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Time reduction in changing of plastic injection mold part bottom cover injection machine size 380 ton

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Abstract: This study focuses on enhancing efficiency by reducing the time required to adjust plastic injection molds on a 380-ton machine. The setup time for mold change was 61 minutes, exceeding the company's target of 30 minutes. The research employed a quasi-experimental approach, capturing pre-improvement data, measuring the time for each mold change, and documenting sub-work steps using a Flow Process Chart and a Man-Machine Chart. The main activities identified were mold change and Jig robot adjustment using the Quick changeover technique, involving internal and external activities. The study revealed that some mold-changing steps could be prepared in advance, and applying SMED (Single Minute Exchange of Die) and ECRS (Eliminate, Combine, Rearrange, Simplify) principles led to the identification of seven external adjustment steps. Assigning another employee to assist in these steps significantly reduced the average mold adjustment time to 28 minutes, representing a 54.09% improvement.

Keywords: *Injection machine, Injection molding process, Set up time reduction.*

1. Introduction

The case study company is a manufacturer in the household electrical appliance industry. Established in 1978, the company's primary product line comprises rice cookers, multi-purpose blenders, irons, water heaters, electric fans, and hot and cold water dispensers. A data survey was conducted in the plastic injection section using the department's computer storage system to gather all necessary information for production costs. The study focused on primary data stored, waste, and the overall effectiveness of machinery (OEE: Overall Equipment Effectiveness). The research revealed that the average monthly waste for every machinery group over the past six months was 0.09%, well below the department's target of 3%.

Additionally, the study collected information on the overall effectiveness of the department's 28 machines from January 2022 to June 2022. Each machine's average overall effectiveness was 82.37% per month, slightly below the company's OEE target of 85.00%. It was found that the plastic injection factory lost Breakdown Times due to changing mold models. An injection molding machine size of 380 tons had the highest lost time from changing molds, ranking number 1 among all injection molding machines. The average mold change time is 5,438 minutes per month, as shown in Table 1.

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Table 1.
Mold change time information During the period January 2022 - May 2022.

Machine	(Ton)	Jan22	Feb22	Mar22	Apr22	May22	Average Waste/Month
M113G	350	2.050	2.060	3.130	3.120	2.230	2.518
M114G	380	4.450	4.460	6.430	6.420	5.430	5.438
M115G	420	2.100	2.020	2.140	2.600	2.040	2.180
M119G	350	2.000	2.020	3.000	3.100	2.020	2.428
M120G	470	2.120	2.010	2.540	2.900	2.010	2.316
M121G	350	3.450	3.460	5.430	5.420	3.430	4.238
M135G	420	2.100	2.020	2.140	2.500	2.010	2.154
M136G	470	2.150	2.160	3.230	3.220	2.330	2.618

2. Research Objective

To minimize downtime due to mold changes for Bottom Cover parts on a 380-ton injection machine.

3. Literature Review

3.1. Kaizen

Kaizen, a Japanese term, refers to continuous improvement or gradually changing for the better. It is the foundation of lean manufacturing, aiming to enhance results constantly. The notion of Kaizen originates from Gemba Kaizen, pioneered by Masaaki Imai. The primary goal of Kaizen is to continuously improve results across three key areas: quality, cost, and delivery, in order to meet customer satisfaction while increasing efficiency by eliminating wasteful work methods and resource use. It underscores three fundamental principles: quit, reduce, and change. The core Kaizen system comprises Total Quality Management (TQM), Just-in-Time (JIT) production, Total Productive Maintenance (TPM), and policy deployment within the organization.

It is important to remember that implementing Kaizen in an organization requires consideration of three key factors: Firstly, Kaizen represents a shift in organizational culture, which takes time to establish. Secondly, Kaizen should be ingrained in our daily activities, allowing us to build upon past efforts with greater rigor and adherence to principles. Lastly, the essence of Kaizen lies in making work more manageable and reducing costs. Implementing Kaizen cannot be considered adequate if it leads to more challenges. Therefore, implementing Kaizen should be about something other than additional work; it is about refining existing processes. Furthermore, the participation and mutual support of all employees within the organization are crucial. The principles of Kaizen offer a systematic approach to improving operational effectiveness and enhancing efficiency.

