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Design of Numbering Machine Control System based on Omron CJ2M PLC with Omron NB10 Touchscreen HMI for Improving Manufacturing in Motorcycle Assembling Industry PT XYZ

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Abstract

Engine numbering process is the earliest step in assembling a motorcycle engine and it is strictly prohibited to make slightest mistake. Because if it happens, it will disrupt the next process and / or jeopardize vehicle engine registration process required by National Police Department. However, in 2017 alone there have been no fewer than 200 engines produced with wrong number. This is because the existing machines are prone to errors, with inadequate protection system, and unavailability of human machine interface (HMI) for operator monitoring the machine. In this paper we present a new design for numbering machine control system with more reliable protection logic, so that zero mistakes can be realized. Improved protection system includes checking repetition of process for the last 100 data, better type selection protection, protection of sequential numbering process, and acknowledgment using fingerprint scanner. The programming language used was made using structured text language which making it easier for programming, monitoring and troubleshooting. An intuitive interface has also been made using HMI touchscreen. Testing all input data protection logic shows very good results with 100% success rate, so that it can fulfil zero mistake requirement. In this way this machine can be declared ready for mass production.

Keywords: human machine interface, numbering machine, programmable logic controller,

1. Introduction

Engine numbering process is the most vital and critical process in assembling a motorcycle engine. It was said so, because engine number was used for the administrative process of registering a motorcycle at the National Police Vehicle Registration Department. So, it is strictly forbidden to make slightest error. Therefore, the machine numbering process must be very thorough in terms of the quality and accuracy of its processing.

The engine numbering process currently running at PT XYZ is done automatically by machine. Input data to determine the engine number to be processed by machine comes from barcode. Data is then received and processed by Programmable Logic Controller (PLC) before being forwarded to the numbering machine printing actuator. Data processing consists of three subprocesses, namely, data reception, data checking, and data sending (John and Tiegelkamp, 2001).

Data received by the PLC from barcode scanner were then translated into a form that can be processed by the PLC. Furthermore, data checking process consists of, checking suitability of number with barcode, suitability of engine type that is running, checking sequence number, and checking repetition of the machine numbering process. Finally, process of sending data consists of process of separating data into two rows (according to visuals on number of the motorcycle engine) and process of translating the data so that it can be processed by the engine number printing actuator. Engine number printing is done by implementing the *scribing* method.

However, with a series of data checking processes, several printing errors were still found. The following is the error printing data collected by the PT XYZ PPIC (Production Planning Inventory Control) Department as presented in Table 1. Efforts made after printing errors occur is to analyze the problem with the *why-made* and *why-send* methods in each different case, then make improvements. The following table is result of the analysis and the efforts made by the Department as listed in Table 2.

Table 1: Case of Incorrect Print for Case Period of January - March 2017

Case	Case Detail	Number of Incidents
1.	Same number reprinted	47
2.	Numbers are printed out in sequence	106
3.	Numbers printed do not match the barcode entirely	28
	Total	181

Table 2: Why-made and Why-send Analysis to Discovered Cases

Case	Case Detail	Analysis Method	Problem Description	Improvement Efforts
1.	Same number reprinted	*why-made*	The machine only checks the repetition of number in the last 5 data	No improvement, because it's the engine's limit
		why-send	There is no number repetition checking	It is not possible to check number repetition
2.	Numbers are printed out in sequence	*why-made*	The machine only raises a warning when processing nonconsecutive numbers	Adding buzzer
		why-send	There are no sequential serial number checking procedures	Adding points of attention to the next operator SOP
3.	Numbers printed do not match the barcode entirely	*why-made*	New types have not been included in the program	Program modification for new and discontinuous types
		why-send	Found in the numbering machine	Found in the numbering machine

In the case of reprints and non-consecutive prints error, no further repairs can be made due to the machine's limited capabilities, so it only relies on efforts of the *why-send* analysis. But, apparently after a few months since these improvements, a new case emerged that is a print error only on the type code (initial 5 digits) of the machine number. Dept. PPIC XYZ has collected data of 23 engines with errors that have passed to become motorcycle units (presented in Appendix).

