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Integrating cultural lean practices with innovations to advance quick changeover for enhanced productivity in compressor manufacturing in Thailand

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Abstract

This study integrated cultural lean practices with innovations to enhance efficiency and streamline quick changeovers in a compressor manufacturing organization. Monthly production of compressor housing components consistently fell short of targets due to excessive changeover times, which averaged 4,733 seconds (approximately 1.31 hours) per model, impacting overall production efficiency. To address this issue, the study combined traditional lean and Single-Minute Exchange of Die (SMED) techniques, such as shifting tasks from internal to external processes, a well-known method for reducing changeover time. In addition, new innovations were introduced, including the development of an M24 T-slot bolt clamp to expedite the setup process and the design of die stoppers to enable rapid and precise die placement. A steel forklift wheel stop was also installed to aid in the proper alignment and positioning of equipment. These improvements resulted in a 61.86% reduction in changeover time, lowering the average time to 1,805 seconds (0.514 hours) per model. The findings emphasized that innovation-driven lean practices not only simplified tasks for workers but also supported their engagement and productivity, contributing to long-term organizational success.

Keywords: Changeover time reduction, Compressor manufacturing, Lean culture, Lean innovation, Poka-Yoke, Quick changeover, single-minute exchange of die.

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1. Introduction

In today's highly competitive and fast-paced manufacturing landscape, organizations are constantly striving to enhance their processes, systems, and products to maintain a competitive edge. Companies that embrace a Lean manufacturing culture—one that places a strong emphasis on continuous improvement—are especially successful at driving operational efficiency. Lean manufacturing is not solely concerned with waste reduction; it is also about fostering a culture of ongoing improvements that enable organizations to remain flexible and responsive to evolving market demands.

This study focused on a compressor manufacturing company that had successfully embedded Lean principles into its organizational culture. The company specializes in the production of hermetic reciprocating compressors used in air conditioning and refrigeration systems, catering to both domestic and international markets. A significant challenge faced by the company was the inefficiency encountered during the changeover between different compressor models. Specifically, the time required to switch between the production of the bottom shell of the AE model averaged 4,733 seconds (approximately 1.31 hours) per model. This long changeover time represented 8.19% of the total available working hours in a given month, leading to a substantial loss in productivity.

In response to this challenge, the research focused on improving the changeover process, specifically by reducing the time taken for model transitions. A commonly employed method for achieving such improvements is the Single-Minute Exchange of Die (SMED) technique, which has long been recognized for its ability to reduce changeover times. The SMED method works by shifting tasks that are traditionally carried out during machine downtime to be completed while the machine is still running. While the SMED technique has proven effective in many contexts, its application alone might not have been sufficient to meet the increasing demands for efficiency in modern production environments. Merely converting tasks from internal processes (those performed while the machine is stopped) to external ones (those done while the machine is running) did not result in the desired level of changeover time reduction.

Therefore, this study did not limit itself to just applying the traditional SMED principles but also incorporated innovative hardware solutions to enhance the overall changeover process. By integrating custom innovations with the foundational SMED approach, the research demonstrated how cultivating a Lean culture that actively supports and promotes innovation could lead to substantial operational improvements. The findings of this study highlighted the importance of combining the continuous improvement philosophy inherent in Lean practices with creative problem-solving techniques. This approach not only reduced the complexity of the tasks involved in the changeover process but also streamlined operations, leading to higher levels of productivity.

The paper is structured as follows: Section 2 provides a comprehensive review of relevant literature, Section 3 outlines the research methodology used in the study, Section 4 presents the results of the implemented changes, and Section 5 offers recommendations for further improvements in the changeover process.

2. Literature Review

Lean manufacturing, which originated from the Toyota Production System (TPS), became widely adopted across various industries. The core focus of lean manufacturing was on minimizing waste while maximizing productivity, efficiency, and value for the customer [1]. By streamlining processes, lean practices enhanced operational performance and flexibility, allowing organizations to respond more effectively to changing market conditions and customer demands [2]. A central tenet of lean philosophy was the culture of continuous improvement (Kaizen), which encouraged employees to identify inefficiencies and implement incremental changes that improved workflow and productivity [3].

One of the most influential lean tools was the Single-Minute Exchange of Die (SMED) technique, pioneered by Shigeo Shingo during his work at Toyota in the 1960s [4]. SMED was designed to dramatically reduce machine setup times by transforming internal setup tasks (those requiring machine stoppage) into external ones (those that could be performed while machines were running), thus reducing downtime and improving productivity [5, 6]. The SMED process involved five steps: analyzing the current setup process, separating internal and external tasks, shifting external tasks outside of machine downtime, converting more internal tasks to external, and simplifying all setup activities to further minimize time [7].

Research highlighted the importance of organizational culture in sustaining lean practices. A lean culture fostered a mindset where employees engaged in problem-solving and were empowered to make process improvements [8]. According to Bortolotti, et al. [9] and Amaro, et al. [10], organizations with a strong lean culture were better equipped to implement continuous improvements, as cultural norms aligned with lean principles. This environment was especially conducive to innovation in quick changeover processes.

Innovation played a crucial role in complementing traditional lean methodologies. Schumpeter [11] defined innovation as the introduction of new goods or processes that drove economic growth, a concept applicable in lean environments where new methods were sought to improve efficiency. Rogers [12] emphasized that innovation was not only about new ideas but also their successful adoption within an organization. In lean practices, this often involved technological advancements or new work procedures that complemented existing techniques.

