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# REDESIGNING EFFECT OF AUTO TAPING MACHINE SYSTEM IN SMALL PRODUCTION SCALE

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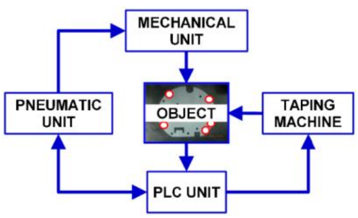
**Graphical abstract**




**Abstract**

Productivity increase can be achieved by reducing the standard time that is used in a production process, especially due to human movement and by using an automation system. In this paper, changing the design and development of a semi-automation of Brother Hitap BT-61, a taping machine to become full-automation is presented by implementing the PLC and Electro Pneumatic system onto the mechanical system of feeding, taping, and pick up process. This research can contribute higher value added output, such as increase of productivity from 95.66% to 97.09%, reducing defects of sample products chassis RH that is used for revolving lights fabrication from 0.65% to 0.01%. Also, the system can avoid on-site working accident during machine operation. Based on the calculation of cost saving, the return of investment period of this research project is 8.5 months.

*Keywords*: automation, productivity, PLC, auto taping



## 1.0 INTRODUCTION

Currently, the requirement of full automation machine is getting higher and higher so as to fulfill the growing market demand, to recover the minimum wage increment and to provide safer processes. However, the investment for a new automated machine is so high and will take a long return of investment period, especially for small production scale production processes. An alternative solution is to modify current machines which are operated by semi-automation to become fully automatic.

There are a number of researches on auto pick and place machines [1-[4], such as using new MEMS micro gripper that can handle the release and gripping of objects. This gripper can be implemented in an automated pick and place machine for micro objects [1].

In this paper, a design and a development of semi-automation of taping machine Brother, i.e. Hitap BT-61 to be full automation is presented. The taping machine is a production machine which is used for making threads of a screw on the hole of metal part. The operator needs to hold the part during loading, taping and unloading in the conventional method. This research is designed to operate automatically without interference from operator during the main process by implementing the control of PLC Keyence and Electro pneumatic system on the mechanical system of feeding, taping and pick up process. The object part of this research is called as chassis RH that is used for fabrication of a branded revolving light [5]-[8].

According to the data collected before this research began, the conventional process needs about 21 seconds to complete the whole process, i.e. the through put is about 170 units per hour. Figure 1 shows a photo of a conventional taping machine. With reference to the cumulative data of product quality, the percentage of defect parts is 0.65% during 6 month before the start of this research. The root cause of the defect is human error, such as uncentered placement of the taping head into the hole, or the part is scratched by the head during the unloading process.

**Figure 1** Conventional taping process

The detail of the process flow is shown in Figure 2. The basic concept of this research is to replace human movement by a mechanical system which is driven by an electro pneumatic system and controlled by a PLC system [5],[9].

