AUTOMATION OF INJECTION MOULDING MACHINE USING PLC

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Abstract*: In this fast developing and revolutionary era, automation of industry have become a necessity. A Programmable Logic Controller (PLC) is a programmable system used for automation. It is a user friendly microprocessor based specialized computer that carries out control functions of many types and levels of complexity. Its purpose is to monitor crucial process parameters and adjust process operation accordingly. In an industrial setting PLC is used to automate manufacturing and assembly processes.*

This project deals with the automation of INJECTION MOULDING MACHINE using PLC and pneumatic cylinders. Four cylinders are used where each cylinder represents a specific task. The four processes involved here are clamping and de-clamping of the die, opening and closing of vibratory bowl lid, injection of the molten plastic material and then finally ejecting the component. These entire processes are controlled by PLC. The PLC based on the logic given, controls all the operations and performs the task.

In a manufacturing environment, where this assembly is done manually would be labor intensive and would cause substantial reliability problems due to operator fatigue and manual errors. Therefore, there exists a need for an apparatus capable of accurately and reliably handling articles, in a manufacturing environment, while substantially avoiding the difficulties which is accomplished by the project with the help of PLC.

Keywords*:PLC, Automation, Injection Moulding.*

1. INTRODUCTION

Automation is the use of control systems and information technologies to reduce the need for human work in the production of goods and services. In the scope of industrialization, automation is a step beyond mechanization. Whereas mechanization provides human operators with machinery to assist them with the muscular requirements of work, automation greatly decreases the need for human sensory and mental requirements as well. Automation plays an increasingly important role in the world economy and in daily experience.In, an industrial context, we can define automation as technology that is concerned with the use of mechanical, electronic and computer based systems in operation and control of production.

1.2 CLASSIFICATION OF AUTOMATION

Automation is the use of technology in manufacturing machines that take over work normally done by humans. It is nothing but the manual operation done by computerized techniques and advanced technologies, usually electronic hardware.Based on the production quantity and the product variety the automation has been classified into three types. They are:

1. Fixed Automation: In fixed automation, the production equipment is designed in such a way the continuous or sequence of operations is fixed or made constant by the equipment configuration. Each operation is simple and the required motions may be linear, rotational and even the combination of the two, such as rotating spindle. Fixed Automation is combination and coordination of many operations into single equipment which makes the system complex.

2. Programmable Automation: In programmable automation the production equipment is a system where the sequences of operations are going to be changed to accommodate different production configurations. The operation sequence is controlled by a program which is a collection of different instructional codes which are read and interpreted by the system. To produce new products new programs are to be written

3. Flexible automation: It’s an extension of the programmable automation. It produces a variety of products with no time lost. There is no loss in the production time when the reprogramming is done.

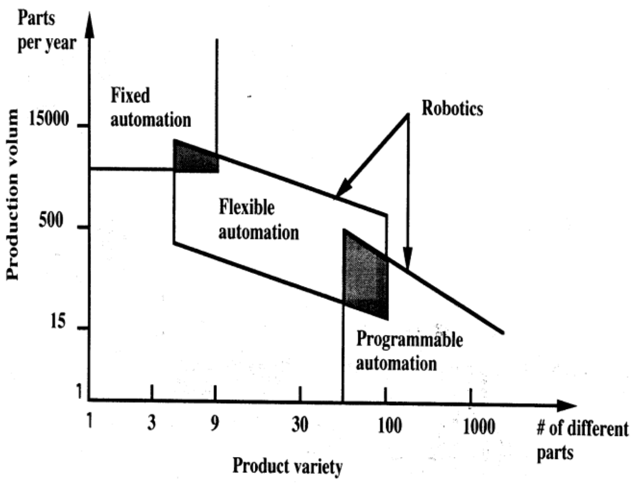


Fig1.1 Productivity variety and volume

1.3 AUTOMATION TOOLS

An automated online assistant on a website, with an avatar for enhanced human–computer interaction. Human-machine interfaces (HMI) or computer human interfaces (CHI), formerly known as man-machine interfaces, are usually employed to communicate with PLCs and other computers. Service personnel who monitor and control through HMIs can be called by different names. In industrial process and manufacturing environments, they are called operators or something similar. In boiler houses and central utilities departments they are called stationary engineers. Different types of automation tools exist:

- ANN - Artificial neural network
- DCS - Distributed Control System
- HMI - Human Machine Interface
- SCADA - Supervisory Control and Data Acquisition
- PLC - Programmable Logic Controller
- PAC - Programmable automation controller
- Instrumentation
- Motion control
- Robotics

2.PRINCIPLE

2.1 Injection Moulding:

Injection moulding is a manufacturing process for producing parts by injecting material into a mould. Injection moulding can be performed host of materials, including metals, glasses, elastomers and most commonly thermoplastic and thermosetting polymers. Material for the part is fed into a heated barrel, mixed, and forced into a mould cavity where it cools and hardens to the configuration of the cavity. After a product is designed, usually by an industrial designer or an engineer, moulds are made from metal, usually either steel or aluminium, and precision-machined to form the features of the desired part. Injection moulding is widely used for manufacturing a variety of parts, from the smallest component to entire body panels of cars.Parts to be injection moulded must be very carefully designed to facilitate the moulding process; the material used for the part, the desired shape and features of the part, the material of the mould, and the properties of the moulding machine must all be taken into account. The versatility of injection moulding is facilitated by this breadth of design considerations and possibilities.

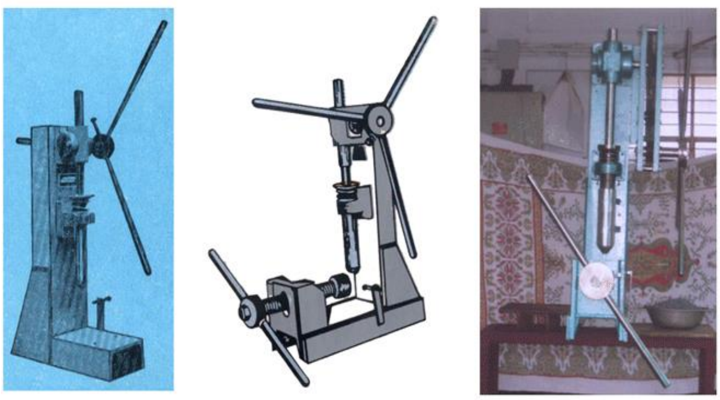


Fig 2 Injection moulding machine

For production of components by injection moulding the present method is a manual method. In this method the operator has to start the process for each and every cycle. The clamping and injecting have to be done manually. After the component is formed the person has to take the product out and send it for cooling.

In order to achieve good quality with less time we can go for PLC's. Here we need just one operator to look after the process. The main advantage of using this method is less time consumption, productivity is increased, once programmed no need to check frequently, batch inspection can be done, deployment of labour and because of all these assets the cost of the component can also be bought down..

2.2Programmable Logic Controller(PLC):

A programmable logic controller (PLC) is a digital computer used for automation of electromechanical processes, such as control of machinery on factory assembly lines, control of amusement rides, or control of lighting fixtures. PLC is a device that is capable of being programmed to perform a controlling function.

The programmable logic controller is solid-state equipment designed to perform the functions of logical decision making for industrial control applicationssystem.Control engineering has evolved over time. In past humans were the main methods for controlling a system

Ladder logic is the programming language used to represent electrical sequences of operation. In hardwired circuits the electrical wiring is connected from one device to another according to logic of operation. In a PLC the devices are connected to the input interface, the outputs are connected to the output interface and the actual wiring of the components is done electronically inside the PLC using ladder logic. This is known as soft wired.

In an automated system, the PLC is commonly regarded as the heart of the control system. With a control application program (stored with in the PLC memory) in execution, the PLC constantly monitors the state of the system through the field input device's feedback signal. It will then, based on the program logic, determine the course of action to be carried out at the field output devices. The PLC may be used to control a simple and repetitive task, or a few of them may be interconnected together with other host controllers or host computers through a sort of communication network, in order to integrate the control of a complex process.

