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"Automation of Heat Treatment Process line using PLC"

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Abstract - *An automated system is one in which a process is performed by a machine without direct participation of human worker. The material handling in heat treatment (annealing, hardening, quenching etc.) of steels, materials are brought from the storage place to heat treating furnace, then the materials are to be loaded into the furnace, and finally after the heat treatment process has been finished it has to be taken out of the furnace, this complete process has been done by manual if not automated, but in this project to overcome some disadvantages by manual handling we did automated material handling process line using programmable logic controller (PLC), complete process line shown by prototype model and hardware software interface.*

Key Words: Heat treatment, Material handling, PLC, Pneumatic Cylinders, Ladder diagram.

1. INTRODUCTION

Automation is the use of various control systems for operating the equipment without human intervention. Material handling is defined as "the movement, storage, protection and control of materials throughout the manufacturing and distribution process including their consumption and disposal". Automation reduces labor costs, decreases production cycle times, and increases product quality and consistency. In this paper mainly concentrated on heat treatment like, annealing, hardening, quenching material process.

1.1 OBJECTIVE

This paper describes the automatic control of material movement in the heat treatment processes for annealing and hardening. This developed model will provide flexibility to operator for material handling. The operator has to just enter the input as of either Annealing or Hardening through man machine interface. All the operations will occur automatically without any intervention in a prescribed sequence stored in programmable logic controller (PLC). This automated model helps- To reduce labor cost, mitigate the effects of labor shortages, reduce or eliminate routine manual and clerical tasks, and improves worker safety as well as increasing quality and quantity.

1.2 METHODOLOGY

The automated material handling system for loading and unloading material for annealing and hardening processes into the heat treating furnace consists of a ladder like structure which will be capable of moving in X, Y&Z coordinate. The input to the process will be given as of either A or H which indicates annealing and hardening respectively.

If input is A: The ladder picks up the material to be heat treated and loads it into the furnace and comes back to the safe position. At the end of the process, a signal actuates the ladder to pick the material from the furnace and places it outside the furnace for further processing.

If input is H: The ladder picks up the material to be heat treated and loads it into the furnace and comes back to the safe position. At the end of the process, a signal actuates the ladder to pick the material from the furnace and places it on the quenching mechanism. The quenching mechanism dips the material into the water for some time and takes it out for further processing. The ladder will have the following motions: X axis – Linear, Y axis – Lifting Z axis – Rotary. All these motions will be controlled using ladder logic through PLC.

2. EXPERIMENTAL SETUP

Some of the components used for setup purpose are as shown below.

Double Acting Pneumatic cylinder

Double Acting Pneumatic cylinder

5/2 Direction control valve

Limit switch

Motor

Pipe

Fig -1: components used for setup

Specifications are:

Pneumatic Cylinders
100 mm and 20 x 50 mm double acting, single pilot with 5/2 DCV and 24 V solenoid.
GEARED MOTOR – 3.5 rpm
SLIDES/RUNNER – 200 mm
Plastic Gears
Limit Switch – NC/NO Condition
Proximity Sensor– Range 5-8mm,10mm.

2.1 DESIGN OF THE MODEL

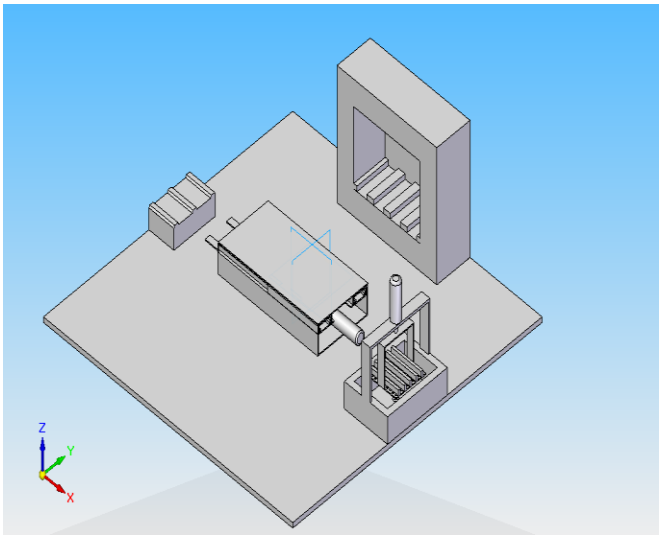


Fig -2: CAD model design

The CAD model design as shown in the Fig -2, and its working is as that of the methodology. The design is made through the software called solid edge.

