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Implementation of Single Minute Exchange of Die Method to Reduce Setup Time of Terminal Lead Welding Machine

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Abstract: This study is focusing on Single Minutes Exchange Die (SMED) method and other lean tools or system that support or make improvement to the SMED method on the terminal lead welding machine, also known as auto activation cum impulse and medium frequency welding machine at TDK Electronics (Malaysia) Sdn. Bhd. Single Minute Exchange of Die (SMED) is the main lean tool used in this study. Meanwhile, root cause analysis and value stream mapping are used as supporting lean tools in this study. This study focuses to reduce changeover or setup time on the terminal lead welding machine by implementing Single Minute Exchange of Dies (SMED). This study also analyses the changeover process or setup operation and suggests an efficient way to decrease production downtime and, therefore, the production cost of the industry. The SMED methodology began with the data collection of current practices through interview, observation, document review and data analysis. Then, time, value stream mapping (VPM) and root cause analysis (RCA) was conducted to identify current changeover or setup time for each internal and external activity. By externalizing and parallelizing some internal activities, the existing changeover time managed to be reduced by 48.42% from a current 2.3 hours of changeover time by integrating SMED techniques. This leads to the reduction and elimination of wastes from the setup or changeover process of the terminal lead welding machine.

Keywords: Single Minute Exchange of Die, Value Stream Mapping (VPM), Root Cause Analysis (RCA).

1. Introduction

Shigeo Shingo, the creator of the fast machine setup method, commonly known as SMED, was tasked with developing an appropriate technique for lowering setup time (single minute exchange of dies) [1]. SMED method is one of the lean manufacturing tools that enable successful competition in both domestic and international markets [2] (Figure 1). SMED assists in facilitating model change processes in the most efficient and time-efficient manner possible. SMED is a method in which all activities or changeovers must be completed in a single number of minutes (less than 10) [3].

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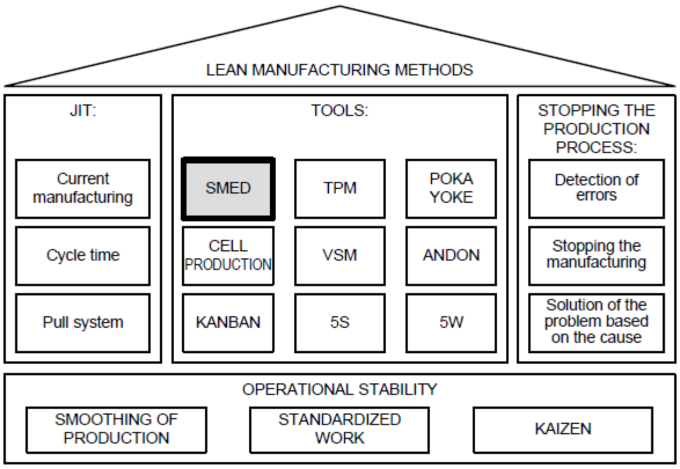


Figure 1: Lean manufacturing methods and tools [2]

This study is conducted in a manufacturing company named as TDK Electronics (Malaysia) Sdn. Bhd. located at Kawasan Perindustrian Tebrau, Johor Bahru, Johor. TDK Electronics (previously EPCOS) designs, manufactures, and markets electronic components and systems under the TDK and EPCOS brand names, with a focus on rapidly expanding cutting-edge technology markets such as automotive electronics, industrial electronics, consumer electronics, and information and communications technology. This study focuses on the Single Minutes Exchange Die (SMED) approach and other lean tools or systems that complement or enhance the SMED method on the terminal lead welding machine (Figure 6 in Appendix B) at TDK Electronics (Malaysia) Sdn. Bhd. To achieve the product variation demands, the terminal lead welding machine at TDK Electronics (Malaysia) Sdn. Bhd. must undergo changeovers and this machine need to be stop during the changeover or setup.

