DESIGN AND FABRICATION OF AUTOMATIC LOADING AND UNLOADING MECHANISM FOR A JOB ON CNC LATHE

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Abstract--Industries in the recent days are concentrating on Computer Numerical Control machineries for mass production by replacing conventional ways to improve productivity and quality. However recent machine tool manufacturers are coming with solution including automatic loading and unloading to reduce fatigue of labor and reduce cycle time and increasing productivity. The automation of machine tool resulted in higher cost of machinery, hence medium scale company find difficult to invest more and it becomes difficult to upgrade the old machines that were purchased earlier. This project aims to provide a low cost automation solution to the problems faced by the company in terms of quality, quantity, time and cost. The mechanism fabricated was driven by a pneumatic circuit consisting of pneumatic actuators, DCVs, FCVs, air compressor and an FRL unit. The sequencing of the cylinders was achieved by using a PLC Ladder Logic. The solution provided resulted in reduced operator fatigue, cycle time and labor cost thereby increasing the productivity of the company.

Keywords -- DCV, FCV, PLC Ladder Logic, FRL Unit.

1. INTRODUCTION

The present techno-economic scenario is marked by increasing competition in almost every sector of economy. The expectations of the customers are on rise and the manufacturers have to design and produce goods in as many varieties as possible. [5]

Thus there is a challenge before the industries to manufacture goods at right time and at minimum cost for their survival and growth. This demands the increase in productive efficiency of the organization. Automation technique plays a pivotal role in increasing the productivity. Various automation techniques are used to analyze and improve the work methods, to eliminate waste and proper allocation and utilization of resources. Automation is concerned with the development, improvement, implementation and evaluation of integrated system of people, knowledge, equipment, energy, material and process. Automation draws upon the principles and methods of engineering analysis and synthesis, as well as mathematical, physical sciences together with the principles and methods of engineering analysis and design to specify, predict and evaluate the results to be obtained from such systems. Engineers work to eliminate waste of time, money, material, energy and other resources. Thus, automation helps company grow and expand. [5]

1.1. Need Based Analysis:

In order to meet the challenges of sharply increased global competition, manufacturers are being forced to cut costs more drastically than ever before. Now a day, CNC machines are used in almost all manufacturing industries for continuous production and more accuracy. For the achievement of high production, low cost and less cycle time, the system has to be fully automatic like automatic loading and unloading the component. [4]

1.2. Problem Identification:

1.2.1. About the company:

The company is engaged in the precision machining activity in the true sense. Presently it is working for BOSCH Ltd., HAL, AIR FORCE (11 BRD), SIEMENS Ltd., TRANSASIA BIOMEDICAL Ltd., HALDEX Ltd., RING + AQUA Ltd. The company takes up the component for fabrication in the accuracy of up to 10 microns and consistently maintains the quality performance for customers.

The main objective of the company is to manufacture the components of high precision with no compromise on quality at economical price.

1.2.2. Conventional Method:

One of the components manufactured by the company is a needle pin which is used in the manufacturing of the nozzles. The manufacturing of the needle pin involves the turning operations to be performed on CNC lathe (ACE Jobber XL) machine.

The conventional process of loading the component on the chuck and then unloading it after the operations were performed was manual. As a result, the machine was required to be switched off at the intervals and tea time. Due to this, the company was having a shortfall of 5052 components per month, even when the machine was run 24 hours a day. To overcome this, the company used to take help of another machine. Also the cycle time was high and inspection of the needle diameter was required to be done after the job was finished due to inefficiency of the operator in loading the job on the machine with perfect alignment. And the chances of rejection of the component were also high since it depended on operator's efficiency and the amount of freshness which was not constant throughout the day.

Hence, in order to reduce all the above problems occurred due to manual loading, the concept of automatic loading and unloading of the job on machine was proposed to the company.

2. **AIM OF THE PROJECT:**

Considering the problems identified by detailed study of the processes in the manufacturing of the job (i.e., needle pin), following objectives were targeted to be achieved:

(i) To reduce cycle time/ machining time.
(ii) To reduce labor hours.
(iii) To increase the productivity of the machine.
(iv) To meet the customers demand.

