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Optimization of the cold profiling process through SMED

T. Vieira[a], J. C. Sá[a,b]*, M. P. Lopes[a], G. Santos[c], M. J. Félix[c], L. P. Ferreira[a], F. J. G. Silva[a], M. T. Pereira[a],

[a] *ISEP – School of Engineering, Polytechnic of Porto, Rua Dr. António Bernardino de Almeida, 431, Porto 4200-072, Portugal*
[b]*IPVC – School of Business Sciences, Polytechnic Institute of Viana do Castelo, Av. Pinto da Mota, Valença 4930-600, Portugal*
[c]*IPCA – School of Design, Polytechnique Institute of Cavado Ave, Vila Frescaínha S. Martinho, Barcelos 4750-810, Portugal*

Abstract

In a more and more competitive and industrialized market, it is essential that companies realize that the way forward must go through the optimization of their production processes, reducing the costs and increasing product quality. Nowadays it's necessary to adopt innovative management models that can provide increased productivity at minimal costs, such as the Lean thinking. The metalworking industry is integrated into one of the most competitive existing markets in Portugal. Given this, it's fundamental to reduce the waste in all sectors of the production process, using the good Lean principles and practices, such as the Single Minute Exchange of Die, also known as SMED methodology. This paper presents a project of implementing the SMED methodology in the cold profiling process, in a population of five different profiling machines. The results of the SMED implementation show an average OEE improvement of 10,8%.

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Keywords: Optimization; SMED; Product Quality; Lean Thinking; Reduction of Waste.

1. Introduction

Nowadays, the corporate industry is increasingly globalized and competitive, where the quality, cost, variety and fulfilment of the delivery deadlines are fundamental factors for the customer. Thus, to better respond to these demands, companies need to find strategies to make their processes more flexible, efficient and effective [1]. Today, industrial environments focus on waste elimination to maximize value-added activities and this often leads to shorter downtime

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

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[2]. The SMED (Single Minute Exchange of Die) methodology emerges from the Toyota Production System and is today one of the tools embedded in the Lean Manufacturing philosophy. It deals with a set of techniques to minimize setup times, contributing to the reduction of equipment downtime and increasing production throughput. In addition, the diversity of products and increased volume of small orders lead organizations to optimize their equipment setup processes to produce the different range of products. Making the setups faster means to reduce machine downtime, while converging with the need to decrease non-added value operations.

2. Literature Review

According to Shingo, the Lean philosophy aims to achieve the most effective way, through continuous improvement of processes, eliminating all those activities that do not add value, never forgetting the needs of the customers [1]. The concept of waste, with its origin in the Japanese term "Muda", is any activity that consumes resources, but does not create any value [3]. The most well-known tool used to reduce setup times is known by its acronym, SMED. The acronym stands for Single Minute Exchange of Die. Setup time is the time required to prepare the necessary machines to perform an operation [4,5]. The implementation of this method reduces machine changeover time, which is a waste [5]. This method enables the implementation of a continuous flow of the product without long periods of waiting time and, most importantly, without loss of performance [6,7]. For the implementation of this tool in a company, several stages of development should be followed (Fig. 1).

Fig. 1: *Implementation of SMED, Adapted from [1]*

Sabadka et al. [8] applied SMED at a shaft manufacturing company, which led to an increase of 0,48% in annual productivity. Puvanasvaran et al. [9] carried out a study of an industrial sterilization process with the purpose of enhancing OEE. The choice of the sterilization process was due to the fact that this constituted a bottleneck in the production process. The implementation of SMED allowed for a reduction of 30 minutes in the time required for value-adding tasks, which corresponds to a reduction of setup time by 5,12%. In relation to non-value-adding activities, a reduction of 70 minutes was achieved, corresponding to an improvement of 19%. Brito et al. [10] were able to increase productivity by 23% through the implementation of SMED, by means of a new ergonomic tool. During the second phase, times were improved by adopting new ergonomic postures in two activities, which allowed for a reduction in the initial time, from 105 minutes to 57 minutes, thus corresponding to a 46% decrease. Through the implementation of SMED, Roriz et al. [11] were able to reduce the average changeover times of three machines by 47%. Rosa et al. [12] succeeded in reducing machine setup by 58,3% in the assembly lines of metallic control cables in the automotive industry. Antosz et al. [6] undertook a study to determine the results generated for the company after SMED has been applied at various workstations. The greatest impact of this implementation was observed on the CNC machine-tool, where changeover time was reduced by 64%. In another study developed by Timasani et al. [13], its main objective was to improve productivity and increase the variability of products on a CNC machining line through SMED implementation, and the study has demonstrated that it would be feasible to achieve a time reduction of over 85%. Sousa et al. [4] implemented several actions regarding the SMED methodology in the cork composed stoppers, changing internal activities to external ones, allowing to achieve a reduction by 43%, in the average changeover time. Martins et al. [7] applied the SMED methodology to the electron-beam process in the production of electrical cables for the automotive industry, detecting that problem cannot be solved by changing internal task by external ones, being necessary to act in the equipment in order to improve the changeover process.

