Equipment Efficiency
Availability, quality and SMED

It has become increasingly important to economically manufacture products in smaller and smaller product batches. On one hand, new management philosophies demand that product lead times (both development and then manufacturing times) are kept as small as possible. On the other hand, product customization has increased, thereby increasing the number of parts in a product family. As a result, batch sizes have been reduced and continue to shrink.

In this context companies should be as agile and flexible as possible. Part of the required agility is to reduce machine setup time times to minutes instead of days. Unless setup time can be significantly reduced, it will be difficult to economically produce small batches and reduce lead time.

The Single-Minute Exchange of Dies (SMED) methodology, as it is called, is a clear easy-to-apply methodology, that has produced good results in many cases very quickly, and amazing results in some other cases.

The SMED methodology was developed by Shigeo Shingo in Japan from 1950-80s. With this methodology, it is possible to achieve good results without costly investments, which makes implementation in many factories an easy decision to make.

Introduction

A setup process corresponds to the time required to go from the end of the last good part from one batch to when the first good part of the following batch is produced. Using this definition, the trials needed to obtain the first good product are considered part of the setup process and therefore, must be studied, analyzed and improved.

Single-Minute Exchange of Die methodology, as the name implies, is designed so that the setup process should be made in less than 10 minutes. During the 1960s in most automotive body shops, press changeover was consuming a large part of the available production time. It was not unusual for setup time for a large stamping press to take more than a full day. This was Shingo's first focus, and his hope was to bring the setup times down to a few minutes. In most cases, it is not possible to reach that objective, although it is possible to achieve reductions around 60% of the original setup time. In several cases, reductions of about 90% are obtained, but as a general rule, the project costs become significant to obtain these gains. Therefore, when trying to convince firms to apply this tool, it is recommended that you first go after the more reachable (less expensive) solutions.

It is also necessary to point out that it will not always be necessary to reduce the machine setup process, and even an 8 hour machine setup process can be acceptable under certain circumstances. For instance, when you are replacing the tires on your personal vehicle, what does it matter if it takes an hour to change all four tires? However, in car racing (Formula 1, or NASCAR) losing 15 seconds may have very catastrophic consequences for the driver's success.

The reduction of the setup process is contemplated in the Just in Time and in the 20 keys methodologies (key number 5).

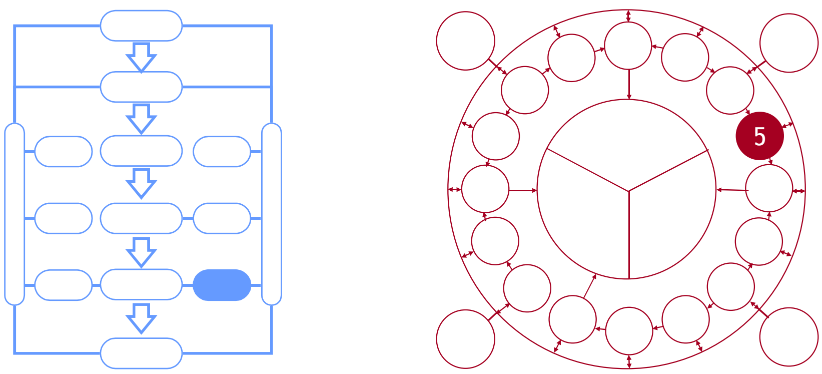

Figure 5.1. Location of setup process reduction in Just In Time and 20 keys diagrams

The SMED implementation improves the availability rate as well as the quality rate, because SMED reduces the setup process time where as we discussed, this setup time includes the trial phase for qualifying the first good piece to follow setup. Therefore, startup losses included in the quality rate are produced in this trial phase.

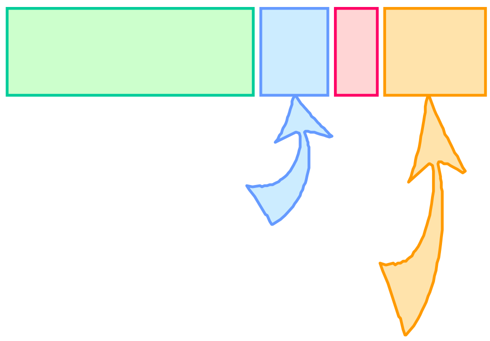

Figure 5.2. SMED improves the availability and quality rates

Theoretical Bases

Basic steps in a setup process

Before embarking on an in depth discussion of the SMED methodology, it is necessary to describe the stages that make up a general setup process.

Regardless the type of the machine or equipment that is going to be studied for setup evaluation and reduction, the following classification can be used to distinguish the four typical classes of setup operations:

- Prepare, adjust and check (new materials and tools.)
- Remove old tooling and install new tooling on the machine.
- Measure, set and calibrate (fixtures, tools and tooling).
- Produce initial parts (production trials) and adjust the machine.

These activities occur for any setup whether they are significant (from a time and labor view-point) or not, and the relative proportion of time required for each type of setup operation can vary significantly.

The prepare, adjust and check operation focuses on make sure that the tools and materials that will be used for setup are available when the setup is scheduled and that idle time will not occur while the new setup material is being accumulated.

The produce initial parts and adjust depends, in most cases, on the setup specialist's know-how; and therefore, can be difficult to predict with precision.

Traditional strategies to improve the setup process

For early manufacturing applications, the setup process duration was not particularly important. Manufactures could afford to have customers waiting for their products (e.g., the next model year car), and production was scheduled based on manufacturing needs, so that these setups hardly affected the product's price. For instance for early automotive production, it was not unusual for a production facility to shutdown for two weeks while machines and tools were setup for new model year production.

Today, manufacturing lot sizes have decreased. This reduction in manufacturing lot size does not mean that the customer demand has shrunk, but rather that individual needs and expectations have increased. This directly implies that manufacturing flexibility needs to increase. That is to say, if several years ago, a customer requested 50.000 of a specific part; today the same quantity of parts are requested but, in increased part variety and with smaller delivery quantities, which forces manufacturers to produce in smaller lots.

Unfortunately, the possible production of defective parts at setup coupled with the increased frequency of setup has forced manufacturers to make more products than required and in many cases store them for future orders, i.e., build to stock.

