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Applying SMED methodology in cork stoppers production

E. Sousa[a], F. J. G. Silva[a*], L. P. Ferreira[a], M. T. Pereira[a], R. Gouveia[a], R. P. Silva[b]

[a]*ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, 4200-072 Porto, Portugal*
[b]*Cork Supply Portugal, S.A., Rua Nova do Fial, 102, Apartado 19, Sao Paio de Oleiros 4536-907, Portugal*

Abstract

Organizations are increasingly required to have a high level of quality and flexibility in production. In order to remain in the market and become competitive, the working methods practiced must be reliable and efficient. The present project sought the improvement of an equipment of the cork industry by introducing a variation, through the application of Lean methods. The equipment under study performs the union of a cork stopper to a capsule, which is done by gluing it with hot-melt glue. The amount of production makes the changeover activity a regular process. The method followed in this work was the study and collection of information on the Lean production philosophy and its application in the cork industry. The working conditions of the assembly machine were also analyzed in order to find opportunities for improvement. Thus, the tool used was the Value Stream Mapping (VSM) technique in order to acknowledge the processes that really add value to the product. The SMED (Single Minute of Exchange of Die) methodology was applied in a way to reduce the downtime caused by tool changes, and a reduction of 43% in total changeover time was obtained. It was also created an A3 model to monitor the entire development of the SMED project, Finally, the OEE (Overall Equipment Efficiency) calculation was implemented as an indicator of overall equipment efficiency, in order to improve the monitoring of possible deviations during production. The feedback also proves that lean tools are a powerful method to get solid returns without large investments.

Keywords: Cork Stoppers, A3 Methodology, VSM, SMED Methodology, OEE

* Corresponding author. Tel.: +351 228 340 500; fax: +351 228 321 159.
E-mail address: fgs@isep.ipp.pt

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1. Introduction

Nowadays, the global competitiveness and the technological development give customers the chance to choose customized products, with exclusive details to fit their specifications [1]. The most effective way to achieve that is to increase the flexibility of the production by producing in smaller batches [2-5]. However, this type of production leads to an increase in the setup frequency [6, 7]. Thus, companies must find a way to reduce setup times and eliminate wasting time, as well as limiting activities without real added value. In order to identify, qualify and minimize major wastes, it is important to use the value stream mapping tool (VSM) [8, 9].

The Single Minute Exchange of Die (SMED) methodology is crucial to improve the production processes and its flexibility [10]. This technique is comprised within the lean manufacturing production philosophy, and its purposes are to reduce waste in the production system and to standardize setup times that should be executed within a maximum time of 10 minutes [11]. This can be accomplished by the machine operator on performing some tasks to improve efficiency [12].

The present study was developed based on an equipment of the cork industry, by reducing its setup time. This type of investigation is an innovation in this kind of industry since there is a lack of information on this area.

The study's main objective was to design the VSM of the sector, apply the SMED methodology accompanied by an A3 model and the OEE (Overall Equipment Effectiveness) calculation of the equipment. After this introduction, Section 2 provides a brief literature review on Lean Production, SMED methodology, A3 report and the OEE. Section 3 describes the methodology used in the development and application of the study. Section 4 presents the problems which were detected, as well as the proposals for improvements and the results obtained through the industrial implementation of SMED methodology in the company. Lastly, in Section 5 it will be presented the conclusions, describing how this study contributed favourably to the setup time reduction.

2. Literature review

The Toyota Production System (TPS) was created in Japanese automotive company, Toyota, during 1950's. Due to its global superiority in cost, quality, flexibility and quick respond, was applied in multiple industries [13]. TPS has become a widely acceptable and adoptable best manufacturing practice across countries and industries [14]. The primary goals of this methodology were to reduce the cost of the product and improve productivity by eliminating wastes or nonvalue-added activities [15]. The most important TPS tools to remove the different kinds of waste in production are the value stream map (VSM), cellular manufacturing, total productive maintenance (TPM), and single minute exchange of dies (SMED). A great amount of literature has addressed the first four tools, while information on SMED is a bit scarce [16]. According to Nash and Polin [17], the VSM should allow the identification of all activities, whether or not they add value; from the raw material to the customer.