Fig.1: ACE Jobber XL Machine

3. METHODOLOGY:

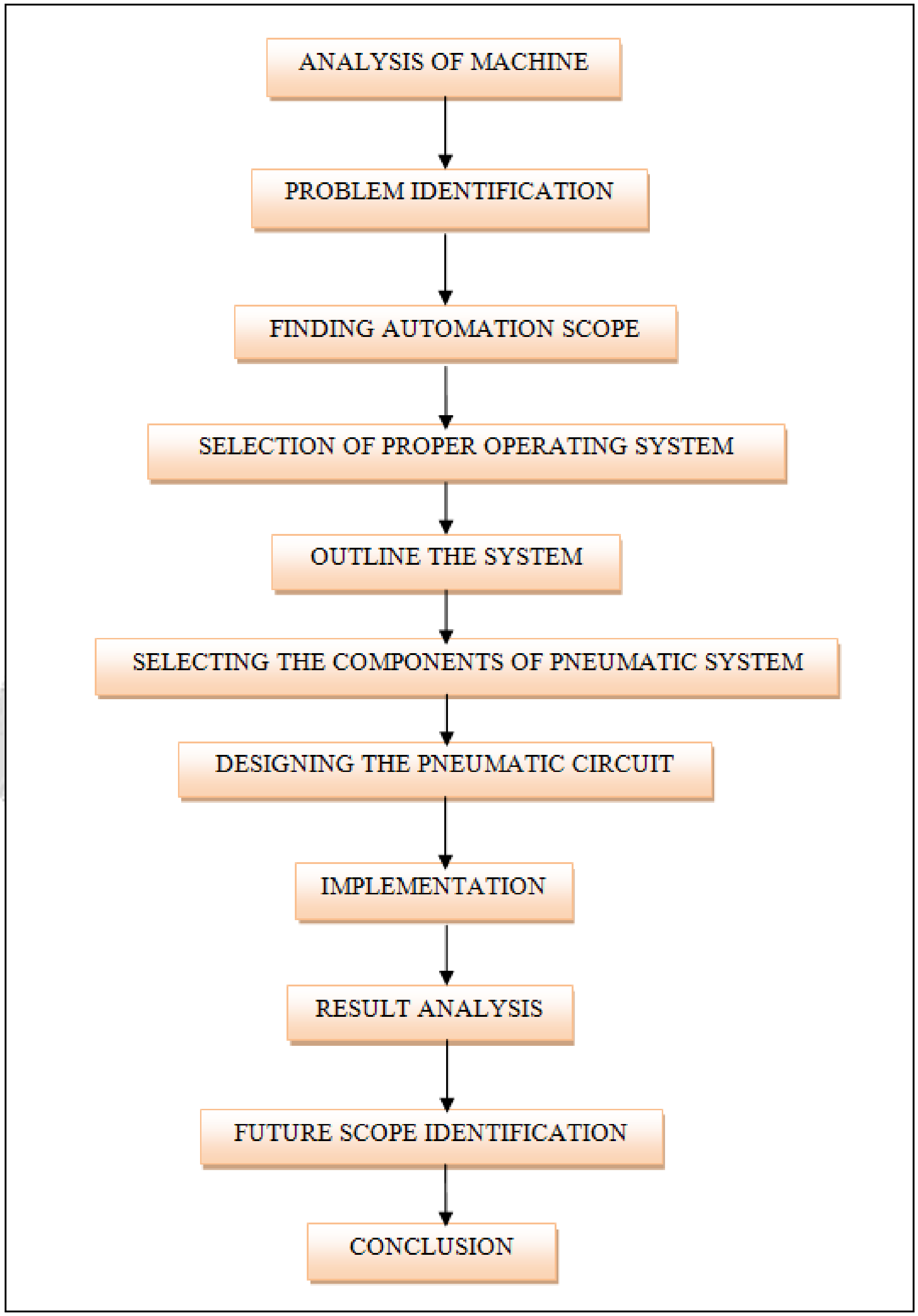

Fig.2: Methodology

4. SOLUTION IDENTIFIED:

4.1. Layout of the mechanism:

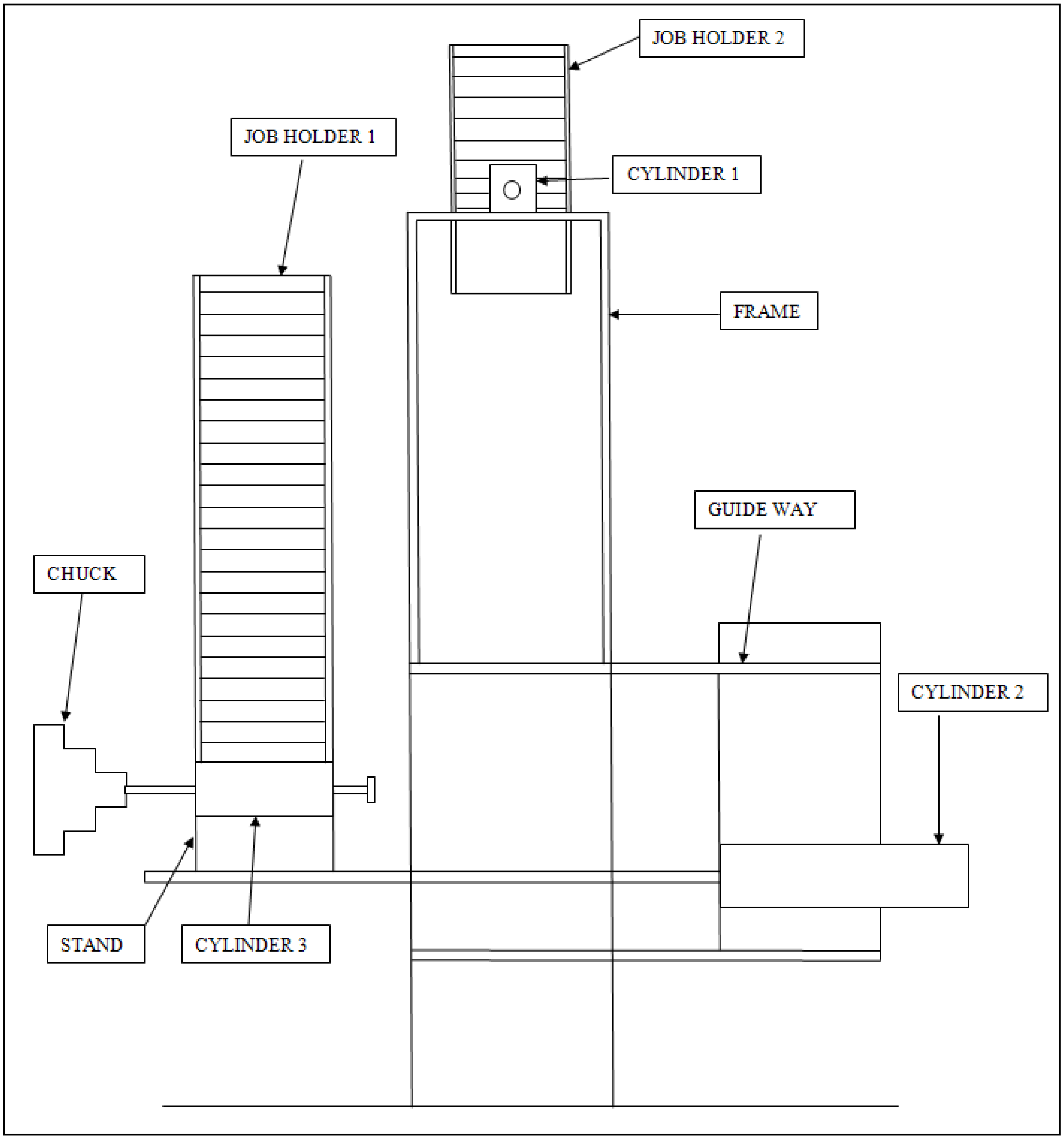

Fig.3: Layout of the mechanism

Above is the layout that was proposed and approved by the company for the automation of the automatic loading and unloading process.