For example, let us suppose that an 500 parts order for 500 parts is made; the setup process takes 3 hours to get the press ready, and the defects rate is 6%. The machine will be scheduled to produce 530 parts to cover the possible defective parts. If the 530 parts were correct it would be necessary to store 30 parts, with the related inventory costs.

In order to reduce setup process affects, companies usually use two different strategies: 1) They try to make the setup as fast as possible, or 2) They increase the production lot size.

Skilled based strategies

Many companies have used setup specialists to reduce changeover and setup times. These special workers are skilled in the operation of specific machines, and they are familiar with the needed tools and methods to carry out the exchange. In some cases, a company's dependence on these specialists is so strong that the exchange has lasted more than 8 hours because the specialist did not work in the shift in which the exchange was needed.

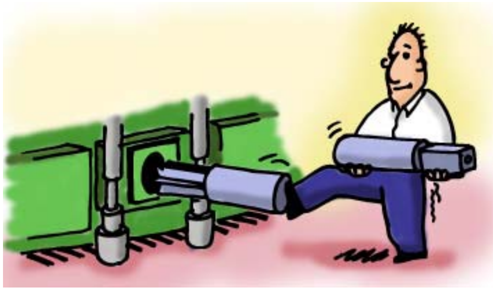

Figure 5.3. Skilled strategy tries to make the exchange faster

The amount of skill that a setup specialist needs for placing and removing machine elements as well as the setup process difficulty seems to make improvements in the exchange in some machines more difficult. However, not all the tasks that setup specialists carry out are critical, and the specialist can get help from the machine operator, making the setup process faster and easier.

Large batches based strategies

This strategy is based on the idea that, the larger the batch size is, the smaller the impact of the set up time will be on the production cost of each part. Cost per part is based on the company cost estimation system. The system shares all company costs (direct and indirect costs, raw material costs, etc) to each product.

Regardless the cost estimation system, there is a section in the cost per part that depends on the time to manufacture a single part and also on its respective set up time. This time can be named T_M.

$$T_M = \text{single part production time} + \frac{\text{set up time}}{\text{batch size}}$$

If the lot size is large, the setup time effect is spread out more than if the lot size is small. As a result, T_M decreases according to the batch size increase as it is shown in the table 5.1.

Batch size	Setup time	Production time	Product manufacturing time (including part of setup time)
50	240 min.	2 min.	2 + 240/50 = 6,8
500	240 min.	2 min.	2 + 240/500 = 2,48
5.000	240 min.	2 min.	2 + 240/5.000 = 2,048

Table 5.1. Effect of setup time in product time

T_M is proportional to the set up time. The higher the setup time, the bigger the profit will be as it is shown in the following table.

Batch size	Setup time	Production time	Product manufacturing time (including part of setup time)
50	360 min.	2 min.	2 + 360/50 = 9,2
500	360 min.	2 min.	2 + 360/500 = 2,72
5.000	360 min.	2 min.	2 + 360/5.000 = 2,072

Table 5.2. Effect of large setup time in product time

This reasoning supports the lot size increasing. Some companies only accept orders that exceed certain lot sizes to make production with setup profitable. In many cases, a company cannot choose not to supply a product, and it is necessary to manufacture smaller lots.

The previous case if setup time and production time were about the same magnitude, setup expense would not dominate the times as shown in the tables. In that case the saved time would be minimum (Table 5.3) and, therefore, it would not make sense to search for large lots size.

Batch size	Setup time	Production time	Product manufacturing time (including part of setup time)
50	10 min.	2 min.	2 + 10/50 = 2,2
500	10 min.	2 min.	2 + 10/500 = 2,02
5.000	10 min.	2 min.	2 + 10/5.000 = 2,002

Table 5.3. Effect of short setup time in product cost

Economic Lot Size strategy

From the previous discussion, one can infer that when setup times are large, then manufacture batch size should also be large. However, this policy ignores the increase in inventory cost and potential loss for products becoming obsolete.

The economic lot size is not more than a direct relationship between the inventory cost and the setup cost. This traditional formulation can be found in any book that contains inventory management techniques. In all these methods, the effect of the setup cost decreases exponentially according to the increase of the batch size. On the other hand, in order to calculate the economic lot size, it is supposed that the setup cost is constant, that is to say, the setup time is constant.

This traditional starting hypothesis is based on a constant setup time, that is, it is not possible to reduce the setup time. More often than not, set up time can be reduced (Fig. 5.4).

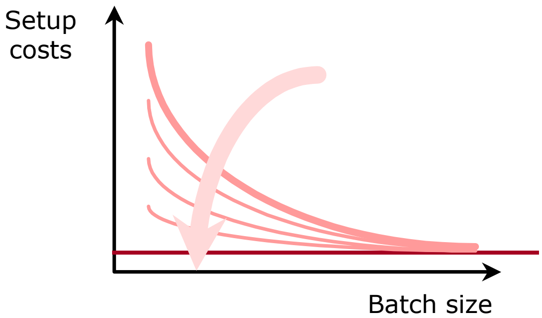

Figure 5.4. Decreasing of the lot size according to the setup cost reduction

As setup cost decreases, the economic lot size would also decrease until reaching the unit product lot size, that is to say, it would be profitable to only accept orders made up of one article – a batch size of one!

SMED methodology

In 1950 Shingo discovered, in Toyo Kogyo factory, that the exchange of an 800 tons press was delayed because of a missing screw. He understood then that it should have two types of operations in the process of change:

On one hand, those operations that should be carried out with the machine running producing parts from the previous lot. Shingo called these types of activities External Setup. Those activities that required the machine and for it to be idle while they were performed, Shingo denoted as Internal Setup.

In 1957 Shingo improved the SMED methodology when, while placing an extra table in a Mitsubishi Company machine, significantly reduced the setup time. Shingo discovered that it was possible to convert some of the internal setup tasks to external setup operations.

The SMED methodology consists of 4 conceptual stages, with the first corresponding to documenting the setup activities or the current exchange study as it is called.