The VSM aggregates the value and the information flows throughout the production, being a great tool in the analysis and implementation of the Lean philosophy. This is also characterized by adding value to the product onto the service required by the customer. It should also be highlighted the importance of this tool in the identification of all the waste and possible improvements in the production process [18].

The A3 methodology is often used in order to solve the problems. This methodology was developed by Toyota Motor to show the essential information about the problems and that it should be noticeable in a short space of time and outlined in an A3 sheet, which should contain the following points: Background, Current Condition, Targets to improve, Gap Analysis, Planned Milestones, New Confirmed State and Learned lessons [19].

The demand for diversity has forced the adoption of the Toyota Production System (TPS), which results in the production of smaller lots. This shows a direct relationship between lot size and setup times [20]. If the time required to carry out the setup is too long or unwieldy, there is a tendency towards the production of large lots. Besides limiting operational flexibility and making it more difficult to meet the customer's needs; this process also generates other types of waste. To respond to the increasingly competitive market demands, setups must imperatively be performed quickly [21,22].

The well-known SMED methodology reports the issue of time reduction in the preparation, exchange, equipment tuning, and which tools are associated with these exchanges [23]. Changeover time is defined as the time needed to set up a given production system to run a different product with all the requirements. This is a typical example of waste, since changeover is a non-added value activity that incurs hidden costs [24].

This methodology was developed by Shigeo Shingo as a way of responding to the emerging Japanese automobile industry need for reducing batch size [12].

A fundamental aspect of the SMED methodology relates to its features of internal and external activities. All setup activities which do not interfere directly with the equipment, and which can be carried out without interrupting production, are designated as external activities. The actions which imply a stoppage in the equipment running are described as internal activities. The correct separation of the two is what fundamentally contributes to a reduction in setup times [20,25]. SMED methodology is formed by four single stages [25]; a preliminary stage where the internal and external setup conditions are not differentiated; the first stage is separating internal and external setup takes place; the second stage where internal activities are converted to external ones; and finally, the third stage focusing on streamlining all aspects of the setup operation [26]. This set of procedures demands a continuous monitoring of all the process, which is crucial to achieve good results. The operational method ensuing from the result obtained through SMED must be recorded; the purpose of this register is to promote a standard work and act as a basis for the training and improvement of teams [27]. SMED application results lie in higher productivity, less stock, improved quality, reduced lead-time, greater flexibility and smaller lot sizes [20].

The OEE data is used to understand the impact of the equipment improvements. This indicator was presented by Nakajima [28], in the context of Total Quality Management as a key indicator of equipment/machine performance. One of the main reasons for the widespread application of OEE, among researchers and practitioners, is that it is a simple, yet comprehensive measure of internal efficiency [29]. Three factors influence this indicator: the availability of the equipment, its performance and quality in production; that is calculated by the following formula [30]:

$$\text{OEE}=(\text{A})\ \text{Availability}\times(\text{P})\ \text{Performance}\times(\text{Q})\ \text{Quality} \tag{1}$$

The availability is defined as a ratio of planned production time minus downtime (breakdowns and changeovers) over planned production time. Performance efficiency is the ideal cycle time times the number of products produced over actual runtime. The quality rate is the ratio between accepted products over the number of products produced [31]. According to Muchiri and Pintelon [32], the availability, performance and quality factor can be calculated by the following expression (2), (3) and (4), respectively

$$(\text{A})\text{Availability}=\frac{\text{Loading time - Downtime (h)}}{\text{Loading time (h)}}\times 100 \tag{2}$$

$$(\text{P})\text{Performance}=\frac{\text{Theoretical cycle time (h) x Actual output (units)}}{\text{Operating time (h)}}\times 100 \tag{3}$$

$$(\text{Q})\text{Quality}=\frac{\text{Good parts (units)}}{\text{Total Production (units)}}\times 100 \tag{4}$$

