Increase the efficiency of the machine production process in textile companies through a model based on TPM and SMED

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Abstract – The textile sector is one of the most competitive markets globally and nationally, so companies are increasingly aware that they must constantly innovate and eliminate waste such as preparation times for product change, adjustment and unscheduled stoppages. This waste in the machines causes an increase in the percentage of defective products and efficiency of the line is poor, which generates that companies are forced to reject orders and as a consequence fail to meet the market demand. This research aims to propose a maintenance management model to increase the efficiency of garment manufacturing in textile companies that are affected by unplanned shutdowns and very long set up times that reduce processing times. Likewise, the objective of this research is to increase the production efficiency of medium-sized companies in the textile sector, through a model based on TPM and SMED, which belong to the Lean Manufacturing philosophy and will be developed jointly to reduce unplanned stops due to failures and breakdowns in the machines and reduce high preparation times through standardization.

Keywords— Textile, TPM, SMED, production capacity, Lean Manufacturing

I. Introduction

In recent years, the textile and clothing industry has had great relevance worldwide, as garments stand out as the most dynamic manufactured product, having a growth of 3.3% in 2018. Also, among the countries with the largest share of exports are China, the European Union and India. However, countries such as Bangladesh, Vietnam and numerous Latin American countries have had rapid growth recently [1]. In Peru, the textile industry is one of the most important secondary economic activities, contributing 1.1% to the national GDP and 8.3% to the manufacturing GDP. On the other hand, if we talk about textile exports, clothing such as short-sleeved polo shirts, shirts, pullovers and jerseys are the ones with the largest share. In addition to that, the main destinations in which the garments are provided are the United States, Brazil, Germany, Chile and Canada [2]. Although it is evident that Peru has a good participation in the textile sector, it is important for companies in the industry to ensure that their production capacity is within the acceptable average, which, in the textile sector, the average efficiency rate should be 57.98% [3]. That is why there is a need to investigate and identify the existing problems within textile companies so that they can approach the average of the sector. Waste such as high unplanned downtime as well as high machine preparation times affect the efficiency of the production line and can bring significant losses for a manufacturing company. Many companies take care of their machinery by adopting Lean Manufacturing strategies, since in a study it is proposed to solve the unplanned downtime due to failure and breakdown, implementing the planned maintenance pillar of the TPM in the press machines of a company located in Ludhiana managing to increase the average production of machines by 15.63% as well as reducing the average machine downtime by 23.14% and increasing the OEE by 17.08% [4]. In another investigation, the high set up times of a footwear company using SMED were solved, reducing the average set up time by 60%, generating savings of up to $40,000 per year for these reduced times and increasing production capacity by 3% [5]. The motivation of this research is to contribute to improve production efficiency in medium-sized textile companies whose problems are downtimes generated by equipment failures and breakdowns, as well as high preparation times. It is important to mention that there is research in which the TPM and SMED have been applied to solve the aforementioned problems. However, the articles are applied in large companies that have an enormous resource capacity or the methodologies are adjusted to the needs of small companies, contexts that do not occur in medium-sized companies, since the amount of resources is not as limited as small companies, but they cannot be compared with multinationals. Then, if they manage to improve production capacity, companies will be able to increase their annual production of clothing and thus be within the acceptable average of the sector.

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II. State of the Art

A. Problems in the textile sector

Among the common problems present in companies in the textile industry are unplanned downtime caused by failures (The machine continues to work but does not fulfill the function for which it was designed) and breakdowns (total inoperability of the equipment). Likewise, the duration of the preparation and adjustment times of machines that are higher than necessary is considered in the same way as wasted time [6][7]. The aforementioned problems have a greater impact on the equipment that makes up a critical process, because in an investigation in which a steam boiler whose role is important for the textile company, for each stop generated by failures and breakdowns in the equipment generated stoppages in production, that its availability decreased and, therefore, decrease in production and, consequently, profitability decreases [8]. In addition, the lack of maintenance programs, not securing the necessary spare parts also affect the efficiency of equipment, so it is necessary to adopt effective maintenance strategies to solve these problems in order to reduce maintenance costs, cost for rework and opportunity cost [9].