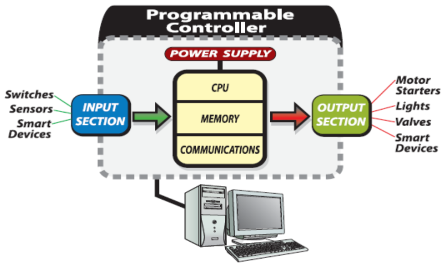


Figure4.3 Block representation of PLC

2.3 PLC PROGRAMMING:

One of the important features of PLC programming language is its flexibility. We can write the user program in anyone of the following forms:

- Statement List (STL)
- Control System Flowchart (CSF) or Functional block diagram (FBD)
- Ladder Diagram (LAD)

I) STATEMENT LIST

The statement list method uses mnemonic abbreviations in programming which consists of operation and Operand. A statement list provides another view of a set of instructions.The operation, what is to be done, is shown on the left.The operand, item to be operated on by the operation, is shown on the right.A comparison between statement list shown below, and the ladder logic shown on the previous page, reveals a similar structure.The set of instructions in this statement list perform the same task as the ladder diagram.

II) CONTROL SYSTEM FLOW CHARTS

The Control System Flowchart Method (CSF)/Function Block Diagram (FBD) use graphical symbols to formulate the control task. This method is preferred by that user who is familiar with the logic symbols/logical machine and process sequence. A Control System Flow Charts provides another view of a set of instructions.Each function has a name to designate its specific task. Functions are indicated by a rectangle Inputs are shown on the left-hand side of the rectangle and outputs are shown on the right-hand side.

III) LADDER LOGIC

Ladder diagrams are specialized schematics commonly used to document industrial control logic systems. They are called "ladder" diagrams because they resemble a ladder, with two vertical rails (supply power) and as many "rungs" (horizontal lines) as there are control circuits to represent. Ladder logic has been there for very long time, but it has not let outlived its usefulness.

Ladder Logic, (the PLC programming language) is very closely associated to relay logic. In relay logic there are both contacts and coils that can be loaded and driven in different configurations. As there are in ladder logic, but a lot more configurations are possible. However the basic principal remains the same. The program is written to switch the desired outputs for a given set of inputs energized.

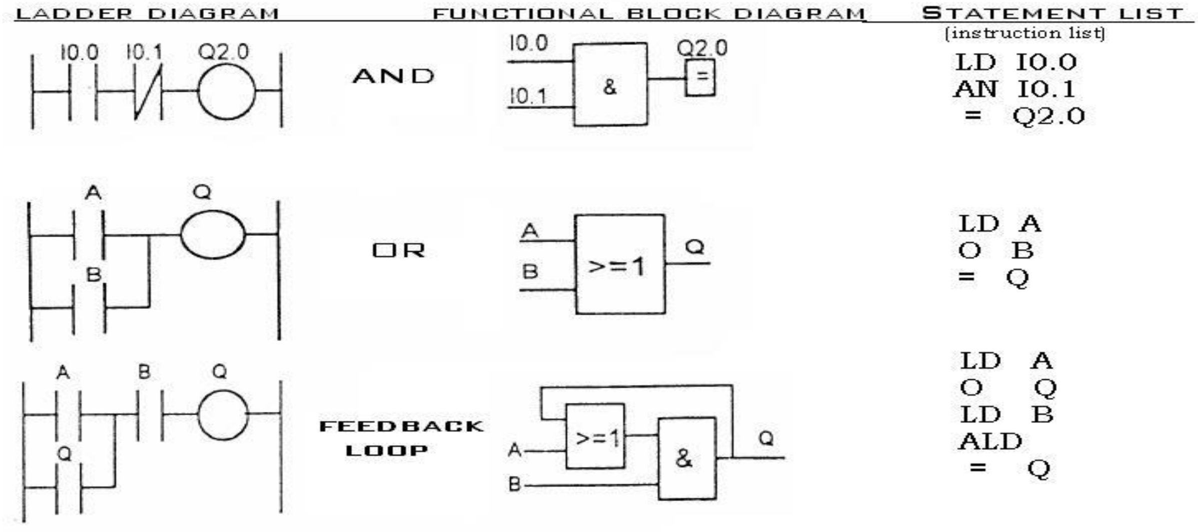


Fig 4 Example of Ladder Logic

The instruction set that is used to design ladder logic are explained below:

Type of instruction	Display Contact	Passes Power to Right
Normally Open	—| |—	When reference is ON.
Normally Closed	—|/|—	When reference is OFF.
Coil	— ( )—	It turns on when ever input is on
Set coil	—(S) —	when set the coil remains at on state
Reset coil	—(R) —	when reset coil is set, set coil resets

3. WORKING

3.1 Equipments Used:

The aim of project is to achieve automation of Injection Molding machine. To achieve this aim following equipment are needed:

(1) PC with Siemens Step7-300 software (2) Siemens Step7-300 PLC (3) Gas Compressor
(4) Air tank (5) Solenoid Valves (6)Cylinders (7) Motor (8)Relay Box (9)Sensors

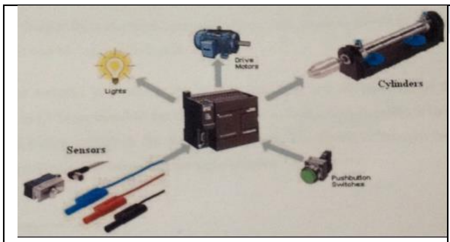
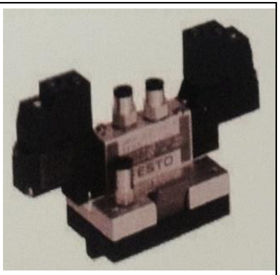
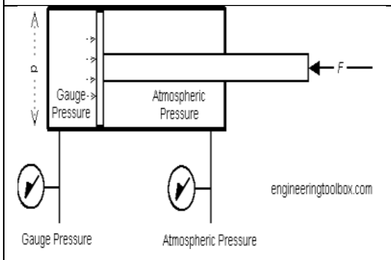
 Step7-300 PLC	 Gas Compressor	 A pressure tank	 Solenoid valve
 Single Acting Cylinder	 Motor	 Relay box	

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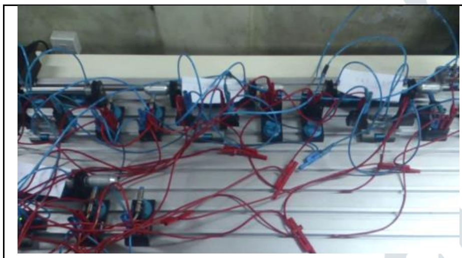
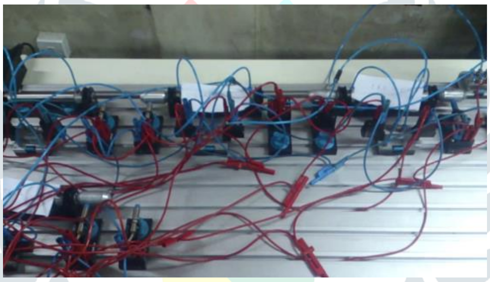
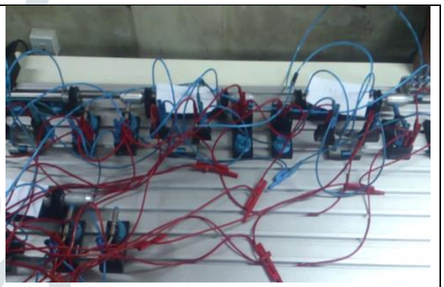
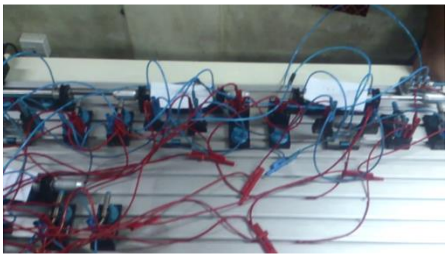
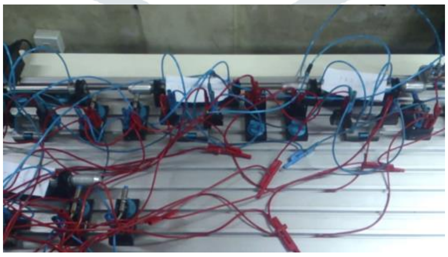
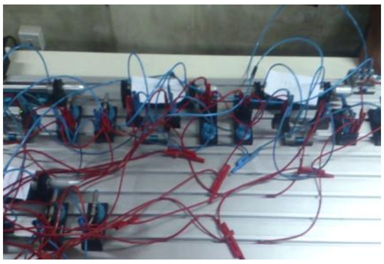
Fig 5 Equipments used

