

Design and Analysis of Automatic Feeding System

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Abstract

This report aims to place a part in a rotating indexing plate of a machine without any human assistance. In this report the part is a torque prevention nut. This report includes design and analysis of bowl feeder and magazine for conduction of nut up to the placing system. Two possible placing methods were identified. The first method includes use of a flexible strip fixed to a rigid support and a ram fixed to the power press. The second method consists of a pneumatic cylinder, 5X2 DCV, micro-controller (Arduino board), hosing and associated equipment.

Keywords: *Bowl feeder, Placing systems, Flexible strip, Pneumatic cylinder*

INTRODUCTION

In the industry, various machines across all operations use a rotating plate for part feeding. In many cases this is done with human assistance. Thus a project was carried out in RTF Ltd. Nashik to design and analyse a system to replace manual work with an automation system. The project is being carried out at Right Tight Fasteners Ltd., Satpur MIDC, Nashik. Right Tight Fasteners India Pvt Ltd (RTF) was founded and incorporated in 1979The

company produces special types of fasteners. The products of the company are all metal prevailing torque type nuts, axle tube nuts, slotted nuts, flange nuts, nylon insert nuts, washer assembly nuts, wheel nuts, special bolts and screws, studs and weld nuts. The company manufactures a wide array of precision cold forged high tensile fasteners & components of various grades of carbon alloys for automobile, engineering, electrical, electronic and construction industries. The project would

not be successful without the valuable input of Prof. Sonali Mate (Professor at K.K. Wagh Institute Of Engineering Education And Research) and Mr. Amol Gaikwad (Industrial guide at RTF Ltd.).

The machine under consideration was a power press with a rotating indexing plate. The indexing plate has 25 slots in which bushes are placed. The nuts are placed in the bush slots by manual labor. The manual labor is to be reduced to introduce automation and increase productivity. 35 nuts are to be crimped in 60 seconds. The objective of the project is to automate the feeding process by decreasing manual labor, increase production rate, to reduce production cost and increase profitability and to increase reliability of system.

A. Objective

- i.** To automate the feeding process by decreasing manual labor.
- ii.** Increase in production rate.
- iii.** To reduce production cost and increase profitability.
- iv.** To increase reliability of system.

B. Methodology

This paper aims to provide solution to the given problem statement by following steps:

- i.** Study of feeding systems
- ii.** Selection of most feasible mechanism
- iii.** Surveying and selecting components
- iv.** Designing of feeding system
- v.** Analysis of components
- vi.** Cost and productivity estimation

LITERATURE REVIEW

B. K. A. Ngoiet al. [7] in his paper seeks to verify that the existing hypotheses, which predict the natural resting aspects of small engineering parts on soft and hard surfaces, are able to predict the orientation of parts on the track of a vibratory bowl at different vibrating amplitude levels.

Most of the existing hypotheses developed were verified using the "drop test" method in which parts were repeatedly dropped from a certain height onto a surface in order to analyse the natural resting behaviour of parts.

Y. Yokoyama et al. [8] in his paper treats a method of calculating natural frequency of vibratory feeders. In a bowl-type feeder, the deformation of the spring is complicated and the exact calculation of

its constant is difficult. Therefore an approximate calculation is presented under some assumptions. The equations of natural frequency for the fixed type and the semi-floating type feeder are represented briefly.

B. S. Mashalkaret al. [9] presented the information about the design, development and manufacture of range of automated orientation tools which, in combination, make up a typical orientation system for the VBF. They developed four prototype tools: the wiper blade, the needle, the sprocket, the edge riser tool. These tools were focused for the purpose of the project on the feeding of a specific target component. The target components for which they are designing and orienting VBF are Square Metal Washer and Square Plastic Washer.

