REDUCING THE PRODUCT CHANGEOVER TIME USING SMED & 5S METHODS IN THE INJECTION MOLDING INDUSTRY

Daniel Agung¹, Hasbullah Hasbullah²
¹Manufacturing Department, P.T. Bumimulia Indah Lestari
Jl. Jababeka, Bekasi, Jawa Barat 17550, Indonesia
²Department of Industrial Engineering, Universitas Mercu Buana
Jl. Raya Meruya Selatan, Kembangan, Jakarta 11650, Indonesia
Email: danielagung0508@gmail.com hasbullah@mercubuana.ac.id

Abstract -- Along with the increasing market of plastic packaging products resulting from the injection process and the rapid development of existing technology, we need a strategy to be able to continue to meet the customer's needs and to be able to compete in the industry. One of the strategies that may be employed is Lean. Lean is a concept aimed at eliminating existing waste. One of the implementations of Lean's concept is the SMED (Single Minute Exchange of Dies) concept. SMED is a concept aimed at reducing the changeover time, so the eliminated time can be used in the production process. P.T. BIL is one of the companies engaged in the production of plastic packaging with an injection process. Problems occurring at P.T. BIL was the absence of a measurement process for changeover time. The Operation Analysis Chart concept was used to analyze the carried-out activities. To optimize activities employing the SMED concept, Analytical Cards were used so that the change over time can be reduced. The 5S concept was applied to support the SMED concept, so the waste in the work area could be eliminated. By implementing the SMED concept, we reduced 18% of the change over time.

Keywords: SMED; Injection molding; Changeover; 5S; Lean

INTRODUCTION

In 2019, the market for plastic injection products amounted to US$ 8940 million, and it was predicted to continue to increase due to its technological advancement. The market for plastic injection products is expected to grow at roughly 2.1% for the next five years, and it is predicted to have reached US$10100 million by 2024. This increasing opportunity of the plastic industry makes the injection molding industry a promising sector. To be able to keep up with the global competition, we need competitiveness strategies, one of which commonly used is Lean's concept.

Lean is a strategy used to make the manufacturer able to stay competitive. Moreover, its principle is to increase productivity by reducing waste. Wahab et al. (2013) explained that the lean concept used everything with fewer resources in the mass production manufacture. Besides, fewer labors in the production line, less space needed for the manufacturing processes, less investment in equipment, fewer hours used in the development. Moreover, it may also produce much more inventory capacity by providing fewer defects. Lean is not limited to the production process; in fact, it deals with all activities starting from product development, purchasing tools, manufacturing processes, and distribution processes. Lean is aimed at increasing productivity, improving quality, reducing waiting time, and reducing costs. Activities in Lean are classified as activities that provide added values and activities that do not offer added values. Regarding Lean’s principles, waste is defined as a source of 8 activities that do not offer added values such as Defect, Overproduction, Waiting, Non-Utilized Talent, Transportation, Inventory, Motion, and Extra Processing.

Sundar et al. (2014) explained that one pillar in Lean’s concepts was the Just-in-Time (JIT) concept. The Just-in-Time concept was a concept aimed at producing and delivering the right product, in the right amount, at the right time using the minimum resources. The JIT concept quickly identified any problems due to its reduction in inventory in the production system. Inventory reduction will bring up any issues that are produced quickly, so immediate
improvements could be made to overcome these problems.

The SMED concept is one of Lean’s concepts supporting the Just-in-Time principle. Gaikwad et al. (2015) explained that SMED focused on reducing unproductive time by increasing and standardizing the operating process to replace equipment using simple and easy application techniques. Companies were required to produce products with small quantities but with a large variety by the JIT concept. Based on these needs, the time of product change settings became a significant effect.

When the product change setting was the measured time interval of the last product of the previous type with good quality, the first product of the next type was produced with good quality. Shingo (1985) classified of changing the product settings activities into two types, namely internal activities, and external activities. Internal activities were activities that could only be done when the engine was not operating, while external activities were activities that can be done even though the engine was operating. The basic idea of the SMED concept was to do as many activities as possible from the internal activities to external activities.

