Development of Autonomous Maintenance in a Furniture Company

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***Abstract*— This article presents a work performed in the maintenance department of a furniture company in Portugal, in order to develop and implement autonomous maintenance. The main objective of the project was related to the objective to increase and make effective the autonomous maintenance tasks performed by production operators, and in this way avoiding unplanned downtime due to equipment failures.**

Although some autonomous maintenance tasks were already carried out within the company, a preliminary study revealed weaknesses in the application of this tool.

In the initial phase of this pilot project, the main problems encountered at the level of autonomous maintenance were related to the lack of time to carry out these tasks, showing that the stipulated procedures were far from the real needs of the company.

To solve these problems a pilot project was conducted, making several changes in the performance of autonomous maintenance tasks, making them standard and adapted to reality of each production line. There was a general improvement in the factory indicators, and essentially there was a behavioral change, since the operators felt that their opinions were taking into account and began to understand the importance of small tasks performed by them.

***Index Terms*— Autonomous Maintenance, Maintenance management, Total Productive Maintenance.**

I. Introduction

THE competition between companies has been intensifying over the years. In this global economic crisis environment, this factor plays an even more crucial role in the performance of companies.

A few years ago the concept of competitiveness was almost nonexistent. However, over time the existence of new companies made the market more complex, causing consumers are more demanding in all aspects.

The existence of a large number of competitors in the same area requires businesses to adopt new tools and methodologies that allow remaining competitive and sustainable in the market. The application of effective methodologies is essential so that they achieve success.

To achieve the expected competitiveness, and the best possible results, companies tend to adopt methodologies for continuous improvement. Studies indicate that the application of continuous improvement methodologies combined with a good human resource management can significantly increase the performance of an industry [1].

One of the methodology that has been recognized as a strategic weapon to increase the productive performance of companies is Total Productive Maintenance, Which has been applied successfully in many companies [2].

Maintenance was initially seen by many companies as a necessary evil that should only be performed when absolutely necessary. However, with the growth of markets, increasing competitiveness, and the development of new production paradigms, the maintenance concept has evolved.

Following this evolution, came the concept of Total Productive Maintenance. This methodology originated in Japan [3], is considered an evolution of the concept of preventive maintenance that emerged in the United States.

TPM is a methodology that aims to increase the availability of existing equipment, and thus reduce the need for more capital investments [4], allowing companies a break in their budgets.

TPM is supported by eight pillars that define it, namely: autonomous maintenance, planned maintenance, targeted improvements, education and training, quality maintenance, new equipment management, administrative TPM, and the last pillar health, safety and hygiene.

Among the various TPM pillars, there is one that is the cornerstone of this methodology, the autonomous maintenance. This pillar stands out in that it includes a series of systematic work to be performed frequently [5].

In the autonomous maintenance the operator must be involved in the maintenance of equipment and is responsible for taking care of it, performing minor repairs and suggesting improvements that reduce failures and/or its consequences [5]. To endow operators with knowledge about their equipment is a way to maximize their efficiency.

Good management and effective maintenance policy can influence the productivity and profitability of a production process, and maintenance can now be seen as a profit generating function and not as a cost center [6].

This paper presents the results of the development and implementation of autonomous maintenance in a furniture company that organizes its production in areas and production lines.

This paper is organized as follows. Section II presents TPM methodology and the pillar of autonomous maintenance. Section III is about the diagnosis phase of the project. Section IV presents the implemented improvements. In section V, the results are discussed and finally, section VI draws the main conclusions.

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II. Total productive Maintenance

TPM is defined as the productive maintenance performed by all employees who perform activities in small groups, and can be seen as the performance of service integrating the entire company. This means that the TPM is a maintenance methodology developed with the participation of everyone from employees, service technicians, including supervisors.

TPM is supported by a set of pillars that define and enable their implementation. Autonomous maintenance is considered one of the most important pillars in TPM philosophy. The autonomous maintenance consists in performing small maintenance activities that are performed by the employees responsible for each machine, thereby distinguishing TPM of any other type of philosophy [8].

In autonomous maintenance, it is intended to develop a set of skills in employees so that they easily dominate their equipment [9], sensing its first signs of wear, misfits, leakage or even parts loose, being able to easily suggest improvements needed to eliminate these losses [5].