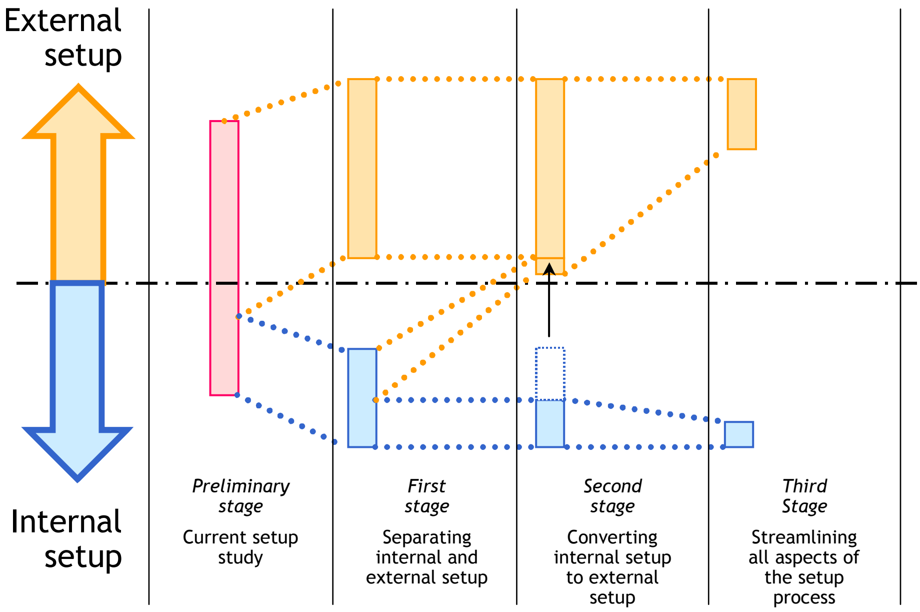

Figure 5.5. SMED methodology and its impact in the setup process

Thanks to the SMED application, Shingo reduced the setup time for a screw machine manufacturer from 8 hours to 58 seconds and, at the Mitsubishi Company from 24 hours to 2 minutes and 40 seconds for press working setup.

Preliminary stage

This first stage consists of studying the current setup process because simply put "what is unknown cannot be improved". It is necessary to know the process, the variability and the cause(s) that produce this variability.

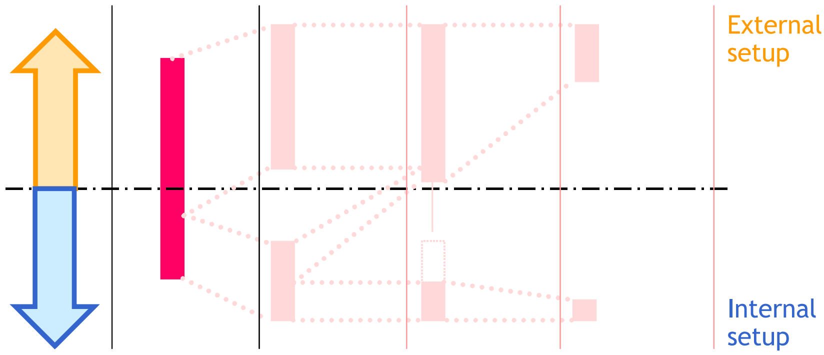

Figure 5.6. SMED preliminary stage

Therefore, in this stage, it is necessary to collect values for the setup times. In some companies setups are frequent/usual, and it is simple to carry out several measurements. In other companies, the setups can be sporadic/rare and therefore, it is necessary to get as much information as possible from limited data, with only one or two setup process studies.

Setup data acquisition consists of process modeling and then using the time study process as explained in Chapter 3 to measure each activity. In fact, a setup process is no more than a group of operations.

It is important when beginning the study to clarify, mainly to the setup specialists (if the company has this kind of workers) that the SMED's goal is not to eliminate their job. A specialist will always be necessary for certain tasks. Sometimes, setup specialist opposition can lead to project failure, so special care should be taken to make sure that these skilled technicians do not feel threatened.

Stage 1. Separating internal and external setup

The first stage consists of separating the operations that should be carried out when the machine is still processing the previous lot (external setup) and those where it is necessary to carry out setup with the machine stopped (internal setup).

The goal for this stage is to separate/classify setup operations according to the given definition of external and internal setup. This classification takes into account the same operations and duration included in the current method, that is to say, without improving any particular operation.

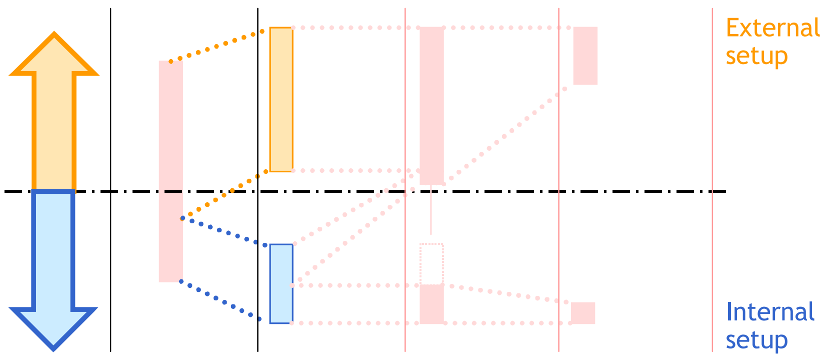

Figure 5.7. SMED first stage

Also, in this stage it is necessary to assure that the operations that are defined as external setup can all be carried out with the machine running. At first, this seems obvious, but it is always worth explaining to the worker that the necessary tools for the setup changeover and the new die should be prepared beforehand so that production time can be gained. In practice, it is not unusual for the external activities to begin until after a batch has been completed. The main reason for this is that time to get the necessary tools and materials is not allocated to the operator while he/she is overseeing production operations.

In this stage, the largest SMED cost gains are achieved. It is not unusual to reduce the exchange time by as much as 60%, in some cases, without any capital investments.

Stage 2. Converting internal setup to external setup

The setup process time reduction from the first stage can be very significant but is not where SMED ends. To reduce setup time as far as possible (or economical), it is necessary to study the possibility of converting some internal setup operations into external setup, so that they could be carried out while the machine is running.

