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## **AN INDUSTRIAL APPLICATION OF THE SMED METHODOLOGY AND OTHER LEAN PRODUCTION TOOLS**

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### **ABSTRACT**

This paper describes the improvement of the setup process of a mechanical press machine in the metal-mechanic area of an elevators company. The work results from a master thesis project conducted during a period of five months. The Single-Minute Exchange of Die (SMED) methodology and other Lean Production tools (5S, Visual Management and Standard Work) were applied to reduce the setup times observed at the beginning of the project. With the developed solutions it was possible to reduce setup times, work-in-process (WIP) and distances travelled by operators. Additionally, the setup operations were standardized and consequently the process has become more fast and intuitive for the operators. These improvements allowed the reduction of energy and materials consumption and, consequently, a decrease on the Greenhouse Gases' emissions.

**Keywords:** lean production, lean tools, setup process, SMED, eco-efficiency

### **INTRODUCTION**

Globalization has created the need for companies to increase their production flexibility, by producing in smaller batches. However, this type of production leads to a significant increase on the setup frequency. Thus, the ability to perform quick setup processes is widely acknowledged as an essential requisite to flexibility and small batch manufacturing (McIntosh et al., 2000). Lean Production aims to systematically identify and eliminate waste through continuous improvement, enabling increased flexibility and organizations' competitiveness (Womack et al., 1990). Within the Lean Production paradigm there is a huge range of tools and techniques (e.g. SMED, 5S and Standard Work) that can be applied by organizations to improve their performance, namely in terms of setup time. The SMED methodology consists of a set of techniques that enable the execution of setup processes in less than ten minutes (Shingo, 1985). During the last years several authors and organizations have discussed the relationship between Lean Production and eco-efficiency. Eco-efficiency is associated to the sustainable development and intends to provide more value with less environmental impact, which meets the Lean expression "doing more with less" (Moreira et al., 2010).

The project presented in this paper was developed in the context of a master thesis of the Industrial Engineering and Management master course at University of Minho. In this work it was analysed the setup process of a mechanical press machine, in the metal-mechanic area of an elevators company. The objectives of this project were: (i) implementation of a methodology to reduce setup times, (ii) increase of the production flexibility and (iii) standardization of setup activities. As the press machine works with a great amount of products, it was necessary to develop an ABC analysis to choose an important product for the

company – the results pointed out a product whose production requires three different setups. It was developed a methodology consisting of nine steps to analyse and implement the improvement solutions for each of the three setups through the use of several tools, including SMED methodology and other Lean tools. The eco-efficiency aspect was also considered.

This paper is structured in five sections. After this introduction, section 2 provides a brief literature review on Lean Production, SMED and eco-efficiency. Section 3 presents the industrial application of SMED in the company's mechanical press machine. Section 4 presents the main results obtained and their discussion. Lastly, in section 5 some conclusions about the project are outlined.

## LITERATURE REVIEW

With the global market increasingly competitive it is important the adaptation of companies by introducing new approaches to their production systems, in order to meet the needs and requirements of customers, namely short lead times and high quality of products. One possible approach to achieve these objectives is to adopt the Lean Production philosophy to revolutionize the way of thinking, regarding the production system performance.

The Lean Production concept has its origin in the TPS - Toyota Production System (Ohno, 1988). TPS was developed in the 1950s at Toyota, Japan, and its main mentor was the engineer Taiichi Ohno. The two pillars of TPS are Autonomation (or *Jidoka* in Japanese) and Just-In-Time (JIT) production. The first pillar corresponds to the productive equipment's capacity of stopping production whenever occurs an anomaly. The second pillar means producing only what is necessary, in the required quantity and at the right time. The main objectives of TPS are continuous improvement of processes and cost reduction through the elimination of waste (Monden, 1998). The concept of waste (*muda* in Japanese) is defined as any activity that does not add value to the product in the customer's perspective (Ohno, 1988).