Numerous studies explored the implementation of SMED to reduce changeover times. For example, Carrizo and Pais [13] applied SMED in a mold-making firm by preparing new molds next to machines before setup, reducing machine idle time. Morales and Rodríguez [14] increased Overall Equipment Effectiveness (OEE) from 77% to 85% in interconnection axle production by using SMED. Dhankhar and Kumar [15] improved productivity in a shock-absorber assembly process by converting internal tasks to external ones. Filla [16] reduced changeover times in a flat glass processing firm by redistributing setup activities, and Ahmad and Soberi [17] integrated SMED with the Eliminate, Convert, Combine, and Simplify (ECRS) approach, enhancing changeover efficiency in 5-axis trimming operations.

Further studies adopted alternative methods to reduce changeover times. Lozano, et al. [18] emphasized the importance of standardized machine setup documentation in the food industry, alongside metrics such as MTBF, MTTR, and OEE. Cakmakci [19] highlighted the use of process capability analysis in automobile rim production, while Sabadka, et al. [20] designed a universal palette for shafts to reduce changeover times in shaft manufacturing. Boran and Ekincioğlu [21] integrated ergonomic risk assessment with SMED to minimize worker fatigue in aluminum profile production, and Patel, et al. [22] reduced setup times to under 15 minutes in a small aerospace parts manufacturer by implementing SMED and Poka Yoke.

In addition, integrating ergonomic safety into lean practices boosted productivity and employee well-being. Sirikasemsuk and Leerojanaprapa [23] emphasized that ergonomic assessments improved work posture risks, aligning with lean principles that advocated optimizing processes and workplace conditions for sustained productivity. After changing the mold set or tools of the machinery, ensuring the correct machine settings was also essential. Sirikasemsuk, et al. [24] examined the optimization of assembly processes in hard disk drive manufacturing, identifying key parameters that influenced defect reduction, which provided valuable insights for enhancing quick changeover methods.

Research demonstrated the versatility and effectiveness of SMED across various industries, but modern manufacturing demands often required innovations beyond traditional methods to meet efficiency goals. Literature emphasized the importance of shifting internal tasks to external ones, a core SMED principle, to reduce setup times and improve changeover processes. However, there was a gap in studies exploring innovative approaches within the piston compressor industry, which faced challenges related to flexibility and rapid changeovers. The traditional SMED technique may have fallen short in meeting the needs of frequent product customization, highlighting the potential for incorporating custom tools to enhance efficiency.

This study addressed this gap by examining how innovation could improve quick changeovers in compressor manufacturing within a lean culture. It focused on the development of tools like the M24 T-slot bolt clamp and die stoppers, extending SMED's capabilities. The research demonstrated that integrating lean principles with innovative solutions could significantly reduce setup times and boost overall productivity.

3. Methodology

The methodology employed in this research consisted of a structured approach, beginning with a survey of the current state and overall conditions of the organization. This initial assessment aimed to analyze the existing changeover processes in production, particularly transitioning internal machine setup activities to external processes. Subsequently, innovative solutions were designed to address identified issues. The performance outcomes were then compared, leading to a summary of results and relevant recommendations.

3.1. Current State Analysis

The company under study is a manufacturer and distributor of key products, including piston compressors for refrigeration and air conditioning applications. It also produces and sells condensing units, compressor motor components, and electric motor parts. The piston compressor is categorized into three main components: the housing (top and bottom shells), the stator, and the pump kit, as shown in Figure 1. This research specifically examined the production process of the AE model's lower compressor shell due to the inefficiencies observed in the existing operations, which resulted in delays and suboptimal performance relative to established production targets.

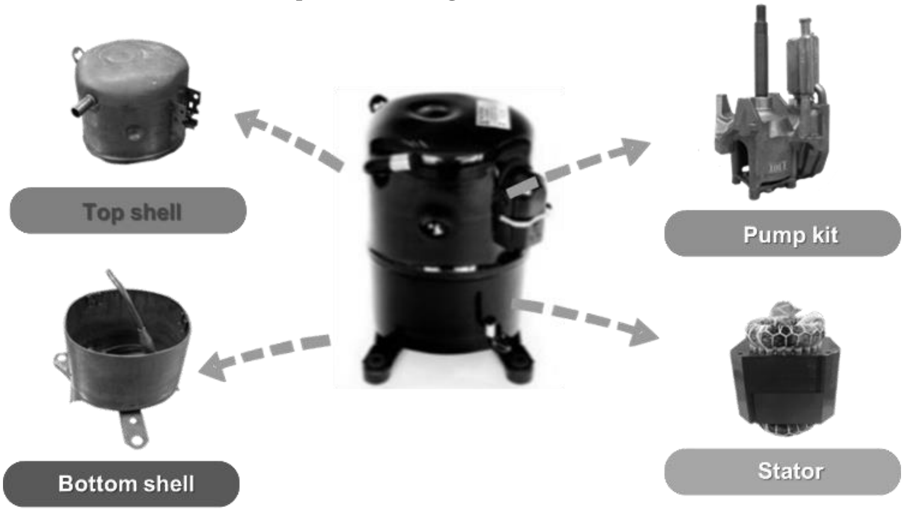


Figure 1.
Components of a reciprocating compressor.

The production process of reciprocating compressor motors in the case study company consists of seven main processes, as shown in Figure 2, as follows:

Process 1: Compressor casing forming process: This step involves stamping steel into the upper and lower casings of the compressor. The process uses semi-automatic machines to stamp each piece individually with molds.

Process 2: Machining process for various subcomponents: This includes turning, drilling, boring, and grinding processes for the suction and discharge assembly.