B. Case studies related to the SMED tool

In an investigation carried out, the company under study stopped producing an average of 29403 pieces due to high set up times. However, through the SMED, the conversion of internal to external activities and subsequent improvements of equipment preparation activities, the company under study managed to increase the OEE by 4%, reduce production losses per set up by 20.11% which translates into an increase in annual production to 70956 parts [10]. Similarly, in another case study, production records showed that the time needed to change product 40-60% represented unproductive times, and after implementing the SMED the results obtained were reduction of activity time by 48% and total process change time by 44% [11]. In another research, 27.7% of the total downtime corresponded to the preparation of machines of a Portuguese SME, so the lean SMED and 5S tools were applied to remodel the workspace and decrease the set up times of equipment, managing to reduce the cutting set up times, enamelled and knurled by 15%, 67% and 69% respectively, which means savings of up to €100,000 [12]. In the same way, in the following case study, it is intended to solve the long machine preparation times in an assembly line of a company dedicated to manufacturing automotive components in which through the SMED and 5S, managing to decrease the stop times on the line by 58.3% which entails an increase in the availability period of 210 minutes and reducing the intervention of specialized technicians in a 94.4% [13].

C. Case studies related to the TPM tool

In a study, equipment maintenance and repair costs can represent between 15 to 40% of total operating costs, so total productive maintenance was implemented, emphasizing the autonomous maintenance pillar to reduce as much as possible the downtime of equipment caused by failures and breakdowns, reducing inactivity by 40%, creation of an effective preventive maintenance plan allowing the same strategy to be replicated in other production lines [14]. Similarly, in a footwear company in which 247 failures were detected in its machines, which translates into excessive unproductivity times, they implemented the pillars of the TPM whose results were to increase the production of footwear by 5% and the reduction of human errors by 72.2% [15]. Likewise, it is pointed out that the TPM is complemented by another lean tool such as the OEE, which is an ideal indicator for maintenance and diagnostic improvements, because, for example, in an investigation it is intended to improve the initial OEE of equipment (73.4%) which generated that 8333 pieces / hour equivalent to $ 2500 are no longer produced, all the pillars of the TPM were implemented and this indicator was increased by 4.2% [16]. Similarly, in another study it is desired to increase the OEE in machining cells whose appearance of breakdowns, workspace and arrangement of disorganized tools has generated that the initial OEE is 49% and 54%. Then, after implementing the TPM in conjunction with the 5S, it was possible to increase the OEE of equipment by 5%, reduce average failures by 23% and 38%, which translates into an increase in the availability of equipment by 2% [17].

III. CONTRIBUTION

A. Foundation View

In order not to decrease their efficiency, it is important to keep the machines operational, especially the critical machines, as long as possible, because failure to achieve this would have a negative impact on the income of the companies. That is why, many organizations usually opt for maintenance strategies such as the TPM that, through its pillars, manage to reduce the unproductive times caused by failures and breakdowns in the equipment. On the other hand, the SMED tool is an effective option if it aims to reduce the preparation times of the equipment, since by converting external and internal activities and standardizing the activities involved in the set up. Then, integrating the aforementioned tools would reduce the unproductive times caused by stops and breakdowns, as well as decrease the high set up times of machines which leads to an increase in the efficiency of machines.

B. Overview

The proposed model is based on Lean Manufacturing tools such as TPM and SMED in order to increase the efficiency of equipment. The contribution of the research focuses on medium-sized companies, since normally the companies that implement lean tend to be transnationals whose resource capacity is exorbitant or these tools adapt to the needs of small companies whose resources are quite limited, a situation that does not fit medium-sized companies. Likewise, the model has use of the PHVA cycle in which each component is developed in each of the stages of the Deming cycle to ensure the maintenance of machines through the development of a culture of continuous improvement.

