Denso RC7M Robot Integration with PLC Based on Device-Net Communication in a Visual Line Of Automotive Industry

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Abstract. An automotive company that manufactures pistons integrates a DENSO-type robot into an existing control system. The visual process of controlling and checking the product quality control has the purpose gets a good product. Previously, the process was carried out conventionally through the eyes of Manpower. The visual inspection carries out by utilizing the robots they have. The desired goal is to reduce cycle time on the Visual line. Therefore, the author and the engineering maintenance team decided to replace the system on the visual line using a robot through integration with the existing HMI control system. The integration of this robot supports an auto-visual inspection scheme with the help of the Device-Net control system communication. After doing the trial process, the result is that the cycle time drops until 36%. This research paper applies to an automotive company in which cycle time is something critical point. The decreasing of cycle time becomes something urgent in a production process.

Keywords: Device-Net, integration, system control.

1 Introduction

An automotive company has various divisions to support the production process. The author and maintenance engineering division team make improvements that exist in the company. The purpose of this improvement is to increase the amount of production by decreasing cycle time. The process carried out on the visual line is stamping, moving, and inspecting the piston by the operator before packing it. Currently, the target for visual inspection and packaging is 4900 pistons per day which the maintenance engineering team hopes to increase to 9800 pistons per day. The value is equivalent to the expected target of 36% in the visual processing cycle time. Therefore, the authors and the maintenance engineering team strive to achieve the desired target are; (1). Robot integration with PLC; (2). Robot control by HMI. In conclusion, this project also makes work easier for operators to check in visually the piston. It expects to maximize the process up to the packaging process.

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2 State Of The Art and Theoretical

2.1 State Of The Arts

In this research paper, the author has conducted a study of several studies that were previously carried out either by other researchers or the author himself. The first paper belongs to Brusey. He wrote elementary use of networks in making a ladder diagram entitled Nonautonomous Elementary Net Systems and Their Application to Programmable Logic Control [1]. Meanwhile, communication technology takes a paper entitled The Design and Development of OMRON Multi-PLC Control System Based on Multi-net as a communication reference [2]. Meanwhile, the authors' research in papers [5] and [6] has initiated before this paper. In this paper, the author describes the communication and integration of robot use with the developed process in the industry.

2.2 Theoretical

Device-Net is an automatic communication device usually used in the industry by connecting control equipment in a communication network. This protocol uses CAN (Controller Area Network) as the technology backbone and defines the application layer for some controlled devices. Generally, this communication is in several control systems, including Omron system control. The communication control in Device-Net usually includes; communication characteristics, protocols used, and addresses. In this paper, several sources of previous research have used this type of communication.

Device Net uses CAN (Controller Area Network) as the communication protocol. CAN is a serial communication standard used by various devices to communicate with each other. Baud rate is the data flow rate that consists of many bits of data sent in a second. Network in a Device Net connects to up to 64 units of modules, including master units and slave units. Each node or unit connects directly to the master unit. The device-net setting parameter shows in Figure 1.

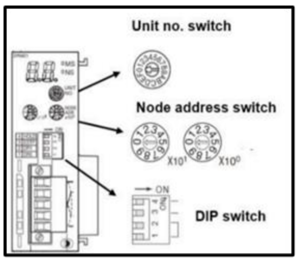
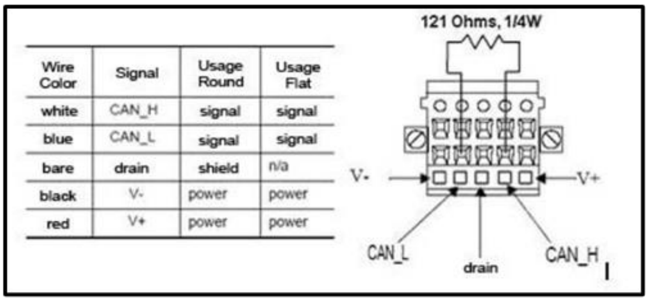


Fig. 1. Device-Net Setting Parameter.

Device-Net connects in various ways, such as Multi-drop and T-Brach connections. Parameters part unit number on the switch is at a value of 0 (zero). This value indicates that this device is a PLC module number 1 (one). The node address switch parameter is at a value of 0 (zero). Figure1 shows the other ways that this device will function as a master unit controller. The dip switch number 2 (two) set on parameter 500 kbps baud rate indicates the ON position. Figure 2 shows the need for an additional 121-ohm resistor between the CAN_L and CAN_H sockets. The resistor can reduce the reflection of communication data when it is transmitted.