Process 3: Drive assembly production process: This step involves winding copper wire, which serves as the power source of the compressor.

Process 4: Suction and discharge assembly process: This step involves assembling machined subcomponents into a complete unit.

Process 5: Compressor assembly process: This step combines the drive assembly, suction and discharge assembly, and casing components. The assembly is then sealed by welding, painted, and baked to remove moisture.

Process 6: Final compressor testing process: This involves testing the functionality of the compressor system before storage and distribution.

Process 7: Storage process: This step involves packaging and transporting compressors to storage areas before delivery to customers.

This study focused on the scope of stamping the lower casing of the AE model compressor, which is used exclusively in refrigerators. A total of nine molds are used for stamping, supporting the production of 22 AE compressor models, such as 3KPU 410B-1FM, 3KPU 410B-2FM, 3KPU 410B-3FM, 3KPU 412B-1FM, 3KPU 412B-2FM, and 3KPU 412B-3FM.

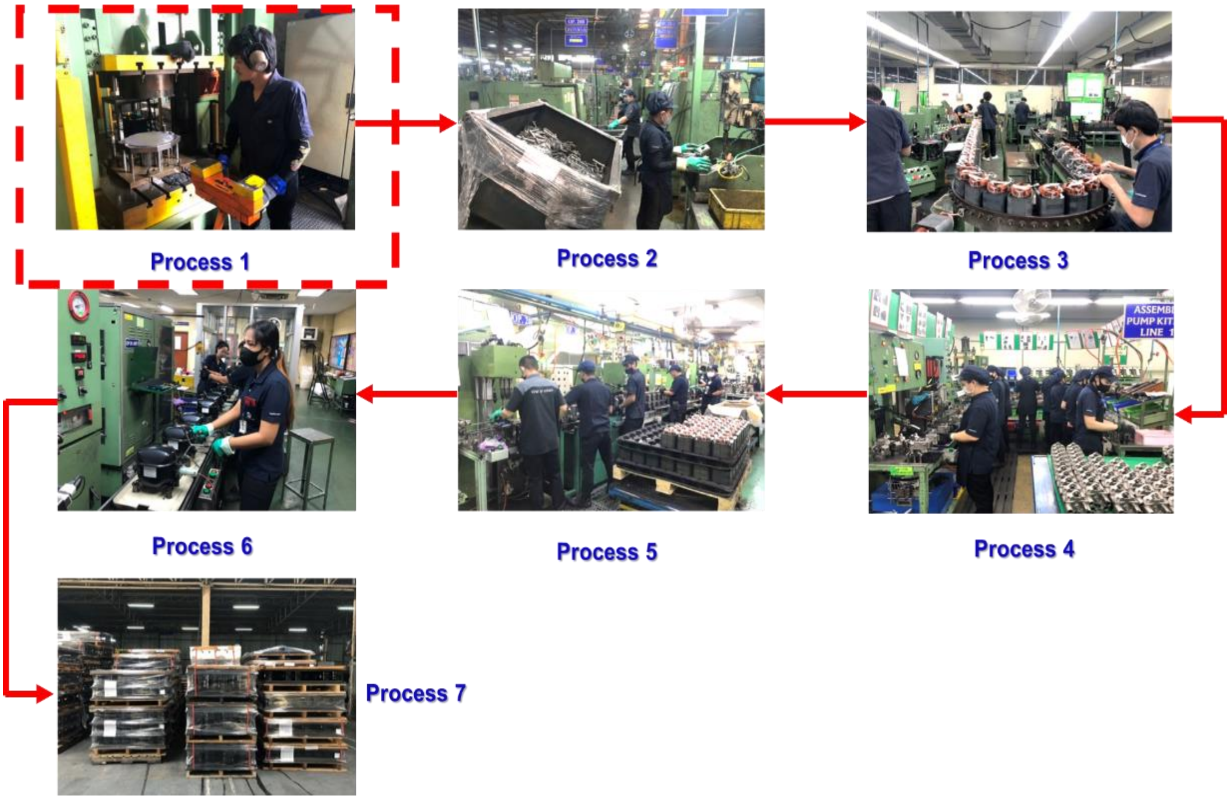


Figure 2.
The production process of reciprocating compressor motors.

By breaking down the activities involved in producing the AE model's lower compressor shell, it was found that the time allocated for changeovers constituted a larger proportion of total activity time compared to machine breakdowns. The primary problem statement of this research was that the changeover process for the AE model's lower shell was excessively time-consuming, negatively impacting production output. Therefore, the main objective of this research was to improve the changeover procedures for the AE model's lower compressor shell to reduce the time taken for these processes, with the current average time recorded at 4,733 seconds per changeover (approximately 1.3147 hours).

The compressor shell formation process encompassed the production of both the upper and lower housings through steel drawing to shape the shell. This semi-automated production utilized advanced drawing machinery and was organized into three sequential stages: Step 1, drawing the lower housing; Step 2, edge flattening of the workpiece; and Step 3, trimming of the workpiece edges, as shown in Figure 3.