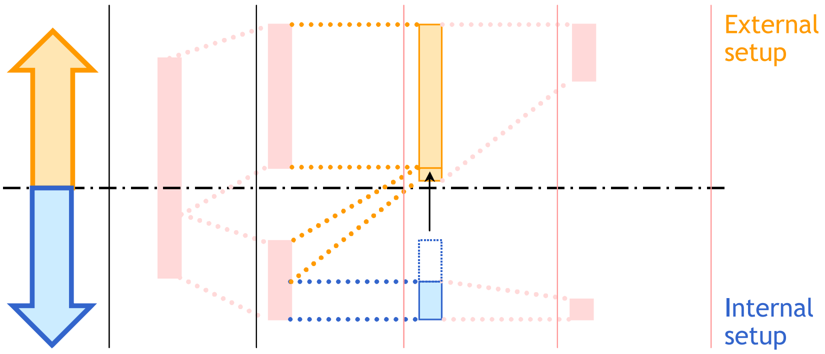

Figure 5.8. SMED second stage

This stage examines two important aspects:

- Re-evaluate the internal setup operations to check or see if some of them were considered erroneously as internal.
- Look for alternatives that allow internal setup to be carried-out in whole or in part as external operations, with the machine working. For example, is it possible to screw a die to a press before placing it inside the press chamber? The answer is yes.

Logically, most of the ideas that arise in Stage 2 will require an economic investment, and it will be necessary to carry out a cost justification to determine the best strategy.

It is necessary to distinguish the case in where the investment is necessary in spite of the economics. That is to say, in the case where a company could lose an important customer if delivery time can not be reduced.

In order to decide on an alternative's viability, it is not only necessary to analyze the economics, but one should also study the new process or system reliability; the possible appearance of new operations (both internal and external) that increase the setup time; and of course, the benefits and possible risks of the new process.

The development of this stage can achieve, in some cases, setup process time nearing single minutes (< 10 minutes).

Stage 3. Streamlining all aspects of the setup process

This stage tries to improve all the setup operations, both internal and external, reducing their duration or even, if it is possible, trying to eliminate some operations.

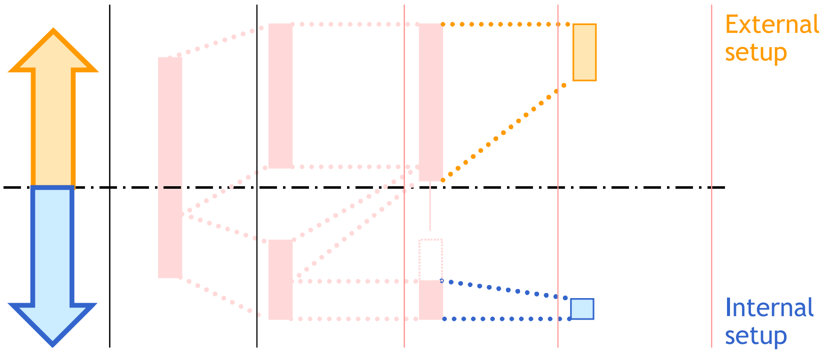

Figure 5.9. SMED third stage

Although the SMED methodology recommends that one follows systematically these four stages, common sense can sometime dictate that, in the second stage, time and money will not be invested in operations that previously have not been optimized.

For this reason, the application of the third stage usually run parallel to the second one, leaving a final "stage 3" for the improvement of the external setup operations and a revisit of the internal activities that have not been possible to convert into external.

SMED tools

First stage tools

It seems logical that one should know what operations should be conducted while the machine is still processing the previous lot. Unfortunately, numerous time wastes take place in many setup processes. For instance:

- Materials are moved to the warehouse with the machine stopped.
- Tools and dies are supplied late, or incorrectly.
- Tools and dies that are not needed, are taken back to the supply room before starting the machine.
- Some needed screws and tools were not collected during the setup process.
- Some nuts are just too tight when trying to remove them.

It is necessary to eliminate all these wastes trying to answer certain questions before starting the setup. Some good questions to ask include:

- What has to be done before starting the change?
- How many screws are necessary in order to fix the die? Of what type?
- What tools are necessary? Are they prepared for proper conditions?
- Where should the tools be placed after using them?

In order to facilitate this checking process, a group of visual controls have been developed to assure that the needed operations are carried out before starting the setup.

Figure 5.10. The visual control is the most important stage 1 tool

Checklist

This tool consists on a questionnaire that should be checked before each setup process. The goal of the checklist is to verify in advance that all elements that should be prepared before the machine finishes the current lot are in fact ready and available.

The checklist can be universal for all products changeover or specific for each product. In the first case it will be placed near the machine, while in the second case it will be enclosed with the manufacturing order.

Check panel

If the number of tools is small, or if the machine has exclusive tools, a check panel can be placed next to the machine.

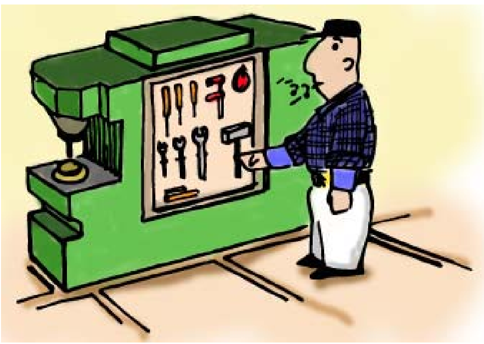

Figure 5.11. An example of a check panel

Utilizing this tool has many advantages. For example, the worker can visually check if all the necessary tools are located in the right place or if a needed tool is missing. In some check panels, the tools are silhouetted, so if a tool is missing, it can be very obvious for the worker. Another strategy is to code the tools with two stickers. A sticker is placed in the machine and another is placed on the tool in order to pair the tool with the machine.

Function checks

The checklist or the check panel do not show the die and tools status. Some plastic injection molds can have material inlays that should be cleaned. If they are discovered in the trial step, cleaning of the mold can be carried out before the machine is stopped.

There are special devices for checking the molds before placing them in the machine. However, if the company does not own one it might be necessary to invest in a mold checking devise. This possibility should be investigated and analyzed in the second SMED stage.

In other cases, it is better to inspect the mold after many pieces have been manufactured, even though the machine will be idled. Some defects will not be detected until the mold reaches the steady state operating temperature. To examine this problem, it might be necessary to cool the mold again while inspecting product, with the corresponding time waste.

