PLC Controlled Roller Clamp Automatic Assembly Machine

S. S. Ngu
Universiti Malaysia Sarawak, ssngu@feng.unimas.my

L. C. Kho
Universiti Malaysia Sarawak, lckho@feng.unimas.my

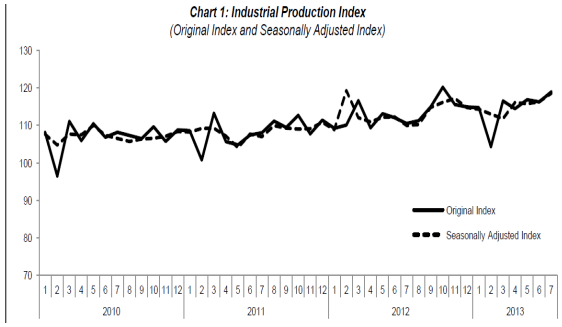
T.P. Tan
Act Multiaxis Sdn. Bhd., alextan@yahoo.com

ABSTRACT
This work deals with the mechanical design of the automatic assembly system for the roller clamps. The assembly system will be working in high speed condition with high yield. A rotary assembly machine is proposed in this paper. The function of different machine parts that performed the assembly processes is explained in detail. The machine control system is designed and analyzed. Then human machine interface (HMI) is presented. Experimental operation results show that roller clamps can be assembled at high speed and high efficiency thus reducing labor power and production cost.

Key Words: Assembly machine, Roller clamp, Automation, Machine design.

INTRODUCTION
In an automatic assembly process, discrete components are gathered for production. These components must be inserted in some specific sequences and positions so that the machine can handle them with ease. The applications of assembly machines are found in the automotive industry, consumer products (H. A. F. Almurib et al., 2012; A. N. Das et al., 2012; J. Li et al.) and manufacturing (S. S. Ngu et al., 2012; T. Giesen et al., 2012; V. J. Reddi et al., 2012). Fig. 1 below shows the steadily increasing demand on the manufacturing sector in Malaysia from year 2010 to 2013. In order to cope with the demand of the market, manufacturers will need to improve their production line to increase productivity.

Figure 1 Industrial production index of Malaysia (Index of Industrial Production Malaysia, 2013).

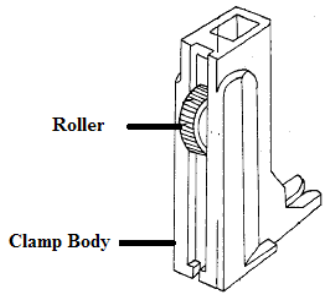


The needs of assembly machine are further emphasized for situations where it involved high production volume, intolerable production hazard, unsuitable parts size, or when the labor force is impractical from an operational or economic point of view.

ROLLER CLAMP

A roller clamp is used for regulating the flow of fluids in flexible tubing used for intravenous (IV) fluid administration to a patient (J. Tollefson et al., 2012; G. D. Pickar et al., 2007). It consists of mainly a clamp body and a roller as shown in Fig. 2. 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.

Figure 2 Roller Clamp Assembly Parts



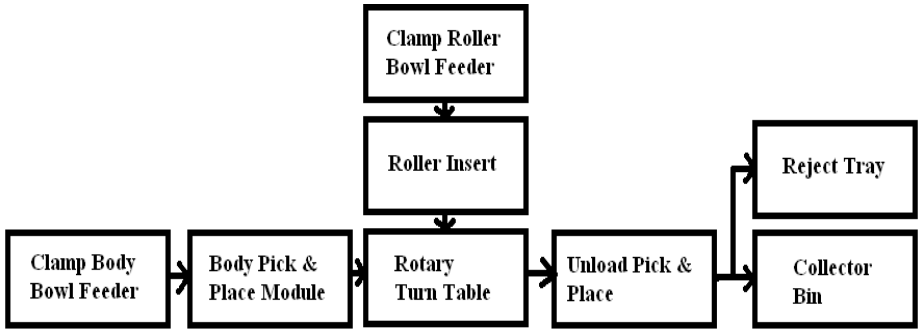
The performance of currently available automation techniques is often insufficient. As a solution to this problem, the concept of a fully automated assembly system is proposed. Such systems should also assist the human worker instead of replace him. The robotic assembly system is mainly autonomous robots 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.