The KAIZEN process commences with understanding the current state of the problem. By enabling a working group or relevant individuals to visit the actual factory location and observe the causes of each problem, everyone can comprehend and acknowledge the problematic situation and work towards similar improvement. Additionally, accurate information and facts are acquired through data collection, various documents, numerical data, and historical statistics. These are analyzed using quality tools or QC 7 Tools, such as inspection sheets, Pareto charts, various graphs, cause-and-effect (fishbone diagrams), distribution diagrams, control charts, and histograms. These tools aid in systematically recording data, analyzing cause-and-effect relationships, identifying the actual problem and its causes, determining the appropriate fixes and improvements, and planning solutions to the problems. By applying the 5W1H principles or using the ECRS principles, which focus on enhancing operational convenience and speed while selecting the most suitable solution based on feasibility, value, and impact, this study discovers ways to improve and solve problems. Subsequently, an action plan is prepared by creating a table starting with the problem, root cause, and solution/improvement (in line with the fishbone diagram). The person responsible and the timeframe for implementation must be determined,

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and the plan should be adjusted accordingly. Planning is intended to aid in identifying and reducing losses in various operations.

Subsequently, identify the methods derived from the analysis. Carry out experiments to ascertain the effectiveness of these methods or improvement measures. Analyze the results by developing an evaluation plan to assess operating procedures and their outcomes based on the established plan. The committee in charge of implementing the plan undertakes this self-evaluation process. Analyzing the results will enable us to determine the practicality of the work improvement activities and devise strategies for overcoming any obstacles.

Additionally, this process establishes performance standards. The evaluation outcomes are then utilized to enhance the plan by leveraging the improved or improvable operating procedures, creating a new operating model suitable for our operations. Subsequently, work activities are enhanced using the PDCA model's six steps. If any issues arise at a particular step, staff members are encouraged to revisit and address them at their discretion. Kaizen eliminates unattainable old ideas, encouraging a shift toward embracing new possibilities and generating ideas that offer more excellent success opportunities in assignments.

4. Experimental Process

1. Assess the current conditions of plastic injection mold adjustment. Observe the working conditions of employees adjusting the plastic injection mold at a 380-ton plastic injection machine, machine number M114G, for the Bottom Cover model. Record work methods to detail the steps and time involved in plastic injection mold adjustment.

2. Analyze mold adjustment time using the Flow Process Chart before making any improvements. A form to collect work data and a flow chart to gather information on the steps and times of plastic injection mold adjustment were created in this phase. The timer starts at the last good part of the previous model injection and ends at the first good part injection. Data on plastic injection mold adjustment for each model is collected by recording each sub-step in a form before the adjustment to compare with the target time based on information regarding time and steps for adjusting the mold each time before any improvements were made.

3. Analyze the work data previously recorded to understand the process of adjusting the mold. Classify the types of work (internal or external adjustments) performed by operators to identify opportunities for reducing the time required for adjustments.

4. Organize the work area using the 5S method, separate external and internal adjustment tasks, and ensure that necessary tools and equipment are readily available. Additionally, consider assigning more employees to work on mold adjustments to streamline the process concurrently.

5. Use a process flow chart to study the mold adjustment time after making the improvements. Test the new process by having employees adjust the mold and record the time and steps taken for each adjustment in a post-renovation form.

6. Compare operating results: This step compares the time taken for plastic injection mold adjustment before and after the improvement. It includes gathering time data from the process flow chart and calculating the average time after the improvement. The results are then compared with the time data recorded before the improvement to see if the time after the improvement is lower or meets the company's target time.

Summarize the operation results and create new work standards: This step involves summarizing the results. This may reduce the number of steps required to install the plastic injection mold before and after the renovation.

By studying the flow of the plastic injection process and the structure of the sample mold, this case study allows for a better understanding of the operational steps involved in plastic injection work, leading to intended improvements. As shown in Figure 1.

