Increased efficiency of a metalworking SME through process redesign using SMED, Poka Yoke and Work Standardization

Anell Huertas-Reyes, B.Eng.[1], Stefany Quispe-Huerta, B.Eng.[2], Claudia Leon-Chavarri, M.Eng.[3], and José Velasquez-Costa, PhD[4]

[1234]*Industrial Engineering Program, Peruvian University of Applied Sciences*, Lima, Peru,

[1]u201717398@upc.edu.pe, [2]u201711311@upc.edu.pe, [3]pcincleo@upc.edu.pe, [4]pcinjosv@upc.edu.pe

Abstract– After the difficult period during the year 2020, the metal-mechanic sector has been characterized by its high participation in the Peruvian GDP. However, by not having established working methods, productivity in the production process is affected and in comparison, at national level, companies in other sectors have an efficiency greater than 80% in their processes, which generates an increase in competition. This article intends to incorporate to the literature through the combination of Lean Manufacturing tools: The SMED tool will be used for the reduction of Set Up times; Poka Yoke, to avoid human errors through a mold that will prevent defects in the bending machine and through the standardization of work, to establish best practices in the various manufacturing processes of metal racks. The main result of this proposal is the reduction of man-hours lost in non-value generating activities to increase efficiency in the analyzed processes of the organization.

Keywords-- Productivity, metalworking, work standardization, SMED, Poka Yoke, Set Up time.

I. Introduction

Despite having faced the economic and health crisis in the context of Covid-19, the metal-mechanic industry was affected, reducing its production by up to -73% during 2020. However, according to the last national report, growth and recovery of the manufacturing sector of metal products for structural use was observed at 66.25% [1]. In the development of various sectors, where it is necessary to make the most of the limited space available in the warehouse and facilitate the handling of products with greater access and ease, metal racks are used [2]. However, the main problem referred to in this article is the loss of productivity in the production plant.

During the literature review, this problem is referred to as Productivity Loss or, also, Low Productivity with origin in the loss of man-hours. Other organizations in the same sector present, on average, efficiencies between 90 - 97% after having used several lean manufacturing tools to solve the occurring incidences. However, there is not enough literature related to the application of more than one tool focusing on the critical processes of painting, bending, and stamping. The economic impact of the problem is the loss of opportunity for increased production of metal racks since resources are not used and rather the planned man-hours are invested in unproductive activities and reprocesses. Several authors refer as a solution to the implementation of Lean Manufacturing tools such as SMED to reduce Set Up times [3-5]. Likewise, Poka Yoke is pointed out to prevent reprocesses and loss of products in process that occur due to human errors during the use of machinery. [6]. Finally, to standardize the improvement procedures applied, the standardization of operations is proposed, and measurements are carried out by means of observation cards and redesign of the activities. [7-8].

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The company in which this research is carried out is a metal-mechanical SME that produces metal racks. There is evidence of unproductive times during the set-up of the diecutting process. Regarding the painting process, this is not yet standardized, which causes the loss of man hours and defective products when carried out according to erroneous procedures by the operators. Mention is also made of the bending process, in which there are quality nonconformities. It is expected that the proposed model will be very useful for any organization that wishes to increase its productivity and from which the associated production costs and product delivery times will be reduced, thus improving the company's competitiveness, and increasing the perceived profits.

This article is divided into five sections: First, it comprises the general level summary of the content. Second, the introduction is described, highlighting industry data, the type of product manufactured and the tools to solve the problem. Third, the state of the art is presented. Fourth, the contribution of the proposal is detailed. Finally, the validation of the proposed model and conclusions are presented.

II. State of the Art

A. *SMED for the reduction of set-up times*

The SMED methodology is considered a tool belonging to lean manufacturing for the reduction of set-up times that provides positive and beneficial results to the productivity of acompany.

This methodology is applied starting with a study of the set-up process considered as critical, whose time must exceed 10 minutes to be considered as high or critical; the activities of this process are classified as internal or external, depending on the activities, the internal ones must be transformed into external ones to be eliminated or reduced as much as possible to achieve the reduction of the total time [11].