This machine is producing two types of gas tube arresters (tin coated and copper coated) and each type uses different types of printed arresters and terminal lead wires (silver-plated or tin plated). The tin coated 2-electrodes gas tube arrester is welded using medium frequency while the copper coated 2-electrodes gas tube arrester is welded using impulse frequency. The changeover or setup process for the terminal lead welding machine involves the conversion of different types of welding methods which are impulse and medium frequency (MF) welding. The current setup or changeover for both welding method and conversion takes about 2.5 hours. The duration of each major activity is depicted in Figure 2.

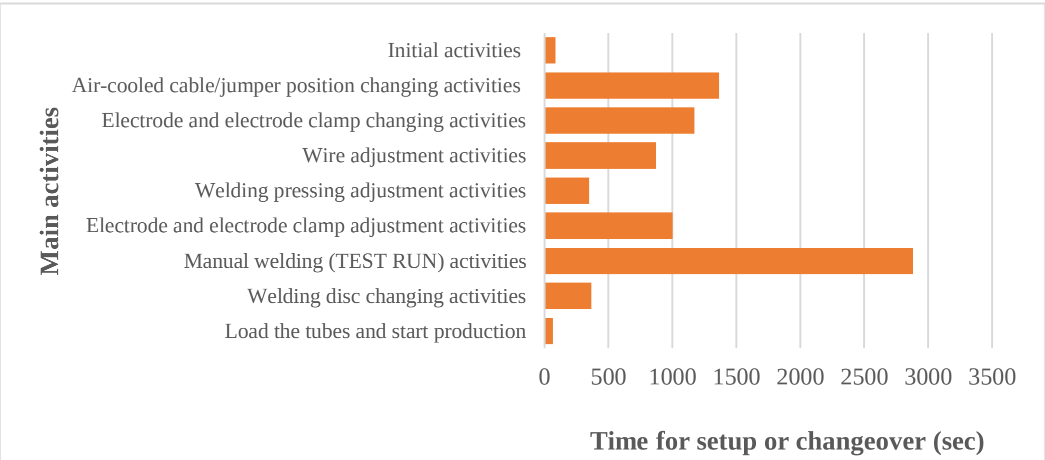


Figure 2: A current changeover chart for terminal lead welding machine

The main objective of this study is to reduce the changeover or setup duration of the terminal lead welding machine to 45 – 50% from a current 2.3 hours of changeover time by integrating SMED techniques.

2. Literature Review

Shigeo Shingo, a Japanese quality management pioneer, was the first to introduce SMED. Shingo is a famous pioneer in lean manufacturing and a world-leading industrial engineer and expert on the Toyota Production System [4]. He is the recipient of the prestigious Shingo Prize. Shingo created SMED after observing that replacing dies on transfer-stamping machines may take anywhere from twelve hours to nearly three days. When applying SMED, Shingo observed that there are eight primary strategies to consider. External setup, on the other hand, can be completed without shutting down the line, whereas internal setup necessitates shutting down the line [5]. The eight techniques recognized by Shingo are:

- Separate internal from external setup operations
- Convert internal to external setup
- Standardize function, not shape
- Use functional clamps or eliminate fasteners altogether
- Use intermediate jigs
- Adopt parallel operations
- Eliminate adjustments
- Mechanization

2.1 Lean Manufacturing

The best definition of lean manufacturing is the removal of waste in the production process; everything that does not add value to the final product is considered waste. In other words, lean manufacturing is an approach to production that regards the use of resources for any purpose other than the creation of value for the end consumer as wasteful and hence a candidate for deletion. Lean production aims to decrease waste in human labour, inventory, time to market, and manufacturing space to become extremely responsive to consumer demand while creating products of world-class quality in the most cost-effective manner feasible [6].

This lean manufacturing method is comprised of universal management concepts that may be adopted in any business, not only in Japan [7]. Lean manufacturing combines the greatest aspects of mass production and handicraft production, such as the potential to lower prices per unit and substantially increase quality while delivering a greater variety of items and more challenging labour [7]. The objective of lean manufacturing is to decrease waste in human labour, inventory, time to market, and production space to become extremely responsive to consumer demand while creating products of world-class quality in the most cost-effective manner.

