Design of the Roller Clamp Robotic Assembly System

S. S. Ngu, L. C. Kho, T. P. Tan, M. S. Osman

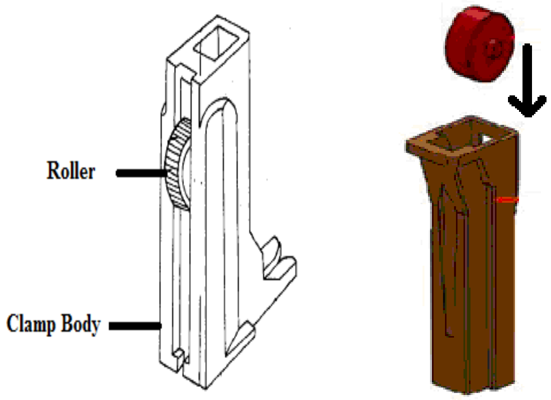
***Abstract*—**This work deals with the design of the robotic assembly system for the roller clamps. The task is characterized by high speed, high yield and safety engagement. This paper describes the design of different parts of an automated high speed machine to assemble the parts of roller clamps. The roller clamp robotic assembly system performs various processes in the assembly line which include clamp body and roller feeding, inserting the roller into the clamp body, and dividing the rejected clamp and successfully assembled clamp into their own tray. The electrical/electronics design of the machine is discussed. The target is to design a cost effective, minimum maintenance and high speed machine for the industry applications.

***Keywords*—**Machine design, assembly machine, roller clamp, industry applications.

I. Introduction

TODAY manufacturing companies need to increase efficiency and productivity in order to remain competitive. Robotic assembly systems have evolved as solutions to counter this challenge. To achieve this objective, the companies are willing to invest monies and time in research and development of innovative and creative manufacturing machines or assembly system. The potential benefits of robotic assembly systems are reducing the cost of product, labor, and waste. Besides that, it also increases the production quality, repeatability and work safety. Automation processes are greatly applied in manufacturing such as the semiconductor industry [1]-[3], food industry [4], electronics industry [5], textile industry [6] and the others.

A roller clamp is used for regulating the flow of fluids in flexible tubing used for intravenous (IV) fluid administration to a patient [7], [8]. It consists of mainly a clamp body and a roller as shown in Fig. 1(a). Traditionally, the roller clamps are assembled by human operators. The problems with human operators are lower and inconsistent production rates, high risk of product exposure to diseases, and long term working in this area may cause unnecessary fingers injuries due to repeating movements. The growing demand for roller clamp, accelerated time to market and shorter product life cycles have led to increasing demands on assembly machine and concepts. In order to meet these challenges, innovative approaches and technologies are required. Human operators' involvement in modern automatic manufacturing system should be minimized. The performance of currently available automation techniques is often insufficient. As a solution to this problem, the concept of a fully automated assembly system is proposed. Such systems should also assist the human worker instead of replace him. The robotic assembly system is mainly autonomous robots for handling, assembly and controlled transport systems. The innovated and custom designed manufacturing solutions are needed. The main purpose of the assembly machine is to insert the roller into the clamp body as shown in Fig 1(b).



(a) (b)

Fig. 1 The roller clamp

To start with the design, 8 main processes have been identified as shown in Fig. 2. The first step will be feeding the clamp body and roller to the robotic assembly system, this is the loading stations. Secondly, the clamp body supply rail will transfers the loaded body to the desired position and the body pusher cylinder will push the clamp body to the holder jig. The body pick and place module will then transfers the clamp body to the rotary turn table. Simultaneously, the roller will be loaded to the desired position. The rotary turn table holding the jigs with clamp body will then turn to transfer the clamp body to the next position. Here the roller will be inserted into the body. After that, the turn table will turn again. The unload pick and place module will detects the unloaded clamp body and place it into the reject bin. Lastly, the successfully assembled roller clamp will be collected at the collector bin.

S. S. Ngu is with the Electronic Engineering Department, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Malaysia (phone: +60-82-543200; fax: +60-82-543200; e-mail: ssngu@feng.unimas.my).

L. C. Kho is with Department of Information Science, Japan Advanced Institute of Science and Technology, Nomi, Ishikawa, 923-12 Japan. (phone: +81-761-51-1222; fax: +81-761-51-1149; e-mail: lckho@yahoo.com).

