

Combining SMED Methodology and Ergonomics for Reduction of Setup in a Turning Production Area

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ABSTRACT

The aim of this study is to prove that it is possible to reduce the setup time and improve ergonomic conditions at the same time. This research took place in a turning production area of a metallurgical factory where workers' complaints due to shoulder pains and tendinitis were high, due to the awkward postures and forceful hand exertions to perform the manual tasks. Moreover, the high setup time of 105 minutes caused productivity problems and delays for customers. Through the SMED tool and increasing ergonomic conditions, the setup time was reduced 46% and the MSD risk also decreased. This study demonstrated that ergonomic condition improvements considered in a lean process help in the achievement of good results and it is very important to consider ergonomic conditions at the project phase, otherwise changes in the equipment could be very expensive, and difficult to justify.

Keywords: SMED Methodology, Lean, Ergonomics, Musculoskeletal Disorders.

1. Introduction

Companies frequently find techniques and tools to enhance productivity and quality for success in the long-term in order to maximize competitive advantage. To date, lean manufacturing principle is one of the successful improvement concepts that have been applied to eliminate waste and non-value added activities that occur in many companies [1].

Market's acceptance of products and services depends now not only on their price, but also on their quality, on-time delivery, variety and volume flexibility. The required capabilities needed to achieve the above purposes have been developed through the implementation of various technologies and work philosophies that accomplish high levels of waste reduction, integration and coordination among processes. One of the basic, and fundamental programs suggested, consists on the setup reduction in the shop floor [2].

According to [3], this is a key program to increase production capacity utilization, and hence productivity, and at the same time lifting the level of flexibility of the plant in terms of volume and variety of products.

Lean manufacturing dedicates a particular attention to setup time reduction, in order to get rapid changeover of dies and equipment. In 1985, Shigeo Shingo introduced his methodology, which was later to be widely known as Single Minute Exchange of Dies (SMED). Nowadays, SMED is vital because it allows for the reduction of setup and fine-tuning time that has a direct impact on productivity and production efficiency [4]. Reducing setup times means that productivity is affected in a controlled manner and to the least degree possible, which becomes key when

a company manufactures a wide range of products. This methodology provides a rapid and efficient way of converting a manufacturing process when product changes [5].

Unfortunately, lean processes can make jobs highly repetitive, while eliminating critical rest time for employees. The repetitive jobs take their toll on employees as stressful postures and high forces are repeated over and over throughout the day. In the long run, the financial savings from the productivity gains and quality improvements are used to pay for the higher cost of workers' compensation claims for musculoskeletal disorders (MSDs) [3].

With regard to Europe, the data emerging from the 6th European Survey on Working Conditions in 2016 [6] reports that it is clear that posture-related risks— in particular, repetitive hand and arm movements – are the most prevalent and musculoskeletal disorders are one of the most common work-related complaints, affecting millions of workers and costing billions of euros to employers. Some 34% of women are exposed to such movements ‘all or almost all of the time’— two percentage points more than men. Ergonomic assessment of Work-Related Musculoskeletal Disorders (WMSDs) involves the evaluation of risk of developing a range of disorders to muscles, nerves and joints, primarily to the upper limb and low back, associated with occupational tasks. REBA is one of the most popular and widely used observational ergonomic assessment tools in various industries and services. [7].

The present study took place in a turning production of a metallurgical factory that produces bath and kitchen taps area, where absenteeism rate and workers’ complaints due to shoulder pains and tendinitis were high, due to the awkward postures and forceful hand exertions to perform the manual tasks.

The company management is interested in reducing the total setup time as part of an operations strategy to improve productivity and order delivery time. In the initial situation the setup time took an average of 100 minutes and was performed two times per machine, one per shift. Each operator being responsible for 3 machines and doing on average 3 setups per workday.

The research question of this study was: would it be possible to reduce the setup time and improve ergonomic conditions at the same time?

2. Methodology

This research will be conducted by a case study research. According to [8] a case study should be defined “...as a research strategy, an empirical inquiry that investigates a phenomenon within its real-life context.” Following this key idea, the case study, as a research methodology, helps to understand, explore or describe a given system/problem in which several factors are simultaneously involved, in a real context.

Through the application of the SMED methodology, along with ergonomic analysis, various interventions took place with the purpose of reducing setup times and increase ergonomic conditions.

