"MATERIAL FLOW SYSTEM IN ROBOTIC ASSEMBLY"

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE

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In

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BY

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C E R T I F I C A T E

This is to certify that the work in thesis entitled **"MATERIAL FLOW SYSTEM IN ROBOTIC ASSEMBLY"** submitted by **Mr. Rajat Narayan Bhuyan** in partial fulfillment of the requirements for the award of **Bachelor of Technology degree** in the department of Mechanical Engineering, National Institute of Technology, Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the work reported in this thesis is original and has not been submitted to any other University/Institute for the award of any Degree or Diploma.

He bears a good moral character to the best of my knowledge and belief.

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Date:

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ABSTRACT

The traditional design methods normally demands long throughput times, more effort and high cost. Hence implementation of new efficient design strategies along with application to robotic assembly has become highly necessary. Hence an automated system should be designed that holds much greater promise for productivity improvement and cost reduction. Vibratory Feeders are extensively used for Automatic Feeding and Orienting. It is one of the most widely used feeding devices.

This paper includes some literature collection on Automatic Assembly Transfer Systems along with the vibratory bowl feeder and its functioning. It also describes the mechanics of vibratory conveying and the design of a "vibratory bowl feeder feeding ball bearings". The paper includes the individual part analysis of the vibratory bowl feeder such as the vibratory bowl, electromagnet, control unit, leaf spring, and base along with their design. Finally the assembled figure of vibratory bowl feeder is achieved along with some analysis.

CHAPTER-1:

INTRODUCTION:

Most of the traditional design methods demand high cost, longer duration and much more effort. Hence it has become highly necessary to implement new efficient design strategies which can apply the robotic assembly. In the near part robots have been very widely used in different assembly systems which called as robotic assembly lines. Basically there used to be a central robot in the flow-shops that carries out transfers of different assembly system, better productivity, increased accuracy and lesser consumption time is achieved.

In the past decades, robots have been extensively applied in assembly systems called robotic assembly lines. Consider a robotic cell, i.e. flow-shops with a central robot that carries out the transfers of the parts between the machines.

For feeding different small engineering parts a very widely used device is "Vibratory feeder". A vibratory feeder uses the combined act of force or gravity and vibratory force. In a vibratory bowl feeder at first the parts that to be fed are dumped and with the help of gravity and vibration, the parts move along the helical path that is present in the inner wall of the bowl. An electromagnet is used to create the vibration. The electromagnet is placed on the bare of the vibratory feeder. There is also a support system to constrain the movement of the bowl. Hence the bowl gets a torsional vibration about vertical axis coupled with a linear vibration in vertical direction. As a result of vibration, the parts more along the helical path and collected at the outlet.

PROBLEM STATEMENT:

The objective is to design a proper part feeding and assembly system which should be always efficient. An efficient way of feeding parts is feeding them with a "Vibratory Bowl Feeder". Hence the problem can be stated as **"Design of a Vibratory Bowl Feeder."**

CHAPTER-2:

LITERATURE REVIEW AND THEORY:

Assembly lines are flow-oriented production systems that have high importance in the industrial production of high quantity standardized commodities. It is equally important in low volume production. Now a days robots have been extensively used in assembly systems as called robotic assembly lines. The assembly robots can work 24 hours a day without any fatigue.

The benefits of robot implementation are:-

- High productivity
- Quality of product
- Manufacturing flexibility
- Safety
- Less demand for skilled labors
- Removal of operators from hazardous operations
- The opportunity to reconsider the design of the product

It is often found that if a product is designed appropriately, manual assembly is so inexpensive that automation cannot be justified. When considering the manufacture of a product, various things are taken into account. The factors that affect the choice of assembly method for a new product, the following considerations are generally important:

1. Suitability of the product design
2. Production rate required
3. Availability of labor
4. Market life of the product

2.1 Automatic Assembly Transfer System:

According to **Boothroyd** [Assembly Automation and Product Design by **Geoffrey Boothroyd, Second Edition, 2005**] in Automatic Assembly Transfer System a machine is used to transfer the parts from one station to other. It may be classified into four groups:-

a) Continuous transfer
b) Intermittent transfer
c) Indexing mechanism
d) Operator paced Free transfer machine

2.1(a) Continuous transfer:

In Continuous transfer the workheads keep pace with the workstation. When the full operation is completed the workheads return back to the initial position and again keep pace with the work carriers.

Continuous transfer is widely used in food processing, cosmetics industries when bottles are need to be filled with required liquids.

The Continuous transfer is of two types:-

1. Rotary Continuous transfer
2. In-line Continuous transfer

2.1(b) Intermittent transfer:

In Intermittent transfer the work carriers are transferred intermittently but the workheads remain stationary. These are also termed as indexing machines.

Intermittent transfer is also classified into two types:-

1. Indexing transfer: These are further divided into rotary indexing and in line indexing.

Rotary indexing machines are those in which indexing of the table brings different work carriers under various workheads in a turn. Here the assembly is completed in a single revolution of the table. Hence in rotary indexing at an appropriate station a completely assembled product can be taken off after each indexing.

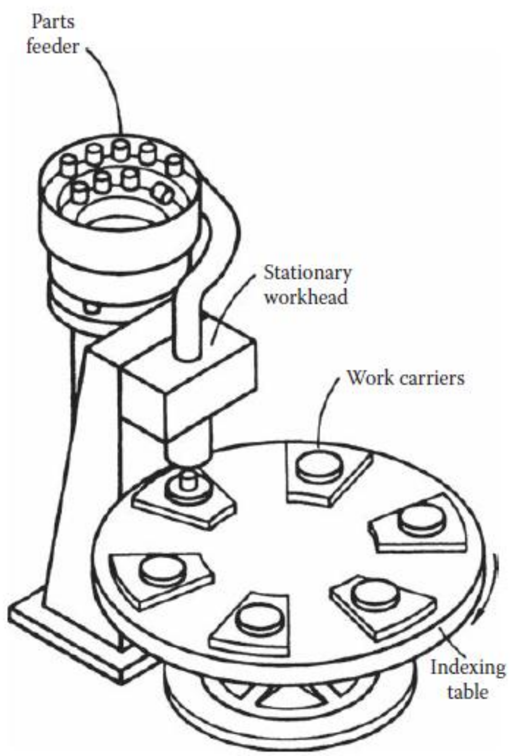

FIG-2.1(a) ROTARY INDEXING MACHINE

Free transfer or In line transfer: These are also further divided into shunting work carriers and belt driven work carriers.