2.2 PNEUMATIC CIRCUIT

Each cylinder has 2 limit switches for knowing the end positions of extraction and retraction except for the cylinder 2 which has a sensor for end of extension. In the home position, limit switches L1, L3, L0, L5 are in NC (normally closed) condition.

The working principal of cylinders and model is as below. The power is supplied to the circuit by switching on the start button. Cylinder extracts till the limit switch L2 and cylinder 2 extracts till sensor L4 to take the material on the fork. Now cylinder 1 retracts till limit switch L1. Only after the completion of retraction motor starts rotating from limit switch L0 till sensor L45. As the sensor L45 is sensed, motor stops. Now cylinder 1 retracts till limit switch L1 and cylinder 2 retracts till limit switch L3 to keep the material into the furnace. Then cylinder 1 retracts back till limit switch L1. Now timer TON (on delay timer) starts to give a time delay of 15 seconds. This time delay indicates the completion of heat treatment process. Now cylinder 1 extracts till limit switch L2 and cylinder 2 till L4 to take the material from the furnace. After this cylinder 1 retracts back and motor starts rotating to next $45^0$and it stops at limit switch L90. Now the cylinder 1 extracts till L2 and cylinder 2 retracts till L3 to keep the material into the mechanism provided. If the input were given as "hardening" hardening takes place by the extension of cylinder 3 till limit switch L6 to quench the material for some time. After this it retracts backs. If not in both the conditions motor rotates 90^0 back to the home position. The line diagram of the pneumatic circuit is shown in Fig. 3.

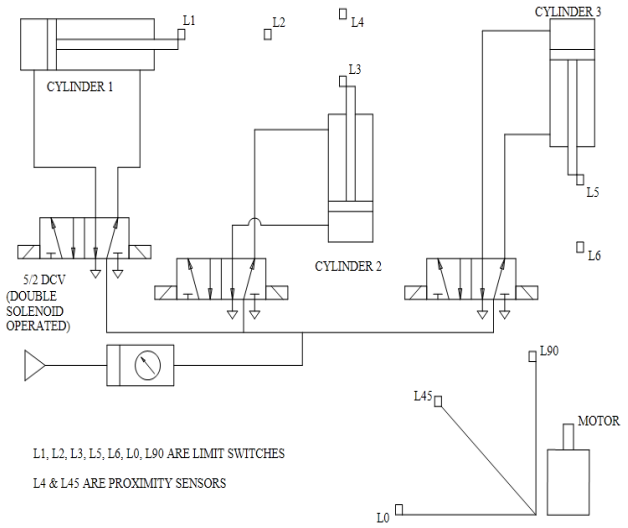


Fig -3: Operation of Pneumatic circuit.

3. PROGRAMMABLE LOGIC CONTROLLER

A programmable logic controller can be defined as a micro computer based controller that uses stored instructions in programmable memory to implement logic, sequencing, timing, counting and arithmetic functions through digital or analog input / output (I/O) modules, for controlling machines and processes.

3.1 REXROTH INDRA CONTROL L10 PLC

The Rexroth Indra control L10 PLC is as Shown in the Fig- 4 below and it also represents the parts of PLC. It consists of integrated display, operation, onboard I/Os, power supply and inline I/Os.

