International Journal of Analytical, Experimental and Finite Element Analysis (IJAEFEA), Issue. 3, Vol. 4, Sept 2017
e-ISSN: 2394-5141, p-ISSN: 2394-5133, pp 59-64
DOI: 10.26706/IJAEFEA.3.4.20170907

PLC Based 2D Pneumatic Palletizer Design and Manufacturing

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***Abstract*—The proper material handling has a huge impact on production and distribution system. The use of pallets is efficient to handle small objects in large quantities so as to properly pack in cartons. The manual palletization is time consuming, expensive and also puts unnecessary stress on workers. The palletizers available are manual and microcontroller based. These solutions are not flexible enough to match production system requirements, and not cost effective as well. In this study the main aim is to incorporate flexibility with the help of PLC while being cost effective. It is proposed to have desired flexibility in pallet array size and layers in pallet. The proposed system has the pallet array size of 3×3 to 5×5 and single layer to 3 layers. The neatly and aesthetically designed control panel is used to select array size, layer control with advance PLC programming features. The algorithm is so designed it shall smoothly bridge other FMS components like conveyer. This system is not only cost effective but also adds the dimension of flexibility to palletization, so as to make it capable of handling future requirements including change in operation, etc. with the help of simple change in programming and/ or control and thus shall be avoiding expensive hardware changes.**

To design, manufacture a PLC based 2D pneumatic table top palletizer with the pallet array size of 3×3 to 5×5, consist of single layer to 3 layers and suitable control panel to indicate object presence in the process at particular stage, essential buttons, a special button to integrate the palletizer with supporting conveyor.

***Index Terms*—** Palletizer, Palletiser, Programmable PLC, Material Handling

I. INTRODUCTION

The manual material handling continues to be an inevitable component in mechanization and automation on Indian canvas, as of economic considerations, practical situations, or social consideration, etc., posing a great challenge to industrial productivity.

Manual Material Handling (MMH) of pallets generally causes health problems. Survey carried by the Mine Safety and Health organization (MSHA) 1999, USA shows that manual material handling causes increase in development of Musculoskeletal disorders (MSDs) by 68% , mainly low back sprains and strains.The automation of palletization is a required since it can reduce MMH and material handling activities could be more efficient. A recent market research carried on Logistic Service Providers (LSPs) 2009, US and Europe says that total number of pallet used in US is estimated
To 1.9 billion, and forecasts an increasing annual demand for new pallets about 3.5% per year until 2018.

The proposed system intended not only to reduce fatigue of operator by using specific height of operation but also to minimize human need to handle pallet with help of vertical motion, horizontal motion and rotational motion. It leads to minimize the operator efforts in pick and place operations involved in palletizing. The system also provides ability to reprogram with minimal or without hardware changes and having ease troubleshooting with help of software in compilation mode which also provides ability to check system logic ladder offline.

The MMH can cause mental and physical illness in human workers, decreasing material handling efficiency. Hence the prime objective of the dissertation work is to implement an alternative solution to palletizing which is economic, efficient, involving minimum repair & maintenance and flexible in operations so as to increase the productivity in automation [1].

In discussion on Evaluation of palletizing aid, It is reported that simple palletizing aid with ergonomic change in height of pallet reduces bending by the operator. In the tests consist of 16 identical boxes, weighing 10kg arranged in four layers and proceeded with 80 experimental trials. With the aid the incident of lower back pain in 200000 working hrs/yr drops from 0.086 to 0.022. Results from the discussion motivated to improve ergonomic factors of palletizer such as height and position of controls [2].

The significant concepts of (1) Logic for operation sequencing (2) Possible component list (3) Basic design idea for working system (4) Experimentation procedure as discussed Development of Automatic Pallet Handling System [3], leading to stacking of 1416 trays/hr, with 95% of pallet loading success rate with the unloading capacity of 1380 trays/hr, were analyzed and adopted in the present work.

In the Survey of Pallet Loading Problem (PLP) Consideration taken in to account are: (1) maximizing area of pallet used, (2) maintaining integrity of system during transportation, (3) efficiency of palletization, (4) access to palletized loads. The considerations are also taken in account during design of the system. [4]

The primary concepts of design and algorithm are adopted and developed from the discussion on physical model for robotics palletization. The discussion gives information regarding algorithm for demonstration system development with the help of a Scorbot ER-V robot and conveyor model with example, which gives 100% pallet utilization [5].