Jian S Dai et al. [10] in their paper investigated the vibratory bowl feeder for automatic assembly, present a geometric model of the feeder, and developed force analysis, leading to dynamical modelling of the vibratory feeder. Based on the leaf-spring modelling of the three legs of the symmetrically arranged bowl of the feeder, and equating the vibratory feeder to a three legged parallel mechanism, the paper

reveals the geometric property of the feeder.

Dahiru SaniShu'aibuet al. [16] presented details of the design and development of an electromagnet for use in magnetic levitation control. The methods used in paper were pure numerical methods. Cast steel was used as the material in their design procedure, because of its high permeability. The basis of the design calculation is based on the lifting force required to be produced by the magnet. In the final analysis, the electromagnet was designed and built. The electromagnet suspends different weights at different distances below the pole by taking a current. The force constant of the magnet was determined.

THEORY

Main components

- A.** A.Vibratory Bowl Feeder (VBF) and magazine
- B.** Placing mechanism
 - i.** Flexible Strip Method.
 - ii.** Micro-controlled Pneumatic actuator

A. Vibratory bowl feeder and magazine

Vibratory bowl feeder is the most commonly used machine in industries to feed parts. The bowl feeder has a bowl

mounted on an assembly of striking plate and electromagnet. There is a helical track lined to the inside of the bowl, the parts climb up this track with the help of circular vibratory motion. There are a certain mechanical obstacles present on the helical track that help orient or eliminate the parts that are not oriented. These obstacles are called as tools. The track length, width, and depth are carefully chosen to suit the component shape and size.

In a VBF as a part moves up the inclined track in a bowl there are a lot of different forces that act upon the part and make the movement of part possible. As the striking plate vibrates it transfers its vibration to the bowl and track. This vibration is the main cause of the parts being conveyed. The conveying of the parts is a result of phase difference between the parallel and normal components of track vibration, which are produced by the forced vibration of the electromagnet. Magazine should also be designs separately to conduct the parts to the plate.

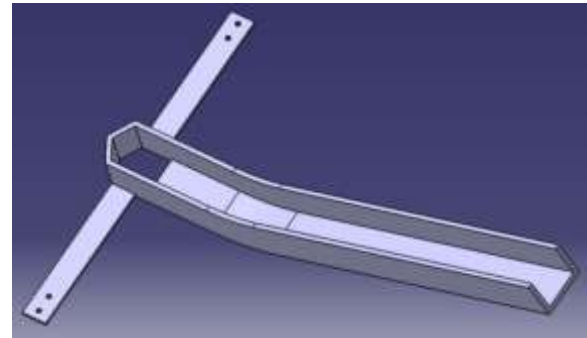


Fig 3.1 Magazine

B. Placing mechanism

i) Flexible Strip Method

a) Components

- Vibratory bowl feeder
- Magazine (containing a hexagonal slot)
- Flexible strip
- Ram
- Indexing plate

b) Working

At present the nuts are being fed manually by a worker into the power press. In order to automate the machine we have designed a system using vibratory bowl feeder and a magazine and push-ram. The nuts would be poured into the bowl of the vibratory bowl feeder. In the bowl feeder, the nuts would start to climb the helical track of the feeder and nuts that are not oriented properly would be rejected by the tooling present in the helical track. These rejected components would fall back into the bowl and start to move up again. The rightly oriented parts that move out of the bowl

feeder will enter the magazine and keep moving forward by the inclined slope of magazine and the push from the following nut. The nut to reach the tip of the magazine will be held by two spring steel strips and stop it from tilting into the indexing plate slot. The tip of the magazine will be properly aligned above the hexagonal slots of the indexing plate. The push-ram which will be fixed to the punch will push the nut perfectly into the slot without tilting it. As the punch is crimping the nut in the operation, the ram will push the nut from the magazine into the indexing plate ready for punching. In this way the operator will only have to fill the vibratory bowl feeder once it gets below the marked level. This can save a lot of time for the operator which can be used in other required places.

