Setup time reduction in flexo machine with SMED and internet of thing method

Ivander, T H S Rimo, and F A O Reynaldi
Industrial Engineering Department, Faculty of Engineering, Bina Nusantara University, Jakarta, Indonesia 11480
Email: ivander001@binus.ac.id

Abstract. PT. ABC is a company that engaged in the production of carton boxes. In the production of carton box, setup time is an important and unavoidable process. The current setup time required by the flexo machine at each changeover product is 39.8 minutes, while the target setup time that must be achieved by PT. ABC is 20 minutes. Whereas within one day the number of product changeover is quite high, which can reach 20 products/day. This research will focus on creating an efficient production process, by reducing setup time. The reduction of setup time in flexo machine can be achieved by implementing Single Minute Exchange of Dies (SMED) method and internet of things. In the implementation, SMED method will focus on converting internal setups to external setup. Besides converting the internal setup to external setup, in SMED method, improvements are also made by eliminating and combining the work of process with the application of the internet of things.

Keyword: carton box, internet of things, setup time, SMED

1. Introduction
Producing an efficient setup time is the target of all carton box manufacturing industries today. The setup process is a job that categorized as an important job, but it does not provide added value[1]. Currently, PT. ABC, which is engaged in the production of carton boxes, has a problem where the setup time required on the flexo machine is longer than the target setup time set by PT. ABC. PT. ABC has set a target setup time of 20 minutes/product, but the actual setup time is 39.8 minutes/product. The problem of high setup time is also getting more urgent because PT. ABC is facing a condition where the product variants that must be produced are very diverse. This condition cause high frequency of setup time that needed to change from one variant to others. So the total target setup time and the actual setup time has a big difference. Therefore, it is important for PT. ABC to reduce setup time so the production process time will be more efficient and the time reduced from the setup time can be allocated to produce outputs rather than being spent on actions that do not provide any added value. Several studies have been conducted to discuss about reduction of setup time by implementing Single Minute Exchange of Dies (SMED) method. Single Minute Exchange of Dies (SMED) is one of methods than can reduce setup time in production [2]. The application of the SMED method has been applied to the automotive industry at welding work stations with a reduction in setup time of 33%[3]. In mold-making production process, the SMED method also succeeded in reducing setup time by 38% [4]. In addition, the application of the SMED method to the punching machine can
also reduce setup time by 64% [5]. However, there is no research that discusses the reduction in setup time for the carton box industry, even though the frequency of setup per shift in the carton box industry is very high and the duration of the setup has a close relationship with the achievement of production output target. In addition, setup time reduction also can be achieved by implementing smart manufacturing. One of the ways to implement smart manufacturing is by using Internet of Things (IoT) [6]. IoT will build networks that connecting all manufacture machines and tools in one digital network communication [7]. The application of the IoT method has been applied to the fuel industry that can reduce the inspection costs by 80% [8]. In addition, there have been no other studies that applied the Internet of Things to reduce setup time, whereas decreasing setup time requires an effective communication flow which can be resolved by implementing the Internet of Things. Internet of Things can generally help to improve the function of the processes undertaken in companies [9]. IoT has a capability in providing communication access in real time [10]. Main purpose of IoT is creating smart environment in smart device which can be applied in many sectors such as energy, foods, social environment and medical sector [11]. IoT implementation can make company become more efficient, speedup the process, reduce human errors, avoiding data theft and organize complex system [12].

2. Methodology

2.1. Phase 1
In this phase, preliminary information gathering is carried out. The data obtained at this stage are the initial setup process procedure and the setup duration of each activity. The information is gathered directly by doing observation in PT. ABC, especially in the flexo machine area.

2.2. Phase 2
The second phase is the process of separating the internal setup from the external setup. Internal setup is setup process which perform while the machine is stop, while external setup is setup process which perform while machine is operating [2]. In addition, data recording is also carried out with a checklist form of the resources needed, such as workers, procedures and tools in the setup process.

2.3. Phase 3
In the third phase, the conversion is carried out from internal setup to external setup. At this stage, initial preparation of the machine before machine is operating and work standardization in the setup process are also carried out. The implementation of the internet of things is applied in this phase to create integrated communication lines between several divisions so that all divisions can get a real time information.

