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Design and Fabrication of Automatic Material Handling System for Engraving Machine

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Abstract

This paper aims at the automation of feeding, clamping and retrieval process to carry out the manual job. The limiting parameter was the size of the table. Based on the constraints the components are designed, assembled, tested and interfacing of microcontroller done. During testing the subsystems are considered for the free movement of piston, blockage in solenoid valve, leaking in pressure regulator valve, working of buzzer and clamping mechanism. Final setup was tested with the engraving machine. The cost of the whole project was Rs.5800 and the cycle time was recorded as 18 seconds. It was noticed that a perfect sync between feeding, clamping and retrieval of the job. Thus the designed automatic engraving machine is feasible as well as profitable for the polyhedron Pvt. Ltd.

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Keywords: Engrave;Material handling;Automation; Fabrication.

1. Introduction

Rising costs, shorter lead time, complex customer specifications, competition from across the street and around the globe. Business today faces an ever-increasing number of challenges. The manufacturer who develops more effective and efficient forms of production will be the ones who take on the challenges. The current age solution for the above problem is automation. Society in its daily endeavours has become so dependent on automation that it is hard to conceive of life without automation engineering. The materials handling is the art and science of moving, positioning, packing and storing substances in any form. Designers undertake the design of special elements based on the material-to-be-handled, range available in the market, affordability etc. In the area of research, there has been a substantial amount of literature published in this area though the published work is mostly limited to cylindrical and regular prismatic components. Goldberg et al discussed about orienting polygonal parts without the aid of

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sensors. Lynch et al discussed on inexpensive conveyor based part feeding system for simpler components. Vandal et al introduced the concept of creating a permanent air field which forces the part into the desired orientation without the need for any control by sensors. Daddy Gudmundson et al proposed a methodology to maximize throughput in a vision based part feeding system, where robots are utilized. Wee et al developed a flexible belt parts feeder to separate cylindrical parts. Patrick S.K. Chua et al developed an active feeder for handling cylindrical parts having grooves at one end. Omno C Goemans et al discussed about blades for fee- ding 3D parts on vibratory tracks. In this paper, an attempt is made to design a simple, inexpensive material handling system with the available air compressor line, without the aid of robots.

The mechanical subsystems that are most essential for finalizing the conceptual design of a material handling system are designed, fabricated and microcontroller is interfaced to develop the automated material handling system.

2. Design of Mechanical Subsystems

The components of the automated material handling system are shown in figure 1, and its descriptions are given below

a) Piston extension and extension boss

The plate in the process is of thickness 6mm. The diameter of the pneumatic piston is 10mm. So, if the piston would have directly used to move the plate, it would try to move two plates simultaneously. Hence a piston extension which has less thickness than the plate is needed. The piston extension has a thickness of 5mm and width of 10mm. It is fitted on the piston threads with the help of a cylindrical boss which has mating threads on its bore. The piston extension plate (5x10mm) is welded to the cylindrical boss. Other two plates are welded to the piston extension to arrest the revolving motion. A small part is welded to the bottom of the extension to fix the wedge assembly.

b) Wedge

To clamp the plate properly, movement of the plate in 4 directions must be arrested. Guides arrest the motion in 2 parallel directions. Pneumatic piston clamps the job from behind and the stopper has to clamp from the other side i.e. the front side. To actuate the vertical motion of the stopper through the motion of the piston itself, wedge assembly is fabricated. The wedge has tapered surface along the direction of the motion of the piston. Hence, as the piston advances, the tip of the stopper which is sliding on the wedge rises. The angle of inclination of the wedge is maintained at around 150. It assumed that the top most point of the stopper movement is obtained at 2/3rd length of the wedge. If the wedge would not have been used, a separate actuator was required to pop out the stopper. A mechanism such as a motor - screw or other pneumatic piston was required. The use of the wedge proved helpful and eliminated separate mechanism as well as it reduced an output from the microcontroller.

c) Guides

Guides arrest the motion of the plate in the direction perpendicular to the direction of the piston. They are fixed on the table by the drilling holes in the guides and tap on the table. The distance between the two guides is maintained exactly same as the plate width i.e. 65mm. The thickness of the guides is 6mm i.e. same as that on the plate engraved. This facilitates the movement of the engraving tool to move freely. Earlier, the thickness was 8mm, but it was observed that it hindered the movement of the engraving tool. So to solve that problem, thickness was reduced to 6mm.

d) Piston extension Plate

These plates are included to arrest the revolving motion of the piston extension in the slot. Additionally, when the piston extension pushes the bottom most plate, all the other plates in the stack rest on the extension itself. This exerts downward force on the extension. The piston extension is only supported by the welding in the round piece. Hence, it acts like a cantilever. To minimize the cantilever action, these plates are provided. These plates slide on the table giving additional support.

e) Piston extension threaded piece.