3. Methodology

3.1. Preparation tasks to apply SMED methodology

In the preliminary stage, it is necessary to record the tool changeover times. As the internal operations (IED) are those that can only be carried out with the machine immobilized, and the external operations (OED) are those that can be carried out with the machine in operation, in the stage 1 of implementation it is important to divide the operations according to these two groups. Stage 2 is carried out after a detailed survey of all the operations, to be able to make a better preparation of the change to be made. At this stage, a current tool exchange procedure will also be elaborated, describing the operations to be carried out. In the last stage, training should be provided to the employees of the new tool change procedure. The main advantages of the implementation of SMED are as follows [14]:

- Flexibility, since it does not require a high stock of raw material due to the constant changeover;
- Faster deliveries due to smaller batches;
- Higher quality, due to the reduction of cycle times;
- Increased efficiency by reducing tool change periods;
- Increased rate of return on invested capital;
- More efficient occupation of the space reserved for stocks;
- Increased availability of equipment;
- Increase in productive capacity;
- Improvement of product quality;
- Reduction of the need for qualified personnel;

Despite all the advantages of this methodology, there are also some critics, such as:

- Shingo's enormous importance given to the differentiation between internal and external setup de-emphasizes the third stage of this methodology and, the importance of machine design improvements [4,14-18];
- Shingo does not refer to the importance of the production sequence when studying tool changes [14];
- Shingo's approach to tool change activity neglects the run-up and run-down periods. The most significant losses outside the setup period occur during the equipment stabilization [19];
- Influence of design: the design phase of machines, equipment and tools significantly influences the improvement of setup activities [20];
- Human factors: the human component is considered as implicit in the whole process, but not studied in more depth [21].

3.2. SMED implementation

The company where this study was developed is specialized in the manufacture of technical profiles for the civil construction area. The company contains in its structure 5 profiling machines, PF01 - Ceiling Profiling, PF02 - Aluminum Profiling, PF03 - Omegas Profiling, PF04 - LSF Profiling Machine, PF05 - Upright Profiling Machine and BL01 balancing machine producing pivots, each of these equipment's consisting of an unwinder, profiler, unloading table and packaging machine. The initial OEE calculation for each equipment, presented the following results: OEE below 50% measured in the PF02 and PF04 equipment indicates that we are in the presence of a low OEE value, characteristic in companies where there is no monitoring of their performance of production, and a typical OEE, characteristic in companies whose space for improvements is enormous. The three-dimensionality of OEE makes it easy to see that availability and performance are the lowest measured indices. For PF01, PF03, PF05 and BL01, the OEE values obtained were 60%. The typical OEE values to the companies that have good productivity are between 50-70% [14]. The world-class organizations have OEE values of about 85% [22].

3.2.1. Preliminary stage

This phase corresponds to the situation initially found, that is, where there is no distinction between internal and external setup (Table 1). It should be noted that some activities were already carried out with the equipment in operation, however, there is a notable lack of criteria, because there are certain activities that are sometimes performed when the equipment is in operation and other times they are performed when the equipment is stopped.

3.2.2. Stage 1

Stage 1 separates internal and external setup. In order to identify activities or other aspects of setup not previously identified. At this stage, small interviews were conducted with the operators responsible for the equipment. In this operation, the separation of internal and external activities, confirmed that of the total time consumed in setup about 55% of the time is spent in internal activities, representing external activities only 45%.