2.2 Single Minute Exchange of Die (SMED)

The expression "single minute" does not suggest that all startup and changeover times should be less than one minute, but rather less than 10 minutes (in other words, single-digit minute) [4]. SMED is one of the primary lean production techniques for minimising manufacturing set-up time [8]. This technique differentiates between set-up tasks that must be conducted during downtime (internal activities) and actions that may be performed while the machine is operating (external activities) [9]. It enables a production process to move quickly and efficiently from running the current product to running the next product [10]. Rapid changeover is a crucial approach for attaining just-in-time (JIT) manufacturing and resolving concerns of flexibility and responsiveness; it is also a crucial aspect of the lean mindset. Shingo presented his Single Minute Exchange of Dies technique for this application (SMED) [1]. It is a collection of organised strategies that permit a large decrease in setup time (up to

90 percent) with small expenditures [11]. SMED is crucial for production adaptability. However, SMED's applicability is not restricted to manufacturing [10].

The objective of SMED is to shorten the time necessary to switch between products from hours to minutes. A fair objective for a SMED implementation would be a 75 percent reduction in setup time [10]. SMED is a world-renowned technique that has a proven track record of aiding organisations in attaining exceptional business results and boosting customer satisfaction [12]. SMED's emphasis on active employee participation in both issue solving and decision making, which has resulted in extraordinary setup time reduction examples, is another key contribution [13]. Due to management's lack of attention and dedication, the lack of long-term sustainability is one of the key downsides of SMED procedures. Available SMED methodologies do not adequately represent the lack of attention on hardware part rebuilding, which is another problem [1].

2.3 Setup or Changeover Time

The setup or changeover time is the duration between the conclusion of one work and the beginning of the next. Setup refers to the process of preparing a machine or workstation for the next activity, which might vary based on the task, the machine, or both [10]. Setup time is one of the most critical characteristics in any manufacturing business, and every machine or workstation need it as an input [14]. Due to the decreasing amount of series orders, the period between creating the final product of a series and the first product of a new series that satisfies all quality criteria has traditionally been regarded wasteful or an extra expense. The formula for calculating the required time is as follows [10]:

$$t = t_s + mt_1$$

where,

t = time required for manufacturing parts and assembling components [Nh/series]

t_s = machine setup time or assembly workplace setup time [Nh/series]

m = number of units within a series [pieces/series]

t_1 = manufacturing/assembly time per unit [Nh/piece]

3. Methodology

In this case study, based on the actual production, data was collected and recorded, and the time taken was measured from recorded video. The details of the operator's activities on the terminal lead welding machine and the time spent on each are tabulated (time study). Initially all activities were internal. Table 4 in Appendix A shows the activities performed on the terminal lead welding machine and corresponding time consumed. Value stream mapping (VSM) (Figure 7 in Appendix B) is done in this study on the terminal lead welding machine to provide a clear picture of the setup and changeover process in the machine and also to visualise how long each setup and changeover process in terminal lead welding machine. Root cause analysis (RCA) (Figure 8 in Appendix B) is also done in this study based on the data collected through interview and observation by using the cause-and-effect diagram or "fishbone" diagram as shown in Figure 3.6.

The proposed SMED methodology is based on Shingo’s SMED Methodology [4] and McIntosh’s Changeover Improvement [15]. It consists of five stages and each stage are elaborated in this topic.

3.1 Stage 1: Setup process map / Mapping the current state

The objective of this phase is to have a comprehensive understanding of all setup operations included in the changeover process. This will be accomplished by gathering information on present setup methods through interviews with machine operators and technicians, and then decomposing the setup activities into a sequence of steps. Then, a time and motion analysis are conducted to determine the standard time for each operation. All setup procedures and their corresponding resource requirements are listed on a specific sheet (standard operation setup check sheet).

3.2 Stage 2: Recognize external and internal process steps (Identify elements)

During this stage, all activities have to be analysed based on whether they can be accomplished while the auto cum impulsive and MF welding machines (C2, C3, C4 & C5) are running or not. The most efficient approach to accomplish this is to record the entire transition and then construct an ordered list of items for each of the following:

- Description: what tasks are carried out
- Cost in Time: how long it takes to finish the task
- Tools: what tools are used to perform the task

3.3 Stage 3: Separate external work and internal work

After identifying the setup process map, the activities are divided into two groups: internal (executed while the computer is offline or stopped) and external (performed when the machine is online or operating) (performed as the machine is running). To distinguish internal from external, three distinct instruments will be used:

- Check list: list of all the necessary resources (tools, manpower, processes) for setup.
- Function checks: display the availability and condition of all required installation tools.
- Prepare tools and components in advance before beginning setup duties.

