Diagnosis and improvement of a production line through Lean Manufacturing methods

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Abstract

Nowadays, the needs and demands of the consumers are increasing and diversified. To meet the needs and demands and due to the great existence of diversification and market competition, companies are forced to develop methodologies of continuous improvement so that their productive systems be able to produce more and, in addiction, be flexible in their production. Thus, Lean methodologies arise as tools of continuous improvement to remove waste and, therefore, an increase in the productive capacity of each company. The increases of productive capacity, through these methodologies, seek the maximum satisfaction of the costumer (always guaranteeing the highest quality of products) with the fastest response time.

In this case study Lean methodologies were applied to two production lines of a paperboard company. This work comprises the realization of a diagnosis to two production lines through the calculation of OEE – Overall Equipment Effectiveness. After analyzing the indicators and identifying the wastes inherent in each of them, some solution was presented to the company to improve the performance of each of the production lines. These solutions were primarily based in SMED and TPM methods. With these solutions I tis intended an effective improvement and a better adaptation to the different production requirements of each product.

Finally, it was possible to verify the potential of the solutions found through the results obtained from the application of the same.

Key-words: Lean Manufacturing, OEE, Overall Equipment Effectiveness, 5S, SMED, TPM, 5Why's

1. Introduction

Over time, industry has undergone changes to take account of consumer needs and market requirements. Currently, competition between companies is increasing, looking for the best product for the best price. But for this to happen, companies need to invest more and more in a better management of all resources and in the application of new technologies and methodologies to achieve the main objective common to all of them: to produce more and better a child cost. Therefore, efficiency and effectiveness are the slogans.
In this context, Lean methodologies arise that, through systematic approaches, identify and eliminate wastes, to obtain continuous improvement.
In this dissertation, Lean methodologies applied to a company, which is dedicated to the production of cardboard paper and packaging in its various forms. The company's main objective in the medium term is to increase daily productivity since, for the moment, it cannot respond to all orders.
For the accomplishment of this study was used the study of methods and times to collect the relevant information of the current state of the lines of production under study. To identify the root causes of the losses of these lines, 5Why's tool was used. Then, after the production line was diagnosed using the OEE performance indicator, it was possible to proceed with the elaboration and application of some improvements in both production lines. SMED was used to reduce Setup time and to better delegate tasks during Setup. In addition, this tool has meant that, for example, losses due to lack of MP to start production have decreased significantly. Another Lean tool used was the TPM. Starting with the elaboration and design of 5S to both productive lines and proceeding the creation of documents and methodologies with the aim of improving the preventive maintenance of each line. In the same way, the TPM also allowed the creation of methodologies for autonomous maintenance of each operator. In this way, each operator can identify problems in the production lines and may have

tools to solve the problems that identify them. However, not all methodologies have been put into practice, being the object of application by the company in the future. Finally, the future OEE was calculated to have a quantitative measure of what has already been improved and what can result after the proposed solutions have been applied.

2. Research

2.1. Historical Background

From the beginning of time Man has always sought to perfect and find other materials for his needs, discovering and replacing materials with more resistant ones in search of the best weapons, tools, among others.

Between 1760 and 1840, the industrial revolution occurred, which introduced the first steam engines, causing some artisanal work to now be made by machines. With the advent of new machines, the work became mechanized and there was a need to train workers to operate these machines. There was thus a division of labor and simplification and standardization of operations. There was also the need to create supervisory and managerial frameworks, as well as sales management development and production planning and control techniques.

The end of the nineteenth century, Taylorism arises. Taylorism sought a higher income, depending on the skills of the worker, as well as a standardization of operations, to eliminate interruptions and the existence of a production planning (existence of working hours and breaks). With this method, operators felt that their skills were valued (there was also a monetary incentive). However, this method, over time, showed some problems. Operators started to be treated as machines and to do the same type of function with no prospect of evolution, since it was in what they were good, they could not be creative and have initiative, which caused wear, fatigue and friction between operators and administration. [1]

He followed Henry Fayol, Father of the Classical Theory of Administration. Henry Fayol was the first to create standards in administrative practices because he believed that good practices on the part of the administration reflect better results with the operators. His work was essentially characterized in the structure that the organization must possess to be efficient. The 14 principles of Henry Fayol are: Work Division, Authority, Discipline, Control unit, Management Unit, Subordination of individual interests to common interests, Compensation, Centralization, Hierarchy, Order, Equity, Stability, Initiative and Team Spirit. [2] Between 1910 and 1920, Frank and Lillian Gilbreth deepened the study of movements. Frank and Lillian sought to perceive and identify all work movements and their times, as well as identify which movements bring added value to the work. In addition, they studied workers 'motivational factors, as well as the influence of workers' attitudes on the process. [3]