The procured pneumatic piston is of 10mm diameter. To install the a plate of cross section 5x10mm, this cylindrical piece is fabricated which has M10 tap on one side which mates with the external threads on the piston and a slot to accommodate the piston extension on the other side. The extension is welded in the slot.

f) Stopper

Stoppers arrests the motion of the plate in one direction and provides a means of clamping. It moves through the table vertically. It slides down inside the slot to facilitate removal of the job. Its dimensions are maintained to conform to the slot dimensions in which it slides. It has a tap on the bottom to bolt the threaded piece which will guide on the wedge.

g) Main base plate

Main base plate supports all the components and provides a surface on which the job slides. It also supports stack of plates. The table is fabricated from relatively hard material and is ground to get smooth surface which enables low friction. It has tapings to mount guides, etc. it also has a slot for stopper to move. The main base plate is bent and holes are drilled to mount the piston plates.

h) Stopper threaded piece

It is a cylindrical shaped part which has external threads on one of its ends. Other end is made round which slides on wedge. The length of the threaded part is 158mm which meshes with tap in the stopper. The threaded portion enables to adjust the total effective height of the stopper. Improvement in this part would be to use a ball to roll on the wedge. This will reduce the friction and smoothen the movement.

i) Stack supports

A stack of plates (say 15 to 20) is placed before the clamping position. A structure is required to support this stack. This structure should be such that it restricts the movements of the plates in the stack in all but downward direction. To reduce the machining and the fabricating, existing holes were used and a structure comprising of two square bars were made. But this structure did not work well because it allowed the movements in forward and backward directions. Hence, new structure comprising of 4 L sectioned aluminum angles was made. This would arrest the movements in all directions, yet allow downward motion by gravity. The material chosen was aluminum since it is light, soft and easy to fabricate.

Figure 1 (a) Piston extension and extension

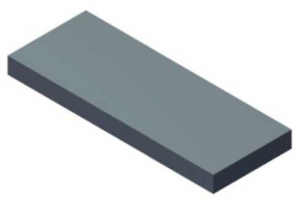

Figure 1 (f) Piston extension Plate

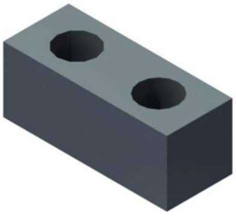

Figure 1 (b) *Extension boss*

Figure 1(g) Piston extension threaded piece

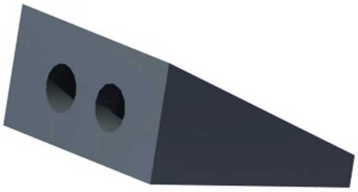

Figure 1 (c) Wedge

Figure 1 (h) Stopper to clamp the job

Figure 1 (d) Wedge sheet metal link

Figure 1 (i) Main base plate

Figure 1(e) Guides for Job alignment

Figure 1 (j) Stopper threaded piece

Figure: 1 Detailed design of mechanical subsystems

3. **Force Calculation for Material Feed**

Force required to push the bottom most jaw was calculated, based on which the required pressure of the pneumatic cylinder was determined: the free body diagram of the component feeding is shown in figure 2.

Here,

M-- Mass of the bottom most block = 200g

F -- Force required to overcome the friction, thus moving the block.

f_1 – Frictional force between block and surface
f_2 – Frictional force between two blocks

Figure 3 shows the free body diagram of the bottom most block:

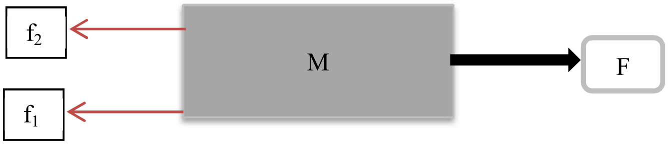

Figure 2 FBD of block 1

Thus, from the equation of equilibrium we have,

$$F_{net} = f_1 - f_2 \quad \text{......... A}$$

But since f1 and f2 are frictional forces, their values can be calculated as,

$$F_{net} = \mu_1 N_1 - \mu_2 N_2 \quad \text{......... B}$$

$$F_{net} = [\mu_1 (9M) g] - [\mu_2 (8M) g]$$

$$F_{net} = [0.3*9*0.2*9.81] - [0.3*8*0.2*9.81]$$

$$f_2 = \mu_2 N_2 \quad \text{......... C}$$

$$F_{net} = f_1 - f_2 \quad \text{......... D}$$

Where,

N_1 – Normal reaction on bottom most block.
N_2 – Normal reaction on the block above the bottom most block.