The first step was the election of a multifunctional team, including operators, to analyze the processes of the production area and evaluate the initial situation in terms of ergonomic conditions and productivity. Regarding ergonomic conditions, the team chose a postural analysis system - Rapid Entire Body Assessment (REBA) - to assess the level of MSDs risk because it provide a scoring system for muscle activity caused by static, dynamic, rapid changing or unstable postures [9], that fits well to the case study.

After the initial situation analysis, the team suggested some modifications in order to improve ergonomic conditions and reduce the setup time.

After the implementation of the suggested improvements, the team measured both the setup time and the ergonomic conditions, and compared the attained results with the base scenario.

2.1 Ergonomic Assessment

REBA was proposed by Hignett and McAtamney (2000) in the UK as a requirement observed within the range of postural analysis tools, specifically with sensitivity to the type of changeable working positions.

REBA is the ergonomic assessment tool used to evaluate musculoskeletal disorders (MSDs) and the risks associated with occupation tasks. The rapid upper limb assessment method (RULA) method is similar to REBA but is limited to the upper body [10]. REBA adapts better than RULA to highly varied workstations. This can be attributed to the development of RULA within a specific research context that makes it unreliable when applied in a different context [11]. REBA provides a quick and easy measure to assess a variety of working postures for risk of WMSDs. It divides the body into sections to be coded independently, according to movement planes and offers a scoring system for muscle activity throughout the entire body, stagnantly, dynamically, fast changing or in an unsteady way. REBA also gives an action level with a sign of importance and requires minor equipment: pen and paper method [9], [12].

Table I depicts the REBA action levels.

Table 1. REBA action levels

Action level	REBA score	Risk level	Action
0	1	Negligible	None necessary
1	2-3	Low	May be necessary
2	4-7	Medium	Necessary
3	8-10	High	Necessary soon
4	11-15	Very High	Necessary NOW

The team decided to assess the level of WMSDs risk of the four most critical postures regarding ergonomic conditions:

- Posture 1: Replacement of machine gutters;
- Posture 2: Use of work tools whose handles are poorly ergonomic;
- Posture 3: Difficult access to the machine;
- Posture 4: Machine programming.

The choice was made taking into account the feedback from the operators.

2.2 SMED Methodology

The key idea of lean is “doing more with less”, where less means less space, less inventory, fewer resources, among others [13]. As shown by [14], setup time reduction is a key initiative of lean manufacturing. The idea that setup time could be reduced significantly was recognized in 1985, when Shigeo Shingo developed a methodology for that purpose in Toyota.

Setup time has been defined as the time taken from the production of the last item of a product lot to the production of the first item of the next product lot. This definition has been enriched afterwards by [15]. This new definition is described in Figure 1.

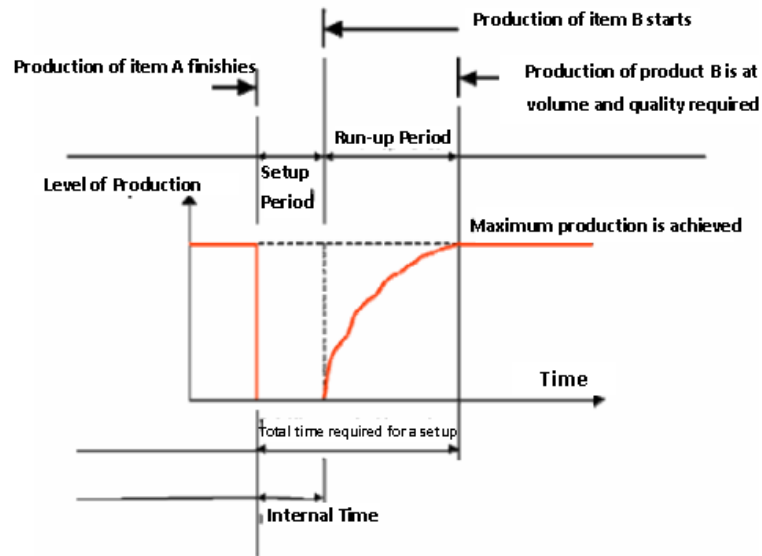


Figure 1. Description of Setup time [6]

The initial stage consisted of mapping all the activities required to perform a setup. This was performed by using a video recording to collect activities and times data.

Then, the first step had the objective of identifying and separating activities that are internal and those that are external. Internal and external activities are defined as:

Internal time: It is the time taken for setting up while the machine is not running or operating.

External time: It is the time period required to perform setup related activities before and after carrying out the setup period.

This step intended to transform internal activities into external ones.

