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## 5 PLC Omron CJ1M CPU-21 Control Modification for Drill Oil Hole Machine in an Automotive Company

Abstract. Nowadays, PLC (Programmable Logic Control) is one of the common controlling devices in machines in the industry, including the automotive industry. An automotive company in Indonesia that produces component motorized vehicles in the form of pistons using machines that controlled by PLC. Piston is one of the main automotive components in motor vehicles that play a role in the combustion process. In the order of making piston there is a process of making oil holes which is carried out using a Drill Oil Hole (DOH) machine. This machine currently uses on / off operation mode use push-button. In addition, there is no interface to display information needed by machine and maintenance operators. There are some modifications that will be made to the drive section to synchronize between the engine and the robot. This paper presents a review of the modification of DOH engine controls using the CPU- 21 CJ1M Omron PLC with an interface in the form of a Human Machine Interface (HMI) to provide information and set data needed.

Keywords: Drill Oil Hole (DOH) machine, control system, PLC, HMI, servo motor

### 1. Introduction

Nowadays, the manufacturing industry has used automation on its manufacturing process. Reciprocally, in an automotive manufacturing company in Indonesia that produce piston for vehicles. Pistons are sliding plugs installed inside the combustion cylinder engines in hydraulic, pneumatic and pump cylinders. In the manufacturing process the piston of the vehicle moves through various stages. One of the steps taken is to make an oil track in the form of a hole to get out and into the piston.

The process of making oil holes is carried out by the Drill Oil Hole (DOH) machine. This company has a maintenance department that requires preventive and corrective engine

maintenance so that the engine remains in good condition for production process activities. At the maintenance repair area there is a damaged DOH machine that still allows it to be modified to support the automation concept on the production line. The shortcomings of these machines include; (1)the engine is still controlled on-off using push-button, (2)the engine does not have a production display, (3)engine's work settings still have to see the PLC program ladder and (4)the engine still uses an open loop drive motor in the form of a stepper motor. In addition, the engine cannot be integrated with a robot because it does not have a drive system that supporting of a drilling table. Because of this condition the machine need modification to fulfill automation concept.

In this paper, the authors will modify the DOH machine's engine. Modifications made in the form of replacing the engine control system using the Human Machine Interface (HMI) as a controller input and production display. Besides that, the actuator system is changed using a servo motor which is closed loop. In addition, a mechanical system <sup>1</sup> in the form of a rotary index table was added which was driven by a pneumatic cylinder so that the engine could be integrated with the robot.

Modification <sup>of the control system</sup> has several objectives. Some of the objectives include: the engine can be controlled and monitored through HMI by the maintenance operator.

Besides that it aims to accelerate the rotation of the drive and increase the precision of the drilling point by replacing the

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previous driver motor. This modification engine is the first step to make engine allows to be integrated with robots that can support the automation of production systems line.

## 2. Theoretical and State of the Art

In piston manufacturing there are many process includes; material selection, smelting, printing, cutting, heat treatment, machining, cleaning, coating and visual checking. The process that will be discussed in this paper is the machining process that controlled by the PLC. This process aims to produce an appropriate piston product which is high precise in hole drilling.

A piston is components of internal combustion engines which has functions in compression, suction, and dispose of combustion gases inside the engine and transmit the combustion power **7 through the connecting rod** into the crankshaft to be used as a source of power for engine rotation [1]. The piston products discussed in this paper are pistons that commonly used in vehicles. The **parts of the piston are** divided into; crown, skirt, and body piston. The detail parts of piston can be seen on Figure.1.

Figure 1. Detail parts of a piston.

The piston crown or piston head is the top **part of the piston** which serves as a collision barrier due to the combustion process. The piston crown receives high temperature and pressure, moves at high speed continuously when the engine is on. In this section the oil flow regulation in and out of the piston through the existing hole. So DOH machine must work properly to make the appropriate oil path.

The control system can be viewed as a system where an input or certain input is used to control its output at a certain value. **1 A control system can** control various aspects such as controlling a variable to get the desired value, controlling the sequence of events / processes and controlling whether an event occurs or not. Basically **a control system is used to** control the sequence of sequential processes [2].PLC **is a device used to** control a

process or machine. The working principle is in general that is receiving input from the input device (input device) [3]. Its use based on the program stored in it then produces an output to move the output device. PLC is likened to 'the heart' of the control system. Its use based on the program stored in it then produces an output to move the output device. PLC can monitor the state of the system through signals from input equipment, then based on the logic of the program determines the series of actions to control external output equipment. Figure.2 Show various brand of PLC that used in Indonesian industry.

PLC has three main parts they are input, CPU (Central Processing Unit) and output. CPU is consists of memory and power supply. Basically the PLC has two general forms they are compact and modular. PLC compact has I/O, CPU and power supply unit combined into one part. Meanwhile, for PLC modular types each part of the PLC is divided into separate modules so that we can add or reduce the number of I/O as we need. Based on these considerations, in this paper the author uses the OMRON brand PLC with CJ1M type CPU20 which is a compact type PLC.

