

Improving SMED in the Automotive Industry: A case study

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Abstract

The Single Minute Exchange of Die (SMED) is one important lean tool to reduce waste and improve flexibility in manufacturing processes allowing lot size reduction and manufacturing flow improvements. SMED reduces the non-productive time by streamlining and standardizing the operations for exchange tools, using simple techniques and easy applications. However the process doesn't give the specific actions to implement which can result in overlooking improvements. To overcome this, common statistical and industrial engineering tools can be integrated in the SMED approach to improve SMED implementation results. The applicability of the proposed SMED approach was tested for injection machines changeovers in the automotive industry. The implementation has enabled reduction in setup time, through company's internal resources reorganizations without the need for significant investment.

Keywords

Lean manufacturing systems, Lean tools, Single Minute Exchange of Die, Quick ChangeOver

1. Introduction

Globalization has created the need to produce small lots, causing a significant increase in the frequency of setups, causing the reduction of times production for each lot. For this reason it's important that changeovers are quick, so that the flexibility of respond to demand is not affected (Mcintosh et al, 2007). Time spent in the setups is considered waste, because they are tasks that do not add value, causing increases in costs associated with the product and time spent that could be used in activities that add value. The need of shorter setups isn't new; the time spent between in the production of the last product of a series and producing the first product of the new series, has always been considered as waste or added cost (Goubergen and Landeghem, 2002). These authors categorize the different reasons for short setup times into three main groups:

- Flexibility: Because of the large number of existing products and the decrease in quantity, the companies must be able to react quickly to customer needs. So if you need to produce in small batches, it is essential that these tools make the exchange as soon as possible.
- Bottleneck capacities: especially in these machines, every minute lost is wasted. The tools of trade must be minimized, providing an increase in capacity for production.
- Cost minimization: the production costs are directly related to the performance of equipment.

Several authors have been proposed different approaches to reduce the time spent in the exchange of tools: Mondem (1983) proposed a model that supports the mechanization as a major strategy for reducing the time of setup. Fogliatto, Fagundes (2003) study several proposed approaches indicating that although some little differences exists all methods proposed (see

table 1) are based on the Single Minute Exchange Dies approach (best known as SMED) and the method of reduction of the setup that is the more spread around the world is still SMED based.

Table 1: Differences between the SMED and other approaches for setup reduction.

Differences relatively to SMED	Author	Date
The conversion of internal operations in external operations is discussed together with the standardization of operations. The elimination of adjustments must be made since the beginning of the project. The elimination of setup can be achieved through mechanization and production of several products simultaneously.	Modem	1983
Considers that the support of the company's management is crucial to the success of a proposed reduction of the setup. Study of fixation systems and reduction of movements.	Hay	1992
Their proposal is principally the study of time and movement. Proposes an analysis of economic viability for the elimination of setup.	Black	1998

The SMED methodology resulted from Mr. Shigeo Shingo's need to improve the productivity of presses in the fifties of the last century. Shingo defends that SMED system is a method that includes a set of techniques that makes it possible to have a setup in less than 10 minutes, that is, the number of minutes expressed by only one digit (Shingo, 1989). This methodology emphasizes shop floor issues, with no use of information technology (Mcintosh et al, 2000).

Shingo applied the SMED in different companies, and he identified the existence of two kinds of activities associated of setup, making them the basis of SMED: Internal setup, only be done when the machine is shut down, and the External setup, can be done while the machine is still running. These two concepts are extremely important in the implementation of SMED. Shingo developed some techniques that are applied during the different stages of SMED (Shingo, 1989):

- **Stage 0 (Internal and External setup):** In this stage we can't distinguish between internal setup and external setup. This stage consists in the observation of the ongoing process of setup and should include the participation of operators responsible for doing that task to help in the analysis of the current process. To obtain the time corresponding to the various operations, Shingo suggests using the stopwatch, interviews with players or make the filming of operations that are part of an exchange of tools.
- **Step 1 (Separating internal and external setup):** This stage is the identification and separation of the internal setups of the external setups. Shingo defends that this step is extremely important in implementing SMED, since the times of setup can be reduced by 30% to 50% of total time of setup (Shingo, 1989). To assist in achieving this step Shingo implemented three practices that help in the separation of the external setup:
 - Checklists: this list can contain all that is necessary to know about setup, such as tools, temperature, pressure and workers needed.
 - Function Checks: helps determine if the tools are available and if they are in good condition. This list must be completed before the setup, which is made for repair in case of any tool is not working properly, or to have them replaced.

- Transport of the moulds, tools and components in advance: to reduce the time that the machine is stopped is crucial the transport of the moulds, tools, components and accessories needed for the setup before its start.
- **Step 2 (Converting the internal setup to external setup):** in this step internal setups possible are converted in external setup, because all setups classified as external will be carried out with the machine still running. Shingo argues that the implementation of this step leads to an improvement of about 10% to 30% of the total time of internal setup from the previous stage and suggests some techniques that help in this conversion, namely:
 - Preparing operating conditions in advance, there are transactions that can be prepared in advance, allowing a reduction in the time of exchange of tools, for example: preheating machine parts or material to outside of machine.
 - Standardizing essential functions: some functions can be standardized, such as the size of tools and accessories, grouping the screws as the key to use in order to facilitate the identification of the key to use.

Is important to note that according to some authors the conversion of internal operations in external operations, for herself doesn't reduce the contents of the work and the total of operations to be executed, and that improvements can only be obtained through the modification of equipment and disposal of settings, techniques belonging to the third conceptual stage (McIntosh et al, 2000).