3.4 Stage 4: Shift internal work to external work, wherever it is possible

This stage's enhancement may be achieved by altering the equipment and eliminating some configuration. Several conversion-facilitating approaches are suggested:

- Prepare the machine in advance to the needed operating conditions, i.e., pre-heat machine components and raw materials before feeding them into the machine.
- Use consistent techniques wherever feasible while doing setup activities; standard tool sizes are also essential.
- Implement ECRS (Eliminate, Combine, Rearrange and Simplify) chart or flow process chart

3.5 Stage 5: Streamline all other activities / Parallelism of Present Activities

This phase's improvement can be accomplished in two steps:

- Improving external setup: this stage involves actions that enable workers in doing setup duties in a more efficient manner, i.e., eliminating waste associated with finding, transferring, and replacing supplies and tools, as well as earlier tool examination to verify that they are in working order.
- Improving internal setup: this stage may be improved in several ways, including executing several setups simultaneously wherever possible and reducing the usage of manual clamps and fasteners. These actions are anticipated to significantly reduce the setup time.
- Combine some activities that can be performed concurrently and are also feasible.

4. Results and Discussion

The key to the success of any research or study is the adoption of an acceptable strategy and technique. In addition, it is vital to tackle the issue using a methodical method. The organization's confidence will rise because of the appropriate approach to the issue. Without one, the proposed remedies may be ineffectual and result in unpleasant outcomes. Single-minute exchange of dies (SMED) is one of the most essential lean tools that demands dedicated work. As indicated in Figure 4.1, a six-step technique is followed for the successful implementation of SMED.

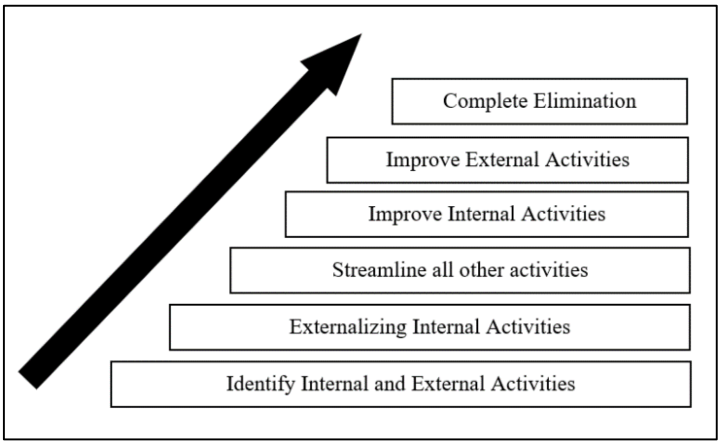


Figure 3: Six-step technique for changeover time reduction

4.1 Identify Internal and External Activities

SMED stages are often divided into two categories: external and internal setup activities. Internal activity take place while the equipment, machine or process is turned off. While the equipment, machine or process is functioning, external steps take place. In other words, internal activities are those that can only be completed when the process is paused, whereas exterior activities can be conducted while the process is in progress. Both activities are necessary for SMED to be implemented and completed. From the Table 1 in Appendix A, all activities are carried out internally. The objective is to convert as many internal tasks as feasible to external tasks to save as much time as possible and increase terminal lead welding machine productivity.

4.2 Externalizing Internal Activities

Through observation, it was found that some of the setup activities can be externalized (converting internal activities to external activities). Some examples of external activities are retrieval (parts, tools, supplies, etc.), cleaning, inspection, and quality checks. In this step, the setup activities which can be convert from internal activity to external activity has been converted. The externalization of internal activities could save 47 minutes of changeover time. Table 1 show the time saved after externalizing some internal activities.