According to Hedman [28], these three factors are influenced by the six big losses in production (see table 1):

Table 1. Six big losses in production

Downtime losses	1	Time losses	When productivity is reduced
		Quantity losses	Caused by defective products
	2	Setup and adjustment time losses	Occur when a changeover operation is performed
Speed losses	3	Wasting and minor stop losses	Temporary malfunction or when a machine is wasting
	4	Reduced speed losses	Difference between design speed and actual operating speed
Quality losses	5	Reduced yield losses	Occurs during the early stages of production from machine startup until stabilization
	6	Quality defects and rework	Caused by malfunctioning production equipment

Consequently, the downtime losses are used to calculate the availability factor, the speed losses determine the performance efficiency of the equipment, and the quality losses are incorporated to calculate the quality rate [29].

3. Methodology

The methodology used to develop this study consisted of four main stages. In the first stage, a brief literature review was performed in order to support the work to be developed, which was based on scientific articles. In the second stage, it is presented the equipment in which the study is based on, as well as the identification of the problems. Then, on the third stage, is elaborated the VSM to verify which operations add value to the process. After this, an A3 model is prepared to follow the SMED project. With the A3 model defined, the various improvements implemented through the SMED methodology are presented, and the OEE calculation of the equipment is then displayed. Finally, in the fourth stage, there is the description of the results as well as the conclusions of this article.

4. Analysis and improvements of setup times for the assembly machine

The key equipment of this section consists of one machine, which the main function is the process of gluing a top (capsule) to a cork stopper. To manufacture the final product on this machine, the following raw materials are required: top, cork stopper and glue containers.

4.1. Problems identification

Since there may be an almost infinite combination of cork stoppers and tops, it leads to frequent tool changes in the process of their joining. As in some cases, there are changes between very different sizes, this type of tool changes ends up taking a lot of available time. The data of the tool changes were grouped to characterize the initial situation of the equipment, referring to a month of production. The total dataset has a relatively small size, and there is a large heterogeneity in the records, not only at the numerical level (daily production, changeover times, etc.) but also from the writing point of view. In order to facilitate the analysis of the current condition, the data related to the tool change time were organized in the following graph (see Fig. 1):

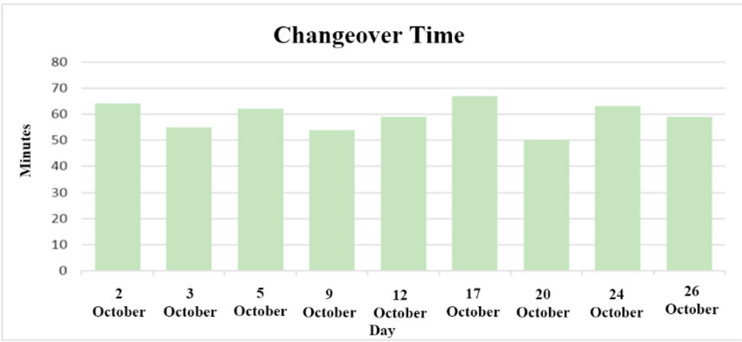

Fig. 1. Changeover time for one month.

After analyzing the data, it's possible to see in table 2 the time values, cork quantity and monetary value lost in tool changes during the month of October 2017.

Table 2. Minutes, cork quantity and monetary value lost on tool changes.

Month	Time lost (min)	Cork Quantity (units)	Monetary Value (€)
October	533	62.000	4.500€

Through these data, it is therefore possible to realize that there is a huge opportunity for improvement. In the next chapter, it will be presented some ideas to try achieving a changeover time reduction and consequently a reduction of all the waste that exists for each stop for a tool change.

4.2. Processes mapping

The material and information flows were monitored from the beginning o draw the VSM, since the stoppers production until the final product (bartop) is ready to be shipped, in order to observe the main movements of the referred product. As far as the flow of information was concerned, it was necessary to arrange a meeting with all those involved in the process.