The techniques used in the Lean philosophy are based on five fundamental principles (Womack & Jones, 1996): (i) create value for the customer, (ii) identify the value stream, (iii) create flow, (iv) produce only what is pulled by the customer, and (v) pursue the perfection by continuous identification and elimination of waste. Shingo (1989) considers seven types of waste: overproduction, inventory, waiting, defects, over-processing, motion and transportation. Lean Production provides a set of tools and techniques that can be applied to reduce those wastes, namely SMED, 5S, Visual Management, Standard Work and Value Stream Mapping.

The Single-Minute Exchange of Die methodology is a theory and a set of techniques that make it possible to perform the equipment's setup and changeover operations in less than ten minutes (Shingo, 1985). A setup or changeover represents the complete process necessary to change from the production of a product to the production of a different product, until it is achieved a certain production rate with quality (McIntosh et al., 1996). To accomplish JIT production and, consequently, a small-batch production it is necessary a quick setup process. This ensures that the flexibility of the response to the demand is adequate, as small batch production results in a significant increase in the setup frequency (McIntosh et al., 2007). Goubergen & Landeghem (2002) classify the different reasons for reducing setup times into three main groups:

- Flexibility – due to the large amount and variety of products and due to the reduction of the quantities requested by customers, a company must be prepared to quickly react to customers' needs;

- Bottlenecks capacity – especially in these cases, every minute lost is crucial. Setups should be minimized to maximize the available capacity for production;
- Costs minimization – production costs are directly related to the equipment's performance. With setup time reduction, machines stop during less time, thus reducing production costs.

The SMED methodology is a Lean tool that supports organizations in the reduction of setup times and in the elimination of wastes identified in the changeover operations. The implementation of SMED requires a previous analysis to clearly understand the changeover process, in order to know in detail each setup operation (Sousa et al., 2009). Shingo (1985) mentions that the setup operations are divided into two types: internal operations (which can only be performed while the machine is stopped) and external operations (that can be performed while the machine is operating). The application of this methodology consists of four distinct stages:

- Preliminary Stage - Internal and external setup not differentiated;
- Stage 1 – Separate internal and external setup;
- Stage 2 – Convert internal into external setup;
- Stage 3 – Rationalize the internal and external setup.

The reduction of setup time usually provides many benefits to the companies, e.g., reductions in terms of stock, WIP, batch size and movements, and, improvements on quality and production flexibility.

An important aspect that has been discussed throughout the last two decades is the relationship between Lean Production and eco-efficiency. Eco-efficiency is “The delivery of competitively priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impact and resource intensity throughout the life cycle, to a level at least in line with the Earth's estimated carrying capacity” (WBCSD, 1996). In this context, Moreira et al. (2010) present a study that shows that Lean has a positive contribution in the improvement of the environmental performance of production systems. More specifically, and related to this work, these authors give the example that the reduction of equipments' setup time, by applying the SMED methodology, contributes to reduce both overproduction and inventory. This means a consumption of less energy and materials while reducing the emissions.

## **INDUSTRIAL APPLICATION**

This project was carried out in the metal-mechanic area of an elevators company. The setup process of a mechanical press machine was studied. Due to the large quantity of existing products, and consequently of different setup processes, it was necessary to perform an ABC analysis to choose a representative product for the press machine. The chosen product requires three different setups: one to perform the cutting of the product and the other two to perform bending processes.

After a first analysis it was possible to identify some problems that affected the quality and efficiency of the process. Thus, the main problems registered were: high setup times; large amounts of movements made by the operator; lack of a standardized process; high quantity of stock and WIP; lack of space in the shop floor; and disorganization of equipment and materials. Therefore, it was decided to resort to the SMED methodology, together with other Lean tools (5S, Visual Management and Standard Work), in order to try to solve these problems. For this purpose it was created a methodology consisting of nine steps:

1. Initial observation: to identify the tools used during the setup, locations where the operator moves around and all other aspects involved in the process;
2. Dialogue with the operator: to identify potential problems in the setup;
3. Video recording: to register all the operations and movements during the setup;
4. Sequence diagram construction (current state): to describe each setup operation, register its duration and the distance travelled by the operator, and to classify the type of activity (operation, transportation, inspection, waiting or inventory);
5. Spaghetti chart construction (current state): to represent the movements that the operator performs during the setup process and to identify areas of greater affluence;
6. Stage 1 SMED application: to separate the internal and external setup;
7. Stage 2 SMED application: to convert the internal into the external setup;
8. Stage 3 SMED application: to rationalize the internal and external setup;
9. Analysis of results: to analyze the results obtained and verify the impact of the methodology implemented.