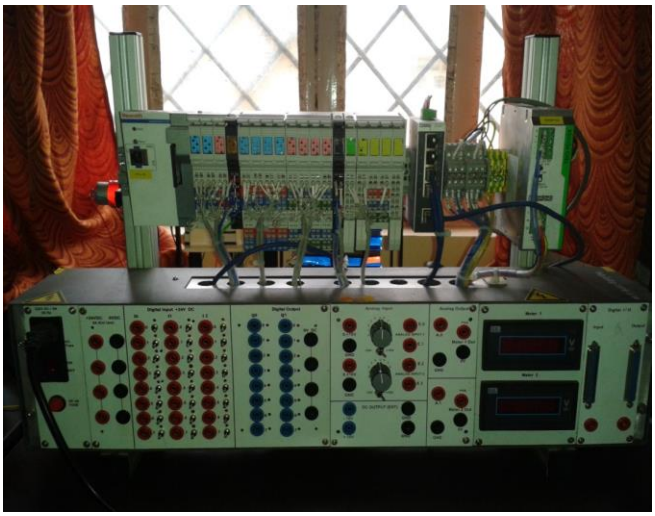


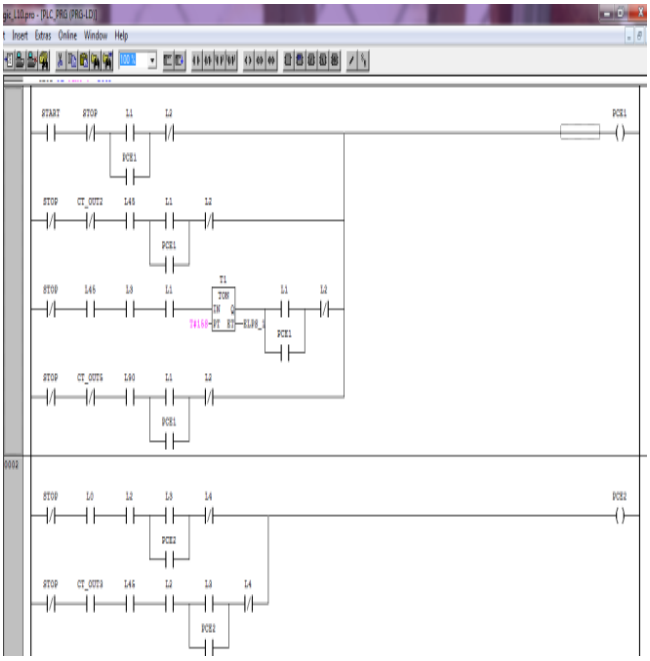
Fig -4: Operation of Pneumatic circuit.

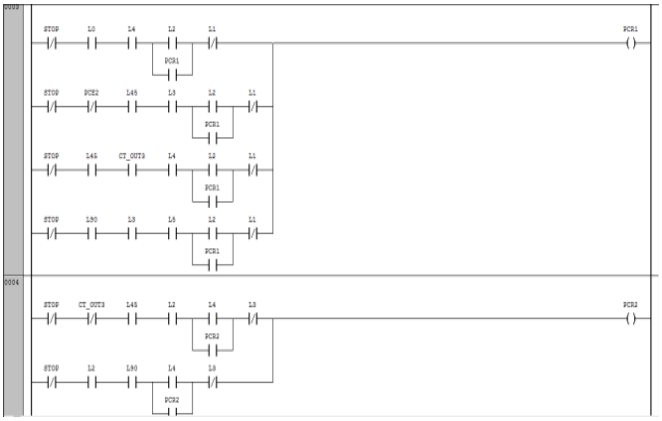
3.2 WORK FLOW PROCESS AND LADDER LOGIC PROGRAM.