Wire Color	Signal	Usage Round	Usage Flat
white	CAN_H	signal	signal
blue	CAN_L	signal	signal
bare	drain	shield	n/a
black	V-	power	power
red	V+	power	power

Fig. 2. Device-Net Connection.

Integration is a unity process of several components. All components are connected. In this paper, part of the components connects to a system. They are a robot, PLC, and HMI.

In this paper, the process of integrating robots and control systems is the main point. In the integration process, it is necessary to adjust the parameters of the pendant robot, CX-Programmer, and CX-Integrator. The parameters of the Denso RC7M Robot are (1). H/W setting in auxiliary I/O menu; (2). Setting robot as slaves device net address and baud rate used; (3). Large data I/O settings.

In the settings, CX-programmer determines the use of the program name, PLC type, and CPU as the elementary thing to do. After that, the communication settings with the Human Machine Interface (HMI) become settings in this software. The HMI communication uses the parameter settings on the CX-Designer. Three integration hardware devices (PLC, HMI, and Robot) on the CX-integrator software.

3 Experiment

3.1 The Robot's

Fig. 3. The robot's appearance.

The robot used in the line visual is the Denso RC7M robot. This robot work to pick and place pistons from the piston box onto a conveyor. The process used in assisting the visual of checking the line. The physics of the robot shows in figure 3. The Denso robot used has a range of six axes. Position detection uses the absolute encoder method. AC servo motor drives the entire axis the robot has. The maximum load that can be moving is 7 Kg with a cycle time of 4 to 6 seconds. A picture of the robot's working range shows in Figure 4.

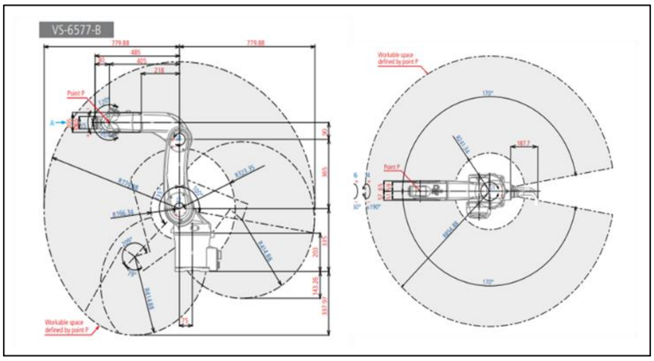


Fig. 4. Robot's range of movement

As a safety factor, the authors add several photoelectric sensors with several positions. In both tables, these sensors' locations are near the piston box. This sensor function checks existing of a piston box in the working area. The existing box triggers the automatic program to run on the robot. The sensor is also placed on the conveyor to check a piston. The position of the sensor where the robot puts the piston on the conveyor, the physical sensor shown in figure 5.

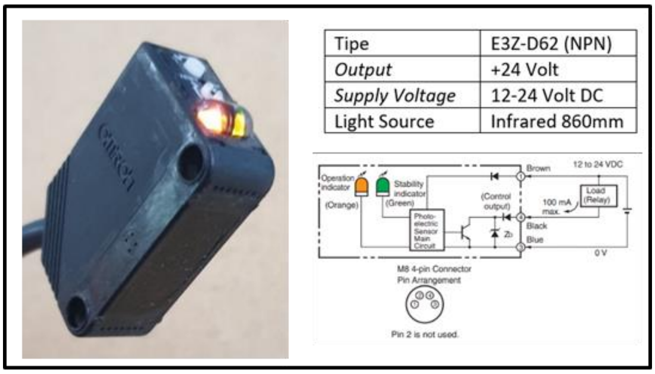


Fig. 5. Photoelectric sensor

3.2 Control System Design

Visual line modification is a process from a conventional line into a semi-automatic line modification by the author. Previously this line produced a piston-type racing motorcycle. The piston-type generated by the line visual does not change. This line has one conveyor and several tables to place the piston boxes. The box will go through the visual check process.

In the first step, The Denso RC7M robot follows a work process that begins with MP-1 and MP-2 to prepare the piston that has gone through the machining process and will go through a visual check process on this line. Second step, the MP presses the start button on the HMI. The robot responds if the box detects the product with a sensor. In the third step, the robot carries out the stamping process in the two boxes containing the piston. The stamping process has finished, and the robot starts the pick and place process from the box to the conveyor. In the last step checking the piston, MP-1 and MP-2 wrap the piston in plastic and place it into a cardboard box. Figure 6 shows the design positioning of the system.

