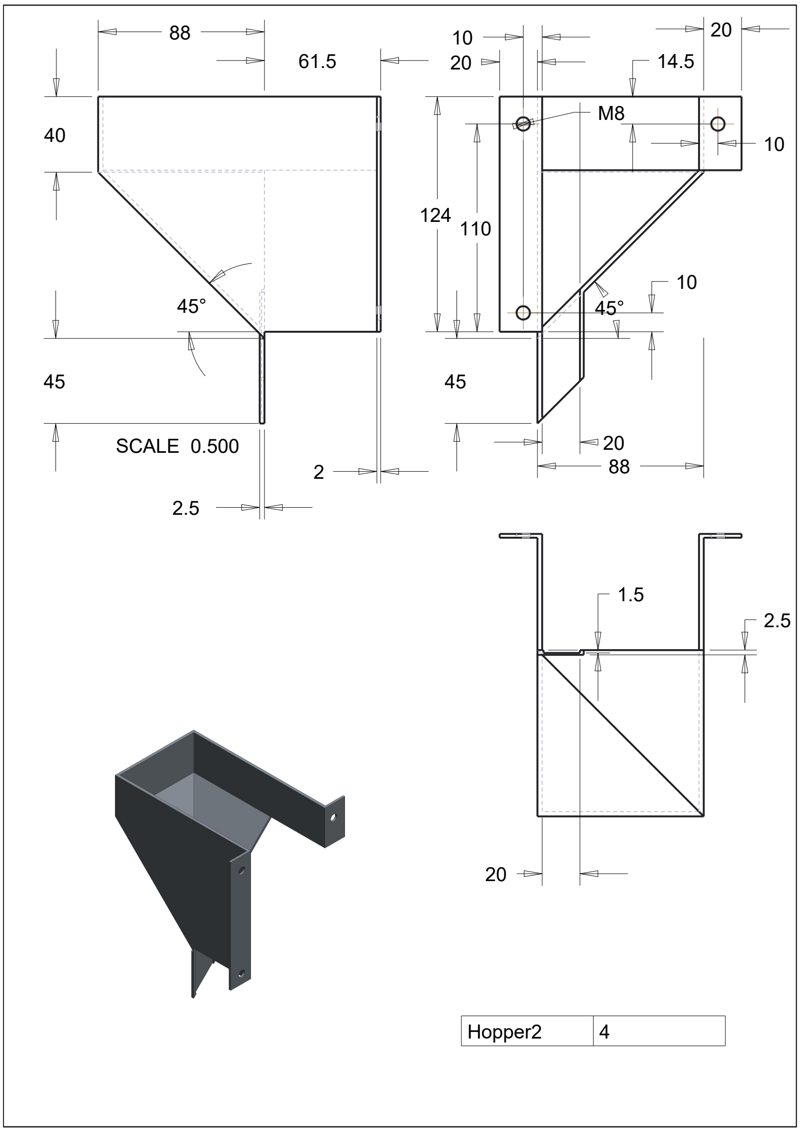

Figure 3.9: Hopper for small parts

Thus the belt layout of elevating hopper feeder as shown in fig.3.10 for the different parts are stated in table 3.4.

Parts	Volume (mm^3)	Volume for 1000 parts(mm^3)	Capacity of Hopper (mm^3)
Wheel Shaft	223.84	223840	356112
Shaft Flywheel	249.41	249410	371994
Flywheel	384.20	384200	423420
Gear Flywheel	19.63	19630	374430
Gear	235.17	235170	374430

Table 3.3: Hopper Volume

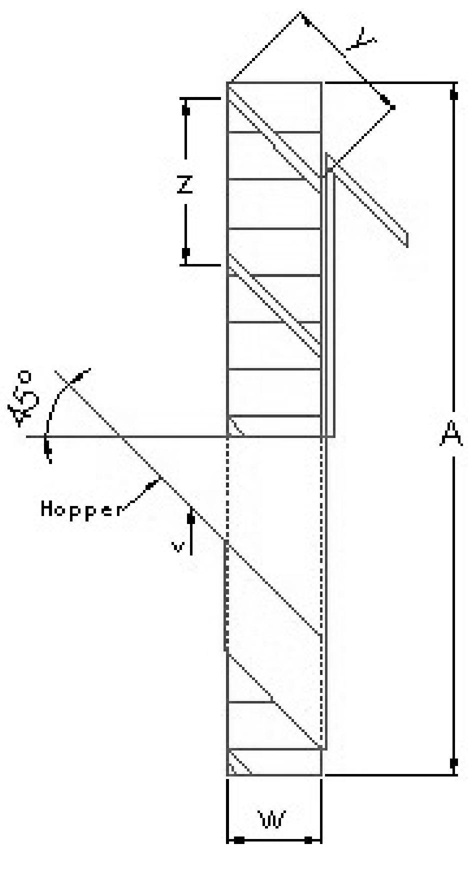

Figure 3.10: Belt Layout[20]