Parts and tools transportation improvements

Parts and tools transportation from the warehouse to the work area should be carried out before the exchange begins. In a “traditional press exchange process”, the worker removes the used mold, loads it in a crane, takes it to the warehouse, and loads the new mold to place it in the machine. If the mold is heavy, the transportation movements will be slow, time will be wasted while the machine seats idle.

In order to implement this stage of the SMED methodology, it may require doubling the labor required to tend the machine, but the machine stop time decreases.

For the “new change-over process”, the worker would go to the warehouse while the machine is working, would load the new mold and would leave it ready to install next to the machine. The worker would then wait until the machine finishes its work. Once the machine finished, the worker would take out the mold and would leave it next to the machine. After, the worker loads up the new mold, it would set the machine into operation. Finally, the worker would carry the used mold to take it to the warehouse.

This “new change-over” looks like it takes longer than the traditional method. However, according to Shingo’s definition of setup time, the time with the machine stopped is drastically reduced. As a result, the setup time is reduced.

Second stage tools

It has been commented previously that the second stage usually runs parallel with the third stage when an operation is optimized before converting it.

However, the SMED methodology offers some recommendations that facilitate complex cases studies. For example, in this second stage the movements around the machine should not be questioned and they must be considered as internal setup. These movements will be analyzed in the third stage. It is not that, in the second stage, some operations will be eliminated. However, if it is evident, they will be eliminated.

There are several methods broadly intended to enhance the setup process. Some of these methods, policies and tools are briefly explained next section.

Endless material method

In some processes, reels are used to collect and store product. When a reel is empty, it should be removed and replaced with a full one. For example, in a rolling mill or on packing machines.

The change-over time of reels potentially be eliminated if the end of a reel is welded or tied to the beginning of the following one. The machine would work continuously. As a result, setup time would be zero.

In this case, the product made with the welding seem would be scrape. This however is easily offset by gains made from setup reduction, and in many cases, the last part of the previous reel is also discarded.

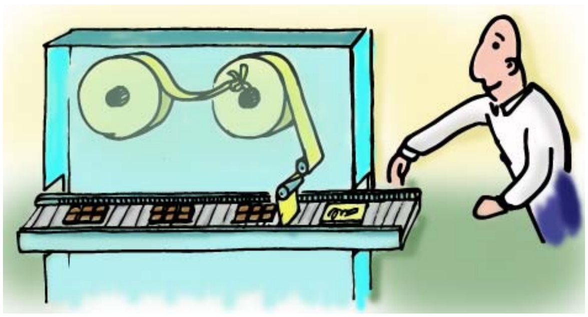

Figure 5.12. Example of a endless material method

In some packing lines, the previous process cannot be stopped during the reel change, and some products are scraped, which increments productions costs and reduces the quality rates.

Temporary containers

Unfortunately, it is not always possible to weld or tie the reels to carry out the change-over operation. In this case, there is no other alternative but to stop the machine. Temporary containers (see Figure 5.13) do not convert the whole reel change operation to external setup but, they can reduce an important part of it:

- These temporary containers save setup time considerably because they eliminate the movements to locate and bring in the new reel.
- If the reels allow it, it might be possible to tie/weld the previous reel with the following reel and with a simple turn, carry out the exchange. This operation increases time savings.

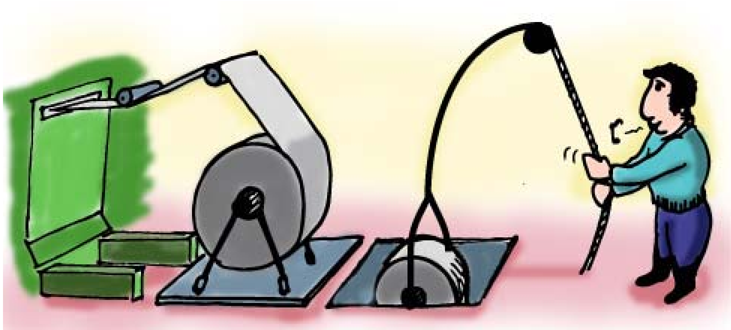

Figure 5.13. Example of a temporary container

Press die preheat

In most of the plastic injection molding processes, the mold has to reach an specific temperature to begin the manufacturing process. There are devices that heat the molds up before being placed in the machine.

The main concern in this case is labor safety. Manipulating hot molds represent a very dangerous task to perform. Nevertheless, it is possible to preheat until a moderate temperature, reducing the time needed to reach the working temperature once the mold is placed into the machine and making the process safer for the worker.

Function standardization

A good way to convert certain mold measures such as the height and depth adjustments of some presses and injection molding machines into external operations is to standardize these measures. For example, the injector distance for an injection molding processes.

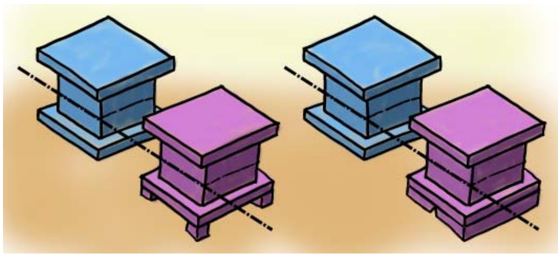

Figure 5.14. Standardization and improvement of molds

Only the most important components for the exchange will be standardized, taking into account two main conditions:

- The setup process should be as safe as before.

- The quality of the manufactured pieces should not be adversely affected.

Sometimes, when standardizing a particular measure, it will be necessary to develop a new device. It can be the right time to add new functionalities or features to the mold. For example, a centered guide hole.

In many cases, it will not be possible to standardize all the machine tooling, due to the large number of different tools used. Nevertheless, developing constraints and restrictions to use for the specification of future tooling, coupled with the standardization of most existing tooling can be very beneficial.

Tools duplication

Sometimes it is possible to have two or more identical elements (cranes, tools, pallets,...) to reduce the setup time. A single six pack is as easy to handle as a single can of soda. This way, if the company has, for example, a double crane it is possible to prepare the next two molds and to extract the previous one without the need of removing and placing the molds again. A good example is shown in the Figure 5.15.