Between 1910 and 1939, Fordism appeared, a system of production created by the American businessman Henry Ford, whose emphasis is the mass production. Ford's main goal was the mass production of its cars, which until then had been made by hand. With the mass production of its cars, Ford intended to have the lowest possible costs in its manufacture and thus could reduce the price of automobiles. Consequently, the possibility of reaching a larger number of consumers increased. However, this system was considered negative for the operators, since the work was repetitive and caused more wear in them. Because the operators performed only one operation (and low qualification led to lower wages), it made it impossible for them to progress in their careers, which made their motivation level decline. [4] [5] [6]

The TQM, Total Quality Management, was developed by some Americans such as W. Deming, Joseph Juan, Armand Feigenbaum, Philip Crosby and Karoo Ishikawa. In 1961, TQM was defined as an integral system of all sectors of the company for the development, maintenance and improvement of quality, in order to obtain a product that meets the needs and tastes of consumers, while being economical in its production. The principles of TQM consist of the involvement of management, delegation of powers and tasks, elimination of errors, development of human resources, customer satisfaction, among others. [7] Toyota, in Japan, was one of the first companies to use TQM. In this system, it was intended to eliminate the defect at the origin (zero defects), as well as the elimination of waste (production in cells and reduction of setup times) and greater efficiency and efficiency of the resources used, -in-time, pulled production and Kanban) or labor (motivation, flow of ideas). With this, the TPS is born, Toyota Production System, the culmination of the union of all the ideas and philosophies acquired and developed by Toyota. [8] [9]

Today, Lean emerges as the methodology used to eliminate waste (reduction of associated costs), quality construction in the process (quality assurance in all products, quality in all stages of the process, inspection at work, among others), reduce costs, develop its own approach to management and develop integrated techniques for continuous improvement. [11] [12] [13]

Womack and Jones (1996), in their book Lean Thinking, established that the Lean philosophy rests on 5 principles: Value (what your products really value to the customer), Value flow (identification of steps that add value to (elimination of waste), Continuous flow (production leading to the reduction of stocks and, thus, reduction of associated costs as well as elimination of the need to create solutions for stock disposal) and Perfection (search for continuous improvement). In addition to Womack and Jones, Roost also joined in the study and exhaustive documentation of the advantages of the lean production system compared to mass production, concluding that lean production would be much more advantageous. Together they created the book The Machine that changed the World. Nowadays, this book is a great guidance tool for managers from all walks of life who want to turn their industry into a lean success. [14] [15]

2.2. Lean Tools

2.2.1 OEE

OEE, Overall Equipment Effectiveness, is an indicator that generally measures the potential of an equipment, i.e. identifies waste and loss during the production process of an equipment and helps in identifying windows of opportunity for process improvement productive. Therefore, its main objectives are: to increase productivity, reduce losses, increase and control of quality, increase equipment life. With this, companies aim to increase their profits and reduce production costs. The OEE is then obtained by multiplying the availability by the performance and quality of the product produced. [16]

$$OEE = Availability\ x\ Performance\ x\ Quality \quad (1)$$

2.2.2. 5 Why's

The 5 Whys technique is used to analyze the root causes of a problem. It is part of the Toyota Production System, developed by Sakichi Toyoda, Japanese inventor and industrialist. "The basis of Toyota's scientific approach is to ask why five times whenever we encounter a problem ... Repeating the five times, the nature of the problem as well as its solution becomes clear." Taiichi Ohno [17]

2.2.2. SMED

SMED is the method used to enable an equipment to be changed from one product to another in the most efficient way and in the shortest possible time. This tool allows you to identify and separate the change process for key operations. The separation of operations is divided into two categories: Internal operations and external operations, which will be explained posteriori.

The implementation of this tool involves the following steps: analyze the current state, convert the internal activities to external, Standardize the activities, improve internal activities and improve external activities. [20] [21]

2.2.2. TPM and 5S

The TPM philosophy, Total Productive Maintenance, rests on 8 pillars each with their own areas of responsibility, although some of them overlap. They are: Safety and environment, TPM in administration, Quality maintenance, Initial equipment control, Education and training, Planned maintenance, Stand-alone maintenance and Individual improvements. In addition, it should be based on a solid base of 5S.