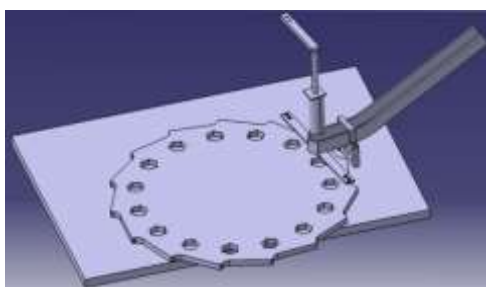


Fig 3.2 Flexible strip construction

ii) Microcontroller Operated Pneumatic Actuator

a) Components

- Pneumatic cylinder (double acting)
- Pipes and fittings,

- 5X2 DCV with coil
- Pressurised air (from company, 6 bar)
- Microcontroller (Arduino board)
- Relay
- Filter
- Regulator
- Lubricator
- Bread board
- 5V DC adaptor
- Support

b) Working

- The nut already in the hexagonal slot will support the nut from the magazine.
- The pneumatic cylinder will then exert force on the corner of the top nut during its forward stroke this force will be conducted to the nut at the bottom
- The force on the bottom nut will prevent its turning in hexagonal slot of the indexing plate.
- The pneumatic cylinder will then retract 0.5s before the nut is about to be aligned with the hexagonal slot of the indexing plate. The retraction of the cylinder takes 0.001 s.

- The bottom nut will then get placed and the nut from the magazine will enter the hexagonal slot of the magazine and the process is repeated.

IV. DESIGN AND ANALYSIS

A. Flexible Strip

i) Material

As per its application discussed before, the material should be elastic and flexible. Thus by considering availability constraint, spring steel with SAE grade 50CrV4 is selected.

ii) Design

During punching operation it will serve as a cantilever beam subjected to point load at the end.

Given: Yield strength, $S_{yt}=1200\text{Mpa}$

Modulus of elasticity, $E=200\text{GPa}$

iii) Assumptions

1. Length of hanging portion, $l = 90\text{mm}$.
2. It has rectangular with width $(b) = 12\text{mm}$ and depth $(d) = 1\text{mm}$.
3. Factor of safety $N_f = 1.2$.
4. Length of the strip on which nut will be placed $= 3.5\text{mm}$

iv) Calculations:

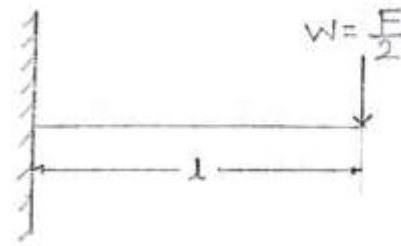


Fig 4.1 FBD of cantilever beam

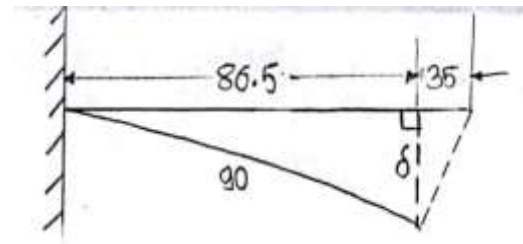


Fig 4.2 Deflection of flexible strip

$$\begin{aligned}\sigma_{all} &= (S_{yt}/N_f) \\ &= (1200/1.2) \\ &= 1000\text{MPa} \\ \delta &= \sqrt{(90^2 - 86.5^2)} \\ &= 24.85 \\ &\approx 25\text{mm} \\ I &= (b*d^3)/12 \\ &= (12*1^3)/12 \\ &= 1\text{mm}^4\end{aligned}$$

For proper functioning of strip, it should satisfy two equations,

- Equation of maximum deflection
- Equation of maximum bending stress

Equation of maximum deflection [19]

$$\begin{aligned}\delta &= (W*L^3)/(3*E*I) \\ W &= (3* \delta*E*I)/L^3\end{aligned}$$

(See Figure: 4.3, 4.4)