In the case of the research conducted by Sousa, the problem is focused on the configuration processes of a capping machine; in order to identify the main problem and implement improvements to the process, the SMED methodology is applied to understand, analyze and create efficient conditions for the work, thus obtaining a reduction of up to 43% of the Set Up times that would provide the company with the flexibility and quality improvement it was looking for as an organization [4]. Among other results obtained in different investigations, Set Up time reductions of 40 and 57% are obtained for the Set Up processes of two machines studied, a reduction of more than 15% of Set Up time by modifying movements and times by activity of three operators, and an increase in production of up to more than 50% [9-11]. Several authors conclude that applying the SMED tool guarantees the flexibility and optimization of production processes by reducing downtime caused between set-up times. On the other hand, the solution proposals from the SMED application are focused on eliminating the external times, allowing a redesign of the processes, but, also, the human or worker must be considered as an implicit component if the optimization of this set up time is sought.

B. *Poka Yoke to minimize rework and defective products*

The Poka Yoke system is mostly used for the correction and prevention of human errors to ensure the elimination or reduction of defective products caused by these errors; its application starts from the identification of the problem and its causes to design the Poka Yoke mechanism to be used according to the conditions of the problem and the work [7].

The implementation of a Poka Yoke device, for a case focused on the welding station of a metalworking company, aims to ensure the progress of the production of orders and meet customer requirements by identifying the quality problems that customers themselves demand. This study showed satisfactory results of reduction of claims for defective products from 34.7% to 5.3%. [6]. Likewise, for the welding process in another manufacturing company, a Poka-Yoke interdiction device is implemented that detects and stops the operation if the welding assembly part is misaligned or if the machine in question wobbles, thus avoiding reprocessing or waste of raw material in the following operations. [18] On the other hand, in the molding machine of a plastic company, the application of a Poka Yoke system meant the process capacity increased from 0.63 to 1.65. Although the solution to the metal bending process in question has not been addressed, several authors agree on the implementation of the error preventive device to contribute to the improvement of the quality of the manufactured products.

C. *Standardization of work in the production processes*

Work Standardization is applied with the objective of achieving the optimization of the use of resources and an increase in production efficiency by eliminating what are known as non-value activities and bottlenecks that are the causes of low productivity and possible production shutdowns within organizations [8].

There is currently a lack of research articles covering specific metal-mechanical processes. For a manufacturing company, the use of Work Standardization was proposed to obtain higher profits by optimizing productivity; through the identification of activities and their value analysis, waste and non-value activities were eliminated, which generated a process control through a new perspective that allows continuous process improvement since activities with value, transparent and fluid are obtained [15]. Likewise, the authors analyze crucial information about the company such as the distribution of workstations, the production process, critical points in production, among others; study of times and movements, where significant improvements of 40 to 45.90% reduction of cycle times are subsequently presented, through the study of times and movements, and the subsequent redesign and delimitation of operations. [8]. In other investigations, a standardization of the work focused on the man-machine relationship of a process that causes low productivity in the company is carried out; starting with the analysis of the process and continuing with diagrams that detect the dead times in relation to man-machine, finally, a solution proposal was implemented that consisted mainly of a redistribution of machines and the implementation of support furniture that would improve the work of the operator, thus obtaining a reduction of up to 41% of dead times [19]. From the same, it incorporates observation taking sheets based on man-machine activities, standardized operations and a combined worktable representing a 12% increase in production [13].

In the present research, the use of Work Standardization is proposed to achieve a defined process with a shorter average execution time that, through the modification, reclassification, and definition of activities, eliminates or reduces defective products due to erroneous procedures and, finally, increases the productivity of the organization.

III. CONTRIBUTION

The proposed model shown in Figure1 is built based on what has been pointed out by the authors according to the typologies of implementation of lean manufacturing tools to increase the productivity of the company. Likewise, it is based on the optimization and delimitation of procedures through the redesign of processes and their integration. Considering the previously analyzed literature, it will be compared with the proposals found in the literature, to validate its effectiveness in a problem that affects several Peruvian SMEs. [15].