Algorithm and PLC logic ladder is further developed with help of deep look in the research investigation on Control System Design of Palletized Loading System based on PLC and fuzzy control technology for special purpose vehicle

developed on the basis of type II chassis of cross country automobile. It is used to illustrate method for developing the algorithm of pallet loading [6].

The rack design and suitable rack material for palletizer is discussed in research named: Design of Down Aisle Pallet Rack Structures and Behavior of Steel Storage Pallet racks. The discussion referred typical European practice for pallet racks, structure by Devies and Lewis. It helped not only in design and selection of material but also to better understand effect of beam to column joint, base plate joint modeling on total frame response at ultimate stress. Result during the study also mentioned that effect of the base plate joint is more remarkable [7, 8].

In deep study of A Robotic Palletizer Control Strategy Redesign author contributed towards simplification of process for pallet pattern generation, palletizer configuration according to required pattern and shown the way to connect sub systems with help of Human Machine Interface (HMI). It became helpful to understand the method of connecting subsystems like conveyor to palletizer [9].

A. Objectives

(a) The total dimension of the PLC based 2D pneumatic table top palletizer shall be less than 600×600 mm,
(b) The Palletizer shall be PLC based.
(c) The Palletizer shall have a START and STOP buttons with conventional meanings.
(d) The Palletizer shall have one to three layers of pallet.
(e) The Palletizer shall have pallet array size of 3×3 to 5×5.
(f) The Palletizer shall use counters to count object passing from particular location up to set value and to signal for further step process once set value is reached.
(g) The Palletizer shall have a suitable control panel to indicate object presence in particular stage of the operation, START and STOP button, interlock push buttons (if any) and button to integrate the palletizer with supporting conveyor.

II. Process Algorithm For The System

To execute the task of palletization the system needs to follow the algorithm:

i. Start
ii. Select array size
iii. Array selection sets the counter value for row former and row pusher according to array size
iv. Check object presence at conveyor
v. Set pick and place system at position A near to conveyor
vi. Pick up the object
vii. Turn pick and place system to position B near row former surface
viii. Extend row former cylinder up to desired position
ix. Repeat the process until complete row is formed
x. After complete row formation push the complete row with row pusher
xi. Repeat the process until complete layer is formed
xii. After successful filling of one layer move to next vacant layer
xiii. Stop

Flowchart on next page gives exact idea about the sequence of steps during execution of process

III. Layout Of The System

System layout consists of following major parts:

A. Rack

Rack is needed to hold the pallets and provide structural support. It intended to hold units/boxes having size of 60×60×60 and weighing 100gm each. As per requirements following components of rack are selected:

a. Aluminum Extrusion**:**

It is required for column structure, needs to be light weight and strong enough to hold the structure. Aluminum extrusions are light weight, strong and corrosion resistant (low weight to high strength ratio). Best suited for the structure because it offers required features like fixings, channels, and interlocking systems. Fixing and interlocking provision is used to connect aluminum extrusion column to base plate. Channel sliding provision is used for loading next pallet level.

Specifications: Cross section area of 40×40mm
4 bars of 400mm length and
weighing 300 gm each