C. Detail view

Component 1: SMED

SMED is the preferred tool to reduce machine preparation times by converting internal to external activities and standardizing set-up activities. The implementation will take place throughout the PHVA cycle in which the planning phase consists of the initial observation of the set-up activities and the classification of these into internal or external through registration sheets. Second, the do phase consists of the conversion of internal to external activities, which consequently generates a significant reduction in machine downtime. Third, the Verify phase lies in the replacement and improvement of set up activities looking for new methods of execution or implementation of support tools to further reduce equipment preparation times. Finally, the Act phase focuses on documenting all the incidents and successes of the implementation in case it is considered to apply in other production lines.

Component 2: TPM

The TPM is an effective tool to reduce downtime caused by failures and breakdowns. For the research, the following pillars will be used: Training, TPM office, autonomous and preventive maintenance. Similarly, the implementation of the TPM will be through the PHVA cycle to ensure continuous improvement.

The first planning phase consists of the implementation of the training pillar whose objective is to increase the knowledge of the operators and for this the TPM team will be created, continuous meetings will be held for the elaboration of educational programs and the pillars of autonomous and preventive maintenance will be deeply trained. The phase lies in the implementation of the pillars of autonomous and preventive maintenance in which with respect to the autonomous one the basic inspection of equipment is carried out first, then the standardization of the cleaning and lubrication activities through instructions and then have a consolidate the commitment of the operators through checklist to demonstrate the fulfillment of the tasks of autonomous maintenance. With respect to preventive maintenance in which the assets owned by the company and the critical components of this are recorded, then proceeds to create the maintenance plan that the elaboration of maintenance instructions for critical components and a schedule where the maintenance and its frequencies are indicated. The Verify phase will proceed to measure the performance of the implementation through indicators such as the OEE in order to verify how much has been improved since the initial state. Finally, the Act phase consists of documenting all incidents, challenges and implementation considerations to have a history of cases that, if they occur again, can be studied in greater detail.

D. Indicators

The proposed model aims to reduce high machine downtime and breakdown, as well as high preparation times via TPM and SMED. In order to verify the functionality of the model, scientific articles with similar or equal problems are presented in which opportunities for improvement were identified and the reduction of these times was achieved by making use of the techniques used in this model.

TABLE I

INDICATORS

Indicator	Improvement		Article
Machine stop time	↓	25%	[4] [17]
OEE	↑	15%	[4]
Set Up time	↓	68%	[5]
Line Efficiency	↑	10%	[15] [10]

Indicator 1: Machine downtime

$$1 - (Downtime\ New / Downtime\ Current\ ).\quad (1)$$

In similar cases such as [4] and [17], downtime was reduced by 23% after applying TPM in conjunction with another lean tool. Also, in both cases of studies they are applied in medium-sized companies, but in other manufacturing sectors. So, it is considered that in the textile sector an approximate percentage of improvement can be achieved. This indicator shall be responsible for measuring the percentage reduction in downtime compared to the initial situation.

Indicator 2: OEE

$$OEE = (Availability \times Performance\ \times Quality).\quad (2)$$

In [4], a similar case study, Lean tools were used that managed to increase the OEE indicator by 15%. The OEE is a basic maintenance indicator, which will help measure the efficiency of equipment at the beginning and end of implementation.

Indicator 3: Set up times

$$\sum Internal\ Set\ up\ time.\quad (3)$$

In this case, what is proposed to reduce are the internal times of preparation of machines, since these times are considered unproductive, since they are activities that are carried out while the machines are turned off. So, it will be essential to reduce them as much as possible. In [5], the SMED was used in an Ecuadorian SME of footwear and this being a sector similar to textile, it is considered to obtain a similar improvement, since similar machines are used such as cutting, embroidery, finishing among others.

Indicator 4: Line efficiency

$$1 - (Line\ Efficiency\ New / Line\ EfficiencyCurrent\ ).\ (4)$$

Finally, the improvement of the Line Efficiency indicator was based on articles that applied the same tools in footwear manufacturing industries, achieving an improvement of up to 10%. This indicator will indicate the improvement in the efficiency of the production line and how many additional garments this improvement translates into.

IV. Validation

A. *Description of the validation scenario.*

For the research validation scenario, simulation was chosen due to the COVID-19 pandemic and the company's refusal to conduct a pilot test. For the simulation, the TPM and SMED components were based on which the corresponding simulation was carried out through the Arena Simulation software version 16.00.