3.2 WORKING OPERATION

The operational sequence used in this project is as follows:
A+ B+ B- C+ C- A- D+ D-

1. The initial position of the unit refers to its position when all the cylinders are in returned position '+' refers to forward motion of cylinder and '–' refers to backward motion of cylinder.
2. Firstly, the cylinder A moves forward which is represented as A+ in the sequence to be performed. During this operation the cylinder moves forward and the Die gets clamped.
3. Now the cylinder B moves forward which is represented as B+ in the sequence. During this operation the cylinder moves forward and opens the lid for the granules to fall into the barrel.
4. Then, the cylinder B moves back which is represented as B- in the sequence. During this operation the cylinder moves backward and closes the lid.
5. Next, the cylinder C moves forward which is represented as C+ in the sequence. In this, the cylinder moves forward to move the ram or plunger to force molten plastic material into the Die.
6. Then, the cylinder C moves backward which is represented as C- in the sequence. In this operation the cylinder moves back so that the Ram or Plunger retrieves back.
7. Now, the cylinder A moves back which is represented as A- in the sequence. In this the cylinder moves backward and the Die is gets De-clamped.
8. Next, the cylinder D moves forward which is represented as D+ in the sequence. During this, the cylinder moves forward and ejects the component.
9. After this, the cylinder D moves back which is represented as D- in the sequence. In this process, the cylinder moves back and the ejector gets retrieved.

 The die gets clamped by cylinder A in Forward position	 The granules are allowed into the barrel by cylinder B in Forward position	 The granules are restricted into the barrel by cylinder B inBackward position
 The plunger is forced into the barrel by the cylinder C in Forward position	 The plunger is retrieved by cylinder C in Backward position	 The die is Declamped by cylinder A in Backward position

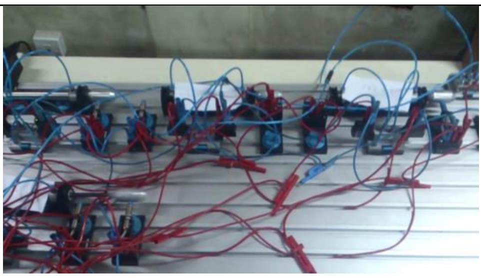
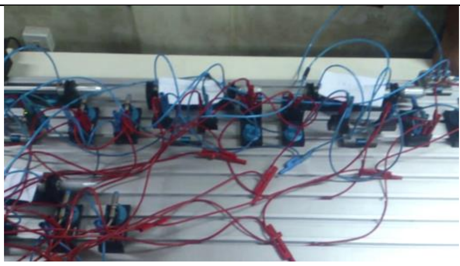
 The component is ejected by cylinder D in Forward Position	 Cylinder D is returns to Backward position

Fig 6 Automation of Injection Moulding Machine using PLC

4. DESIGN ANALYSIS

4.1 CALCULATION OF CYLINDER DIAMETER

4.1.1 DIAMETER OF INJECTING CYLINDER

Injecting thrust $= s \times Fs$

Where,

s=Injecting length * Thickness

Fs=Allowable shear stress

P=Applied Pressure

D=Injecting cylinder diameter

Injecting thrust $= (2 \times \pi \times t \times r) \times Fs$

= (2 × 3.14 × 0.5 ×0.1) × 400kgf

= 125.6kgf

Force exerted by cylinder = 125.6kgf

$\frac{\pi}{4} \times D^2 \times P$ = 125.6kgf

D = 4.47cm=1.76 inches

4.1.2 DIAMETER OF CLAMPING CYLINDER

Clamping force = 1.5 × injecting thrust

= 1.5 × 125.6kgf

= 188.4 kgf

Force exerted by cylinder =188.4kgf

$\frac{\pi}{4} \times D^2 \times P$ = 188.4 kgf

Diameter (D) = 5.47cm=2.15 inches

4.2 SPECIFICATIONS

Compressor- 2 stage air compressor delivering 1.2m per min at 9 bar

Cylinder- 5 Inch stroke length with 1 Inch diameter unless otherwise specified

Material Thickness- 0.04 Inches

Materia- Low carbon steel(0.2% to 0.3% C)