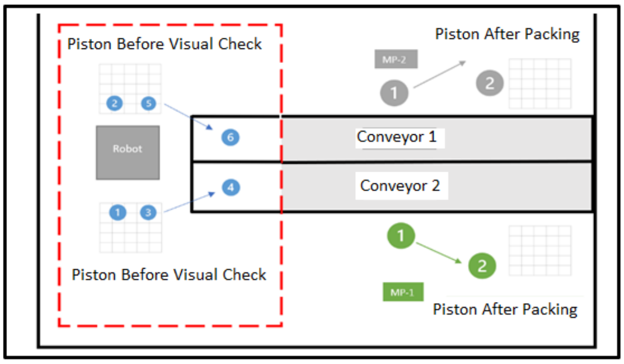


Fig. 6. Design position of Robot replaced two man power

The design system program consists of PLC and Robots programming. Broadly, the program covers initiating a process, checking, loading/unloading, and stamping. This program is carried out repeatedly through the teaching process so that the robot can recognize its work area.

3.3 Control System Experiment

In this discussion, the author will explain how to create this project. The process includes I/O addresses, integration and parameter settings, and programming.

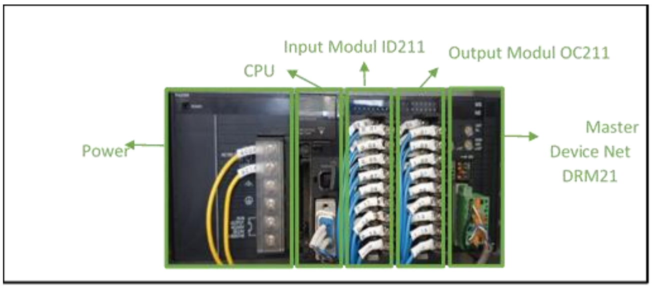


Fig. 7. Modular PLC Racks

The addresses used for programming are 3200.00 - 3216.15 as output to the master and 3300.00 - 3316.15 as input to the PLC master. Figures 7 and 8 are examples of several programs carried out on both PLCs and robots.

The Robot has an address on the device-Net slave racks. The node specifications address use is 8 (eight) with baud rate set in option number 2 (two) with 512KB. The data were 32 bytes used. It means 256 bits of the addresses used for programming are 3200.00 - 3216.15 as output and 3300.00 - 3316.15 as input. The addresses used for programming are 3200.00 - 3216.15 as output and 3300.00 - 3316.15 as input. In connecting each node to a master Device-Net, you can use the CX-Integrator software.

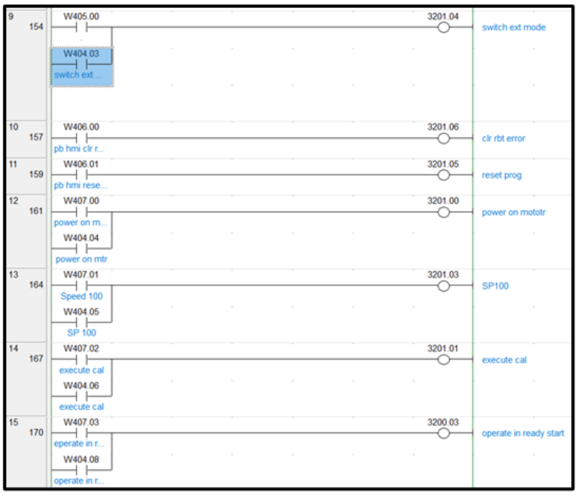


Fig. 8. PLC program for preparation (init)

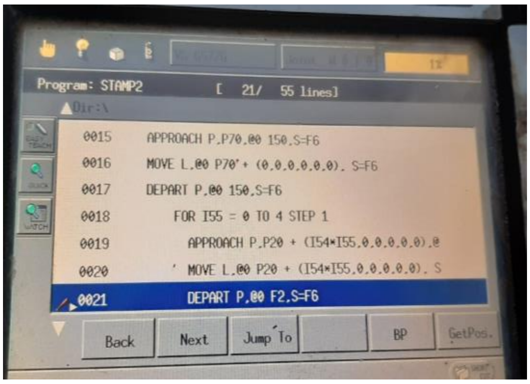


Fig. 9. Robot program for set motor velocity

These factory-applied experiments divide into mechanical and control. The discussion in this paper is both design and application technology. In this paper, the authors discuss the mechanical and control parts. The author alludes to a little about the general description of the mechanical design of the automatic storage machine. The mechanic part is about the robot's range of movement.

4 Result and Discussion

Before discussing the experimental results, the author conducted several tests. The test includes components, outputs, communication, and working of the Robot with the control system. Tests are carried out based on hardware functions and also communication between devices.