Ferradas & Salonitis (2013) suggested that there were five steps in the implementation of SMED, as shown in Fig. 1, namely:
1. Identifying internal activities and external activities
2. Separating internal activities from external activities and eliminating unnecessary activities
3. Changing internal activities into external activities
4. Focusing on reducing internal activities
5. Focusing on reducing external time

![Figure 1. Stages in the implementation of SMED (Ferradas & Salonitis, 2013)](image)

SMED concepts positively impact on the industry. Moreover, by applying SMED, we can reduce changeover time, so we will make the industry better respond to the customer’s demand. Heriansyah & Ikatrinasar (2017) conducted a study on SMED, where changes in internal activities to external needed to be supported by the system improvements and work methods. With these changes, they expected that some internal activities could be done when the production machine was still operating or turning into an external activity. After SMED was implemented, the changeover time could be reduced by 52%. Arief (2015) implemented a SMED concept in a pharmaceutical company that could optimize the changeover by reducing 26% of the total changeover time. Mulyana & Hasibuan (2017) showed that one of the causes of the length of changeover time was many internal processes carried out when the engine was off and that there was no division of labors among the operators. A study conducted by Mulyana & Hasibuan (2017) showed that it was able to reduce the changeover time by 75.59%. Hendri (2015) also conducted a study on SMED. He found out that if SMED was implemented, it could reduce the changeover time by 21.29%, where the reduction was made possible by optimizing the external time and reducing the internal activities.

SMED now becomes more and more needed due to the increasing variability of the products, the reduced product life cycles, and the increased market requirements. SMED increases the flexibility of the existing process, where the product change setting process can be done more quickly so that the product can be made in the right amount and on time by the customer’s demand. To ensure that SMED will be well implemented, we can also apply the 5S concept to regulate the work area so that operators can work more effectively. With the 5S concept, some occurring waste can be eliminated.

Hindoliya & Sarathe (2017) suggested that 5S was a technique to regulate workplaces in order that the quality of work, workability, and productivity of workers could be enhanced. Hindoliya & Sarathe (2017) suggested that 5S consisted of 5 main points that meant as follows:

- Seiri (Sort): regulating all existing items, where the required items would be stored, while removing items that were not needed.
- Seiton (Set in Order): arranging the layout of the goods and giving identity to each object. Everything had to be in its place to eliminate the potential for searching products and to eliminate waste.
• Seiso (Shine): keeping every item clean and tidy. The cleaning process was an inspection process to detect any abnormal or potential failure.
• Seiketsu (Standardize): documenting each work method and making 5S a part of the corporate culture in addition to developing systems and procedures for maintaining and monitoring the first 3S.
• Shitsuke (Sustain): establishing the habits of continuous improvement procedures, so the continuous improvement process could be maintained and repairs that had been made previously remained at the predetermined standards.

Hindoliya & Sarathe (2017) suggested that by implementing 5S, we could enjoy benefits as follows:
• Transparent work process flow
• Clean and well-maintained work environment
• Reducing changeover time
• Reducing cycle times
• Adding space available at work
• Reducing the potential for workplace accidents
• Reducing waste time carried out by workers
• Increasing the effectiveness of the use of equipment

In the implementation of SMED, we often combined it with the 5S concept, since a reduction in the changeover time could also be affected by the workplace environment. Bevilacqua et al. (2015) combined the SMED concept with the 5S concept, where the method that was used could reduce the changeover time by 61.5%. Roriz et al. (2017) integrated and implemented the SMED concept with the 5S concept and got a 47% reduction changeover time. Rosa et al. (2017) integrated and implemented the concepts of SMED and 5S, resulting in a reduction in the changeover time by 58.3%.

Plastic injection is a process most commonly used to produce plastic components. The injection process cycle starts from melting the material, the injection process by filling the material into the mold, and ends with the process of cooling and releasing the product. Plastic raw materials, usually in the form of granules or powders, are melted in the injection unit at a working temperature ranging from 200 to 250°C. The melted material will be entered by being injected into a plastic mold with a certain pressure and speed. Molds that are injected with a certain pressure will be held back by the engine pressure, commonly called the clamping force. The advantage of the injection process is that this process is a process to produce plastic products in bulk economically. Besides, the products can be produced with high precision and good accuracy. The products that are produced do not require additional processing or workmanship, and they can be directly used by the customer. Bharti & Khan (2010) classified factors affecting the quality of plastic injection products into four categories, namely product design, mold design, engine performance, and process parameters. To print a plastic product, we need a mold to be formed in accordance with the desired product. The injection mold consists of 2 main parts, namely core, and cavity. A core is a mold part forming the inside of a product, while a cavity is a mold part forming the outside of the product. Injection mold can be made with a multi-cavity system. The multi-cavity is in 1 mold that has more than one cavity, so in one cycle of the injection process, more than 1 product can be produced.