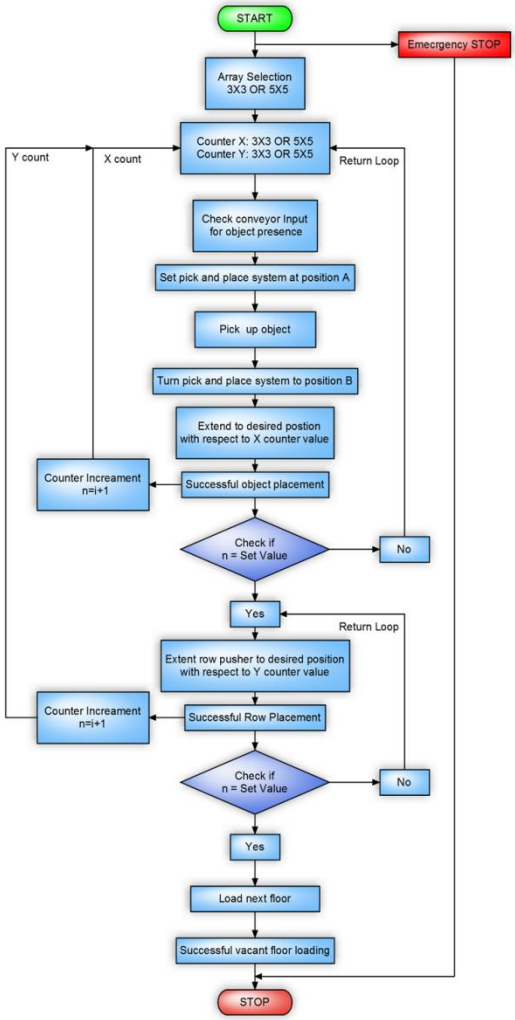

Figure 1: Flow chart for the system

Following figure shows profile drawing for aluminum extrusion, all dimensions are in mm.

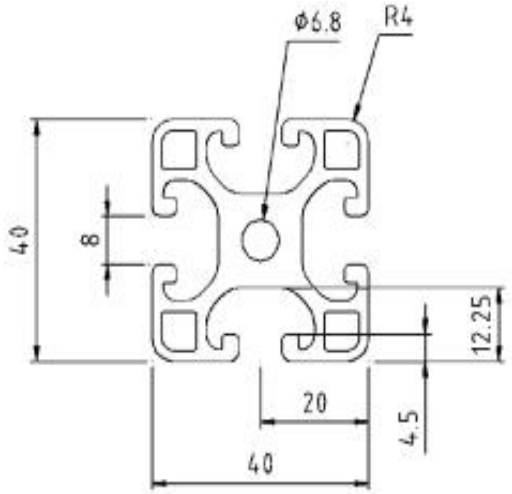

Figure 2 : Aluminum profile

b. Base Plate (Layer Forming Area):

Base plate is horizontal flat surface is used to place the units and form the pallet; basically it is support for units against gravitational force. Used acrylic sheet as it consist higher impact strength, higher durability, higher overall life as compared to other plastic materials and it is lighter as compared to steel plate with adequate strength required.

Specifications: Dimension 600×600×4mm
With 40×40mm square sized cuts on each
Corner for column fixings
3 plates weighing 500gm each

Following figure shows the layout of base plate, all dimensions are in mm.

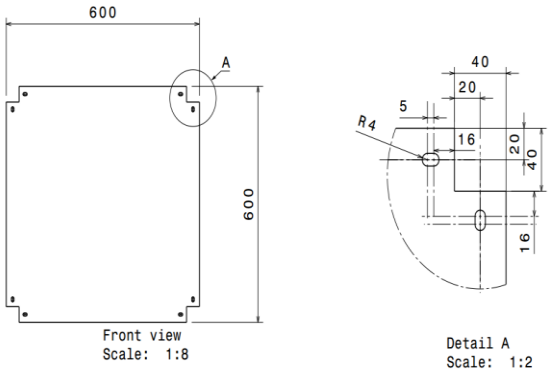

Figure 3: Base plate layout (Layer forming area)

B. Row former

It is area of palletizer where product is oriented to make the pattern. Needs to support units and provide lower friction surface where product allowed sliding to form units row. Acrylic sheet used for the purpose along with aluminum extrusion support as acrylic sheet provides necessary support for units and its low friction surface allowed sliding units over it to form a row of units as per requirement.

Specifications: i) Acrylic sheet: Dimension
600×120×4mm weighing 100gm
ii) 2 Aluminum extrusion 40×40 cross section area and 600 mm length and weighing 400gm each

Following figure shows the layout of acrylic sheet working surface, all dimensions are in mm.