T. P. Tan is with the Act Multiaxis Sdn. Bhd., 43600 Seri Kembangan Selangor, Malaysia. (e-mail: alextan@actmatech.com).

M.S. Osman is with the Mechanical and Manufacturing Engineering Department, Faculty of Engineering, Universiti Malaysia Sarawak, 94300 Kota Samarahan, Malaysia. (msosman@ feng.unimas.my).

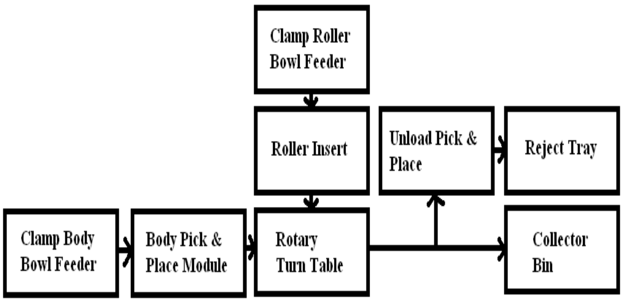


Fig. 2 Block diagram showing the essential processes of roller clamp assembly system

II. Robotic Assembly System

The robotic assembly system must be designed carefully to successfully achieve the manufacturing process discussed in the previous section. Proper system design reduce the construction cost, working area and the production cost of the overall manufacturing process.

A. Loading Stations

At the two loading stations as shown in Fig. 3, the clamp bodies and rollers are loaded simultaneously. Both the bowl feeders come with sound enclosure and hopper is optional. The clamp body bowl feeder will have the feed rate ranging from 100-120 pieces/min/track. The supply rail for the clamp body only has 1 track. The roller bowl feeder has the feed rate of 40-50 pieces/min/track and its supply rail comes with 5 tracks. The buffer sensor is installed at the supply rail to ensure the continuous supply of clamp body.

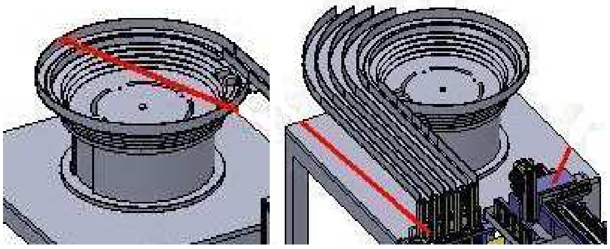


Fig. 3 (left) Clamp body loading station (right) Roller loading station

B. Clamp Body Pick and Place Module

Fig. 4 shows the clamp body pick & place module. The list of components in this module includes the up/down cylinder, pneumatic gripper, motorized rotator, body sensor, pusher cylinder, and supply rail. The body present checking sensors at the end of the supply rail are used to endure the body is in the correct position before being pushed out by the body pusher cylinder. The clamp bodies are pushed to the body holder jig. The motorized rotator is used to ensure accuracy and repeatability of the positioning. The clamp body will be transferred to the body holder jig on the rotary turn table. The individual controlled pneumatic gripper and pusher process continuously without being affecting each other. This means the failure of one gripper or pusher will not affect the process of another gripper or pusher. If any gripper or pusher fails to perform its task for 3 times continuously, alarm will be triggered to get the attentions of human operator to do the routine checks on the gripper or pusher.

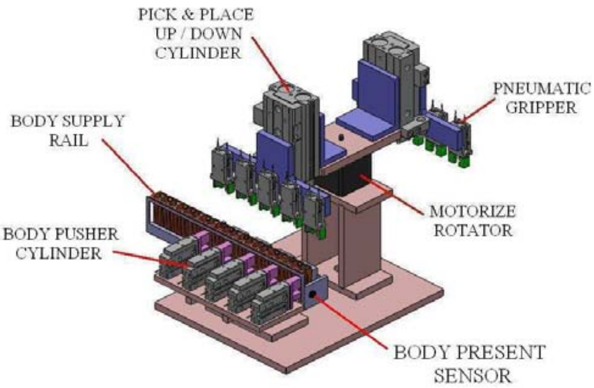


Fig. 4 Clamp body pick and place module

C. Rotary Turn Table

The diagram for rotary turn table is shown in Fig. 5. There are 4 rows of body holder jig which are fixed on the round plate. The distance between each holder jig must be equal/uniform. Holder jig in position 1 receives the clamp body from the body pick and place module. It will then turn 90 degrees to position 2 where the roller is inserted into the clamp body. At position 3, the clamp body will be picked up. At position 4 which is the checking station, the sensor will work to ensure no clamp body is left in the holder jig before the empty holder jig is turn back to position 1.