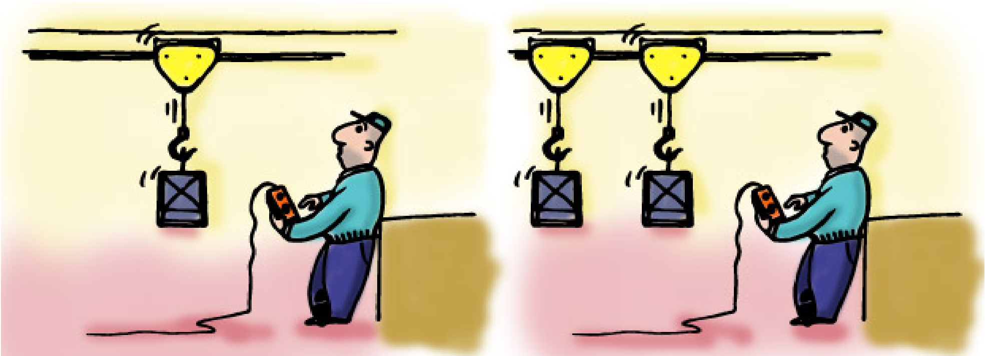

Figure 5.15. Crane duplication

The same scenario could be seen if a machining center had a tool changer, where the needed tools could be ready and available at all times.

Third stage tools

The improvement or elimination of an operation requires reengineering some aspect of the product or process. Reengineering can help to analyze and consider several important factors such as: it is possible to make the operation in a different way? Is this operation necessary? Is this procedure the most appropriate?

Up to this stage, external operations have not been analyzed. They had simply been distinguished and some internal operations have been converted to external. However, at this point some questions are presented: Will the setup specialist have enough time to organize the material and tooling and also carry out all the external operations?

Although it is not considered a time critical part of the setup (according to the definition that was given at the beginning of the topic), performing external operations efficiently is always important since a setup specialist is considered a valuable resource.

It is necessary to study the setup specialists workload and to schedule the change-overs so that the specialists are not needed at the same time in two machines; otherwise, the work carried out in the setup time improvement will be pointless.

Internal operations can be improved in different ways. In this stage, it is very important to analyze in detail the movements around the machine and to determine the optimal number of workers that should take part in the setup process.

Different techniques can be used to improve and to eliminate operations. Some of these techniques are presented as examples.

Streamlining external setup

Improving tool storage. Indicators' strategy

This strategy is explained in a subsequent chapter dedicated to the 5S's.

However, it is not necessary to undertake the complexity of a 5S methodology. The strategy here is to organize in an efficient way the warehouse, keeping high use items close for easy access, and organizing the tooling so that it is easily located and identified, perhaps using a code. The 5S methodology offers a common orientation when choosing the coding standards, so that the different sections of the company can use the same nomenclature.

Figure 5.16. Sign strategy allows ease of use for tool storage.

Streamlining internal setup

Parallel operations

In large size machines, it is necessary to carry out operations at the front of the machine as well as at the back of it. The worker can waste important setup time when walking around the machine.

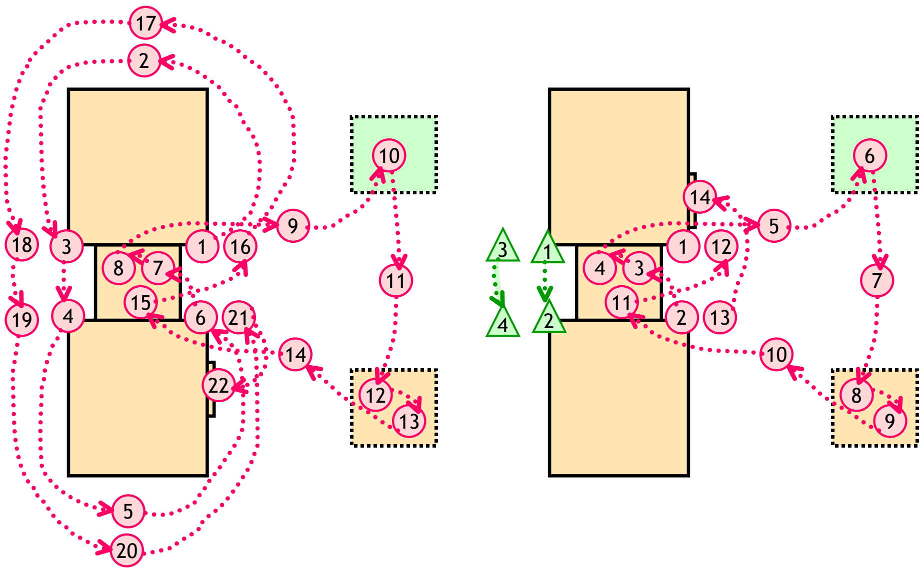

Figure 5.17. Comparison between one or two workers in a setup process

As shown in Figure 5.17, the setup time and complexity can be reduced with the help of a second worker. If a worker needs 2 hours to carry out the exchange, two workers could take less than 1 hour, when movements around the machine are eliminated (although it is also possible that they use more time based on the task sharing and the operations sequence).

It is convenient to utilize a task map to indicate what operations will be carried out by each worker, starting with the initial situation shown in next Table 5.4.

Worker procedure	
1	Remove front bolts
2	Movement to machine back side
3	Remove back bolts
4	Remove back wiring
5	Movement to machine front side
6	Remove front wiring
7	Put used die up
8	Lift used die
9	Move used die next to machine
10	Remove used die
11	Move crane to new die
12	Put new die up
13	Lift new die
14	Move new die to machine
15	Get new die down
16	Fix front Bolts
17	Movement to machine back side
18	Fix back bolts
19	Fix back wiring
20	Movement to machine front side
21	Fix front wiring
22	Fix new machine parameters

Table 5.4. Initial situation

When two workers execute the exchange in a parallel way, the exchange procedure is presented in a table (Table 5.5). It shows the task sharing and those tasks that can be carried out simultaneously as well as the times where the workers should be waiting.