Note that the first five steps can be considered integral parts of the Preliminary Stage of the SMED methodology. However, it was decided to make this separation to better illustrate the sequence of steps used in this project to implement SMED.

After analyzing the initial setup of the press machine, in the Preliminary Stage, it was realized that all operations were executed as internal setup, since they were performed with the machine stopped. With the separation of the operations into internal and external setup (stage 1 SMED) it was possible to significantly improve the entire changeover process. The techniques used at this stage were the creation of a checklist, to indicate the information necessary for the setup execution, and the planning of the transportation of tools during the external period.

In stage 2 SMED it was used the technique of preparing operating conditions in advance by duplicating the die's upper base (Figure 1 (a)). With the existence of only one base, the operator was spending time removing that base from one die to another (with the machine stopped). By using two bases during the setup process, the machine's operator only has to remove the old die and place the new one in (with the upper base already assembled).

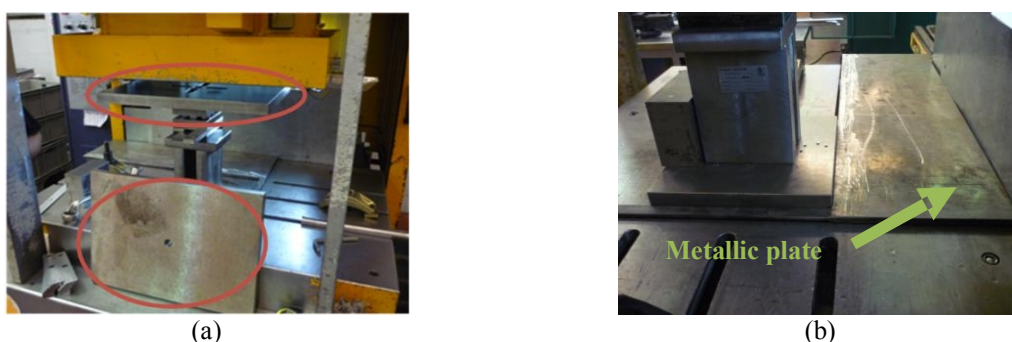


Fig.1 (a) Duplication of the dies' upper base (b) System of die centering

To rationalize the various aspects of the setups analyzed (stage 3 SMED), improvements in internal and external operations were distinguished. The external improvements do not act directly on the setup time reduction but can assist the operator in improving his tasks. In the case of internal improvements, two techniques were applied: utilization of quick clamps and elimination of functional adjustments. The die centering system was improved with the inclusion of a metallic plate, at the rear of the machine's table, which ensures a direct and immediate positioning of the die (Figure 1 (b)).

It was also improved one of the most critical aspects of the press machine; the process of configuring the machine, in which the operator was spending too much time whenever a new setup was performed. Due to lack of formation, when a new die was installed, it was necessary to manually adjust its parameters in the machine control panel. However, these operations had a long duration since various movements are made by the operator in order to validate information. Thereby, a technician from the press machine manufacturer was requested to minister training sessions to the operator. Each die was assigned to a number and its parameters' configuration was recorded in the machine control unit (configuration identified by the die number). Thus, the process has become much quicker as the operator only as to input the die number in the machine.

Regarding the external improvements, some aspects that influence the storage and transportation of materials and tools have been improved. To solve the problem of lack of space for dies' storage, a new rack was introduced, which also enables a better organization and identification of the dies. Another improvement was the introduction of a roller tool cabinet, in which were placed the necessary tools for the operator. The Lean technique 5S was also applied to improve the organization of the workstation. With this solution it was eliminated a rack where the tools were located in a disarranged way and away from the workstation, allowing to increase the workspace and reduce unnecessary movements. Figure 2 represents the improvement made.