Thus,

$$F = \mu_1 N_1 + \mu_2 N_2 \quad \text{......... E}$$

$$F = [\mu_1 (10M) g] + [\mu_2 (9M) g]$$

$$F = [0.3*10*0.2*9.81] + [0.3*9*0.2*9.81]$$

$$F = 22.6N$$

Figure 3 shows the free body diagram of the pneumatic block (second block from bottom):

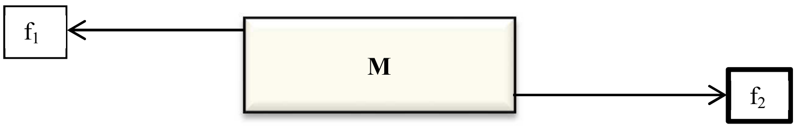

Figure 3 FBD of block 2

Here the frictional force for bottom most block becomes the driving force for the block above it. Thus, net force on the block is

$$F_{net} = \mu_1 N_1 - \mu_2 N_2$$

$$F_{net} = [\mu_1 (9M) g] - [\mu_2 (8M) g]$$

$$F_{net} = [0.3*9*0.2*9.81] - [0.3*8*0.2*9.81]$$

$$F = 0.5886N$$

This force makes the block moves forward. But this motion is restricted by stack arrangement which also does the job of holding the work piece. Following figure: 4 depict the arrangement.

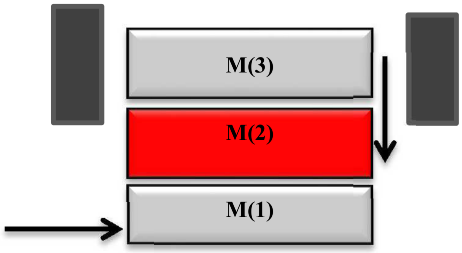

Figure 4 Stack arrangement

A suitable cylinder pressure can be selected such that the outer force is greater than 22.6N it is found that output force of the cylinder at 2 bar working pressure is,

$$F_1 = 88N$$

Hence the pneumatic cylinder can be easily used at 2 bar working pressure in this case. The pressure of airline running through the factory is reduced from 8 bar to 2 bar using a pressure regulator. Figure 5 shows the AMHS CAD model.

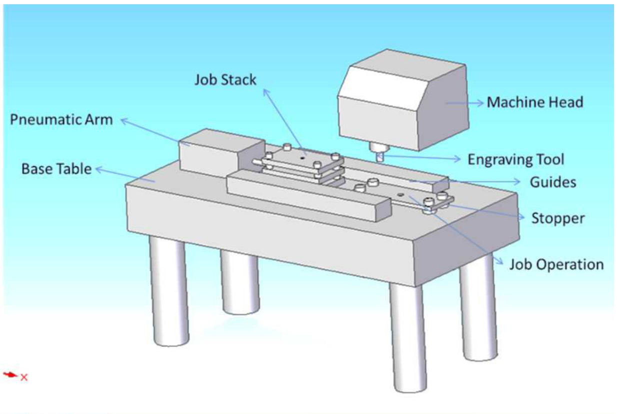

Figure 5 AMHS CAD model

4. Automation Algorithm

Step 1: The IR sensor checks for stock availability. If the stock is available then it gives a signal to the microcontroller or else the buzzer is actuated. This sensor signal is used as a feedback for stock availability.

Step 2: If the stock is available then microcontroller receives signal from sensor and sends an output signal to the pneumatic arm to start the feeding process.

Step 3: When the job is properly aligned, the microcontroller sends an output signal to the engraving machine.

Step 4: Engraving machine takes its fixed time to engrave the work piece; the flow chart is shown in figure 6

Step 5: The microcontroller able to count the cycle time engraving operation then sends an output signal to the pneumatic arm which then retracts back.

Step 6: The cycle is repeated from step 1.