The second step was conceived to further simplify internal activities. The design of devices, the automation of activities and the coordination and synchronization of operators are activities commonly implemented at this stage. Finally, the last step, aimed to simplify external activities. Figure 2 depicts these steps in diagram format.

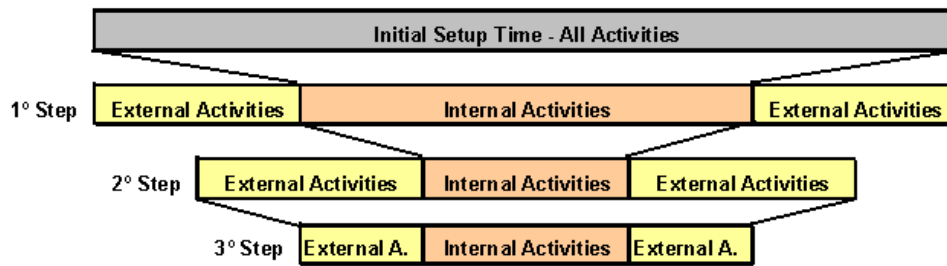


Figure 2. SMED steps diagram

3. Results

3.1 Ergonomic Conditions

Regarding posture 2 ergonomic conditions, one of the taken measures was the replacement of the tool called “Umbrako”, which was far from being ergonomic, by another one which was more ergonomic and agile, called “Ergonomic T-handle” wrench.

This improvement resulted in a productivity gain of 23% in this operation, through the reduction of the time needed to perform the activities of tightening and loosening screws.

Figure 3 depicts this tool change.



Figure 3. Tool change: “Umbrako” for “Ergonomic T-handle”

This ergonomic improvement reduced the REBA score from 7 to 5.

The team also proposed to change this manual tool to an automatic one. This proposal would increase productivity and decrease ergonomic risk through the reduction of the forceful hand exertions to perform this manual task. However, this idea was not accepted because it was considered a high investment.

Another ergonomic improvement was the implementation of a tray cart in order to eliminate the trunk flexion during the activity of replacing the rails of the machine – posture 1.

Figure 4 depicts both postures: before and after the implementation of the tray cart.

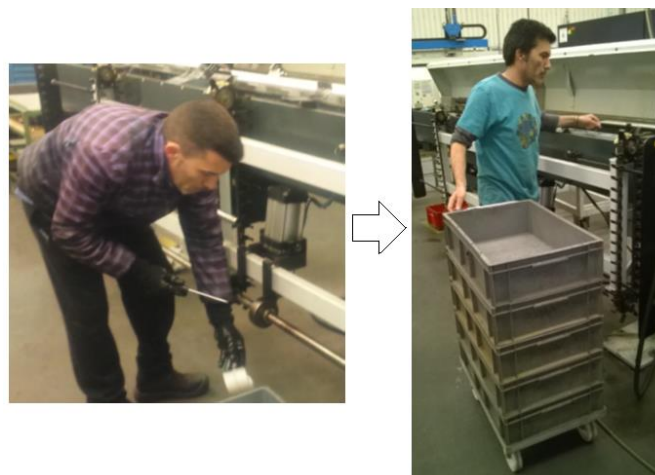


Figure 4. Operator performing the activity of replacing the gutters from the machine before and after the implementation of the tray cart (Posture 1)

After this ergonomic improvement the physical MSD risk was reduced from very high to low. Furthermore this improvement resulted in a 24% increase in the productivity of this operation.

Table II Depicts the REBA score of the initial situation and the situation after the ergonomics improvements for each segment and the correction factors. Table III summarizes the productivity gains and the final REBA score of the initial situation and the situation after the ergonomics improvements described above.

Table II. *REBA score of the initial situation and the situation after the ergonomics improvements*

Segment and Correction Factors	Posture 1 REBA Score		Posture 2 REBA Score	
	Before	After	Before	After
Trunk	5	2	2	2
Neck	3	2	2	2
Legs	3	1	1	1
Upper Arms	4	1	3	3
Lower Arms	2	1	1	1
Wrists	1	1	3	3
Coupling	-	-	2	-
Activity Score	1	1	1	1

Table III. *Summary of the productivity gains and the Final REBA score of the initial situation and the situation after the ergonomics improvements*

Posture	REBA Score		Operation Time (min)	
	Before	After	Before	After
1	12	3	6.6	5.0
2	7	5	2.4	1.8

The team also analyzed two other awkward postures, one related to the difficult access to the machine and the other related to the access to the machine controls, which are so high that force arm lifting above a 45° angle for a long period of time (about 62 minutes of the 105-minute setup time).