- **Step 3 (Streamlining all aspects of the setup operation):** This is the last phase of improvement or elimination of internal setup and/or external. The techniques presented below help are used to achieve this improvement:

- Improvement external setups: external setup improvements include streamlining the storage, transport of components, tools and accessories, etc. These improvements do not act directly on the reduction of
- The setup time, but help the operator to execute their tasks in a better way, avoiding unnecessary physical damage.
- Improvement internal setups: the improvements made in these operations produce significant reductions in the duration of the changeover. These improvements may be: execution of parallel operations, elimination of functional adjustments and fasteners.

Some authors argue that proposals for significant improvement may occur in the third stage, becoming a key factor in reducing the time to setup, because in some cases, techniques of stage three, especially as regards the improvement of equipment and devices should be held before the same steps 1 and 2. This is because the work can become useless in the case of tools and /or the devices are not adequate (Sherali et al, 2006).

According to other authors the stages of SMED are described sequentially in accordance with the degree of improvement that this step will decrease the time for exchange of tools (McIntosh et al, 2007). There are however authors who argue that the stages 1 and 2 are the most important, and there are some companies that choose only the application of two stages, not realizing the third (Sugai et al, 2007). But according to Shingo, SMED methodology is divided into three conceptual stages to better understand the methodology. Although looking the first two stages, the separation of the internal and external operations (stage 1), is a direct consequence of the identification of internal and external operations (stage 2), (Sherali et al, 2006).

2. The Proposed Approach

The proposed approach developed is based on SMED, but integrates some differences comparatively with the originally developed by Shingo SMED and other known approaches, discussed earlier.

The proposed approach is to integrate the SMED methodology with other classical tools, such as Chart Analysis, which is classic tool of Industrial Engineering and also Statistical Analysis to check relevancy of detected differences, if any. The introduction of these tools in the SMED system were intended to allow obtaining a clearer picture about the whole process of changeover, and to improve the identification actions to be implemented in order to obtained better focused action and results through the implementation of proposals improvement actions.

The chart analysis is essential to characterizing the process of changeover, because it allows classifying all activities that are necessary for carrying out this process, identifying them in the following classical industrial engineering categories: operation, transportation, inspection, storage and waiting. This classification helps in the process analyzes and in the identification of operations in which action should be done, because they are slow operations, operations that can be performed simultaneously, or unnecessary operations, which can may be eliminated. Therefore chart analysis can be an extremely useful tool in the analysis of processes of changeovers, mainly if the process involves a large number of operations, and has very different types operations.

The statistical analysis can be used to check the existence of distinct groups of changeovers, which if considered together can be an imprudent decision because if the time pattern of the groups will be different is expectable to have also different suggested proposals for

improvement, or in how they are implemented, due to the impact that each proposal may provide for in each group.

3. The Proposed Approach Implementation

The implementation of the proposed approach was undertaken in a supplier of components for the automotive industry. The case study was based on the need to obtain time reduction of changeovers in horizontal machines of plastic injection, through the implementation of the modified SMED approach. The SMED based approach used during the study was implemented as next presented.

Initially was observed of a significant number of changeovers occurred in horizontal machines in order to make the collection of time spent on tasks performed during this activity, allowing to obtain a deeper knowledge about the procedure used in changeovers.

Due to the absence of the possibility of recording the changeovers observed, it was only possible to know the current process of changeovers made in horizontal machines by observing and recording each of the operations carried out during the exchange of templates, making the measurement of time spent in each of the operations. The initial observation found that the achievement of a changeover is an extremely complex, since it involves many operations which can be grouped into four classical stages as shown in Figure 1.

The first step is the process of stopping the machine. Each time it is necessary to make a changeover the machine must be stopped. After the machine is stopped, proceed with the dismantling of the old order which is inside the machine (so you just have a lot of production). After the removal of the old order has to be set up so new, that is, it is the assembly of the die mould will start its production after the completion of the exchange of moulds.

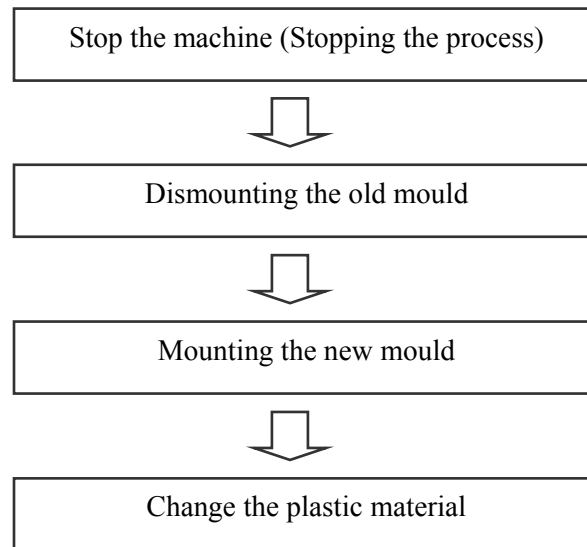


Figure 1: Stages of the changeover.

Finally, it is necessary to make the exchange of material. This is only made for the product that has just been produced (old mould) and the product will start its production (new mould) doing not use the same raw material, which is quite common. Figure 2 shows the chart of analyse of all operations of the changeover to horizontal machines.

Initially the study was based on changeovers performed in all horizontal machines group together but the detailed analysis of changeovers made in each of the machines and confronting operations that they were perform during the activity patterns of exchange using the chart analysis presented soon identified that there were some differences between the horizontal machines changeovers, making the time spent in trade patterns of these machines quite different and introducing the need to considered two groups of different changeovers (see Table 2).