Parts	A(mm)	w(mm)	z(mm)	y(mm)
Wheel Shaft	500	90	100	127.27
Shaft Flywheel	300	25	50	35.35
Flywheel	300	15	50	21.21
Gear Flywheel	300	15	50	21.21
Gear	300	15	50	21.21

Table 3.4: Belt layout for parts

3.3.3 Design of Shaft

Based on Bending

T = 1 N m

l = 125mm

W = 500 N

From the Design data book[23]

τ = 60 Mpa

σ_b= 60 Mpa

Now,

$$T = \frac{\pi}{16} * \tau * d^3$$

$$d = \sqrt[3]{\left(\frac{16 * T}{\pi * \tau}\right)}$$

$$d = 4.39\, mm$$

Based on Stiffness

Polar moment of inertia, J = $\frac{\pi}{32} * d^4$

$$J = 0.0982 * d^4 \tag{3.11}$$

Now,

Bending Moment for simply supported beam

$$M = \frac{Wl}{4}$$

$$M = \frac{500 * 125}{4}$$

$$M = 15625\, N\, mm$$

The Bending Stress,

$$\sigma_b = \frac{M}{Z}$$

$$\sigma_b = \frac{15625}{0.0982 * d^4}$$

$$d = 13.84\, mm$$

Thus, 15 mm diameter of the shaft is selected to drive the sprocket through the motor.

3.3.4 Bearing for support

For low and medium radial loads, ball bearings are used. So for this mechanism we use single row deep groove ball bearing.

The radial load acting on the shaft (P) = 300 N

Shaft rotation (N) = 40.4054 from 3.8

The expected life of bearing L_{10h}= 30000 h

$$P = F_r = 300\,N$$

$$L_{10} = \frac{60 * N * L_{10h}}{10^6}$$

$$L_{10} = \frac{60 * 40.4054 * 30000}{10^6}$$

$$L_{10} = 73 \text{ million rev.}$$

Now, Load carrying capacity of bearing

$$C = P * (L_{10})^{(\frac{1}{3})}$$

$$C = 300 * 73^{(\frac{1}{3})}$$

$$C = 1254\,N$$

Now from SKF Bearing manufacturer catalog[24]

For Bore diameter = 15 mm and load carrying capacity C=1254N, suitable deep groove ball bearing is bearing **620**2.

3.3.5 Motor Selection

3.3.5.1 Torque for motor

The torque can be evaluated by the weight that is acting while the belt is operated and the perpendicular distance. From the torque the required motor is selected.

For Wheel Shaft Belt

Roller Diameter (D) = 0.117 m 3.1

mass of belt and part (m1) = 3 kg [22]

Sprocket mass (m2) = 2 kg [22]

Speed (N) = 40.4054 rpm from 3.8

Coefficient of friction(μ) = 0.4 [23]

Load Torque T_L

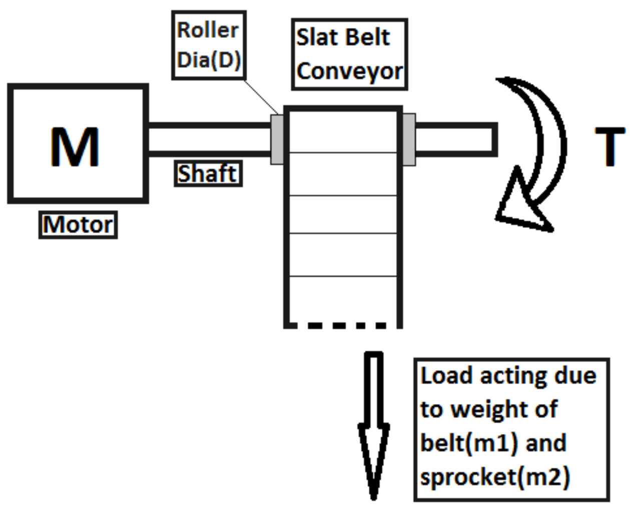

Figure 3.11: Motor Torque

$$F = m_1 g\,(sin\phi + \mu cos\phi)$$

$$F = 1 * 9.81 * \{sin(80) + 0.4 * cos(80)\}$$

$$F = 12.1230\,N$$

$$T_L = \frac{F * D}{2}$$

$$T_L = \frac{12.1230 * 0.117}{2}$$

$$\mathbf{T_L = 0.7273\,N.m}$$

$$\mathbf{T_L = 7.4172\,kg.cm} \tag{3.12}$$

Likewise for all parts required torque is stated in table 3.5.