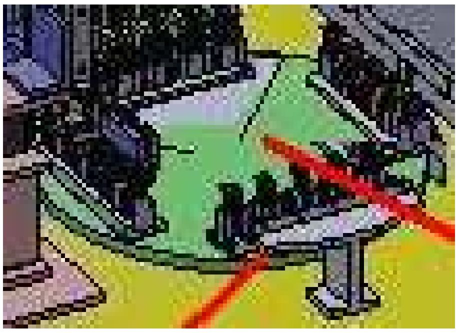


Fig. 5 Rotary turn table

As we can see from the Fig. 5 the holder jig is mounted on the rotary turn table to hold the clamp bodies. The holder jig design is shown in Fig. 6. It is designed for easy replacement and therefore reducing the maintenance cost. This is the part which will have the most frequent contact which involves holding, loading, and the unloading processes. The design of the holder jig is shown in Fig. 6.

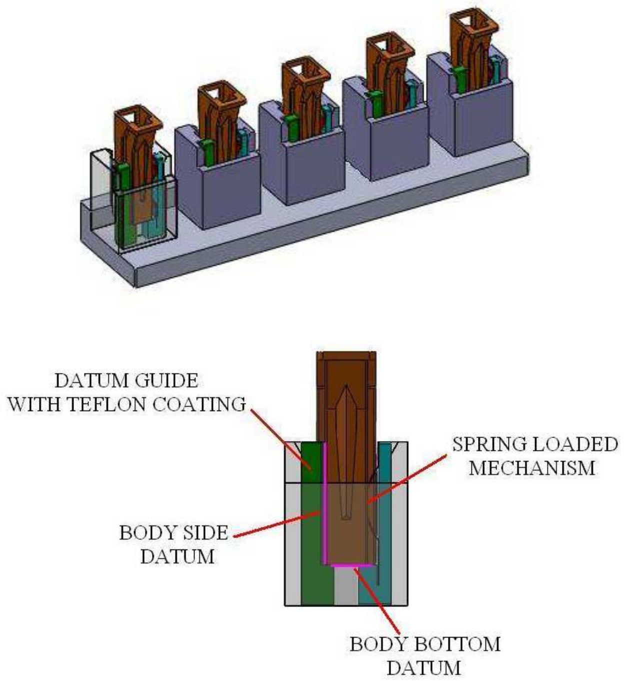


Fig. 6 Holder jig design

D.Roller Pick and Place Module

The diagram for roller pick & place module is shown is Fig. 7. The list of components in this module includes the buffer sensor, supply rail, press cylinder, body sensor, roller sensor, and supply cylinder. A buffer sensor installed on the supply rail will ensure the roller is continuously supplied. Again in this case, the roller supply are isolated which means individual supply and press failure will not affect the others. However, if one supply rail of roller press fails for 3 times continuously, alarm will be triggered and routine checking will need to be performed to identify the problems and solutions. The roller press force is adjustable using the regulator controller. The body present sensor will sense the presence of clamp body before the roller is supplied through the roller press action. If the clamp body is not sensed, the roller press will not be triggered and the roller will not be installed. This is crucial to prevent the roller from falling onto the machine and cause other machine failures. The roller in-position checking sensors are used to ensure that the roller is fully inserted into the body.