Figures 5 and 6 depict the awkward postures to perform the programming activity and the machine access, respectively.



Figure 5. *Programming activity (posture 4)*

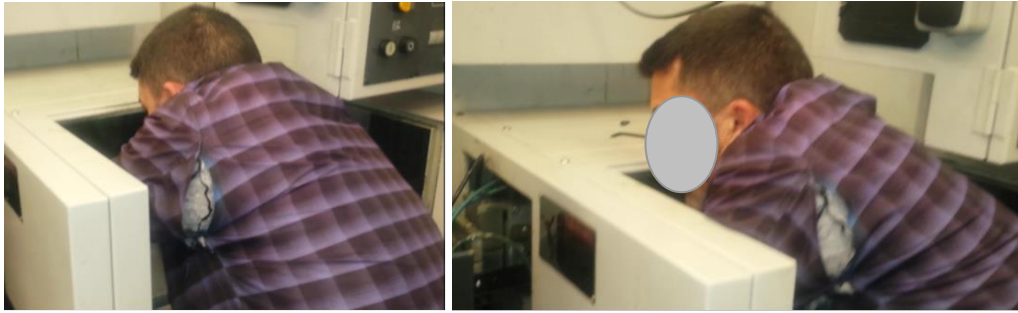


Figure 6. Difficult machine access (posture 3)

These postures, trunk flexion and arms above 45° had a REBA score of 10 and 5, respectively. That means that the posture 3 had a high level of MSD risk and the posture 4 a medium level of MSD risk. The team proposed several machine changes to solve these ergonomic problems, such as lowering the command box, but again, these proposals were not accepted by the company top managers due to the high investment.

3.1 SMED Study

Regarding the SMED tool, the first step was filming all the setup activities. Then, the team got together to analyze in detail all the activities. They identified the internal activities that could be external, such as data registration, part of the machine programming and the delivery of the ok part plus gauge (from the previous setup) to the quality control department. This change reduced the setup time from 105 to 85 minutes and the number of internal activities from 84 to 71.

The next step was the optimization of the internal activities through the implementation of some measures, such as, the elimination of transport and movement of tools now within reach, identification of the activities that could be performed simultaneously by 2 operators, etc... We can also consider the ergonomic improvements at this stage, as well as other measures to simplify the internal activities. All of these optimizations resulted in a reduction of the number of the internal activities from 71 to 43 and, consequently, a setup time reduction of from 85 to 57 minutes.

The last step was the simplification of the external activities. The reduction of several movements and transport of tools was one of the measures taken at this stage. As well as the simplification of the registration activity through the elimination of useless data filled in by the operator. Four external activities were eliminated at this stage as well as the time to perform the 9 left.

Table IV summarizes the results of the number and the time spent in each type of activities during all the steps performed.

Table IV. Summary of results of the number and time spent in each type of activities

	Internal		External		Simultaneous		Eliminated	
	Time	Number	Time	Number	Time	Number	Time	Number
1 Step	85	71	20	13	-	-	-	-
2 Step	57	43	20	13	9,5	18	18.5	10
3 Step	57	43	14.4	9	9.5	18	24.1	14

At the end, the required time changed from approximately 105 minutes to 57 minutes, which meant a reduction of 46%.

4. Conclusions

Nowadays, it is very important to consider productivity measures while implementing improvements in the shop-floor. On the other hand, jobs are more repetitive leading to musculoskeletal disorders, increasing absenteeism and reducing productivity. The results of this study demonstrated that,

according to the evaluation carried out using the REBA method, the level of MSDs risk was reduced (ex. REBA risk level of the Posture 1 was reduced from very high to low). That means that condition' improvements considered in a lean process helps in the achievement of good results.

On the other hand, several measures proposed for improving the production machine, from an ergonomic point of view, to prevent the occurrence of the WMSDs were not accepted because, some decision-makers do not view ergonomics as an investment, but rather as an expense.

There is no doubt that it is very important to evaluate the ergonomic conditions at the moment of purchasing a new production equipment, otherwise changes in the equipment could be very expensive, and difficult to justify.

Lean tools as visual management, such as 5S and standardization were very important in the achievement of these results. Also important was the separation of production tasks from logistics and the operators' involvement since the beginning of the process.

The team was very pleased with the results and a new SMED action is already planned in another machine setup.

The success of this SMED action was achieved due to the involvement of the operators from the beginning. They realized that it is possible to be more productive while improving the quality of life at work and they are looking forward the next action.

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