First worker procedure		Second worker procedure	
1	Remove front bolts	1	Remove back bolts
2	Remove front wiring	2	Remove back wiring
3	Put used die up		
4	Lift used die		
5	Move used die next to machine		
6	Remove used die		
7	Move crane to new die		
8	Put new die up		
9	Lift new die		
10	Move new die to machine		
11	Get new die down		
12	Fix front Bolts	3	Fix back bolts
13	Fix front wiring	4	Fix back wiring
14	Fix new machine parameters		

Table 5.5. Task sharing and simultaneous operations

This representation allows the Lean thinker to discover which are the most important tasks that should be improved, or which are the tasks that the other worker can carry out in order to make the worker's job easier.

First worker procedure		Second worker procedure	
1	Remove front bolts	1	Remove back bolts
2	Remove front wiring	2	Remove back wiring
3	Put used die up	3	Movement to machine front side
4	Lift used die	4	Fix new machine parameters
5	Move used die next to machine	5	Movement to machine back side
6	Remove used die		
7	Move crane to new die		
8	Put new die up		
9	Lift new die		
10	Move new die to machine		
11	Get new die down		
12	Fix front Bolts	3	Fix back bolts
13	Fix front wiring	4	Fix back wiring

Table 5.6. Improve in the task sharing

Labor safety once again, is a priority in this type of synchronized work. There are special devices that decrease the probability of an accidents(labor risk,) such as safety mats that stop the machine when they are activated. Safety-mechanisms that halt the machine until some signal can be provided, confirmation buttons, etc., can save accidents and injury.

One-Motion Method

Some setup processes allow machines or people to perform more than one task simultaneously. For example, performing electric and hydraulic connections on a refrigeration circuit while the mold is being slowly fit into position.

In the case where these connections cannot be carried out simultaneously, similar connections can be grouped onto a device that allows an operator to connect all the connections even faster.

Functional clamps

Functional clamps are devices that are used to passively hold an object in a fixed position with the minimum effort. Setup tasks such as screwing in and out nuts or tying and untying a component can be eliminated.

The SMED methodology seeks to eliminate the use of screws and nuts as fixing elements. Shingo found that of the entire screw body (thread), the only thread that carries the press function is the last one. Therefore, all the screws should only have one thread. In that case the screw would be considered as a functional clamp.

From a technical point of view, a one thread screw bolt is not viable, but in many cases, the number of screw threads can be decreased.

There are a large number of functional clamps that, although many of them are used with screws, facilitate putting in, fixing and the removing dies.

- *Pear-shaped holes*: In many tops or surfaces with a great number of screws is not necessary to unscrew all the bolts until the end. Using a pear-shaped holes (See Figure 5.18), it is enough to unscrew them only until the top can be turned.
- *U-shaped washers/candle rings:* Similar to the previous clamp but they are used in a large number of cases, since they are useful in any joint between a screw and a nut.
- *C-shaped washers:* These washers are used in difficult access situations when the worker has the risk of loosing the U-shaped washer into the machine.
- *Guttered thread:* Is an approach to the ideal screw with only one thread, the guttered threads allows to fix the elements with just 1/3 of a turn.
- *Single- movement method:* Axels that do not turn in high speeds can be held with simple elements that can be let free by turning a lever.
- *Reduce the tools variety:* In order to unify the screws so that the same tool can be used at all times, or having simple earflaps bolts.

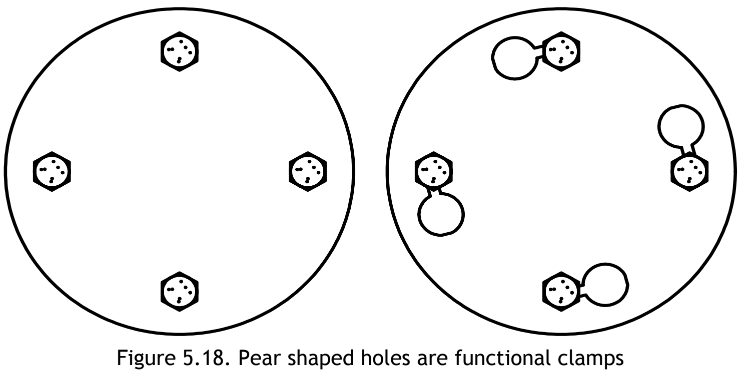

Figure 5.18. Pear shaped holes are functional clamps

Eliminating testing procedures (trials) and adjustments

Adjustments and trials with many changes, can easily represent 50% of the total change-over time, i.e., until obtaining the first good piece.

Trials and adjustments should be viewed carefully, so that they are not only decreased but eliminated. Whenever possible a set-point should be used instead of an adjustment.

Figure 5.19. The trial and adjustments should be eliminated

In many companies, the setting and positions from the previous batch can be used without applying the trial and error method.

If adjustments are necessary, the adjusting procedures must be written and the machine parameters value should be perfectly specified. This way, in the case of having to perform trials and adjustments, they will only be the extremely necessary ones.

A new technique has been developed that in some cases the adjustments are eliminated. It is called OTED (One Touch Exchange of Die).

Process Automation

A total (fully) automation of a process is the last resource after the successful implementation of the previous methods. It will only be effective if and only if the operation on which process automation will be applied is already optimal.

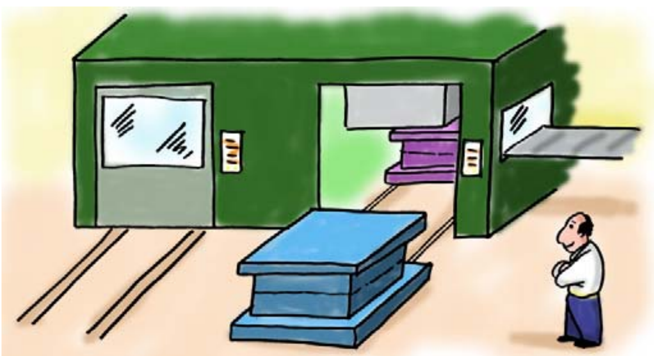

Figure 5.20. Mechanization is the last method to apply

Generally, Process automation supposes high investments costs. Regardless of its expensive implementation, in some cases it is the best alternative.

Zero changeover

With the SMED implementation, amazing time reductions can be achieved however, the small improvements that can be achieved with SMED are much more significant.