The goal of 5S is to create a clean and organized work environment, placing the operators in maintenance. Thus, the 5S decomposes into: Seiri (elimination of everything that is not essential to work), Seiton (organization of components that remain in the machine), Seiso (importance of cleaning and its maintenance to the good working environment and detection of machine and / or production problems), Seiketsu (standardization, making a habit and common the sense of responsibility of the organization and cleaning space by creating standards for its realization) and Shitsuke (sense of discipline, monitor). It is a way of educating the maintenance of everything that was previously applied. With respect to each of the pillars, these intend to place responsibility on all operators and managers in the execution and fulfillment of a properly planned maintenance. [24] [25] [26]

3. Case Study and Methodology

This project aims to improve a production line of carton paper packaging, more precisely in the transformation zone of the same, through Lean Manufacturing methodologies. In this thesis, an analysis was made of the current state of the production line, which diagnosed the less positive aspects to improve in the company to achieve its objectives and increase its daily responsiveness to customer orders.

A follow-up of the production line was done during approximately two months, in which it was possible to perceive of a more complete and in depth form the production lines under study and familiarization with the collaborations and all type of manufacture made on each of the lines. This company has several production lines and several machines; however, this thesis will only be focused on two of them in which two rotaries presses, A and B, work. First, there was a phase of adaptation and familiarization of the process and all the surrounding operators. In this way, it was intended that the observations made represent the production reality of each of the production lines as accurately as possible.

After this phase, we analyzed the time (productive and non-productive) the movement of operators and materials and the transportation of materials, in order to obtain the data needed to calculate the OEE. In addition to observations of times and methodologies, it was also necessary to provide information provided by shift supervisors and production manager so that the calculation of the performance indicator was calculated as closely as possible to reality. Finally, after analyzing the OEE and the improvement points, some improvement solutions were studied and applied based on the Lean methodologies presented previously.

4. Diagnosis

The diagnosis will be made using the OEE: Overall Equipment Effectiveness indicator. Then, an analysis of the associated losses is made, and their root causes are characterized.

4.1. OEE

Although the company uses the four indicators mentioned above (Time Setup, Unscheduled Shutdowns, Speed and Productivity) to verify its performance, in this thesis the OEE indicator will be used as performance indicator. We intend to analyze the current state of the machines and compare it with the maximum that they can produce in order to verify where the losses are in order to reach their maximum potential.

According to equation (1) and with the results obtained in each indicator, an OEE of 26.36% for PRESS A and 26.24% for PRESS B was obtained. Two schemes are presented for a better understanding of the results obtained.

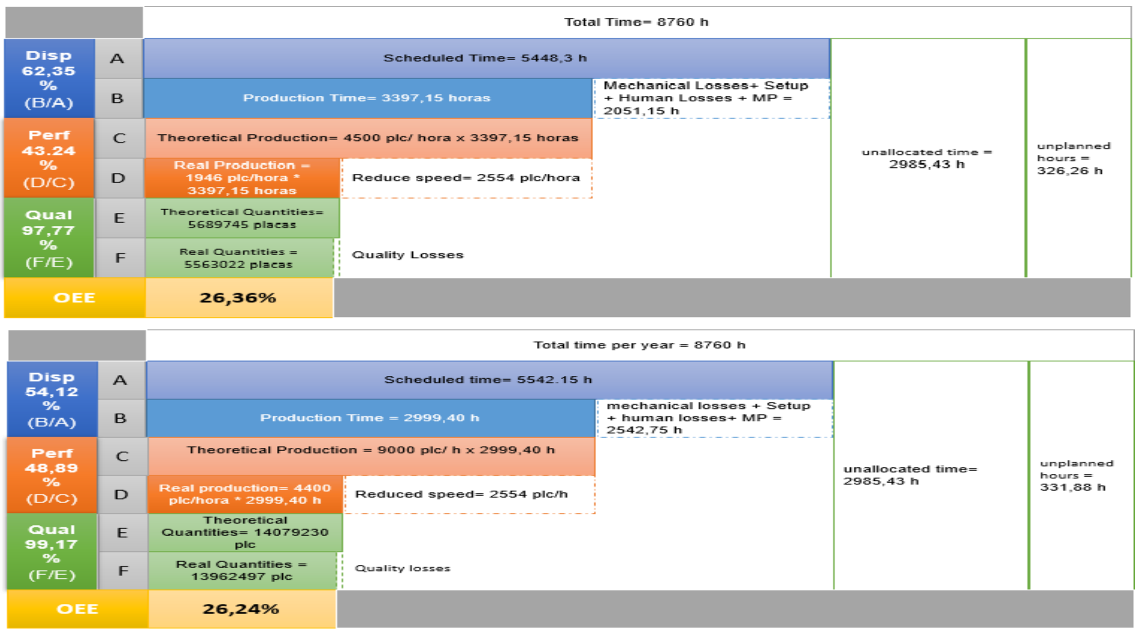

Figure 1 - OEE PRESS A (superior - .a) e PRESS B (inferior- .b)

4.2. Analysis to the OEE obtained

This subchapter will analyze in detail the problems that relate to and condition with the values obtained previously, that is, it is intended to make a detailed analysis of the root causes of the problems associated with the low performance of the machines so that it is possible to present effective solutions in their resolution.