In shunting work carrier transfer system the distance moved during one index is equal to length of work carriers. No assembly takes place at the beginning and end of assembly line where work carriers are positioned. A line of work carriers are pushed in a line to the work head and assemblies collected at the end of the line. The empty carriers then sent back to the initial position.

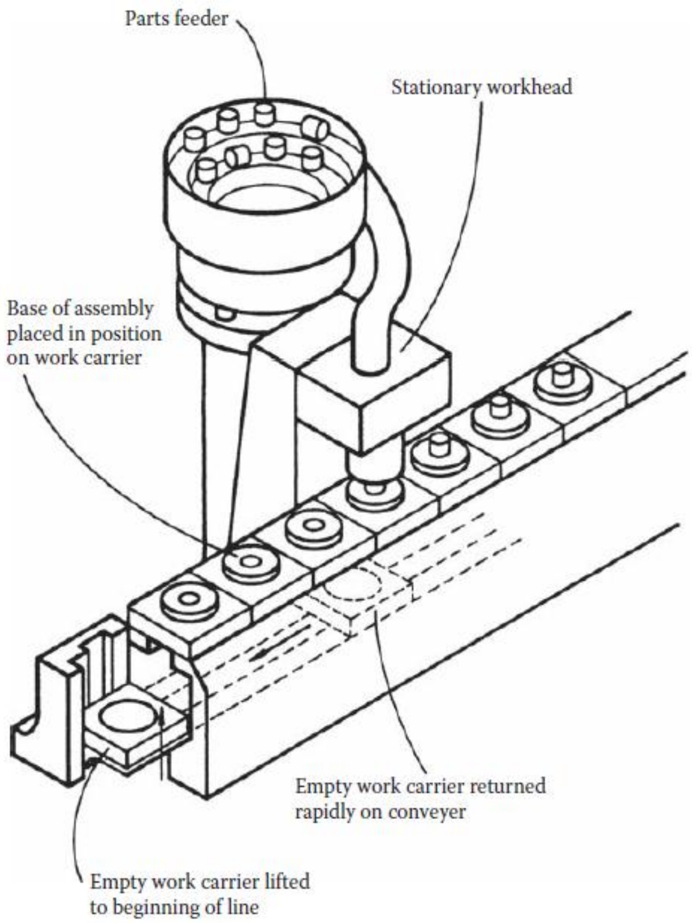

FIG-2.1(b) IN-LINE TRANSFER MACHINE WITH SHUNTING WORK CARRIERS RETURNED IN VERTICAL PLANE.

There are some disadvantages of shunting work carrier transfer, such as:-

- In this method it will be difficult to access to various workheads.
- Here if any error is there then it gets multiplied and increased. An error of 0.02mm in each station and if a total of 20 stations are there then, the error becomes 0.02*20=0.4mm.

In belt driven work carrier transfer system an indexing mechanism is used by the machine to drive the belt or flexible steel band. The work carriers are attached to it being spaced distance between workheads.

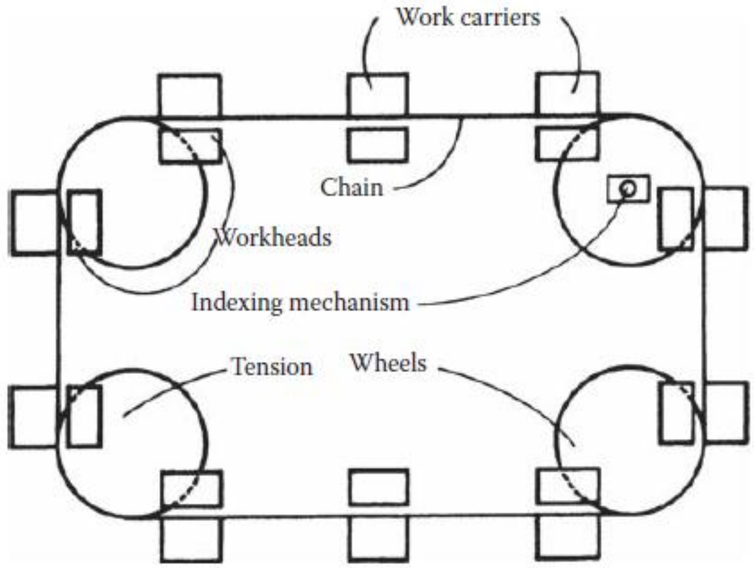

FIG-2.1(c) BELT DRIVEN TRANSFER SYSTEM

2.1(c) Indexing mechanism:

There are various parameters that decide the choice of indexing mechanism, such as:-

- ✓ The required life of the machine:
  The life of the mechanism can be increased by increasing its size.
- ✓ The required dynamic torque capacity:
  The torque supplied by the indexing unit at the index of a fully loaded machine is called dynamic torque capacity.

DTC= (Effect of inertia + Effect of friction) Life factor of the unit

There are also some other parameters that decide the choice of indexing mechanism, such as:-

- ✓ The required static torque capacity:
  The sum of torques produced during the operation of the workheads at the unit is called static torque capacity.
- ✓ The required power source to drive the mechanism.
- ✓ The required acceleration pattern.
- ✓ The required accuracy of positioning from indexing unit.

The indexing machines are of two types:

- The machine that converts intermittent translation motion to angular motion by use of rack and pinion or ratchet and pawl. These are not suitable for low speed and small indexing tables.
- The machine that is continuously driven. Ex:- Geneva Mechanism, Crossover Cam indexing unit.