After analyzing the cause of printing errors, the main problem is programming error, which causes the type code error. Based on analysis and simulation carried out, error arises when type change is performed. The effort made of course is to improve the program. But these efforts still have potential to cause errors, because when there is an error, the PLC does not provide a warning or show error message when running the program.

After being evaluated, the existing machines are considered to be inadequate and unable to serve production demands that are very dynamic, e.g. still have potential to cause printing errors, are difficult when troubleshooting, and do not have an interface for operators on duty for these machines. For this reason, it is necessary to create a new control system for this numbering machine that can run a better inspection process, easy troubleshooting, and an intuitive interface. Therefore, in this research a new numbering machine control system has been created which is replacing the previous system and eliminate existing problems.

2. **Problem Definition and Scope**

2.1. Numbering Machine

Numbering machines are machines for printing machine numbers on a motorcycle. These machines print the number using the scribing method. The pin with a diamond at the end is used for scribing process on the engine. The numbering machine consists of four main components, namely barcode scanner as input, PLC as data processor, Human Machine Interface (HMI) as interface, and head marker as scribing process actuator. The display of the numbering machine is shown in Figure 1.

Fig. 1: Numbering Machine

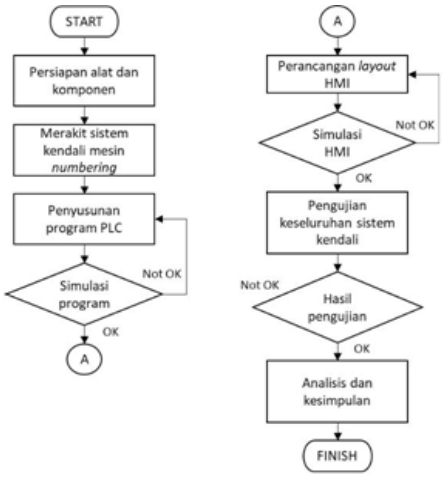


Fig. 2: Design Process Flowchart

2.2. Problem *Definition and Objectives*

In designing this numbering machine control system, the focus is to eliminate the potential causes of scribing errors. The following breakdown problems in the design of this control system:

- How to design a PLC program on this machine to translate number data from barcode scanner to numbering machine for printing.
- What is the procedure and process of checking the input number data by the machine when changing type to avoid printing error?
- What is the process of checking number input data by the machine when number repetition occurs so that data is not printed?
- What is the process of checking number input data by the machine when numbering process is not sequential, as well as the procedure for printing / not printing the number so that no errors occur?
- What is the design of PLC program on this machine when numbering process is interrupted, such as an emergency stop, so that input data that has been entered is not stored in the machine's memory?
- How to produce intuitive interface design to display information about the condition of the machine, data being processed, error status, and guidance when an error occurs.
- How to design a PLC program and HMI display that enables the machine to troubleshoot in case of error / abnormality on this machine.

With this new numbering machine control system, zero mistakes will be expected in the production numbering process. That is because the process of examining input data is more detailed with a fingerprint scanner-based acknowledgment process. In addition, there is a touch-layer HMI that makes it easy for machine operators to monitor process data. Also, program design is easy to assist troubleshooting when there is abnormality in this numbering machine since programming was made using structured text language (Antonsen, 2018).

2.3. Scope and Limitation

The following are the limitations of this research on the PLC Omron CJ2M-based numbering machine control system with Omron NB10 touch screen HMI (OMRON 2012, 2013):

- There are 3 number types of motorcycle engine that is processed referring to the production process carried out on the line where this engine is placed.
- Inspection of the type of machine number that has been processed is carried out on the last 100 data (according to the agreement of the meeting / discussion with related parties: Dept. of Production, Dept. of Quality Control, and Dept. of Engineering).
- The design and construction of this numbering machine has been discussed and carried out separately by the mechanical team from Dept. Engineering.

The data limit is based on the amount of machine production before changing to a different type. So that at least for 100 data there will not be an error because the type that is running is still the same, and in fact the 100th engine has been assembled and has passed the Scan-out assembly process for the next process, namely shipping. The next data limit will be accommodated in further research using a centralized database which will involve the Information Technology (IT) Department.