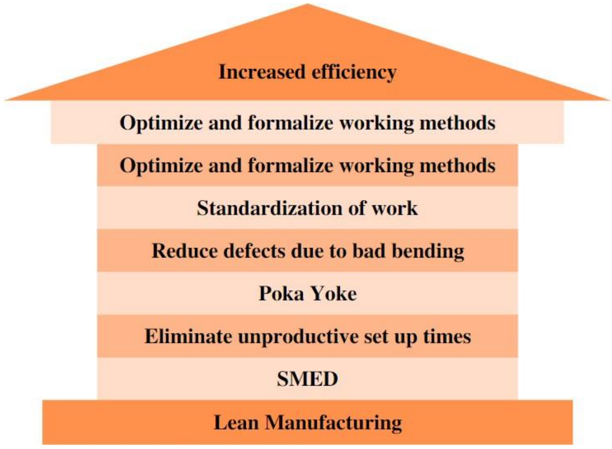

Fig. 1. Proposal model

The proposed model consists of three components, the first component refers to eliminating unproductive times. The second component aims to reduce non-conformities resulting from errors in the bending area and the last component aims to optimize and formalize work methods.

For the first component, the SMED tool is presented as a solution technique, also applied during the studies of [4,9-11] in the evaluation of unproductive set up times in the cutting, painting and die cutting processes. For this, it is necessary to perform the analysis of internal or external activities performed by the operators, with the objective of eliminating the latter type of activities and externalizing the internal activities. For this solution method, we propose the implementation of a new area, close to the die-cutting area, to store the set-up tools; also, a piece of furniture will be incorporated to help organize these tools, together with the use of visual aids to guide the operators.

On the other hand, for the second component, the implementation of a Poka Yoke system is proposed to reduce nonconformities caused by operator - machine errors as detailed [6, 14,17] in the bending process. In this component, it is required to analyze the workstation, design and implement a Poka Yoke device, which will be placed between the bending machine and the support surface. It also incorporates, as part of the operations performed by the operator, the checking procedure as a method of controlling and monitoring the performance of the device.

Finally, for the third component, the Standardization of the work in the painting process is selected to optimize and formalize the work methods performed. For this, it is necessary to determine the activities necessary for an optimal process flow. Likewise, through the preparation of procedure sheets, flow charts and visual aids, it is proposed to train the operators to formally define the actions of the process.

The sequence of the solution to the problem is detailed previously taking into account the diagnosis of the painting, cutting and die-cutting processes, from this, they will be redesigned taking into account through the analysis of valueadded activities, whether or not they add value to the processes and a storage cabinet for set up tools will be incorporated previously taking into account the availability of space in the facilities and the capacity needed. Next, for the implementation of the Poka Yoke system, it is required to be designed according to the measures between the support surface and the machine in question, also, the procedure of preoperation verification of the machine is incorporated. After the analysis of the activities carried out in the first step, the optimal painting process will be established, and it will be necessary to elaborate procedure sheets and train the operators about the formal process.

The main advantages of the proposed model are its low cost and easy implementation in the SME sector under study. In comparison with other proposals found in the literature, which only theoretically define the solution but do not find optimal numerical results, the model of this study proposes the increase of efficiency in more than one process necessary to produce metal products through the redesign of the processes and the prevention of defective products during its operations.