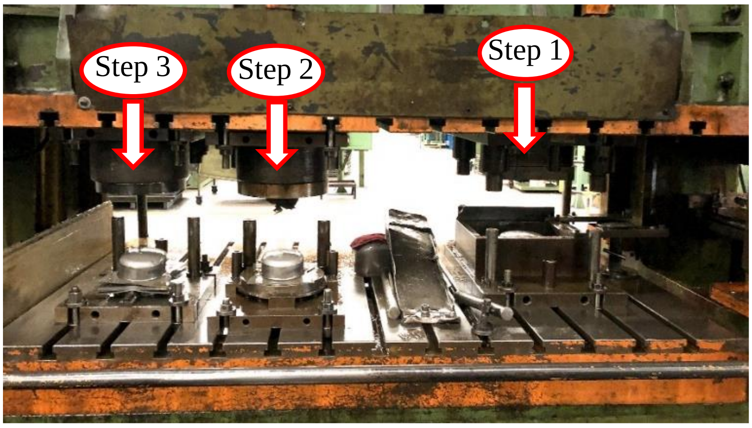


Figure 3.
Machine front view for AE model compressor housing production.

The AE model compressor production encompassed 22 different models, categorized into three primary die groups: KEH440, KEH441, and KEH443. Each primary die group contained three sub-dies corresponding to the three operational steps, resulting in a total of nine sub-molds utilized in the drawing process. Two technicians were required for each changeover of the lower shell drawing machine.

The changeover activities for the AE model's lower compressor shell were grouped into seven distinct categories:

Group A: Reviewing the production plan.

Group B: Removing the existing die set from the drawing machine.

Group C: Storing the old die set and replacing it with the new die set.

Group D: Assembling the steel roll and adjusting the steel feeder for the drawing machine.

Group E: Adjusting the die set.

Group F: Installing the new die set onto the drawing machine.

Group G: Conducting test stamps and inspecting the workpieces.

During the observation process, the first technician reviewed the daily production plan in the office of the compressor shell forming department. Next, the technician retrieved a cart containing necessary tools from the tool storage area and brought it to the drawing machine. Both technicians worked together to remove the existing die set. After this was completed, the first technician moved to the steel feeder to assemble the steel roll and adjust the feeder, while the second technician assisted the forklift operator in retrieving and storing the old die set and bringing in the new one. Meanwhile, the first technician prepared the new die set at the adjustment table prior to its assembly in the drawing machine. Once the new die set was successfully adjusted, the forklift operator delivered it to the drawing machine, where both technicians installed it. Finally, the first technician conducted a test stamp on the workpieces and inspected them. If the measured values did not meet the standards, adjustments were made to the die set until the readings fell within acceptable limits.

It was noted that the upper base of the machine, known as the Slide, and the lower part, referred to as the Bolster, were both used to secure the mold to the machine. The upper part of the machine featured 12 cushion holes. The dimensions of the machine slots are illustrated in Figure 4.

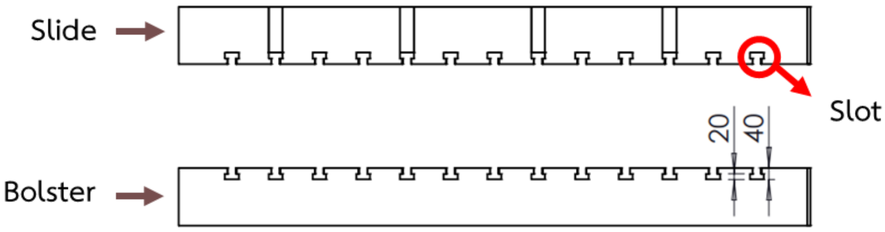


Figure 4.
Front view of the machine and the dimensions of the slots on the machine's base.

3.2. Analysis and Transition from Internal to External Work

Flow process charts and workflow diagrams involving two technicians (Technicians 1 and 2) were utilized to study the changeover processes for the AE model's lower compressor shell. The researchers then analyzed the changeover process using a multi-activity chart, as shown in Figure 5.

As depicted in Figure 5, the total changeover time recorded was 4,733 seconds. This was distributed as follows: Technician 1 engaged in 4,680 seconds of active work with 53 seconds of downtime, while Technician 2 completed 2,643 seconds of work with 2,090 seconds of downtime.

	Technicians 1	Time (seconds)	Technicians 2	Time (seconds)	Drawing machine	Time (seconds)
1.	Group A: Reviewing the production plan.	1,804	Idle	1,804	Idle	1,804
2.	Group B: Removing the existing die set from the drawing machine.	307	Group B: Removing the existing die set from the drawing machine.	307	Idle	307
3.	Group D: Assembling the steel roll and adjusting the steel feeder for the drawing machine.	436	Group C: Storing the old die set and replacing it with the new die set.	885	Idle	885
4.	Group E: Adjusting the die.	396				
	Idle	53				
5.	Group F: Installing the new die set onto the drawing machine.	1,548	Group F: Installing the new die set onto the drawing machine.	1,548	Idle	1,548
6.	Group G: Conducting test stamps and inspecting the workpieces.	189	Group G: Conducting test stamps and inspecting the workpieces.	189	Machine working	189
	Total working time	4,680	Total working time	2,929	Total working time	189
	Total idle time	53	Total idle time	1,804	Total idle time	4,574
	Total	4,733	Total	4,733	Total	4,733

Operators working on a machine   Independent working   Idle

Figure 5.
Chart illustrating the multi-activity changeover process for the compressor bottom shell.

The analysis of Group A activities identified a significant amount of time required for organizing sub-production sequencing. To address this inefficiency, the study proposed transferring these tasks to external processes following the principles of Single Minute Exchange of Die (SMED), as they could be performed before the production model changeover. This adjustment enabled technicians to initiate the changeover without additional sequencing setup.

For Group D activities, delays stemmed from adjustments to the steel feeder in the drawing machine, due to the considerable size and weight of the steel coil and the need for crane attachment. To mitigate these delays, the study recommended designating tasks D2 and D3 as external activities that could be prepared prior to the changeover process.