  The Geneva Mechanism can transmit high torque but it has a short life. It also has a restriction on number of stops per revolution.

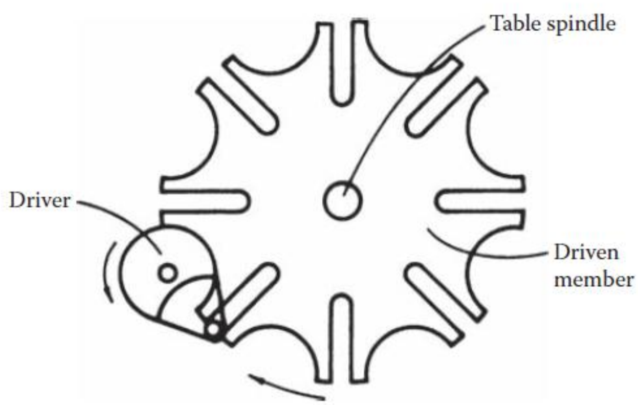

FIG-2.1(d) GENEVA MECHANISM

The Crossover cam type can also transmit high torque. It is one of the most consistent and accurate type. It always has at least two indexing pins in contact with the cam.

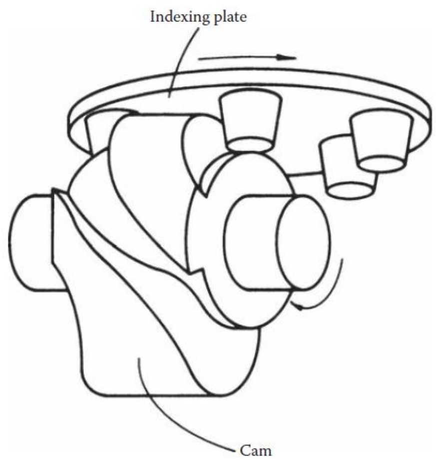

FIG-2.1(e) CROSSOVER CAM TYPE INDEXING MECHANISM

2.1(d) Operator paced free transfer machine:

It is basically referred to both machine pacing and operator pacing. An above type of machine is free transfer or nonsynchronous machine. As each workhead operates independently, a fault at any one station will not prevent the other station from working.

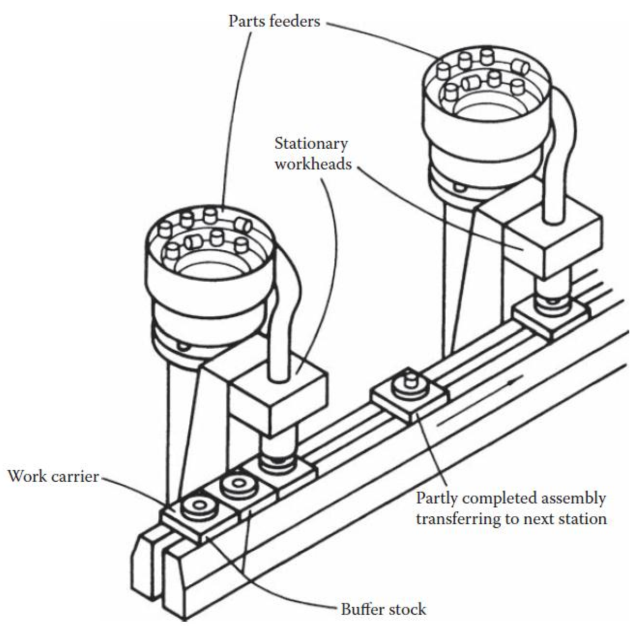

FIG-2.1(f) OPERATOR-PACED FREE-TRANSFER OR NONSYNCHRONOUS MACHINE

2.2 VIBRATORY BOWL FEEDER:

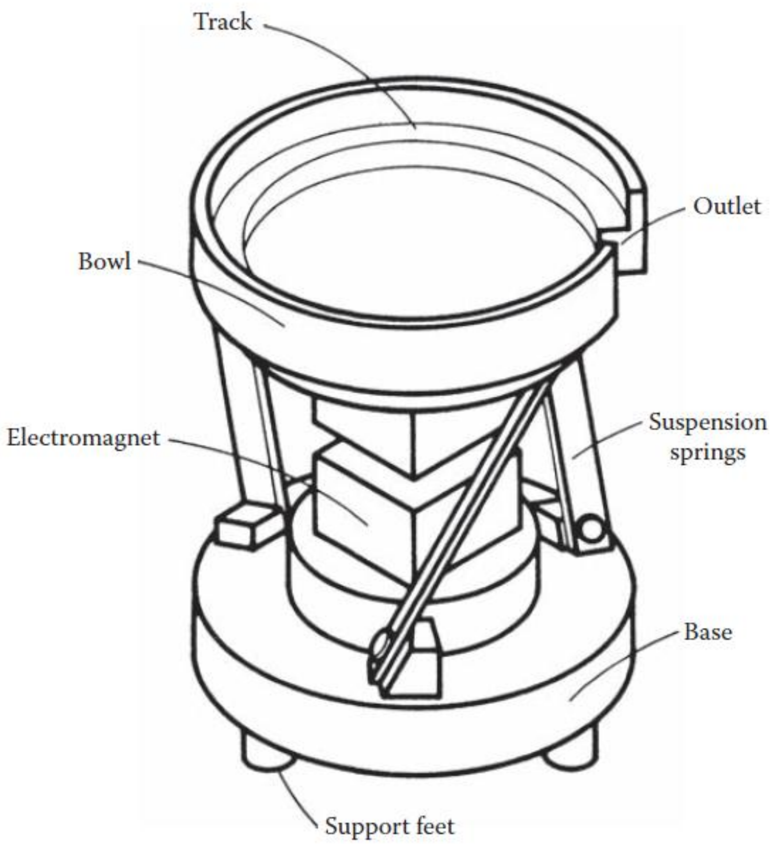

FIG-2.2(a) VIBRATORY BOWL FEEDER

A vibratory feeder is a device that feeds parts to a process or a machine with the help of vibration. Both vibration and gravity play an important role in moving the parts. The part will move upward or downward that depends upon the vibration. The part that to be moved usually a dry substance and never any liquid part. The part usually never slides down the inclined path without any assistance of vibration. A vibratory feeder is usually cone shaped where parts in uncontrolled manner dumped inside it and at the outlet a controlled delivery is achieved.