3. **Methodology and Implementation**

3.1. Design Process

Stages of implementing the Omron CJ2M PLC-based numbering machine control system with the HMI interface the Omron NB10 touch screen, contained in the form of flowchart in Figure 2.

The design of this control system starts with preparation of tools and components, where main components of this control system are barcode scanner, PLC, HMI, and scribing head marker. Furthermore, the components are assembled into a machine in construction that has been prepared previously. After assembly is complete, PLC program is compiled, then simulated to check the algorithm, if it is correct then previous process continues, if it is not correct then an improvement will be made. Next, we design the HMI layout and simulate those layouts, if it is correct, then we proceed to the next process. After the whole control system is tested on this numbering machine and the results are correct, then we perform analysis and draw the conclusion.

3.2. System Specification

The following system specifications of the Omron CJ2M PLC-based numbering machine control system with Omron NB10 touch screen HMI (OMRON 2012, 2013), including:

- The numbering machine control system uses the Omron CJ2M PLC as the main controller. These PLCs are used to control two pneumatic cylinders (as clamper and sliding jig) and controlling the head marker for printing engine numbers (Putra, 2014). The PLC is also used to processing barcode scanning data, until it is ready to be sent to the number printer's head marker.
- This machine has an interface in the form of Omron NB10 touchscreen HMI. With a screen size that is wide enough about 10 inches, the HMI can contain many control functions and machine performance monitoring function (Winahyu, 2015). For example, in the auto operation mode there is a barcode scanning number, last number printed, type selected, counter, sensors that are active, menu move button to recorded data menu, as well as date and time information.
- This machine is designed to store data that has been printed up to 100 data. So that barcode scan data inspection is performed on the last 100 data. If data storage has reached limit, new data will enter the FIFO (First In, First Out) system. 100 of these data can also be erased entirely through HMI by an engineer with a password.
- This machine has a fingerprint scanner, with function of running acknowledgment system. There are two cases that require this system, namely when replacing the model and when wanting to process data that is not sequential with the last data. The way it works is, when barcode is scanned, a warning will appear on the HMI indicating that the data is different (different type or not in sequence) with the last data, then the data must be checked again whether the same as the scanned data. If they are the same, the machine can process the data with approval or acknowledgment from the foreman by scanning the fingerprint.

3.3. System Architecture and Design

The following is the architecture of the numbering machine control system which is represented in Figure 3.

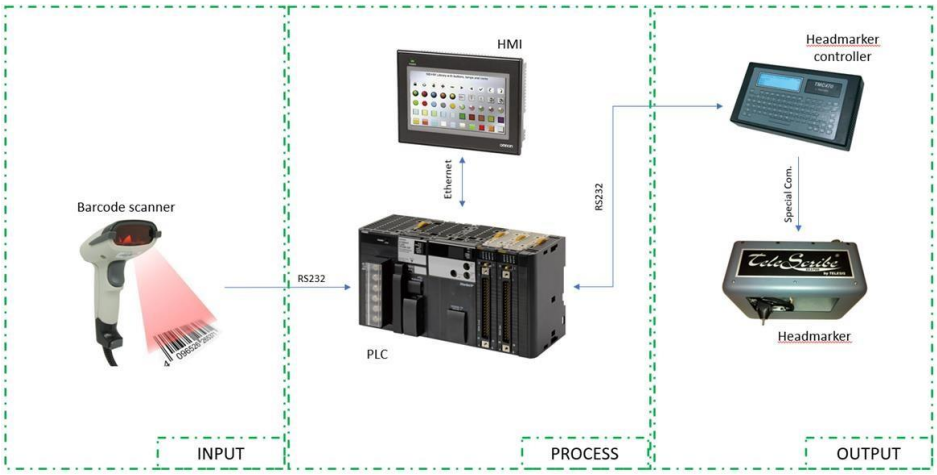


Fig. 3: Numbering Machine System Architecture

The system block diagram is also presented by dividing 3 main parts of the system, namely input, process, and output. At the input, there is a barcode scanner whose duty is of course to read the barcode. Then the data will be forwarded to the PLC to obtain. In the process section, there is a PLC for processing data and HMI Touchscreen for the system interface. Data from the barcode scanner will be processed through a series of checks and translated into data that can be read by the head marker controller. HMI Touchscreen will display the data that is being processed, the type that is running, the data that has been processed, as well as the error that is happening. In the output section, there is a head marker and its controller, which is the actuator to do the engine numbering process.