The implementation of the first pillar, autonomous maintenance, also called first level maintenance, provides the basic foundation for the implementation of the other pillars.

The main goal of autonomous maintenance is to reduce the number of equipment failures, and for that purpose employees should eliminate the anomalies of the machines. These anomalies are seen as minor flaws, abnormal operation of the equipment or even small errors that may appear on their machines [10].

III. Diagnostic phase

A. Maintenance Management

In the company under study, several tasks of preventive maintenance are monthly planned. This planning is of utmost importance so that in the short time planned for maintenance operations, all procedures necessary for the proper operation of the equipment should be completed since the plant works 24 hours a day.

Due to the large number of equipment, this planning is hard-working and should take into account especially the most critical equipment needs.

In the company under study essentially three types of maintenance, preventive maintenance, corrective and autonomous maintenance are held.

In the factory the main way of information registration about maintenance and failures is a software application that supports maintenance management. In this software, all interventions of preventive and corrective maintenance which are held in the company are registered. However, as concerns autonomous maintenance, the record is only manual and the monitoring of the implementation of this type of interventions is lacking.

Although there is no much reference to TPM within the company, it is noticeable that some of its pillars are implicit in its maintenance philosophy. However, it cannot be considered that TPM is successfully and entirely implemented.

The autonomous maintenance is one of the pillars that is implemented in the company. However, not all stages of implementation of autonomous maintenance were performed or successfully completed.

B. Selection of production lines for pilot project implementation

The project took place in some selected lines to move forward with the pilot project. The lines chosen for the pilot project were two line of the edge band area, one line of the foil area, two lines of the cutting area.

The choice of two lines of the edge band area is due to the fact that in these lines many damages and unscheduled downtimes are happened due to lack of cleanliness. In addition, a large amount of dirt is accumulated at the end of the third shift, since maintenance only takes place after three shifts. For these lines, the time and the number of operators required for performing autonomous maintenance tasks were not set, the standards were outdated with respect to the real needs, and there was a discrepancy of tasks performed by different work teams. An analysis of collected data has also shown that only about 55% of autonomous maintenance tasks planned was actually performed in a line and about 24% in the other line, being only carried out daily tasks, weekly or monthly tasks were not performed.

The line of the foil area in its turn is considered one of the most problematic lines of business where it is often necessary forced stoppage to perform cleaning. In this line, there was no schedule or set time to perform maintenance, not even an adequate number of operators to perform maintenance. The analysis of the records of maintenance has shown that only 61% of planned maintenance tasks were performed. In addition there was also a significant difference in the tasks carried out by different teams.

The first line of the cutting area, despite being a line considered new in the company, is already very degraded due to lack of cleaning and maintenance. In this line, autonomous maintenance is often not performed, registering only about 6% of planned tasks performed, and no standards are available to facilitate its implementation.

Finally, in the second line of the cutting area, the realization of first level maintenance is also not frequent and standards are similarly not available.

The selection of these lines has enabled a comprehensive project, testing the impact of autonomous maintenance in lines with different state of maintenance development.

IV. IMPLEMENTATION OF IMPROVEMENTS

A. Autonomous maintenance

The implementation of the pilot project of autonomous maintenance followed a plan set in advance, defining all stages of the project and what it would take place in each of them. The project focused on seven key steps or stages. The first stage was essentially to decide what would be the pilot areas and lines and, then, built the overall project plan. In the second stage, the time and resources required in each of the lines were defined. The third stage consisted on the analysis of the problems in carrying out the first level maintenance and of the current instructions of record keeping. This stage of the project was under the

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responsibility of the maintenance department. It was necessary to adapt the changes to the needs of each area, taking into account all the criteria defined in the previous stages. In stage four, an outline of how the project would take place in each of the lines was made. The fifth stage has focused primarily on visual management to make events more visible and at the same time to follow the first level maintenance activities.

Stage six consists on the implementation phase which was intended to monitor and ensure compliance with the plan. Finally in step seven, the results were analyzed.