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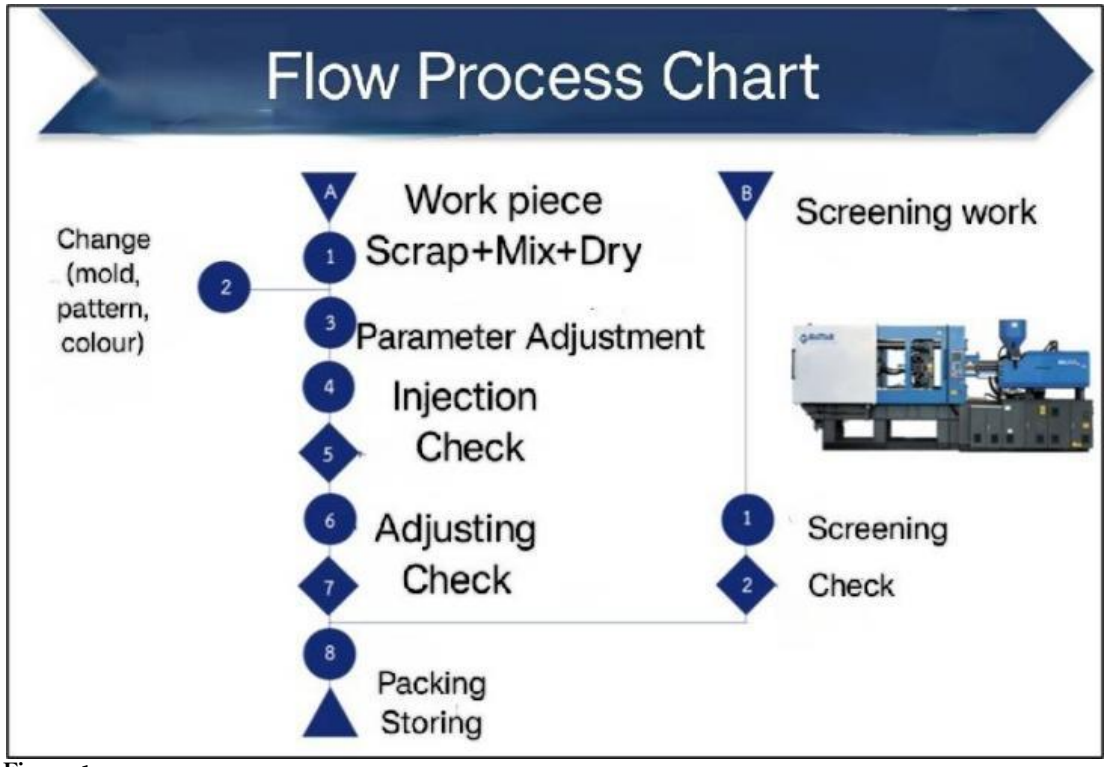

Figure 1.
Flow chart of the plastic injection molding process of the case study company.

From the above information, the study team entered to time the mold installation. Before the improvement, the average time to change the mold for the bottom part was 61 minutes per time, which exceeds the company's target value of 30 minutes for installing the mold. Therefore, the principle of assembling rice cooker products is that the research team is interested in studying the lost time from changing and installing molds in the plastic part injection molding process. In this model, we aim to find ways to improve and reduce the time required to install molds within the target values set by the company. Respond to the company's policy of increasing production capacity and be ready to respond to the diverse needs of customers.

5. Problem Analysis

Prior to analyzing the issue, the researcher gathered data on the steps and durations of plastic injection mold adjustments in the existing process. The timing commences when the last acceptable part of the previous batch is injected and concludes when the machine produces the first acceptable part. The dataset encompasses timing and adjustment steps, the average duration for each step, and the overall duration for plastic injection mold adjustments before any enhancements are made.

Table 2.
Steps and average time for plastic injection mold adjustment before adjustment.

No.	Procedure for modifying plastic injection molds	Average time(Min)
1	Turn off the water to expel water in and out of the mold.	0.50
2	Spray rust prevention / Remove water, and store the pipe.	1.73
3	Close the mold / Use the crane to hook the Eye Boat.	0.67
4	Loosen the clamps, four on each side.	2.27

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5	Press to open the platen machine.	0.08
6	Remove the old mold and put it away.	3.28
7	Find a mold for the next model.	1.83
8	Bring the mold to the machine.	5.15
9	Place the mold in the injection molding platen hole.	1.02
10	Measuring mold distance	1.40
11	Press to close Platen.	0.25
12	Walk to find a distance measuring device / Choose a water line.	1.13
13	Lock clamps, four on each side.	3.93
14	Take the crane out of the mold and put it away.	0.70
15	Press the open button on the machine to open the mold.	0.23
16	Connect the Limit Switch cable/Connect the water line into the mold.	0.23
17	Clean the mold	6.08
18	Prepare the equipment to assemble the jig.	1.05
19	Assemble the Jig	5.68
20	Remove the original beads from the screws.	2.52
21	Search and call the Condition to be injected next.	2.92
22	The trial injection works in Semi-Auto mode.	4.92
23	Experiment with injection work and adjust the robot arm.	10.18
24	Test injection work in Auto mode and check.	3.53
	Total adjustment time before adjustment	**61**

Once the current mold adjustment information is available, it should be used to analyze the root cause of the issue. The researcher will examine the reasons for the prolonged duration of plastic injection mold adjustments, which exceeds the company's target of 31 minutes per adjustment. This examination will be based on the data gathered during the case analysis. Initially, a cause and effect diagram will be utilized to help identify the underlying factors contributing to the extended duration of plastic injection mold adjustments beyond the intended timeframe. As shown in Figure 2