Chart analysis

Sheet n.* _____
 Place of work: Area of Plastics _____
 Designation of work: Changeover _____
 Station: _____
 Subject Studied: Time spend in changeover _____
 Name: _____

	Second		
	Present	Proposed	Desv
○	3438		
◻	863,5		
◻	0		
◻	646		
◻	1231		
Distance	766,5		
Time	6179		

Operation n.°	Operations	Operation	Transport	Inspection	Waiting	Storage	Distance (m)	Time (sec)	Porquês				Observation	Remove	Conclude	Redistribute	Simplify
									What?	Who?	When?	Where?					
1	Place the controller in the water cooling	●	◻	◻	◻	◻		5									
2	Reports to the control panel of the machine	○	◻	◻	◻	◻	7	7									
3	Place in Semi-automatic machine (end of cycle)	●	◻	◻	◻	◻		10									
4	Raise flag and start record C/O	●	◻	◻	◻	◻		4									
5	Time of cooling water	○	◻	◻	◻	◻		417									
6	Place machine in manual mode / Close Molde / Reverse cylinder	●	◻	◻	◻	◻		91									
7	Get the material to do the purge	○	◻	◻	◻	◻	37	37									
8	Purge the cylinder	●	◻	◻	◻	◻		156									
9	It is addressed to the controller of the water	○	◻	◻	◻	◻	7	7									
10	Disconnecting the controller of the water	●	◻	◻	◻	◻		2									
11	Moves to the control panel of the machine	○	◻	◻	◻	◻	7	7									
12	Remove the pressure of closing the old order	●	◻	◻	◻	◻		29									
13	Remove the final production of the mold of former	●	◻	◻	◻	◻		5									
14	Directed to the front of the machine	○	◻	◻	◻	◻	3,5	3,5									
15	Record the final production of the old order	●	◻	◻	◻	◻		4									
16	Get the tools	○	◻	◻	◻	◻	73	73									
17	Dismount the new mold	●	◻	◻	◻	◻		55									
31	Remove the eye or to bar of transportation of new mold	●	◻	◻	◻	◻		0									
32	Place eye in order to bridge old molde and engage mobile	●	◻	◻	◻	◻		15									
33	Dismount the old mold	●	◻	◻	◻	◻		176									
34	Close front door	●	◻	◻	◻	◻		3									
35	Connect motor and drop the old mold of mobile dish	●	◻	◻	◻	◻		66									
36	Open back door	●	◻	◻	◻	◻		3									
37	Open front door	●	◻	◻	◻	◻		3									
38	Remove stem from removal of old mold	●	◻	◻	◻	◻		7									
39	Release the mold of fixed dish and place it beside the machine	●	◻	◻	◻	◻		37									
73	Get the paper the parameters of new mold (new product)	○	◻	◻	◻	◻	31	31									
74	Seek documentation of new mold	○	◻	◻	◻	◻		71									
75	Exchange of documentation	●	◻	◻	◻	◻		168									
76	Define parameters (introducing setup)	●	◻	◻	◻	◻		32									
77	It is addressed to the place of supply of material	○	◻	◻	◻	◻		20									
78	Connect the equipment to plastic material	●	◻	◻	◻	◻		32									
79	Directed to the front of the machine	○	◻	◻	◻	◻		8									
34	Purge the new mold	●	◻	◻	◻	◻		30									
95	Producing parts of the new product	●	◻	◻	◻	◻		0									
96	Remove pieces stuck in the cavities of new mold (semi-automatic)	●	◻	◻	◻	◻		102									
97	Settings setup	●	◻	◻	◻	◻	4,5	4,5									
98	Reports to the control panel of the machine	○	◻	◻	◻	◻		35									
99	Connect and adjust the carpet	●	◻	◻	◻	◻		56									
100	Check the parts produced from new product	●	◻	◻	◻	◻											

Figure 2: Chart Analysis of Changeover operations.

Table 2: Identified groups

Base Group	Group I	Group II
(Changeover of all horizontal machine)	(Machines 5 and 6)	(Other machines)
n operations	n operations	(n-4) operations

All the transactions listed earlier, with the exception of four operations are made in the changeovers of the horizontal machines excepted for four that are executed only when the exchange is made in two specific moulds machines (see Figure 3).

16	Get the tools						73	73										
17	Dismount the new mold							55										
18	Carry the new mold						290	290										
19	Get the necessary materials (hoses, clamps, etc ...)						0	0										
32	Place eye in order to bridge old molde and engage mobile							15										
33	Dismount the old mold							176										
34	Close front door							3										
46	Open front door							3										
47	Mount the new mold							500										
48	Assemble the components of new mold							16										
81	Arrange the old order							211										
82	Mount the old order							37										
83	Arrange the tools							1020										

Figure 3: Operations in only two horizontal machines.

The detected difference is due to the characteristics of these equipments that do not allow templates to be installed inside it when already assembled. Thus, when considering the changeovers of all horizontal machines together, we have the problem of not being able to characterize such operations, in the machines that they aren't made.

The detected operations were: Dismantle the new order outside the machine, which will begin its production; Remove the old order, which is inside the machine, which ended its production, so further up the inside of the machine and the Mount so outside the old machine, prior to storage.

The detected differences are an important factor in the proposals of improvement, as well how they are applied because they are directly related to the changeover standard time characterisation. So, in this case study two separate groups should be considered, but in order to know if the detected differences in the changeovers times of these two groups were significant, statistical analysis of the results were used as presented in next section.

3.1 Analyze of Changeover procedure and data collection

To make a better and deeper analysis of the operations belonging to the changeovers we used a chart analysis (see an example in Figures 4a and 4b) of the changeovers. The study detected that in two machines, (machines 5 and 6) it was necessary to disassemble the moulds before these are mounted on the machine but the same wasn't needed in the other machine. These operations cause an increase in the additional time spent in the changeovers on these machines. For this reason two separate study groups were considered:

- Group I: Changeovers on machines 5 and 6 (Figure 4a);
- Group II: Changeover on other machines, since the procedure to be used is the same for everyone (Figure 4b).

As we can see in Figure 5 the time of changeovers observed, in each two group seems to be quite different. The changeovers belonging to Group I take longer to perform than the changeovers belonging to Group II.

To check if the difference in the changeovers times were statistically significant a t-test was used. To carry out this test is necessary to verify if values are normally distributed. To this we first used the Kolmogorov-Sminov, which allowed the normality verification of the results (see Figure 6).