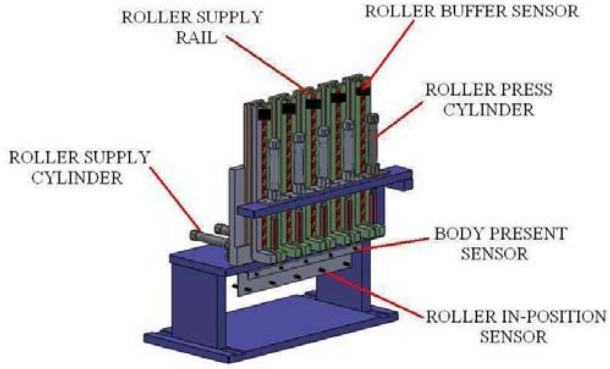


Fig. 7 Roller Pick and Place Module

E. Roller Clamp Unload Pick and Place Module

The unload pick and place module is shown in Fig. 8. The list of components in this module includes the vertical cylinder, horizontal cylinder, linear actuator, gripper, reject bin, and collection bin. Here, the motorized linear actuator will provide high speed, precision, repeatability and durability performance for the horizontal cylinder. Again, the individual gripper is made isolated, so each gripper is programmable to perform the reject function. 2 collection bins are provided to ensure continuous process when one of the bins is full.

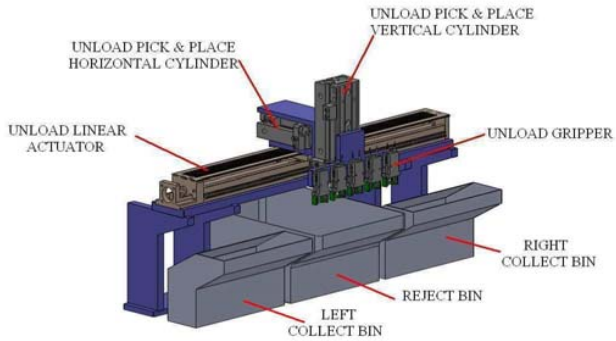


Fig. 8 Roller clamp unload pick and place module

F. Overall Machine Design

The overall machine design is shown is Fig. 9. It has the length of 1.7 m, width of 1.75 m and overall height of 1.75 m. It is completed with the protective frame enclosure which can ensure safe and clean operating environment for both the roller clamp and the human operator. The alarm light tower is added to indicate the machine's working condition. The electrical and electronics parts will be fixed in the space below the working table. The detailed machine parts are clearly shown in Fig. 10.

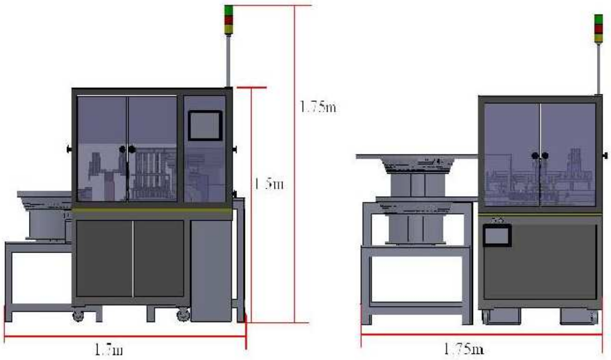


Fig. 9 Overall machine footprint

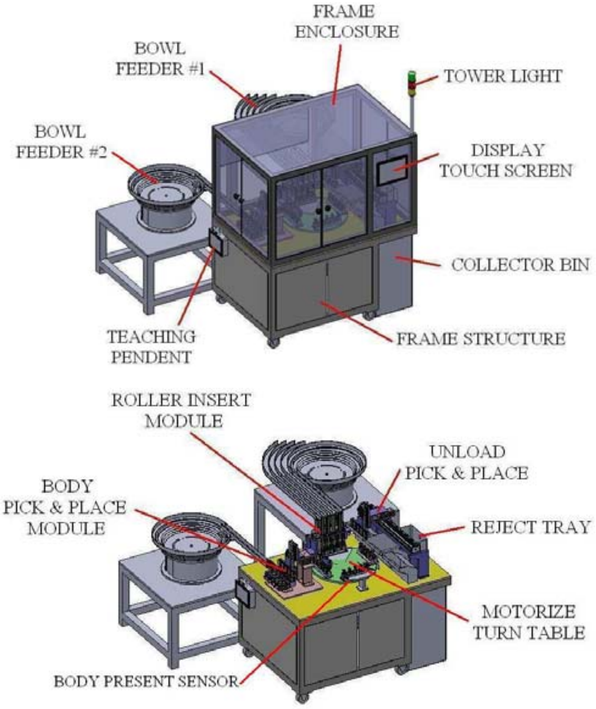


Fig. 10 Detailed machine parts

III. Machine Electrical Design

Another important aspect in machine design is the machine electrical design. Without the proper electrical and electronics design, the machine may not function as required. Good electrical and electronics design will ensure the optimization of the mechanical design. For this machine, the electrical design can be divided into few sections which are the AC distribution, DC distribution, PLC controllers input and output, circuit breaker connections, motor drivers, components wiring, sensors connection, incoming air connections, and pneumatic connections.