PT BIL is a company located in Cikarang that engaged in the production of plastic packaging products using the injection process. PT BIL experienced a problem, namely the absence of a measurement process for changeover time. Without measuring the change over time, they would not know what potential improvements could be made to reduce changeover time. SMED is a method aimed at reducing the changeover time by eliminating the occurring waste, where it could detect by first measuring the change over time. Moreover, they found out that the work equipment was not properly sorted, and the equipment identity was not available. The waste potentially created in the work environment could be overcome with the 5S method, which, in this study, focused on the first 2S, namely seiri and seiton. This study was aimed at reducing the changeover time by eliminating wasteful activities and irregularities in the work area that could create waste. The SMED concept, combined with the 5S concept, was implemented to reduce the changeover time.

MATERIAL AND METHOD
Material
The data used as the materials in this study included:
• Type of injection mold used on P.T. BIL
• Duration of the changeover before the implementation of SMED & 5S
• Types of activities done during the changeover process
• Observation of the work area before it was improved with the 5S method
• Observation of the work area after it was improved with the 5S method
• Duration of changeover after SMED & 5S were applied

Types of injection mold on P.T. BIL were used as the data to divide mold types into several types. Distribution of the types was made based on mold, the dimensions and the type of accessories used in the mold. Mold dimensions and types of accessories used in the mold would affect the changeover time that was required.

The duration of the changeover time before SMED & 5S was applied was required as the initial changeover duration data. The whole process of both the value-added process and the non-value-added process was accumulated as the time of changeover on injection mold.

The types of activities done during the changeover process were classified into external activities and internal activities. An external activity was a changeover activity that could be done while the machine was operating, while an internal activity was a changeover activity done while the machine was stopped. Moreover, the activities were also classified as value-added activities and non-value-added activities in order that we could prioritize non-value-added activities to be eliminated or reduced.

We also observed the work area to analyze the waste occurring in the work area. All waste that was found would be used as a standard reference for improvement in the working area.

The duration of changeover after the SMED and 5S were implemented was required as the data compared to changeover time before SMED, and 5S was implemented.

Method

This study was aimed at measuring the change over time and identifying the occurring waste, so when the available waste was reduced, it would reduce the change over time of the injection mold. The study was conducted as follows:

1. Collecting changeover schedule data of the injection mold
2. Measuring the change over time of the injection mold using a stopwatch and recording it on the Operation Analysis Chart. The data collection period was October - November 2018
3. Analyzing the work elements and potential waste that occurred using the Operation Analysis Chart
4. Separating the internal activities from the external activities in the changeover process using Analytical Cards
5. Conduct 5S in the workplace to support the SMED concept
6. Measuring the change over time of the injection mold after being done at the workshop

In displaying observational data, we could use the Operation Analysis Chart, as Simoes & Tenera (2010) stated. Fig. 2 shows five types of activities, namely: Processing, Inspection, Transportation, Storage, and Waiting. By using the Operation Analysis Chart, we could analyze the processes that occurred and the waste that took place during the changeover process. When we separated the internal activities from the external activities as SMED was applied, we could employ a tool called the Analytical Card. The Analytical Card contains tables that classify which activities are internal activities and external activities. Analytical Cards can be made in several periods, namely analyzing the conditions of the current product change settings, analyzing internal activity activities and external activities that have been separated, analyzing the conversion of internal activity activities into external activities, and analyzing the results of improvements in internal activities and external activity.