Table 1: Time saved after externalizing internal activities

Activity No.	Activity	Actual Activity	Planned Activity	Time Saved (sec)
3.	Take an Allen key and a plier / toolbox	I	E	65
10.	Take some washers	I	E	37
26.	Check and ensure the connections of both ends of the air-cooled cables are tighten. (Weak connection will result in weak welding) (Inspection)	I	E	15
27.	Call another operator to check the connections of air-cooled cables. (Inspection)	I	E	60

28.	Take and choose new electrodes and electrode clamps from technician's desk	I	E	110
41.	Searching for Allen keys set	I	E	40
69.	Check and ensure the connections of the air-cooled cables are tighten. (Inspection)	I	E	62
77.	The electrode clamp is shorten/cut using a flat steel file to ensure the electrode and electrode clamp are in the equal height	I	E	225
83.	The electrode clamp is shorten/cut using a flat steel file to ensure the electrode and electrode clamp are in the equal height	I	E	287
86.	Take some tubes (arrester)	I	E	120
90.	Check the welding of the one side welded tube (inspection)	I	E	185
91.	Check the length of the wire on the one side welded tube using a Vernier calliper (length of the wire should be more than 11.30mm)	I	E	220
92.	Check the bending strength of the one side welded tube	I	E	95
93.	Current supply is adjusted (low or high) to get perfect welding	I	E	105
94.	Steps above (88-94) are repeated multiple times until the welding strength and the wire position are perfect on the tube	I	E	1075
95.	Take new welding disc from technician's desk	I	E	96
	Total time saved			**2 797 sec (47 minutes)**

4.3 Improvement on Internal and External Activities

Following separation from the internal operations, the external activities were standardised and enhanced. The separation of internal and external operations has been accomplished by providing operators and other production staff with explanations and inputs. Under the framework of the 5'S methodology, a SMED trolley is prepared for temporary tool storage for continuous setup to reduce tooling search and wait time.

After externalizing and enhancing some internal activities, the remaining portion consists of internal activities. This must be prioritized, and the efficacy of internal operations must be enhanced, to shorten the changeover or setup time of the terminal lead welding machine. One of the improvements that can be done on the internal activities is parallelism of activities. Parallelism of activities are activities that can been done simultaneously or concurrently. Through observation, it was found four main activities from the setup of the stations in terminal lead welding machine can be made parallel feasibly. Table 4.4 shows the details about the main activities combined and equivalent time saved. From the parallelism of internal activity, a total of 19 minutes has been saved from the changeover time.

Table 2: Main activities combined and corresponding time saved

Activities combined	Main activities done parallel	Time consumed before parallelism (sec)	Time consumed after parallelism (sec)
E+J	Electrode and electrode clamp changing activities at welding station	908	322

	6 (left hand side) + Electrode and electrode clamp adjustment activities at welding station 6 (left hand side)		
F+K	Electrode and electrode clamp changing activities at welding station 7 (right hand side) + Electrode and electrode clamp adjustment activities at welding station 7 (right hand side)	1 268	701
	Total time taken (sec)	**2 176**	**1 023**
Time saved after Parallelism = 2 176 – 1 023 = 1 153 sec (19 minutes)			

4.4 Changeover Time After SMED Implementation

After identifying internal and external activities and externalizing some internal activities and then parallelizing four main activities, a changeover time reduction of 48.42% can be seen. The following bar charts in figure 4.2 and 4.3 shows the comparison in changeover or setup time of the terminal lead welding machine before and after SMED implementation. Table 4.5 shows the result obtained after SMED implementation.