As previously explained, the PLC control system will run through the program inside. Computer programming requires software, one that supports OMRON CJ1M CPU21 hardware is the CX- Programmer that operates under a Windows operating system. In PLC there are several commonly used programming languages such as; function blocks, structured texts, statement lists and ladder

diagrams. In this paper the author will only discuss the use of ladder diagram as a programming language.

Human Machine Interface (HMI) is a system that connects human beings and machine technology. The HMI system usually works online and in real time by reading the data sent through I/O port used by the controller system. The ports used for the controller and will be read by the HMI include comport, USB port, RS232 port, and there are also serial ports.

### 2.3. State of The Art

Previously, the authors have studied several literatures of publications regarding the use of PLCs as industrial machine controls [15, 16]. In addition, it also deals with communication between PLC and servo motor [14, 18] and HMI [19]. Most of these controls are used for special purpose machines.

In this paper the authors will make modifications to the machine used to do machining in the piston production process. Machine modifications made include electrical and PLC programming modification. The machine was initially manually controlled using the push-button to be replaced using the HMI as its input and display. In addition, to increase the precision of the engine work, the previous actuator is replaced by a servo motor that works in a closed loop. This paper discusses about combining HMI and VFD controls **1** in the form of an inverter on a servo motor.

### 3. Experimental Design

In this section to achieve the objectives of the existing ideas, some data is collected. These data include, the working principle of the engine, **2** the condition of the engine the engine control system before modification and programming using CX-Programmer software. The data **1** can be used as a reference in the design process and comparison to the results of machine control after going through the modification process.

Drill Oil Hole (DOH) machine is a drilling machine used to make oil holes on the piston.

The drilling process is included in the machining stage which aims to make one **7** part of the piston in the form of some oil holes that is in accordance with the standard sheet that has been determined by the engineering team based on the request or customer needs.

Figure.2 show what DOH machine do in piston product.

Figure 2. Oil hole drilled by DOH machine.

Drill Oil Hole (DOH) machine has several steps on the work process; the first steps is

manually set crown piston on the jig position by the operator (in the future it will be replaced by a robot). Second, operator presses the start button then the engine clamps to piston position so that it is aligned with drilling tool and does not move during the drilling process.

Third, the machine is drilling perpendicular to the piston according to the number of oil holes and predetermined angles. Fourth, drilling hole tilted against piston according to the number of oil holes and specified angle as well. If the drilling process is complete, piston clamp will be released and ready taken from the jig by the operator (in the future the robot will be replaced) to carry out other machining processes.

The picture above is the oil hole that is drill by a DOH machine. Detail of DOH machine flow process can be shown on Figure.3 below.

Figure 3. DOH machine flow process.

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Fig.4 Show DOH machine before modification in the maintenance area.

Figure 4. DOH engine parts to be modified.

The picture above DOH machine parts to be modified. For more details, it will be shown in the following Table 1. Beside modification, the authors also do any replacements for some parts in DOH machine that will show on Fig.5 and detail shown Table 1 and 2.

Figure 5. The DOH engine part to be replaced.

Table 1. Detail of DOH machine parts modified (1).

Table 2. Detail of DOH machine parts modified (2).

Figure.8 show electric design of DOH engine control system. This design **9** divided into **four parts they are;** power design, input device design, process design, and output device design.

Base on the electrical main source is 3 phases 380VAC that connected to step down transformer to reduce the voltage into 1 phase 220 VAC. Then it is connected with NO Fuse Breaker (NFB) to maintain the main panel **2** when there is a disruption of over load current and a short circuit. The NFB is connected to a Servo Amplifier, AC Motor Inverter and MCB. The output device are using 220V AC source.

Then the MCB is connected to the PLC and HMI as a voltage source. Besides that it is connected to a power supply that produces a 24 VDC output voltage. The 24 VDC voltages are used as input device voltage sources. PLC as engine controller have a process design as show on Figure.6 below.

Figure 6. Block diagram of PLC wiring.

DOH machine is controlled using **a PLC. There are** connected input devices such as push buttons and sensors. As well as output devices also connected they are; solenoids, indicator lights, pumps and motors. Servo Amplifier use to control the rotation of servo motor and inverter to regulate the rotation of the 3 phase induction motor. The system also uses HMI as input and output. Figure.7 show the HMI that authors used.



Figure 7. HMI used on engine modification.

Actually we used RS-232 as communicator port between PLC and HMI. The detail specification will show on Table III below. The choice of PLC is based on its ability to communicate with servo drivers. Based on the design, the Omron Sys-Mac CJ1M PLC was chosen as the center of its control. Because this PLC is a modular type PLC, allowing for the addition of I / O modules that are adjusted to the engine input and output.

Table 3. Detail of HMI connection and specification.

Basically the PLC program is divided into two parts; they are manual and auto programs. Manual program **2** is used for the process of repairing or reed switch settings, checking the movement of each part. Auto program is used for the production process.