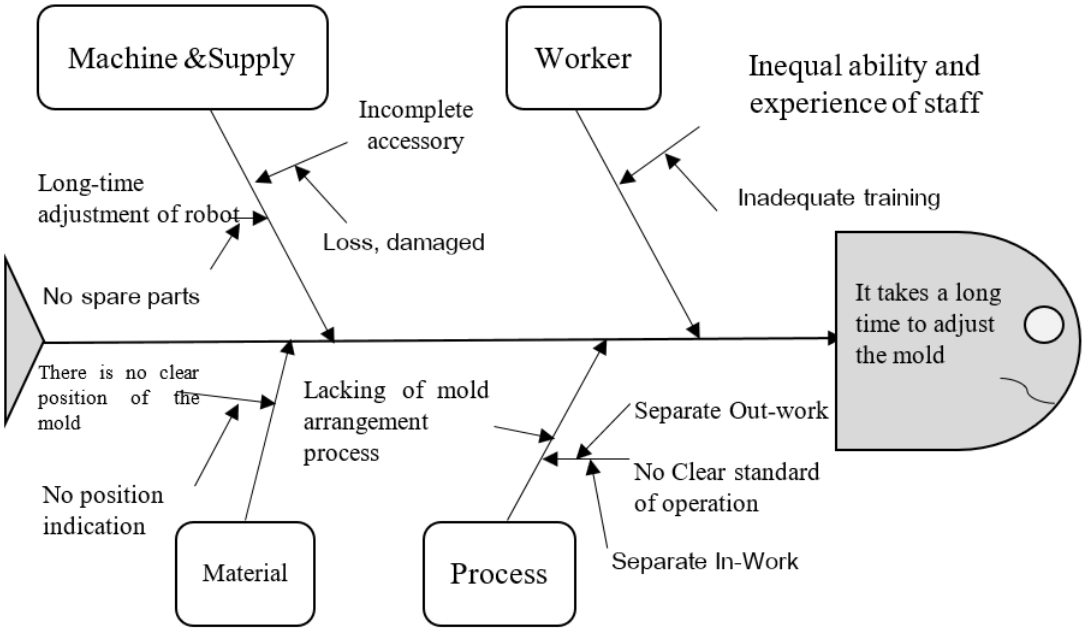

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Figure 2.
Cause and Effect Diagram of mold adjustment.

1. One issue caused by human error is the variation in employees' working skills and expertise. This leads to differences in the time required to adjust the plastic injection mold until the first suitable workpiece can be produced.
2. Other problems arise from machinery and equipment, such as equipment being used outside the designated area for mold adjustment and the presence of incomplete spare parts. For instance, the excessive length of the clamp bolt causes the Clamp Lock to release slowly
during mold adjustment.
3. Issues caused by materials result in wasted time when removing molds and bringing in new ones. Adjusting to a new mold requires preparation, leading to additional time employees spend adjusting.
4. Challenges arising from the work method include the need for machine operators to prepare for tasks that could have been done beforehand. As a result, the machine stops during adjustments, leading to further time consumption. Another issue is the need for clear work standards for employees, resulting in varying work quality across different employees.

6. Results

6.1. Improving The Plastic Injection Mold Adjustment Process

involves researching the work information and analyzing the causes of longer adjustment times. This is done by breaking down the work process into smaller steps and measuring the time for each step. The aim is to apply SMED principles to classify work types and reduce plastic injection mold adjustment time. Additionally, external work setting can be done before stopping the machine, while internal work adjustment is the focus when the machine is stopped

. Classifying the types of plastic injection mold adjustment operations aims to minimize waste in the adjustment process.

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Table 3.
Classification of work, defining internal activities and external activities.