![Activity Symbol Activity Type](attachment:Simoes&Tenera,2010)

Figure 2. Activity on Operation Analysis Chart (Simoes & Tenera, 2010)

Fig. 3 shows the study’s steps. Changeover time that had been analyzed with the Operation Analysis Chart would be converted to Analytical Cards to see any potential activities that could be used as the external activities. Improvements would be made based on the SMED concept and the 5S concept. The SMED concept would optimize the internal activities that could be converted to external activities, while the 5S concept would improve the organization of workplaces; thereby, its enhanced work productivity.
RESULTS AND DISCUSSION

General data on the injection molds that would be elaborated were data of the classification of plastic molds at P.T. BIL. The classification of plastic molds was based on the volume of plastic molds and the accessories used in the injection molds. The greater the volume of injection molds, the more injection molds would have to be used in the injection machines. The greater the engine capacity that was used, the more coolant hoses, nipples, and other components that had to be installed on the mold, so it would result in longer changeover time. Accessories used in the injection molds affected the classification of injection molds. Injection molds that had accessories that had to be employed would result in longer changeover time. Based on the classification, the data was collected in regard to the general data of injection molds, as showed in Fig. 4 showed.

Table 1. Classification of plastic molds for injection of P.T. BIL

| Category | Information | Quantity |
|----------|-------------|----------|
| A        | Volume < 123000 cm³ with accessories | 29 |
| B        | Volume < 123000 cm³ without accessories | 38 |
| C        | Volume > 123000 cm³ with accessories | 23 |
| D        | Volume > 123000 cm³ without accessories | 10 |
| Total    |             | 100 |

Based on Table 1, there were four categories, namely categories A, B, C, and D, with 100 plastic injection molds in total. In the data collection period of October - November 2018, the data was obtained for the purpose of the changeover time for each category, and they were presented in the average value below. Table 2 showed examples of the Operation Analysis Chart. The Operation Analysis Chart shown as the example was category A.

Table 2, as an example of Operation Analysis Chart, showed that some wastage occurred, where the waste could be eliminated or moved into an external activity. The Analytical Card was used as a tool to separate and analyze which activity could be categorized as external activities and internal activities. Table 3 – Table 6 showed the Analytical Card of each category.
Table 2. Operation Analysis Chart Category A

| No | Job description                  | Duration (minute) | Category       | Setup type                  |
|----|----------------------------------|-------------------|----------------|-----------------------------|
| 1  | Remove the cooling hose          | 16                | Added Value    | Internal                    |
| 2  | Remove the auto close sensor     | 13                | Added Value    | Internal                    |
| 3  | Remove auto close                | 13                | Added Value    | Internal                    |
| 4  | Remove the side grip             | 9                 | Added Value    | Internal                    |
| 5  | Set down mold                    | 7                 | Added Value    | Internal                    |
| 6  | Bring mold to the mold maintenance | 10             | Non-Added Value | Internal (convert to external) |
| 7  | Looking for an eye bolt           | 6                 | Non-Added Value | Internal (convert to external) |
| 8  | Waiting for the next product's mold preparation | 10             | Non-Added Value | Internal (eliminate)        |
| 9  | Looking for the next mold product | 7               | Non-Added Value | Internal (convert to external) |
| 10 | Replace mold's nipple            | 11                | Non-Added Value | Internal (convert to external) |
| 11 | Bring mold to the production line | 8               | Non-Added Value | Internal (convert to external) |
| 12 | Waiting for production information | 20              | Non-Added Value | Internal (eliminate)        |
| 13 | Looking for a spanner            | 6                 | Non-Added Value | Internal (eliminate)        |
| 14 | Set up mold                      | 7                 | Added Value    | Internal                    |
| 15 | Install side grip                | 10                | Added Value    | Internal                    |
| 16 | Look for allen spanner           | 4                 | Non-Added Value | Internal (eliminate)        |
| 17 | Looking for auto close            | 9                 | Non-Added Value | Internal (eliminate)        |
| 18 | Install auto close               | 14                | Added Value    | Internal                    |
| 19 | Install the auto close sensor    | 13                | Added Value    | Internal                    |
| 20 | Install the cooling hose         | 17                | Added Value    | Internal                    |
| 21 | Look for additional hoses        | 17                | Added Value    | Internal (eliminate)        |
| 22 | Turn on machine heater           | 21                | Added Value    | Internal                    |
| 23 | Purge material                   | 21                | Non-Added Value | Internal                    |
| 24 | Run In                           | 50                | Added Value    | Internal                    |
| 25 | QC Approval                      | 28                | Non-Added Value | Internal                    |