4.2. Parts of the mechanism:

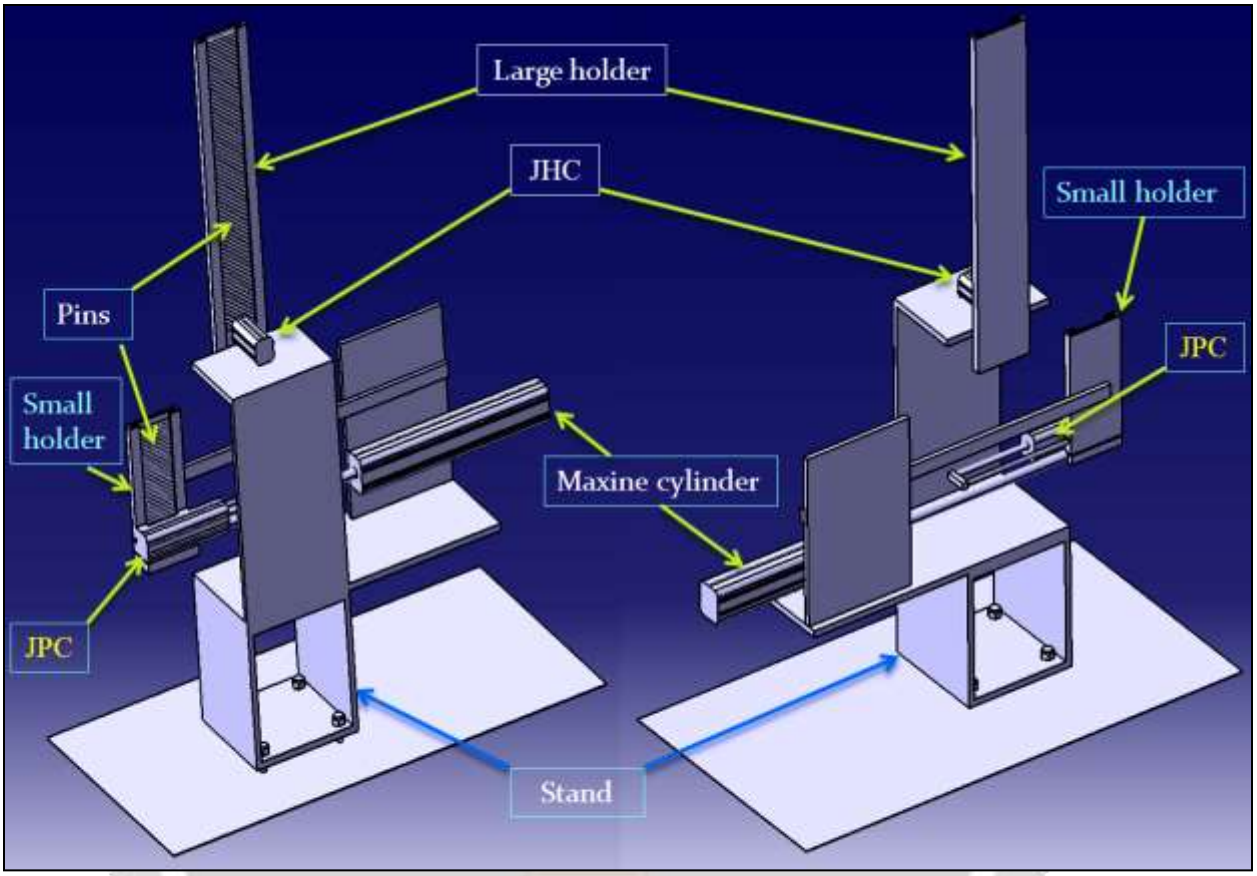

Fig.4: 3D model of the mechanism designed in CATIA V5

The mechanism consisted of following parts:

(i) Stand
(ii) Four Pneumatic Actuators
  (a) Maxine Cylinder
  (b) Job Pushing Cylinder (JPC)
  (c) Job Holding Cylinder (JHC)
  (d) Job Ejection Cylinder (JEC)
(iii) Job Holders
  (a) Small Holder – 50 jobs capacity
  (b) Large Holder – 150 jobs capacity
(iv) Direction Control Valves (DCVs)
(v) Flow control Valves (FCVs)
(vi) Filter Regulator and Lubricator (FRL) Unit
(vii) Compressor
(viii) Reed Switch
(ix) Connectors and fittings
(x) Nuts and Bolts

4.3. Working:

The entire process of working is illustrated in the form of process flow chart shown in the following figure:

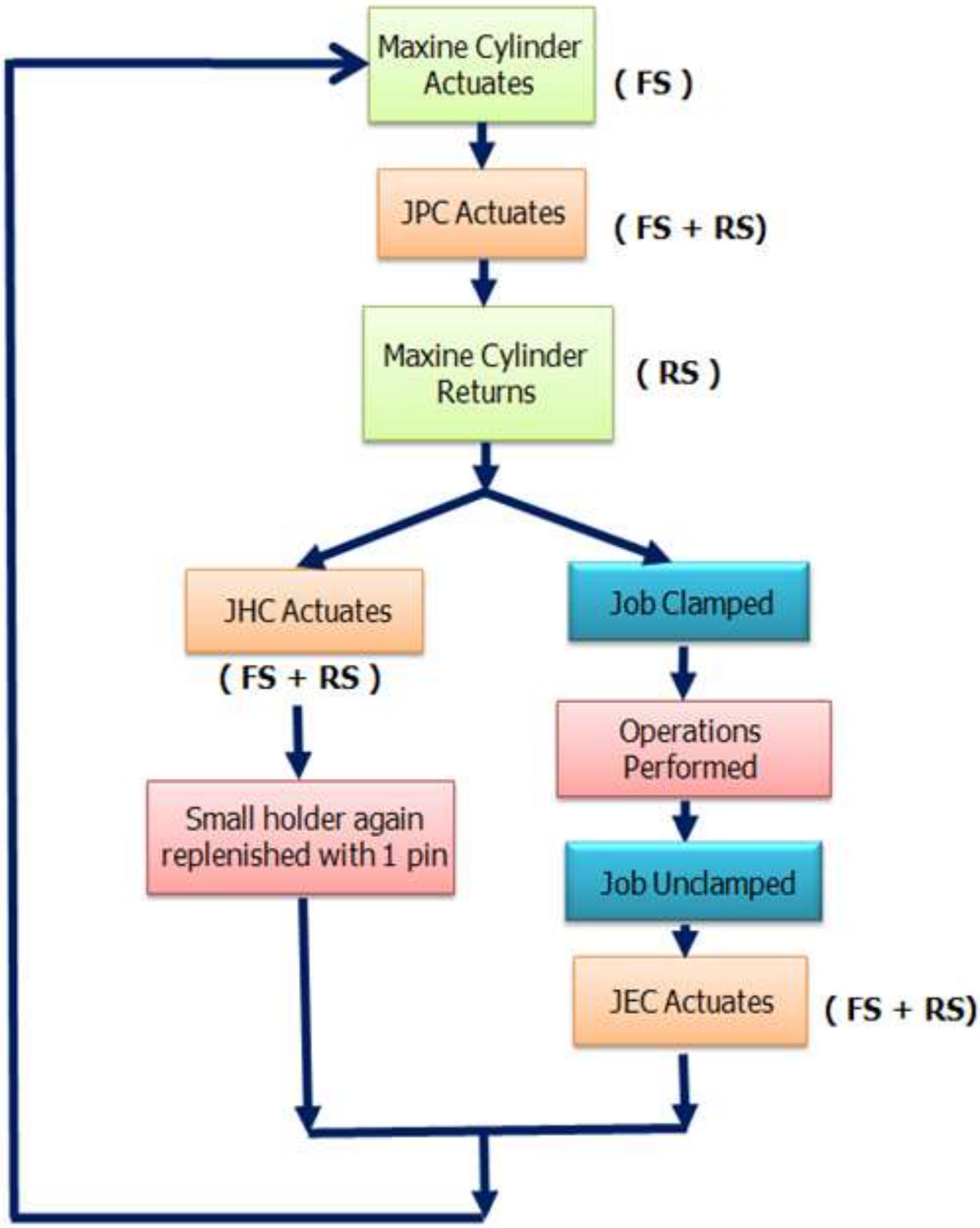

Fig.5: Process Flow Chart

Initially, the Maxine Cylinder actuates in the forward direction to push the small holder towards the chuck for loading of the job. The JPC is mounted on the small holder and acts like a magazine of the gun. The rod end of the JPC is connected with a small plate that is used to push the job towards the chuck with the help of a rod mounted on it. Now the JPC starts it return stroke (RS) which transfers the motion to the job loaded in the small holder, thereby pushing it towards the chuck. Then the JPC completes its forward stroke (FS). And the small holder assembly returns to its original position with the return stroke of the Maxine cylinder. Now the operations are performed on the job by the tool already loaded in the Automatic Tool Changer (ATC). Then the Job Ejection Cylinder (JEC) actuates which is mounted behind the chuck, thereby pushing the job for ejection from the chuck. Once the job is ejected from the chuck, again Maxine cylinder is actuated and the cycle repeats. The sequencing of the cylinders is achieved by the PLC Ladder Logic.