No.	Detail	In-work (Min.)	Out-work (Min.)
1	Turn off the water to expel water from the mold.	-	0.50
2	Spray to prevent rust / Remove water, and collect water pipes.	1.73	-
3	Close the mold / Use the crane to hook the Eye Boat.	0.67	-
4	Loosen the clamps, four on each side.	2.27	-
5	Press to open the platen machine.	0.08	-
6	Remove the old mold and put it away using a crane.	-	3.28
7	Find a mold for the next model.	-	1.83
8	Bring the mold to the machine using a crane.	-	5.15
9	Place the mold in the injection molding platen hole.	1.02	-
10	Measuring mold distance	1.40	-
11	Press to close Platen.	0.25	-
12	Walk to find a distance-measuring device.	-	1.13
13	Lock clamps, four on each side.	3.93	-
14	Take the crane out of the mold and put it away.	0.70	
15	Press the open button on the machine to open the mold.	0.23	
16	Connect the Limit Switch cable.	0.23	
17	Connect the water line to the mold / Clean the mold.	6.08	
18	Prepare the equipment to assemble the jig.	-	1.05
19	Assemble the Jig		5.68
20	Remove the original beads from the screws.	2.52	-
21	Search and call the Condition to be injected next.	2.92	-
22	The trial injection works in Semi-Auto mode.	4.92	-
23	Experiment with injection work and adjust the robot arm.	10.18	-
24	Test injection work in Auto mode and check.	3.53	-
Total time		Total time	18.62

From Table 3, when categorizing activities that need improvement, it is found that activities that can be separated into external work can be done in only some steps. However, the data collected found that some activities can shorten the time required to complete those steps by applying SMED principles and ECRS principles to improve problem-solving, which is why the researcher studied and summarized the previous topic. The researcher has laid out guidelines for improving the problems of the plastic injection mold adjustment process as follows.

Modifying internal activities to external activities and work preparation Table 4.1 analyzes various activities that can be separated into external activities. The researcher has guidelines and measures for improvement, as follows.

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Steps for shutting off water to expel water from entering and exiting the mold were reviewed. It was observed that an employee turned off the water to flush it out while the machine stopped, resulting in wasted time. The employees altered the process of shutting off the water and expelling water from the mold as an external task. This change was to be performed 3 - 5 days before the end of the final injection cycle. Additionally, both employees were assigned to assist in spraying the mold with anti-rust spray. This adjustment aims to reduce the overall time required by using the SMED technique as a guide for improvement; it was identified that shutting off water to expel water from entering and exiting the mold should involve separating work steps that can be done while the machine is running (external work) from work that can only be done. In contrast, the machine is stopped (internal work). Prior to the improvement, this process took an average of 2.90 minutes. After the improvement, the time was reduced to an average of 1.72 minutes, representing a decrease of 1.18 minutes. Detailed comparisons can be made for each guideline step before and after the improvement.

From the analysis through the SMED technique, separating work steps that can be done while the injection machine is working (outside work) from steps that can be done when the injection machine has to stop (inside work), it is found that in the process of taking out the old mold and Go to storage, the process of finding the mold that will be used for the next model causing wasted time, Therefore, employees are required to prepare the molds that will be changed in advance by preparing the mold at the mold placement location where the production model will be changed and set it to be placed on the prepared table, including the old mold that has been lifted from the machine. By setting it aside on the table first. After installing the new mold is complete. Gradually put it away to reduce the time required to move the crane. As a result of the improvements, the time spent in finding the next model of mold has been reduced, and bringing the mold to the machine can reduce the time

According to the guidelines for improvement using the SMED technique, breaking down internal work into external work as much as possible took an average of 10.26 minutes before the improvement. After the improvement, it took an average of 2.00 minutes, a decrease of 8.26 minutes, which can compare the details in each guideline step before the improvement.

Employees should prepare equipment before starting work to reduce time when walking to find a distance measuring device and selecting a water line.

The process of preparing the jig equipment and assembling the jig was reviewed. It was identified that employees needed to prepare the equipment prior to commencing work. Additionally, it was noted that a new jig had to be assembled each time the product model was changed. Furthermore, adjusting the jig's distance to the robot was time-consuming, resulting in inefficiencies. As a result, it was determined that equipment preparation must precede work, and it was specified that a jig should be made for each product model. The design was enhanced to include a jig with a movable slot, allowing for easier adjustment and saving time.

According to the SMED technique improvement guidelines, separate work steps can be carried out while the injection machine is operating (external work) by preparing equipment and assembling the jig prior to commencing work. Prior to the improvement, this process took an average of 2.18 minutes. After the improvement, it was completed in an average of 0 minutes, resulting in a decrease of 2.18 minutes. A comparison of each step of the guideline prior to the improvement can be made to assess the details.

In order to reduce the duration of internal activities, the study focused on shortening the time required for tasks such as removing the old mold and installing a new one. This involved steps such as releasing four clamps on each side, placing the mold in the injection molding machine's Platen holes, locking four clamps on each side, connecting Limit Switch cables and water lines, and removing the original plastic beads from the screws.

By applying the ECRS (Simplify) principle for improvement, waste, unnecessary movement, and unnecessary work were minimized. Before the improvement, the average time for these activities was 6.28 minutes. After the improvement, the time reduced to 2.08 minutes, resulting in an overall decrease of 4.20 minutes.