Losses Relating to Officials (Human Mitigation) and Other: These losses represent the highest percentage of stops during production and during Setup time for both machines being 9.80% - for Press A - and 14.60% for Press B.

As stated earlier, these losses are related to the movements, activities and attitudes of employees during the time of production. After these types of losses were observed, it was possible to break them down into the different types of losses inherent in them. It was verified that in PRESS A and PRESS B the major problems identified (with the greatest number of incidents) were: Lack of RM to produce, Mold defects / repairs, No flow of finished product, Bad planning and New reference (PRESS B mainly)

Setup Losses: During analysis of the Setup it was possible to verify the existence of several losses (high SETUP time) due to the poor organization of the tasks to be performed, the lack of material to perform the SETUP, the absence of operators during SETUP time to search the RM) to produce the order they had already started to prepare or to have lunch and the Mix Order.

RM Losses: These losses relate essentially to the state in which the RM arrives at the machines. It has been observed that, lately, the card has arrived with many defects such as gable, cool or with high humidity. These are problems that need to be avoided for better quality of the final product and higher productivity of the machines.

Losses due to mechanical stops: Although there is a level I preventive maintenance schedule (3 hours a week), this is rarely achieved due to planning requirements and lack of response from the machines to the orders. Therefore, corrective maintenance is the most practiced in the company. In addition, operators do not follow the machine's daily cleaning schedule (20 minutes) and when they do not perform the most important cleaning actions (existing in a checklist) or take advantage of that time to pause.

Reduced Speed Losses: These losses essentially have three types of origin: poor RM quality (too wet, dry and / or warped), lack of finished product flow (when high production occurs on all machines causes congestion of product output) and lack of discipline in the operators (operators have no method of warning the forklift the need for greater and faster outflow).

To summarize this analysis, a table (table 1) with the type of losses, their respective problems and suggested points of improvement is presented. Only a few improvements were possible due to the short duration of the thesis, resistance problems encountered by the operators and their superiors, as well as the lack of funding to apply these same improvements, which are:

- Improvements in the SETUP of each machine (creation of table to control material existence to start SETUP)
- Beginning of the application of the PMS pillars (5S, preventive maintenance and planned maintenance).

Other improvements are under study to be able to be applied by the company to the later, being these:

- Creation of space with separation of blades and rubbers and tools for repair of molds (chapter 7)
- Speed control of each order (chapter 7)

Type of loss	Problems	Main Improvements to be main
Human Attenuation	• Lack of RM to produce • Molds Defects/Repairs • No flow of finished products • Bad planning • New reference (PRESS B mainly)	• Methodology / Communication system between operators and forklift to order (Lack of card) • Slot with separation of blades and rubbers and tools for repair of molds (defect / repair molds)) • planning rules (bad planning - part of the TPM)
RM	• Hipster Card • Warped card • RM with excess glue	Monitoring of all the production of the reamer (It will not be part of this thesis)
Reduced Speed	• Inadequate RM quality • No flow of finished products • Low speeds (lack of discipline on operators)	• Quality control RM (will not be part of this thesis) • Increase in the area of transfer and assignment of transfer operator on days of higher production • Awareness of operators for the need to produce more and speed control for each order.
SETUP	• Ineffective delegation / organization SETUP tasks • Lack of material during production • No operators during Setup • Mix orders	• SMED / SMED's audits / team stability/ training • Material verification methodology before SETUP • Creation of methodology to prevent no operators during SETUP • Creating a file with a better sequence of orders favorable to PRESS B so that it is possible to wash the printer units during SETUP (not included in this thesis).
Mechanical	• Preventive maintenance time is not met • Daily cleaning time is not fulfilled, or cleaning is not done	• Creation, allocation and compliance of mandatory weekly schedule for preventive maintenance level 1 and creation of checklist of critical points of each machine to be revised (TPM) • Awareness of the importance of daily cleaning and the creation of a checklist of critical components to be cleaned (TPM)
Others	• Wip disorganization	• New Layout

Table 1 - Summary of diagnosis

5. Solutions

After analyzing the diagnosis, we will now present the solutions that were possible to be applied in the company during the thesis and others that were left so that the company can apply in the future.