To define what would be necessary to change in each line in order to make the most efficient and effective autonomous maintenance, it was necessary to conduct a series of meetings with all personnel concerned in the project. This initial phase of setting changes, to be more efficient, was not exclusively under the responsibility of the maintenance department. In each area, a series of meetings attended by the heads of area, area's experts, foreman's of each team, the trainer, and maintenance personnel responsible for the pilot project, including the maintainer, were conducted.

The decisions were taken together, trying to meet the objectives and opinions of all present, thus ensuring that the changes would be made in the best way. All these meetings have enabled to gather the information needed to complete phase one and two of the project.

After analyzing the problems (stage 3), several improvements to try to solve these problems and normalize the realization of the first level maintenance were defined. These improvements will be presented below for each pilot line.

In the two lines of the edge band area, autonomous maintenance performing time was divided into three blocks to reduce dirt at the end of the third shift, ensuring that in all shifts some maintenance was performed. All the maintenance tasks required were redefined as well as the time and the number of operators required for each.

In line of the foil area, the time and duration to perform maintenance was defined, as well as all the tasks to be performed, the length and required operators.

Finally, in the two lines of the cutting area all aspects required to implement the maintenance from the initial stage were also defined.

B. Standard Work

In order that all the previously work done became standard and was formally used and recognized in the company, a set of documents were developed according to all the company rules, to transmit all changes in the realization of first level maintenance. This task is included in the stage 3 of the project.

In the document designated by work element sheet, all tasks to be performed by equipment were placed, separated by frequencies. Thus, each machine may have more than one work element sheet, if it has different periodicities for associated tasks. In addition, it is also described how to accomplish the task, the reason of its need, and the personal protective equipment to be used. The work element sheet also has a set of photographs associated with each task, allowing operators to easily see the component where it is intended to accomplish each task. Finally, the total time of the first level maintenance is also placed on each work element sheet.

Besides work element sheet, company uses also another document to standardize work designated by standard operating sheet which are less detailed to convey general information, with times associated to each task. In addition, the standard operating sheet, allow representing a layout to easily perceive where each task should be performed.

With the completion of standard operating sheet for autonomous maintenance, employees easily became acquainted with what needed to be done and, since each standard operating sheet refers to the respective work element sheet with the detail of the task, all the information was interconnected.

The same was done for all operators who have to perform tasks on multiple equipment, being described in standard operating sheet the various equipment and the number of tasks that must be performed as well as the respective reference of work element sheet.

Standard operating sheet were built for all pilot lines in order to facilitate the understanding of all made changes.

In addition to the formal documents, a set of project supporting documents were also made.

C. Organization and improvements in workstations

To assist the implementation of the project, it was simultaneously necessary to make some changes in order to improve and to facilitate the realization of first level maintenance. Many of the changes arose from conversations with operators that, giving their opinions, presented also some suggestions. Others arose by observing the realization of the first level maintenance and the perception of the difficulties of operators (stage 5 of the pilot project).

Together, and with the help of maintenance and production department, some changes was then made.

One of the improvements was the placement of suction tubes within some of the equipments. This modification allowed the reduction of dirt inside the equipment since the constant vacuuming reduces the accumulation of dirt. At the same time, the placement of the tube allowed that, to perform autonomous maintenance, operators does not need to resort to an external vacuum cleaner, or even compressed air, and may use the tube itself to perform aspiration.

To facilitate cleaning of rolling machine, a system with recirculation of hot water was implemented. That is, in first level maintenance, two buttons are triggered to allow the inlet of hot water, facilitating cleaning. The application of the hot water allowed that the cleaning time of the inside of the rolling machine be reduced in approximately 15 minutes, since the hot water actives the glue and hardener, making it easier to remove.

To reduce contamination of dirt, in some equipment an extendable curtain was placed so as to prevent the dust spreads in the particularly dirty area, circulate to other parts, keeping them at the lowest possible dirt.

During the monitoring of the implementation of first level maintenance on the first line of the cutting area, a very critical point for the realization of autonomous maintenance

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arose. In one of the areas where it would be necessary to perform maintenance, the access was difficult due to safety guardrails and to the existence of a suction tube, making the area almost unreachable. To address this situation, it was decided to find a different layout for the placement of suction tubes for easy maintenance.