Chart analysis- Group I

Sheet n.º1
 Place of work: Area of Plastics
 Designation of work: Changeover
 Station: Máq. 5
 Subject Studied: Time spend in changeover of LEGR SPOOL for the CAP-212 SPOOL
 Name:

	Second		
	Present	Proposed	Desv
○	2424		
⇨	682,5		
□	19		
⏸	2852		
▽	132		
Distance	337		
Time	6110		

Operation n.º	Operations	Operation	Transport	Inspection	Waiting	Storage	Distance (m)	Time (sec)	Porquè				Observation	Remove	Conclude	Redistribute	Simplify
									What?	Who?	When?	How?					
1	Place the controller in the water cooling	●	○	□	⏸	▽		5									
2	Reports to the control panel of the machine	○	⇨	□	⏸	▽	7	7									
3	Place in Semi-automatic machine (end of cycle)	●	○	□	⏸	▽		10									
4	Raise flag and start record C/D	●	○	□	⏸	▽		7									
5	Time of cooling water	○	⇨	□	⏸	▽		232									
6	Place machine in manual mode / Close Molde / Reverse cylinder	●	○	□	⏸	▽		146									
7	Get the material to do the purge	○	⇨	□	⏸	▽	20	20									
8	Purge the cylinder	●	○	□	⏸	▽		163									
9	It is addressed to the controller of the water	○	⇨	□	⏸	▽	7	7									
10	Disconnecting the controller of the water	●	○	□	⏸	▽		2									
11	Moves to the control panel of the machine	○	⇨	□	⏸	▽	7	7									
12	Remove the pressure of closing the old order	●	○	□	⏸	▽		14									
13	Remove the final production of the mold of former	○	⇨	□	⏸	▽		14									
14	Directed to the front of the machine	○	⇨	□	⏸	▽	3,5	3,5									
15	Record the final production of the old order	●	○	□	⏸	▽		12									
16	Get the tools	○	⇨	□	⏸	▽	22	22									
17	Dismount the new mold	●	○	□	⏸	▽		143									
18	Carry the new mold	○	⇨	□	⏸	▽	105	105									

Figure 4a: Partial procedure for changeovers in Group I.

Chart analysis - Group II

Sheet n.º1
 Place of work: Area of Plastics
 Designation of work: Changeover
 Station: Máq. 28
 Subject Studied: Time spend in changeover of SPC-266 SPACER for the PTC-267 SPACER/SUPPORT
 Name:

	Second		
	Present	Propose	Desv
○	1199		
⇨	445,5		
□	143		
⏸	2642		
▽	140		
Distance	452,5		
Time	4570		

Operation n.º	Operations	Operation	Transport	Inspection	Waiting	Storage	Distance (m)	Time (sec)	Porquè				Observation	Remove	Conclude	Redistribute	Simplify
									What?	Who?	When?	How?					
1	Place the controller in the water cooling	●	○	□	⏸	▽		5									
2	Reports to the control panel of the machine	○	⇨	□	⏸	▽	7	7									
3	Place in Semi-automatic machine (end of cycle)	●	○	□	⏸	▽		10									
4	Raise flag and start record C/D	●	○	□	⏸	▽		5									
5	Time of cooling water	○	⇨	□	⏸	▽		202									
6	Place machine in manual mode / Close Molde / Reverse cylinder	●	○	□	⏸	▽		82									
7	Get the material to do the purge	○	⇨	□	⏸	▽	0	0									
8	Purge the cylinder	●	○	□	⏸	▽		0									
9	It is addressed to the controller of the water	○	⇨	□	⏸	▽	7	7									
10	Disconnecting the controller of the water	●	○	□	⏸	▽		2									
11	Moves to the control panel of the machine	○	⇨	□	⏸	▽	7	7									
12	Remove the pressure of closing the old order	●	○	□	⏸	▽		72									
13	Remove the final production of the mold of former	○	⇨	□	⏸	▽		20									
14	Directed to the front of the machine	○	⇨	□	⏸	▽	3,5	3,5									
15	Record the final production of the old order	●	○	□	⏸	▽		11									
16	Get the tools	○	⇨	□	⏸	▽	93	93									
17	Carry the new mold	●	○	□	⏸	▽		115									
18	Get the necessary materials (hoses, clamps, etc ...)	○	⇨	□	⏸	▽	0	0									

Figure 4b: Partial procedure for changeovers in Group II.