Total Time (min) 219 28 68 0 30 345

Table 3. Analytical Card of Category A before SMED Improvement

| Work element | External Activities | Internal Activities | External Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|----------------------|
| 1            | Work element description | Remove the cooling hose | Waiting for the next product's mold preparation | Turn on machine heater | 10 21 |
| 2            | Work element description | Remove the auto close sensor | Looking for the next mold product | Purge material | 10 21 |
| 3            | Work element description | Remove auto close | Replace | Run In |
| Work element | Description | Duration (min) |
|--------------|-------------|----------------|
| 4            | Remove the side grip | 9             |
| 4            | Bring mold to the production line | 8             |
| 4            | QC Approval | 20            |
| 5            | Set down mold | 7             |
| 5            | Waiting for production information | 20            |
| 6            | Bring mold to the mold maintenance | 10            |
| 6            | Looking for a spanner | 9             |
| 7            | Looking for an eye bolt | 6             |
| 7            | Set up mold | 7             |
| 8            | Install side grip | 10            |
| 9            | Look for Allen spanner | 4             |
| 10           | Looking for auto close | 9             |
| 11           | Install auto close | 11            |
| 12           | Install the auto close sensor | 12            |
| 12           |  | 13            |
| 13           | Install the cooling hose | 17            |
| 14           | Look for additional hoses | 14            |
| 14           |  | 17            |

| Internal Activities | Duration (min) | 73 | 153 | 120 | 345 |
|---------------------|----------------|----|-----|-----|-----|
| External Activities | Duration       |    |     |     |     |
| Total Time (min)    |                | 73 | 153 | 120 | 345 |
### Table 4. Analytical Card of Category B before SMED Improvement

| Work element | External Activities | Internal Activities | External Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|----------------------|
|              | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities |
| 1            | Remove the cooling hose | Looking for a nipple | Turn on machine heater | | |
| 2            | Remove the side grip | Looking for an eye bolt | | Purge material | |
| 3            | Set down mold | Waiting for the next product's mold preparation | Run In | | |
| 4            | Bring mold to the mold maintenance | Replace mold's nipple | QC Approval | | |
| 5            | Bring mold to the production line | | | | |
| 6            | Looking for a spanner | | | | |
| 7            | Set up mold | | | | |
| 8            | Install side grip | | | | |
| 9            | Install the cooling hose | | | | |
| 10           | Look for additional hoses | | | | |

| Work element | External Activities Duration | Internal Activities Duration | Total Time (min) |
|--------------|-------------------------------|------------------------------|------------------|
|              | 35                            | 73                           | 105              |
|              | 105                           |                              | 213              |

Total Time (min) 213
Table 5. Analytical Card of Category C before SMED Improvement

| Work element | External Activities | Internal Activities | External Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|---------------------|
|              | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities |
| 1            | Work element        | Remove the cooling hose | Waiting for the next product’s mold preparation | Turn on machine heater | 23 |
|              | duration            | 21                   | 14                  |                      | 345 |
| 2            | Work element        | Remove hydraulic hose | Looking for the next mold product | Purge material | 20 |
|              | duration            | 12                   | 9                   |                      | 345 |
| 3            | Work element        | Remove the auto close sensor | Bring mold to the production line | Run In | 54 |
|              | duration            | 18                   | 10                  |                      | 345 |
| 4            | Work element        | Remove auto close     | Looking for a spanner | QC Approval | 26 |
|              | duration            | 16                   | 5                   |                      | 345 |
| 5            | Work element        | Remove the side grip | Set up mold | 14 |
|              | duration            | 12                   | 14                  |                      | 345 |
| 6            | Work element        | Set down mold         | Install side grip | 14 |
|              | duration            | 14                   | 14                  |                      | 345 |
| 7            | Work element        | Bring mold to the mold maintenance | Look for Allen spanner | 8 |
|              | duration            | 10                   | 8                   |                      | 345 |
| 8            | Work element        | Looking for auto close | 3 |
|              | duration            | 11 |
| 9            | Work element        | Install auto close    | 11 |
|              | duration            | 18 |
| 10           | Work element        | Install the auto close sensor | 19 |
|              | duration            | 19 |
| 11           | Work element        | Install hydraulic hose | 25 |
|              | duration            | 25 |
| 12           | Work element        | Install the cooling hose | 25 |
|              | duration            | 25 |
| 13           | Work element        | Look for additional hoses | 9 |
|              | duration            | 9 |