2.4. Phase 4
In this phase, simplification of all setup types is carried out. Simplification of external setup can be accomplished by improving operator setup procedures as well as eliminating unnecessary actions and ensuring the tools and machines presence and condition. The internal setup improvements can be conducted by doing parallel work in the setup process and trying to avoid adjusting the machine while the machine is stop. The implementation of the internet of things will be applied at this stage. Thus, production queue data can be integrated so that it can help operators to get actual information about machine setup schedules. The implementation is to place TV panel screens in strategic locations, such as PPIC room, flexo machines, ink warehouse, rubber warehouses, and coor production headroom as well as connecting flexo machine panels to the server. The aim of this implementation is to give information of start and completion time of a production process and the transition of changes from one variant to another on a flexo machine can be known by the ink room operator, the rubber warehouse PIC, and the flexo machine operator themselves. In addition, there will be notifications appearing on the Panel screen to the ink room operators and rubber warehouse PIC to help them
preparing the ink and rubber on time. With this application, flexo machine operators no longer have to wait for ink to be mixed and find for rubber during the setup process. This will reduce the overall setup time. All phases in SMED method are summarized in figure 1.

This research begins with field observations, especially in the production process in flexo machine, and the next step is doing a literature study as a basis for this research. After that, data was collected by direct measurement and interviews. The direct data collection process is carried out by collecting internal and external setup information with a stopwatch. Time measurement is carried out in two stages, which are the measurement of time before and after the application of the SMED method and internet of things. The amount of data collected in each measurement is 100 job orders. To reduce the other factors that affect setup time in flexo machine, the same operator and machine are used, both before and after the implementation of SMED and internet of things. Interviews with operators were conducted to find out the obstacles in the setup process and useful information to support the data that had been obtained from direct time data collection. After data collection is completed, the next step is to compare the average time before implementing and after implementing the SMED method and internet of things. After the data is collected, it can be analysed whether the application of the SMED method and internet of things can help PT. ABC reaches the predetermined target setup time.

3. Implementation of SMED and IoT

3.1. Phase 1
In this section, data collection is applied to understand the current setup process and setup time of each process. The setup process sequence in PT ABC flexo machine is shown in figure 2, while the current setup time is shown in table 1 and table 2.

3.2. Phase 2
In this section, all setup activities are analyzed and process of separating the internal setup from the external setup is applied. Based on the observation in PT ABC, initial external and internal setup is shown in table 3.
Table 1. Average setup time based on observation (categorized by setup item)

| Category         | Setup activity | Setup time (minutes) |
|------------------|----------------|----------------------|
| Rubber           | Taking         | 10.64                |
|                  | Installation   | 7.31                 |
|                  | Returning      | 3.60                 |
|                  | Taking         | 10.82                |
|                  | Installation   | 6.77                 |
|                  | Returning      | 2.96                 |
| Ink              | Taking         | 15.52                |
|                  | Installation   | 1.95                 |
| Sheet/Material   | Taking         | 11.75                |
|                  | Installation   |                      |
| Adjusting process|                |                      |

Figure 2. Setup process in flexo machine
Table 2. Average setup time based on observation (categorized by operator job desk)

| Operator     | Setup activity       | Setup time (minutes) |
|--------------|----------------------|----------------------|
| Spv Operator | Rubber taking        | 10.64                |
|              | Material taking & Installation | 17.47               |
|              | Adjusting process    | 11.75                |
| Operator 1   | Rubber installation and returning | 10.91               |
|              | Ink taking           | 10.82                |
| Operator 2   | Ink installation     | 6.77                 |
|              | Ink returning        | 2.96                 |

Table 3. Initial internal and external setup activity

| Internal Setup                  | External Setup                                      |
|---------------------------------|-----------------------------------------------------|
| Rubber taking                   | Adjusting process based on standard                 |
| Rubber discharing and installation |                                                     |
| Sheet taking                    |                                                     |
| Sheet installation              |                                                     |
| Ink ordering and taking         |                                                     |
| Ink installation                |                                                     |
| Rubber returning                |                                                     |
| Ink returning                   |                                                     |

3.3. Phase 3
In this stage, conversion from internal setup to external setup is conducted. Based on the observation and analysis process, the internal setup activity that can be converted into external setup are:

3.3.1. Material taking process converted from internal setup into external setup
Current condition: the material/sheet taking process is conducted until it is finished, then the adjusting process will begin.
Propose: before the adjusting process, the operator only needs to take some of the material (1 board only), 1 board of sheet (approximately 200-300 sheets) is sufficient for adjusting process. Then the rest of the material required will be taken when the machine is running. When this condition is applied, the overall material taking time will be reduced.

3.3.2. Rubber and ink returning process converted from internal setup into external setup
Current condition: Rubber and ink are returned to the rubber and ink warehouse when the machine is not running (internal setup).
Propose: Rubber and ink returning process are conducted when the machine is running. The operator should be focused on material taking process when the machine is not running, so it can reduce the time of material taking process.