This program specialized in simulation is easy to use and has the particularity of using historical data to create a digital simulation model and compare it with the real results of the system. Arena simulation uses the discrete event method in which it will allow to find the best approach for the optimization of processes, reduce risk through a simulation model through tests, changes in operations before making significant investments of capital and resources.

B. *Initial Diagnosis*

The company under study is Textiles Something different that is dedicated to the manufacture of garments such as polo shirts, divers, t-shirts, jackets, among others. Its main clients are well-known companies. However, throughout 2019 the company has been forced to reject orders because it does not have the production capacity to meet its demand.

First, an ABC analysis was carried out, with the aim of determining the standard product being the short-sleeved poles whose contribution to sales is 44%. Then a time study was carried out to determine the maximum capacity of each process that participates in the manufacture of poles, the bottleneck being the stamping process whose efficiency of the line is 49.22% which is below the average of the sector that is 57.81% which means a technical gap of 8.69% which generates an economic impact of 9.06% to the annual turnover of the company. Subsequently, the reasons that cause the low efficiency of the company were identified, the first of which being the high downtimes caused by failures and breakdowns in the screen printing machines. Figure 1 shows the total number of hours lost due to failures and breakdowns in 2019 based on the historical ones provided by the company.

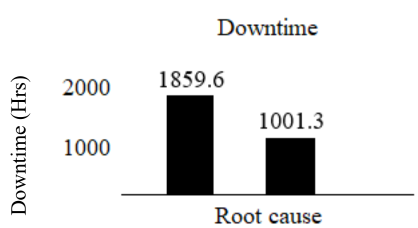

Fig. 1: Total Stop Times of Screen-Printing Machines

It is called failure when the machine is still operational but does not fulfill the function for which it was designed, while breakdown is when the machine suffers a total stoppage. The total time lost due to failure and breakdown in 2019 is 2860.9 hours which translates to 331846 poles stopped producing.

For the analysis of set up time, a sampling of 30 shots was carried out to verify the behavior of these whose result were these

TABLE II
Statistical data

Statistical data	
Media	104.56
Median	388
Desv. Standard	170.6424
Minimal	65.6
Maximum	476

From Table II it can be inferred that the behavior of the data does not follow an established pattern, the standard deviation represents 43.98% of the mean which means that the process is not standardized and its mean is 104.56 min.

Finally, for the calculation of the initial OEE of the screen-printing machines, we proceeded to calculate each of the indicators that compose it (Availability, Performance and Quality). Thanks to the historical data provided by the company, it was possible to have data on failure times by average equipment, scheduled maintenance, among others.

TABLE III
Initial OEE of SCREEN-PRINTING Machines

T. Calendar	2496 h
T. Operative	1736 h
Availability	71.85%
Good Production	1,050,300
Total Production	1,140,000
Capacity on the line	927
Yield Rate	70.84%
Quality rite	92.13%
OEE	46.90%

According to Table III, the OEE of screen-printing machines have a value of 46.90%, that is, the company currently has significant losses and low competitiveness, which is necessary to apply corrective measures.

C. *Validation Design*

The Arena Simulation program will be used to validate the proposed model. First, the number of samples needed from the service times of the machines involved in the pole-making process was determined. Below, in Table IV, a summary of the standard deviations can be seen.

TABLE IV
STANDARD DEVIATION OF MACHINES

Machine service time	Desv. Standard
Cut 1	0.910
Cut 2	0.894
Cut 3	0.915
Stamp 1	1.12
Stamp 2	1.24
Stamp 3	1.12
Stamp 4	0.862
Stamp 5	0.862
Stamp 6	1.16
Stamp 7	1.16
Stamp 8	1.08
Finish 1	1.01
Finish 2	0.871
Finish 3	0.89

With these data we proceeded to calculate how much is the amount of sample that the research is needed for the simulation to be meaningful and in Table V, the necessary amounts of data to be collected for each machine involved in the process are detailed.

