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Applying SMED to Reduce Changeover and Setup Time in Plastic Injection Molding for Automotive Parts

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Abstract

This research aims to reduce the time required to change and install plastic injection molds for automotive parts and to increase the number of injected automotive parts produced at an automotive parts manufacturing plant. The current situation shows that the machine to be improved undergoes mold changes an average of 21 times per month, with a mold change and installation time of 66 minutes per instance. The researcher studied the mold change and installation procedures using work-study principles and direct time study methods and analyzed ways to improve by applying the Single Minute Exchange of Die (SMED) technique in conjunction with the ECRS (Eliminate, Combine, Rearrange, Simplify) and 5W1H (Who, What, Where, When, Why, How) principles. It was found that there was a mix of internal and external setup tasks. By separating internal and external tasks, it was discovered that 39.65% of the tasks were external, which could be performed while the machine was running. Utilizing ECRS principles, a separate color hot-runner system was installed to facilitate easier installation, and quick-connect couplings were added to reduce the time needed for hydraulic setup. After applying ECRS and 5W1H principles, the time for changing and installing plastic injection molds for automotive parts was reduced by 31%, and the number of injected automotive parts increased by 10%.

Keywords
SMED, ECRS, 5W1H, Plastic Injection Molding

Introduction
Thailand is a significant global production base for the automotive industry. In 2022, Thailand produced 1,883,515 vehicles of all types, ranking 11th globally, 5th in Asia (behind China, Japan, India, and South Korea), and 1st in ASEAN. The production increased by 12% compared to the previous year, reflecting a gradual recovery from the COVID-19 pandemic. Positive factors include China's reopening, which has led to a recovery in global trade and tourism, benefiting Thailand. Issues such as the semiconductor shortage and shipping container scarcity are also easing. This has led to positive signals in economic activity and consumer demand/purchasing power domestically and in Thailand's key export markets. However, challenges such as oil prices, inflation, the appreciation of the Thai baht, and tensions from the Russia-Ukraine war remain significant factors impacting the growth of the global and Thai automotive industry [Abdulmalek & Rajgopal 2007]. The case study factory is classified as a Tier 1 plastic parts manufacturer, directly supplying automotive manufacturers/assemblers. This group includes approximately 529 companies, accounting for 23% of all automotive parts manufacturers [Cakmakci et al. 2009].

In Thailand's highly competitive automotive industry, manufacturers must improve production efficiency to reduce waste and costs in the production process, thereby enhancing their competitiveness. The company in the case study is an automotive parts manufacturer that produces plastic engine compartment parts. The production line under study is a primary product line for the company, which aims to increase production capacity due to machinery limitations and

high customer demand. The case study company operates two plastic injection machines: small (650T) and large (1600T – 2000T). The researcher identified issues with the small plastic injection machine (650T) at machine number KM-03, which underwent mold changes 21 times in October 2023, 27 times in November 2023, and 18 times in December 2023. The average mold change and installation time over these three months was 66 minutes.
Therefore, the researcher is interested in studying mold change and installation procedures on machine KM-03 in the automotive parts plastic injection molding process.

1.1 Objectives
The goal is to find ways to improve the procedures, reduce mold change and installation time by 35%, and increase the number of injected automotive parts produced by 10%.

2. Literature Review
The literature on lean manufacturing techniques, particularly the Single Minute Exchange of Die (SMED) method, highlights its significant impact on improving production efficiency. Developed by Shigeo Shingo, SMED focuses on reducing the time required for equipment changeovers, which is crucial in high-mix, low-volume production environments. The method involves converting internal setup tasks (performed while the machine is stopped) to external tasks (performed while the machine is running) and streamlining all setup operations to achieve rapid changeovers.