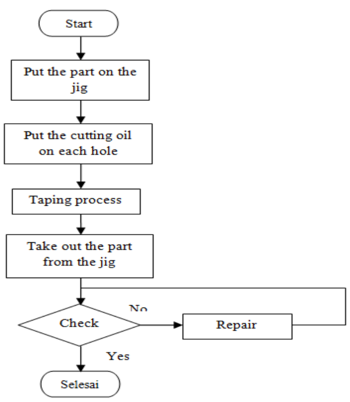



**Figure 2** Flow chart of conventional taping process

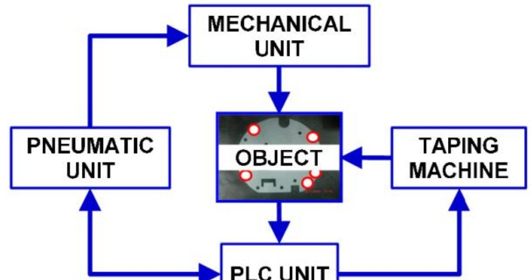



**Figure 3** Main block diagram of taping machine automation

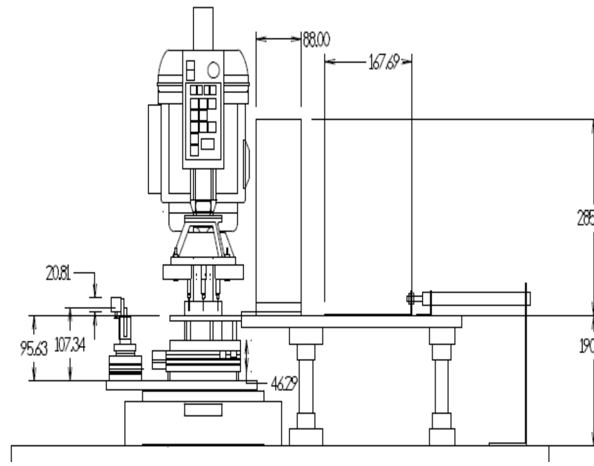



**Figure 4** Design of mechanical unit

## 2.0 SYSTEM OVERVIEW

### 2.1 Taping Machine

The research started by designing the main block diagram as shown in Figure 3. The mechanical unit consists of three main sections: Feeding, Stage and Pick up section. A magazine unit placed for stacking the object parts and a cylinder with arm pusher placed on the base metal, and supported by four supporting poles on the feeding section. This section will send the part onto the stage for taping process. To prevent the part from moving during the process, a locked pin will prod and hold it. The taping process will be done in two sequences, as the number of hole is five while the taping head is four set. When the taping is completed, a pick up arm will take out the part from the stage and bring it to the designated place. These parts are driven by an electro pneumatic unit and controlled by PLC. The PLC unit also gives a triggering effect to the taping machine to activate the taping process as shown in Figure 4.

In section 3, the research and evaluation of the system function are presented. This activity focused on machine operation for mass production. Continuous improvement was implemented for any problems encountered during the simulation process.

The analysis of final result in accordance with productivity, product quality, safety and return of investment will be explained in section 4 based on data taken from monthly monitoring of the output.

The taping machine that used for this research is Hi-Tap BT61-511 produced by Brother Co. Ltd. An additional multiple taping head replaces the original single head. The power source is AC 220V and equipped with panel control and remote switch. Figure 5 shows the machine condition before the commencement of the research.

**Figure 5** Taping machine before research started

The remote switch is use as the interface between the machine and the PLC unit which is connected with connector TB4 on the Power PCB in the control panel of the taping machine. Figure 6 shows the connection of taping machine interface and PLC output.

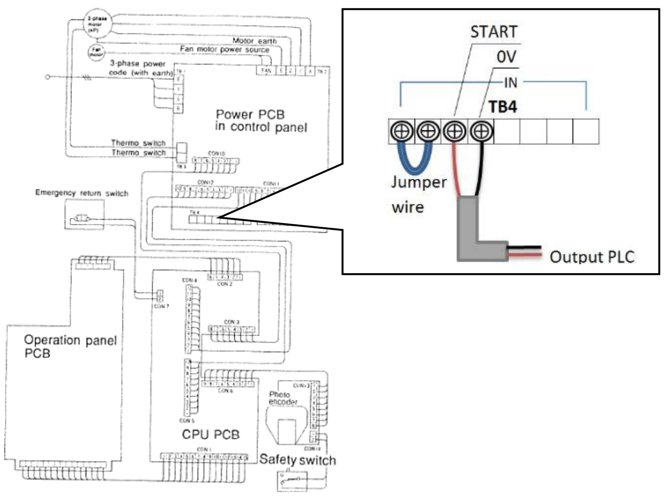



**Figure 6** Connection of taping machine interface

The PLC output will provide the signal to the machine to start the taping process. In this research, the PLC unit will trigger twice in a cycle of process.

## 2.2 Programmable Logic Controller and Electro Pneumatic Unit

The PLC controller was used in this auto taping machines. Keyence PLC was selected as the controller. The next step is to build the unit by following the wiring diagram as shown in Figure 7. There are seven sensors which are applied directly in this PLC system. Five of them are reed switch sensors and the rest are proximity sensors [10]. The reed switch sensor is attached onto each pneumatic cylinder to detect the moving of piston and the proximity switch is used for detecting the object on the stage and on the pick-up arm. The description of each sensor is shown in Table 1. The address is fixed already to ease of use in the programming. All cylinders are driven by a group of solenoid valve (model VQZ1150-5M which is produced by SMC). This group consists of 5 integrated solenoid valves. The input of this unit with reference to the output of PLC is shown in Table 2.