Internal Activities Duration | 73 | 153 | 120 | 345 | 345
Table 6. Analytical Card of Category D before SMED Improvement

| Work element | External Activities | Internal Activities | Total Duration (min) |
|--------------|---------------------|---------------------|----------------------|
|              | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities |
| 1            | Work element description | Remove the cooling hose | Waiting for the next product’s mold preparation | Turn on machine heater | |
|              | Work element duration | 17 | 12 | 25 | |
| 2            | Work element description | Remove hydraulic hose | Looking for the next mold product | Purge material | |
|              | Work element duration | 14 | 6 | 27 | |
| 3            | Work element description | Remove the side grip | Bring mold to the production line | Run In | |
|              | Work element duration | 13 | 7 | 46 | |
| 4            | Work element description | Set down mold | Set up mold | QC Approval | |
|              | Work element duration | 9 | 11 | 29 | |
| 5            | Work element description | Bring mold to the mold maintenance | Install side grip | |
|              | Work element duration | 8 | 15 | |
| 6            | Work element description | Looking for an eye bolt | Install the cooling hose | |
|              | Work element duration | 5 | 24 | |
| 7            | Work element description | Look for additional hoses | |
|              | Work element duration | 12 | |
| Internal Activities Duration | 66 | 86 | 127 | 279 |

Based on Tables 3 through Table 6, before the implementation of the SMED, all activities were carried out internally or waiting until the machine was not operating. This is a waste because it can be optimized when the machine is still operating. To reduce the change over time, we needed several improvements, including changes in the workflow by referring to the SMED concept, converting internal activities to external ones.
| Work element | External Activities | Internal Activities | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|----------------------|--------------------|---------------------|---------------------|----------------------|
| 1            | Looking for an eye bolt | Remove the cooling hose | Set up mold | Turn on machine heater | Bring mold to the mold maintenance | 8                   |
|              | 9                   | 21                  | 14                  | 23                   | 12                 | 19                  |
| 2            | Bring mold to the production line | Remove hydraulic hose | Install side grip | Purge material | 20                   |
|              | 10                  | 14                  | 23                 | 8                   |
|              | 14                  | 23                 | 8                   |
| 3            | Remove the auto close sensor | Install auto close | Run In | 54                   |
|              | 18                  | 11                  | 20                 |
| 4            | Remove auto close | Install the auto close sensor | QC Approval | |
|              | 16                  | 18                  | 26                 |
| 5            | Remove the side grip | Install hydraulic hose | |
|              | 12                  | 19                  | 20                 |
| 6            | Set down mold | Install the cooling hose | 318 |
|              | 94                  | 110                 | 123                |
| Internal Activities Duration | 53                  | 105                 |
| External Activities Duration | 19                  | 36                  |
| Total Time (min) | 336                  | 336                 | 336                |

Table 8. Analytical Card of Category B after SMED Improvement

| Work element | External Activities | Internal Activities | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|----------------------|--------------------|---------------------|---------------------|----------------------|
| 1            | Looking for an eye bolt | Remove the cooling hose | Set up mold | Turn on machine heater | Bring mold to the mold maintenance | 9                   |
|              | 8                   | 11                  | 9                   | 21                   | 12                 | 19                  |
| 2            | Looking for an eye bolt | Remove the side grip | Install side grip | Purge material | 18                   |
|              | 3                   | 8                   | 10                  | 18                   |
| 3            | Replace mold's nipple | Set down mold | Install the cooling hose | Run In | 45                   |
|              | 9                   | 7                   | 14                  | 45                   |
| 4            | Bring mold to the production line | QC Approval | |
|              | 7                   | 25                  | 32                  | 105                  |
| Internal Activities Duration | 25                  | 32                  | 105                 |
| External Activities Duration | 27                  | 9                   | 36                  |
| Total Time (min) | 199                  | 199                 | 199                 |
Table 9. Analytical Card of Category C after SMED Improvement