3.3.1. PLC Program Design

The following is a schematic of the PLC program that flows in the form of a flowchart in Figure 4.

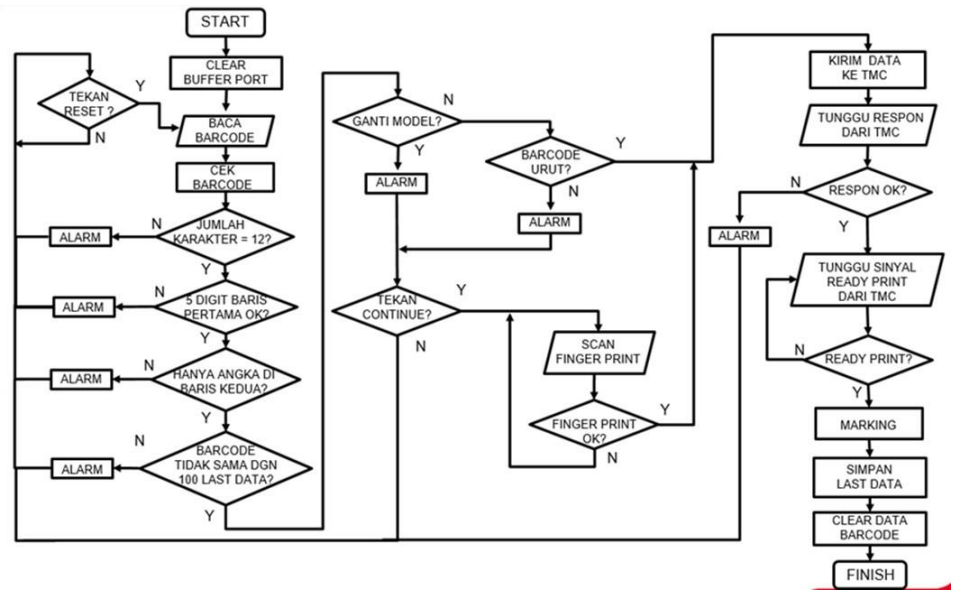


Fig. 4: PLC Program Flowchart

After pressing the start button, the program sequence starts with clear buffer port process, which ensures that no data is left on the barcode reading variable. After that, barcode is read by barcode scanner, and protection system is executed serially. The order of protection is checking the number of characters, checking the data type in the first 5 digits, checking only the numbers in the last 7 digits, and checking the repetition of data against the last

100 data. If an error is found, an alarm will appear depending on each type of protection.

Then the same data is checked whether the data is in order, if it is correct then the program will send the data to printer. Conversely, if you change the data and / or the number is not sequential, it will enter the acknowledgment logic to check the actual scan results. Data will proceed to data sending program if a fingerprint has been scanned by the registered operator.

If it has gone through previous processes according to logic designed, then data will be sent to TMC (Telesis Marking Controller). TMC feedback is needed to ensure data has been received and is ready to be printed. After print-ready feedback is provided, data will be printed, stored in memory after completion, and processing data on the PLC is deleted.

3.3.2. HMI Layout Design

Next is the design of the HMI layout on the numbering machine control system, divided into several pages with their respective functions:

- Engine Initialization: On this HMI page, a machine readiness status is displayed. Information displayed includes the status of the printer controller, the status of the wind pressure, the status of the home position for each pneumatic cylinder, the status of the emergency stop switch. If there is one that is not ready, it will appear on this page with NG status. After all are OK or ready to run, the page will switch to Auto mode operation.
- Auto Mode Operation: The HMI auto mode operation page is a display that will appear when the machine is in standby. There is data information that has just been scanned, the last data, counter, type selected, jig installed, also date and time. There are also buttons to switch pages to the data record page and input type code page.
- Manual Mode Operation: On this page there is a function to control the engine, especially pneumatic cylinders manually. There are 4 buttons, each of which functions to enter and remove the workpiece, and to grip and release stress on the workpiece. Also equipped with a light indicator that shows the status of each button.
- Error Display: An error is being displayed on this page, some of which are incorrect data types, the data is not sequential, and the data has been processed before. This page also provides a reset button to restore the engine to its original position or home position, and a continue button to continue the process if the error in question is the change of type and number are not sequential.
- Warning Display: On this page a warning is displayed for the operator to check the compatibility of the barcode with the scanning data. This warning appears when the data is not sequentially processed or will make a type change. After the operator checks the suitability of the data, the foreman of the operator must come to find out and check, then perform the acknowledgment process by scanning the fingerprint.
- Type Code Input: On this page is displayed a function to add the type that can run on this numbering machine. This page is password protected and can only be accessed by engineers. There are 4 types of engine provided to run on this engine, and each has 3 advanced types. The advanced type in question is the type of motorcycle color and striping.
- Last Recorded Data: This page displayed data that has been processed before, and a function to delete all data. Data displayed are 100 data that are divided into 4 pages which are navigated by the back and next buttons. Then on the last page there is a clear memory button to erase all data. This page can only be accessed by the responsible engineer.

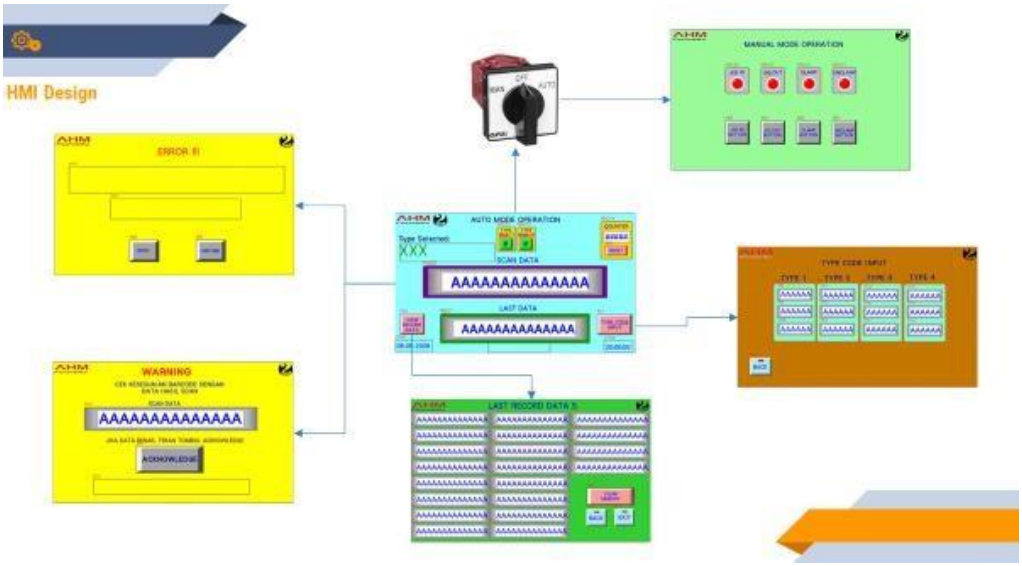
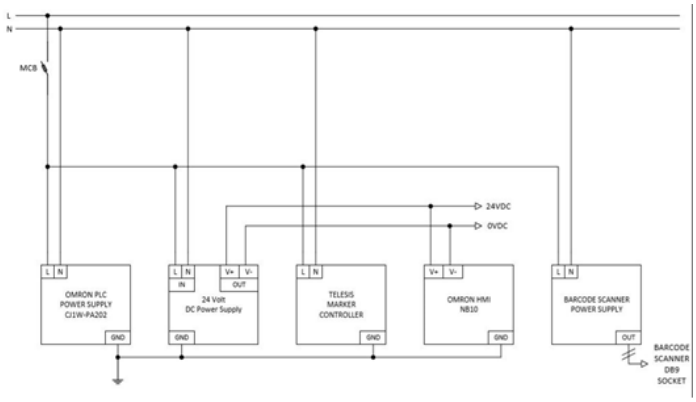


Fig. 5: HMI Layout Design

3.3.3. Electrical and Communication Wiring Design

The electrical design of the machine is divided into three parts of the network namely power line, control circuits, and communications cable (OMRON 2012):