2.2(a) How the vibration takes place:-

In vibratory bowl feeder, the electromagnet present at the base generates the vibration.

When the magnet receives power from an external source, a pulsating magnetic field is established between the magnet and the armature. Hence this pulsating magnetic field leads to the vibration. There are leaf springs present in vibratory bowl feeder. Usually there are four sets of leaf springs present in a feeder. These leaf sprigs play an important role in vibration. The leaf springs help the armature to move towards the magnet and away from it. Hence the vibration into the bowl is imparted and it finally moves the parts. To make the parts to leaf off the surface of bowl the leaf springs are mounted at an angle.

The vibratory bowl feeder is very common in different industrial parts feeding. There is a helical climbing track inside the bowl. When the bowl is given circular vibratory motion and the parts are dumped into the bowl then the parts start climbing the helical track in a single file. When the parts climbs up the track they face some obstacles which re-orient the parts. They also deflect the disoriented parts to the centre of the bowl back.

2.2(b) Rotation:-

To develop maximum spring energy there should always be proper rotation. Proper rotation is also required to keep the coil assembly cool.

In the case when the drive unit is under turned, the feeder mass could not return to its neutral position and the next magnetic pulse takes over. This may be because the spring tension is not great enough as the drive unit is under turned. Hence the mass never reach to its staring on neutral position as it is not allowed to. In case of overturning in energy available becomes insufficient, the drive unit demands more energy than that is available in coil assembly. It may result in minimizing development of spring but never harm the coil.

So it is very important to maintain a good balance between the spring tension and the coil assembly energy development for efficient and smooth feed system.

The electromagnet present provides the driving force to actuate the bowl feeder. A tensional vibration is translated in vertical direction as the plates that are attached to the cross arms and constrained by the leaf springs are pulled by the coil. There is an important role of the rubber feet which are present at every corner of bare drive in turning and hence must be having proper hardness.

2.2(c) Mechanics of Vibratory Conveying:-

There is a mechanics of the movement of the parts inside the bowl of Vibratory Bowl. It can be described as:

Θ-> Angle of inclination of the track

Ψ-> Angle between the track and its line of vibration

f-> Frequency of vibration

ω-> Angular frequency of vibration = $2\pi f$ rad/sec

a_0-> Amplitude of vibration

m_p-> Mass of part

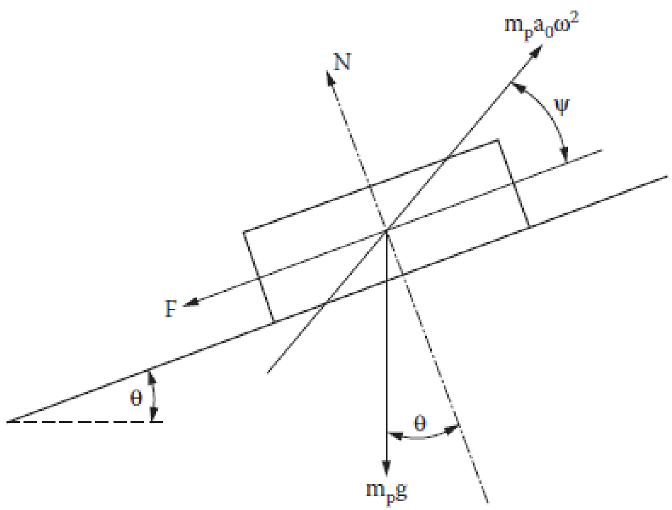

FIG-2.2(b) FORCE ACTING ON A PART IN VIBRATORY FEEDING

Let F-> Frictional resistance between part and the track

For a part to slide up:-

$$M_p a_0 \omega^2 \cos\Psi > m_p g \sin\theta + F$$

Where $F = \mu_s N = \mu_s(m_p g \cos\theta + m_p a_0 \omega^2 \sin\Psi)$

CHAPTER-3:

Part selection:

With the help of the vibratory bowl feeder the Ball Bearings are going to be fed.

Ball Bearings:-

The ball bearings are to be fed using the vibratory bowl feeder. Ball bearings are used in moving parts where it serves both as supporting radial and axial loads as well as reducing rotational friction. The material of ball bearing is selected to be AISI 440c stainless steel. Stainless steel bearings are better at anti-corrosion and heat –resistance properties.

FIG-3.1 BALL BEARING

The chemical composition of AISI 440C stainless steel bearing is given below:-

3.1 Chemical composition in %:-

Carbon (C)	: O.95- O.12 %
Silicon (Si)	: max 1%
Manganese (Mn)	: max 1%
Phosphorous (P)	: max 0.04%
Sulphur (S)	: max 0.03%
Chromium (Cr)	: 16-18%
Molybdenum (Mo)	: max 0.75%
Hardness	: 58-60 Rockwell

The dimensions of the bearing are given below:-

3.2 Boundary dimensions:

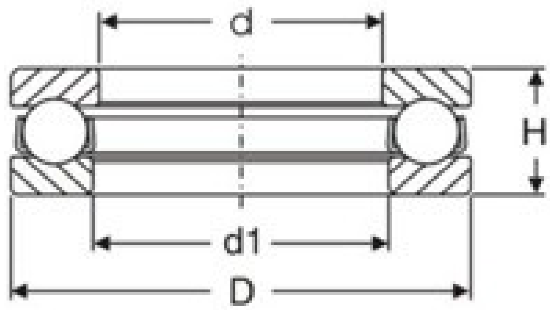

FIG-3.2 BALL BEARING DIMENSIONS

d= 20.000mm

d_1 = 21.000mm

D= 35.000mm.