A. AC Distribution

The AC distribution design shows the connections mainly on the power supply connection to the live, neutral and ground connections. The connections of 3 pin plug and AC to DC converters are shown in Fig. 11. The circuit breakers are connected to protect all the components.

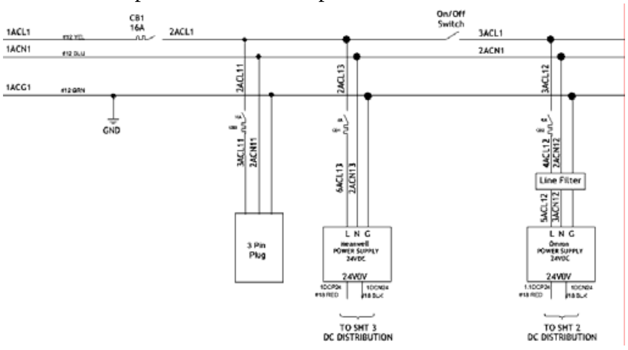


Fig. 11. AC distribution

B. Programmable Logic Controller (PLC) Wiring Diagram

One of the PLC design uses the Omron CP1H to control the machine. The input wiring diagram is shown in Fig. 12(top) and the output wiring diagram is shown in Fig. 12(bottom). Port 00 is connected to "Turning Arm Home Sensor", port 01 is connected to "Turning Arm Position Sensor", port 02 is connected to "Body Supply Home Sensor", port 03 is connected to "Vertical Cylinder Exit Sensor", port 04 connected to "Vertical Cylinder Return Sensor", and with the other ports that are connected to the "Gripper Open Sensors", "Gripper Close Sensor", and "Turn Table Home Sensor".

For the PLC output, it shows the connection of PLC to the output peripherals. While the input connects mainly to the sensors, the PLC output connects mainly to the motors. For examples, it shows the connection of "Body Supply Motor", "Pick and Place Motor", "Turn Table Motor", "Body Supply Motor", "Vertical Cylinder" and "Gripper Cylinder".

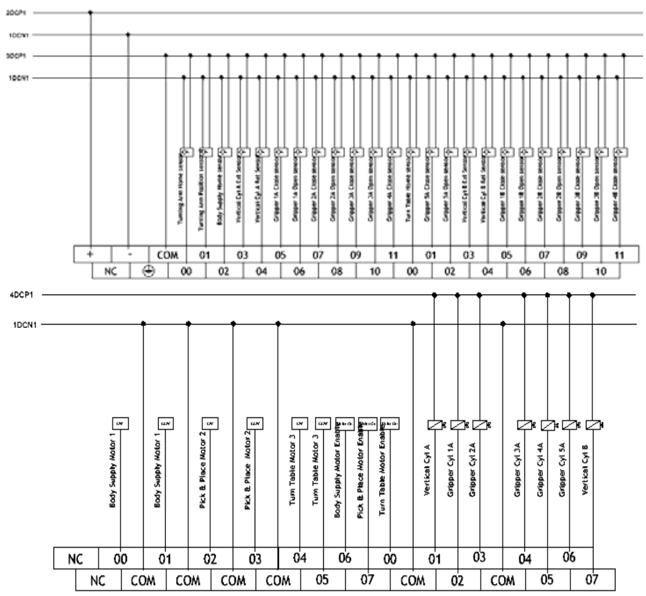


Fig. 12 (top) PLC CP1H input (bottom) PLC CP1H output

International Journal of Mechanical, Industrial and Aerospace Sciences
ISSN: 2517-9950
Vol:6, No:8, 2012

C. AC Circuit Breaker Connections

The connections of circuit breakers are shown in Fig. 13 with the 3 pin plug connected to the 10 A fuse, the Omron power supply connected to the 6 A fuse, and the Meanwell power supply connected to the 4 A fuse.