CONCEPTUAL DESIGN OF MACHINE PROCESSES

To start with the design, the main processes were identified as shown in Fig. 3. Firstly, the roller clamp parts which are the rollers and clamp bodies will need to be oriented to the correct position and fed to the assembly machine. This will be the two separate loading modules of the machine. The bowl feeder will be orientating the parts. The roller clamp parts will be supplied to the machine using a rail transfer system.

Figure 3 Automatic Machine Processes



This will be followed by the insertion process where the roller will be inserted into the clamp body. A pick and place robot arm will be designed to move the clamp body from the rail system to the turntable. A holding jig will be designed to hold the clamp body. The clamp body will be transferred using the turntable for the insertion of the roller.

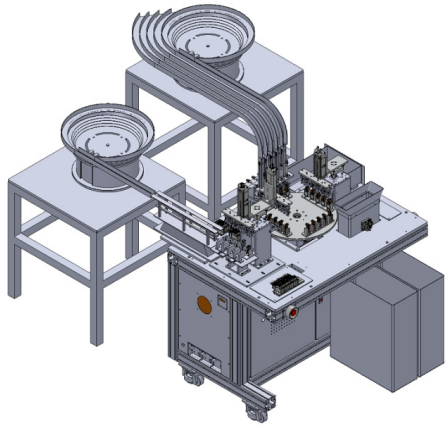
Finally, the inspection of the roller clamp using sensors will be completed. Roller clamps that passed the inspection will be collected at a bin while those failed will be collected by a separate bin or resent back to the second process for insertion process again. The roller clamps will be handles by another pick and place robot arm. A counter will be added to calculate the number of successfully assembled roller clamp.

MECHANICAL DESIGN

The mechanical design of the assembly machine is realized using Computer Aided Design (CAD) software. The system must be designed carefully to achieve the assembly processes discussed in the previous section. The factors of product size, weight, volume of production, product life cycle, future and current flexibility needs, human resources and return on investment are all considered while designing the machine. An overview of the machine designed is shown in Fig. 4. Two bowl feeders are needed to supply the clamp body and roller separately. The clamp body bowl feeder has the capability to feed the clamp body at the rate of

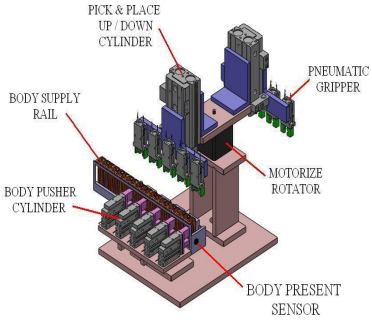
100-120 pieces/min/track and it only has one track. The roller bowl feeder has a feeding rate of 40-50 pieces/min/track and there are 5 supply rails.

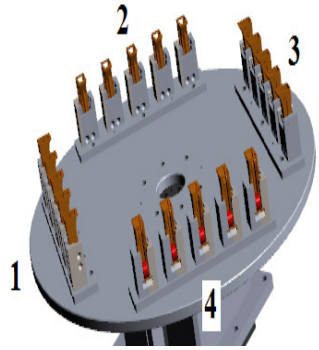
Figure 4 Overview of Roller Clamp Assembly Machine



A close in view of the clamp body pick and place robot arm specifically designed for this machine is shown in Fig. 5 (left). Once the body pusher cylinder pushes the clamp body to the desired position it is detected by the sensor, the vertical cylinder will move towards the clamp body. The pneumatic gripper will grip the clamp body and the vertical cylinder will move upwards. Then the rotator will turn and the robot arm will place the clamp body into the holder jig on the turntable. The machine turntable is shown in Fig. 5 (right). The clamp body is loaded at position 1 and roller is inserted at position 2. Position 3 is the location where inspection is done. Position 4 is just an idle position to make sure all the roller clamp have been removed before turning back to position 1.