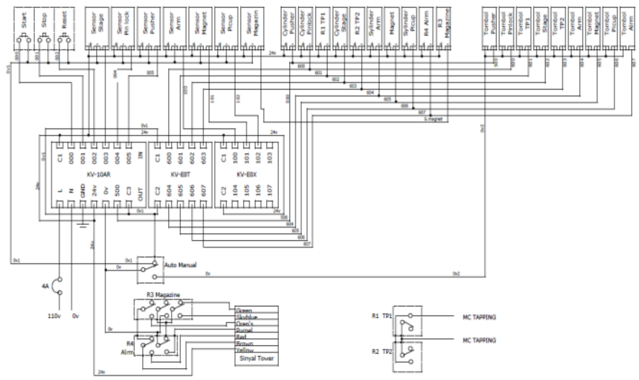


**Figure 7** Wiring diagram of PLC unit

**Table 1** List of input & relay address of PLC unit

| No | Input description | PLC | Relay address |
|---|---|---|---|
| 1 | START | KV-10AR | 0000 |
| 2 | STOP | KV-10AR | 0001 |
| 3 | RESET | KV-10AR | 0002 |
| 4 | STAGE SENSOR | KV-10AR | 0003 |
| 5 | LOCK PIN SENSOR | KV-10AR | 0004 |
| 6 | PUSHER SENSOR | KV-10AR | 0005 |
| 7 | PICKUP ARM SENSOR | KV-E8X | 0100 |
| 8 | MAGNET SENSOR | KV-E8X | 0101 |
| 9 | PICK UP SENSOR | KV-E8X | 0102 |

**Table 2** List of output & relay address of PLC unit

| No | Output description | PLC | Relay address |
|---|---|---|---|
| 1 | PUSHER | KV-10AR | 0500 |
| 2 | LOCK PIN UP | KV-E8T | 0600 |
| 3 | TAPPING DOWNUP1 | KV-E8T | 0601 |
| 4 | STAGE FORWARD | KV-E8T | 0602 |
| 5 | TAPPING DOWNUP2 | KV-E8T | 0603 |
| 6 | PICKUP ARM COME | KV-E8T | 0604 |
| 7 | PICKUP MAGNET | KV-E8T | 0605 |
| 8 | PICKUP DOWN | KV-E8T | 0606 |
| 9 | ALARM ON | KV-E8T | 0607 |

After all parts of the system are connected, the next step is to create the PLC programming based on the flow chart as shown in Figure 8.

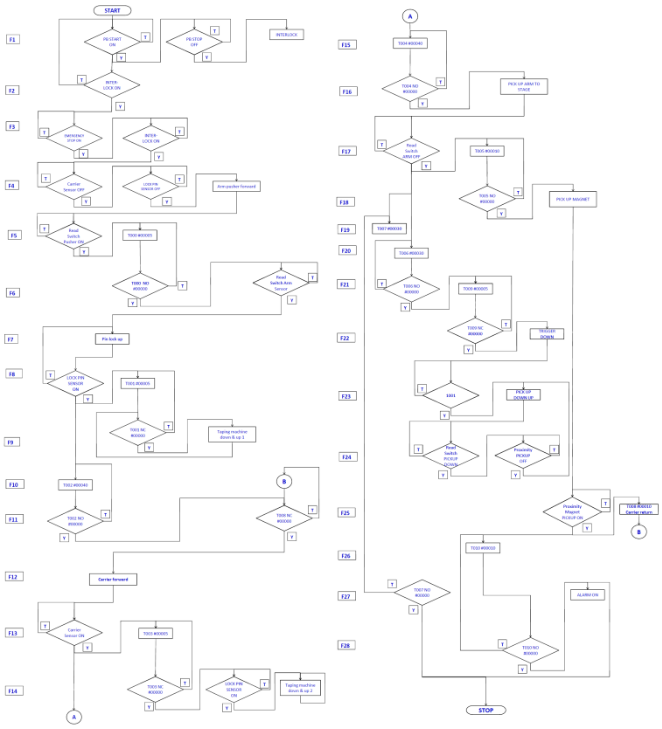


**Figure 8** Flow chart of PLC programming

This program consists of 24 programming steps and is divided into four main blocks:

1. System activation & Master Control Relay (MCR);
2. Auto feeding process;
3. Taping process; and
4. Pick up process.

To ensure the system runs well, internal timers were applied. The function of each timer is shown in Table 3.