2.1 SMED (Single Minute Exchange of Die)
SMED methodology seeks to reduce setup times to less than 10 minutes. It consists of several steps, including separating internal and external setup operations, converting internal setup operations to external ones, streamlining all aspects of the setup operation, and continuously improving the setup process. The ultimate goal is to minimize downtime and increase flexibility in production. Studies have shown the effectiveness of SMED in various industries. Abdulmalek and Rajgopal (2007) implemented SMED in a packaging company, reducing changeover time by 50%, which led to significant cost savings and increased production capacity. Similarly, Cakmakci (2009) applied SMED in an electronics manufacturing company, achieving a 45% reduction in setup time and improving overall equipment effectiveness (OEE). These results demonstrate that SMED can substantially enhance operational efficiency and productivity.

2.2 ECRS (Eliminate, Combine, Rearrange, Simplify)
ECRS is a lean tool used with SMED to optimize setup processes further. It involves:

- **Eliminating** unnecessary steps in the process.
- **Combining** steps where possible to streamline operations.
- **Rearranging** steps to enhance workflow and reduce motion.
- **Simplifying** the process to make it more efficient and less prone to errors.

Ferreira and Cabrita (2014) applied ECRS principles along with SMED in the textile industry, achieving a 30% reduction in setup time. This improvement enhanced the company's flexibility and responsiveness to customer demands. Integrating ECRS with SMED facilitates a comprehensive approach to process improvement, ensuring that all aspects of the setup process are optimized.

2.3 5W1H (Who, What, Where, When, Why, How)
The 5W1H method is a problem-solving tool used to analyze and understand all aspects of a situation or problem by answering the following questions:

- **Who** is involved?
- **What** is happening?
- **Where** does it occur?
- **When** does it occur?
- **Why** does it happen?
- **How** can it be improved?

This method is instrumental in the SMED process as it helps identify all factors affecting setup time and provides a structured approach to analyzing and improving these factors. Patel and Thakkar (2015) used the 5W1H approach to identify inefficiencies in an automotive parts manufacturing setup. Their study led to a 40% decrease in changeover time and a 15% increase in production volume. By systematically addressing each aspect of the setup process, the 5W1H method ensures a thorough analysis and effective implementation of improvements.

2.4 Case Studies of SMED Implementation

Numerous case studies illustrate the successful implementation of SMED in various industries:

- In a food processing plant, implementing SMED reduced setup time by 38%, significantly increasing production efficiency (King 2016).
- A study in the pharmaceutical industry showed a 32% reduction in changeover time, resulting in improved production scheduling and reduced lead times (Smith & Brown 2017).
- In the automotive industry, a company applied SMED to its stamping operations, achieving a 50% reduction in setup time and a 20% increase in machine utilization (Johnson 2018).

These case studies demonstrate SMED's broad applicability and effectiveness across different sectors, highlighting its potential to improve production efficiency and competitiveness. In conclusion, the literature underscores the significant benefits of SMED and complementary lean tools like ECRS and 5W1H in optimizing setup processes and enhancing production efficiency. This research aims to apply these principles to a plastic injection molding process for automotive parts, expecting similar improvements in setup time reduction and production output.

3. Methods

3.1 General Information and Problem Identification

The case study factory is a plastic injection molding plant in Makham Khu Subdistrict, Nikhom Phatthana District, Rayong Province. The factory operates six injection molding machines, categorized into small (650T) and large (1600T – 2000T) machines, as shown in Table 1.

Table 1. Details of Injection Molding Machines in the Case Study Factory

Machine Number	Brand / Type	Size (Tonnage)
KM-01	Krauss Maffei / 2K Machine	1600T
KM-02	Krauss Maffei / 2K Machine	1600T
KM-03	Krauss Maffei / 2K Machine	650T
HT-04	Haitian / 1K Machine	650T
WT-05	Wintec / 1K Machine	650T
EN-06	Engel / 2K Machine	2000T

The factory has identified a problem related to the frequency of mold changes, which affects production efficiency. Table 2 shows the number of mold changes per month for each machine in October 2023.

Table 2. Number of Mold Changes in the Case Study Factory (October 2023)

Machine Number	Number of Mold Changes/Month
KM-01	2
KM-02	10
KM-03	21
HT-04	2
WT-05	11
EN-06	2

The data shows that machine KM-03 has the highest number of mold changes, with an average of 21 changes per month. This high frequency of mold changes indicates a significant area for improvement to reduce setup times and increase overall production efficiency.