Parts	m_1(kg)	m_2(kg)	T (kg.cm)
Wheel Shaft	1.172	2	7.4172
Shaft Flywheel	1	2	6.4869
Flywheel	1	2	6.5755
Gear Flywheel	1	2	6.4236
Gear	1.181	2	7.4741

Table 3.5: Torque require for different parts

3.3.5.2 Inertia for the motor $\mathbf{J_{Total}}$

W = Load

e = Belt efficiency

r = Radius of sprocket

Load inertia,

$$J_w = \frac{W * r^2}{g * e}$$

$$J_w = 0.0038\ lb - inch - sec^2$$

Sprocket Inertia,

$$J_{Sprocket} = \frac{\pi L \rho r^4}{g}$$

$$J_{Sprocket} = 0.0043\ lb - inch - sec^2$$

Total Inertia of motor

$$J_{Total} = J_w + J_{Sprocket}$$

$$\mathbf{J_{Total} = 0.0081\ lb - inch - sec^2}$$

Thus for inertia 0.0081 lb-inch-sec^{2}and torque 7.42 kg-cm NEMA 23 Motor is selected.The specification of the motor is given below.

Item	Specifications
Rated Voltage (V)	2.3
Current/ phase (A)	2.8
Holding Torque (kg-cm)	10.1
No. of Leads	4
Rotor Inertia	275
Weight (kg)	0.65
Length (mm)	51
Step Angle	1.8
Step Angle Accuracy	5% (full step, no load)
Shaft Length (mm)	20.6
Shaft Diameter (mm)	6.35
Length (mm)	51

Table 3.6: Motor Specification

3.3.6 Support Structure

Support structure is used to support the belt drives as well as to support the motor and control system. The support structure is capable to withstand the load of belt drive as well as the control system. The support structure is designed as shown in fig.3.12

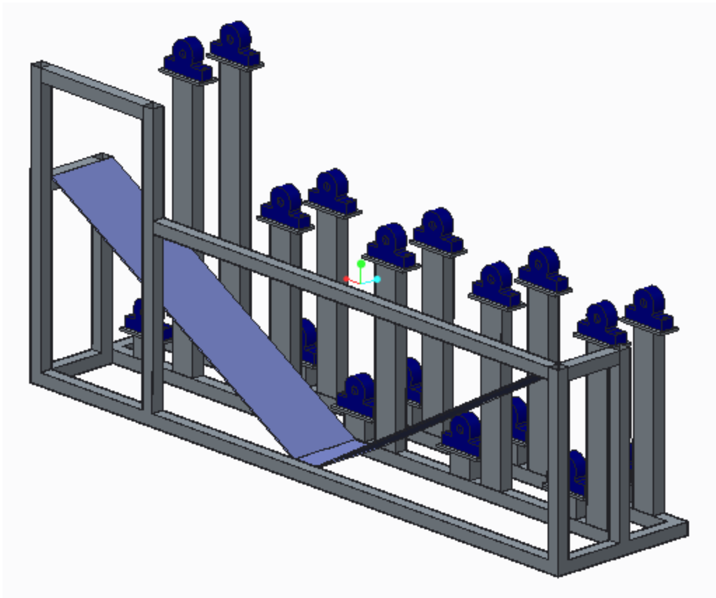

Figure 3.12: Support Structure

3.3.6.1 Analysis of support structure

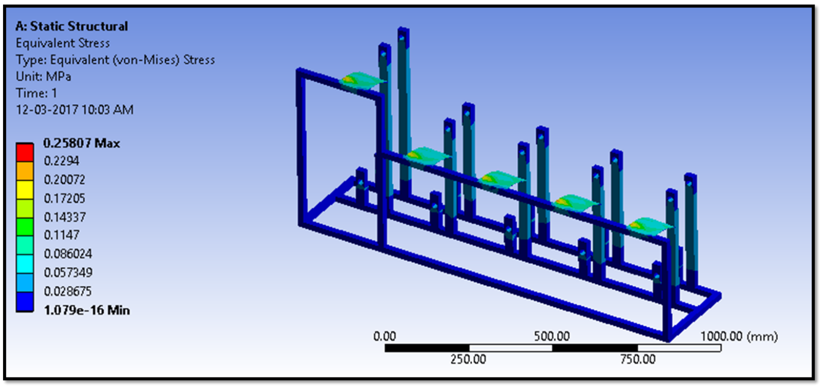

Figure 3.13: Equivalent Stress in support structure

From the analysis maximum stress is 0.2580 Mpa which is very low.So, the designed structure is safe.