**Table 3** List output and relay address of PLC Unit

| Timer | Description | SV (second) |
|---|---|---|
| T000 | PUSHER FORWARD | 5 |
| T001 | TAPPING DOWNUP1 | 5 |
| T002 | STAGE FORWARD | 40 |
| T003 | TAPPING DOWNUP2 | 5 |
| T004 | PICKUP ARM TO STAGE | 40 |
| T005 | PICKUP MAGNET | 10 |
| T006 | PICKUP DOWN | 7 |
| T007 | PICK UP FAIL | 30 |
| T008 | STAGE RETURN | 10 |
| T009 | PICK UP UP | 5 |
| T010 | RELEASE FAIL | 55 |

Figure 9 shows the latest condition of taping machine after the implementation of the automation system.

**Figure 9** Machine condition after the implementation

## 3.0 RESULTS AND DISCUSSION

The evaluation of this system is done as much as four times from November 2012 until middle of June 2013. To measure the result of this project, the previous data were collected, i.e. productivity, quality, working accident and investment.

### 3.1 System Evaluation

Evaluation must be done to ensure this system is functional and has safety features as well. The evaluation places the main priority on the safety operation, quality and productivity [13-15]. Four simulations were conducted to get the best result. Every problem that occurred during the simulation was solved and recorded to avoid the same problem being repeated in a process known as continuous improvement. Table 4 shows the summary of the simulation results, and Table 5 shows the comparison of the parameters.

**Table 4** Comparison of evaluation result

| No | Parameter | Simulation #1 | Simulation #2 | Simulation #3 | Simulation #4 |
|---|---|---|---|---|---|
| 1 | Standard time (seconds) | 11.14 | 10.15 | 10.16 | 10.06 |
| 2 | Part surface condition | No sratch | No sratch | No sratch | No sratch |
| | Machine stopped when miss pick up | No | No | Yes | Yes |
| 4 | Machine stopped when miss release | No | No | Yes | Yes |
| 5 | Signal lamp on when part in lower stock | No | No | No | Yes |
| 6 | Total sampling (pcs) | 25 | 25 | 25 | 25 |
| 7 | Percentage of taping process "pass" | 100% | 52.00% | 100.00% | 100.00% |
| 8 | Percentage of pick up process "pass" | 100% | 28.00% | 96.00% | 100.00% |
| 9 | Percentage of good product (OK) | 100% | 52.00% | 100.00% | 100.00% |
| 10 | Miss pick up evaluation | No applied | No applied | No applied | Applied |
| 11 | Miss release evaluation | No applied | No applied | No applied | Applied |

**Table 5** Comparison of system parameter of each simulation

| No | Parameter | Simulation #1 | Simulation #2 | Simulation #3 | Simulation #4 |
|---|---|---|---|---|---|
| 1 | System operation | Semi Auto | Full Auto | Full Auto | Full Auto |
| 2 | System control | Timer & sensor | Timer & Sensor | Timer & Sensor | Timer & Sensor |
| 3 | Pick up system | Coil relay | Pneumatic | Magnetic | Magnetic |
| 4 | Magazine sensor | No applied | Applied | Applied | Applied |
| 5 | Stage sensor | No applied | Applied | Applied | Applied |
| 6 | Pick up sensor | No applied | No exist | No exist | Exist |
| 7 | KV-10AR | Applied | Applied | Applied | Applied |
| 8 | KV-8ET | Applied | Applied | Applied | Applied |
| 9 | KV-8EX | No applied | No applied | Applied | Applied |
| 10 | Cutting oil dispensing aaplication | Manual | Manual | Manual | Auto |
| 11 | Signal tower lamp | No applied | Applied | Applied | Applied |
| 12 | Stopper magazine | No applied | No applied | Applied | Applied |
| 13 | Plastic cover for product | No applied | Applied | Applied | Applied |
| 14 | Master control relay | No applied | No applied | No applied | Applied |

## 3.2 Productivity

Historical data was collected in six month before the re-design of the machine was implemented. To calculate the productivity, efficiency and operating hours in production area, there are three categories of working time:

a. Actual work time, total number of manpower in a working area multiply by the actual working hours in a month.
b. Nett time, total actual work time minus daily regular activity which are related to production process directly, such as briefing, house-keeping and preventive maintenance.
c. Standard time (valued time), total of production time which is obtained from multiplying of the total output and cycle time of each product.

