Control system design of arc welding by hand machine based on Programmable Logic Controller (PLC) and CC-link master module

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Abstract. This paper presents research conducted at an automotive manufacturing company that manufactures automotive components, including the rear axle. The housing assembly is one part of the rear axle assembly process that serves as a place to put other rear axle components, namely: axle shaft, differential, inner retainer bearings, brakes, drum brakes, and others. A new machine will be designed on the housing assembly production line with a larger capacity, which is 3000 pcs per month. The arc welding by hand machine was designed by adding a motor and an inverter, a pneumatic cylinder as a gripping, a reed switches as a controlling cylinder. The main function of this machine is to connect the upper-lower assembly parts with the housing tube and housing end and to keep the three parts fixed on one axis. If the three connected parts are not on the same axis, it can cause defects in the product. In this paper, we discuss the control system design of the housing assembly arc welding by hand machine using the PLC as its control, and the CC-Link master module which functions as the expand input-output of this machine. With a new machine control design, production targets can be achieved, and product defects have decreased from 0.96% to 0.06%.

1. Introduction
This research was conducted at an automotive manufacturing company. This company manufactures rear axles, propeller shafts, etc. The manufacturing production process includes welding, painting, machining, and assembling. The objective of this research is the housing assembly process, which is one part of the Rear Axle. The making of rear axle includes 5 processes, namely: housing tube process, housing end process, rear axle shaft process, housing assembly, and rear axle assembly.

To increase production capacity for new models, where housing line A gets a shared loading of 3000 units. However, for the housing assembly line model D01N is a new model and has not been produced before. Therefore, there are replacements for some machines that must be adjusted

Arc by hand housing assembly machine with M12 machine code is a machine designed in this research. This M12 machine is used to carry out the tack welding process between upper-lower assembly with the housing tube and housing end. The main function of this machine is to keep the parts connected to one axis. Because, if the connected parts are not on the same axis, it can cause defects in the product.

The use of PLCs for various control systems has been carried out [1-7]. Also, various researches have been carried out related to the use of PLCs as control systems for various systems and machinery, especially in the area of manufacturing and automotive industries [8-13]. Furthermore, this research is
focused on the design of the system aimed at meeting the increasing needs of rear axle products, and reducing product defects in housing assembly, especially in arc welding by hand machines.

2. Methodology and design

2.1. The Housing assembly

The Housing assembly is one part of the rear axle that serves as a place to put other rear axle components such as axle shaft, differential, inner retainer bearing, brake and drum brake. Figure 1 shows the rear axle component.

![Figure 1. The rear axle component.](image1)

It can be said that the housing assembly is protective for the other rear axle: axle shaft and bearing. Because of its function as a protector, the construction of the housing assembly must be strong and rigid. Housing assembly has components that are divided into two parts, namely: the main component and supporting components. The main components consist of upper-lower, cover housing, housing tube, and housing end. While the supporting components are: small part brackets. Figure 2 shows the components of the housing assembly.

![Figure 2. The components of the housing assembly.](image2)

2.2. Housing assembly production process

In the production process line housing assembly, there are 3 sub-processes to produce 1 unit housing assembly, namely: welding sub-assembly parts, welding assembly parts, and machining. The first sub-process is the welding sub-assembly part. This process is a process to produce an upper-lower assembly. The second sub-process, namely the welding assembly part process, is the process of connecting the upper-lower assembly with the housing tube and housing end, and the installation of the small part bracket. The third sub-process is machining, which is the process of removing material that is not used in a housing assembly such as boring, facing, drilling, and tapping.

This research discusses the second sub-process, namely welding assembly parts. There are six processes in the welding assembly part sub-process. The process of connecting the upper-lower assembly with the housing tube and housing end is done in the arc by hand housing assembly machine, with the M12 machine code, and the arc by auto housing assembly welding machine, with the machine code M13. As for the installation of small bracket welding, it is carried out on small by arc welding by
hand machine (M15-1 and M15-2) and small by arc welding robot machine (M16-1 and M16-2). Figure 3 shows the M12 machine flow diagram.