5.1. SMED

The recording of a SETUP was carried out on both machines and after an analysis of the video in conjunction with all the operators of each machine so that, with the involvement of the same ones, we achieved a better realization of the Setup and that the involvement of this one generated a greater interest in achieving the objectives. Generally, the Setup consists of the change of paint, mold and stamp, the mold can be made up of two parts and there may be a Setup where two stamps are required which means that you will use two inks. Therefore, the Setups can have the following configuration:

Setup	Mold	Stamp	Paint
1	OK	OK	OK
2	OK	-	-
3		OK	OK

Table 2 - Types of Setups

After analyzing the type of Setup and its number of occurrences, it was possible to verify that the most usual type of Setup is the Setup 1, in both machines. After the filming and analysis of activities and times, the activities of each operator were analyzed.

1. **Convert internal activities to external ones**

When viewing the videos, we had 14 minutes and 12 seconds for PRESS A and 25 minutes and 55 seconds for PRESS B (Setup's times). After analysis and division of tasks into internal and external tasks it was possible to obtain new Setup times: 15 minutes for PRESS A and 18. This new Setups are superior to the times after task outsourcing since they include the existence of more than a type of Setup and, in addiction, some SETUPs are more complicated to perform due to the dimensions of the tools.

2. **Standardize Activities**

At this stage two document were created to be placed on the machines with the activities, duly described, for each operator including the activities to be performed internally or externally.

In both machines 1st helper is the operator who is dedicated to removing and placing the mold. In addition to the mold, it is also responsible for adjustments to the output of the machine (parallel, stops, among others).

The main operator, as expected, is mainly engaged in checking the order (PcTopp), placing the pre- assemblies (stamps), adjusting the parameters of the machine according to the order and rectification of the quality of the final product. The 2nd helper, as a rule, is the less experienced operator so he will deal with adjustments at the entrance of the machine (from delivery settings, loading the card hopper, among others).

In addition, it is the operator who removes the pre-assemblies (stamps) and should, if necessary, assist the 1st helper to remove and lay the mold (PRESS A). The first helper, at PRESS B, is to finalize the orders, sign the mold in the machine and place it in its proper place as well as perform necessary cleaning actions. Since it operates during production at the exit of the machine, it will not be this operator to prepare the mold for the next order, but the 2nd assistant. In PRESS A, it performs the same functions, but unlike PRESS B, it is this one that prepares the mold. The 2nd helper at PRESS A has as main external activities to check the ink for the next order and to carry out cleaning actions in the space surrounding the machine. In PRESS B, due to the proximity of this operator to the place of entry of the molds, the mold must prepare the mold, ie remove the mold from the support and if possible, place it closer to the cutting unit, wash the stamps, request the clean the units that are not being used. A system of audit to the SETUPs in which, at least once per shift, a person in charge can audit and realize if the SMED is being fulfilled.

3. **Improve Internal Activities**

Regarding the internal activities of both machines, all of them are manual and little or nothing is possible to change so that there is an effective improvement in SETUP time. In relation to PRESS B, a possible improvement would be the use of elastic wires to fasten the seals. Currently, the two machines, PRESS A and PRESS B, use tape to attach to the stamps which makes the stamps unstable and increases the preparation time, SETUP. However, PRESS B has its own protrusions to attach the stamps to the roll, but is not currently used due to the lack of elastic yarns suitable for this purpose.

4. **Improve external activities**

It has been found that during production the operators do not perform many tasks that they could perform externally, such as a proper preparation of the next SETUP. That is, check if there is material for the next SETUP. As such, there was a need to create a material check table prior to the completion of each SETUP.

5. **SMED RESULTS**

It is expected that in the first 3 months, that is, in the months in which the first diagnosis of the machines was made, the Setup time oscillated between high values in both machines, between 19 minutes - to PRESS A - and 23 minutes - to PRESS B. In January, during the meeting with the teams and their involvement in SMED, the following goals were defined for each machine (Press B must finish 2018 with 18 minutes of Setup time and PRESS A with 15 minutes.