Conversions of the internal setup into external setup are summarized in table 4. After converting internal setup to external setup, the next step will be implementing the standardization on setup time preparation which explained in 3.3.3 and 3.3.4.
3.3.3. **Function anticipation**
In this improvement process, inspection of the machine condition is conducted before the setup process begins. The purpose of this inspection is to ensure the machine is in a good condition without any issue. The inspection includes quality inspection of cutting blades/slotters, glue, packing machines, and feeders for input sheets.

3.3.4. **Function preparation**
Before the production process begins, all of the tools must be available in the production area and should be placed in the same place as determined before, so the operator can find the tools easily. It can solve the current problem at PT ABC which the operator takes time for searching the tools every time the setup begins. Function preparation process will use a checklist table containing a list of machine and tools required, the condition of the machine and tools, and the number of stocks available. It is suggested that PT ABC should provide additional tools for rubber installation and discharging, while the ink installation process does not require any additional tools.

| Internal Setup                          | External Setup             |
|-----------------------------------------|-----------------------------|
| Rubber taking                           | Adjusting Process           |
| Rubber discharging and installation     | Sheet taking                |
| Sheet installation                      | Rubber returning            |
| Ink ordering and taking                 | Ink returning               |
| Ink installation                        |                             |

**Table 4. Conversion from internal to external setup**

3.4. **Phase 4**
In this stage, some of the internal setup and external setup are simplified, improved, and conduct in parallel to reduce the setup time. The improvements implemented in this stage are:

3.4.1. **Internet of things implementation**
The purpose of this implementation is to make information flow run smoothly and several activities can be prepared in advance so the waiting time that caused by lack of information is eliminated. Implementation of internet of things will focus on preparing monitor/panel that can show all required information that is explained in Figure 3 for the information flow and Table 5 for the panel information interface.
3.4.2. Providing the rubber rack
Current condition: After the operator supervisor receives the job order, the operator supervisor will take the rubber at rubber warehouse, and then bring it to the flexo machine for rubber installation.

Propose: Rubber rack is provided near the flexo machine (as shown in figure 4) and the rubber operator will provide the required rubber for that shift based on job order list in panel information. The implementation of rubber rack will reduce setup time because it eliminates the waiting time for searching rubber in rubber warehouse and transportation time from rubber warehouse to flexo machine. In the rubber preparation, the internet of things is applied. Panel information in Rubber warehouse is integrated with the coor machine and flexo machine room panels, so the operator in the rubber warehouse can prepare and place the rubber in advance in rubber rack.

![Figure 4. Rubber rack implementation](image)

3.4.3. Improvement process in ink order and taking
Current condition: Flexo machine operator come to the ink warehouse, then operator in ink warehouse will prepare the ink based on the color guide on the job order. The ink operator will mix the ink, and the flexo operator will wait for the ink mixing process, and then bring the ink back to flexo machine for ink installation at flexo machine.

Propose: As the implementation of the internet of things, panel screens will be provided, which integrated among PPIC team, coor machine operator, flexo machine operator, and rubber warehouse. Ink operator can prepare the ink at appropriate time, so when the flexo machine operator comes to take the ink, the ink will be ready and it can reduce waiting time.

3.4.4. Improvement in sheet structure
Current condition: The sheet produced by coor machine is not arranged to obtain good flow for transporting sheet from the conveyor to flexo machine. In addition, the size of the boards used for carrying the stack of sheets are not uniform, so sheet flow is not running smoothly.
Propose: The size of the boards must be uniform and boards in conveyor must be arranged well so it will not collide with each other.

3.4.5. Improvement in adjusting process
The adjusting process is the setup process which needs the longest time among the other setup processes. In this adjusting process, the operator ensure the color range, design placement, design, size, and the function of carton box are already fulfill standard approved by the customer. Alternative that can be conducted for reducing this adjusting time by allocating 2 operators in this adjusting process.

Current condition: There is only 1 operator assigned in the adjusting process, so the operator has to move from the machine panel (for starting and stopping the machine also controlling ink usage) to the output panel (for checking the output) and it is not efficient for the operator (shown in figure 5).

Propose: Allocating 2 operators in the adjusting process. Operator 1 will be allocated in the machine panel to start and stop the machine, while another operator will be assigned to check the output of the carton box produced. This additional operator previously handled the ink and rubber taking process, but as the waiting time for ink and rubber preparation is reduced, their time can be allocated for the adjusting process (shown in figure 6).