The VSM was based on a wooden top bartop with a cork stopper for white drinks, because these ones have a longer delivery lead time and the stopper suffers a surface treatment also with a longer lead time. The batch size considered was 52 thousand bartops, since it is the average value per order according to the history of the previous year (see Fig. 2).

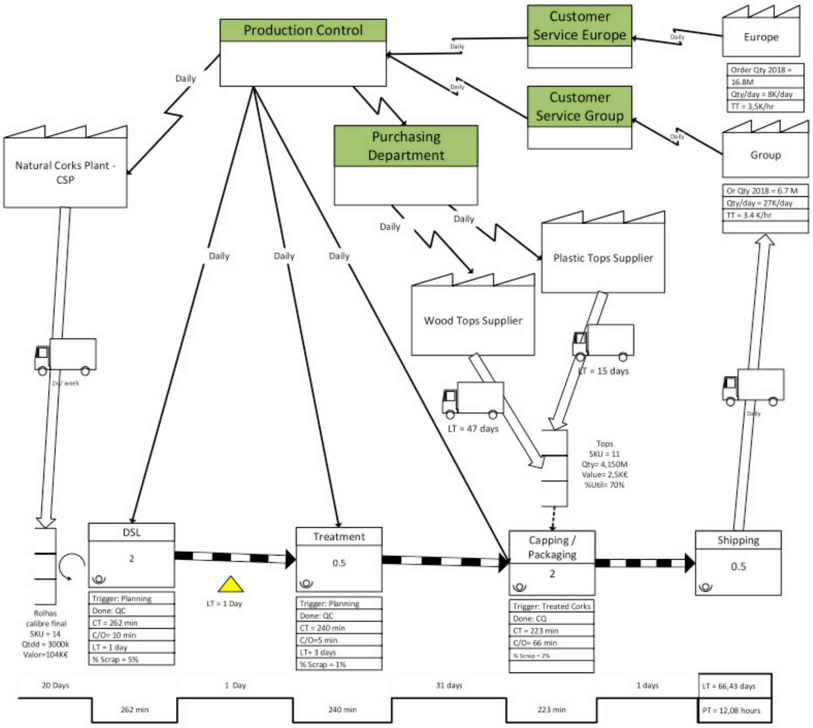

Fig. 2. VSM of current state.

The production process starts with the customer order. The data related to this order is sent to the production control, daily. Then, the production control places the corks requests to the Natural Corks Plant and the tops requests to the purchasing department. These tops only enter in the production flow in the capping operation.

Regarding the corks, Natural Corks Plant takes 20 days to deliver the request. Upon receipt, they undergo a visual sorting process called DSL (double sorting line); with visual quality ready, the corks go through the surface treatment process. Upon the end of this operation, the stoppers are moved to the capping operation.

This process is all continuous, making only stock in the final gauge before capping because there are clients in which the lead time required does not allow to make MTO (made-to-order), and consequently, there is a need to have stoppers already finished in stock. The Capping operation is the process that determines the rhythm of the productive flow. Analyzing the VSM, it´s possible to verify that the total lead time is 66,43 days and the processing time is 12,08 hours. This reveals the need to eliminate or minimize activities that do not add value.

In a future state, the change in the VSM will be in the changeover time that will influence the lead time. With the proposed goal of reducing the changeover time by 50 %, the change in terms of lead time will be reduced from 66,4 days to 65,8 days.

4.3. A3 Report

In order to start and follow the development of the project in question, the following A3 model was created (see Fig. 3):