#### 4. Result and Discussion

In this section the authors will discuss modification results. These results include; actual machine electrical wiring, actual pneumatic wiring, HMI display and PLC programming. The authors hope that our objectives; the engine can be controlled and monitored through HMI by the maintenance operator. Besides that it aims to accelerate the rotation of the drive and increase the precision of the drilling point by replacing the previous driver motor can be achieved. In addition, net quality income (NQI) will be calculated for companies with this modification process.

Electrical wiring in this paper is divided into power and control wiring. Power wiring is only devoted to connecting the current source to the components that need AC source, while the wiring control is specifically in the input, process, and output lines in a PLC.

The DOH machine requires a power voltage of 380VAC 3 phase to drive several motors and this voltage is also lowered through the transformer to convert its voltage to 220VAC 1 phase as source

that will convert into 24VDC power supply for PLC source, servo amplifier and several other components.

Other important wiring in this modification is PLC that consisting of processes and I/O wiring. The I/O wiring to be discussed is HMI and actuators wiring which is the focus of output modification.

On this PLC wiring gets source 220V AC voltage. In the input device module (CJ1W-ID211) wiring a negative voltage of 24V DC is given to the common module and a positive voltage of 24V DC on each input device. While on the output device module (CJ1W-OC211) wiring voltage 220V AC is given to the common module and 0V AC voltage on each output device. Fig.8 show detail I/O address wiring.

Figure 8. Detail input wiring. Figure 9. Detail output wiring.

The inputs devices are push button, emergency stop, reed switch, proximity sensor connect to PLC input module CJ1W-ID211. The outputs device consists of a Pilot Lamp (PL), Magnetic Contactor (MC) and solenoid valve **2 will be connected to the** PLC with the addresses on the output module CJ1W-OC211. Beside that we also use HMI as I/O device. Detail for HMI that connected into PLC show on Figure.10

Figure 10. HMI to PLC connection.

Based on Fig.14 above, it can be concluded that configuring PLC and HMI connections greatly simplifies I / O wiring used previously. Figure.16 shows the different on wiring before and after modification system.

Table 4. Detail of DOH wiring panel.

This pneumatic control system **2** is controlled by a PLC in order to move the desired sequence. All pneumatic cylinder movements move according to the program ordered by the PLC. The pneumatic wiring diagram can be shown in Figure.11.

This DOH machines have four double acting cylinders; three 5/2 double solenoid valves, and 3/2 single solenoid valves which are used to drive self-feeder, drilling table, and clamp. Table 5 show detail address in the PLC output.

Table 5. Detail of DOH pneumatics connection address.

Figure 11. The pneumatic connection diagram

The HMI screen display is used to facilitate the operator in operating DOH machine. In HMI there are 6 main screens for operating DOH machine, they are; preparation, manual, auto, servo, value 1 Settings, value 2 setting, and information.

Figure 12. Display of home menu on HMI screen

Base on Figure 12. When we push the screen button will run into sub menu mode. Manual mode is a screen to operate the DOH machine manually. Auto Screen is a screen to operate the engine automatically. Screen Setting Value is used to adjust the motor motion of the servo. Screen Initialization program is used to set the rotation angle of index based on drilling point to be determined through the input parameter position.

The modified DOH machine control panel **2** can be seen in the Figure.13 below. Based on the picture we can see that the role of many push-buttons, selector switch as input is replaced by a simpler HMI display.

Figure 13. Machine control panel modified

Making the Drill Oil Hole engine program is divided into 6 sections. Figure.21 shows sample program on screen section. Screen section is a program used for configuration between PLC and HMI. All settings in the DOH configuration are in servo IOwr section that shows on Figure.14. Servo IOwr is a program that is used to set the logic of a servo motor through the NC-113 module.

Figure 14. servo IOwr ladder program

Sequential section is a program used to regulate the sequential drilling process on DOH machines. All drilling position settings are arranged in this section. The output section is a program that is used to manage all **2** the output of a DOH machine, for example clamp, coolant pump, self-feeder, and others. Reset section is a program that is used to reset the DOH machine if an error occurs **1** in the form of an alarm displayed on the HMI. Self-feeder section is a program that is used to specifically set self-feeder in terms of **the position of the** drilling point. They are section that cannot display ladder diagram detail here.

The following Figure.15 is show the results from DOH engine. The results on the DOH engine are in accordance with production demand and engineering. Based on these results, DOH machines can be used in mass production and integrated with robot's on loading and unloading product.

Figure 15. Result of drilling from DOH machine

## 5. CONCLUSION

Base on the experimental that we have done the objectives to make automated machine are achieved. The first objective is the DOH engine now is controlled by HMI. Second, DOH engine have a production display and also, third engine's work settings can be done by machine operator or maintenance operator from HMI. Fourth the DOH engine uses a close loop drive motor **1** in the form of a servo motor. This modification also has meet engineering needs on product result. In addition this result can be integrated into next automation steps after drilling process with robotic.

## Sources

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