3.2.1 Mold Change and Installation Process

Each plastic injection molding machine requires mold changes when switching production models. Two employees are assigned to the mold change and installation: one mold injection technician and one support staff. During the mold change process, if other machines encounter problems, the technician may need to attend to those issues, causing delays in the mold change process.

3.3 Study of the Mold Change and Installation Process

The mold change and installation process consists of the following steps:

3.3.1 Equipment Preparation

The technician prepares the necessary equipment for changing and installing the mold and positions the crane to where the mold will be removed.

3.3.2 Removal of the Old Mold

After producing the final part, the technician stops the machine and attaches the crane chain to the mold to remove it. Then, they disconnect the water hoses, hydraulic lines, hot runner cables, and valve gate control cables. The bolts on the cavity and core sides (four bolts on each side) are then loosened.

3.3.3 Mold Transportation

Once the old mold is removed, the machine is turned on to open the platen, and the crane is used to lift the mold and place it in the designated mold storage area.

3.3.4 Installation of the New Mold

The crane lifts the new mold and positions it in the machine. The technician aligns the mold with the nozzle, closes the mold, and then sets the clamping mechanism. They attach the securing bolts (four on the core side and four on the cavity side) and reconnect the hydraulic lines, cooling water hoses, hot runner cables, and valve gate control cables.

3.3.5 Changing the Robot Arm (End of Arm Tooling)

The employee replaces the old robot arm with the new one and loads the program for the new production model.

3.3.6 Starting the Machine for Production

After installing the new mold and robot arm, the employee starts the machine to heat the mold to the required temperature (200 – 240 degrees Celsius). Once the mold reaches the set temperature, production can begin.

From studying the time required for mold changes and installation in the injection molding machines, it was found that delays occurred due to waiting for equipment, waiting for the mold to reach the required temperature, and waiting between the technician and support staff. Therefore, the researcher chose to study the mold change and installation process for the plastic injection molding machine KM-03 to identify areas for improvement.

4. Results and Discussion

4.1 Problem Analysis and Identification of Improvement Areas

The researcher began by timing the steps in changing and installing the mold on machine KM-03. The timing started with the production of the last part of the mold being changed and ended when the new plastic injection mold was installed, and production resumed. The study results and detailed steps are shown in Table 3.

Table 3. Steps in the Mold Change Process for Technician 1 and Technician 2

Step	Technician 1 Activities	Technician 2 Activities
1	Prepare equipment	Assist in preparation
2	Remove old mold	Assist in mold removal
3	Transport old mold to the storage area	Assist in transportation
4	Install new mold	Assist in mold installation
5	Change robot arm	Assist in robot arm change
6	Start the machine and set the temperature	Monitor machine settings

From Table 3, the researcher analyzed the steps based on the principles of SMED, separating tasks that can be performed while the machine is running (external tasks) from those that can only be performed when the machine is stopped (internal tasks). This analysis aimed to identify wasteful steps and determine ways to improve efficiency.

Table 4. Separation of Internal and External Tasks According to SMED

Task Type	Internal Tasks	External Tasks
Internal	Stopping the machine, removing bolts	Preparing equipment, positioning crane
External	Removing the mold, installing new mold	Changing the robot arm, starting the machine

4.2 Analysis of Problems Using Fishbone Diagram

The researcher used the initial study data and employee activities to analyze the causes of problems and potential improvements using a fishbone diagram, as shown in Figure 1.