All the data use minute as the measurement unit.

The calculation of productivity, efficiency and operating hours are as follows:

- Productivity = Standard time ÷ Actual work time
- Efficiency = Standard time ÷ Nett time
- Operating hours = Nett time ÷ Actual work time

The productivity of previous data shown in Figure 10.


**Figure 10** Productivity data before implementation

With reference to Figure 10, the productivity at the stamping area was below 96.50%, with average achievement of 95.66%. At the beginning of fiscal year 2013, the management targeted 97.0% achievement.

Based on the flow chart on Figure 2, the cycle time of previous taping process is 25 seconds instead of 90.84 seconds of total standard time of chassis RH process. Assuming this re-design of the machine can reduce the cycle time in taping process as much as 50% and average order 7754 unit per month, the pre-achievement can be calculated as follows:

Monthly standard time
= 7754 unit X 90.84 seconds
= 740373 seconds = 11739 minutes
Monthly required capacity
= no. of operators X working hours (mins) X working day in a month
= 115980 minutes
Capacity used for chassis RH only
= 11739 minutes / 115980 minutes = 10.12%
Expected standard time after reducing 50% cycle time of taping process
= 90.84 seconds - (50% X 25 seconds )
= 78.34 seconds
Monthly required capacity after improvement
= 7754 unit X 78,34 seconds
= 607448 seconds = 10124 minutes
Capacity used for chassis RH only after improvement:
= 10124 minutes / 115980 minutes
= 8.72%
Expected improvement result based on required capacity
= required before – required after
=10.12% - 8.72%
= 1.4%
Productivity pre-achievement after improvement
= Previous achievement – Expected improvement result
= 95.66% + 1.4%
= 97.06%
This pre-achievement is 0.06% higher than top management target on the beginning of fiscal year 2013.

According to monitoring result that is collected since implementation until mid of June, the actual productivity achievement is shown in Fig. 11 below.

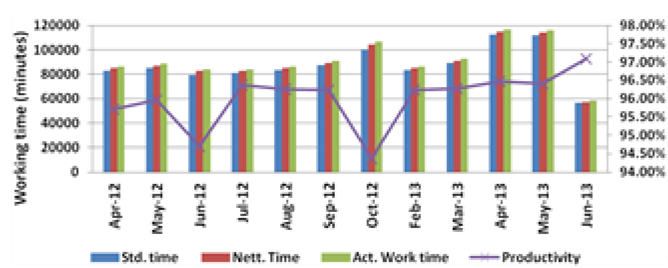



**Figure 11.** Productivity data before and after implementation

Based on the aforementioned data, the average of productivity increment since February 2013 until middle of June 2103 is 96.50%. The significant achievement obtained in the middle of June with

97.09% that is 0.03% of expected improvement or 0.09% more than management's target. This result was achieved after doing some improvement activities during the system evaluation.

### 3.3 Quality

Figure 12 shows the quality achievement of previous fiscal year.

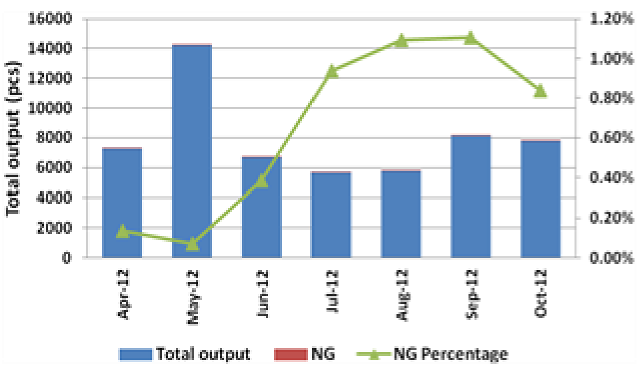



**Figure 12** Quality data before implementation

The types of defect of taping process divided to four categories as follows:

1. No taping, there is no thread on selected hole because of skipped process
2. Dented, dents were found on the surface of the product.
3. No center, the thread is not align with the hole.
4. Others, types of defect seldom found, such as demage and scratch

Based on actual data, the dented output is the highest defect of this product; it is 60% of total no-go (NG). Figure 13 shows the comparison among defect type.