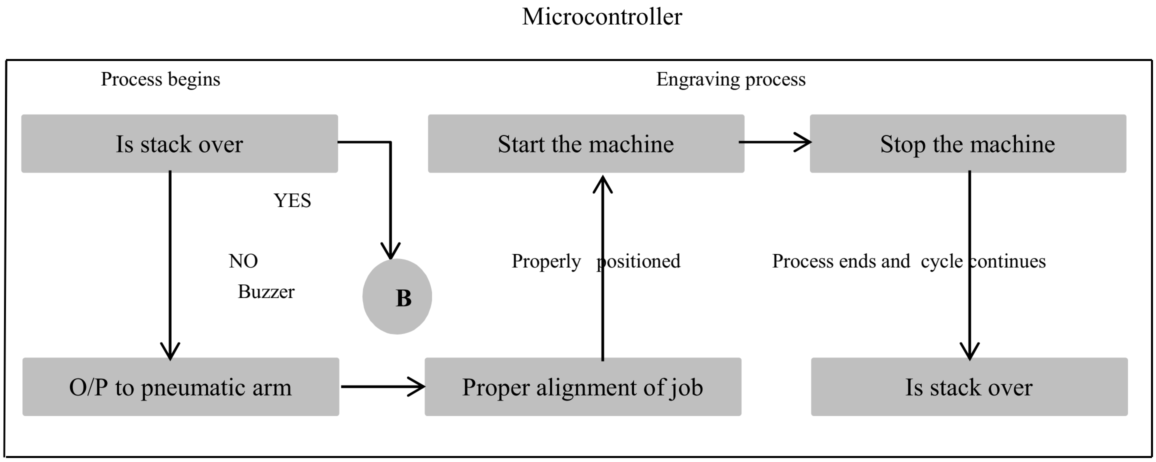

Figure 6 Automation Algorithm

5. Fabrication of Automation System

The sub systems listed in chapter 3 and the designed base plate and the other components described in the previous paragraph were manufactured. The figure 6 shows the final assembly of the automatic material handling system with the engraving machine. Pneumatic cylinder can be mounted in various configurations. In this system table mounting is chosen. As a mountings supplied by the manufacturer of the piston were not appropriate, mountings are fabricated of sheet metal. A piston mounting has Φ23mm hole to mount the cylinder and two Φ6mm holes to fix on the piston plate.

5.1. Fabrication Procedure

The fabrication procedure for various components is as follows.

Guides:

- Facing is done on the work piece to set the width at 12mm.
- Two through holes of 6mm were drilled to fix the guides to the table.
- M5 tapping was done on the work piece to accommodate stack stoppers

Piston extension:

- The material was milled flat to get a thickness of 5 mm.
- Piston extension is welded to the cylindrical piece.
- Bottom plate having M6 tap is also welded to the extension.
- Two plates to arrest the revolving motion of the extension are welded.

Piston extension boss:

- The work piece was to reduce the diameter to 2mm
- Facing is done on the work piece to set the width at 12mm.
- Facing is done on the work piece to set the width at 12mm.
- Facing is done on the work piece to reduce the length to 12mm.
- An M10 x1.25 tap was drilled to accommodate piston of the pneumatic cylinder.
- Finally a slot of 5 mm and width of 5mm depth was drilled.

Bottom piece:

- Two M6 taps were drilled on the job to fix the wedge assembly

Piston mountings:

- The job was cut to appropriate dimensions from sheet metal.
- A Φ23mm hole was drilled for mounting on the table.
- Two Φ6mm holes for fixing on the plate were drilled.
- Finally bend by 900.

Wedge:

- Accurate marking were done on the work piece.
- Two M6 taps were drilled to fix the link which connects the wedge to piston extension.
- Finally milled to get a tapered surface.

Sheet metal link:

- The work piece was to cut to appropriate dimensions.
- The slot was milled for fixing it to the piston extension.
- Two holes of Φ6mm were drilled to fasten the sheet metal link to the wedge.
- It was bent at two points to get the required shape.

Stopper:

- Facing was done on the work piece to get smooth surface.
- An M5 tap was drilled to accommodate the threaded piece.
- Grinding was done to round the edges and to maintain close tolerances.

Stopper threaded piece:

- The specimen was turned to reduce the diameter to Φ10mm.
- M5 threading was done on the job with the help of the die.
- Finally machining was done to get rounded edge.

Stopper support:

- The sheet metal was to cut to appropriate dimensions.
- A Φ10 mm hole was drilled to accommodate stopper threaded piece.
- Two Φ6mm holes were drilled for mountings.
- It was bent at various points to get the required shape.