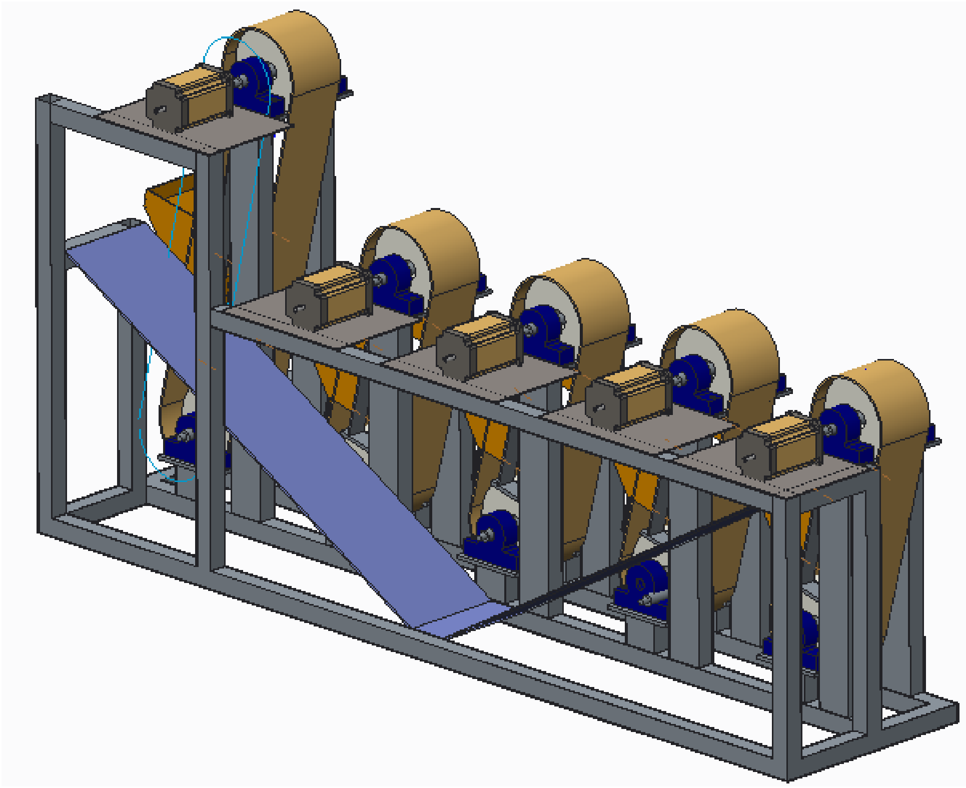

Figure 3.14: Isometric view of Assembly vending machine

Chapter 4

Control Systems for a Vending Machine

4.1 Components for Control System

For operating the vending machine precisely, we need to control the motor. Motor is controlled by the controller and sensor. Following components are used to control the system.

- Arduino mega 2560
- IR Sensor Control Systems
- Stepper Motor Driver

4.1.1 Arduino Mega 2560

The small controller board Mega 2560 is predicated on the ATmega2560. there ar fifty four digital input/output pins (of that fifteen may be used as PWM outputs), sixteen analog inputs, 4 UARTs (hardware serial ports), a sixteen rate quartz oscillator, a USB association, a power jack, AN ICSP header, and a push button. Power it with a AC-to-DC adapter or battery to induce started[26].

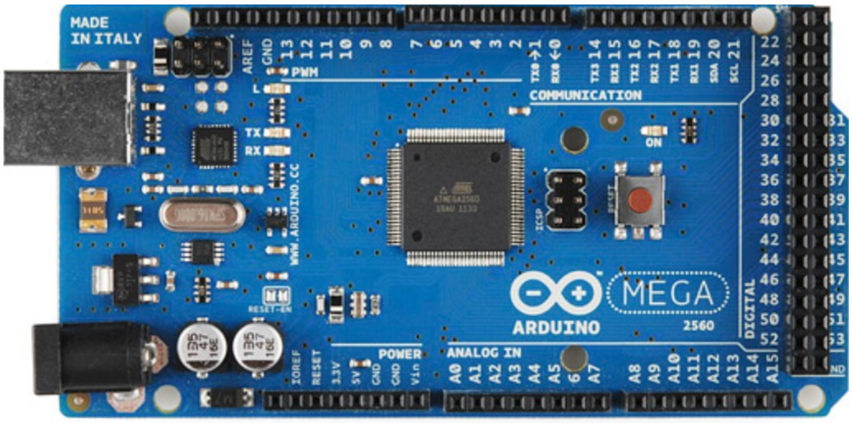

Figure 4.1: Arduino Mega 2560 Micro controller Board[25]