When Shingo died in 1990, Sekine and Arai continued his work, trying to go further than Shingo did in terms of times reduction. They tried to achieve setup times of less than a minute (seconds), instead of minutes as it used to be. In order to achieve this goal, they create a strategy called Zero Changeover.

Unfortunately, the only way to achieve setup times near to seconds was to automate the exchange process, which represents large investments. Many of the achieved improvements, came from ideas developed by Shingo.

SMED effects and benefits

SMED provides several benefits. In the end, all these time reductions are translated into money savings, although there other aspects, such as safety improvements that are difficult to quantify economically.

Easier setup process

The reduction in the number and complexity of operations that the SMED methodology provides leads to the implementation of a new change-over procedures. As a result, the setup process is simplified and easier to carry out.

Thanks to the SMED, many of the operations can be carried out by the majority of the employees (fewer skills required). Therefore, the setup specialist and the worker collaborate in the setup process.

Increased safety also results from the improved change-over simplicity. To reduce the setup time, all operations have to be analyzed in detail which at the same time avoid/eliminate risky situations.

The new setup procedure can eliminate defective parts in the manufacturing process, making sure that, when all the setup steps are performed, the machine is able to produce correct products from the first part.

On-hand stock production

On one hand, if the setup time decreases, the manufacturing batch size can be decreased as well. Therefore, it will not be necessary to make large manufacturing orders and as a consequence, work in process (WIP) will decrease.

If the work in process decreases, the mean time of material flow will decrease, as well as the supply time, because it is directly related with the time of material flow.

Workplace tasks simplification

Tool coding, a clean and upstanding machine environment among many others, are strategies that help to simplified the workplace.

After the SMED implementation, it has to be easier to locate tools, dies and parts in a short period of time.

Productivity and flexibility

The presented benefits are important, but the main benefits of the SMED application are centered in two key concepts: the increase in productivity and in flexibility.

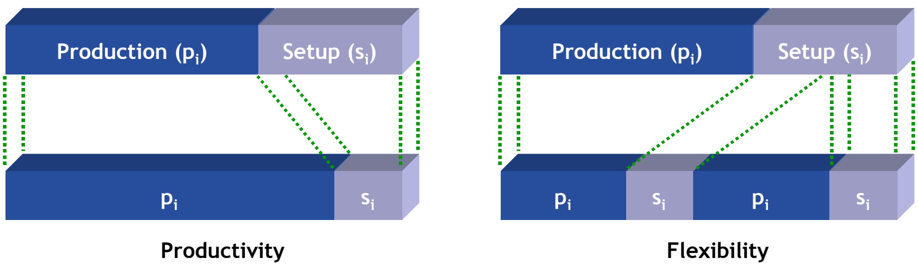

Figure 5.21. The main SMED benefits are productivity and flexibility increment.

Sometimes the SMED methodology is applied to decrease the machine's load in order to increase the productive period. Although the productivity increases, thanks to the SMED methodology, SMED's principal benefit is to increase flexibility as it will be show next.

If a company needs to improve a machine flexibility and needs to decide between buying a new machine, or spending the same amount of money in improving the setup time, by means of a SMED implementation, the decision is clear, as it is illustrated in the following example (Figure 5.21).

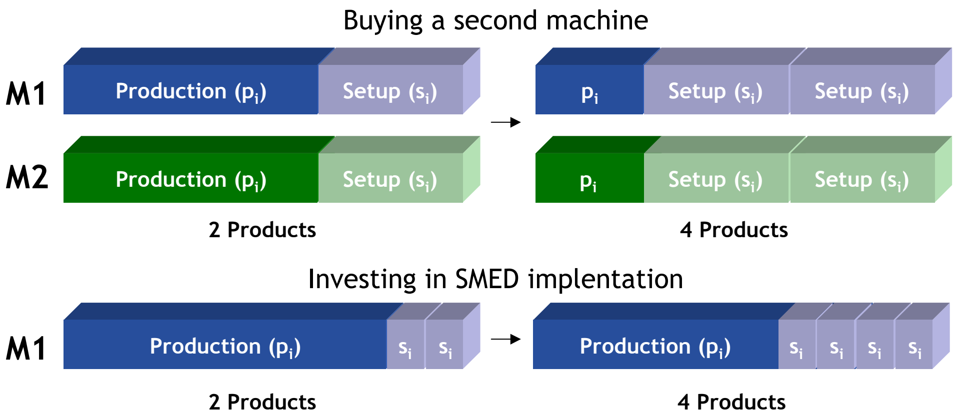

Figure 5.22. A second machine does not improve flexibility if the number of exchanges increases

It can be concluded that ,if the company only looks for a productivity increase then, SMED is an alternative among other methods, for example buying another machine or eliminating idle times. However, if the company is looking for an increase in flexibility, SMED is the only solution, since buying a new machine does not provide an increase on the flexibility. (Figure 5.21).

A flexibility increase is very difficult to measure economically and it is necessary to relate it with the stock level (decrease of the stock) or with other quantifiable benefits. For example, customers' satisfaction that receives in a shorter term their product orders. Nevertheless, the economic justification of a SMED study that looks for a flexibility improvement is always complicated.

Economic benefits

The economic benefits derived from SMED implementation are not always the same and depend on the machine situation in which the SMED is applied.

- In some cases, the machine on which the methodology is applied is saturated. If the objective of the SMED is to liberate the machine from its load time to increase the machine availability, the benefit takes place due to the economic margin in the sales increment.

- If the machine is not saturated, and the number of change-overs is not important, the necessary time to carry out a production order will decrease. If the machine workers can be assigned to other sections, the economic benefit derives from the saved cost in the workforce.

These two examples demonstrate that, in each case, the economics of SMED can vary.

Finally, carrying out an economic study if the goal is to increase flexibility can be impossible. In this case, it is impossible to present economic benefits derived from SMED.

Recommended Readings

Shigeo Shingo, *A Revolution in Manufacturing: The SMED System*.
Portland: Productivity Press Inc, 1985.

Kenichi Sekine and Keisuke Arai, *Kaizen for Quick Changeover: Going Beyond Smed*.
Portland: Productivity Press Inc, 1992.