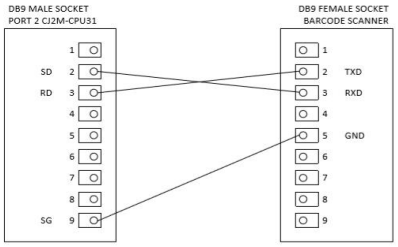
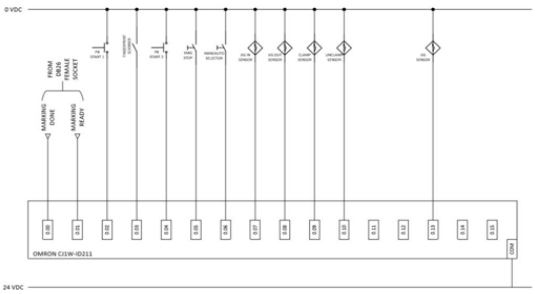


Fig. 6: Power Supply Circuit **Fig. 7: PLC-Barcode Scanner Communication**



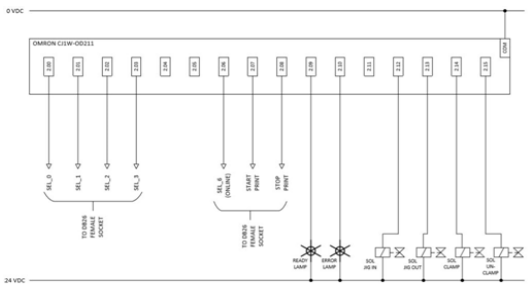


Fig. 8: Control Input Circuit **Fig. 9: Control Output Circuit**

- The power circuits are electrical circuits focused on providing electrical power to each of the main components of this numbering machine. Following is the illustration of the power circuit of this numbering machine shown in Figure 6. As shown in Figure 6, all major components of the system architecture are given resources according to the requirements of each component. PLC, TMC, and barcode scanner are rated 220 VAC. Whereas the HMI touch screen requires a voltage of 24 VDC, so a DC power supply was added beforehand. The 24 VDC voltage will also be a voltage source for the control circuit.

- The control circuits are electrical circuits that are focused on control function of each input and output of the machine processor which in this design is a PLC. Following is an illustration of the control circuit shown in two parts: the input circuit in Figure 8 and the output circuit in Figure 9. In the input circuit, the components used are adjusted to the specifications of the PLC input module. The module requires a voltage of 24 VDC to be active for each address. In the output circuit, the components used have also been adjusted to the specifications of the PLC output module. The module can be used at 220 VAC and 24 VDC for each address. However, the selected voltage is 24 VDC to be safer and adjusted to the availability of components on the market.
- Communication Cable Series Each communication cable used has its own special configuration according to the functions and specifications of the components that will be connected by the cable. In this design the communication cable used is RS232 with DB9 socket, I / O cable with DB26 socket, and RJ45 or Ethernet cable as shown in Figure 7.

3.4. Testing and Verification

Testing is carried out to determine the design of the numbering machine control system works in accordance with the expected design. Testing will be divided into two, namely testing with program simulation methods and testing by running the machine directly (OMRON 2012). Testing program simulation method will be performed on PLC programming software, CX-Programmer, by manually entering all variables to be simulated (OMRON, 2013). While testing by running the machine directly will be carried out with the type replacement method and testing each error condition.

3.4.1. Testing the Machine Control System with the Program Simulation Method

The testing program simulation method is divided into 4 tests as follows:

1. Testing the engine control system under normal and ideal conditions. Normal Condition Testing: Testing is done by running a simulation program and running the machine under normal conditions or without errors. This test has the aim to test this numbering machine can run in normal and continuous production conditions and does not cause errors or printing errors.

2. Testing the engine control system when changing the machine type: Engine Control System Testing on Type Change Condition Tests are carried out by running a simulation program on the type change condition. This test has the aim to test this machine can run type changes without causing errors or print errors as has been done by the machine before. Also, to test the new system at the change of type that requires acknowledgment from the superior operator who has his fingerprint registered on this machine.