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The process of placing the mold in the hole of the platen injection machine. During the process of installing a new mold on the injection machine, there is a delay as the employee has to visually align the Locating Ring on the mold with the platen hole in the machine. To address this issue and improve efficiency, the researcher implemented visual control lines on both the mold and the injection machine. These lines indicate the center position of the mold and the machine, allowing employees to easily align the mold, resulting in a reduction in installation time.

The improvement guidelines involve implementing visual control principles on the mold and injection machine to clearly indicate the center position of both elements. This will make it easier to align the Locating Ring on the mold with the Platen holes in the injection machine. Prior to the renovation, this process took an average of 3.80 minutes, but after the renovation, the time was reduced to an average of 1.15 minutes, resulting in a time savings of 2.65 minutes.

Steps for connecting the water line to the mold: Employees encountered difficulties connecting the water line due to the absence of a clear indication for the water inlet or outlet on the mold. This resulted in significant delays in this step. To address this issue, it was decided to implement a visual control system for connecting the In-Out water lines at the mold, aimed at streamlining the process and eliminating any confusion

In line with the improvement principles, the implementation of Visual Control for connecting the In-Out water lines to the mold reduced the average time from 6.08 minutes to 2.68 minutes, resulting in a decrease of 3.40 minutes.

Steps for removing the original pellets from the screws. The process took longer than expected because the staff had to wait for the employee in front of the machine to finish installing the jig and the robot arm. To address this, the researcher assigned another employee to assist in removing the original plastic pellets using ECRS (Rearrange) principles. This involved reordering the work to enable parallel processing with the installation of the jig and robot arm in front of the injection machine. The result was a reduction in time as shown in Figure 3.

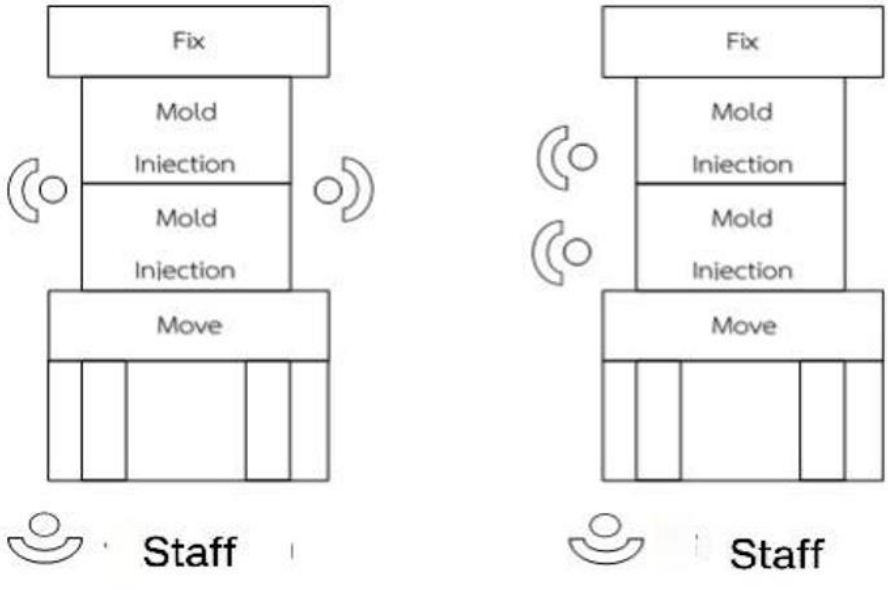

Figure 3.
Plastic pellet removal was done with the Jig installer before and after the renovation.

The researchers have implemented ECRS (Rearrange) principles as part of their improvement guidelines. This concept aims to enhance work processes by increasing efficiency, eliminating unnecessary tasks, and modifying work methods, ultimately yielding superior results. Moreover, this approach can be promptly applied without requiring additional investment. By simply reorganizing the

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existing work ordering guidelines, such as rearranging the workflow, this concept can be effectively implemented. For instance, in order to minimize unnecessary movement or waiting time, the employees responsible for handling the plastic pellets should work concurrently with those installing the jig into the robot arm near the injection machine. Prior to the enhancement, this process took an average of 10.18 minutes. However, after the improvements were implemented, the average time decreased to 3.75 minutes, resulting in a significant reduction of 6.43 minutes. This improvement can be further examined by comparing the specific details of each guideline step before and after the changes were made.