| Work element | External Activities | Internal Activities | External Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|---------------------|
|              | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities |
| 1            | Work element description | Looking for an eye bolt | Remove the cooling hose | Set up mold | Turn on machine heater | Bring mold to the mold maintenance |
|              | Work element duration | 9 | 21 | 14 | 23 | 8 |
| 2            | Work element description | Bring mold to the production line | Remove hydraulic hose | Install side grip | Purge material |
|              | Work element duration | 10 | 12 | 14 | 20 |
| 3            | Work element description | Remove the auto close sensor | Install auto close | Run In |
|              | Work element duration | 18 | 11 | 54 |
| 4            | Work element description | Remove auto close | Install the auto close sensor | QC Approval |
|              | Work element duration | 16 | 18 | 26 |
| 5            | Work element description | Remove the side grip | Install hydraulic hose |
|              | Work element duration | 12 | 19 |
| 6            | Work element description | Set down mold | Install the cooling hose |
|              | Work element duration | 94 | 100 | 123 | 318 |

Internal Activities Duration: 53
External Activities Duration: 19
Total Time (min): 336

Table 10. Analytical Card of Category D after SMED Improvement

| Work element | External Activities | Internal Activities | External Activities | Total Duration (min) |
|--------------|---------------------|---------------------|---------------------|---------------------|
|              | 1. Start Activities | 2. Set Down Procedure | 3. Set-Up Procedure | 4. Run In Procedure | 5. Finish Activities |
| 1            | Work element description | Looking for an eye bolt | Remove the cooling hose | Set up mold | Turn on machine heater | Bring mold to the mold maintenance |
|              | Work element duration | 5 | 17 | 11 | 25 | 8 |
| 2            | Work element description | Looking for the next mold product | Remove hydraulic hose | Install side grip | Purge material |
|              | Work element duration | 6 | 14 | 15 | 27 |
| 3            | Work element description | Bring mold to the production line | Remove the side grip | Install the cooling hose | Run In |
|              | Work element duration | 7 | 13 | 24 | 46 |
| 4            | Work element description | Set down mold | QC Approval |
|              | Work element duration | 9 | 29 |

Internal Activities Duration: 53 | 49 | 127 | 229
External Activities Duration: 18 | 8 | 26
Total Time (min): 255
Based on Table 7 - Table 10, the results of workflow changes are based on the SMED concept, where internal activities are converted to external activities, so the change over time will be shorter.

In addition to the workflow, improvements are carried out in the work area, where improvement is carried out based on the 5S concept so that waste resulting from irregularities in the work area can be eliminated.

Fig. 5 showed a Seiri implementation wherein the grouping of work equipment needed for the changeover was applied, while Fig. 6 shows a Seiton implementation giving the identity to the plastic molds. Seiri's implementation was carried out to eliminate waste that occurred due to incomplete equipment, while Seiton's implementation was carried out to eliminate waste that occurred due to the absence of identity in both injection molds and injection mold's accessories.

After being improved with the SMED and 5S concepts, the changeover time was measured again, and based on the results of the improvement, the results of the change of product change settings were obtained. Table 11 showed the results. Table 11 showed that there was a 16-percent reduced time for category A, a 22-percent reduced time for category B, a 12-percent reduced time for category C, and a 24-percent reduced time for category D. Based on these calculations, on the average of all categories, there was a decrease in the time of product change settings amounting to 18%. Moreover, Table 12 showed that there were reduced activities in all categories, where a reduced activity is an activity resulting in waste in the process of product replacement settings, as well as an activity that could be done when the machine was operating, or it was commonly called an external activity.

| Category | Quantity | Average change over time (minute) before SMED implementation | Average change over time (minute) after SMED implementation | Percentage reduction for changeover time after SMED implementation |
|----------|----------|-------------------------------------------------------------|-----------------------------------------------------------|---------------------------------------------------------------|
| A        | 10       | 268                                                         | 225                                                       | 16%                                                          |
| B        | 12       | 192                                                         | 149                                                       | 22%                                                          |
| C        | 6        | 310                                                         | 274                                                       | 12%                                                          |
| D        | 4        | 246                                                         | 188                                                       | 24%                                                          |
| Average  |          |                                                             |                                                            | 18%                                                          |

| Category | Total activities before SMED implementation | Total activities after SMED implementation | Total reduced activities after SMED implementation (%) |
|----------|--------------------------------------------|------------------------------------------|-----------------------------------------------|
| A        | 25                                         | 14                                       | 11                                            |
| B        | 18                                         | 10                                       | 8                                             |
| C        | 24                                         | 16                                       | 8                                             |
| D        | 17                                         | 12                                       | 5                                             |
| Average  |                                            | 8                                        | 38%                                           |

**CONCLUSION**

Based on all of the data that were obtained and analyzed, we could draw several conclusions. Implementation of SMED could reduce the changeover time by 18% with an average time amounting to 44 minutes. The most
significantly reduced changeover time was 24% that took place at the D mold category. Implementation of SMED could also reduce total activities by 38% with an average of 8 activities. The most significantly reduced changeover activities were 11 activities accounting for 44% that took place at the A mold category. 