4.3 TIME TAKEN FOR THE PROCESS

1) TIME TAKEN FOR CLAMPING

Stroke length, S = 12.7cm = 5 Inches

Diameter of cylinder, D = 2.15 Inches

Diameter of Piston rod, d = 1.5cm = 0.6 Inch

Pressure, P = 8 bar = 117.6 psi

Time taken for outward stroke,

To = 0.00186 × S × D^2 ×(P+14.7)

= 0.00186 × 5 × 2.15^2 × (117.6+14.7)

= 4.8 sec

Time taken for inward stroke,

Ti = 0.00186 × S × $(D^2 - d^2)$ ×(P+14.7)

= 0.00186 × 5 × $(2.15^2 - 0.6^2)$ ×(117.6+14.7)

= 3.78 sec

Total time taken for clamping(Tc) = 4.8+3.78 = 8.58 sec

2) TIME TAKEN FOR GRANULES TO ENTER HOOPER

Stroke length, S = 12.7cm = 5 Inches

Diameter of cylinder, D = 1 Inch

Diameter of Piston rod, d = 1.5cm = 0.6 Inches

Pressure, P = 8 bar = 117.6 psi

Time taken for outward stroke,

To = 0.00186 × S × D^2 ×(P+14.7)

= 0.00186 × 5 × 1^2 ×(117.6+14.7)

= 1.04 sec

Time taken for inward stroke,

Ti = 0.00186 × S × $(D^2 - d^2)$ ×(P+14.7)

= 0.00186 × 5 × $(1^2 - 0.6^2)$ ×(117.6+14.7)

= 0.66 sec

Total time taken for granules to enter hooper (Tg) = 1.04+0.66 = 1.7 sec

3) TIME REQUIRED FOR INJECTING

Stroke length, S = 12.7cm = 5 Inches

Diameter of cylinder, D = 1.76 Inches

Diameter of Piston rod, d = 0.8 Inch

Pressure, P = 8 bar = 117.6 psi

Time taken for outward stroke,

To = 0.00186 × S × D^2 × (P+14.7)

= 0.00186 × 5 × 1.76^2 × (117.6+14.7)

= 3.2 sec

Time taken for inward stroke,

Ti = 0.00186 × S × $(D^2 - d^2)$ × (P+14.7)

= 0.00186 × 5 × $(1.76^2 - 0.8^2)$ × (117.6+14.7)

= 2.56 sec

Total time taken for Injecting (Ti) = 3.2+2.56 = 5.76 sec

4) TIME TAKEN FOR EJECTING

Stroke length, S = 12.7cm = 5 Inches

Diameter of cylinder, D = 1 Inch

Diameter of Piston rod, d = 1.5cm = 0.6 Inches

Pressure, P = 8 bar = 117.6 psi

Time taken for outward stroke,

To = 0.00186 × S × D^2 × (P+14.7)

= 0.00186 × 5 × 1 × (117.6+14.7)

= 1.04 sec

Time taken for inward stroke,

Ti = 0.00186 × S × $(D^2 - d^2)$ × (P+14.7)

= 0.00186× 5 × $(1^2 - 0.6^2)$ × (117.6+14.7)

= 0.66 sec

Total time taken for EJECTING (Te) = 1.04+0.66 = 1.7 sec

Total time taken for the process = (Tc+Tg+Ti+Te) = 17.74 sec

Time taken for manual process = 30 sec

Time taken for automated process = 17.74 sec

Therefore, the automated process output is at least one and a half the maximum output of an equivalent manual process.