Similarly, the analysis of Group E activities showed that significant time was consumed in adjusting die height. Therefore, the study suggested transitioning this adjustment task to an external activity, as it could be carried out 30 minutes before production began. Either Technician 1 or Technician 2 was assigned to perform these adjustments.

The reclassification of certain internal tasks as external tasks effectively reduced machine downtime. The following activities were transferred to external status:

A1: Walking to the shell stamping department office
A2: Checking the daily production schedule
A3: Grouping production batches by order of priority
B1: Walking to the equipment storage area
B2: Moving the tool cart to the lower shell drawing machine
D2: Attaching the steel coil to the crane
D3: Using the crane to move the steel coil to the feeder
E1: Walking to the equipment storage area

E2: Retrieving a steel plate from the tool storage
E3: Walking to the die adjustment table
E4: Using an air wrench to remove the Step 1 die component
E5: Installing the retrieved steel plate onto the die
E6: Using an air wrench to reassemble the Step 1 die component
E7: Walking to the lower shell drawing machine

Following this conversion, Technician 1 now performed 20 internal setup tasks and 14 external tasks, while Technician 2 had 24 internal setup tasks. Additionally, by assigning Group A activities to Technician 2, who previously had available time, setup times were further optimized, enabling both technicians to initiate the model changeover immediately (starting from Group B tasks). This conversion of internal to external activities successfully reduced the total internal setup time from 4,733 seconds to 2,234 seconds.

3.3. Analysis of Group B Activities and Innovations

A total of nine sets of dies were utilized in the production of the AE model lower shell, accommodating 22 different variants. Based on the preliminary analysis, each production model used different fixtures, even though they shared the same mold. There were three different fixture setups for the same mold, as shown in the example of the fixture arrangement in Figure 6. This led to assembly activities involving search and selection processes to ensure that each fixture setup aligned properly. Additionally, there was a changeover between the M20 and M24 wrenches during the tightening process.

Figure 6.
Example of different fixture arrangements (before improvement).

The removal of die sets from the drawing machine employed two categories of fastening methods (as shown in Table 1):

Set 1 featured M20 and M24 socket cap screws paired with flat washers and t-slot nuts. During the die removal process, it was necessary to first use a wrench to unscrew the t-slot nuts, followed by manually removing the flat washers from the t-slot nuts. This setup included both M20 and M24 socket cap screws available in lengths of 80, 90, and 100 millimeters. The t-slot nuts were classified into two types: wide base and narrow base, further categorized into M20 t-slot nuts and M24 t-slot nuts.

The advantage of using t-slot nuts lay in their convenient movement and ease of adjustment, as they fit into the slots of the machine base. However, a disadvantage was the need for careful alignment of the threaded portions of the socket cap screws with the t-slot nuts to ensure compatibility.

Set 2 contained M20 and M24 t-slot bolts along with flat washers and hexagon nuts. To remove the die set, one had to first use a wrench to unscrew the hexagon nuts, followed by manually removing the flat washers from the t-slot bolts. This set could also be divided into two categories: M20x80 mm and M24x80 mm t-slot bolts, with the hexagon nuts further classified into M20 hexagon nuts and M24 hexagon nuts.

The advantage of this assembly method was that the hexagon nuts could be easily threaded onto the t-slot bolts and secured tightly. However, a drawback was that the t-slot bolts could be difficult to move or adjust due to their design, which did not conform to the slots of the machine base.

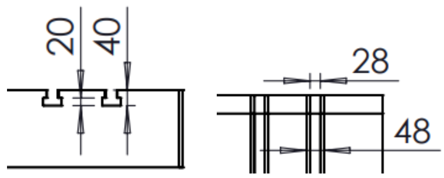
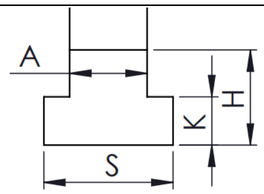
It was evident that the fastening devices employed in each production model differed significantly. The variety of fastening equipment led to instances where the same die set required three different fastening systems, complicating the search for the appropriate tools and necessitating frequent switching between M20 and M24 wrenches.

To address these challenges, researchers proposed an improvement by designing a standardized fastening device that could be utilized across all die sets. This new design developed from Set 2, utilizing M24 t-slot bolts, which maintained a consistent size suitable for the machine base, as outlined in Table 2. This modification enhanced the fastening strength with M24 flat washers and M24 hexagon nuts. Furthermore, this fastening equipment was fabricated in-house from S50C steel, offering superior strength and durability compared to conventional fastening devices available in the market. Consequently, only one type of wrench was necessary for the operation.

Table 1.
Comparisons of screw fastening clamps.

Set 1		Set 2		New fastening device	
	Socket cap screws of sizes M20 and M24 featuring lengths of 80, 90, and 100 mm.		Hexagon nuts of sizes M20 and M24.		Hexagon nuts of size M24.
	Flat washers of sizes M20 and M24.		Flat washers of sizes M20 and M24.		Flat washers of size M24.
	T-slot nuts of sizes M20 and M24.		T-slot bolts of sizes M20 and M24 featuring lengths of 80, 90, and 100 mm.		New t-slot bolts of size M24 featuring a length of 80 mm.

Table 2.
Dimensions of the new fastening device.