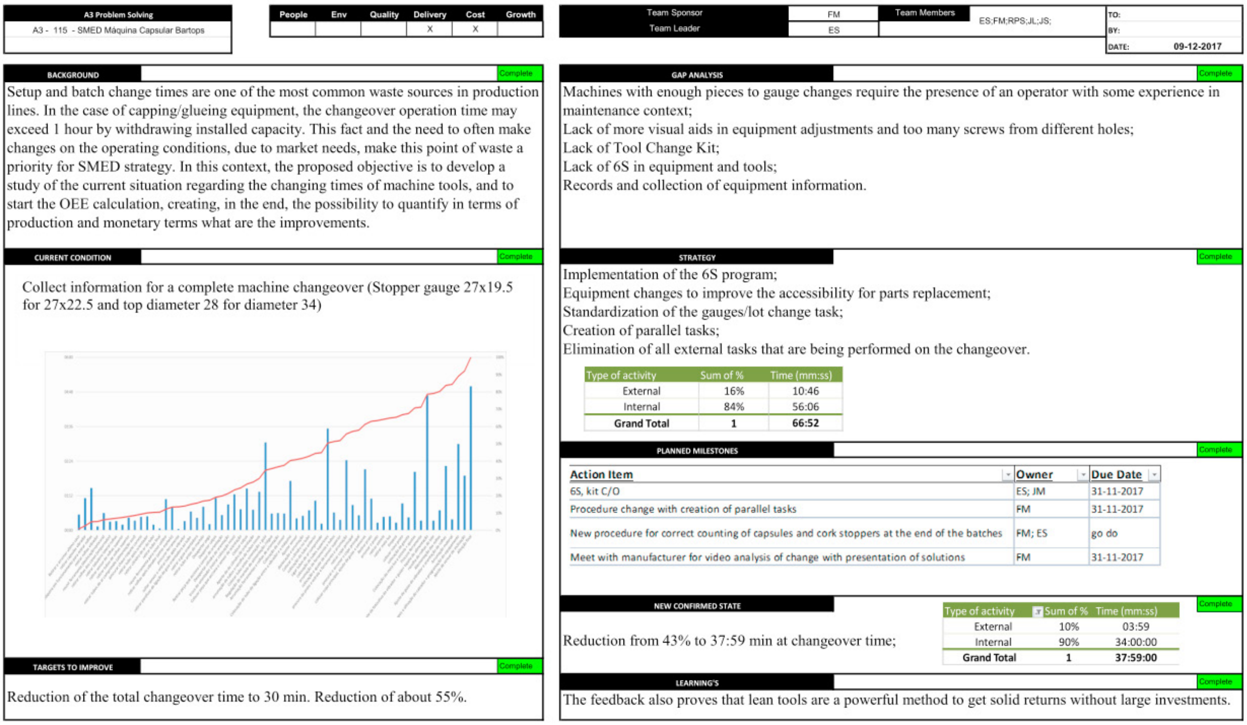

Fig. 3. SMED project A3 model.

4.4. SMED implementation

4.4.1. Identify internal and external setup operations

In order to correctly identify the problems, it is necessary to understand the internal processes of the sector and, in greater detail, all the activities related to the capping machine setup process. As described in the literature review chapter, the first step of SMED is to interview the workers, which is very important to realize the good and the bad of the changeover operation, and the existing possibilities for improvement, as well as filming the changeover situation. After the filming was completed, it was held a meeting with the workers, in order to analyze which are the tasks that are internal or external (step 1 of SMED). From this analysis, it was found that 84% of the tasks are internal and 16% are external; they take respectively 56:06 minutes and 10:46 minutes, totaling the changeover process in 66:52 minutes (see table 3).

Table 3. Distribution of changeover time in external and internal activities.

Type of activity	Percentage (%)	Time (mm:ss)
External	16 %	10:46
Internal	84%	56:06
Total	100%	66:52

Table 3 shows the distribution of the tool changeover times, observed between External and Internal Activities. This data makes it possible to conclude from the outset that there are aspects to be improved in the process of changing line. The enormous amount of time spent in activities that could possibly be external can be explored and worked.

4.4.2. Implemented solutions

In the equipment changes that were defined, it was intended to move the internal tasks to external, and at the same time reduce internal ones. Some of these modifications will be described below. Whenever it was intended to make a changeover, one of the points that occupied 04:32 min of the total changeover time (7% of the total) was related to the factor that each time that the cork stopper diameter was changed, the tubes had also to be replaced. So, to remove these tubes it was necessary to unscrew the sensors and divide the tubes into parts. The solution to this, then implemented, was to fix the sensors externally to the tubes. With this modification the worker will no longer have to unscrew, fix and adjust the sensors, as well as no longer need to divide the tubes, making it possible to pre-prepare the tube kit to be used (see Fig. 4).