The cleaning of large rolls became difficult and dangerous with only a scrub pad. Thus arose the idea of implementing the "scrub board", a kind of metal with a handle to grab and lined with scrub pad. The application of this tool decreased the risk of accident with injuries on the hands and at the same time enabled to perform cleaning of the roller faster, since it covers a larger area.

Compressed air hoses are a very important tool for achieving first level maintenance, but they are not available at all sites where they were needed. To resolve this issue, compressed air dispensers were placed in some workstations of pilot lines. This allowed the improvement in equipment maintenance, keeping the work places cleaned. Furthermore, in areas where there did not exit, it allowed improving the effectiveness of first level maintenance.

In addition to the dispensers of compressed air hoses, a tool was also developed in the maintenance workshops, to be applied as tip hose in the nozzle of the hose, to access to hard to reach places.

Finally, in the pilot lines before the transport rollers a kind of sponge was placed, which on the passage of the wood panels makes panels cleaning, reducing contamination of dirt over the remaining panels.

In order to further facilitate first level maintenance, some changes were made in the workplace for it organization. One of the first changes was to define the place of all equipment or tools and the organization of cupboard, defining what was necessary or not at each location. The locations of ecopoints were also defined and identified. Finally, on all the workplace a first level maintenance kit and a cleaning kit were placed.

D. Training

The implementation of this whole project would not be possible if all operators did neither know what the goals of the project nor understand the importance of the first level maintenance (Stage 6 of the project).

Thus, initially a theoretical formation was performed where some concepts have been explained, as well as the importance of first level maintenance and general maintenance.

In addition to the theoretical training, an informal training was also conducted with all teams of all pilot areas in order to explain all the changes that were to be held at first level maintenance. In this training, it was explained how the maintenance work will be performed after the changes made and operators could withdraw their questions and suggest some minor changes, considering every operational details.

The formation on all formal documents developed under the project was also promoted. Finally, there was a practical training in the workplace, following the completion of maintenance, with the created standards in order to understand whether they agreed with the real needs and also to gather information and opinions of operators about the project.

This phase of the project was very important to understand the real difficulties of operators when carrying out maintenance, and many improvements have emerged of this sharing of experience by operators.

V. RESULTS ANALYSIS

A. Autonomous maintenance

The first line of the edge band area showed a percentage of performed first level maintenance tasks of approximately 79% compared to 55% previously registered. In this sense there is a very positive increase in carrying out first level maintenance tasks. Concerning the realization of tasks of different frequencies, significant improvements were noticed since previously weekly and monthly tasks were not performed. As regards the implementation of first level maintenance tasks for each team there is now uniformity.

The second line of the edge band area also showed significant improvements in performing first level maintenance tasks. The implementation of the pilot project in this line led to a transition of about 24% of tasks performed for about 67% at the end of the review period. In the second line of the edge band area, improvements were also noticeable in the realization of weekly and monthly maintenance, since these were not performed previously. The realization of tasks by the two teams operating in the second line of the edge band area was initially very similar, and at the end of the pilot project it remains also very similar thus fulfilling one of the main desirable goals.

Analyzing the values concerning the completion of first level maintenance tasks, in the line of the foil area about 73% were held at the end of the pilot project, in July. This sum is higher than the previous value of about 61% of the performed tasks. The number of tasks performed was also uniformly distributed among the three teams. The first line of the cutting area was the one with more interesting results from the standpoint of first level maintenance, once the methodology of first level maintenance was defined in full. In this sense the percentage of tasks performed increased from about 6% to 70% at the end of July.

Finally, analyzing the pilot project implementation results in the second line of the cutting area, where previously there were no records, it appears that in July about 73% of first level maintenance tasks were completed. Regarding the distribution of tasks between teams it appears that the workload is balanced.

B. Analysis of the stoppages

In order to examine the improvements that the pilot project provided, it is important to make a comparison of the stoppages of the lines between the beginning and the end of the pilot project.

Thus, making an initial analysis of the stoppages of the first line of the edge band area, there is an overall reduction in every line stoppages, with the exception of stoppages for first level maintenance realization, which means that tasks started to be carried out more frequently. Thus, it appears that the increase in time spent for performing first level maintenance positively influence all other stoppages,

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compensating the line stoppages and preventing damage of the equipment.