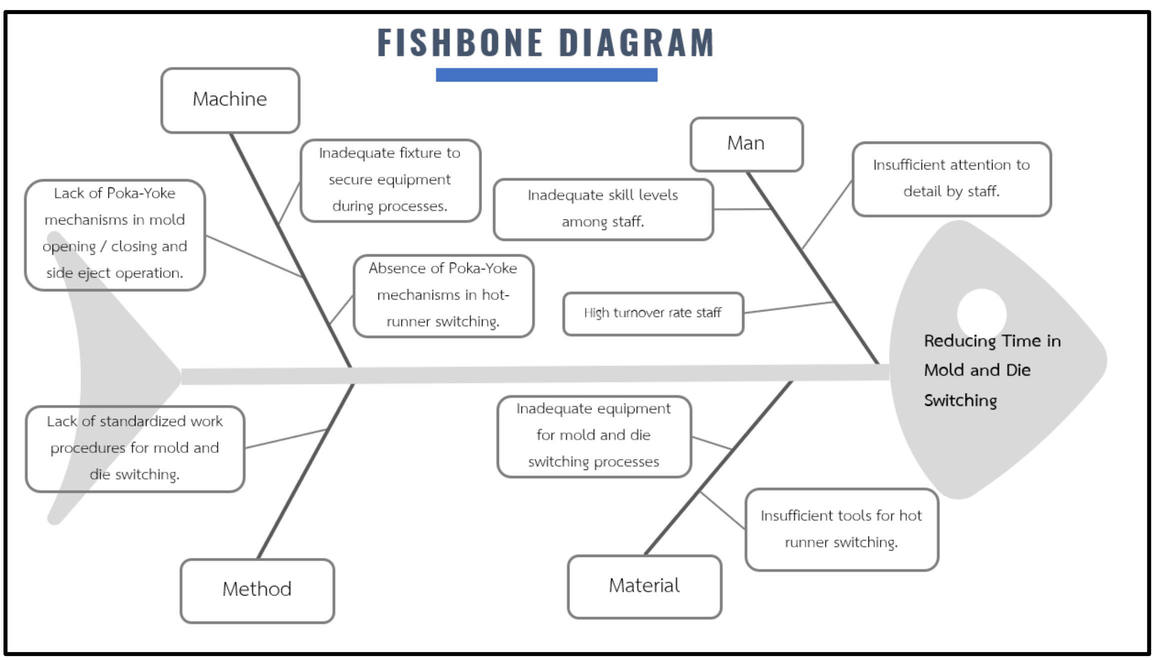

Figure 1. Fishbone Diagram for Analyzing Causes to Reduce Mold Change and Installation Time

Figure 1 illustrates problem analysis using the fishbone diagram, with the following details:

4.2.1 Man:
The problem related to personnel (Man) is that the employees have varying levels of expertise. Some processes that can be performed simultaneously cannot be executed consecutively, leading to delays while waiting for another technician. This affects the time required to change and install plastic injection molds.

4.2.2 Machine:
The problem related to machinery (Machine) is that the plastic injection molds lack Poka-Yoke mechanisms for connecting hydraulic lines, valve gate signal cables, and hot runners. Additionally, the machines do not have fixtures to lock the mold positions, resulting in delays during the alignment and positioning of the molds.

4.2.3 Method:
The issue related to methods (Method) is that employees are unaware of the standard procedures for changing and installing molds, leading to skipped steps and a lack of time tracking during mold setup.

4.2.4 Material:
The problem related to materials (Material) at the case study factory is the absence of tools for preheating the molds, causing delays while waiting for the mold temperature to reach the desired level. Furthermore, there are not enough tools for installing the plastic injection molds, resulting in equipment shortages for the two employees responsible for the task, leading to delays in mold setup.

4.3 Analysis of Problems Using Fishbone Diagram
The study of the process of changing and installing plastic injection molds found that most of the lost time is due to operational procedures, which cause delays in mold changeovers and installations. Additionally, there is a lack of preparedness in the preparation of tools and equipment, leading to delays and inconsistent production rates after each mold change. To address these issues, the researcher plans to improve equipment preparation and streamline work procedures to facilitate employees' work. The detailed steps of the research implementation are as follows:

4.3.1 Results of Quick Machine Changeover to Reduce Time in Mold and Die Switching, Incorporating ECRS Principles
From the analysis of machine changeover issues to reduce time in plastic injection mold switching at the case study company, the SMED technique was utilized to differentiate between internal and external tasks, and the ECRS principles were applied as follows:

- Eliminate Separate tasks that can be done while the machine is running. For example, before the mold changes, the technician can remove the old plastic pellets and add new ones. Additionally, it was observed that technicians were waiting for mold-changing equipment, causing delays. More equipment was added to eliminate the waiting time for tools needed by the mold-changing technicians.
- Rearrange: Divide the tasks between Mold Change Technician 1 and Mold Change Technician 2, reorganize the workflow, and document the procedures. The two technicians were then trained to understand these new procedures, as shown in Figure 2.
- Simplify: Poka-Yoke mechanisms were implemented to reduce the time needed to connect Hot-Runner, Valve Gate control, and Core System control lines using color-coding for easy identification, as shown in Figure 3. In the hydraulic line connections, female and male couplings were added to simplify usage, as shown in Figure 4.

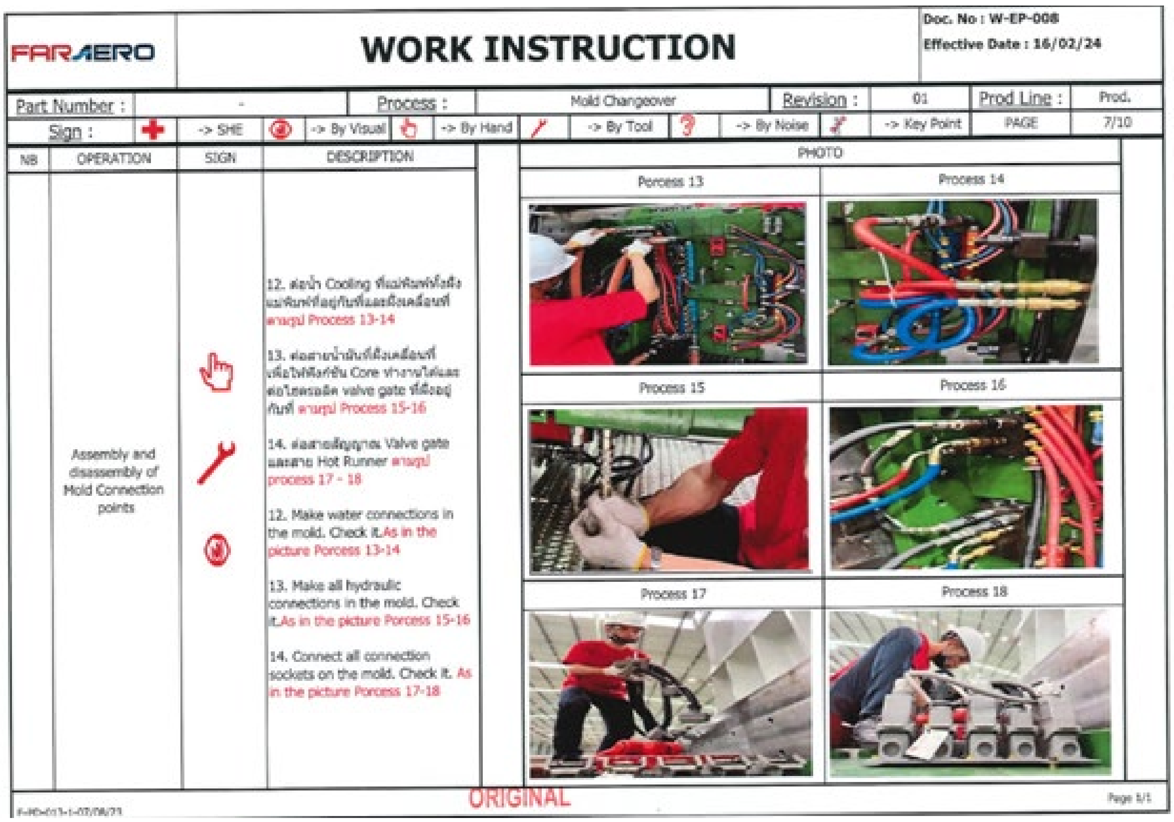

Figure 2. Workflow for Changing and Installing Plastic Injection Molds

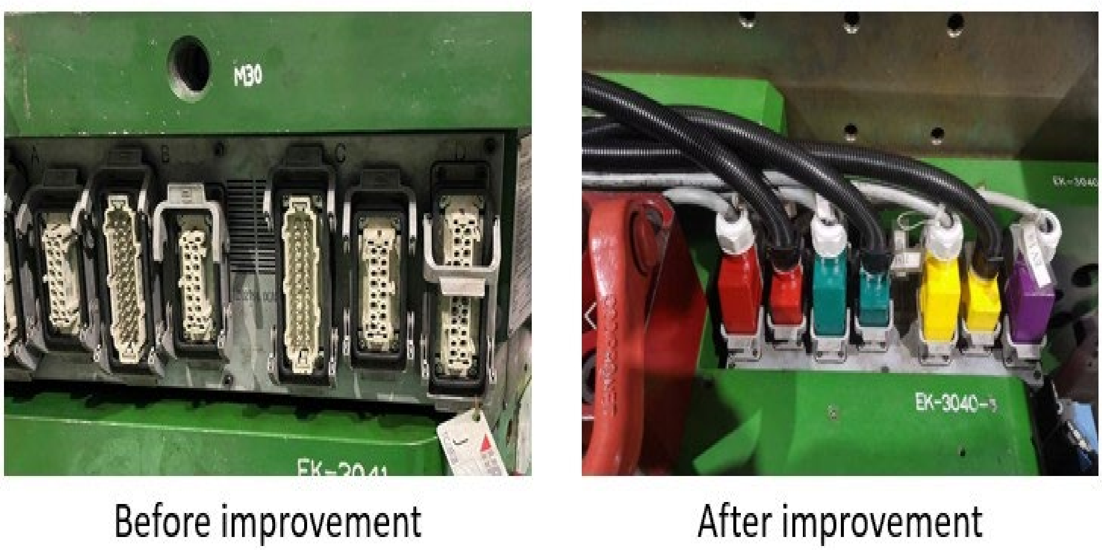

Figure 3. Before and After Improvement Showing Color Coding for Different Signal Lines