4.4. Circuit Diagram:

The pneumatic circuit diagram for the automatic loading and unloading system was designed and simulated in Automation Studio 3.0.5 software and is shown as follows:

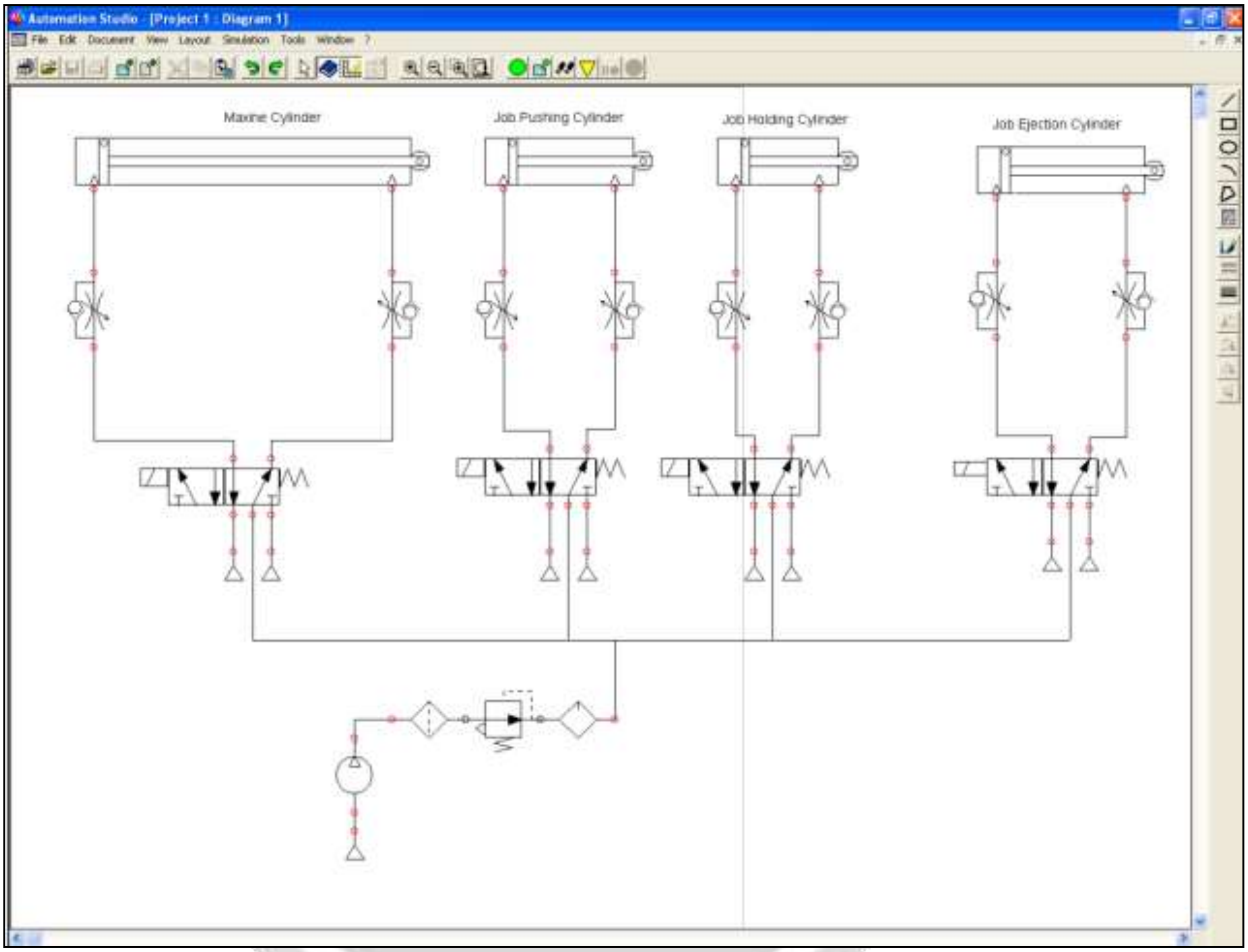

Fig.6: Circuit Diagram designed in Automation Studio 3.0.5 software

4.5. System Design:

1. Selection of pneumatic cylinder:

(a) <u>Maxine Cylinder</u> –

Available Data: $F = 50$ N,

$P = 4$ bar

$= 4 \times 10^5$ N/m^2

Therefore, by considering FOS=2, the force produced will be,

$F = 50 \times 2$ N

$= 100$ N

Now,

$$Area = \frac{\text{Force}}{\text{Pressure}} = \frac{100}{4 \times 10^5} = 0.25 \times 10^{-3}\ m^2$$

$$=> \frac{\pi d^2}{4} = 0.25 \times 10^{-3}$$

$$=> d = 0.0178 \approx 18\ mm$$

Since the minimum bore diameter of 18 mm and stroke length of 250 mm is required, the cylinder with bore diameter = 32mm is selected from catalogue of festo. [6]