Fig. 4. Implemented improvement in tube sensors.

Another improvement identified, was in the regulation of the height of three shafts. In the initial procedure, the operators made the adjustment of a shaft, and with the help of the caliper, measure the height of the shaft and tried to adjust the other two, consuming 02:42 min (4% of the total time). To improve this system, it was created a part that only needs manual adjustment by turning a handle. This process puts the three pins at the same height (see Fig. 5). With this improvement, the use of the caliper, as well as the key used, was eliminated, by the rotation of a handle.

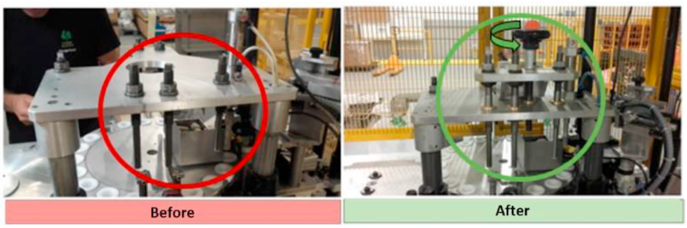

Fig. 5. Implemented improvement in shaft height regulation.

In the part of the cork stopper orientation, improvements that could be applied were also identified. Each time the tool is changed, the part of the cork guide has also to be changed, but the fixing screw of this part was so poorly accessed that workers had to go under and unscrew the cylinder in order to remove this part. The improvement that was implemented was to modify the insert, so that the screw was easily accessible, in order to ease the exchange of this part, and by this time it was no longer necessary to unscrew the cylinder (see Fig. 6).

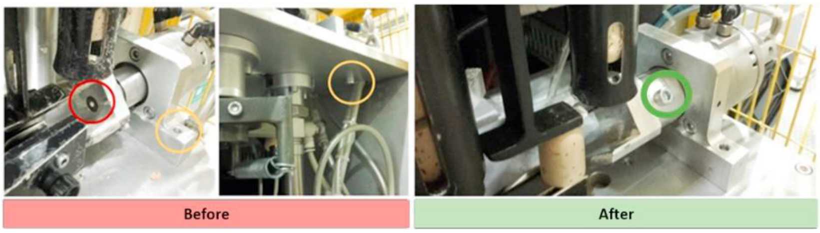

Fig. 6. Implemented improvement in the part of the cork stopper orientation.

In the same section of the machine; the guides that lead the cork to the orientation part have been modified. Formerly, to change the guides, the worker had to use a wrench to loosen these and then re-tighten them. Since the quick grip that these guides had, only served for the worker to open them. The improvement that was made was to replace these fasteners by fastening, improving access to the worker and eliminating one more key (see Fig. 7).

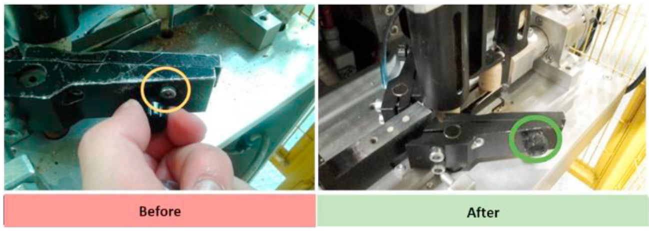

Fig. 7. Implemented improvement in the guides that lead the cork to the orientation part.

Additionally, to the changes made to certain components of the equipment, which led to a reduction in the number of keys needed and the normalization of screw size, the 6S methodology was used in the tools. Of the tasks identified in the video analysis, 08:55 min, that is, 12% of the tool change time was related to the search for tools and/ or poor organization of these. In order to reduce this unproductive time, the following improvements were also implemented:

- Identification of each set of cups with the corresponding diameter (see Fig. 8a);
- Creation of a Changeover Kit (see Fig. 8b);

Fig. 8a. Improvement implemented in the organization of the parts.