Figure 5 (left) Pick and Place Robot Arm (right) Machine Turntable





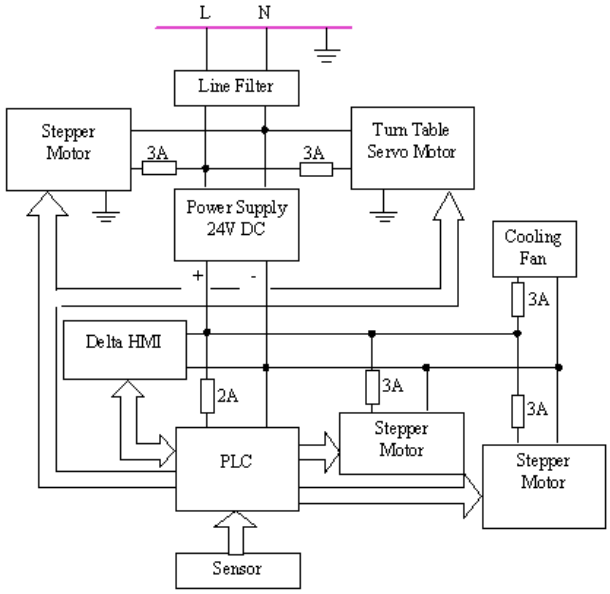
PLC SYSTEM

The roller clamp automatic assembly machine uses the PLC control system which includes the filters, analog to digital (AD) converter, stepper motors, turntable servo motor, HMI, PLC, sensors and so on as shown in Fig. 6. PLC is the main

5- 6 November 2014, One Helang Hotel, Langkawi / eISBN 9789670314198

processor where it receives signals from sensors or HMI, process the signal accordingly and produce the output signals that control the stepper motors and turntable servo motor. The conditions of the machine are reflected in the HMI panel simultaneously. The system parameters can be modified using the HMI upon request.

Figure 6 PLC System Diagram

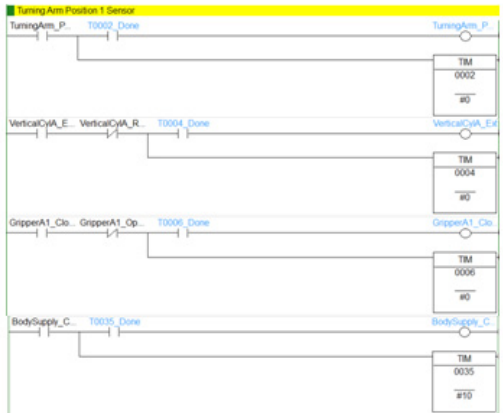


LADDER DIAGRAM

The automatic roller clamp assembly machine can be controlled to work in either the manual or automatic mode. For manual control, operator can press the processing button to control different machine parts to complete the assembly. For automatic control, the operator only needs to turn on the HMI devices and start the machine.

The ladder diagram is used to program the PLC so that the machine works according to the specification given. For successful PLC programming, all the input and output wiring will need to be labeled carefully. A complete PLC ladder diagram for this machine needs about 10000 lines/rungs of instructions. A sample on the ladder diagram construction for the control of the pick and place robot arm is shown in Fig. 7. The PLC ladder diagram is showing the control of the movement of motor, vertical cylinder, and the reaction of sensors. Note that this is not the full ladder diagram of the PLC.