Table 1: Implementation of the preliminary stage

SEQUENCE OF ACTIVITIES	TIME RUN (Minutes: Seconds)	TIME OF ACTIVITY (Minutes: Seconds)	INTERNAL ACTIVITY	EXTERNAL ACTIVITY
1 - Switch off equipment	00:08	00:08	X	
2 - Remove sheet metal waste	00:17	00:09	X	
3 - Remove the safety part of the uncoiler	00:32	00:15	X	
4 - Close uncoiler	00:54	00:22	X	
5 - Go get raw material rolls to the storage location	04:26	03:32		X
6 - Remove plastic from the pallet and write a reference on rollers	06:22	01:56		X
7 - Place roller on uncoiler	08:12	01:50	X	
8 - Cutting tapes	08:31	00:19	X	
9 - Opening uncoiler	08:53	00:22	X	
10 - Place the safety part in the uncoiler	09:16	00:23	X	
11 - Remove plate roller reference	09:38	00:22	X	
12 - Manually engage the plate in the equipment	11:55	02:17	X	
13 - Connecting equipment	11:58	00:03	X	
14 - Removing sheet metal waste	12:06	00:08	X	
15 - Start work	12:09	00:03	X	
			06'41''	**05'28''**

3.2.3. Stage 2

In stage 2 the objective is to convert, as far as possible, the internal setup in external, that is, to start performing activities with the equipment in operation that until now were executed when it was stopped. At this stage, the classification of operations was revised to ensure that there are no external operations classified as internal. The external activities started to be carried out at the same time that the operator is in production and the organization of the tools used to open and close the machine uncoiler was improved (with 5S methodology [23]) so that the employee spent less time looking for them (Figure 2 and Figure 3), decreasing the time required in the internal activities from stage 1 to stage 2.

The sequence of the activities was reorganized (Table 2), and the operators start to take the raw material rolls of the warehouse (activity 5) and removed the plastic from the pallet (activity 6) when the equipment was still running.

Fig. 2 – Storage of wheels of profiling machine, before 5S

Fig. 3 – Storage of wheels of profiling machine, after 5S

Table 2: Implementation of the stage 2

SEQUENCE OF ACTIVITIES	TIME RUN (Minutes: Seconds)	TIME OF ACTIVITY (Minutes: Seconds)	INTERNAL ACTIVITY	EXTERNAL ACTIVITY
1 - Switch off equipment	00:08	00:08	X	
2 - Remove sheet metal waste	00:17	00:09	X	
3 - Remove the safety part of the uncoiler	00:32	00:15	X	
4 - Close uncoiler	00:54	00:22	X	
5 - Place roller on uncoiler	02:54	02:00	X	
6 - Cutting tapes	03:14	00:20	X	
7 - Opening uncoiler	03:27	00:13	X	
8 - Place the safety part in the uncoiler	03:47	00:20	X	
9 - Remove plate roller reference	04:00	00:13	X	
10 - Manually insert the plate into the equipment	06:03	02:03	X	
11 - Connecting equipment	06:08	00:05	X	
12 - Removing sheet metal waste	06:10	00:02	X	
13 - Start work	06:11	00:01	X	
			06'11''	**00'00''**

3.2.4. Stage 3

Stage 3 is characterized by the rationalization of all aspects of the setup, that is, it is intended to streamline both internal and external activities and simultaneously, as far as possible, eliminate the maximum number of operations. At this stage, an organizational improvement was performed by the rearrangement of the machine operators' tasks which allowed a collaboration of the operators of different machines in the process of the roll change, i.e., the roll change started to be made with the help of a second operator, reducing its duration by more than 20% (Table 3).

3.2.5. Stage 4

In stage 4, a new improvement was introduced to reduce mistakes and the probability of work accidents. This improvement also reduces the setup time (Table 4), allowing to increase production time.

Table 3: Implementation of the stage 3

ORDER OF ACTIVITIES	TIME RUN (Minutes: Seconds)	TIME OF ACTIVITY (Minutes: Seconds)	INTERNAL ACTIVITY	EXTERNAL ACTIVITY
1 - Operator 1 shuts off equipment and removes sheet wastage and Employee 2 removes safety part from unwinder and closes it	01:05	01:05	X	
2 - Operator 2 places roller in unwinder with operator guidance 1	01:53	00:48	X	
3 - Operator 1 places safety part in the unwinder	02:06	00:13	X	
4 - Operator 2 cuts the belts and operator 1 opens the unwinder	02:29	00:23	X	
5 - Remove plate roller reference	02:36	00:07	X	
6 - Operator 1 manually places the plate in the equipment	04:24	01:48	X	
7 - Connecting equipment	04:32	00:08	X	
8 - Removing sheet metal waste	04:49	00:17	X	
9 - Start work	04:57	00:08	X	
			04’57’’	**00’00’’**