H=10.000mm

3.3 Load Rating :

Static -> 20.80 KN.

Dynamic -> 12.70 KN.

3.4 Limiting Speed

Grease -> 5300 RPM

Oil -> 7000 RPM

3.5 Mass : -

m=0.040 kg.

CHAPTER-4:

DESIGN OF VIBRATORY BOWL FEEDER:

4.1 FEEDER BOWL DESIGN:-

4.1(a) BOWL MATERIAL:-

Material: - STAINLESS STEEL.

4.1(b) BOWL DIMENSIONS:-

The bowls are available in different sizes according to requirement. As per the dimension the bowls are usually manufactured with the method of casting. The commonly available bowl sizes are: 6^{ll}, 9^{ll}, 12^{ll}, 15^{ll}, 18^{ll}, 21^{ll}, 38^{ll}.

In this design as per requirement the bowl size is taken to be 12^{ll}.

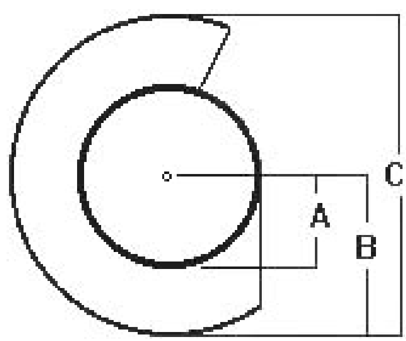

FIG-4.1 FEEDER BOWL

For bowl size 12^{ll} :-

A= 6^{ll}

B=10^{ll}

C=20^{ll}

4.2 ELECTROMAGNET:-

These are correctly engineered to give stability at high speed with minimum maintenance. Most of the drives are for Full Wave operation and hence consume 40% less energy than Half Wave operation.

The units are available in either AC or DC springing. The units that are sprung for AC operates at a line frequency of 60Hz and at7200 vibrations per minute. The units sprung for DC operates at 3600 vibrations per minute.

4.2(a) DIMENSIONS:-

It is a cube shaped structure having sides of length 30cm.

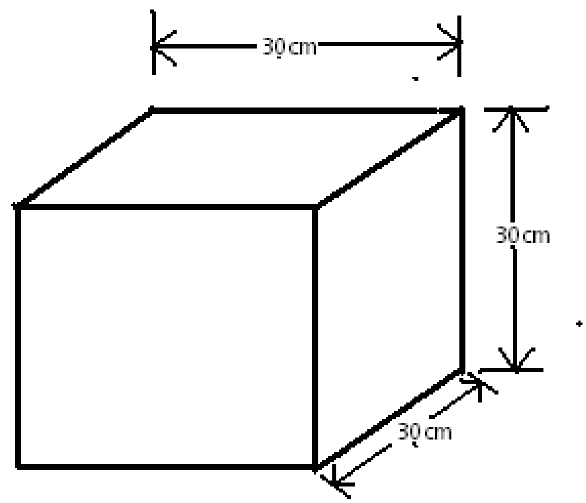

FIG-4.2 ELECTROMAGNET (DRIVER)

4.3 CONTROL UNIT:-

Every Drive Unit is supplied with separate control box so that the speed of the feeder can be controlled. Standard units are for electrical supply of 230Volts and 50Hz.

4.3(a) MODEL OF CONTROL UNIT:

Model E3FC- Ratings upto 360VA with 3Amp current rating.

4.4 LEAF SPRING:-

Leaf springs are also called as flat springs. The advantage of leaf spring over helical springs is that the end of the spring can be guided along a definite path as it deflects. Hence the spring acts as both energy absorbing device as well as structural member.

4.4(a) DIMENSIONS OF LEAF SPRING:

Load on the spring = 500N

Span length = 100cm

4.4(b) Material used:

Plain carbon steel of 0.90 to 1.00 percent carbon in annealed condition is used. After Forming process it has been gone through heat treatment.

Let, the endurance limit = 600 N/mm^2

Factor of safety = 2

Then the allowable or permissible stress = (600 N/mm^2)/2 = 300 N/mm^2

The thickness of leaves = 1.8cm

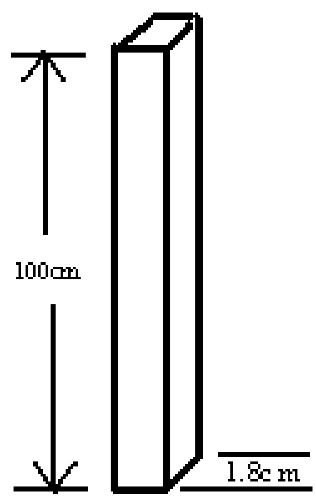

FIG-4.4(a) LEAF SPRING DIMENSIONS

4.5 BASE OF VIBRATORY BOWL FEEDER:

The Base is one of the important members in the support system. Due to its heavy mass and proper structure it provides stability to the whole system. In vibratory bowl feeder the base has three Rubber foot for better support.

The base is made up of Cast Iron and have heavy mass.

The Rubber Foot has Horizontal Stiffness (k_h) = 1800 lb/in.

The Rubber Foot has Vertical Stiffness (k_v) = 8000 lb/in.

4.5(a) DIMENSIONS:

The base is cylindrical in shape.