After implementation of reducing material taking time, conversion from internal setup into external setup, standardization process, rubber rack placement, simulation of implementation internet of things (panel is not provided yet) and improvement in adjusting process have been conducted, PT ABC can
reduce setup time from 39 minutes into 30.1 minutes. Summary of average setup time is explained in table 6 and table 7.

After implementation of rubber rack, it is shown that rubber taking time can be reduced from 10.64 minutes to 4.59 minutes. After implementation of Internet of things in ink preparation process, ink taking time can be reduced from 10.82 minutes to 7.96 minutes. After improvement in sheet structure, sheet taking time can be reduced from 15.52 minutes to 12.33 minutes. After improvement in adjusting process, adjusting process time can be reduced from 11.75 minutes to 11.19 minutes.

Table 6. Average setup time based on observation after improvement (categorized by setup item).

| Category       | Setup activity | Setup time (minutes) |
|----------------|----------------|----------------------|
| Rubber         | Taking         | 4.59                 |
|                | Installation   | 7.78                 |
|                | Returning      | 3.59                 |
|                | Taking         | 7.96                 |
| Ink            | Installation   | 7.65                 |
|                | Returning      | 3.31                 |
|                | Taking         | 12.33                |
| Sheet/Material | Installation   | 2.03                 |
|                | Adjusting process | 11.18              |

Table 7. Average setup time based on observation after improvement (categorized by operator job desk).

| Operator       | Setup activity                      | Setup time (minutes) |
|----------------|-------------------------------------|----------------------|
| Spv Operator   | Rubber taking                       | 4.6                  |
|                | Material taking & Installation      | 14.4                 |
|                | Adjusting process                   | 11.2                 |
| Operator 1     | Rubber installation and returning   | 11.4                 |
|                | Ink taking                          | 8.0                  |
| Operator 2     | Ink installation                    | 7.7                  |
|                | Ink returning                       | 3.3                  |

4. Conclusion
Implementation of Single minute exchange of Dies (SMED) by converting internal setup into external setup and simplify the process in flexo machine were proposed to PT ABC. As a result, it is shown that there is improvement in setup time reduction about 9.7 minutes. Furthermore, it can be proposed to PT ABC to implement internet of things by preparing all the panel and information flow required, so information flow can run smoothly and PT ABC can reduce more setup time in the future.

Acknowledgments
Authors wishing to acknowledge assistance and encouragement from colleagues, special work by technical staff and financial support from Binus University. (Refer to PTB : 025/VR.RTT/IV/2020)
References

[1] Gungor Z E and Evans S 2015 *Eco-effective changeovers; changing a burden into a manufacturing capability* (Cambridge:12th Global Conference on Sustainable) 527-32

[2] Shingo S 1985 *A Revolution in Manufacturing: The SMED System* (Oregon: Productivity Press)

[3] McIntosh R I, Culley S J, Mileham A R and Owen G W 2010 A critical evaluation of Shingo's 'SMED' (Single Minute Exchange of Die) methodology *Int. J. Prod.* 38 2377

[4] Moreira A C and Pais G C S 2011 Single minute exchange of die. A Case Study Implementation *J. Technol.* 6 130-46

[5] Costa E, Bragança S, Rui S and Alves A 2013 Benefits from a SMED application in a punching machine *International Journal of Mechanical, Aerospace, Industrial and Mechatronics Engineering* 7 379-85

[6] Yang H, Kumara S, Bukkapatnam S T S and Tsung F 2019 The internet of things for smart manufacturing: a review *IIE Trans.* 51 1-26

[7] Hadi S and Murti H W 2019 Kajian industri 4.0 untuk penerapannya di Indonesia *J. Manaj. Ind. Logist.* 3 1-13

[8] Ansori A 2018 Studi Pemanfaatan internet of things untuk pengawasan bahan bakar minyak *Journal Wave* 12 31-42

[9] Alarcón F, Perales D P and Boza A 2016 Using the internet of things in a production planning context *Braz. J. Oper. Prod. Manag.* 13 72-6

[10] Ali Z H, Ali H A and Badawy M M 2015 Internet of things (IoT): definitions, challenge, and recent research directions *Int. J. Comput. Appl.* 128 37-47

[11] Perwej Y, Haq K, Parwej F and Hassan M M M 2019 The internet of things (IoT) and its application domains *Int. J. Comput. Appl.* 182 36-49

[12] Madakam S, Ramaswamy R and Tripathi S 2015 Internet of things (IoT): a literature review *Journal of Computer and Communications* 3 164-73

[13] Almomani M, Aladeemy M, Hadi A and Mumani A A 2013 A proposed approach for setup time reduction through integrating conventional SMED method with multiple criteria decision-making techniques *Comput Ind Eng* 66 461-9