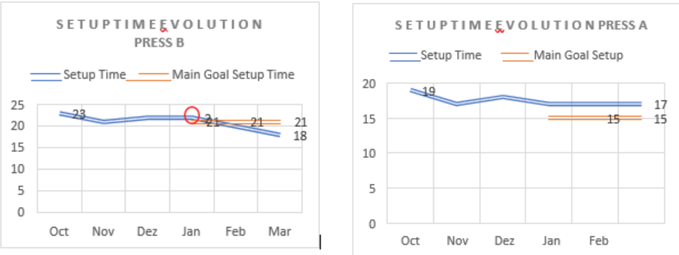

Figure 2 - Setup Time Evolution for 6 months

It is expected that at the end of the year 2018 PRESS A will achieve its goal of 15 minutes as it has more room for maneuver and orders with less degree of difficulty than PRESS B. With respect to PRESS B, it is expected that throughout the year this will maintain the value already reached and in the limit that does not oscillate more than the objectives proposed by quarter (since the mix of orders is very large and the difficulty of each Setup is quite oscillating) and thus reach the end of the year 2018 within the goal of 18 minutes and, perhaps, reach a lower value. Thus, the percentage of losses due to human attenuation has been reduced to about 6.8% (2% reduction) in PRESS A and 8.6% (reduction of 4%) in PRESS B.

5.2. TPM and 5S

In this chapter we will discuss the solutions found based on the TPM methodology and on the 5S methodology.

5.2.1 5S

As already mentioned, the company has applied some solutions related to 5S from previous studies and observations. However, due to the lack of follow-up of their achievement these have been being abandoned or ignored. An example of the need for updating information at PRESS A is the fact that operators produce different types of flanges that require different types of tightening in the rollers and other constituents of the machine and what happens is that different operators make different grips so it is necessary to standardize these tightening for the different flutes so that they are evenly produced and even help and improve their quality control.

Regarding the surrounding space of the machines, it is also necessary to make a survey of what is necessary to be near the machines and what is not useful and is only taking up space.

At PRESS A, it was found that the material used repeatedly for some types of tuning and breakdown was mixed with material that is only needed for the maintenance of the machine and the materials were disorganized and in distant locations where they would be used. In addition, not all material had a place for storage and not all material would be labeled. Another change to be made (in both machines PRESS A and PRESS B) is the organization of the basin to support inks and additives. It is disorganized, and operators do not always know where the paints or additives are (because they are often in buckets that are not identified or difficult to perceive). The change to be made would divide the support basin into X distinct areas through, for example, glue tape. In this way, there would be a zone to place each of the cans: Black ink zone, Ink zone of colors (several colors can be in the same area since they use very few colors - about 3 colors only), Zone of varnish, Zone of humectant and anti-drier. Regarding PRESS B, the biggest problem in the surrounding space is due to the lack of space for the molds and the fact that the operators do not always place the material / tools in the defined place. Given this, one possibility will be the assembly of some bars in the factory pillar and chains to be able to embrace the shape molds or the placement of only an adjustable strap that embraces the molds so that they do not fall naturally or, accidentally, some operator touches them.

5.2.2. Maintenance

Two of the pillars of the TPM are autonomous maintenance and planned maintenance. To apply this pillar of the TPM, a document was requested that lists all the records of faults that the machines obtained in the last 4 years in order to identify the critical points of the same. After analyzing, it was possible to verify the components with the greatest number of faults in both machines. In view of these data, it is necessary to intervene in these components of both machines to reduce their number of faults, that is, it is necessary to create maintenance methodologies (checklists) to prevent these faults. There was then a need to create a stand- alone maintenance and cleaning checklist for each of the machines under study, PRESS B and PRESS A. This checklist is a daily checklist for an average stop of 20 minutes which also includes tasks to be performed with the machine in progress. Each machine has been divided into 3 different zones so that different tasks can be assigned depending on the operator of each zone.
This checklist includes essentially cleaning and checking components for wear.
As previously stated, there was no maintenance planning to be done on the machines. The maintenance was practically of an urgent nature and should be the Planning to give indication for that maintenance to be done. However, Planning was rarely able to release the production machine so that maintenance was done in time to not cause more serious damage so that the machines even reached their limit of fatigue in some of their components and had to stop because they could not produce more. There was thus a need to hold a planning meeting and, together, set a weekly stop-start time for preventive maintenance.

Once a week, for 2 hours, all machines should stop for deeper maintenance and troubleshooting that could have happened during the week, but that did not affect the optimal production of the orders. In this way, the planning should organize the week having already given guaranteed that at that time the machines would be stopped and only with the consent of the director of production and shift heads is that this schedule could be changed. This weekly maintenance should, as stated above, be intended for deeper maintenance of the machines. At this time, a deeper cleaning of the machine must also be carried out by the operators and also the possible maintenance of components or faults which operators have checked so that they can be resolved on the same day or scheduled for next week if they are not of an emergency nature.