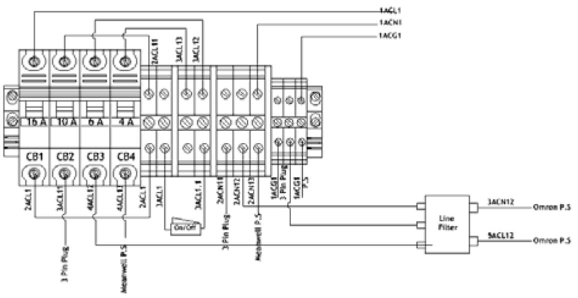


Fig. 13 AC circuit breaker wiring diagram

D. Motor Driver Pin

The body supply and body pick and place motor driver D-Sub 25 Male pin is shown in Fig. 14 (top) and Female pin is shown is Fig. 14 (bottom). The connections of the PLC address, pin number, color and IO name are listed in Table I.

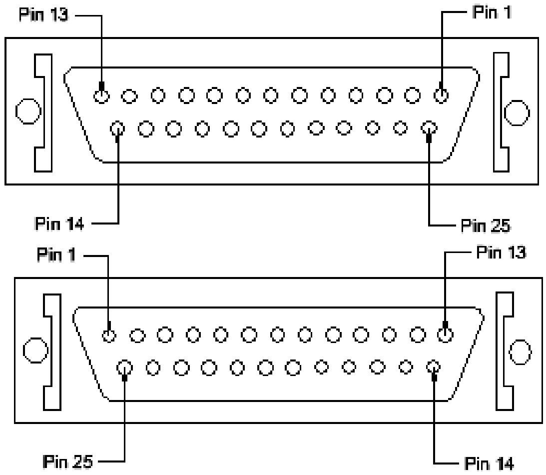


Fig. 14 Body supply and pick and place motor driver D-Sub 25 Pin (top) Male (bottom) Female

TABLE I
MOTOR DRIVER PIN CONNECTIONS

PLC Address	Pin	Color [a]	I/O
7.00	1	Red	Enable/Disable
7.01	2	Pink	Turn Table Rotate
7.02	3	Orange	Turn Table Rotate
7.03	4	Yellow	Station A Cycle Start
7.04	5	Purple	Station A Cycle Reset
7.05	6	Brown	Station B Cycle Start
7.06	7	Gray	Station B Cycle Reset
7.07	8	White	Station C Cycle Start
7.08	9	Blue	Station C Cycle Reset
7.09	10	Green	E-Stop
105.02	11	Light Blue/Black	Enable/Disable LED
1DCN1	14	Red/Black	
1DCN1	15	Pink/Black	
1DCN1	16	Orange/Black	
1DCN1	17	Yellow/Black	
1DCN1	18	Purple/Black	
1DCN1	19	Brown/Black	
1DCN1	20	Gray/Black	
1DCN1	21	White/Black	
1DCN1	22	Blue/Black	
1DCN1	23	Green/Black	
4DCP1	24	Light Blue	

D. Tower Light Connection

The tower light connections are shown in Fig. 15 and the connections to PLC address are listed in Table II.

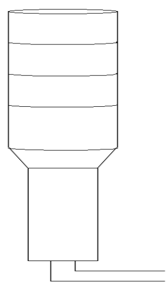


Fig. 15 Tower light connection

TABLE II
TOWER LIGHT CONNECTIONS

Tower Light Color	PLC Address
Red	104.07
Yellow	105.00
Violet	105.01
Black	4DCP1

E. Festo Sensor Connection

The connection of Festo sensor is shown in Fig. 16.

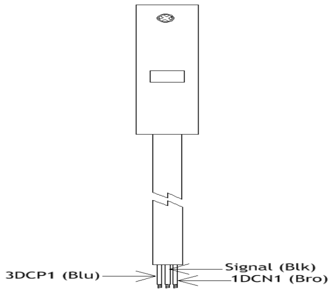


Fig. 16 Festo sensor connection

F. Body Supply Motor Driver

The connection of the body supply motor driver is shown in Fig. 17. The ports for clockwise (CW) rotation and counter clockwise (CCW) rotation are shown. The DC power supply connection is shown as well.