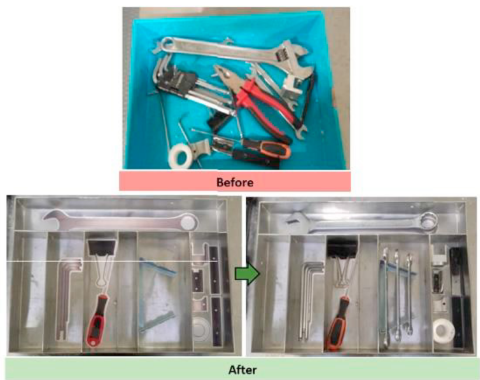

Fig. 8b. Changeover Kit.

- Improvement of the preparation space of the parts before the change (see Fig. 9). We sought to improve the preparation zone for changing tools so that, the operator had more space and the tools were organized.

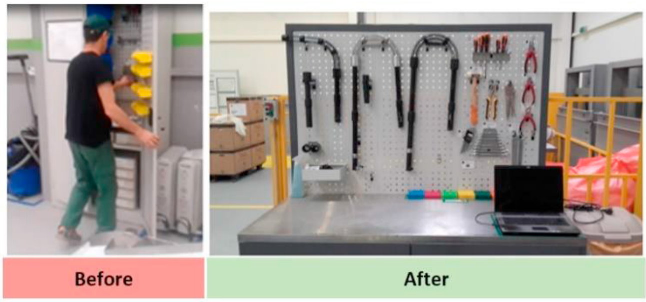

Fig. 9. Improvement implemented in the material preparation space for the change.

The activity of changing the "cups" of the stoppers (a piece of composite material that holds the stoppers before the join to the top) is considered internal, and it was not possible to pass to external, however, it was found a solution to shorten its duration. Prior to the SMED project, the worker changed these parts one by one using a small key. As an improvement, a new “dish” (the wheel-shaped part where the cups are fixed) was purchased, so that the worker could externally prepare the cups for the next stopper gauge. Just by unscrewing two screws this exchange is performed, instead of changing cup by cup. With this improvement, there was a reduction from 02:32 min to 00:30 min in this activity (see Fig. 10).

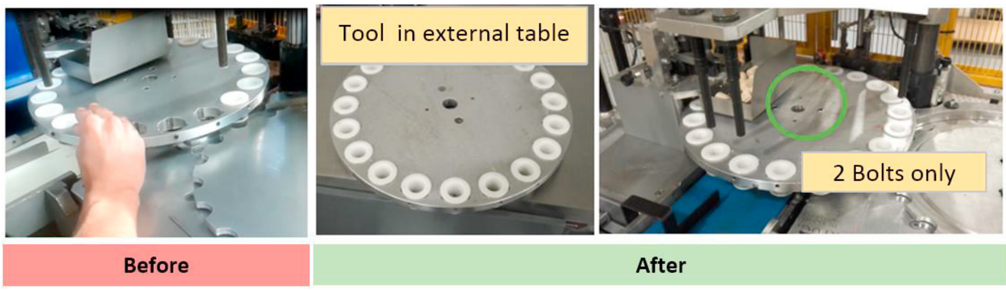

Fig. 10. Improvement implemented in “cup” change operation.

4.4.3. Setup time after improvements

In order to conclude the SMED project, it was recorded a video of the changeovers with all improvements implemented, so that it was possible to gauge if the goal of the project was reached and perhaps make more suggestions for future improvements. In Table 4, it is possible to verify the new division into internal and external tasks. The difference in the total duration of the tool change is noticeable, decreasing from 66:52 min to 37:59 min, resulting in a reduction of 28:53 min. The time spent on external tasks dropped from 10:46 min to 03:59 min, but the most significant decrease was in the time spent on internal tasks, that went down from 56:06 min to 34:00 min. In terms of the tasks distribution between internal and external, before the implementation, these were 84% and 16%, respectively, and after implementation of the improvements began to be divided into 90% and 10%. This increase in the internal percentage is due to the reduction of stages in the setup, from 66 to 47, and also contributed to the fact that some external activities were eliminated.