TABLE V
IDEAL SAMPLE SIZE

Machine service time	Ideal Sample N°
Cut 1	319
Cut 2	308
Cut 3	322
Stamp 1	482
Stamp 2	591
Stamp 3	482
Stamp 4	286
Stamp 5	286
Stamp 6	517
Stamp 7	517
Stamp 8	449
Finish 1	392
Finish 2	292
Finish 3	305

Once the ideal sampling for the simulation was obtained, the missing data was taken. With the data obtained and the, the data was analyzed by means of the chi-square and Kolmogorov-Smirnov goodness of fit test. Where they analyzed whether the values entered meet both tests, that is, having a p- value greater than 0.05 in the analyzed entities. In all cases the condition is met and the following distributions were obtained:

TABLE IV
MACHINE TIME DISTRIBUTION

Entities	Time distribution
Model	TELL
Cut 1	TSCortado1 – NORM (11.6, 0.908)
Cut 2	TSCortado2 – NORM (12.5, 0.892)
Cut 3	TSCortado3 – NORM (10.4, 0.914)
Stamp 1	TS Stamp 1 – UNIF (240, 244)
Stamp 2	TS Stamp 2 - UNIF (242, 246)
Stamp 3	TS Stamp 3 - UNIF (231, 235)
Stamp 4	TS Stamp 4 - UNIF (238,241)
Stamp 5	TS Stamp 5 - UNIF (229, 233)
Stamp 6	TS Stamp 6 - UNIF (235,239)
Stamp 7	TS Stamp 7 - UNIF (245, 249)
Stamp 8	TS Stamp 8 - UNIF (247, 251)
Finish 1	TS Finish 1 – NORM (5.17, 1.01)
Finish 2	TS Finish 2 – NORM (5.97, 0.87)
Finish 3	TS Finish 3 – NORM (5.5, 0.889)

TPM

After the simulation, a significant reduction in downtime caused by failures and breakdowns was obtained, since, in the initial state, the stops were 351 hours for each machine on average, after the improvement it was reduced to 275.5 hours which means an improvement of 23%. Likewise, the new OEE is 60.18% when in the As is situation it was 46.90% which means an improvement of 13.29%.

SMED

In the case of smed, in the initial state, the internal preparation times ranged from 104.5 minutes while in the improvement these preparation times are decreased to 67.6 minutes which translates into an improvement of 35%.

RESULTS

TABLE IIV
MACHINE TIME DISTRIBUTION

Indicators	As is	To be	Mejora
Machine Downtime	357 h	275.5h	23%
System Time - Set Up Time	105 min	67.6 min	35%
OEE	46.90%	60.18%	13.28%
Line Efficiency	49.22%	51.50%	2.28%

After the validation carried out, the following results have been obtained, from which can be seen in Table IIV, in which it can be inferred that the most relevant indicator in which is the efficiency of the line, which, as a result of the improvements in the other indicators, has obtained an improvement of 2.28%.

V. CONCLUSIONS

The proposed model composed of the TPM and SMED tools was able to increase the production efficiency of a medium textile company by 2.28%, as the improvements in the other indicators such as decrease in the time of stops due to failure and breakdown by 23%, decrease in machine preparation times by 35% and increase in the overall efficiency of equipment (OEE) by 13.28%. However, it is still not enough to solve the gap between the company and the sector in which it is 8.69%.

For the company to increase the efficiency of its lines and therefore stop rejecting orders, it is necessary to maintain good practices so that the problems identified in the company are decremented as much as possible. That is why, the measures integrated in the design, constant training, follow-up formats and the participation of staff and senior management must be adopted, since according to several success stories reviewed in the literature is that there are improvements in preparation times, OEE, decrease in downtime, among others.

Although the use of TPM and SMED methodologies achieved an increase in the efficiency of the pole production line achieving positive results. In addition to that, it would be feasible to replicate this model in other production lines that the company has such as jackets, t-shirts or joggers. Also, to support yourself with lean tools such as 5s that would be responsible for applying the basic principles of order and cleanliness in the workspaces, which would bring with it even more opportunities for improvement.

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