It should withstand axial force subjected during punching [19],



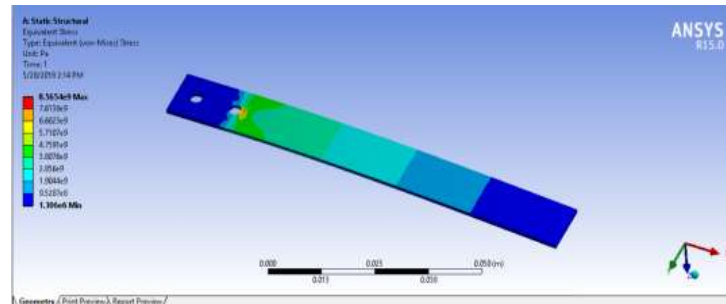


Fig 4.4 Equivalent stress on flexible strip

$$\sigma_{cal} = (4 * F) / (\pi(D^2 - d^2))$$

To conform shape of punch as that of nut

$$D = 24 \text{ mm}$$

$$D = 20 \text{ mm}$$

$$\sigma_{cal} = (4 * 200) / (\pi(24^2 - 20^2))$$

$$= 1.45 \text{ MPa}$$

$$\sigma_{cal} < \sigma_{all}$$

∴ Design is safe

b) Middle Plate

Material: Plain carbon steel

$$S_{yt} = 400 \text{ MPa}$$

It will be subjected to bending stress [19]

$$\therefore (\sigma_b/y) = (M/I)$$

$$\frac{S_{yt}}{N_f} = \frac{3 * F * (\frac{D+d}{2})}{bd^2}$$

$$d^2 = \frac{3 * f * (D + d) * N_f}{2 * b * S_{yt}}$$

Let,

$$N_f = 2, b = 26 \text{ mm}$$

And since,

$$F = 200 \text{ N}$$

$$D = 24 \text{ mm}$$

$$d = 16 \text{ mm}$$

$$d^2 = \frac{3 * 200 * (24 + 16) * 2}{2 * 26 * 400}$$

$$d = 1.52$$

$$d \approx 2 \text{ mm}$$

c) Intermediate Rod

Material: Plain carbon steel

$$S_{yt} = 200 \text{ MPa}$$

$$\sigma = \frac{F}{A}$$

$$= \frac{200}{\frac{\pi}{4} * d^2}$$

$$d^2 = \frac{4 * 200}{\pi * 50}$$

$$\therefore d = 2.25 \text{ mm}$$

For safe design $d = 10 \text{ mm}$ [19].

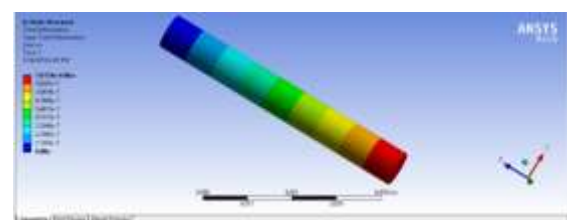


Fig 4.5 Total deformation of intermediate rod

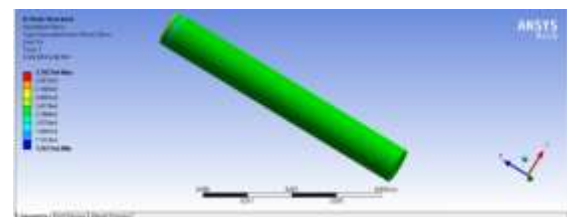


Fig 4.6 Equivalent stress on intermediate rod

d) Horizontal plate

Material: Plain carbon steel

$$S_{yt} = 400 \text{ MPa}$$

$$\sigma_{all} = 200 \text{ MPa}$$

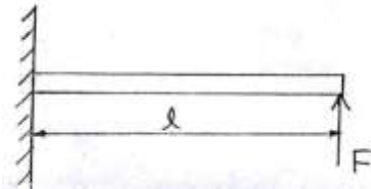


Fig 4.7 FBD of horizontal plate

∴ it will be subjected to bending stress
[19]