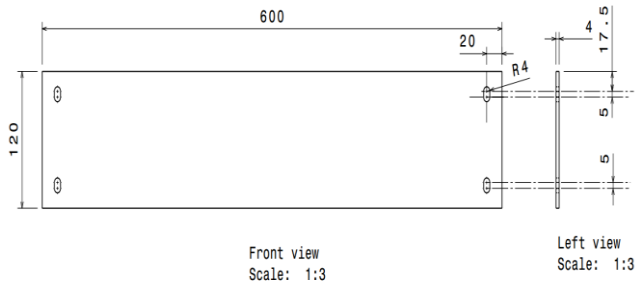

Figure 4: Row former surface

C. Pick and place system

The system is needed to pick up and hold unit from in feed conveyor, unit is 60×60×60mm in size and weighing 100gm. Further it needs to rotate 90 degree and extend forward to desired location and release the unit at it. The system is made up of 3 parts: a) Pneumatic linear cylinder, b) Pneumatic rotary actuator, c) Electromagnetic holder

a. Pneumatic linear Cylinder:

Required for linear motion for positioning the object at desired position required displacement for the system is 400mm, hence 500mm displacement cylinder is used with 3/2 Direction Control valve.

Specifications: Company: SMC
Type: single rod double acting
Stroke: 500mm
Bore size: 25mm
Operating pressure: 0.5-10bar
Weight: 580gm

Support plate is need for the cylinder to provide structural support and fixings with rotary actuator. Steel plate is used for the purpose of size 580×60mm and 4mm thickness. Schematic diagram for design of cylinder support plate as bellow:

b. Rotary actuator

Rotary actuator is needed 90 degree angular motion used during pick unit from conveyor and move it to row former, the motion is controlled with 3/2 Direction Control valve.

Specifications: company: SMC, Size: 20
Rotating angle: 360 degree, Shaft type: single shaft
Operating pressure: 0.5-10bar, Weight: 1200gm

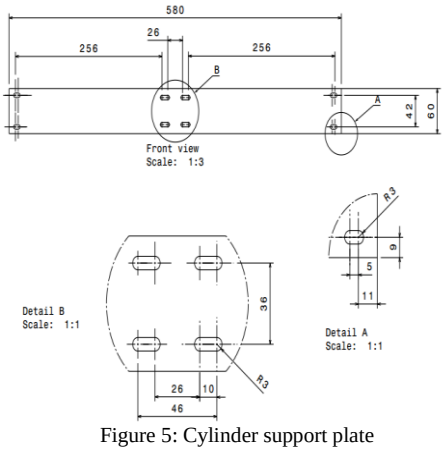

Figure 5: Cylinder support plate

c. Electromagnet:

Electromagnet is needed to pick the unit from conveyor and hold it until the desired position reached, once desired location is reached electromagnet have to release the unit. Need is to hold object of 100gm and pick up range of 5mm. The electromagnet used possesses following specifications:

Specification: dimension: circular cross section area of 20 mm radius and 18mm height
Voltage: 24v
Current: .33A
Lifting power: 5N/2.5kg

D. Row Pusher

The component is needed to push the row formed by row former and place at desire location in layer forming area/ base plate, linear displacement requirement is of 460mm. Requirement of component is to push row of 5 units/3units of mentioned specifications. It's motion with 3/2 Direction Control valve Pneumatic cylinder fits for the specified requirements as mentioned below:

Specifications: Company: SMC
Type: single rod double acting
Stroke: 500mm
Bore size: 25mm
Operating pressure: 0.5-10bar
Weight: 580gm

E. Sensors

Sensors are essential in order to detection of object and input feed to PLC with desired accuracy. Sensors are required in for the following requirements:

A) Position detection of Actuators (Row former linear cylinder, rotary actuator, row pusher cylinder)

i) Row former linear cylinder:
Read proximity sensor:
Cylinder mounted
Type: inductive type NPN/ No
Supply Voltage: 5-30v
Proximity sensor piston head position detection
Type: inductive type NPN/ No
Supply Voltage:5-30v
Size: M12
Sensing range: 5mm

ii) Rotary Actuator: 2 proximity switches required for position detection of rotary actuator shaft:
Read proximity sensor: cylinder mounted
Type: inductive type NPN/ No
Supply Voltage: 5-30v

iii) Row pusher linear cylinder:
Read proximity sensor: cylinder mounted
Type: inductive type NPN/ No
Supply Voltage: 5-30v
Proximity sensor piston head position detection:
Type: inductive type NPN/ No
Supply Voltage: 5-30v
Size: M12
Sensing range: 5mm

F. Control Panel

It is required to control and monitoring the process flow at particular stage.