7. Analysis of Steps and Time After Modification

After implementing ECRS principles and applying the SMED concept, it was identified that certain steps could be prepared in advance to streamline the process of turning off the water and expelling water from the water line as an external task, to be completed 3 - 5 days before the final injection cycle. This approach resulted in time savings, allowing employees to prepare molds for change in advance. The preparation of the mold occurs at the location where the production model will be changed, allowing for seamless placement on the prepared table, and facilitating the removal of the old mold from the machine. By setting it aside on the table first and then gradually completing the installation of the new mold, the time required for crane movement is reduced. Additionally, readiness of equipment before commencing work and the utilization of product model-specific jigs further contributes to time reduction. The design improvement, involving a jig with a movable slot for adjustment, efficiently reduces the time required for internal activities. The study also focused on reducing the time spent on internal activities, specifically in removing the old mold and installing a new one, resulting in a reduction of work steps from 24 to 19, as shown in Table 4.6. Following the improvement, the average time for mold adjustment decreased from 61 minutes to 28 minutes, marking a significant reduction of 54.09%.

The researcher conducted an analysis of the issue and gathered data on the duration and steps involved in adjusting the plastic injection mold after enhancing the adjustment process. This involved initiating the timer from the production of the last satisfactory piece in the previous batch, and concluding when the machine produces the initial satisfactory piece in the current batch. The collected data encompasses the time taken for each adjustment step, the average time for each step, and the total time required for plastic injection mold adjustment after the enhancement, as presented in Table 4.

Table 4.
Steps and average time for plastic injection mold adjustment. After improvement.

No.	Procedure for modifying plastic injection molds	Average time (Min)
1	Spray anti-rust spray	0.55
2	Close the mold / use the crane to hook the Eye Bolt.	0.67
3	Loosen the Clamp Locks, four on each side.	1.00
4	Press to open the machine plate.	0.08
5	Please take out the old mold and place it on the mold table.	0.88
6	Take the new mold prepared on the table to the machine.	1.12
7	Place the mold in the Platen hole.	0.50
8	Measuring mold distance	0.40
9	Press to close Platen.	0.25
10	Clamp Lock locks, four on each side	1.00
11	Remove the crane hook from the mold.	0.43
12	Press the open button on the machine to open the mold.	0.23
13	Connect the Limit Switch cable/connect the water line into the mold.	0.23
14	Install the jig on the robot arm / use Scrap pellets to dislodge the old plastic.	2.95

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15	Clean the mold / Set up the mold clamp.	2.68
16	Find and call the Condition to be injected next.	2.92
17	Inject the workpiece in Sami Auto mode.	4.92
18	Experiment with injecting workpieces and adjusting the robot arm.	3.75
19	Test injection work in Auto mode and check.	3.53
	Total time to adjust after adjustment	**28**

8. Results From the Study And Improvement

The study compared the results using data from before and after improving the adjustment of plastic injection molds. Prior to the improvement, the process took 61 minutes, which was reduced to 28 minutes after the improvement, resulting in a 33-minute reduction. The post-improvement time was also compared with the company's target time of 30 minutes, as shown in Tables 5 and 6.

Table 5.
Compares steps and mold adjustment times. Before and after the renovation.

No.	Before Adjustment	Time (Min.)	No.	After Adjustment	Time (Min.)
1	Turn off the water to expel water in and out of the mold.	0.50	1	Spray anti-rust spray	0.55
2	Spray rust prevention / Remove water, and store the	1.73	2	Close the mold / Use The crane to hook the Eye Bolt.	0.67
3	Close the mold / Use the crane to hook the Eye Boat.	0.67	3	Loosen the Clamp Locks, four on each side.	1.00
4	Loosen the clamps, four on each side.	2.27	4	Press to open the machine plate.	0.08
5	Press to open the platen machine.	0.08	5	Please take out the old mold and place it on the mold table.	0.88
6	Remove the old mold and put it away.	3.28	6	Take the new mold prepared on the table to the machine.	1.12
7	Find a mold for the next model.	1.83	7	Place the mold in the Platen hole.	0.50
8	Bring the mold to the machine.	5.15	8	Measuring mold distance	0.40
9	Place the mold in the injection molding platen hole.	1.02	9	Press to close Platen.	0.25
10	Measuring mold distance	1.40	10	Clamp Lock locks, four on each side	1.00
11	Press to close Platen.	0.25	11	Remove the crane hook from the mold.	0.43
12	Walk to find a distance measuring device / Choose a water line.	1.13	12	Press the open button on the machine to open the mold.	0.23
13	Lock clamps, four on each side.	3.93	13	Connect the Limit Switch cable/Connect the water line into the mold.	0.23
14	Take the crane out of the mold and put it away.	0.70	14	Install the jig on the robot arm / Use Scrap pellets to dislodge the old plastic.	2.95