$$\therefore \frac{\sigma_b}{y} = \frac{M}{I}$$

$$\therefore \frac{\sigma_b}{\frac{d}{2}} = \frac{F \cdot l}{\frac{b \cdot d^3}{12}}$$

$$200 = \frac{6 \cdot 200 \cdot 90}{12 \cdot d^2}$$

$$\therefore d = 6.71 \text{ mm}$$

$$\text{i.e. } d \approx 7 \text{ mm}$$

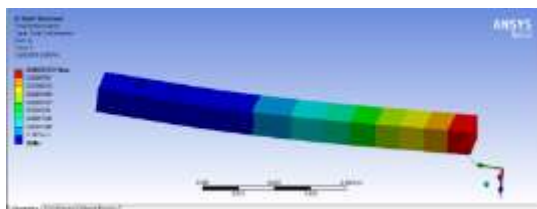


Fig 4.8 Total deformation on horizontal plate

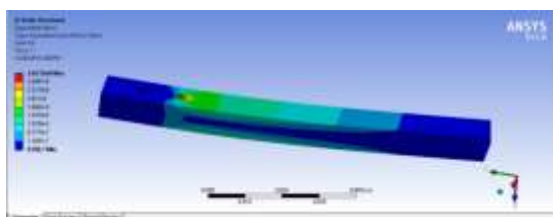


Fig 4.9 Equivalent stress on horizontal plate

C. Magazine

The ring of magazine is extruded by 15.7 mm downwards and placed 13.7 mm above the indexing plate. The rest of the magazine is same as that used in previous method

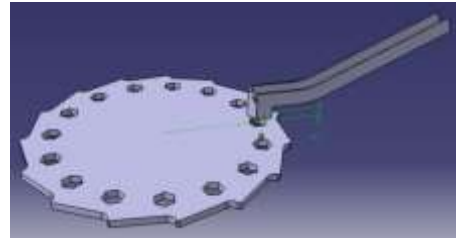


Fig 4.10 Positioning of magazine relative to indexing plate

D. Cylinder

i) Maximum moment on nut

M = Weight of nut × Radius of circumscribed circle of hexagonal slot

$$= 0.035 \times 9.81 \times 0.013$$

$$= 4.463 \times 10^{-3} \text{ Nm}$$

Thus this moment needs to be balanced by our pneumatic cylinder.

The effective distance on which force can be applied on the nut

$$= (\text{Diameter of circumscribed circle} - \text{Diameter of bore})/2$$

$$= (26-16)/2$$

$$= 5 \text{ mm}$$

Now minimum force required by cylinder to counter the moment (F_{cmin}). Though the force can be theoretically applied up to a distance of 5 mm on the nut. The effective

distance of application of force is taken to be 2.5 mm since the type of contact on the nut by the cylinder end will be area contact and not point contact. Thus a mean of the value was selected as effective distance of application of force by pneumatic cylinder.

$$M = F_{cmin} \times \text{effective distance}$$

$$4.463 \times 10^{-3} = F_{cmin} \times 0.0025$$

$$F_{cmin} = 4.463 \times 10^{-3} / 0.0025$$

$$F_{cmin} = 1.785 \text{ N}$$

Thus the force to be applied should not be less than 1.785 N.

$$F_c > F_{cmin}$$

ii) Determination of diameter of cylinder

- 1) D_{min} based on minimum force required to be exerted by the cylinder (F_{cmin}).
- 2) D_{min} based on minimum required velocity of cylinder during retraction.

Diameter of cylinder is selected such that it satisfies both the above conditions.

iii) Cylinder selection

Calculation of D_{min} based on minimum force required to be exerted by the cylinder (F_{cmin}). The pressure available at the industry is 6 bar. We will operate at pressure of 2 bar as force required is very less [6].