Consist of following components:

i) Plastic Board: For the mounting of lamps and switches needs to cut profile for required mountings. Dimension of the board is 250×200×50mm.

ii) Switches: start button: 1× push to ON (NO) 18mm diameter switch
Stop button: 1× push to OFF (NC) 18mm diameter switch
Selector Switch: 1× 1Pole and 3 selector position 4mm diameter switch
Reset switch: 1× push to ON (NO) 18mm diameter switch

iii) Lamps: Process Lamp: 1× 24v 12mm diameter Green Lamp
Emergency Stop Lamp: 1 × 24v 12 mm diameters Red Lamp
Object position indicators: 10× 24v 12mm diameter Green Lamp

G. Pneumatic circuit Layouts

Pneumatic actuators are used in system plays major role considering advantages:

a. Availability of the source

Air is the essential thing in the pneumatic system, and as we all know, air is available in the world around us in unlimited quantities at all times and places.

b. Easy channeled

Air is a substance that is effortlessly conducted from one place to another through a small pipe, the long and winding.

c. Temperature is flexible

Air can be used flexibly at various temperatures are required at industry, through equipment designed for specific circumstances, even in quite extreme conditions, the air was still able to work.

d. Safety

The air can be loaded more safely than it is not flammable and does not short circuit occurs or explode, so protection against both of these things pretty easily, unlike the electrical system that could lead to fires.

e. Clean

The air around us are tend to clean without chemicals that are harmful, and also, it can be minimized or cleaned with some processes, so it is safe to use pneumatic systems to the pharmaceutical industry, food and beverages and textiles.

f. The transfer of power and the speed is very easy to set up

Air could move at speeds that can be adjusted from low to high or vice versa. When using a pneumatic cylinder actuator, the piston speed can reach 3 m / s. For pneumatic rotating actuators can spins at 30,000 rpm.

g. Can be stored

The air can be stored. Moreover, it can be installed so that the pressure boundary or the safety of the system to be safe.

Though considering the advantages improper handling can lead to leakage and noise, hence proper circuit is needed to form in order to efficient system operations. The system posses pneumatic components: Linear cylinder double acting single rod for X and Y axis displacements, rotating actuator,

Direction Control valves and flow regulator. The pneumatic circuit for the components is designed in order to achieve specified movements with efficient operation.

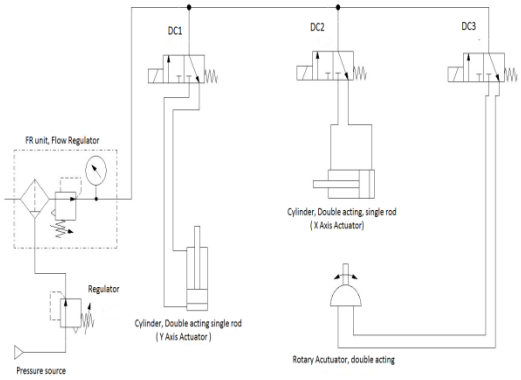

Figure 6: System pneumatic circuit

H. Wiring Layout

The wiring is an essential first phase to installing a palletizer system and configuring the devices so they can all communicate with each other seamlessly. It is done systematically to save time and money. The following figure gives more simplified idea about the wiring layout.