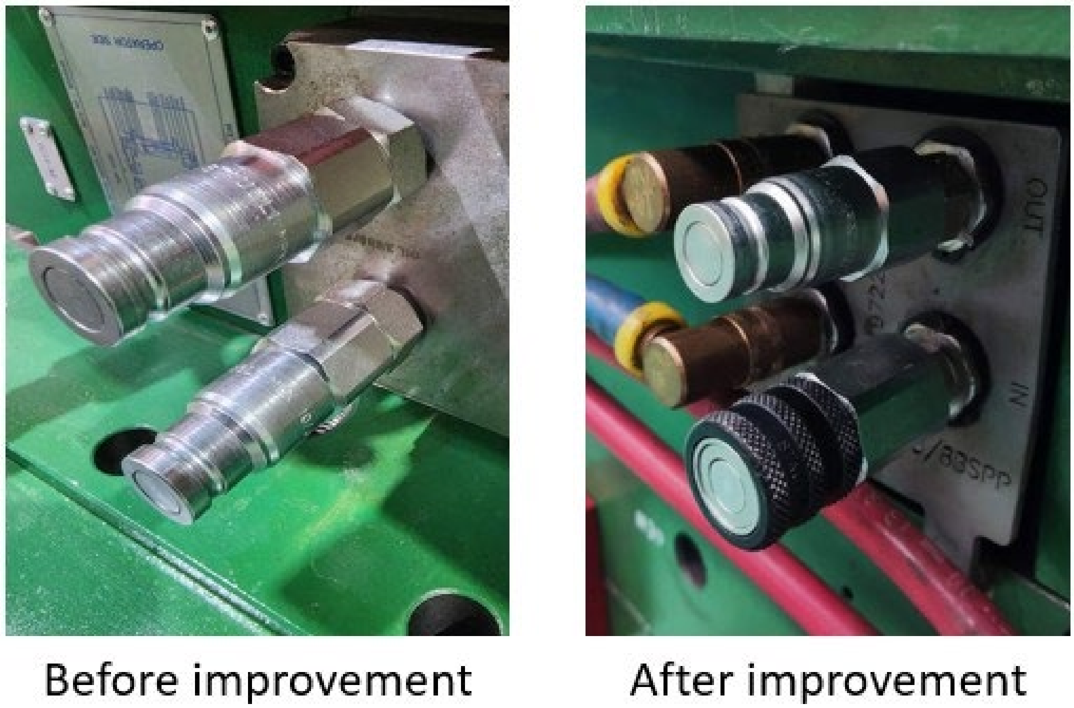

Figure 4. Before and After Improvement Showing the Change to Female and Male Couplings for Ease of Use

After the process of changing and installing plastic injection molds was improved, the researcher timed the process to compare the results of the improvements.

4.4 Percentage Improvement in Time for Mold and Die Switching

The percentage change was calculated to indicate the difference in time before and after the improvement using the formula:

((Time before improvement – Time after improvement) ÷ Time before improvement)×100))

After the process improvement, it was observed that employee efficiency increased, leading to an increase in production capacity. The percentage improvement is as follows:

$$\text{Percentage Time Reduction} = ((3869 - 2650) \div 3869) \times 100 = 31.50$$

The time reduction from the previous process was calculated to be 31.50 %.

After implementing the SMED, ECRS, and 5W1H techniques, the mold changeover time was reduced by 31.50 %, from 64.48 minutes to approximately 44.17 minutes. This reduction in setup time resulted in a 10% increase in the production of injected automotive parts.

5. Conclusion

Implementing the SMED, ECRS, and 5W1H techniques significantly reduced the time required for mold changeovers, decreasing from approximately 64.48 minutes to 44.17 minutes, a reduction of approximately 31%. This efficiency improvement not only streamlined the production process but also increased the production of automotive parts by 10%.

This research made several key improvements to enhance the mold change and installation process. The study began with a detailed analysis of the existing procedures, identifying inefficiencies and opportunities for improvement. The primary improvements included:

Separation of Internal and External Tasks: The process was made more efficient by distinguishing tasks that could be performed while the machine was running (external) from those that required the machine to be stopped (internal). This separation allowed for better time utilization, reducing downtime during mold changes.

Application of ECRS Principles:
Eliminate: Unnecessary steps were identified and removed. For instance, preparing equipment in advance minimized the need for waiting times during tool changes.

Combine: Tasks were combined where possible to streamline operations. For example, setting up cooling and hydraulic lines concurrently rather than sequentially.

Rearrange: The workflow was reorganized, assigning specific roles to each technician, ensuring a more coordinated and efficient process. This reorganization was supported by detailed training for the staff involved.
Simplify: Poka-Yoke mechanisms were introduced to prevent errors and simplify the connection of various lines and components. Color-coding and labeled couplings made it easier for operators to correctly and quickly connect equipment.

Training and Standardization: Comprehensive training sessions were conducted to ensure that all staff understood the new procedures and the importance of adhering to them. Standard operating procedures (SOPs) were documented and distributed, providing a clear and consistent guide for all personnel.

Enhanced Equipment Readiness: By improving the readiness and availability of necessary tools and equipment, the waiting times for equipment were significantly reduced. This included ensuring that all necessary tools were in place before the start of the mold change process.

The results of these improvements were substantial. The overall time for mold changes was reduced by 31%, improving production efficiency and stabilizing the production output, making it more consistent and predictable. This stabilization and efficiency boost allowed the company to meet increasing customer demands and improve overall competitiveness in the market.

The study demonstrates that significant gains in operational efficiency can be achieved through careful analysis and systematic improvements. The methodologies applied in this research provide a valuable framework for other manufacturing processes seeking similar improvements in efficiency and productivity.

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