In order to make this study more perfect, there we suggest things that may be used in further studies. The reduction of changeover time may significantly increase if we invest in mechanical tools, especially used for internal activities. The impact of a reduced changeover time can be investigated further, especially saving the costs in the fields of processing time, speed of delivery, quality of delivery, and the customer's satisfaction.

REFERENCES

Arief, F. N. (2017). Perbaikan waktu set-up dengan menggunakan metode SMED pada mesin filling krim. Operation Excellence, 9(3), 213-220.

Bevilacqua, M., Ciarapica, F. E., Sanctis, I. D. Mazzuto, G., & Paciarotti, C. (2015). A changeover time reduction through an integration of lean practices: a case study from pharmaceutical sector. Assembly Automation, 35(1), 22–34. https://doi.org/10.1016/j.asam.2014.035

Bharti, P. K., & Khan, M. I. (2010). Recent methods for optimization of plastic injection molding process – a retrospective and literature review. International Journal of Engineering Science and Technology, 2(9), 4540-4554.

Ferradas, P. G., & Salonitis, K. (2013). Improving changeover time: a tailored SMED approach for welding cells. Procedia CIRP, 7, 598-603. https://doi.org/10.1016/j.procir.2013.06.039

Gaikwad, S., Avhad, S. Pawar, S., & Thorat, P. (2015). Reduction in setup time on rubber moulding machine using SMED technique. International Journal of Engineering Research & Technology, 4(4), 169-173.

Hendri, H. (2017). Penurunan waktu set-up untuk peningkatan efektifitas pada PT. X. SINERGI, 19(2), 91-100. http://doi.org/10.22441/sinergi.2015.2.004

Heriansyah, E., & Ikatrinasari, Z. F. (2017). Peningkatan kinerja operator pada mesin fukui 600 ton menggunakan metode exchange of dies (SMED). Jurnal PASTI, 9(2), 142-148.

Hindoliya, S., & Sarathe, A. K. (2017). Implementation 5s for efficient manufacturing in a plastic industry. International Journal of Mechanical and Production Engineering, 5(10), 101–105.

Mulyana, A., & Hasibuan, S. (2017). Implementasi single minute exchange of dies (SMED) untuk optimasi waktu changeover model pada produksi panel telekomunikasi. SINERGI, 21(2), 107-114. http://doi.org/10.22441/sinergi.2017.2.005

Roriz, C., Nunes, E., & Sousa, S. (2017). Application of lean production principles and tools for quality improvement of production processes in a carton company. Procedia Manufacturing, 11, 1069-1076. https://doi.org/10.1016/j.promfg.2017.07.218

Rosa, C., Silva, F., Ferreira, L., & Campinho, R. (2017). SMED Methodology: The reduction of setup times for steel wire rope assembly lines in the automotive industry, Procedia Manufacturing, 13, 1034-1042. https://doi.org/10.1016/j.promfg.2017.09.110

Shingo, S. (1985). A revolution in manufacturing: The SMED system, Stanford, CT: Productivity Press.

Simoes, A., & Tenera, A. (2010). Improving setup time in a press line - application of the SMED methodology. Management and Control of Production Logistics IFAC Proceeding, (pp.297-302). Portugal: University of Coimbra. https://doi.org/10.3182/20100908-3-PT-3007.00065

Sundar, R., Balaji, A. N., & Satheeshkumar, R. M. (2014). A review on lean manufacturing implementation techniques. Procedia Engineering, 97, 1875-1885. https://doi.org/10.1016/j.proeng.2014.12.341

Wahab, A., Mukhtar, M. & Sulaiman, R. (2013). A conceptual model of lean manufacturing dimensions. Procedia Technology, 11, 1292-1298. https://doi.org/10.1016/j.protcy.2013.12.327