Dimensions of the slot on the bolster plate					Dimensions of the new M24 t-slot bolts				
									
Position	A’	H’	K’	S’	M24	A	H	K	S
Dimension	28	40	20	48		24	30	15	40

3.4. Analysis of Die Assembly Activities with the Drawing Machine (Group F) and Innovations

The activities in Group F involved the assembly of a new die set, which stood in contrast to the activities in Group B that focused on die removal (discussed in Group B). This section examined the challenges identified in Activity F1, where the adjustment of the die's position aligned with the cushion holes. This activity occurred after the die set was placed on the drawing machine, necessitating that Technician 1 and Technician 2 adjusted the die's position across three steps to ensure proper alignment with the cushion holes before production could commence.

Technician 1 and Technician 2 maneuvered the die set to bring it closer to the cushion holes by tapping, sliding, and pushing or pulling the die set (as illustrated in Figure 7). This adjustment process could be categorized into two scenarios: Scenario 1: If the die set was positioned too far away, the technician pushed it closer. Scenario 2: If the die set was inserted too far, the technician pushed it out.

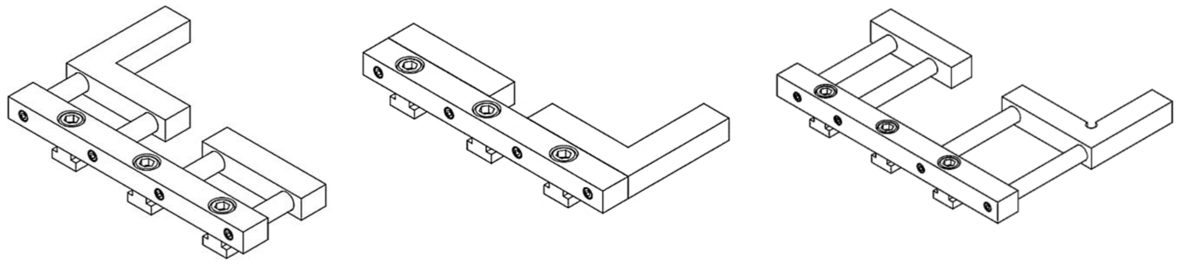
Figure 7. Adjusting the position of the die to align with the cushion holes.

To enhance efficiency and convenience in this process, researchers proposed implementing Poka Yoke principles, which included:

Approach 1: Designing a stopper to assist in adjusting the die's position, thereby addressing issues arising from Scenario 2, where the die set was excessively inserted (as shown in Figures 8 and 9).

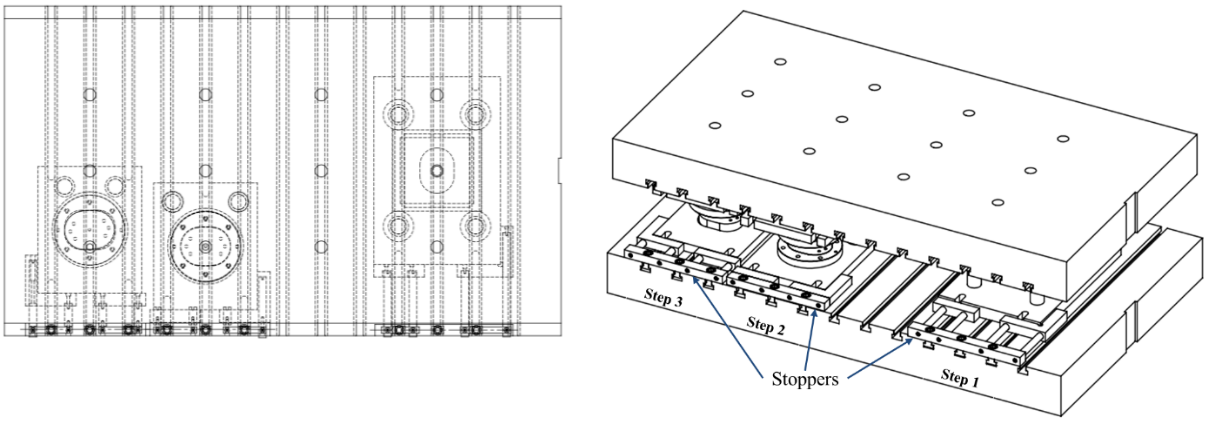
Approach 2: Designing a barrier for the forklift wheels to rectify problems associated with Scenario 1, where the die set was positioned too far away.

The placement of the stopper utilized the dimensions of the Model KEH441 die set as a reference to determine alignment with the cushion holes. Consequently, the stopper for the KEH441 die set required no adjustment. In contrast, the stoppers for Models KEH440 and KEH443 featured color-coded markings on the machine base as a form of visual control, indicating adjustment points. The adjustment values for the stoppers of each die set were detailed in Table 3 and illustrated in Figure 10.



a) Stopper for Step 3 b) Stopper for Step 2 c) Stopper for Step 1

Figure 8.
Design of the stopper.



a) Top view b) Trimetric view

Figure 9.
Assembling the designed stoppers onto the drawing machine.

Table 3.
Adjustment value of the stoppers.

Step No.	Model KEH411	Model KEH440, KEH443
Step 1	0	49
Step 2	0	40.5
Step 3	0	50

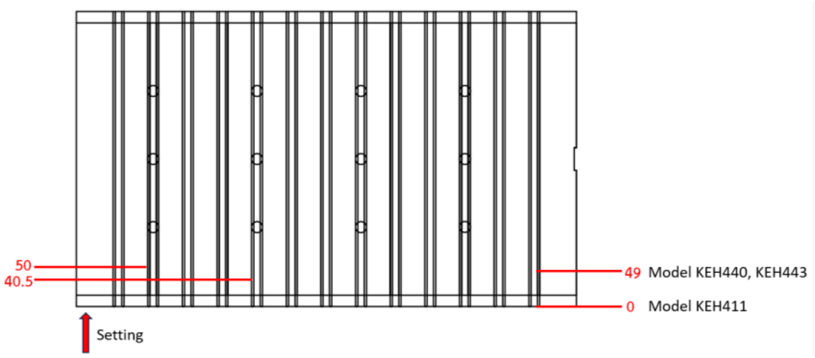


Figure 10.
Positioning the adjustment distance of the stopper.