Fig.2 Tools of the press machine (before and after)

Visual Management was also applied to facilitate the dies' identification process, by creating nameplates (Figure 3 (a)) and color labels (Figure 3 (b)), and to workspace delimitation, by placing yellow lines on the floor (Figure 3 (c)). These solutions mean that the operator spends less time in the searching for dies and the yellow lines avoid the workspace obstruction.

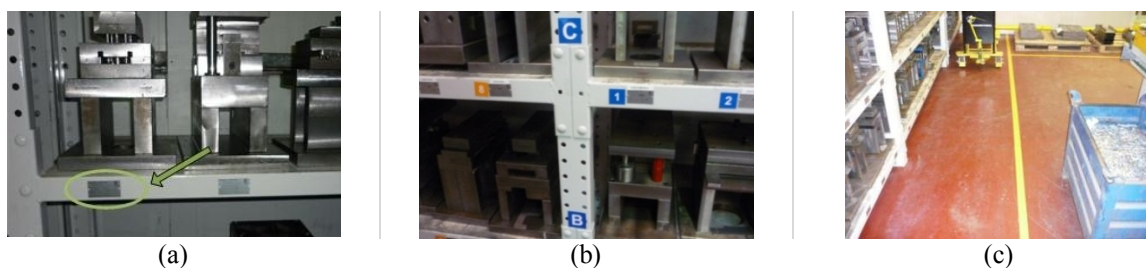


Fig.3 (a) Dies nameplates (b) Color labels (c) Yellow lines on the floor

To finalize the press machine SMED project, the standardization of the three setup processes was conducted. To this end, a Standard Work Combination Sheet (SWCS) was created for each process, with details of each operation.

### ANALYSIS AND DISCUSSION OF RESULTS

The SMED methodology was applied in the press machine to one of the most representative products, which involves three different setups. The results were, somehow, different for each type of setup. Table 1 shows the results obtained for the setup times in each SMED stage.

Table 1 Improvements obtained in the setup time

Setup	Preliminary Stage (min)	Stage 1 (min)	Stage 2 (min)	Stage 3 (min)	Improvement (%)
1	21.65	17.50	16.28	7.57	65
2	24.17	18.95	17.13	7.93	67
3	19.10	17.38	15.45	9.05	53

The SMED objective of achieving a single digit value was reached for all the cases analyzed. Another improvement attained was the reduction of operator's movements during the setup process. Table 2 represents the results obtained for the distances traveled by the operator in each stage of SMED.

Table 2 Improvements obtained in distance traveled

Setup	Preliminary Stage (m)	Stage 1 (m)	Stage 2 (m)	Stage 3 (m)	Improvement (%)
1	102.0	26.1	26.1	22.5	78
2	87.3	42.5	42.5	38.9	55
3	95.4	54.1	54.1	52.3	45

Figure 4 presents examples of spaghetti charts to demonstrate the difference between operator's movements before and after the improvements. Therefore, it is possible to verify that fewer movements are performed during the internal setup, allowing a reduction in the machine downtime. The operations such as getting tools and materials from the rack and from the car are now performed during the external setup by another operator.