Technical Specifications

- **Micro controller**: ATmega1280 or 2560
- **Operating Voltage**: 5V Input Voltage(recommended): 7-12V
- **Input Voltage(limits)**: 6-20V
- **Digital I/O Pins**: 54 (of which 14 provide WPM output)
- **Analog Input Pins**: 16
- **DC Current per I/O Pin**: 40 ma
- **DC Current for 3.3V Pin:** 50 ma
- **Flash Memory**: 128KB or 256KB [26]

4.1.2 IR Sensor

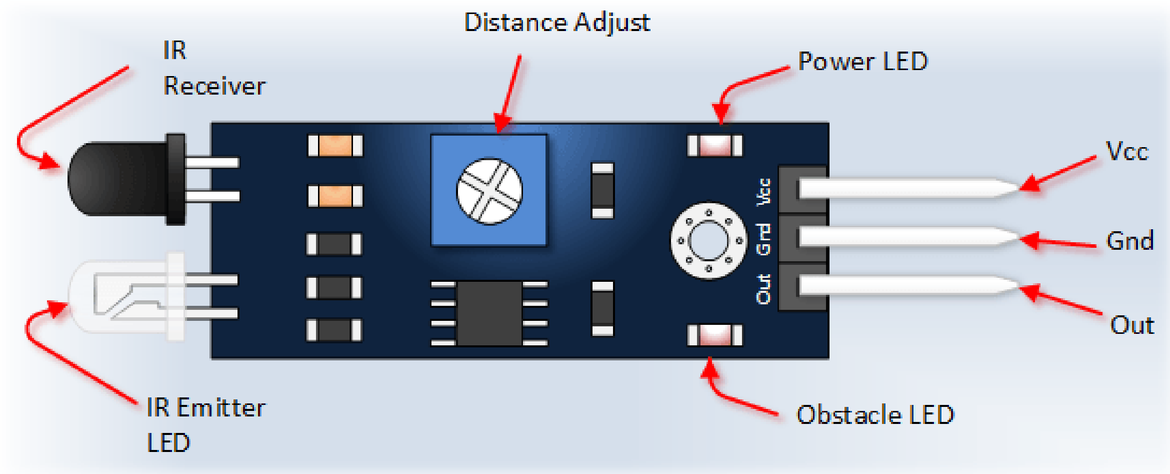

Figure 4.2: IR sensor[27]

Specifications

- **Operating Voltage**: 3.0V – 5.0V
- **Detection range**: 2cm – 30cm (Adjustable using potentiate)
- **Current Consumption**:at 3.3V : ˜23 ma,at 5.0V: ˜43 ma
- **Active output level**: Outputs Low logic level when obstacle is detected
- On board Obstacle Detection LED indicator[28]

Working Principle of IR Obstacle Sensor There are an IR LED and an IR sensor; along they're known as as Photo–Coupler or Opto–Coupler. The Infrared Obstacle detector has builtin IR transmitter and IR receiver.

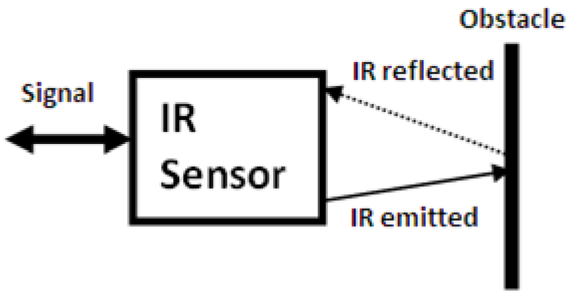

Figure 4.3: Working of IR sensor[28]

Infrared Transmitter emits infrared and it's a light-weight emitting diode (LED). Hence, they're referred to as IR LED's. An IR junction feels like a standard junction rectifier,but the radiation emitted is at the infrared bandwidth which might not be visible by human eye. Infrared receivers additionally called infrared sensors are used to sight the mirrored radiation that came from the obstacle. Infrared exposure diodes are only detects infrared.The radiation emitted by the IR transmitter that reached to the object and a few of the radiation is mirrored back to IR receiver. Depending on the intensity of mirrored radiation, the output of the device is defined[29].