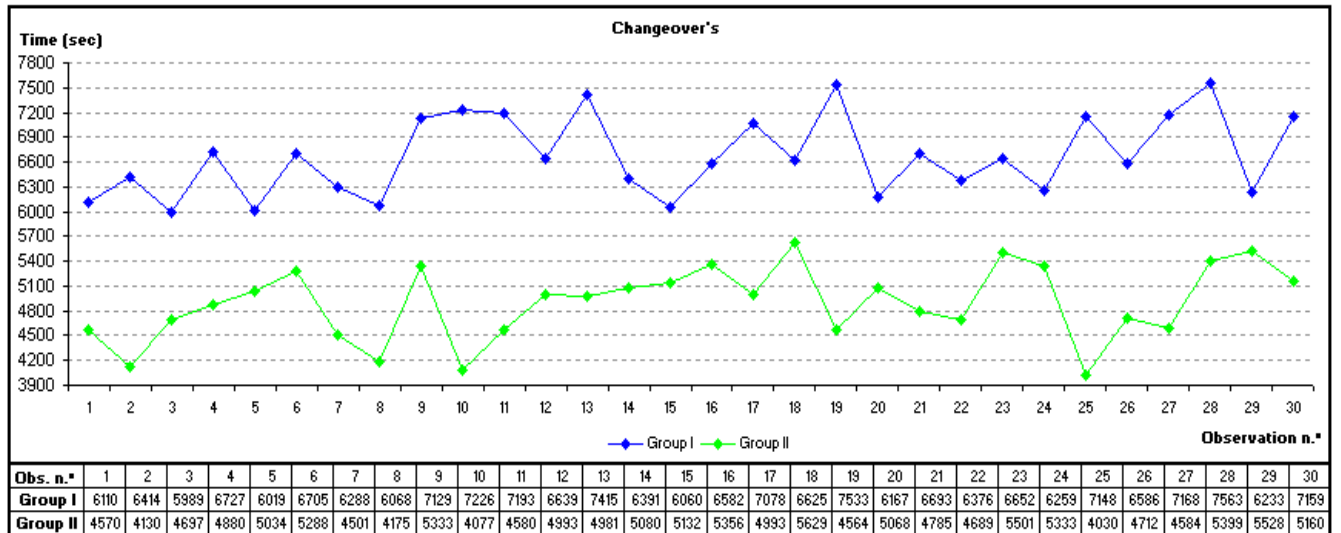


Figure 5: Time observed patterns of trade in the two groups.

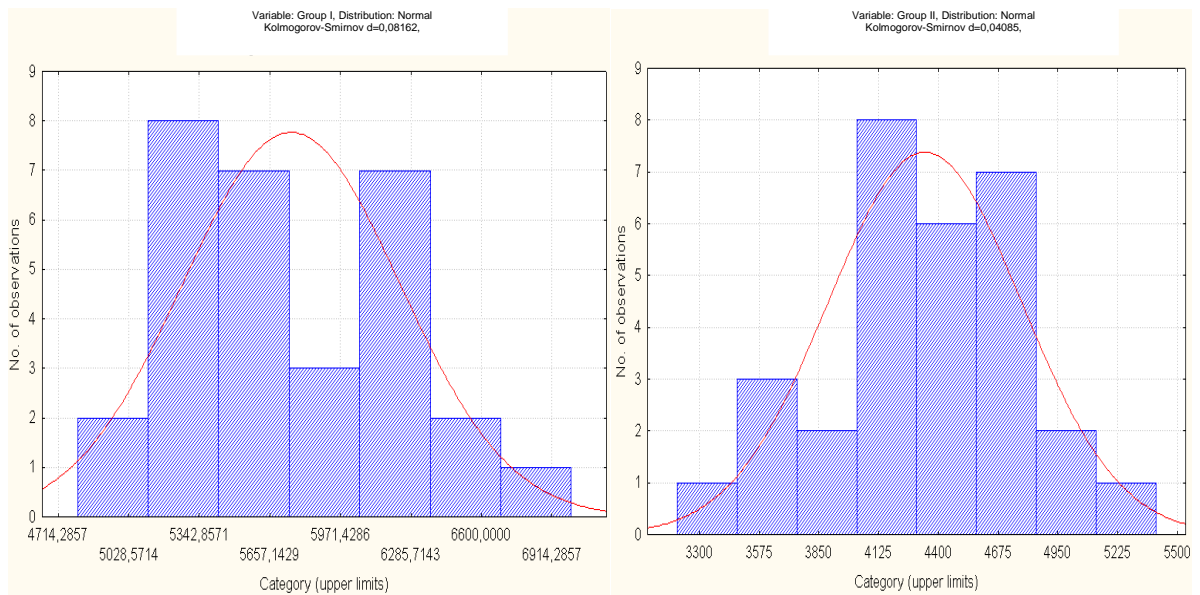


Figure 6: Study of normal data of Group 1 and Group 2, respectively.

To verify if these two groups came from two different statistical distributions we must apply the t test comparing the average times of the two groups and also the F test to check results variance. We had 30 observations in each group so we proceed to the calculation of sampling

variances resulting in a $S_1 = 484.4$ and $S_2 = 446.0$ values. The calculated value for F_0 allowed to reject the null hypothesis indicating that we should considered that the two variances were significantly different with a significant level, α , of 5 percent. So, for the comparison of two means the calculated variances were combined, using the equation (1)

$$S_p^2 = \frac{(n-1)*S_1^2 + (n-1)S_2^2}{n_1 + n_2 - 2} \quad (1)$$

And the t test used to check the null hypothesis of $\mu_1 = \mu_2$ followed the equation (2):

$$t_0 = \frac{\bar{X}_1 - \bar{X}_2}{S_p * \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}} \quad (2)$$

The t-test rejected the null hypothesis considering a significant level of 5%, meaning that the two averages could be considered significantly different, i.e the identified groups could be considered to have quite different operations times and confirming the need to study each group separately.

3.2 Improving the Change Over Process

The identified improvements will be study for both groups, in this case, because they came from common operations, but the impact that each issue in a total time of changeover will be analyze separately, because the time pattern of the two groups are different.

- **Proposal 1 (Separation of external setup to internal setup):** In all changeovers it was observed that there were operations that could be undertaken when the machine is still running, but they were made with the machine is shot down, causing an increase in time of changeovers. Such as for example, seek to purge the plastic machine, took the tools to

outside of the machine, making the exchange of documentation and fix the mould after the exchange of tools is completed.