For Standard stroke of 10mm and 12mm bore cylinder, the force exerted is 20 N which is acceptable as it is greater than our required. The cylinder selected is a miniature cylinder model no.A51, A52Janatics limited.

iv) Volume Flow Rate and Retraction Time of Cylinder

Volume flow rate in a double acting cylinder is given by,

$$CFM = (A \times S \times EC) / 1728 + [(A - a) \times S \times RC] / 1728$$

Where EC=extend cycles per minute

RC= Retract cycles per minute

$$EC = 60 / (t_{ext})$$

$$= 60 / (0.7)$$

$$= 85.7 \text{ cycles/min}$$

$$RC = 60 / (t_{ret})$$

Thus,

$$CFM = (0.175 \times 0.393 \times 85.7) / 1728 + (0.132 \times 0.393 \times [60 / (t_{ret})]) / 1728$$

$$Q = CFM \times 4.7192 \times 10^5 \text{ mm}^3/\text{s}$$

$$= \left\{ \frac{0.175 \times 0.393 \times 85.7}{1728} + \frac{0.132 \times 0.393 \times [60 / (t_{ret})]}{1728} \right\} \times 4.7192 \times 10^5$$

$$V_p = Q / (A - a)$$

$$V_p = \left\{ (0.175 \times 0.393 \times 85.7) / 1728 + (0.132 \times 0.393 \times [60 / (t_{ret})]) / 1728 \right\} \times 4.7192 \times 10^5 / 84.8$$

$$V_p = 17.001 \text{ m} / (2.710 / t_{ret})$$

We also know that required velocity,

$$V = (10 / t_{ret})$$

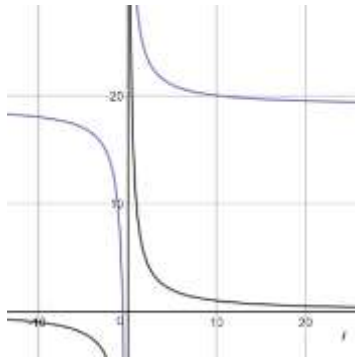


Fig 4.11 Velocity of cylinder vs. retraction time

For $V = V_p$

$$(10/t_{ret}) = 19.004 + (9.978/t_{ret})$$

$$t_{ret} = 0.00115 \text{ sec}$$

$$V = V_p = 8638.18 \text{ mm/sec} = 8.638 \text{ m/sec}$$

(The same fact can be confirmed from above graph where purple and black lines meet at 8368 mm/s at 0.0011 seconds)

Putting t_{ret} in equation of CFM

$$CFM = (0.175 \times 0.393 \times 85.7) / 1728 + (0.132 \times 0.393 \times [60 / (t_{ret})]) / 1728$$

$$= 1.64$$

$$L/min = 46.43$$

$$Q = 7.74 \times 10^{-4} \text{ m}^3/\text{s}$$

$$SCFM = CFM \times (P + 14.7) / 14.7$$

$$= 1.64 \times (29.0075 + 14.7) / 14.7$$

$$= 4.87$$

$$Q = 137.9 \text{ NI/min}$$

v) Filter Selection

As discharge of our cylinder is low pressure drop is negligible. Mist operated FS1 regulator of Janatics Ltd. is selected. (Select filter from company catalogue; make sure it is within operating specifications)

vi) Regulator Selection

Thus R1N Series - air regulator with built in Non-Return Valve for 1/2" port was selected.

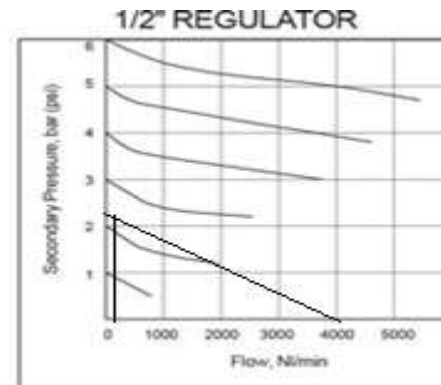


Fig 4.12 Flow graph of 1/2" regulator

From interpolation secondary pressure after pressure loss in regulator is 2.1 bar.