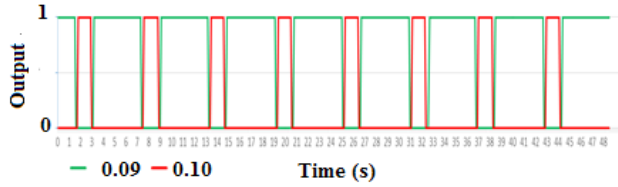
Figure 7 Sample Ladder Diagram for the Control of Pick and Place Robot Arm



PLC RESPONSE

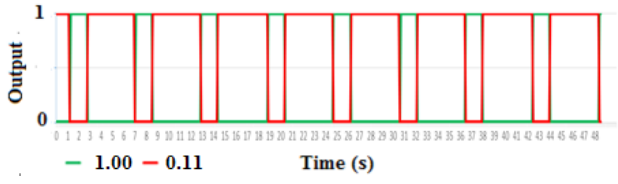
The real time response graph of the PLC for the machine is observed. Fig. 8 shows the response of the vertical cylinder for the pick and place robot arm. The green line is showing the cylinder extend signal and the red line is showing the cylinder retract signal. The cylinder is in extended position for longer time as it needs to wait for the response of the gripper to grip and release the clamp body. One complete cycle of extending and retracting the cylinder take about 6 s.

Figure 8 PLC Response Graph for Vertical Cylinder



The response graph for the pick and place robot arm gripper is shown in Fig. 9. The green line shows gripper close signal while the red line is showing the gripper open signal. One complete cycle of opening and closing the gripper take about 6 s.

Figure 9 PLC Response Graph for Gripper

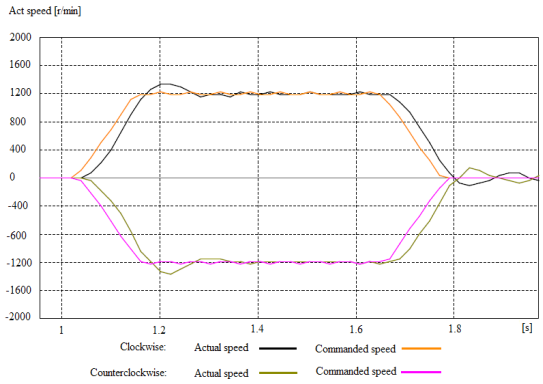


SERVO MOTOR RESPONSE

The servo motor used to control the turntable of the machine is operated at different speed to observe the different operation time. This is a preparation made

for the machine operator to change the production speed of the machine when it is needed. In Fig. 10, only the results of servo motor tested at 1200 rpm is shown. The motion of one complete cycle of the robotic arm takes about 0.8 s.

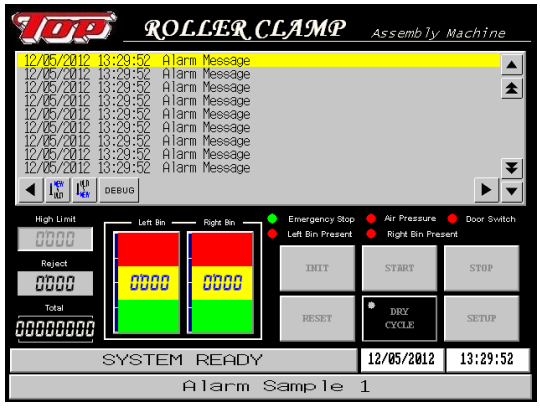
Figure 10 Servo Motor Response Graph



HMI

For convenient use of the machine a touch screen HIM is used. A graphical user interface (GUI) is created to control and monitor the machine, and for the operator to make necessary changes. When the machine is started and set to run at automatic mode, the main screen will be displayed at the HMI as shown in Fig. 11. From the main screen, the status of the machine can be observed. The number of rejected roller clamp, well assembled roller clamp (which can be divided into left and right bin), the total running quantity, date, and time can all me monitored. If everything is working well and the machine is initialized, the machine can now start run.