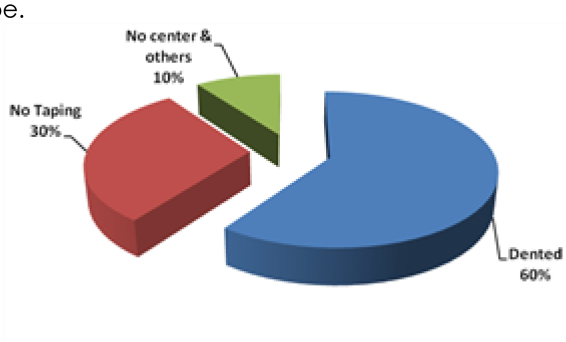



**Figure 13** Category of defect type and composition

The main root cause of those defects is human error, especially during the production process.

After implementing some corrective actions during the evaluation period, the quality of product has improved. Based on the monitoring of the data, there are no significant defects and the NG rate was 0.01% only. Figure 14 shows the monitoring result before and after system implemented. The main factor of this achievement is due to no chance for any human error during the taping process, because the process runs automatically by the system.

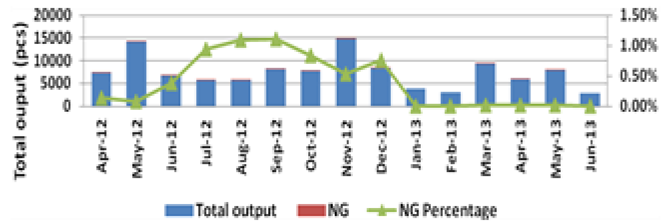



**Figure 14** Quality data before and after implementation

### 3.4 Working Accident

According to manufacturing record, there were two minor accidents during the previous fiscal year. The potential of occurrence of working accident is still high, because the process was still human dependent. To minimize the occurrence, the process was required to run without human interference directly.

As such, there was no working accident since this research was implemented which means this system has maximum level of safety.

### 3.5 Investment

To calculate the value added of this research for the company, the investment cost and other additional production costs need to be reviewed. The total cost required for this research is USD 1,985.00 and the additional production cost of this implementation is USD 10.37 per month. These additional costs come from additional electric consumption of 60 KWH per month.

The calculation of cost savings or the value added of this research is shown in Table 6.

**Table 6** Calculation of cost savings

| Parameter | Before | After |
|---|---|---|
| Standard production cost (USD/menit) | 0.0786 | 0.0786 |
| Standard time (menit) | 1.8 | 1.4 |
| Monthly order (pcs) | 7754 | 7754 |
| Total monthly production cost (USD) | 1097.03592 | 853.25016 |

Based on the calculation, the average monthly cost savings that can be achieved is USD 243.78.

The rate of return of investment can be calculated as follows:

Total monthly saving cost
= USD 243.78 – USD 10.37 = USD 233.41

Total investment cost
= USD 1,985.00

ROI period
= USD 1,985.00/month ÷ USD 233.41
= 8,5 months

## 4.0 CONCLUSION

This research is successful in the design and development of a system by implementing the automation system onto the taping machine which also gives the added value as follows:

- Productivity increment from average 95.66% before the implementation to be 96.50% after the system running. Moreover, in the middle of June, the result is 97.09%.
- The quality results also increase. Total defect has been reduced from 0.65% become 0.01%.
- There is no chance for working accident since the system was implemented, because the operation does not depend on human interaction.

Integration of PLC, electro-pneumatic and other mechanical parts need high accuracy synchronization to get the expected result. But, the importance of good planning and continuous improvement is crucial to finish the research project.

## Acknowledgement

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