(b) Job Pushing Cylinder (JPC) –
Stroke length L = 80 mm,
Load, F = 10 N,
Pressure P = 4 bar
For these required conditions we select cylinder with –
Bore Diameter = 20 mm
Rod Diameter = 10 mm ....from Festo Catalogue [6]

(c) Job Holding Cylinder (JHC) –
Stroke length L = 50 mm,
Load, F = 10 N,
Pressure P = 4 bar
For these required conditions we select cylinder with –
Bore Diameter = 20 mm
Rod Diameter = 10 mm ....from Festo Catalogue [6]

(d) Job Ejection Cylinder (JEC) –
Stroke length L = 100 mm,
Load, F = 10 N,
Pressure P = 4 bar
For these required conditions we select cylinder with –
Bore Diameter = 20 mm
Rod Diameter = 10 mm ....from Festo Catalogue [6]

2. Compressor: -- Reciprocating type
3. Material Selection: -- (i) For Job: High Speed Steel (HSS)
-- (ii) For Parts: Mild Steel – C45 (hardened)
-- (iii) Parameters: - Level of loads
- Humidity
- Temperature
- Stroke Length

4. Selection of DCVs:
Flow rate, Q = A×V
And velocity,

$$V = \frac{\text{Stroke Length}}{\text{Time}} = \frac{0.250}{0.833} = 0.3\ m/s$$ ….. (For max stroke length of 250 mm)

$$Q = \frac{\pi d^2}{4} \times V = \frac{\pi \times 0.032^2}{4} \times 0.3 = 2.41 \times 10^{-4}\ m^3/sec$$

$$Q = 14.47\ lpm$$

Therefore, D_3 model was selected.

We use one 5/2 way double solenoid valve for magazine cylinder, for avoiding accidents during the operation. Three 5/2 way single solenoid valves are used for actuating the remaining three cylinders.

5. Selection of FCVs:

   For achieving speed of 0.3 m/s,

   Q = Annulus Area × velocity

   $$= \frac{\pi}{4}\left(32^2 - 20^2\right) \times 10^{-6} \times 0.3$$

   $$= 0.147 \times 10^{-3}\ m^3/s$$

   $$Q = 8.8\ \text{lpm}$$

   From catalogue [6], F3 model is selected for range 0 - 16.3 lpm.

6. Selection of FRL unit: -- from FESTO catalogue[6]
7. Selection of Piping:

   Available Data – velocity, V = 0.3 m/s

   -- discharge Q = 8.82 lpm

   Pipe of plastic material is selected with following sizes:

S No.	Piping	Outer diameter	Inner Diameter	Thickness
1	From compressor to FRL	8 mm	7 mm	0.5 mm
2	From DCV to cylinder	6 mm	5 mm	0.5 mm

Table no.1: Dimensions of Piping selected

8. Selection of Silencer:
9. Selection of Reed Switch:

} ………….From Festo catalogue [6]

5. TESTING AND OBSERVATIONS:

5.1. Problems in initial trials:

In the initial trials, the problems faced are listed as follows:

(i) Improper timing of PLC Controller

(ii) Timing of machine

(iii) Inaccurate job loading

(iv) Structural offsets or misalignment

5.2. Time analysis:

S No.	Parameter	Before Automation	After Automation
1	Total time for 50 jobs (machining + Non-machining)	76.8 min	69.3 min
2	Machining time for 1 job	1.16 min	1.16 min
3	Machining time for 50 job	58 min	58 min
4	Total non-machining time for 50 jobs	16.8 min (76.8-58)	11.3 min (69.3-58)
5	Non-machining time for 1 job	20 sec $\left\{\frac{16.8 \times 60}{50}\right\}$	14 sec $\left\{\frac{11.3 \times 60}{50}\right\}$
	Reduction in cycle time/ job →	**6 sec** (20-14)	

Table no.2: Time analysis

5.3. Productivity Calculation:

(a) Ideal Production rate:

Ideal production rate is productivity obtained when the efficiency of the operator is 100%, no intervals and the machine operates continuously throughout the day and for all 26 working days in a month.