![Flow Diagram](image)

**Figure 3.** The M12 machine flow diagram (PB: Pushbutton; 0: cylinder reverse; 1: cylinder forward).

The following are a brief explanations of this flow diagram. Button 1 is pressed; the right and left cylinder clamp housing ends are active and gripping the housing end. Button 2 is pressed; the centering cylinder will open and position the upper-lower assembly in the middle position. Button 3 is pressed, the cylinder housing end will advance and connect to the housing part, housing tube, and upper-lower assembly together. Button 4 is pressed to activate the cylinder cover clamp and cylinder housing tube clamp right and left simultaneously. After all, parts are gripped on the jig, the operator begins welding via tack welding at the junction between the housing end and the housing tube, and the housing tube with the upper-lower assembly. Button 5 functions as a release (release) of the currently active cylinder (home position). Based on the M12 grip system and the M12 machine flow diagram, it can be seen that there is no grip that can keep the housing part and upper-lower assembly without gaps. In the third process, when the housing end cylinder advances to close the three parts to be assembled, the operator does not necessarily ensure that the housing tube and upper-lower assembly are tight and tack welding from the housing end first.

2.3. Design concept

The machine design for the M12 was carried out to realize the results expected beforehand. Some things to note are as follows:

- The M12 machine is capable of producing 3 housing assembly models. In this condition, the control system created is the same. To distinguish the three models used mechanics. Several parts in mechanical that can distinguish one model from another.
- M12 machine can eliminate the tack welding process. The method used is to add an electric motor, so the housing does not need to be placed on the rail for tack welding at the rear of the housing. Figure 4 shows the design of adding a motor to the M12 machine.

![Motor Design](image)

**Figure 4.** the design of adding a motor to the M12 machine.
Based on Figure 4, it can be seen that the movement of the motor will be forwarded by a chain connected to the jig shaft. This jig shaft, in addition to functioning to continue the motor rotation from the chain to the jig, also functions to stop the jig rotation. This is because this shaft has a convex that when hit by a limit switch will send a signal to turn off the motor.

- The M12 machine can maintain the upper-lower assembly density and tube housing. The way to solve this problem is by adding a cylinder which is a barrier between the housing end and the housing tube. Figure 5 shows the placement of this cylinder.

![Figure 5. barrier cylinder.](image)

The working principle of this barrier cylinder is that before the housing end is active or forward, the cylinder is activated and becomes a barrier between the housing end and the housing tube. This cylinder will close the housing tube and upper-lower assembly with the help of the cylinder housing end forward.

For the control system design, the following explanations. The control system to control this M12 machine uses PLC. The PLC used is a Mitsubishi PLC. If there are program changes or additional components it will not complicate the maintenance part. The M12 machine uses a pneumatic cylinder as a thrust. Adding a reed switch sensor to control the cylinder. The existence of an electric motor to control the rotary jig. The electric motor is controlled by an inverter, both forward or backward rotation and speed. To stop the rotary jig, use the limit switch. Using a mono lever switch (joystick) as input to control the machining process. The use of a mono lever switch is intended to make it easier for the operator to operate the machine compared to using a push button. There is a mono lever switch that functions as an unclamp per stage, and an unclamp for home position. Using the error code as a viewer if there is an alarm condition. There are indicators to indicate the machine stage. Has two modes, namely mode 1 as the machining process and mode 2 as checking the ejector cylinder and the rotary motor jig. There is a CC-Link component to expand input-output on the machine. The input is used for connections with reed switches, and the output is used for connections with solenoid valves.

2.4. Control system design
Based on the design that has been made, a control system is designed to control the M12 machine, including the inputs and outputs needed for the machine. Figure 6 shows the input, process and output sections of the M12 machine. At the input, there are illuminated push-button, selector switch, push-button selector, mono lever switch (joystick), emergency stop, push button, and reed switch. In the process, there is a PLC. While at the output there are solenoid valves, inverter, pilot lamp buzzer, tower lamp, annunciator, and seven-segment. Both input and output have their own functions and ways of working to help the M12 machine work process. Also, the control and communication link (CC-Link) functions as the expand-output of this machine.
3. Result and discussion

Figure 7 shows the results of the machine condition before and after the design and repair process. In general, the arc welding by hand machine control system has functioned by the order in which the process works. In this case, the electrical control system is tested, and the system works.