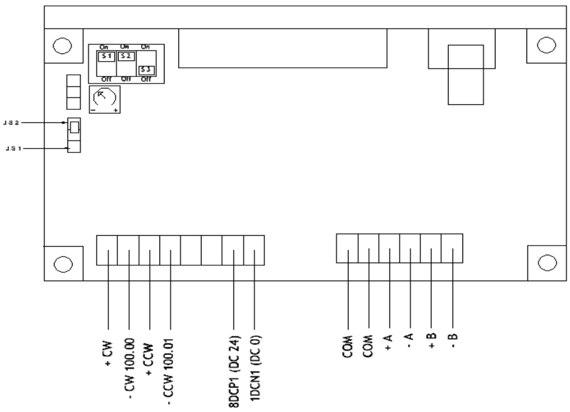


Fig. 17 Body supply motor driver

G. Incoming Air Connections

The connection for incoming air is shown in Fig. 18. The main air supply is transferred to the reservoir tank. Then it will go through air combination process, air filter, mist separator, regulator and pressure gauge. Then it will go through the manifold before being transferred to the body supply station, roller supply station, roller press station, roller vertical and upload station.

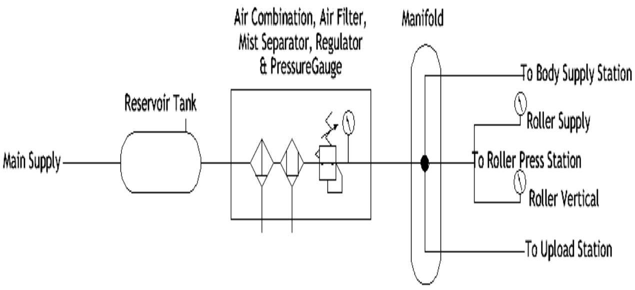


Fig. 18 Incoming air distribution

H. Pneumatic of Body Supply Connections

The connections for pneumatic of body supply are shown in Fig. 19. The diagram shows the connection of vertical cylinder and gripper used in body supply/loading.

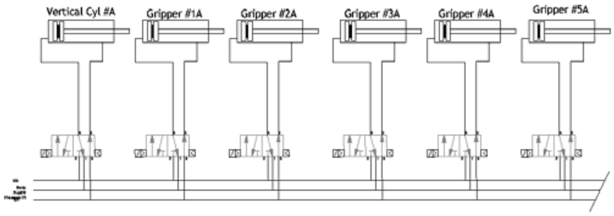


Fig. 19 Pneumatic for body supply distribution

IV. Machine Performance

The machine is constructed using the design information obtained. Fig. 20 shows the constructed machine and Fig. 21 shows the constructions/connections of the wiring and electrical/electronics components. Initial test run of the machine shows the production capability of 5000 pieces roller clamp per hour. If the robotic system runs for 8 hours per day and 22 days per month, the production capability will be 0.88 million pieces. Running for 16 hour per day and 22 days per month will yield the production rates of 1.76 million pieces per month. The electrical power required to run this machine is 220 VAC, 50/60 Hz single phase power supply. It requires current of 20 A and air supply of 6 bar.

Fig. 20 Roller clamp robotic assembly system

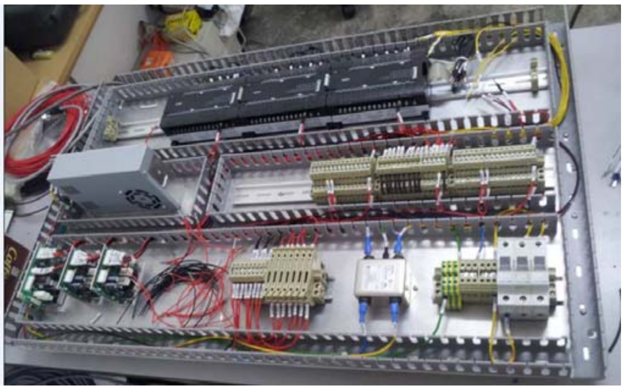


Fig. 21 The connections of electrical wiring and electronics components.

V. CONCLUSION

This paper reports on the cost effective solutions to the development of a robotic assembly machine aimed at assembling the roller clamp. The process design, mechanical design, and electrical/electronics design have been completed to make the machine successfully constructed. It can be used to assemble roller clamp at very high speed which means high production capability. Further work is to use the system to observe the weaknesses, break down time of this machine, and to deal with machine errors.

ACKNOWLEDGMENT

This research was supported by the Department of Electronics Engineering, Faculty of Engineering, Universiti Malaysia Sarawak.

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