vii) Lubricator Selection

(Select lubricator from company catalogue; make sure it is within operating specifications)

As our volume flow rate is less pressure drop is negligible. Lubricator of L15 series of Janatics limited is selected for 0.01 micron and 1/2" port size

viii) DCV Selection



Fig 4.13 5x2 Solenoid operated spring return type DCV

(Select DCV from company catalogue; make sure it is within operating specifications)

ix) Pressure Loss in Pipes

$$P_1 V_1^\gamma = P_2 V_2^\gamma$$

$$V \propto (1/\rho)$$

$$(P_2/P_1) = (\rho_2/\rho_1)^\gamma$$

Where P_2 =Pressure of air after compression by industrial compressor (6 bar)

P_1 =Atm. Pressure (1 bar)

ρ_2 =Density of air after compression

ρ_1 =Density of air at ambient temperature (assumed as 30 C) and pressure Similarly,

$$(P_3/P_2) = (\rho_3/\rho_2)^\gamma$$

P_3 =Pressure after regulation

ρ_2 =Density of air after regulation

$$\rho_3=2.239 \text{ kg/m}^3$$

Using ideal gas law we can find temperature of air at 2.5 bar

$$P_3 = \rho_3 R T_3$$

$$2.5 \times 10^5 = 2.239 \times 287 \times T_3$$

$$T_3 = 389 \text{ K or } 116 \text{ C}$$

Considering D as 14 mm

$$\text{Then } Dh = D/4 = 3.5 \text{ mm}$$

$$\text{Reynolds no. } Re = \left(\frac{\rho V Dh}{\mu} \right)$$

$$= \left(\frac{Q Dh}{U A} \right)$$

$$\text{From table, } U = 9 \times 10^{-6} \text{ m}^2/\text{s}$$

$$= (7.74 \times 10^{-4} \times (0.014/4)) / (9 \times 10^{-6} \times 1.5 \times 110^{-4})$$

$$= 2006.6$$

As $Re < 2100$ the flow is laminar

$$f = 0.035 \text{ [From Annexure I]}$$

$$\Delta p/l = (128/\pi)(\mu \cdot Q/D^{-4})$$

$$\frac{\Delta p}{l} = 4234.7$$

$$\frac{\Delta p}{l} = 0.042347 \text{ bar/m}$$

For 2.5 m of pipe

$$\Delta p = 0.1 \text{ bar}$$

Thus pressure supplied to the piston =
Pressure set by regulator – Pressure losses
= 2.18 - (0.1+0.08)
= 2 bar

Which is as calculated hence operation of regulator at 2.18 bar is correct.

RESULT AND DISCUSSION

A. Comparison of Methods

Table No. 6.1 Comparison of Methods

Micro controlled Pneumatic actuator	Flexible strip method
1.Capital cost is high	1.Capital cost is low
2.Operating cost is high	2.Operating cost is lower
3.This method is more flexible and can be used with little change in other similar	3.This method is rigid and needs completely different setup for other machines

machines	
4. There is no change in press of machine	4. The flexible strip needs to be fixed on the press
5. Timing is controlled by arduino micro-controller.	5. Timing of punch is controlled by the power press itself
6. It needs to be reset after every few hours	6. It doesn't need any resetting

CONCLUSION

We studied basic methods of automation and its types. We garnered information about the methods of automation and on its basis we studied various research papers. We shortlisted various orientation and feeding systems based on relevant research papers which are applicable to our machine. Vibratory bowl feeder is the most common feeder system used to feed parts to machines. The design for basic components vibratory bowl feeder was done and a placing system in the form of a magazine and push-rod arrangement was designed. All the designed components were analysed in ansys for checking if the stresses were in allowable limits and the parts were safe. It is observed that the running cost of the operation after

implementation of the project will reduce by 41.5% and productivity will increase by 46.67%.

ACKNOWLEDGEMENT

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