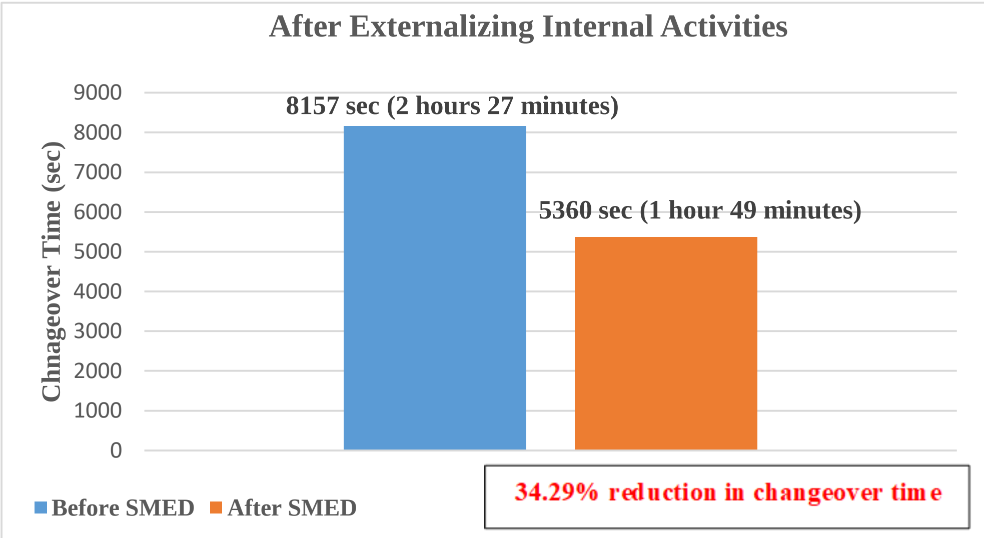
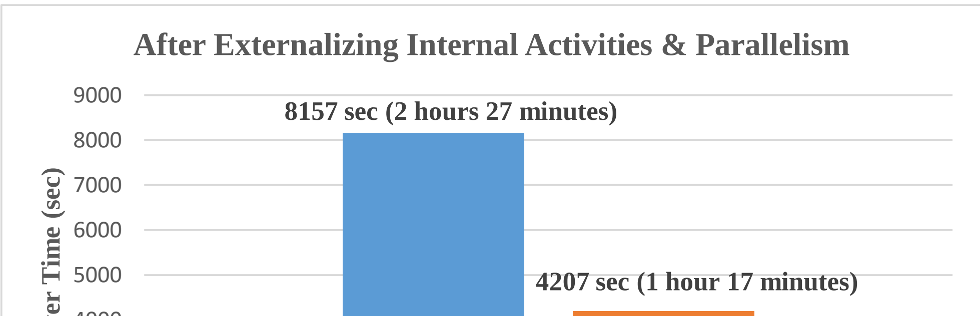


Figure 4: Comparison in changeover time before and after SMED implementation (after externalisation and parallelism of internal activities)



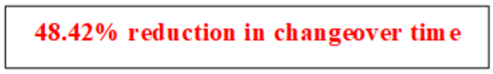


Figure 5: Comparison in changeover time before and after SMED implementation (after externalisation and parallelism of internal activities)

Table 3: Result obtained after SMED implementation

Objective	Time taken before SMED (min)	Time taken after SMED (min)	Time saved (min)	Percentage reduction (%)
To reduce the changeover or setup duration of the terminal lead welding machine to 45 – 50% from a current 2.3 hours of changeover time by integrating SMED techniques.	135.95	70.12	65.83	48.42

5. Conclusion

In this study, Single Minute Exchange of Die (SMED) methodology has been implemented successfully on the terminal lead welding machine at TDK Electronics (Malaysia) Sdn. Bhd. As a result of implementing SMED, the changeover time of the machine has been reduced from 135.95 minutes to 70.12 minutes in overall. 65.83 minutes have been saved, which is about 48.42% from the current changeover time by implementing SMED techniques.

However, more improvements can be done to further reduce the changeover time of the terminal lead welding machine. Firstly, two operators can work parallelly in each welding stations (station 6 and station 7) of the terminal lead welding machine where the same activities can be conducted simultaneously where time of setup activities can be reduced into half approximately since the activities are shared among two operators. Moreover, changeover time result could have been better if some investments are made by the company such as replacing the hex keys with more advanced tools like cordless drill with multi angle bending drill bit extension or ratchets for loosening and tightening process of hex screws in compact areas of the machine and using a pegboard to hang the tools in an organized manner where the time of locating or replacing tools is eliminated. Just changing the way, the processes are done could make things better. Setting up a standard checklist can help to cut down on setup time rapidly because the operators tend to repeat the activities as there was lacked organisation in distribution of parts, tool, and materials.

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