4.1.3 Stepper Motor Driver

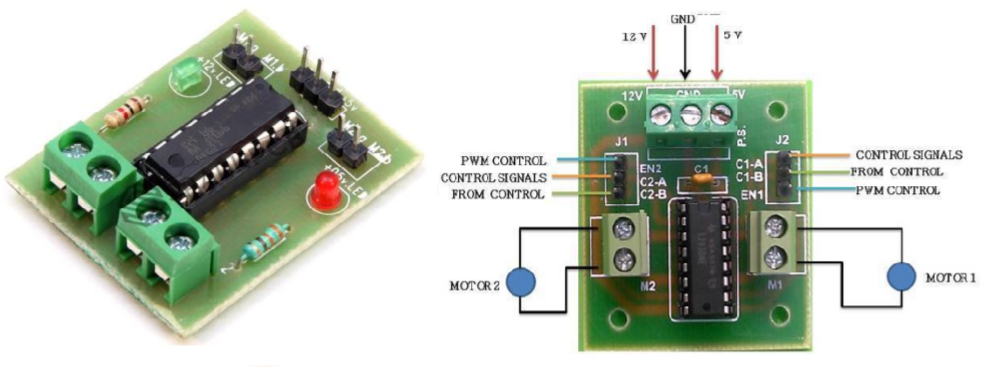

Figure 4.4: Stepper motor driver[30]

Modern stepper controllers drive the motor with voltages that is more than traditional rated voltage, and current is additionally divided. to beat this we want positioning controller, called associate degree trained worker, causing step and direction pulses to separate higher voltage drive circuit that is accountable for commutation and current limiting[31].

Specification

- **Size**: 75*50*35(mm)(LxWxH) / 2.95"x1.96"x1.37" (approx)
- **Rated maximum output**: 3A, peak 3.5A.
- **Working voltage** DC 10V-35V. Recommended to use a switching power supply DC24V power supply.
- **Current** For two-phase within 42 stepping 3A of line four wire stepper motor.
- **Subdivision**: whole step, half-step, step 1/8, 1/16 step, a maximum of 16 Subdivisions[30].