Stack support:

- The job was turned and an external threading of M5 for 25 mm length was done.
- Stack stopper:
- It was cut to required dimensions.
- Hole of Φ5mm for mounting was drilled.

6. **Testing and Inspection**

6.1 Testing of automated system.

Testing was carried out under the supervision of factory officials (M/s Polyhydron Pvt. Ltd.), so that the working system meets the standards. Before testing the assembled system, the sub systems were tested, such as free movement of the piston inside the cylinder was checked, blockage in the solenoid valve was checked by jetting pressurized air into it, leakage in the flow regulator valve was checked, proper working of buzzer was ensured, clamping mechanism was tested. Only after ensuring proper working of the individual systems final assembly was done. Feeding, clamping and retrieval of the job were tested with the engraving machine on.
Upon testing, the following observations were made

- The force exerted by the piston was more than sufficient to push the job along the guide – ways.
- At an operating pressure of two bar the force exerted by the piston was 88N which is more than the force required to push the job.
- All the electrical connections were correct.
- The job was properly oriented with the help of IR sensors.
- The micro-controller made sure that the engraving machine was switched ON/OFF at the right time.
- Finally after the process was completed, the piston was signalled to retract back and then push the new job into position there by pushing the finished job into the tray.

6.2 Test results.

- After testing the following results were obtained:
- The whole process was carried out without any human intervention.
- Human involvement is required only while replenishing the stock.
- The cycle time of the automated process is 18 sec.

6.3 Inspection report

The job on the left side of the image is engraved using an automated material handling system. The job on the right side of the image is engraved using a manual material handling system. It is clearly evident from the images that the job was properly clamped, as the engravings done on the job are proper and there are no shaky impressions on it. Engraving process done with an automated material handling system is good as engraving done manually. Hence the outcome is satisfactory and is well within the tolerance limit.

6.4 Cost Estimation

Components	Cost (INR)
Pneumatic cylinder and accessories	1200/-
Solenoid	1000/-
Flow and pressure relief valve	500/-
Microcontroller board	1000/-
Relay and IR sensors	800/-
Fabrication cost and Misc.	1300/-
Total	5800/-

Table 1: Cost estimation details

It is clearly evident from the report that the cost of automating a material handling system is less and moreover it is just a one-time investment. Hence it is justified to implement this automated material handling system for the engraving machine.

7. Tested Results and Discussion

The testing was carried out under the supervision of factory officials so that the working of the system meets their standards. Before testing the final assembled system, the subsystems were tested for free movement of the piston inside the cylinder, blockage of solenoid valve, leakage in the flow regulator valve, proper working of buzzer, and the clamping mechanism. Only after ensuring proper working of the individual subsystem final assembly was done. Initial trial runs for feeding, clamping and retrieval are carried out without switching on the engraving machine.
The following observations were made during testing:

- The force exerted by the piston was more than sufficient to push the job along the guide ways
- At an operating pressure of 2 bar the force exerted by the piston was 88N.
- The presence of job is identified with the help of the IR sensor
- The microcontroller taken charge of switching ON/OFF at the right time.
- Finally after the process was completed, the piston was signaled to retract back and then push the new job into position thereby pushing the finished job into the tray.

Outcome from the present work:

- After successful implementation of the automation system the following information's are retrieved
- The whole process was carried out without any human intervention.
- Human involvement was required only while replenishing the stock.
- The cycle time of the automated process is 18 Sec.

Inspection Report:

The job on the left side of the image is engraved using an automated material handling system. The job on the right side of the image is engraved using a manual material handling system. It is clearly evident from the images that the job was properly clamped, as the engravings done on the job are proper and there are no shaky impressions on it. An engraving process done with an automated material handling is as good as engraving done manually. Hence the outcome is satisfactory and is well within the tolerance limit.

8. Conclusions

The purpose of this work was designing, fabricating, and implementing automatic material handling system for engraving machine. The limitations of the earlier manual feeding system were analyzed and to increase the productivity and to eliminate workers fatigue, developing an economical automation system was suggested. Accordingly the components and sub components are designed, fabricated and assembled to get the final material handling system. Microcontroller was interfaced to make the system to work automatically. By this work the developed system is able to complete the material handling and the engraving operation with 18 seconds by eliminating the boredom work of the worker. The company is able to increase productivity three times the manual material handling system. .

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