After the identification of external operations it was made to their separation, as can be see in Figure 7 and 8. The figure 7 shows the external operations of the group I, while figure 8 shows the external operations of the group II.

	n.º	Operações	Internal	External	Observações
External Operations	1	Get the tools		●	Operations to do before Changeover
	2	Get the necessary materials (hoses, clamps, etc ...)		●	
	3	Carry the new mold		●	
	4	Dismount the new mold		●	
	5	Get the material to do the purge		●	
	6	Remove the eye or bar transportation of new mold		●	
	7	Get bucket and paper		●	
	8	Get the sheet of the parameters of the new product		●	
	9	Seek documentation of such mold		●	
External Operations	97	Arrange the tools		●	Operations to do after changeover
	98	Exchange of documentation		●	
	99	Arrange the old mold		●	
	100	Mount the old mold		●	

Figure 7: External operations – group I.

	n.º	Operations	Internal	External	Observation
External Operations	1	Get the tools		●	Operations to do before Changeover
	2	Get the necessary materials (hoses, clamps, etc ...)		●	
	3	Carry the new mold		●	
	4	Get the material to do the purge		●	
	5	Remove the eye or bar transportation of new mold		●	
	6	Get bucket and paper		●	
	7	Get the sheet of the parameters of the new product		●	
	8	Seek documentation of such mold		●	
External Operations	94	Arrange the tools		●	Operations to do after changeover
	95	Exchange of documentation		●	
	96	Arrange the old mold		●	

Figure 8: External operations – group II.

To separate the operations of external transactions, we obtained different results in both groups, because some operations that, were classified as external in Group I, are different from foreign operations as in Group II. Since the Group I have nine operations to be executed before the changeover, including the operation to disassemble the mould again, and four external operations to be executed after the end of the changeover. Group II presents a set of external operations relatively minor, should be held before the exchange of only the mould preparation of documentation, and transport of tools and utensils. And external operations to perform after the end of the changeover are operations, repair tools and the mould that ended its production and was removed from the machine.

The implementation of this proposed improvement will provide better results analyzing each group separately and applying it to each individual because one of the groups (Group II) have a smaller number of operations, leading to external operations are also in smaller numbers in this group than in Group I.

- **Proposal 2 (parallel operations):** The use of parallel operations caused a decrease of time in implementing the changeovers unnecessarily, because when the changeover is performed only by a single operator, this has to go to both sides the machine.

The Figure 9 represents the operations of changeover before the implementation of proposals for improvement. Analyzing the figure we can see that the A is the operator that runs almost all the operations of the changeover, while the operator B only performs some of those operations, the exchange of material.

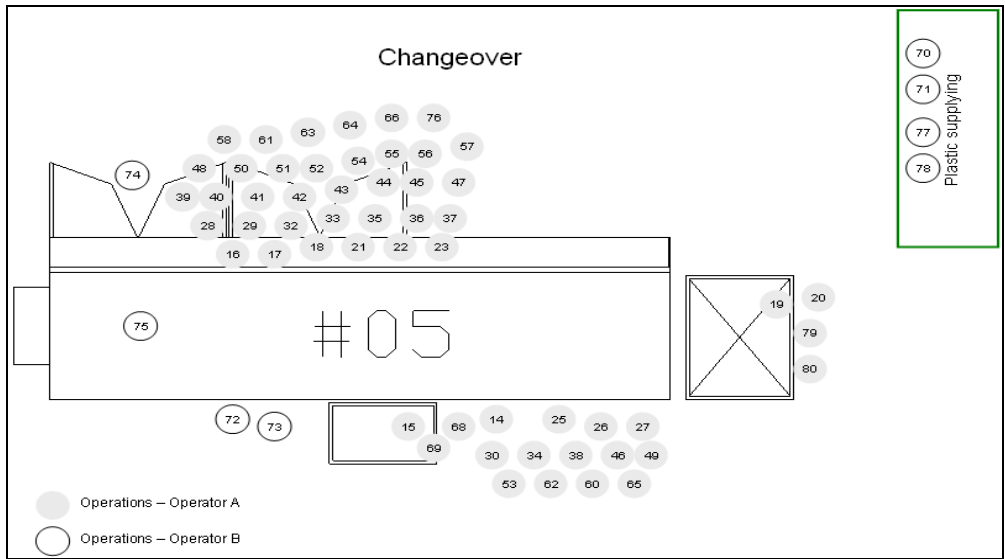
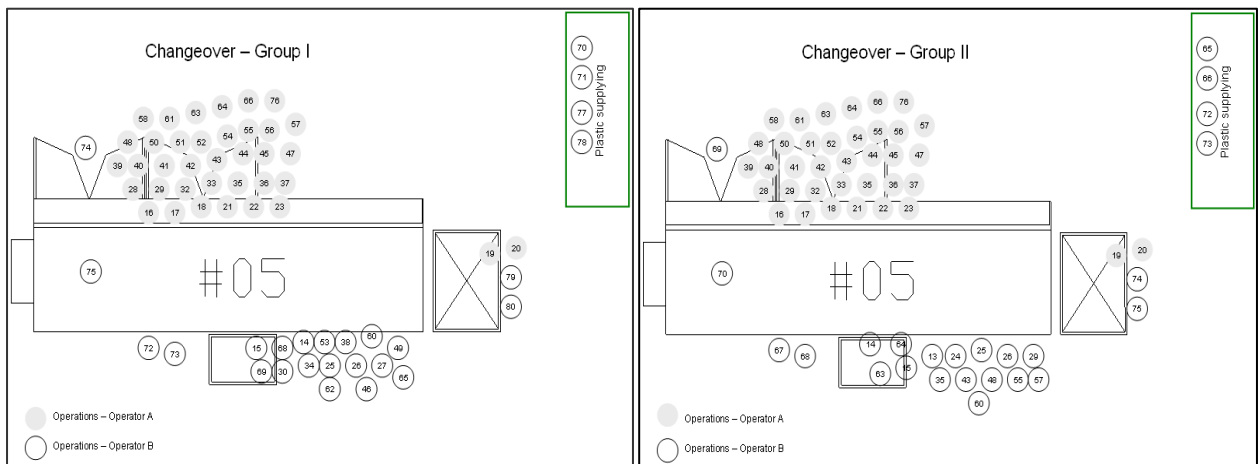


Figure 9: Operations of Changeover – Before.

This representation is valid for the exchange of moulds belonging to two groups, since in both groups is necessary to perform operations on both sides of the machine. The few operations that are not performing at the foot of the machine were domestic transactions, and may occur in parallel with other transactions were covered and assigned to one of the operators.