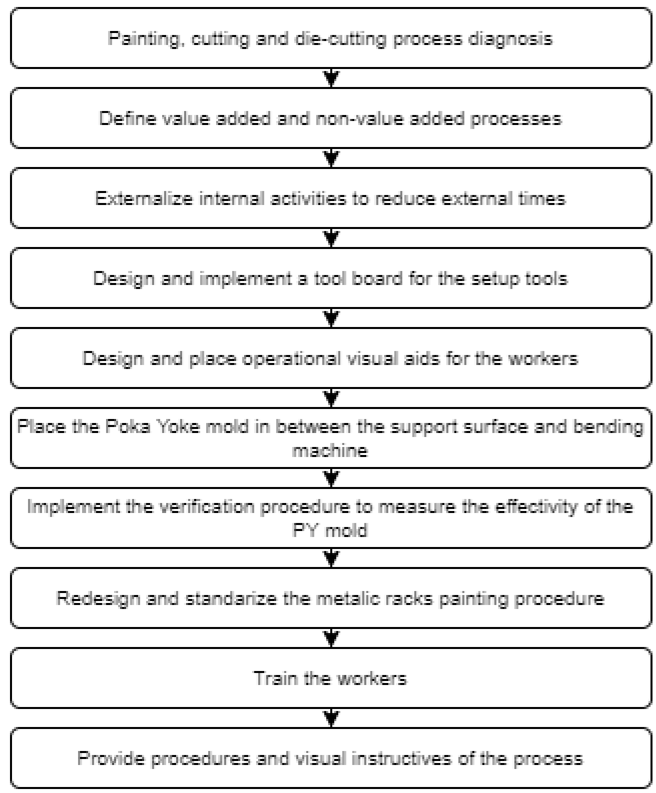

Fig. 2. Implementation process

A. *Detailed view*

The SMED tool was selected because of its simplicity to analyze activities and improve the time available to perform value-added activities in the production processes. Likewise, when analyzing the occurrence of defective products in the bending area, the Poka Yoke tool is used, in which it is required to evaluate and analyze the workstation, given that for the design of the mold it is necessary to evaluate the exact dimensions and the place where it will be located, which will allow reducing quality nonconformities and errors. In the case of work standardization, from this implemented phase, an optimal process flow will be obtained with the objective of reducing the cycle time and the number of defective products in the painting process.

B. Process View

The process flow is shown in Figure 2 for the implementation of the proposed model.

C. Indicators View

To evaluate the impact of the implementation of the proposed model, the following productivity management indicators are established:

1) *Process time efficiency*

$$EVA\ (\%) = \frac{Value\ added\ time}{Production\ time}$$

2) *Number of defective products*

$$DP\ (\%) = \frac{Deffective\ racks\ produced}{Total\ racks\ produced}$$

3) *Efficiency in the manufacture of metal racks*

$$Efficiency\ (\%) = \frac{Real\ production\ of\ rack\ batchs}{Estimated\ number\ of\ rack\ batchs}$$

IV. Validation

The validation of the proposed solution to the problem addressed in this research was carried out using Arena Simulation software. It was decided to perform a simulation of each process under study, thus obtaining three different simulations.

Being the first component of the solution model the elimination of unproductive set up times, the first solution is the application of the proposed solution with the SMED tool in the set-up process. The concept to be carried out is shown in Figure 3.

Fig. 3. Simulation of the improvement proposal for Die Cutting Set Up

Thanks to the redesign of the die-cutting process set-up process, by simulating the new process, a 35% reduction in process time is obtained.

Following this simulation, the simulation was carried out for the bending process, to start with the second component, which is to reduce defects due to errors in this same area. Figure 4 schematizes the proposed solution.

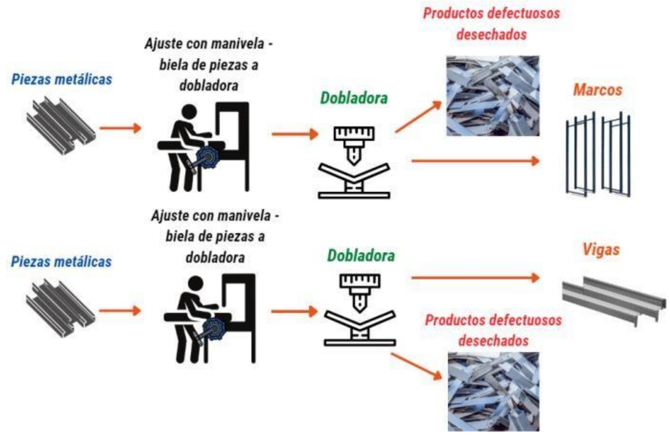

Fig. 4. Simulation of the improvement proposal for the Bending

Carrying out the respective simulation of the application of the Poka Yoke tool in the bending process, the percentage of defective products decreased to 0.80%.