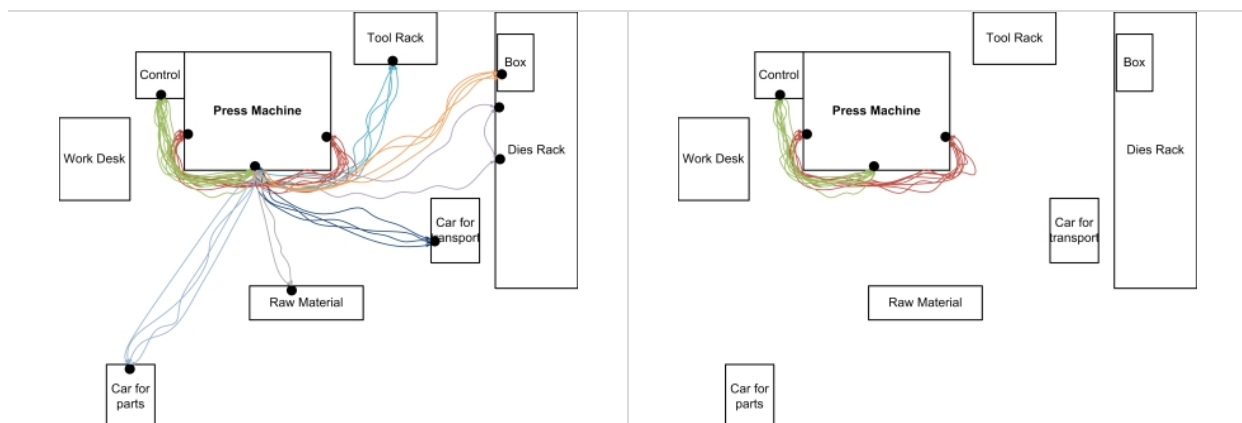


Fig.4 Operator's movements during the internal setup (before and after)

By reducing setup times it was possible to reduce the batch sizes for the product under analysis. This aspect was very significant to achieve an important objective for the company, which is the WIP reduction on the shop floor. For the product in question, the number of parts in boxes is 400 units. However, the operator was producing twice (800 units) to reduce the setups frequency, creating large amounts of WIP and consequently increasing the occupied

space. Thus, by reducing the setup times in over 50% for each of the three analyzed cases, it is now possible to produce only the necessary quantity, i.e. the amount indicated on the box (400 units). Table 3 compares this two situations. With the reduction of the batch size it was possible to reduce the WIP quantity from 12.8 days to 6.4 days.

Table 3 Improvements obtained in work-in-process

Parts in boxes	Daily Demand	Stock (days)	Improvement (%)
800	62.50	12.80	50%
400	62.50	6.40	

In this work, setup processes were standardized, allowing the operator to perform the tools exchange always in the same way and spending a similar time. This contributes to an improvement in production planning and resources management. The implementation of the SMED methodology and other Lean tools allowed the creation of simple and effective setup processes, reducing the efforts required by the operator. The organization of the press machine workspace was improved, as the setup tools were properly ordered and identified.

To analyze the advantages of implementing the SMED methodology in the press machine it is shown in Table 4 the economic impact obtained in the setup processes.

Table 42 Economic impact of the setup times' reduction in the press machine

Average initial setup time (min)	21.64
Average final setup time (min)	8.18
Gains per setup (min)	13.46
Average number of daily setups (units)	3
Production time gains per day (min)	40.38
Working days in a year (days)	242
Production time gains per year (min)	9771.96
Production time gains per year (h)	162.87
Cost per hour of the press machine (€)	10
Gains per year (€)	1628.70

Thus, it is estimated that, by reducing the setup times it is possible to achieve gains around €1628.70 per year. The adoption of Lean Production tools has also promoted production cleanliness to achieve the Lean-to-Green relationship. The setup reduction allows the consumption of less energy and of fewer materials, which could increase the machine's useful time, working only when necessary.

## CONCLUSION

This study shows that the SMED methodology can be effectively applied to reduce setup times. Together with other Lean tools (5S, Visual Management and Standard Work) this methodology was implemented in a mechanical press machine of an elevators company, in the context of a master thesis project in Industrial Engineering and Management. With the identification of problems for the setup processes analysed, it was possible to develop improvement solutions, following a nine-step methodology created during the project.

The main results achieved were reductions ranging from 53% to 67% in setup times, 45% to 78% in distances travelled and 50% in terms of WIP. In addition to these improvements, the setup processes were standardized (with the application of Standard Work) and, by using 5S and Visual Management tools, the workspace became more organized and enjoyable for the operator, with the tools and equipment strictly necessary and properly identified. With this SMED project gains about €1628.70 per year were accomplished. Finally, it was realized that

these solutions can bring a positive effect to the environment, reducing ecological impact and resource intensity, in order to achieve a Lean-to-Green relationship.

### **ACKNOWLEDGEMENTS**

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