In Figure 10 we can see that each operator is responsible for operations to be carried on one side of the machine, eliminating unnecessary movements.



(a)

(b)

Figure 10: Operations of Changeover – After.

Although the implementation of this proposal was made in both groups presents some differences between than, due to inequalities in the operations to be performed on each group. It was necessary to do a thoroughly examination of the operations that belong to each group and that may be performed simultaneously in order to divide them by two operators. Thereby, better optimization of the changeover, since the choice of operations to be performed by each operator, is in accordance with the operations being carried out in changeovers from each group. This does not happen if we considered the changeovers of horizontal machines all together, since the approach that would be closer to the optimum place for the Group I, but would be far below the optimum place for the Group II.

This separation has not yet put the operators at risk ergonomic level, as occurring on average only 5 or 6 exchanges of daily patterns (during the 3 shifts) in the horizontal machines. These operators also perform other functions that have nothing do with the exchange of moulds, such as the supply of material.

- **Proposal 3 (Start of machine done by the operators):** In all the observed changeover, the start were performed by technicians resulting in the existence of periods of time, to wait for the start of machines, because the people responsible for the machine start were busy with other activities, leaving the machine waiting. The occurrence of these situations could be reduced or even resolved, if the operators that do the changeover would be also responsible for the start of all horizontal machines.

- Proposal 4 (Heat the mould during the heat of the cylinder):** Heating the mould could be made during the heating of the cylinder of the machine when the cylinder was not shot down during the changeover. Since the time it takes to heat the mould in these conditions, is almost equal to the time for heating the cylinder. The implementation of this proposal makes it implicit that the cylinder is not disconnected during the operations of an exchange of mould and that when the machine is ready to boot, this is done immediately.

In Figures 11 and 12 we have the changeover times obtained when the mould heat during the heat of the cylinderwith, as well as the implementation of other proposals for improvement previously described. The figures show the times of all the proposed improvements are implemented and their impact on time spent on internal operations, i.e., the time that this is really an exchange of moulds will take the case after the implementation of all proposals those in the picture. For example the exchange number 6 in Group I was 3329 seconds depended upon to make this exchange of moulds after the implementation of the proposals submitted previously, whereas prior to the implementation of the proposals took 6770 seconds. Reducing to about half the time spent in performing this exchange of moulds.

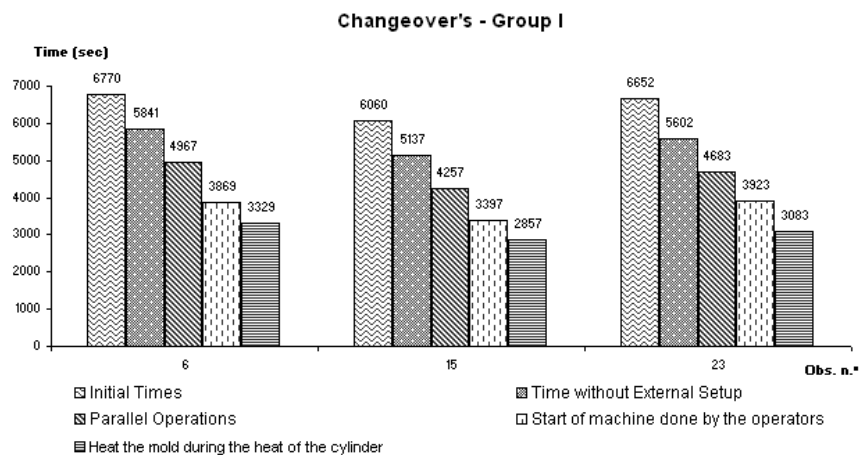


Figure 11: Changeovers of Group I when the mould heat during the heat of the cylinder.

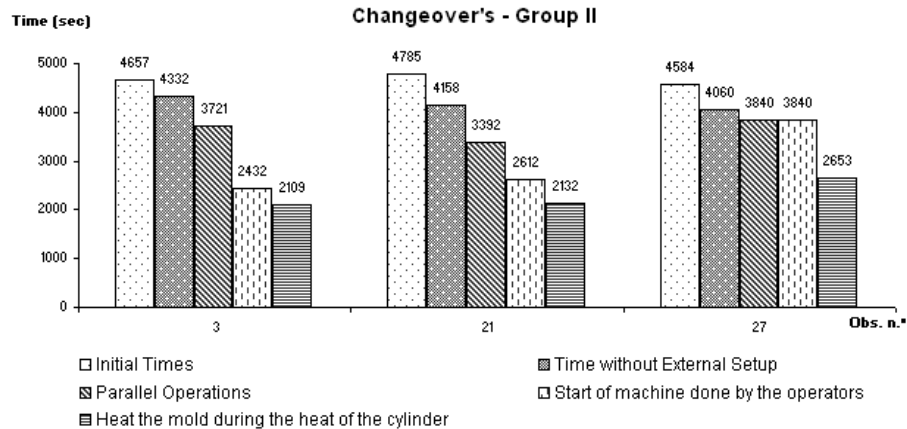


Figure 12: Changeovers of Group II when the mould heat during the heat of the cylinder.

- Proposal 5 (Use a support car):** during the changeover a support car should be used. This support car should include: the tools necessary to conduct the changeovers, accessories, and other useful tools for this operation (see Figure 13).



Figure 13: Use a support car – Before and after.

The use of support car would decrease the number of external operations to be undertaken before the changeover, reducing the time spent on unnecessary travel. This proposal would also facilitate the work of the operator, through the standardization of operations, i.e., the same tools and accessories to remain together, making it easier to use during the changeover.

- **Proposal 6 (Use of integrated file with layers):** replacement of individual economic containing the documentation for a file that had the integrated economic, facilitating the exchange of documentation after the exchange of moulds.