As a last simulation, there is the solution proposal for the painting process by implementing the solution tool (see Figure 5).

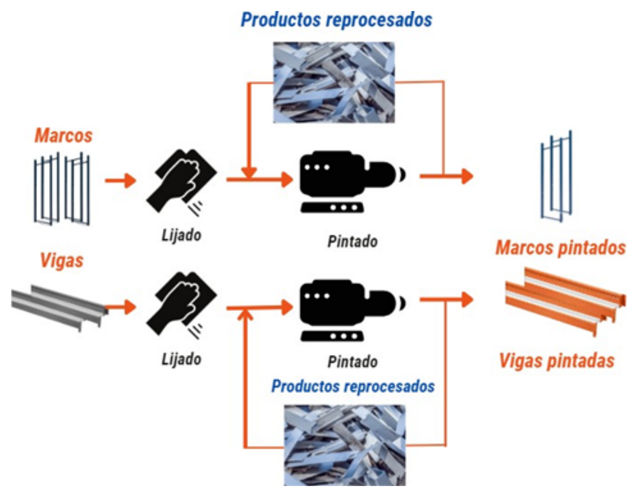

Fig. 5. Simulation of improvement proposal for painting process

In the case of the application of work standardization in the painting process, a reduction of up to 5% of defective products caused by poorly painted parts was obtained.

Thanks to these results, a new calculation of the man-hour efficiency indicator was made, thus obtaining an increase of 20% with respect to the initial value, which was approximately 74%.

In the case of the efficiency of man-hours employed in value-generating activities, this improved from 74% to 94%. Table 2 summarizes the results obtained from the simulation of the proposal.

TABLE 2
EFFICIENCY OF MAN HOURS UNDER THE SIMULATION OF THE IMPROVEMENT PROPOSALS

Month	HH Used	HH Productive	Efficiency
Jul-22	310.80	292.76	94.20%
Aug-22	287.49	268.90	93.53%
Sep-22	393.50	375.47	95.42%
Oct-22	416.81	395.76	94.95%
Nov-22	429.57	409.68	95.37%
Dec-22	417.92	400.77	95.90%
Jan-23	395.16	376.25	95.21%
Feb-23	255.30	234.61	91.90%
Mar-23	294.15	274.91	93.46%
Apr-23	278.61	261.87	93.99%
May-23	285.27	267.84	93.89%
Jun-23	231.99	214.36	92.40%
Total	**3996.56**	**3773.18**	**94.18%**

Similarly, the total savings generated from the implementation of the solution proposals for the root causes treated is almost US$ 16 200. To calculate the savings, the number of man-hours saved during the set up and the man-hours used in the production of defective products discarded from bending and reprocessed from painting were considered. Another consideration during the study is the budget of about US$ 3 000, intended for the solution and the development schedule comprises 4.2 months.

During the first, only the tool cabinet would be implemented; the second month, taking measurements and making the crank-rod; in the third month the training and verification of the device in the bender; and, finally, in the fourth month, the formalization of the painting process and its training would take place.

It is important to mention that the recovery period of the money invested is 6 months. From the economic indicators it is affirmed that the project is viable.

V. CONCLUSIONS

From the results obtained using the simulation using the Arena software, it can be affirmed that the proposed model is effective, since results were obtained that exceeded the objectives and target values of the literature review, allowing the efficiency of man-hours to be increased. up to 94%, the main indicator of this project.

As expected, the improvements in the reduction of reprocessed products in the painting process were reduced from 17% to 5%, the poorly folded discarded products were reduced to 0.8%, meeting and exceeding the objective set in Chapter 2, which is reduce these defective products to 5%.

Similarly, the benefit through the total savings generated from the implementation of the proposed solutions is approximately US$ 16 200 per year.

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