Figure 11 HMI Interface When Runs Under Automatic Mode

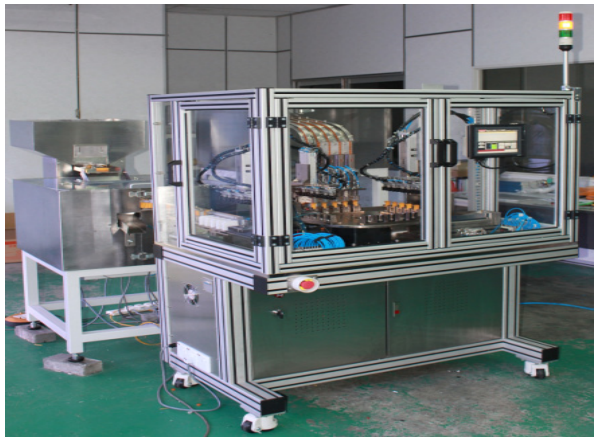


MACHINE PERFORMANCE

The machine is constructed using the design information obtained. Fig. 12 shows the constructed machine. 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 for 22 days per month, the production capability will be 0.88

million pieces. Running for 16 hour per day for 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 supply of 20 A and air supply of 6 bar. Defected outputs are observed to be around 200 pieces out of 5000 pieces, which gives an efficiency of 95%.

Figure 12 Constructed Automatic Roller Clamp Assembly Machine



CONCLUSSION

Experimental results show that the PLC controlled roller clamp automatic assembly machine designed and constructed can performs the assembly processes at very high speed and safe condition. The efficiency of the machine is high, and it reduces the needs of human power and operating cost.

ACKNOWLEDGMENT

The authors wish to thank Department of Electrical and Electronic Engineering Department, Faculty of Engineering, Universiti Malaysia Sarawak (UNIMAS). This work was supported in part by Small Grant Scheme (SGS) from UNIMAS.

REFERENCES

A. N. Das, R. Murphy, D. O. Popa and H. E. Stephanou. 2012. A Multiscale Assembly and Packaging System of Manufacturing of Complex Micro-Nano Devices, IEEE Transactions on Automation Science and Engineering, vol. 9, no. 1, pp. 160-170.

G. D. Pickar and A. P Abernethy. 2007. Dosage Calculations, 9th ed. Delmar Cengage Learning, pp. 439-488.

H. A. F. Almurib, H. F. Al-Qrimli, and N. Kumar, A Review of Application Industrial Robotic Design, 9th International Conference on ICT and Knowledge Engineering 2011, pp. 105-11, Jan 2012.

Index of Industrial Production Malaysia, Dept. of Statistics Malaysia, Malaysia April 2013.

J. Li, Q. Li, J. Zhou, and R. Martin, Performance Evaluation for Industrial Automation System Integration based on Enterprise Architecture Standards and Application in Cotton Textile Industry, 2011 International Conference on System Science, Engineering Design and Manufacturing Informatization (ICSEM), vol. 2, pp. 184-189, 2011.

J. Tollefson, T. Bishop, G. Vatson, and K. Tambree. 2012. Clinical Skills for Enrolled/Division 2 Nurses, 2nd ed. RR Dorbelley Asia Pirnting Solutions Limited, pp. 216-222.

S. S. Ngu, L. C. Kho, and T. P. Tan. 2012. Design of the Roller Clamp Robotic Assembly System, World Academy of Science, Engineering and Technology, vol. 6, pp. 163-169.

S. S. Ngu, L. C. Kho, T. P. Tan, and M. Anyi. 2012. A Novel Design of Tube Printing Machine. Applied Mechanics and Materials, vol. 134, pp. 35-39.

T. Giesen, C. Fischmann, F. Bottinger, A. Ehm, and A. Verl. 2012. Development and Optimization of Automated Dry-Wafer Separation, International Journal of Mechanical and Industrial Engineering, vol. 6, pp. 11-17.

V. J. Reddi, D. Z. Pan, S. R. Nassif, and K. A. Bowman, Robust and Resilient Designs from the Bottom-up: Technology, CAD, Circuit, and System Issues, 17th Asia and South Pacific Design Automation Conference (ASP-DAC), pp. 7-16, 2012.