4.2 Circuit Diagram of the System

The control circuit is shown in fig.4.5

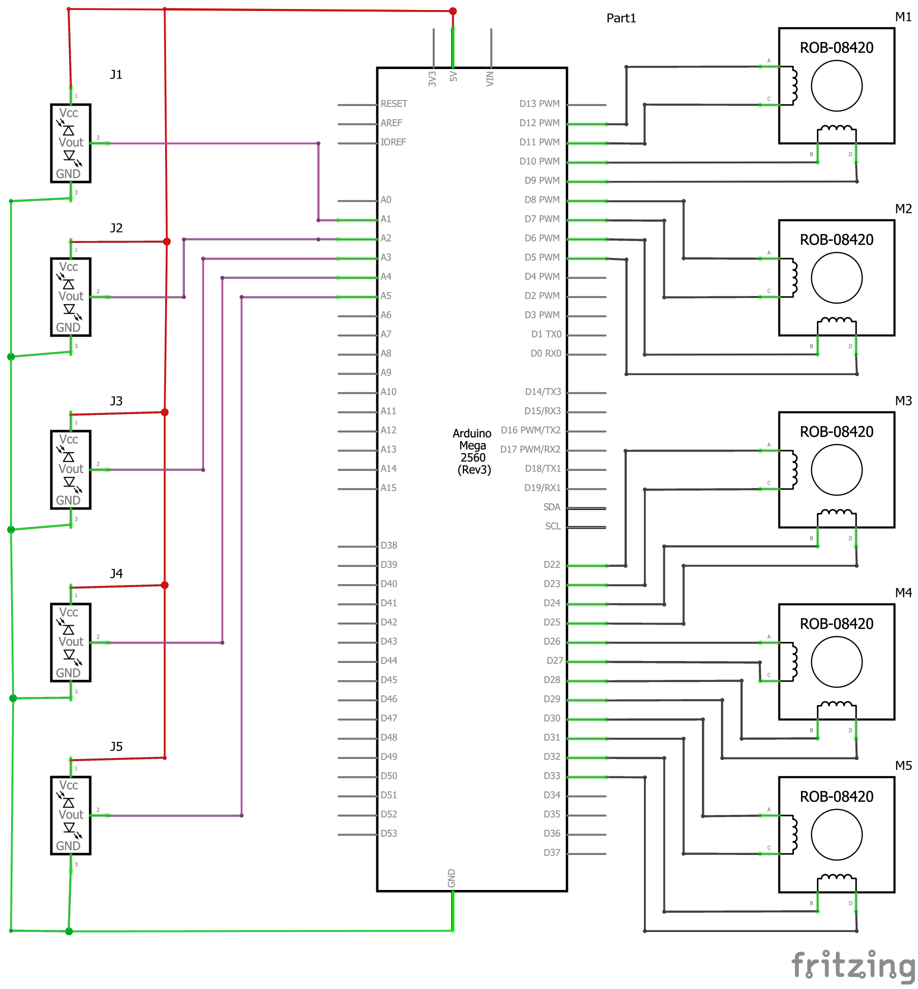

Figure 4.5: Circuit diagram of the system

4.3 Flowchart of the Control System

The flow chart for the operation of delivery of components is shown in fig.4.6. The stepper motor 1 is started and runs until the sensor1 detects the parts. After that the stepper motor2 is started and this process is continue until the last motor.