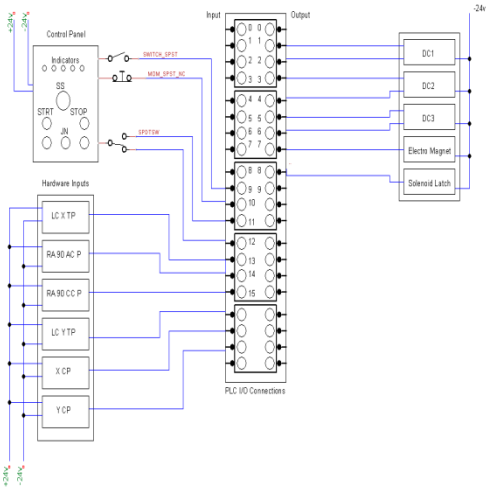

Figure 7: System wiring layout

Where;
LC X TP:
X axis displacement Linear Cylinder Tail Proximity sensor
RA 90 AC P:
Rotating Actuator 90 degree Clockwise Proximity Sensor
RA 90 CC P:
Rotating Actuator 90 degree Anticlockwise Proximity Sensor
LC Y TP:
Y axis displacement Linear Cylinder Tail Proximity sensor
X CP: X axis Counter Proximity Sensor
Y CP: Y axis Counter Proximity Sensor
DC1: Direction control valve 1,
DC2: Direction control valve 2,
DC3: Direction control valve 3.

IV. PROGRAMMING

a. PLC

The batch process of units is sequential in nature, requiting time or event based decisions. PLC is used as total solutions to a batch problem rather than just a tool. In batch process savings are developed principally from reduced cycle time and scheduling. Cycle automation provides rigid control enforcement to eliminate human errors and to minimize manual interventions. Increased efficiency in scheduling is to be expected with maximum utilization of equipment and reduction of fluctuating demands on critical equipment.

In system Allen Bradley ML 1400 PLC is used for automatic control of equipments, having 20 inputs and 12 outputs. The PLC ensures that equipment cannot be started unless all the permissive conditions for safe start have been established. It also monitors the conditions necessary for safe running of the system and trip the equipment whenever any abnormality in the system is detected.

PLC is implemented in system due to following facts taken into account:

1. It is very fast
2. It allows system to change in process logic i.e. flexibility
3. It increases reliability of system.
4. Lowers overall power consumption of system.
5. Adds system facilities in fault finding and diagnostic.
6. Adds good documentation facilities to the
7. Counters and timers can be added.

b. I/O definition and programming

I/O definitions plays role of bridge between the plc and physical setup of the system. It allows to system program to communicate with switches, sensors as inputs and actuators as outputs. At first total inputs and outputs of system are identified. Once physical address is acquired we can start programming with the addressing of the physical address on memory. It is done carefully and systematically so as to avoid any errors and mistakes generally happens at the time of programming due to the wrong addressing. As shown in table bellow, purposefully physical blank addresses are kept in order to further connections of subsystem like conveyor.

c. Programming

RSlogix 500 software is used for the programming purpose which is capable of offline logic failure detection. Following programming is implemented in order to achieve system work done.

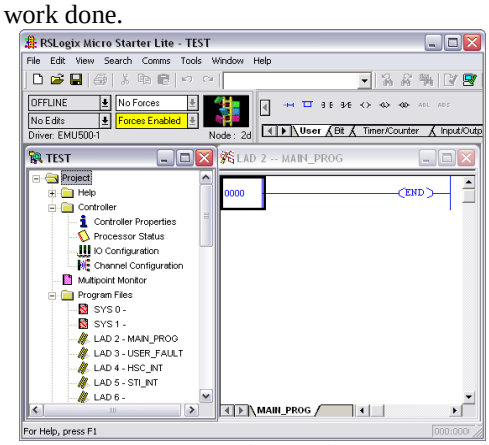

Figure 8: I/O Definition of System

TABLE I
INPUT ADDRESS

Sr No	Input	Description	Address
1		Reserved for conveyor	
2		Reserved for conveyor	
3		Reserved for conveyor	
4		Reserved for conveyor	
5		Reserved for conveyor	
6		Reserved for conveyor	
7		Reserved for conveyor	
8		Reserved for conveyor	
9	Start Btn	Start Process	**I**:0.0/9
10	Stop Btn	Emergency Stop	**I**:0.0/10
11	SS 4	Selector S/W 4 Array Mode	**I**:0.0/11
12	SS 5	Selector S/W 5 Array Mode	**I**:0.0/12
13	LCH-1:1F	Linear Cylinder Horizontal Tail Proxy (Forward Motion)	**I**:0.0/13
14	RA90-1:1A	Rotary Actuator Proxy 1 (Anticlockwise Motion)	**I**:0.0/14
15	RA90-1:2C	Rotary Actuator Proxy 2 (Clockwise Motion)	**I**:0.0/15
16	LCV-1:1F	Linear Cylinder Vertical Tail Proxy (Forward Motion)	**I**:0.0/16
17	P5(HCP)	Horizontal Counter Proxy	**I**:0.0/17
18	P6(VCP)	Vertical Counter Proxy	**I**:0.0/18