In the second line of the edge band area, there has been a decrease of the main stoppages except stoppages for setup.

In the line of the foil area, generally there is also a decrease of stoppages related to failures of specific equipment. At the same time, there is an increase in the number of hours spent on first level maintenance, which shows that the realization of first level maintenance tasks has an influence in reducing stoppages due to equipment damage.

C. Workplace Organization and cleaning

The improvements in the workplace organization and cleaning are always difficult to quantify in value. However, visually, in the work rhythm and satisfaction of operators such improvements are easily perceived. After the implementation of the improvements, it was found that operators were able to perform the tasks more quickly and at the same time, to avoid tasks that were previously performed unnecessarily. All these improvements are positive for the efficiency and availability of lines, motivating to the achievement of first level maintenance.

By keeping clean and tidy workplaces, first level maintenance tasks can be performed more quickly and efficiently, contributing to the overall improvement of the areas.

D. Versatility of operators

The training given to operators encouraged them to perform first level maintenance tasks and rose motivation. All trainings made, theoretical and practical training, or training in the new standards, allowed the employees becoming capable of performing the tasks efficiently. It can be said that the employees received all the necessary information to become autonomous in the realization and perception of all aspects related to first level maintenance.

At the same time that these trainings allowed an evolution in competency of each individual operator, also allowed a better unity of the group and sense of responsibility for the implementation of improvements in the areas.

All trainings enabled operators to perceive the importance of the aspects related to the first level maintenance and also the implications and improvements that carrying out these tasks can influence other improvements in their areas.

In short, these trainings contributed to increase versatility of operators and to motivate them to carry out first level maintenance.

In order to understand how employees feel about the pilot project a questionnaire was carried out with a series of questions or statements to which operators answered whether they agreed or not, and could still give their opinions and suggestions for improvement. The questionnaire analysis allowed perceiving that the new instructions were in accordance with the needs and the stipulated time was adequate in the view point of the operators.

The most added value of the questionnaire was the opinion of operators about some improvements that could be made in equipment to facilitate first level maintenance and even to increase equipment yield.

Later, some of these suggestions have been analyzed and some of them were implemented not with considerable costs, and other, those requiring more costs, had to be examined more closely by the maintainer.

In general, it can be concluded that in view of operators the pilot project brought improvements in the realization of the first level maintenance, thus fulfilling some of the expected goals.

VI. Conclusions

To carry out the pilot project, it was essential to analyze and study the status of first level maintenance in the areas where the project took place and also the factors that affects its development. With the help of competent personnel, the identification of all relevant aspects was undertaken.

One of the main problems in the development of first level maintenance was the lack of standardization throughout the entire process of first level maintenance implementation, in both documentation and procedure. It was noticed that many of the standards were outdated given the actual needs or were inexistent. It was also found that there was no balance between the tasks performed by the teams and the shifts, and the workload was also not balanced between operators. In addition, there was a lack of information to operators about the benefits of performing first level maintenance and lack of motivation to carry it out, causing a low percentage of performed tasks. In addition to these problems, it was found that many of the available tools were not the most appropriate to facilitate the tasks and that some of the workplaces had no tools.

In order to solve these problems, the normalization of first level maintenance realization was accomplished. To this end, schedules and downtime to perform the maintenance tasks were settled, tasks were assigned to operators in a balanced way, and a clear procedure for the realization of the first level maintenance was defined. At the same time, all supporting documents required for the completion of the project were created or updated. Besides, the training for operators required to carry out the project was held and some improvements in stations were implemented to facilitate the realization of first level maintenance.

The implementation of this project enabled some improvements in the performance of the department and the plant that are easily visible through the general maintenance indicators. The comparison of the indicators at the beginning and at the end of the project shows that in all areas the indicators improved. A decrease in downtime was observed, of about 7 hours in the line of the foil area and about 60 hours month in the first line of the edge band area, a very significant result in the latter where the stoppages were really high.

In the future, other lines of the plant will be analyzed to reinforce first level maintenance and, at the same time, other pillars of Total Productive Maintenance such as planned maintenance pillar will be developed.

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