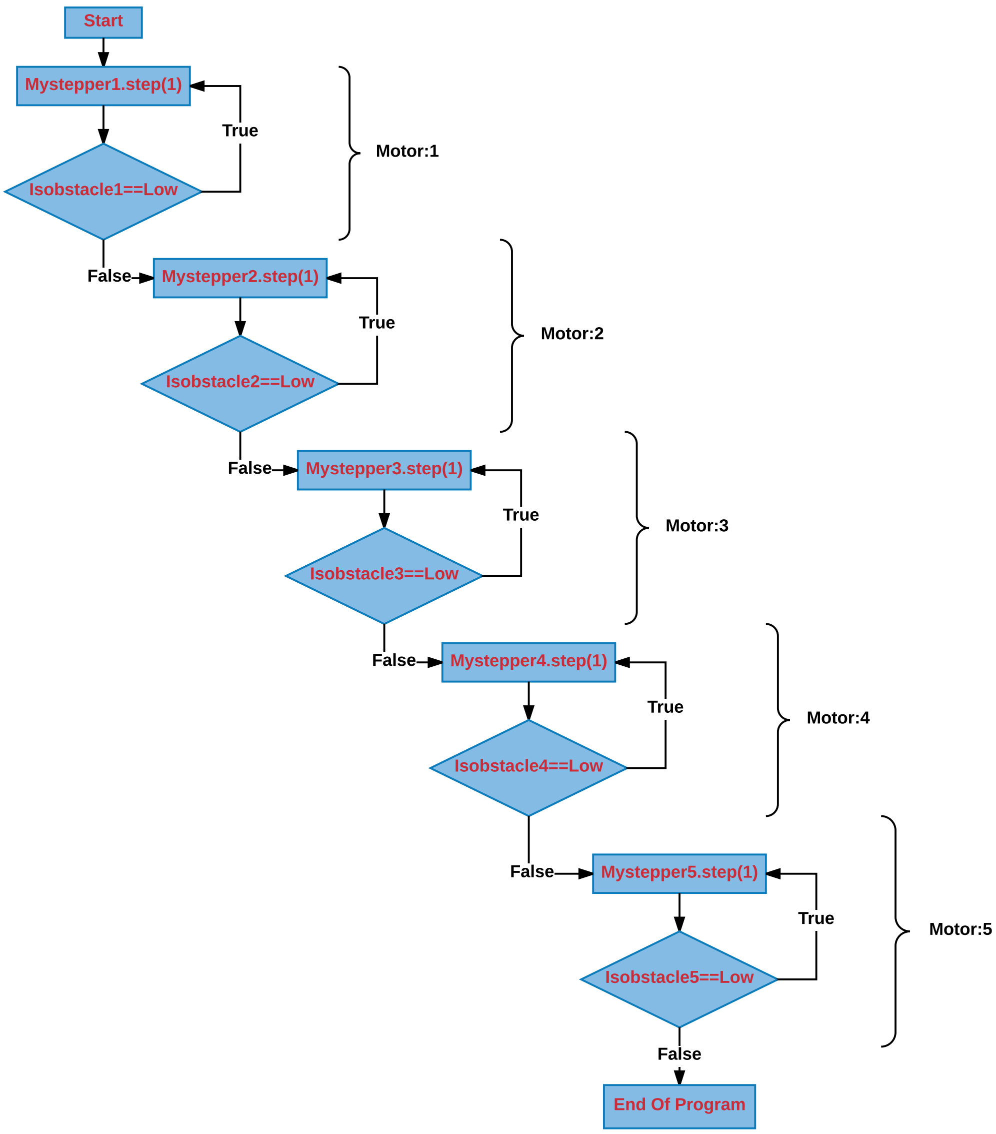

Figure 4.6: Flowchart of the system

4.4 Algorithm of the Control System

Algorithm 4.1 Algorithm of the control system

```
/* Stepper Motor Control - one revolution
This program drives a unipolar or bipolar stepper motor.
The motor 1 is attached to digital pins 1 - 4 of the Arduino. IR Sensor 1 is connected to pin 5.
The motor 2 is attached to digital pins 7-10 of the Arduino. Sensor 2 is connected to pin 11.
The motor 3 is attached to digital pins 14 - 17 of the Arduino. Sensor 3 is connected to pin 18.
The motor 4 is attached to digital pins 20 - 23 of the Arduino. Sensor 4 is connected to pin 24.
The motor 5 is attached to digital pins 26 - 29 of the Arduino. Sensor 5 is connected to pin 30.
The motor should revolve one step in one direction untill the sensor signal came,
then other motor start and this process is going on til lasr motor. */
#include ¡Stepper.h¿
const int stepsPerRevolution = 200;
// change this to fit the number of steps per revolution for your motor
int LED = 13; // led connected to digital pin 13
int isObstaclePin1 = 5; // This is our input pin
int isObstacle1 = HIGH; // HIGH MEANS NO OBSTACLE
int isObstaclePin2 = 11; // This is our input pin
int isObstacle2 = HIGH; // HIGH MEANS NO OBSTACLE
int isObstaclePin3 = 18; // This is our input pin
int isObstacle3 = HIGH; // HIGH MEANS NO OBSTACLE
int isObstaclePin4 = 24; // This is our input pin
int isObstacle4 = HIGH; // HIGH MEANS NO OBSTACLE
int isObstaclePin5 = 30; // This is our input pin
int isObstacle5 = HIGH; // HIGH MEANS NO OBSTACLE
// initialize the stepper library on pins :
Stepper myStepper1(stepsPerRevolution, 1, 2, 3, 4);
Stepper myStepper2(stepsPerRevolution, 7, 8, 9, 10);
Stepper myStepper3(stepsPerRevolution, 14,15,16,17);
Stepper myStepper4(stepsPerRevolution, 20,21,22,23);
Stepper myStepper5(stepsPerRevolution, 26,27,28,29);
int stepCount = 0; // number of steps the motor has taken
```

```
void setup()
{
pinMode(LED, OUTPUT);
pinMode(isObstaclePin1, INPUT);
pinMode(isObstaclePin2, INPUT);
pinMode(isObstaclePin3, INPUT);
pinMode(isObstaclePin4, INPUT);
pinMode(isObstaclePin5, INPUT); // initialize the serial port:
Serial.begin(9600);
}
void loop()
{
// read the sensor and store it in the variable sensor Reading:
isObstacle1 = digitalRead(isObstaclePin1);
isObstacle2 = digitalRead(isObstaclePin2);
isObstacle3 = digitalRead(isObstaclePin3);
isObstacle4 = digitalRead(isObstaclePin4);
isObstacle5 = digitalRead(isObstaclePin5);
//First motor
do
{
// step one step:
myStepper1.step(1);
Serial.println(stepCount);
stepCount++;
}
while(isObstacle1 == LOW);
//second motor
do
{
// step one step:
myStepper2.step(1);
Serial.println(stepCount);
stepCount++;
}
while(isObstacle2 == LOW);
```

```
//Third Motor
do
{
// step one step:
myStepper3.step(1);
Serial.println(stepCount);
stepCount++;
}
while(isObstacle3 == LOW);
//Fourth Motor
do
{
// step one step:
myStepper4.step(1);
Serial.println(stepCount);
stepCount++;
}
while(isObstacle4 == LOW);
```

Chapter 5

Conclusion and Future Scope

5.1 Conclusion

Following conclusion are drawn from the project work.

- A conceptual design of a vending machine for mini components and a 3-D model has been developed using CREO-Parametric.
- A prototype has been built.
- A control system has been developed using ‘Arduino’ controller.
- A program has been developed to execute the delivery of the components as per requirement.

5.2 Future Scope

- The vending machine can be enhanced using interactive console to deliver number of components as per requirement i.e. deploy as an inventory management.
- The vending machine can be further developed to dispense generic medicines.

Appendix A

Parts in Assembly

Parts	**Quantity**	**Price (Rs.)**
Slat Belt	6m	8800
Sprocket	10	8200
Arduino	1	800
IR Sensor	5	850
Stepper Motor	5	7500
Shaft	10	2000
Hopper	5	750
Bearing	20	850
Bearing Pedestal	20	3200
Coupling	5	1300
Slots	125	1400
Total		36000

Table A.1: Parts in Assembly

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