3.1. Testing

Electrical components that have been cleared and programmed need to be tested. This is to ensure that the machining process is by following the design concept and to find various potential or causes of system failure. In control systems, the largest percentage of system failures come from input-output devices. The testing phase is carried out on the hardware and programming.

3.2. Work system testing

The purpose of testing the machine work system is to find out whether the work system on the machine is running well and by following predetermined stages. One reason for testing the work system is that if the work system is running well, the input and output on the PLC or remote Input-Output on the CC-link are also running well.

The things that are tested are: standby machine condition; operation mode 1, which is the auto mode; operation mode 2, which is manual mode; and the abnormal conditions. From the four tests, the programming made is by following the desired work process. Also, the concept of machine design uses 2 working modes and an alarm system that functions as an indicator of the machine is in an abnormal condition.

3.3. Analysis

After replacing the M12 machine in the housing assembly line and making the M12 machine control system, the production capacity at this housing line increases. Based on production data, production shows that production has increased. In this case, it shows that the production of the D01N model has reached the target loading of 3000 units.
4. Conclusions
This paper has discussed the design of the arc welding by hand machine control system using the PLC of Mitsubishi FX2N-64 MR. The arc welding by hand machine control design is used to assist the machine in producing the D01N model housing assembly so that it can produce as many as 3000 units. The machine can function by following the concept of the work process. This can be seen from the same machine flow diagram as the results of work system testing, with machine conditions: stand by, mode 1, mode 2, and not normal. Furthermore, the research can be continued with the addition of the HMI (Human Machine Interface) system as a display that can directly monitor sensors and actuators on this machine, so that it will facilitate the detection process if an error occurs on the machine.

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References
[1] Alciatore D G and Michael B H 2012 Introduction to Mechatronics and Measurement System New York: McGraw-Hill
[2] Alphonsus E R and Abdullah M O 2016 A review on the applications of programmable logic controllers (PLCs) Renewable and Sustainable Energy Reviews 60(2016) 1185-1205
[3] Gelena G and Uzamb M 2014 The synthesis and PLC implementation of hybrid modular supervisors for real time control of an experimental manufacturing system Journal of Manufacturing Systems 33(2014) 535–550
[4] Milik A 2015 On PLCs Control Program Hardware Implementation Selected Problems of Mapping and Scheduling IFAC-PapersOnLine 48 354-361
[5] Valencia-Palomo G and Rossiter J A 2011 Programmable logic controller implementation of an auto-tuned predictive control based on minimal plant information ISA Transactions 50 92-100
[6] Rullan A 1997 Programmable Logic Controllers versus Personal Computers for Process Control Computers ind. Engineering, Nos 1 421-424
[7] Fay A 2015 Enhancing a model-based engineering approach for distributed manufacturing automation systems with characteristics and design patterns The Journal of Systems and Software 101 221–235
[8] Ardi S and Ardyansyah D 2018 Design Control Systems of Human Machine Interface in the NTVS-2894 Seat Grinder Machine to Increase the Productivity IOP Conference Series: Materials Science and Engineering 306 (1) 012112
[9] Ardi S, A Ponco and R A Latief 2017 Design of integrated SCADA systems in piston production manufacturing case study on the conveyor, the coolant, the hydraulic, and the alarm systems using PLC IEEE Xplore 187 – 191
[10] Ardi S and Abdurrahman H 2017 Design of pokayoke systems to increase the efficiency of function check oxygen sensor machine using programmable logic controller in manufacturing industry IEEE Xplore 192 – 196
[11] Ardi S, Ginarto R and Putro A P 2017 Journal of Engineering and Applied Sciences 12 8 2148-2153
[12] Ardi S and Defi W Y 2018 Control Systems Modification of Loading and Unloading in Oil Filling Machine Based on Programmable Logic Controller at Manufacturing Industry AIP Conference Proceedings 2021 060029
[13] Ardi S and Al-Rasyid A 2016 Design of Pokayoke Sensor Systems in Drill Oil Hole Machine to Detect the Presence of Drill using Programmable Logic Controller Advanced Science Letters 22(7) 1813-1816