In addition to this maintenance and the deeper cleaning carried out by the operators, a checklist was also created for the operators of PRESS B to carry out during these maintenance hours a deeper cleaning of the printing units, that is, to the anilox rollers , with bicarbonate (a liquid that allows for a good cleaning of the units but that being a longer cleaning should be carried out on the planned preventive maintenance day and a different unit per week). A maintenance checklist was also created for PRESS B with some critical components (checked during the analysis of the document referred to at the beginning of this topic and during the months of diagnosis with the help of the maintenance engineer) to be inspected / lubricated / replaced day of preventive maintenance. This checklist must, like the previous one, be complied with at the expected date of each element of the machine to reduce the malfunctions of these components. In addition to this checklist, another weekly checklist was also created with the components to be checked by each operator on the day of preventive maintenance so that, if there is an abnormality in the components, it can be rectified on an urgent basis or scheduled for another day if it is not of an urgent nature and there are other priorities on the machines. Compliance with this list may also cause the Maintenance team to conduct an anomaly study of the critical components to optimize the maintenance actions so that these occurrences decrease.

Regarding PRESS A, due to the short duration of the thesis, the fact that the data to be analyzed are inferior to those of PRESS B, was created in addition to the cleaning checklist and a preventive maintenance checklist with the critical components to be verified by the operators in the day programmed for preventive maintenance, as previously done for PRESS B.

5.2.3. TPM application results

In spite of all the checklists created for better maintenance of the machines, they are still not functioning at 100% due to the lack of compliance on the part of the operators and lack of control on the part of the shift heads (this is due to the fact that at the moment there is only one shift leader who is training a new shift leader who will take up duties in the coming weeks so that the current shift manager cannot control whether or not the checklists are being met. However, with the application of these maintenance measures, machine failures are expected to reduce by about 30% by the end of the year, if the TPM is applied on rigid abutments and there is a commitment of all elements (steering, maintenance and operators) to fulfill the objectives and focused on achieving the programmed goals. Since the mechanical stops corresponded to 2% - for PRESS A - and 2.5% - for PRESS B - it is expected that the new stoppage percentage will be around 1.4% - for PRESS A - and 1.75% - for to PRESS B, because with the maintenance plan it is expected to anticipate the biggest problems found so that they do not cause damage in the machines, but that their maintenance is done at the weekly stop dedicated to preventive maintenance. It is also expected that the time devoted to preventive maintenance will be fulfilled at 100% by the end of the year (there is now a greater awareness for its realization and it is found, in both machines, to be fulfilled about of 85%) as well as end-of-shift cleaning.

6. Future OEE

With the results obtained, through the presented solutions, the packaging line future state OEE was computed. The future state OEE was assembled in a scheme, like the one for the current state so that the results can easily be compared. (figure 3)

7. Another Solutions

There are other solutions to be applied by the company so that the results of the OEE are better in the future. One of the solutions proposed is the creation of a space / box with the separation of blades, rubbers and tools for repair of molds, another solution proposed is the monitoring of each order of the machine in order to realize at what ideal speed each order can work, the implementation of a system of warning to the forklift so that it, at any point in the factory, knows when it will have to supply some machine with RM or pallets and reorganization of the WIP.