4. Results

We designed a new fixture for securing the die set, which comprises three main components:

- New M24 T-slot bolts: These bolts were redesigned based on current applications, allowing for easier tightening and loosening while providing enhanced clamping strength.
- M24 Flat Washers
- M24 Hexagonal Nuts

The existing M20 support holes for the dies were enlarged to accommodate the new M24 components. This new die-fixing device was universally applicable to all dies, aiming to reduce operational time and improve efficiency. The improvements led to a reduction in the time required for Group B activities (the process of removing the existing die set from the drawing machine), specifically activities B4, B5, and B6, from 256 seconds to 166 seconds. Similarly, the time for Group F activities (the process of assembling the new die set onto the drawing machine), specifically activities F4, F5, F6, and F7, decreased from 1,548 seconds to 1,325 seconds.

Analysis of Group F activities revealed that both technicians frequently needed to tap and slide the die set back and forth to align it precisely with the cushion holes before securing it with the bolts. This adjustment process extended the assembly time for the new die set. To address this issue, researchers designed a stopper based on the Poka Yoke technique, which was installed on the lower machine table to prevent the die set from moving too far forward, as illustrated in Figures 11 – 12.

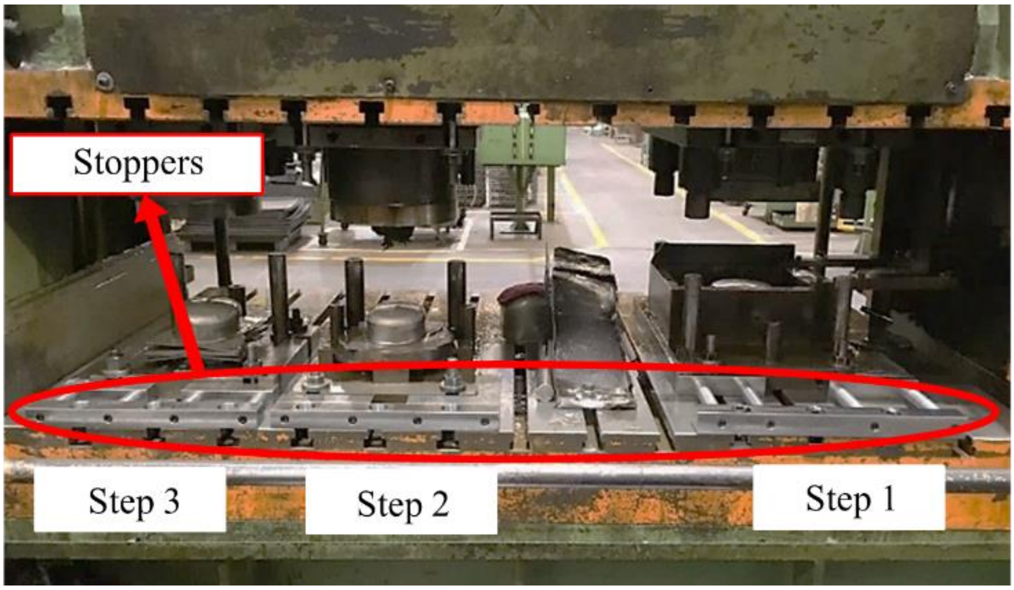


Figure 11.
The designed and installed stopper (after improvement).

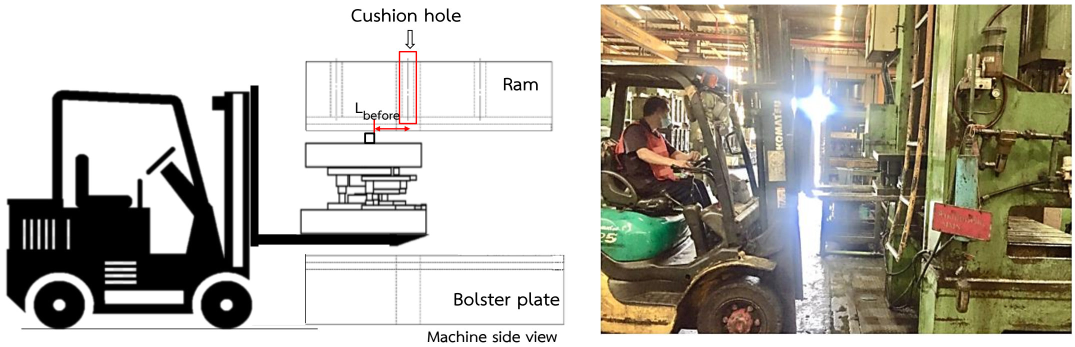
a) Stopper set of step 1 b) Stopper set of step 2 c) Stopper set of step 3

Figure 12.
Actual stopper set has been developed.