Table 4. Distribution of changeover time in external and internal activities before and after improvements.

Type of activity	Before Improvements			After Improvements		
	Percentage (%)	Time (mm:ss)	Number of setup stages	Percentage (%)	Time (mm:ss)	Number of setup stages
External	16 %	10:46	16	10 %	03:59	11
Internal	84%	56:06	50	90%	34:00	36
Total	100%	66:52	66	100%	37:59	47

In Table 5, it is possible to understand the financial impact that the implemented improvements have brought to the production process. With the reduction of 28:53 minutes in the changeover time (around 43%) and with a monthly average of 10 changes, it is possible to quantify a saving of around 2340 € per month and per machine.

Table 5. Savings related to implemented improvements.

Changeover Time Before Improvements	66:52 min
Changeover Time After Improvements	37:59 min
Monthly Average Changeovers	10
Financial savings in each changeover	234 €
Financial savings per month	2340 €

4.5. Start of OEE calculation

As already mentioned, OEE is a simple metric that includes three contributive factors of a given equipment efficiency. The OEE calculation of the capping machine was a proposed procedure as a complement to the improvement work that would be developed, in order to assist in monitoring the evolution of the machine performance over the time. To calculate the OEE, it is necessary to analyse the production records, as well as the equipment stops. By performing this analysis and applying formulas (1), (2) and (3), it is possible to obtain the values of table 6.

Table 6. OEE calculation for shift 1 and 2

Parameter	Availability	Performance	Quality	OEE
Shift 1 (%)	93%	83%	99%	76%
Shift 2 (%)	97%	57%	99%	55%

The calculated OEE values show that equipment operation has some points that must be improved, and that the main cause of the low efficiency is the high number of micro-stops (duration less than 5 minutes) and the low working speed, which contribute to factor with the lowest percentage value is the performance one. In fact, by observing the capsule machine operation, it is obvious that the recommended production rates are often not met, and the equipment is stopped for several reasons throughout the working time.

The way that the registers are carried out by the workers is also the source of the great difference between availability and performance indexes. Many stops influencing the machine performance are certainly more than 5 minutes, and their causes should be recorded.

With respect to the values calculated for the two shifts, it is verified that the availability index is higher in the second shift, while the performance index is higher on the first shift. This is likely to be, due to the fact, that the responsible worker for the records in the first shift is more rigorous and provides more detailed information on the stops recorded, allowing a better classification of stops and micro-stops.

5. Discussion and conclusions

Starting from the initial situation in which the capping machine changeovers were a process with enough space for improvement and several organizational and normalization difficulties, the proposed challenge was to achieve a reduction of 55% in the changeover stop times and also to start the OEE calculation for capping equipment.

This practical experience of applying the SMED method allowed to realize that this method is strongly linked to the understanding of lean concepts, which are often indispensable for creating work conditions that allow workers to work more efficiently. An example of this was the activities that were identified as internal, and with only the installation of two holders, were eliminated from the setup, not requiring the worker to make adjustments.

The improvements implemented had a positive impact on the process and the main goals were almost achieved. The 43% reduction in the average changeover time is significant; there is three identical equipment, but with different parts, so there is a future need to normalize the various equipment tools so that there is a certain stability in the setup process. All the improvements implemented represent only a small step if one considers that are yet many hypotheses to be explored. The search for improvement should be constant and not be limited to the duration of a project. If this thought is followed, not only will the today improvements be maintained, but there will certainly be many more to be developed and applied in the future.

Finally, it is important to emphasize that a good workplace environment, trust in the employees and cooperation among all are fundamental to the success of any project; this fact is even clearer in a project of this type that requires involvement by all and perspective a change of how the work is done. A motivated workforce is a powerful tool and, in particular, in this project, this was a great advantage because it was from this involvement, that many of the ideas were born. This dynamic must be maintained and will surely continue to bring benefits to both the company and all employees.

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