Total time for completing 1 job on machine = 89.6 sec
Which includes – machining time = 69.6 sec
-- Non-machining time =20 sec
Production rate by machine per hour = 3600 / 89.6
= 40 components / month
Production rate of machine per shift = 40 × (no. of hours / shift)
= 40 × 12
= 480 components / shift
Production rate of machine per day = (components / shift) × 2 shifts / day
= 480 × 2
= 960 components / day
Production rate of machine per month = (components / day) × (no. of working days / month)
= 960 × 26
= 24960 components / month
Required demand = **24500 components / month**

(b) Actual Production rate:

Since the operator's efficiency is not always constant as was assumed in ideal productivity calculation, considering operator's overall efficiency as 85%. Also the operator is given a lunch break of thirty minutes along with two tea breaks of fifteen minutes each

(i) Before automation:--(11 hours / shift)
Actual production rate per hour per hour = 40 × 0.85 components / hour
= 34 components / hour
Actual production rate per shift = 34 × (no. of hours / shift)
= 34 × 11
= 374 components / shift
Actual production rate per day = 374 × 2 shifts / day
= 748 components / day
Actual production rate per month = (components / day) × (no. of working days /month)
= 748 × 26
= 19448 components / month
Hence, there was the shortfall of 5052 components / month

(ii) After Automation:--(reduction of 6 sec / job)
Total time for completing 1 job on machine = 83.6 sec
Which includes – machining time = 69.6 sec
-- Non-machining time = 14 sec
Production rate of machine per hour = 3600/83.6
= 43 components / hour
Production rate per month = (components / hr) × (hrs / shift) × (shifts / day) × (days / month)
= 43 × 11 × 2 × 26
= 24596 components / month
This is more than the demand of 24500 components per month.

5.4. Results:

From the time analysis, the reduction in the non-machining time per job was observed to be 6 seconds / job. And the productivity calculation reveals that the actual productivity after automation was increased by 5148 components per month which was more than the shortfall. Also before automation, the machine was required to be switched OFF during intervals due to manual handling but after automation, the machine could be allowed to run continuously for 24 hours in a day in order to meet the extra demand if required since the operator can load the component once and there was no need for further monitoring until all the jobs were finished.

6. PROFIT TO THE COMPANY:

The profit to the company can be explained in terms of:

(a) Operator wages:

Before automation one operator was required to handle two machines at a time. But due to automation of the loading and unloading process, single operator was able to handle two machines at a time easily.
Hence the expense for one operator extra can be avoided which is mentioned as follows:

Profit in terms of wage reduction = salary of one operator
= Rs 9000 per month
= Rs 108000 per year

(b) Cycle time:

The cycle time was reduced by 6 seconds as could be seen from the time analysis.

(c) Productivity:

Actual production rate before automation = 19448 components / month
Actual production rate after automation = 24596 components / month
Increase in productivity = 5148 components / month

7. ADVANTAGES AND DISADVANTAGES:

(a) Advantages:

- (i) Cycle time reduces & remains constant
- (ii) Self cleaning system
- (iii) Less maintenance needed
- (iv) Production is independent from worker's efficiency
- (v) Less manual intervention
- (vi) High accuracy
- (vii) Inspection not required

(b) Disadvantages:

- (i) High initial cost
- (ii) Suitable for small components
- (iii) Compressor required

8. FUTURE SCOPE:

The mechanism designed in this project proves to be a best modification that can be provided on the CNC lathe machine in order to increase the productivity up to a large extent. There is scope for further modifications that can be done in the mechanism in order to decrease the cost and avoid it from getting corroded. Carburization can be done on the plates in order to avoid corrosion. Separate job collection tray can be provided below the chuck in order to avoid scratches on the when it comes in contact with the metal chips. The mechanism designed can be implemented for larger jobs also by changing the job holder dimensions and selecting the pneumatic actuators accordingly.

9. CONCLUSION:

The development of automatic loading and unloading mechanism lead to the improvement in productivity by 5148 components / month, reduction in the cycle time by 6 seconds per job and reduction in number of operators that can be utilized on other machines.

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