4.4 COST ANALYSIS

S.NO	COMPONENT	NO OF ITEMS	COST PER PRODUCT	TOTAL
1.	Double acting cylinder	4	1600	6400
2.	5/2 solenoid valve	3	1500	4500
3.	Sensors	6	500	3000
4.	Compressor	1	21000	21000
5.	PLC	1	15000	15000
6.	Wires	15	2000	2000
7.	Pipes	15	1500	1500

Table 1 Cost Analysis

Total estimated cost 53400

4.5 COST COMPARISION

MANUAL INJECTION MOULDING MACHINE	AUTOMATED INJECTION MOULDING MACHINE
Total components produced per hour = 120	Total components produced per hour = 200
Total components produced per shift =8× 120 = 960	Total components produced per shift =8× 200 = 1600
Total components produced per day = 2 × 960 = 1920	Total components produced per day = 2 × 1600 = 3200
Total components produced per month = 25 × 1920 = 48,000	Total components produced per month = 25 × 3200 = 80,000
Number of labourers = 2	Number of labourers = 1
Number of Operators = 2	Number of Operators = 0
Labour charges = 2 × 2000 = 4000 Rs	Labour charges = 1 × 2000 = 2000 Rs
Operator charges = 2 × 2500 = 50000 Rs	Operator charges = 0
Material cost = 0.50 × 48,000 = 24,000 Rs	Material cost = 0.50 × 80,000 = 40,000 Rs
Total cost = 33,000 Rs	Total cost = 42,000 Rs
Cost per piece = 33,000/48,000 = 0.687 Rs	Cost per piece = 42,000/80,000 = 0.531 Rs
Selling price per piece = 1 Re	Selling price per piece = 1 Re
Total cost for process per month = 0.687 × 48,000 = 33,000	Total cost for process per month = 0.531 × 80,000 = 42,500 Rs
Total selling price = 1 × 48,000 = 48,000 Rs	Total selling price = 1 × 80,000 = 80,000 Rs
Profit per month = 48,000-33,000 = 15,000 Rs	Profit per month = 80,000-42,500 = 37,500 Rs

Table 2 Cost comparison

Pay back period = 53,400/37,500 ≈ 2 months

5. RESULTS AND CONCLUSIONS

5.1 RESULT

- The specification of Pneumatic setup for carrying out this project included a two stage air compressor delivering air at 1.2m/min at a pressure of 9 bar, a cylinder with 5 inch stroke length with 1 inch diameter, the thickness between the cylinder and piston is 0.04 inches or 0.10 cm, the material used is low carbon steel with 0.2% to 0.3% Carbon.
- The diameter of injecting cylinder is calculated as 1.76 inches.
- The diameter of clamping cylinder is calculated as 2.15 inches
- Total time taken fir the Automated process is 17.74 sec, comparatively about one and a half times lesser than time taken for manual process.
- The total estimated cost for the automation of INJECTION MOULDING PROCESS is approximately Rs 53,400.

- The estimated monthly profit for automated Injection moulding machine is Rs 37,500 which is more than that from manually operated Injection moulding machine.
- A program of PLC for LOW COST AUTOMATION of Injection moulding machine was successfully executed.

5.2 CONCLUSION

- The implementation of "LOW COST AUTOMATION" technique for automation of INJECTION MOULDING MACHINE will achieve excellent quality along with high rates of production which is very important for survival of a manufacturing unit.

- Nevertheless, the use of modern management method is of immense value in improving the productivity while it must never be regarded as end of itself, research and development must be encouraged.

- A good understanding of low cost automation technique is very essential. The application of LCA particularly in small industries with the usage of simple devices like limit switches, relay sensors, actuators of pneumatic and hydraulic including electric control to existing ordinary injection moulding machine will make it automatic at "LOW COST" to yield higher productivity, profitability, stability and also growth in building up of National economy of the country to a larger extent.

- Lastly, we feel that the challenges imposed by this project have helped us mature as engineers and give us a hand on experience working with PLC. Overcoming most of the challenges, if not all of them, has left us more confident and determined to take up more projects of this nature.

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