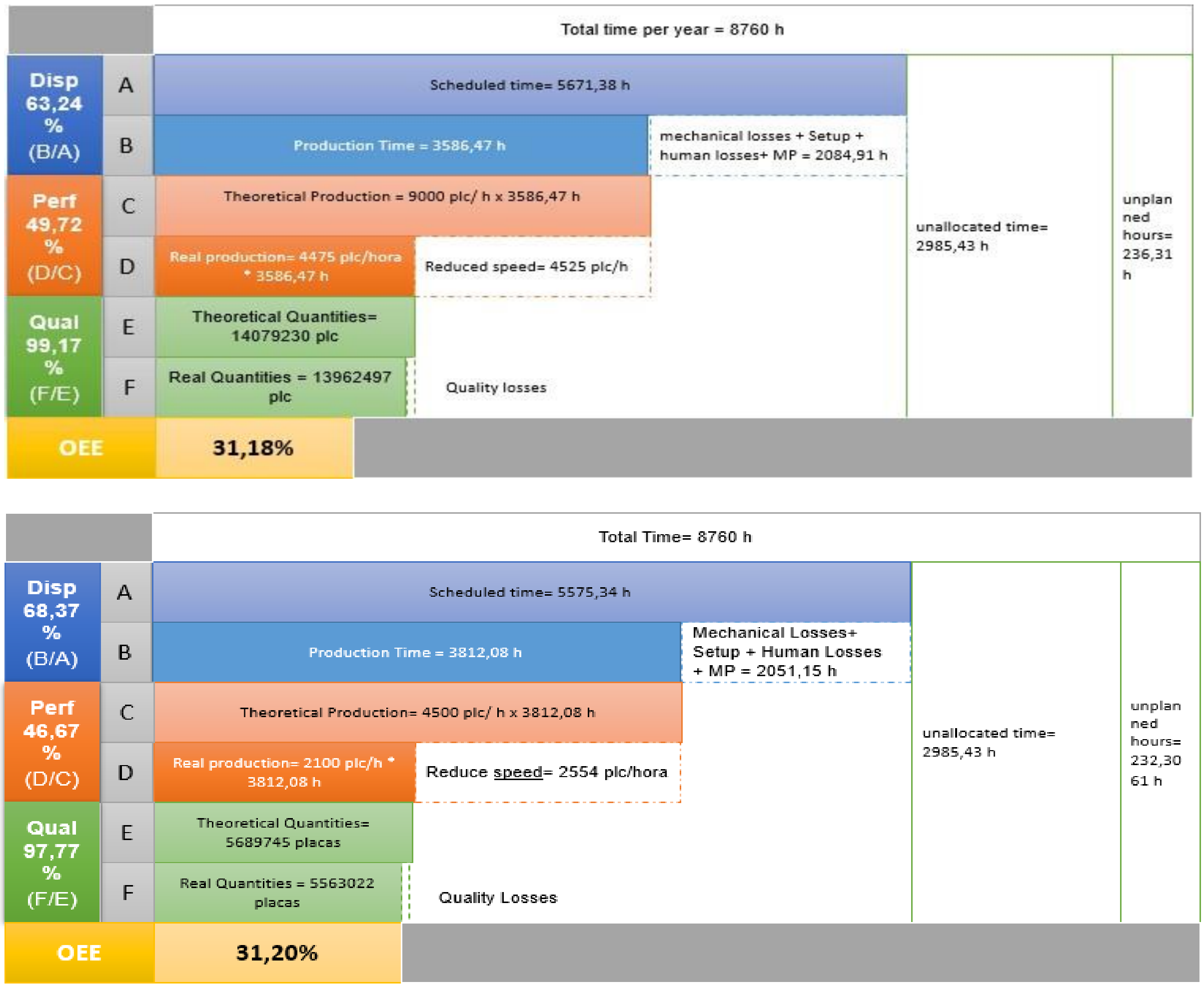

Figure 3 - Future OEE for both machines (PRESS A -up- and PRESS B – below)

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There are other solutions to be applied by the company so that the results of the OEE are better in the future. One of the solutions proposed is the creation of a space / box with the separation of blades, rubbers and tools for repair of molds, another solution proposed is the monitoring of each order of the machine in order to realize at what ideal speed each order can work, the implementation of a system of warning to the forklift so that it, at any point in the factory, knows when it will have to supply some machine with RM or pallets and reorganization of the WIP.

9. Conclusions

OEE allowed to identify and quantify the different losses inherent to the production lines in question: such as lack of material to start production / Setup, failure of communication between operators, among others. In addition, losses due to the state of the raw material are also quite relevant and losses due to reduced speeds. After identifying the main problems and their root causes it was possible to present some solutions and even to apply some of them to improve the production lines. One of the solutions proposed in Chapter 5 is SMED. With the application of SMED it was possible to reduce by about 12% - from 19 minutes to 15 minutes, PRESS A - and 18% - from 23 to 18, PRESS B. With the application of these checklist it is intended that at the end of the year values of reduced mechanical losses are reached. In fact, although we have decreased the percentage of downtime dedicated to maintenance for each machine - from 4.60% to around 2% - it is expected to be more effective. Mechanical losses due to machine failures and problems are also expected to reduce - from 2% to 1.4% at PRESS A and from 3.80% to 1.75% at PRESS B. In short, after applying some of the solutions and estimating the results of others, we can calculate and predict a new OEE for each of the machines. As a result, the OEE improved from 26.36% to 31.20% - for PRESS A - and from 26.24% to 31.18% - for PRESS B. With the accomplishment of this thesis it was intended to apply the Lean methodologies and show how they are effective in improving production lines when well applied (and grounded) after an analysis and diagnosis of each one of the lines. It was also possible to understand throughout the thesis the difficulties inherent to the application of new tools and methodologies in industrial environments resistant to change.

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