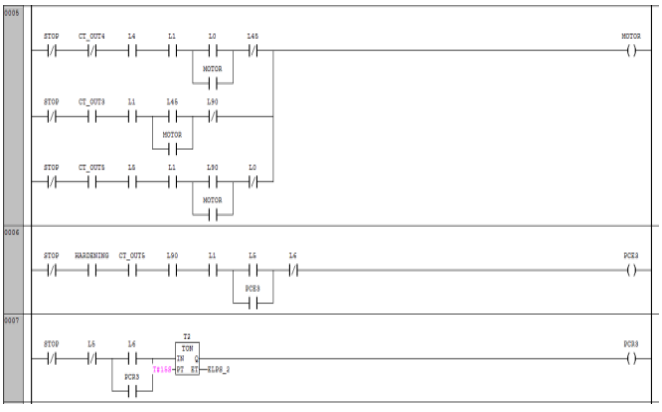
Initial positioning – press the push button. Cylinder (1) moves forward by the ON condition of 5/2 DCV (1) from Limit Switch L1 to till Limit Switch L2.Cylinder (2) moves up by the ON condition of 5/2 DCV (2) from limit switch L3 to till sensor L4. Cylinder (1) comes backwards by the OFF condition of 5/2 DCV (1) from limit switch L2 to till limit switch L1.

Motor Starts rotating from limit switch $L0^0$ to sensor $L45^0$ only when all conditions are satisfied, which rotated at an angle of 45^0. Cylinder (1) moves forward by the ON condition of 5/2 DCV (1) from Limit Switch L1 to till Limit Switch L2. Cylinder (2) moves down by the OFF condition of 5/2 DCV (2) from sensor L4 to till limit switch L3. Again cylinder (1) comes backwards by the OFF condition of 5/2 DCV (1) from limit switch L2 to till limit switch L1. Now the Timer TON is started and makes a delay of 15 sec. After that again cylinder (1) moves forward by the ON condition of 5/2 DCV (1) from Limit Switch L1 to till Limit Switch L2. Cylinder (2) moves up by the ON condition of 5/2 DCV (2) from limit switch L3 to till sensor L4. Cylinder (1) comes backwards by the OFF condition of 5/2 DCV (1) from limit switch L2 to till limit switch L1. Motor Starts rotating from limit switch $L45^0$ to limit switch $L90^0$ only when all conditions are satisfied, which rotated at an angle of 45^0. Cylinder (1) moves forward by the ON condition of 5/2 DCV (1) from Limit Switch L1 to till Limit Switch L2. Cylinder (2) moves down by the OFF condition of 5/2 DCV (2) from sensor L4 to till limit switch L3. Again cylinder (1) comes backwards by the OFF condition of 5/2 DCV (1) from limit switch L2 to till limit switch L1. Now the cylinder (3) moves down by ON condition of 5/2 DCV (3) from limit switch L5 to till limit switch L6. Motor Starts rotating from limit switch $L90^0$ to limit switch $L0^0$, and comes to initial position.

The ladder logic (PLC) for the sequence of the material handling process is as follows—







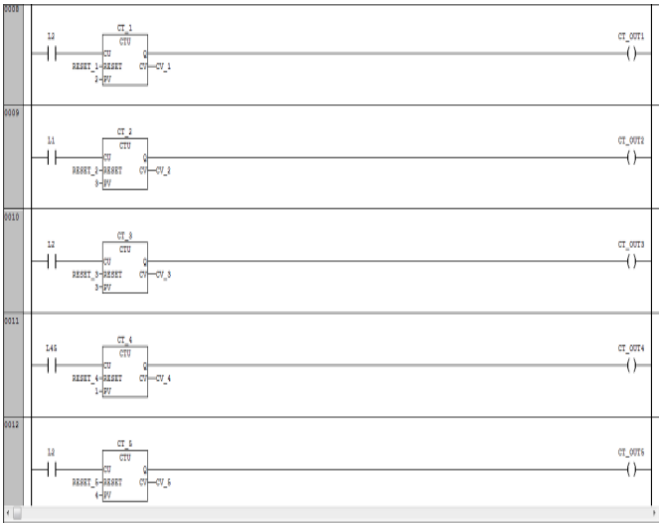


Fig -5: The ladder logic (PLC) for the sequence of the material handling process

3.3 FINAL ASSEMBLED MODEL

After inter facing with software hard ware with PLC and fabricated model demo has been shown, the final assembled model is shown in Fig -6.