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15	Press the open button on the machine to open the mold.	0.23	15	Clean the mold / Set up the mold clamp.	2.68
16	Connect the Limit Switch cable/connect the water line into the mold.	0.23	16	Find and call the Condition to be injected next.	2.92
17	Clean the mold	6.08	17	Inject the workpiece in Sami Auto mode.	4.92
18	Prepare the equipment to assemble the jig.	1.05	18	Experiment with injecting workpieces and adjusting the robot arm.	3.75
19	Assemble the Jig	5.68	19	Test injection work in Auto mode and check.	3.53
20	Remove the original beads from the screws.	2.52		Total time to adjust after adjustment	28
21	Search and call the Condition to be injected next.	2.92			
22	The trial injection works in Semi-Auto mode.	4.92			
23	Experiment with injection work and adjust the robot arm.	10.18			
24	Test injection work in Auto mode and check.	3.53			
	Total adjustment time before adjustment	61			

Table 6.
Summarizes the time before and after mold adjustment. compared to the target time.

Model	Target (Min.)	Before (Min.)	After (Min.)
Bottom Cover	30.00	61	28

The plastic injection molding shop's production process is based on customer orders, with parts typically being produced two days in advance before being sent to the assembly line. Due to the wide variety of products

, it's necessary to produce plastic parts in advance. The production date and delivery due date to the store are determined according to the production plan and the Production Order. Producing items according to the specified date or even ahead of time can have a positive impact on the planning department, assembly department, and overall company planning. This also helps to further meet the diverse needs of our customers. Furthermore, we can achieve cost savings. For instance, let's consider the August - September 2022 production plan of a 380-ton plastic injection molding machine. By making three changes daily over 270 working days and reducing time by 33 minutes at a value of 1.5 baht per minute, hard savings worth 40,095 baht per year can be realized.

In addition, soft savings can be achieved. By reducing time by 33 minutes, we can increase productivity and be more responsive to customer needs by calculating an increase in the number of pieces produced.

This is calculated using the reduced mold change time, the frequency of changes per day, and the injection time per cycle, resulting in an increase in production by 88 pieces per day or 23,760 pieces per year.

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9. Conclusion

The research focuses on enhancing efficiency by reducing the plastic injection mold adjustment time on a 380-ton plastic injection machine, with the goal of meeting the company's target time of 30 minutes. Prior to the improvement efforts, data was collected and analyzed, revealing that the average time for mold adjustment was 61 minutes, exceeding the target time by 31 minutes. A detailed analysis using tools such as the Flow Process Chart and Man-Machine Chart identified overlapping work steps and the need for advanced preparation, particularly in setting up plastic injection molds.

To address these challenges, the research applied SMED (Single Minute Exchange of Die) and ECRS (Eliminate, Combine, Rearrange, Simplify) principles, reorganizing work activities and separating internal and external adjustment steps. Additionally, the mold adjustment process was divided into seven external adjustment steps, with the involvement of an additional employee to carry out parallel tasks.

Following the implementation of these improvements, the average plastic injection mold adjustment time was reduced to 28 minutes, surpassing the company's target time by 33 minutes.

10. Recommendation

In this study, the researchers have summarized the recommendations as follows:

1. The study on reducing the mold change time of the plastic injection molding process is based on a sample injection molding machine. For more comprehensive results, the findings should be extended to include medium and small injection molding machines in addition to large machines.

2. The molds used for all models have a production lifespan of approximately ten years. During the adjustment of settings and experimentation with injection molding, parameters are sometimes set in the machine as needed. However, it has been observed that reusing the data and injecting the workpiece still yields different values, leading to wasted time in adjusting parameters on the new machine.

3. Training programs should be established for new employees and those seeking to enhance their work experience. This will enable them to gain the necessary expertise, knowledge, and understanding to perform to the required standard.

4. It is recommended to expand performance evaluations following improvements in plastic injection mold adjustment. Furthermore, collaborating with other departments that operate plastic injection machines can help reduce mold setup time.

Author Contributions:

Anyarat SONSANAM formulated the conceptual framework and research design. Somporn VONGPEANG carried out the experiment and data analysis. Tanut SRIPANOM conducted the literature review and data analysis. Parvinee ANGBOONTA drafted the report . Tawatchai SONSANAM contributed to the literature review.

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