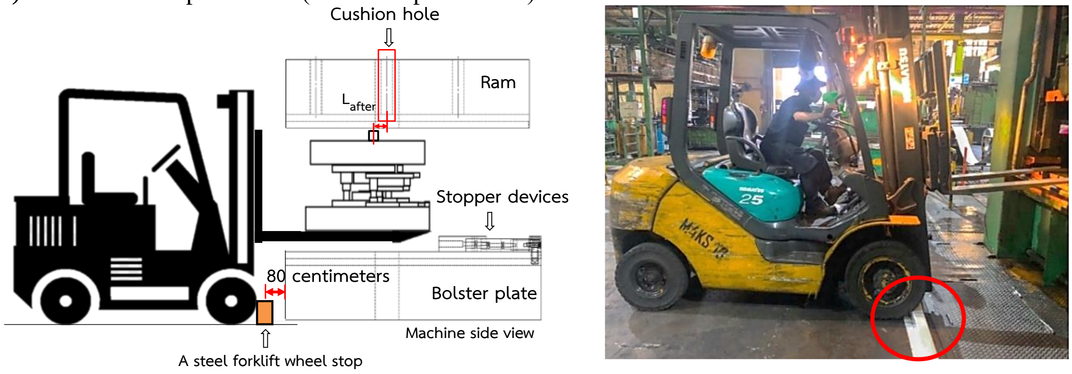
The implementation of the stopper significantly enhanced the alignment of the die with the cushion holes, resulting in a reduction of time for Group F activities (the process of assembling the new die set onto the drawing machine) in activity F1 from 223 seconds to 46 seconds. Consequently, the total time for Group F activities decreased from 1,325 seconds to 1,148 seconds.

In addition to optimizing internal activities and redesigning the die fixture and stopper for positioning, this research also focused on improving the storage area for dies, relocating it closer to the machinery. The design of a steel forklift wheel stop (as shown in Figure 13) represented another enhancement. Following these process improvements, the overall time required for production changeovers decreased from 4,733 seconds per instance to 1,805 seconds per instance, which corresponded to a reduction of 61.86%, as shown in Figure 14. The time for the first technician's changeover dropped to 1,766 seconds from 4,680 seconds, while the second technician's changeover time decreased to 1,598 seconds from 2,643 seconds.

In addition to minimizing waste time, these improvements increased production output by up to 154 units per changeover, resulting in a potential increase in sales of 23,100 Thai Baht per changeover, which translated to 4,712,400 Thai Baht annually.



a) The driver's expectations (before improvement)



b) Steel forklift wheel stop (after improvement)

Figure 13.
Comparison of forklift positioning for placing the die.

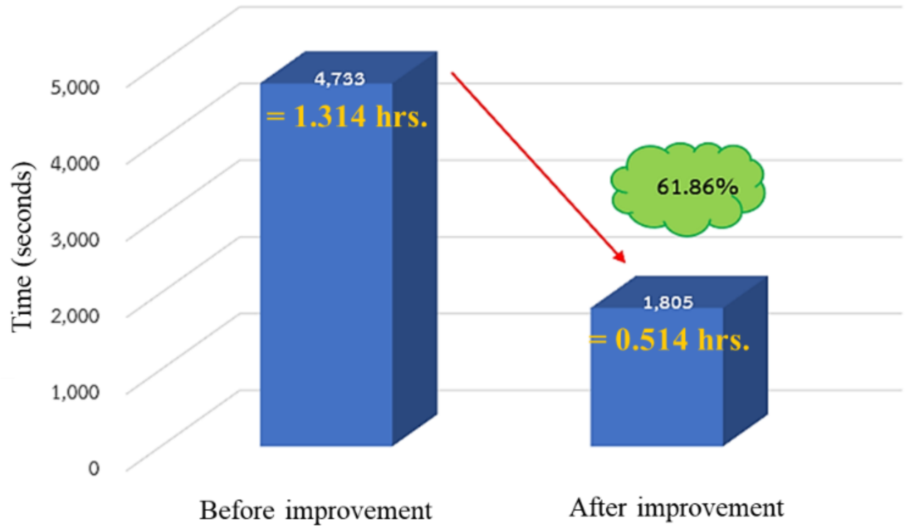


Figure 14.
Bar chart comparing standard times before and after improving the compressor bottom cap changeover process.

5. Conclusion

This research highlighted the effectiveness of integrating Lean work practices with innovative strategies to improve the die changeover process in manufacturing. By designing a new fixture that included redesigned M24 T-slot bolts, M24 flat washers, and M24 hexagon nuts, the study demonstrated significant enhancements in die clamping strength and ease of use. As a result, the time required for production changeovers decreased dramatically from 4,733 seconds to 1,805 seconds, reflecting an impressive reduction of 61.86%.

Moreover, the implementation of Poka Yoke techniques, specifically the development of a stopper, minimized misalignment during die assembly. This improvement reduced assembly time from 223 seconds to just 46 seconds, contributing to a reduction in the overall Group F activities time from 1,325 seconds to 1,148 seconds. These enhancements not only streamlined workflows but also enabled employees to concentrate on core tasks, thereby reducing fatigue and improving productivity.

The increased efficiency led to a production output increase of up to 154 units per changeover, resulting in a potential annual revenue increase of approximately 4,712,400 Thai Baht. Additionally, relocating the storage area for dies closer to the machinery and introducing a steel forklift wheel stop further optimized die management processes.

These findings emphasized the potential of Lean practices when combined with innovative technologies for achieving efficiency gains and improved working conditions. The significant decrease in changeover time exemplified how systematic process management reduced complexity and enhanced production. Future research should explore how technologies such as IoT and AI could refine Lean methodologies, particularly in rapid changeover management. These technologies could provide insights that enhance process agility, while expanding Lean applications to industries like logistics or healthcare could reveal broader benefits.

Ultimately, this study underscored the importance of integrating Lean principles with innovative strategies to not only boost production efficiency but also foster a healthier work environment, lower turnover rates, and sustainable operational improvements across the manufacturing sector.

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