- **Proposal 7 (On and off the plastic supplying):** the supply hoses plastic, are rolled up to each other and the number of hoses is equal for most of the hoses, thus hindering its rapid identification. Some actions could be implemented, such as:
 - Action 1: Increase the distance between the supply hose (about twenty centimeters would be enough);
 - Action 2: Use a color code, that is, all hoses for supplying the horizontal machines have labels with the same color, showing the number that corresponded to the machine.
 - Action 3: support structure for the hoses that were not being used at the time, making up putting it every time a hose was disconnected and was not necessary to turn it on at that moment.

These measures would help reduce the time spent in the operations of the hoses to connect and disconnect the supply of material and facilitate the work of the operator in carrying out such operations.

3.3 Implementation and analysis of results

All the previously submitted proposals for the improvement were possible to implement during this study, except the last one because this proposal involves additional monetary costs

that are in consideration by the company. The implementation of the proposals involved only the reorganization of existing resources and was possible to test in three different changeovers, for each group (see Table 2).

Table 2: Improvement achieved with the implementation of the proposals.

	Change over n.º	Inicial Time (sec)	External setup (sec)	Improvement (%)	Parallel operations (sec)	Improvement (%)	Start done by operators (sec)	Improvement (%)	Heating of the mold during the heating of the cylinder (sec)	Improvement (%)
Group I	6	6705	5841	12,9	4967	25,9	3869	42,3	3329	43,0
	15	6060	5137	15,2	4257	29,8	3397	43,9	2857	44,4
	23	6652	5602	15,8	4683	29,6	3923	41,0	3083	45,0
Group II	3	4697	4332	7,8	3721	20,8	2432	48,2	2109	51,3
	21	4785	4158	13,1	3392	29,1	2612	45,4	2132	48,7
	27	4584	4060	11,4	3840	16,2	3840	16,2	2653	34,7
								Group I (average)		44,1
								Group II (average)		44,9

The Table 2 shows the execution time of three changeovers in each group. Considering the time of execution of changeovers, after implementation of proposed improvements, it appears that the running time is quite different in the two groups, because of the different operations that are necessary make. We can also see that were reduced the internal setup about forty-four percent (44%) in both groups and the time that the machine is shut down has reduced nearly by half.

For external transactions obtained is an improvement of about thirty percent (30%) in external operations that take place before the exchange of templates, in both groups. While the external operations that take place after the exchange of moulds obtained is an improvement of twenty-eight percent (28%) for the exchange of Group I and approximately forty-eight percent (48%) for trade belonging to Group II.

4. Main Conclusions

This study showed that the SMED methodology can and should be combined with other classic tools, providing very positive results for companies. In our case study the application of these tools (and chart Analysis and Statistical Analysis) allowed the identification and separation of different groups for analysis, and added value of traditional SMED methodology.

The identification of the groups seems to be extremely important for a correct analysis of the processes of changeover, because the procedure in the implementation of changeovers in different groups presented differences in the changeovers procedures. This factor is very important in the determination of the time pattern time of each group and allows the inclusion of more specific proposals for improvements to each of the operations that are executed in the changeover of each group, allowing the future to obtain a more significant reduction of time spent in the different groups. So, the implementation of the proposals (Separation of internal setup to external setup and parallel operations) separately in each group will be reflected in the determination of changeover standard times.

It is important to note the methodology developed by Shingo SMED as well as the derived approach proposed don't have a strict, application and it is fundamental to adapt them to the reality of the companies to be successful implemented and that is essential to mixed up functional and structural changes into implementation entails. As we have shown most of the times is not necessary to make big investments to achieve reduced changeover times if we examine well the existing resources and reorganized them to be more effective.

References

1. MCINTOSH, R.I., S.J. CULLEY; A.R. MILEHAM, G.W. OWEN. 2007. Changeover improvement: Reinterpreting Shingo's "SMED" methodology. *IEEE Transactions on Engineering Management*, 54(1) 98-111.
2. GOUBERGEN, D.; H. LANDEGHEM. 2002. Rules for Integrating Fast Changeover Capabilities into New Equipment design. Belgium: Pergamon.
3. MONDEM, Y. 1983. Toyota production system: Practical approach to production management. USA: Institute of Industrial Engineers.
4. FOGLIATTO, F., P. FAGUNDES. 2003. Troca rápida de ferramentas: Proposta metodológica e estudo de caso. *Gestão & Produção* 10 (2) 163-181.
5. FAGUNDES, P., F. FOGLIATTO. 2002. Metodologia para a troca rápida de ferramentas: Proposta metodológica (Vol. 1). ENEGEP, Porto Alegre, RS: ABEPRO.
6. SHINGO, S. (1985). A Revolution in Manufacturing: The SMED system. USA: Productivity Press.
7. SHINGO, S. (1989). A Study of the Toyota production system. USA: Productivity Press.
8. SEKINE, K. (1987). Kaizen for quick changeover: going beyond SMED. USA: Productivity Press.
9. SUGAI, M., R. MCINTOSH, O. NOVASKI. 2007. Metodologia de Shigeo Shingo (SMED): análise crítica e estudo de caso, *Gestão & Produção*, 14(2) 323-335.
10. SHERALI, H., D.V. GOUBERGEN, H.V. LANDEGHEM. 2006. A quantitative approach for scheduling activities to reduce setup in multiple machine lines. *European Journal of Operational Research* 187(3) 1224-1237.

11. MCINTOSH, R.I; S.J. CULLEY, A.R. MILEHAM, G.W. OWEN. 2000. A critical evaluation of Shingo's "SMED" (Single Minute Exchange of die) methodology. UK: Taylor & Francis Ltd.
12. TROVINGER, S.; R. BOHN. 2005. Setup time reduction for electronics assembly: Combining simple (SMED) and IT- based methods. USA: Production and Operations Management 14(2) 205-217.