Radius of the base = 50cm

Height of the bowl = 20cm

Height of the rubber foot = 5cm

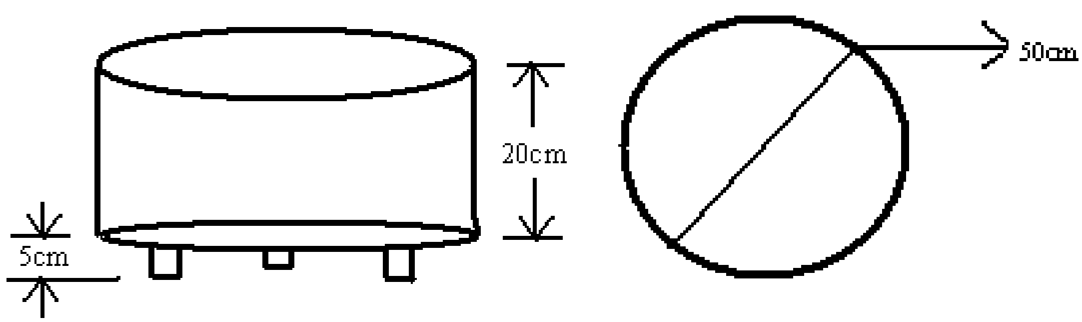

FIG-4.5(a_1) FIG-4.5(a_2)

FIG-4.5(a) BASE OF VIBRATORY BOWL FEEDER

a_1-Front view, a_2-Top view

4.6 OTHER PART DIMENSIONS:-

- Gravity track = 120 degree twist
- Linear vibratory track length = 1.5^{1}
- Friction Coefficient between Part and the Track. (μ) = 0.2
- Bulk material feeders:-

  Bulk material feeding system includes Tube, Pan or V-shaped trough in stainless steel with capacity upto 20tons per hour.

- Machine frame or base designed and fabricated as per requirement.
- Feeder system options:-

  Part sensors- counters, detectors, control.

  Bagging and packing system

  Feed rate controllers for bowls, hoppers, tracks.

  Bowl coating- Electro-polish, ESD protection, Porcelain, PVC, Teflon.

CHAPTER-5:

COMPLETE STRUCTURE OF VIBRATORY BOWL FEEDER:

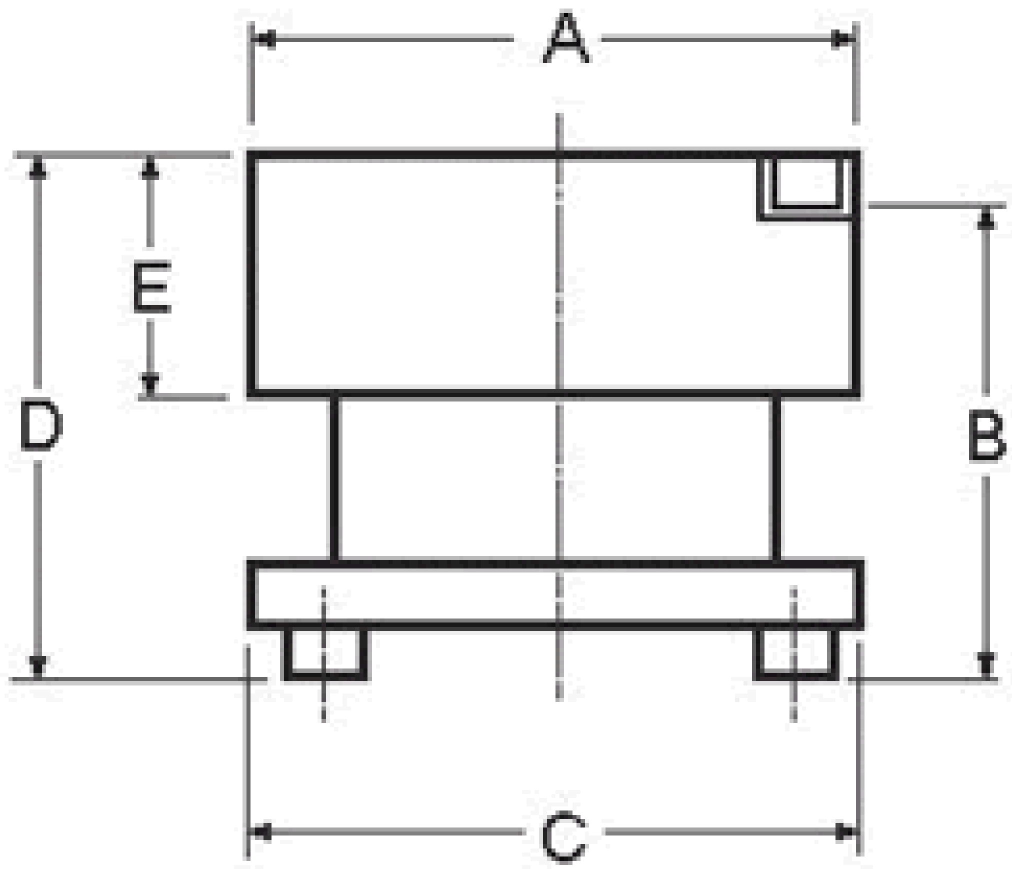

FIG-5.1 VIBRATORY BOWL FEEDER

IN THIS MODEL:

A = 50cm

B = 130cm

C = 50cm

D = 140cm

E = 30cm

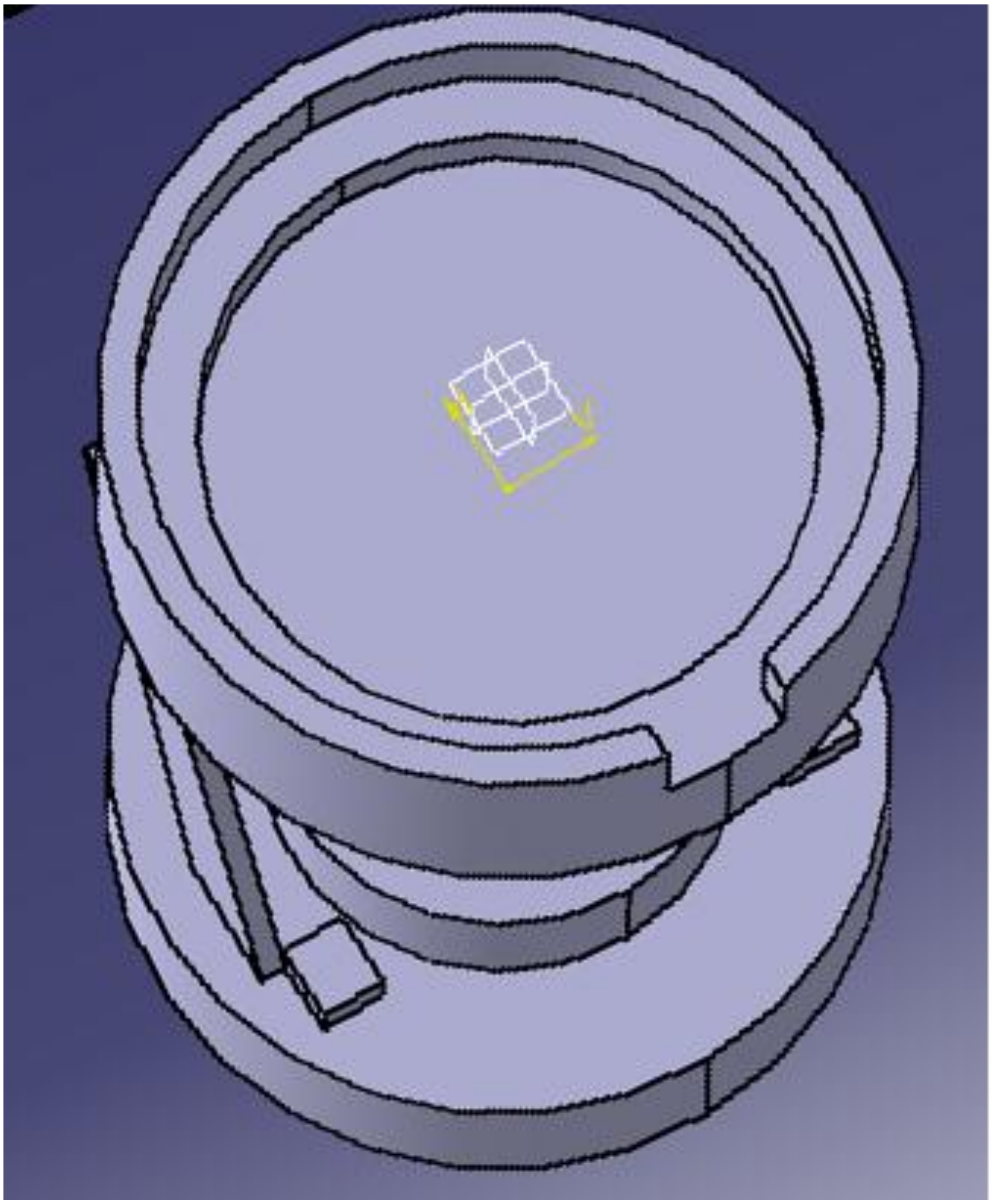

FIG-5.2 VIBRATORY BOWL FEEDER VIEW-1

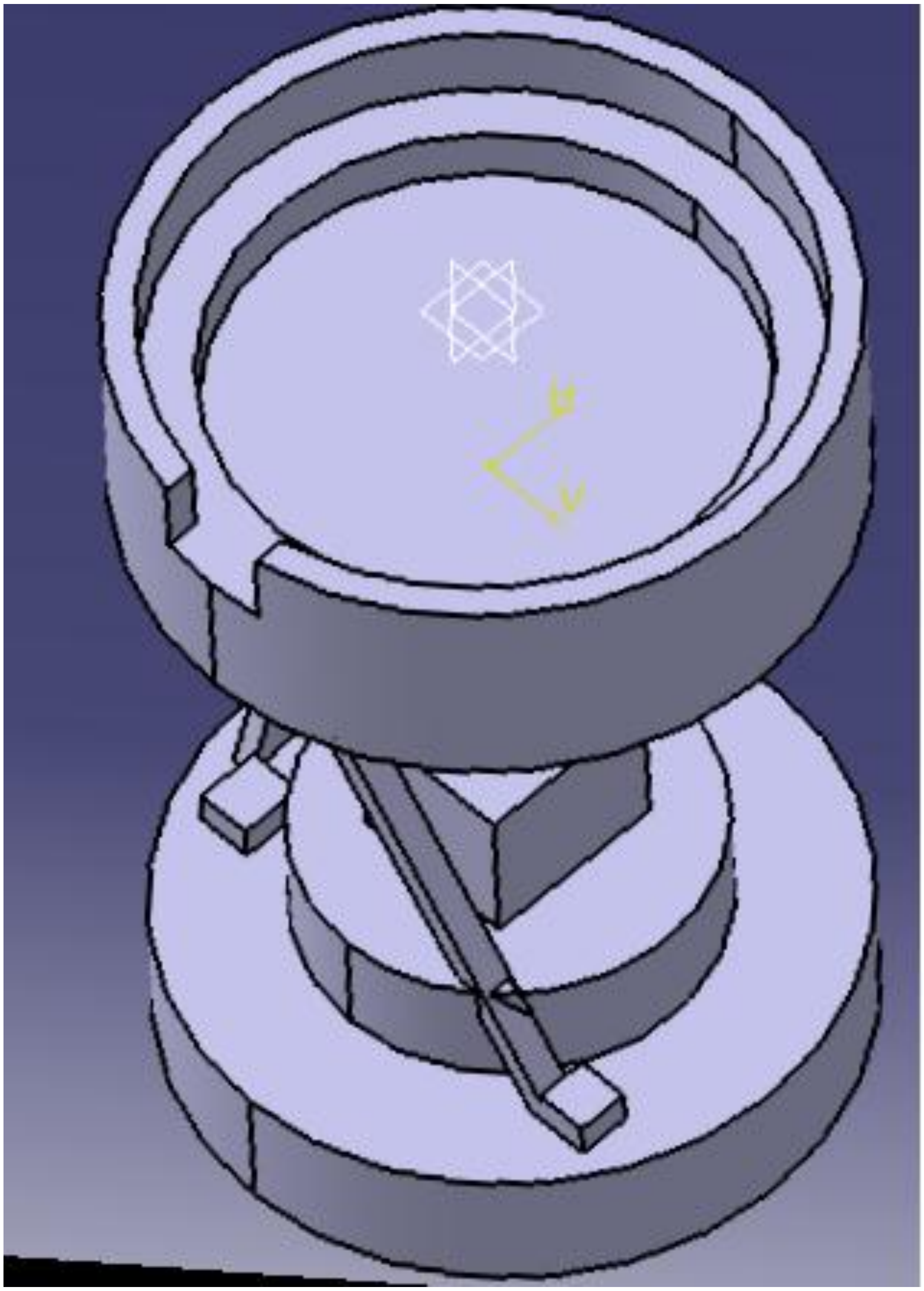

FIG-5.3 VIBRATORY BOWL FEEDER VIEW-2

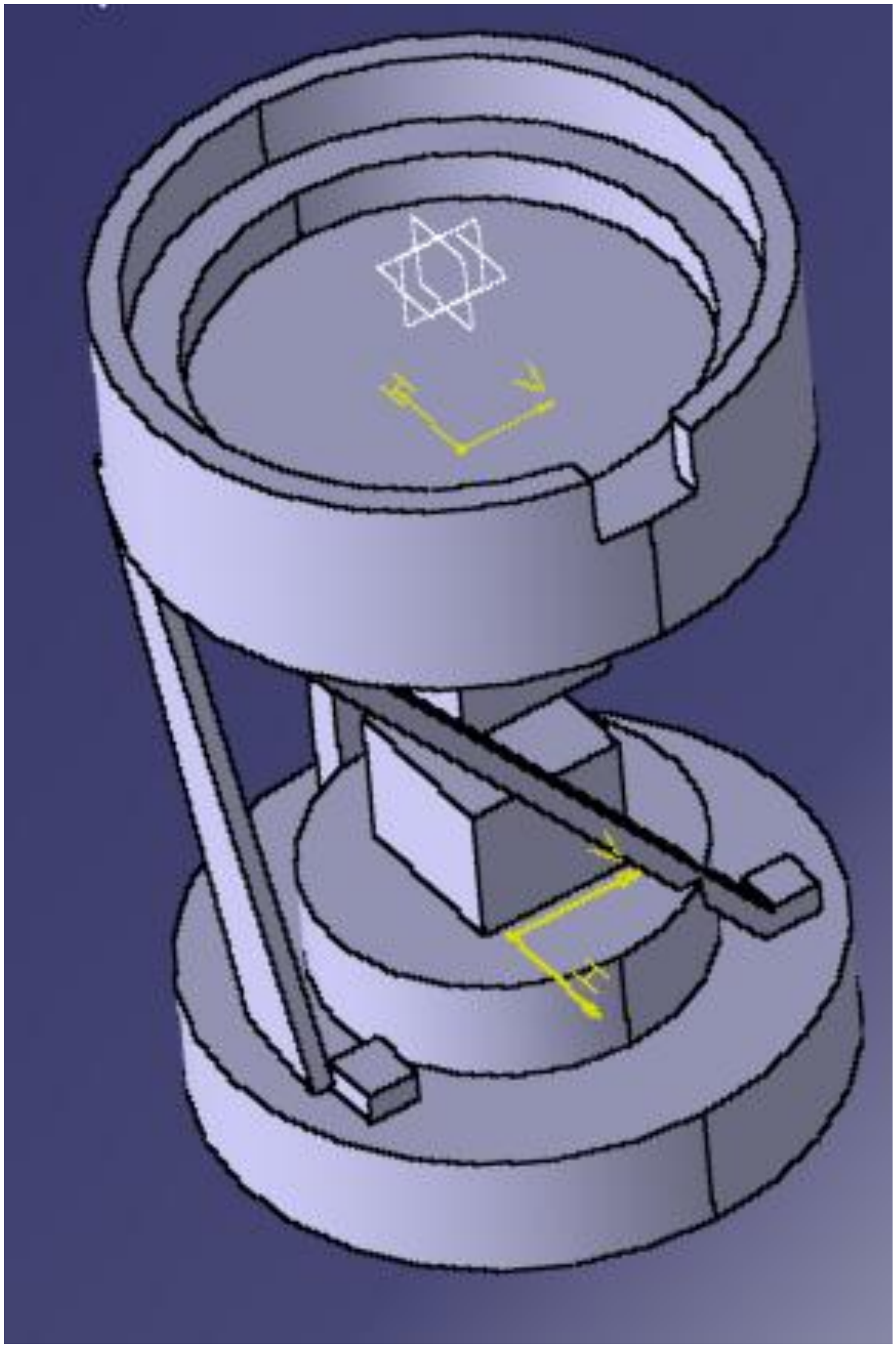

FIG-5.4 VIBRATORY BOWL FEEDER VIEW-3

CHAPTER-6:

ANALYSIS:-

5.1 DETERMINATION FEEDER SPEED:

Basically by using 60-hz power, part feeder normally vibrates at a frequency of either 3,600 or 7,200 vibration cycles per minute. The following equation is used to get a closer estimate of feeder speed,

$$Fx = F \times A \times K$$

Where;

F_X = feeder speed

F = frequency (cycle or vibration per minute)

A = amplitude (length per cycle)

K = constant (factor is 1.3)

For example if,

F = 3,600

A = 0.05in./cycle

K = 1.3

Then,

3,600cycle/min × 0.05in./cycle × 1.3

The estimated feeder speed or part travel = 234in. /min

CHAPTER-7:

CONCLUSION:-

Various methods of part flow system and part feeding system has been studied. Different methods of assembly are studied. The vibratory bowl feeder is found as an efficient instrument for part feeding and its structure and working has been overviewed. Mechanism of vibratory conveying is been understood. A proper part is being selected to be fed by the vibratory bowl feeder. Design of the vibratory bowl feeder is done. The various parts are also studied and designed separately according to the requirement. The assembled drawing has been done. The simulation modeling of vibratory bowl feeder is done using CATIA software.

CHAPTER-8:

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