TABLE II
OUTPUT ADDRESS

Sr No	Output	Description	Address
1	RA 2-1	Rotary Actuator DC Valve anti-clockwise	**O**:0.0/1
2	RA 2-2	Rotary Actuator DC Valve clockwise	**O**:0.0/2
3	LCH 1-1	Linear Cylinder Horizontal DC Valve fwd	**O**:0.0/3
4	LCH 1-2	Linear Cylinder Horizontal DC Valve Bwd	**O**:0.0/4
5	LCV 3-1	Linear Cylinder Vertical DC Valve Fwd	**O**:0.0/5
6	LCV 3-2	Linear Cylinder Vertical DC Valve Bwd	**O**:0.0/6
7	EM	Electromagnet	**O**:0.0/7
8	SOL	Solenoid Latch	**O**:0.0/8
9		Reserved for conveyor	
10		Reserved for conveyor	
11		Reserved for conveyor	
12		Reserved for conveyor	

V. CONCLUSION

Physical setup, system wiring, pneumatic circuit connections and programming of the system are completed. The setup gives better idea of algorithm and real world constrains compared to theory.

In RSlogix 500 logic ladder and sensor inputs are checked and errors are eliminated. The system is geared up for experimentation, bug fixings as well as upgrades.

VI. FUTURE SCOPE

Experimentation is to be done on for different input values. Overall efficiency and accuracy of the system is to be calculated. After the successful experimentation and upgrades system mounting on table according to ergonomics is aimed.

For the future research purpose RFID tagging is will be a direction which will enable operator for real time unit monitoring in process and record keeping.

REFERENCES

[1] Sean Gallagher and John R. Heberger, "The effects of operator position, pallet orientation, and palletizing condition on low back loads in manual bag palletizing operations," Published by Elsevier B.V, 0169-8141, 25 March 2015.

[2] C.G. Drury, D.P. Roberts, R. Hansgenand and J.R. Bayman "Evaluation of a paltetising aid," Applied Ergonomics, vol. Ed.14.4, pp. 242-246, Dec.1983.

[3] Balsubramaniam Ram, "The pallet loading problem: A survey," International Journal of Producation Economics, vol. Ed. 28, pp. 217-225, June 1992.

[4] Yi Chich Chiu, Din Sue Fon and Gang Jhy Wu, "Development of an Automatic Pallet Handling System for Seeded Trays," Published by Elsevier Ltd, Biosystems Engineering, vol Ed. 93.2, pp. 123-138, Jan. 2006.

[5] Pavel Dzitac and Abdul Md Mazid, "A Robotic Palletiser Control Strategy Redesign," Published by IEEE 8th conference on Industrial Electronics and Application, 978-1-4673-6322-8, Aug. 2013.

[6] Nadia Baldassino, Claudio Bernuzzi, "Analysis and behaviour of steel storage pallet racks," Published by Elsevier B.V, vol. Ed. 77, pp. 391-401, 24 March 2000.

[7] M.H.R. Godley, R.G. Beale and X. Feng, "Analysis and design of down-aisle pallet rack structures," Published by Elsevier B.V, Computers and Structures, vol. Ed. 37, pp. 277-304, 24 July 2000.

[8] Chin-Sheng Chen, Balasubramanian Ram and Sanjiv Sarin, "Design and Development of a Physical Simulator for Robotic Palletization," Published by Pergamon Press plc, Computers ind. Engng, vol. Ed. 17 1-4, pp. 202-208, 1989.

[9] Valerio Elia and Maria Grazia Gnoni, "Designing an effective closed loop system for pallet management," Published by Int. J. Production Evonomics, S0925-5273(15)00182-6, 19 May 2015.

[10] J. Singh, E. Olsen, K. Vorst and K. Tripp, "RFID Tag Readability Issues with Palletized Loads of Consumer Goods, "Published by Wiley InterScience, Packing Technology and Science, vol. Ed. 22, pp. 431-441, 4 June 2009.