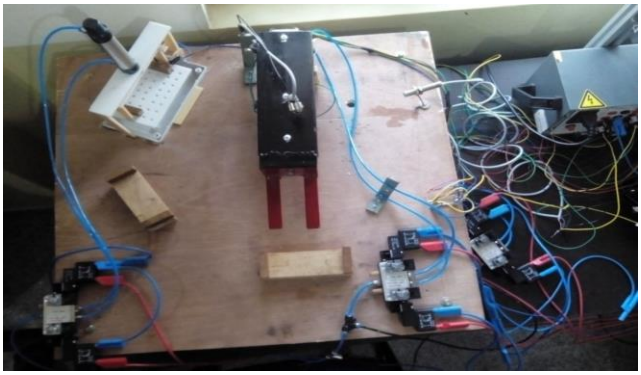


Fig -6: Assembled model.

4. RESULT

Automated heat treatment process line is one of the good examples for automation process. The main objective is to assemble the prototype model for automation of heat treatment process line. The proposed work describes the attempt made to implement some solution to problems in the material transport system. The result as tabulated in the table for all process.

Table -1: Results

Input	Condition	Output
L 1	ON	
L 3	ON	HOME POSITION
L 0	ON	
L 5	ON	
L 2	ON	CYLINDEER 1
L 1	OFF	EXTENSION
L 3	OFF	CYLINDER 2
L 4	ON	EXTENSION
L 1	ON	CYLINDER 1
L 2	OFF	RETRACTION
L 0	OFF	MOTOR ON
L 45	ON	
L 1	OFF	CYLINDER 1
L 2	ON	EXTENSION
L 4	OFF	CYLINDER 2
L 3	ON	RETRACTION
L 2	OFF	CYLINDER 1
L 1	ON	RETRACTION
L 2	OFF	CYLINDER 1
L 1	ON	RETRACTION

Now the delay timer TON starts, time delay of 15 seconds

L 2	ON	CYLINDEER 1
L 1	OFF	EXTENSION
L 3	OFF	CYLINDER 2
L 4	ON	EXTENSION
L 1	ON	CYLINDER 1
L 2	OFF	RETRACTION
L 45	OFF	MOTOR ON
L 90	ON	
L 1	OFF	CYLINDER 1
L 2	ON	EXTENSION
L 4	OFF	CYLINDER 2
L 3	ON	RETRACTION
L 2	OFF	CYLINDER 1
L 1	ON	RETRACTION

If input was given as hardening then,

L 5	OFF	CYINDER 3
L 6	ON	EXTENSION

Now the delay timer TON starts for the quenching mechanism.

L 5	ON	CYINDER 3
L 6	OFF	EXTENSION
L 5	ON	CYINDER 3
L 6	OFF	EXTENSION
L 3	OFF	CYLINDER 2
L 4	ON	EXTENSION
L 90	OFF	MOTOR ON
L 0	ON	REVERSE
L 4	OFF	CYLINDER 2
L 3	ON	RETRACTION

5. CONCLUSION

The present work is to improve the existing material transport system by reducing its drawbacks and increasing the level of automation in the industry level. The same has been done by changing the design by incorporating equipments like pneumatic cylinders, limit switches, sensors, direction control valves, etc. The use of PLC programming provides a skill for learning and developing the program for the problems arising through manual labors and others by automation. PLC provides an option for running the program online as well as offline mode which helps in reduction in errors and damage to the components in the industry.

SCOPE: The present work does not control the heat treatment process inside the furnace. If this is automated, then the whole system of heat treatment process will be automated which may give a very good products without any errors and defects and can be incorporated in the large scale industry level.

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