Table 4: Implementation of the stage 4

ORDER OF ACTIVITIES IN THIS	TIME RUN (Minutes: Seconds)	TIME OF ACTIVITY (Minutes: Seconds)	INTERNAL ACTIVITY	EXTERNAL ACTIVITY
1 - Operator 1 shuts down the profiling machine and Operator 2 removes safety part and uncoiler closes on safety.	00:32	00:32	X	
2 - Operator 2 put the roll the uncoiler with operator 1 guidance.	01:47	01:15	X	
3 - Operator 1 inserts the safety part and open the uncoiler and operator 2 cuts the straps and removes reference from the sheet roller.	02:26	00:39	X	
4 - The 2 operators unroll plate until the entry of the profiling machine	02:37	00:11	X	
5 - The two operators glue the two plates with adhesive tape	03:15	00:38	X	
6 - Starting the machine	04:03	00:48	X	
7 - Remove sheet metal waste	04:08	00:05	X	
8 - Start work	04:22	00:14	X	
			04’22’’	**00’00’’**

It was implemented the adhesive tape in the changeover process, in order to join the roll plate that is finishing, with the new roll plate to be placed on the roll forming machine (Fig. 4 and Fig. 5).

Fig. 4 – Placing the adhesive tape to join the roll plate

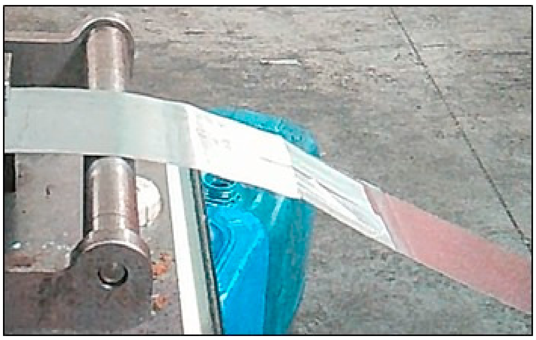

Fig. 5 – The plates attached with adhesive tape before entering

3.3. Results and Discussion

The final results of the SMED project are presented in Table 5. At the end of the project, the OEE was recalculated and the following results were verified: in the PF01 equipment, an OEE of 81% was obtained, representing a 10% improvement; in the PF02 equipment there was a 4% increase in OEE; in PF03 equipment there was an improvement of 10%, going from 73% to 83%; in the PF04 equipment there was one of the largest increases being an advance from 28% to 49%. In the PF05 equipment, the increase was 9%, increasing from 71% to 80%. In BL01 equipment there was an increase in OEE from 64% to 79%. These increases in OEE value are due to the significant improvement in the availability factor that has gone up in all equipment. The new OEE value of 80% obtained through this work is in line with those obtained by Sousa *et al.* [4] for two shifts analyzed in the production of cork stoppers, who found values between 55 and 76%. The values obtained are also in line with those obtained by Moreira *et al.* [24], which ranged from 72% to 75% when analyzing the printing industry. It can thus be observed that, in general, the existing competitiveness in the automotive components industry requires much more precise management of the production processes, leading to higher OEE. This can even be proven through the work developed by Guariente *et al.* [25], also in an automotive components industry, where the OEE obtained increased from 70% to 82% through improvements introduced in the maintenance procedures and management system, always taking into account the quality of the product [26-28], as well as the respect for the environmental [29-31] and safety rules [32-34] where new ideas are welcome [35-37]. Also Antoniolli et al. [38] has reported an improvement of the OEE by 16% mainly based in the application of standard work methodologies in a company manufacturing air-conditioning system for automotive industry.

Table 5: Results of the SMED project implementation

Stage	Internal Activities	External Activities	Improvement
Preliminary	06:41	05:28	-
1	06:41	-	05:28
2	06:11	-	00:30
3	04:57	-	02:46
4	04:22	-	00:35
			08’44’’

4. Conclusions

In this study, SMED methodology was implemented to the cold profiling process of a metalworking industry, in a population of five different profiling machines. The results of SMED implementation show a significative improvement of the equipment availability, resulting in an average OEE increase of 10,8%. These results, demonstrate that significative improvements can be achieved through SMED implementation, following the model presented in this work.

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