3. Testing the engine control system by providing input data that is not appropriate, such as the wrong type, the data is not sequential, the data has been processed before, and the input data is not according to the standard. This test is performed to find out the programmed protections that can filter out NG data or not. Filtering or protection in question is divided into namely, barcode data checking, number repeat checking, and number sequence checking.

    - Checking Barcode Data Checking barcode data which is simulated according to the program designed includes checking the number of characters, making sure the last 7 digits are numbers, and checking the suitability of the data type.
    - Examination Repetition of this Test Number is carried out to find out if entering the same number / has been processed in the last 100 data will cause an error or not, also on the contrary will continue the process on a number that has never been executed before.
    - Number Sequence Check Program simulation is carried out to test the success of number sequence checking protection. If the numbers are in order, the process will proceed normally, and if not, it will cause a warning.

4. Testing the machine control system when the numbering process is running, interruptions such as emergency stops. Engine Control System Testing in Interrupted Conditions This test is carried out to find out the engine response while running interruptions in the form of an emergency stop. It is expected that in accordance with the program that has been designed that is when interrupted, the data will not be sent right to the scribing / scratching machine and the data will not be stored in the machine's memory.

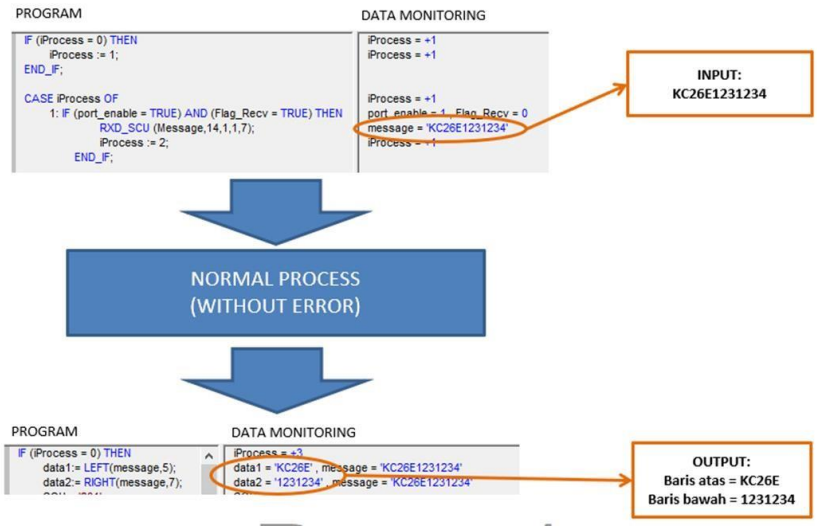


Fig. 10: The Results of Simulation Program under Normal Condition

3.4.2. Testing the Machine Control System Using the Running Machine Test Method

This Test is done by directly running the numbering machine. The test aims to determine the actual performance and real time on the machine that has been designed to control the system in this thesis. Tests carried out are divided into four tests, namely testing the normal conditions by changing the type twice, testing to run the type that is not in accordance with selected, testing numbers that are not sequential, and testing numbers that have been previously processed.

Fig. 11: HMI Testing for Various Scenarios

4. Conclusion and Further Work

The numbering engine control system that has been designed has proven to be successful in line with expectations. After passing a series of tests, the following conclusions are obtained:

- The design of the PLC program was able to successfully translate the number data from the barcode scanner to the numbering machine for printing
- When the type change was carried out successfully according to the procedures and processes designed without errors.
- When entering a number that has been processed, the machine manages to display an error in the HMI and the workpiece is not processed to print number

- In the numbering process that does not sort, there is a choice to continue or not continue the process. When not continuing the workpiece is not printed by the machine, and when proceeding, an acknowledging procedure is carried out by the responsible party whose fingerprint is registered on this machine.
- When the process is interrupted by pressing the emergency stop button, the machine does not continue the process, and the data is not stored in the memory of the machine.

Based on the results of the control system design that has been tested, here are a few suggestions to consider:

- Data checking should be carried out on more than 100 data, that is, to all engines that have been produced before. This was achieved by implementing a data inspection system that was integrated with PT XYZ data bank
- It is necessary to add workpiece sensors to eliminate the potential for double process on the same workpiece by the negligent operator.
- The further development of the machine is the addition of a camera to check the quality of prints and compatibility with the barcode.

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