4.1 Testing

Tests on communication with net devices can be a check on the master device-Net indicator. There are two conditions, namely MS and NS. MS stands for Module Status beside NS stands for Network Status. Both of them show by turn-on led.

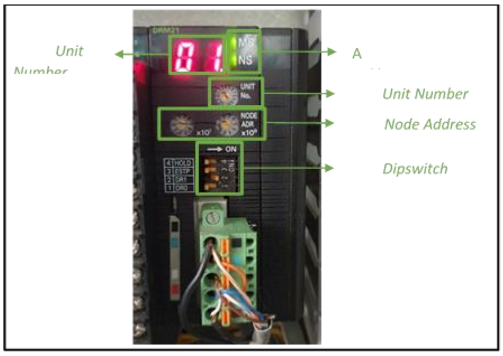


Fig. 10. Testing Communication

4.2 System

Testing steps on the work process of the robot are (1). carrying out the stamping process on the robot tool amounts to 5 at once; (2). stamping on the piston surface on the first layer;(3). carrying out the stamping process, totaling 50 pistons on layer 1; (4). then the robot performs the pick and place process on the first layer piston by moving 5 (five) pistons in a step; (4). moving the layered barrier; (5). stamping ink filling process again; (6). stamping the piston surface on the second layer; (7). picking and placing the piston on the second layer.

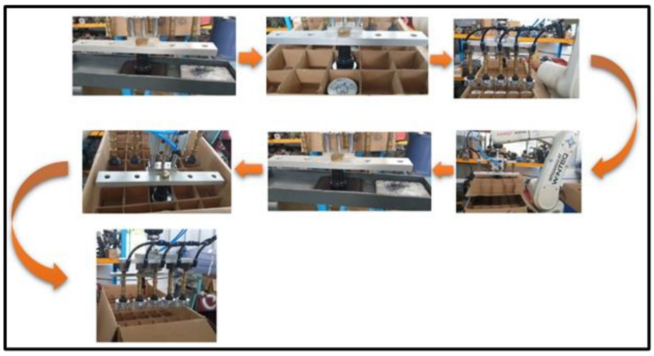


Fig. 11. Robot system

4.3 Result and Discussion

a) Result:

- The number of pistons in 1 box is 100 products = 100 x 2(box) = 200 products
- Sample cycle time data is 240.5 seconds/200 pistons
- So the average time/200 pistons = 1.2 seconds/piston
- So the time required for the stamping and pick and place piston process is 1.2 seconds/piston
- Cycle time line = 1.2 seconds (stamping & pick and place process) plus 2 seconds (piston packaging process)
- So the final result of the cycle time on the visual line is 3.2 seconds/piston.

Table 1. Table title. Table captions should always be positioned *above* the tables.

No	**Data (second/2box)**
1	245
2	239
3	240
4	240
5	241
6	240
7	239
8	241
9	240
10	240
Average	240,5

b) Precentage:

• Conventional visual cycle timeline (according to the data online) = 5 seconds
• Sample data cycle time = 3.2 seconds
(Difference between cycle time/initial cycle time) = 1.8/5 = 0.36 x 100 = 36%
There was a decrease in cycle time of about36%, initially the visual cycle timeline was 5 seconds/piston, then after this project it became about 3.2 seconds/piston.

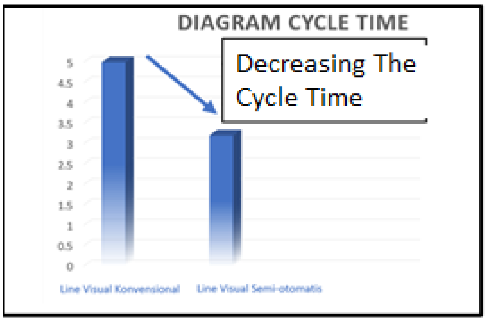


Fig. 12. Cycle time diagram

5 Conclusion

Making an integration system between the robot and the machine control master is done by utilizing the Device Net communication system. The robot system reduces cycle time and increases the results from the previous system line. Previously cycle's time data in the line visual about 5 seconds for a piston. After this project, the cycle time on the line decreased average by 36% that equivalent with 9800 piston in a day. That means the cycle time on the line became approximately 3.2 seconds for every piston. The robot integration with the master control device net based on PLC CJ2M CPU11 aims to make the conventional visual line into a semi-automatic line. This project can reduce cycle time on the line and increase the number of results obtained from the line with the robot integrated on the line. The line visual working process of stamping, picking, and placing products.

6 Acknowledgement

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