Implementation of the autonomous maintenance pillar based on the TPM philosophy

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Abstract- This paper presents the implementation of the autonomous maintenance pillar based on the principles of total productive maintenance (TPM) in a ceramic tiles plant. In order to reduce the contamination of the process and achieve the objective of sustainable production, the proposed methodology was applied. This methodology was structured in three stages that make up the 7 steps described in the literature to achieve the overall application of autonomous maintenance: standardizing the basic conditions (three steps), maintaining the basic conditions (two steps), and systematically improving the conditions of the machine (two steps). The strategy applied reduced large amounts of waste and contamination by dirt, noise, heat, and odor generated in the ceramic tiles plant, which resulted in lower energy consumption as well as lower maintenance and production costs. Through the use of performance indicators, effective compliance with the cleaning, inspection, lubrication, and adjustment standards was verified, as well as autonomous maintenance activities carried out by the equipment operators, which allowed the reduction of waste and contamination of the process.

Keywords – Total Productive Maintenance, ceramic tiles plant, Autonomous Maintenance

I. Introduction

Total Productive Maintenance (TPM) is plant maintenance performed by small groups aimed at avoiding waste and defects in an industrial plant [1]. TPM's contribution to the industry to improve its productivity has been recognized as a way to reduce the six big losses related to the machine [2]. TPM is globally accepted as the most effective maintenance strategy for improving machine performance. Research over the past few years has shown that TPM has a direct impact on improving the performance of the equipment [3].

There are situations where production is untimely interrupted, such as machine preparations and adjustments that take too long, small stops, idling speed, and slowdowns in operation, which are not considered in most cases and go unnoticed by the maintenance staff [4].

TPM has three main characteristics that describe its meaning. The overall equipment effectiveness that pursues economic efficiency, a total maintenance system that includes prevention and improvement of scheduled maintenance, and the participation of all employees that includes autonomous maintenance by operators through small group activities [5]. According to the Japanese Institute of Plant Maintenance, it is clear that a TPM development program should tailor to the particular characteristics of each organization, that is to say, to its needs and problems [6]. However, there are some basic considerations to take into account in most cases:

- Eliminate the six big losses to improve equipment effectiveness.
- An autonomous maintenance program.
- A program for the maintenance department.
- Increase the capabilities of maintenance and operations staff.
- An initial program of leadership and equipment management.

The second of these five TPM activities, autonomous maintenance, is a unique feature that is difficult to implement in practice because the operators have the concept "I operate, you repair" [7]. Autonomous maintenance involves preventive and predictive activities performed by the equipment operators, which generates a greater understanding of the operation and allows them to get involved in improving the performance of the machine [8]. When the operator is responsible for both the operation of the machine and its maintenance, production increases [9].

In order to control the six big losses described in the TPM and achieve the maximum Overall Equipment Effectiveness (OEE), it is necessary to reduce downtime, speed loss, and improve product quality, which can be achieved by maintaining the equipment in proper conditions by removing dirt and contamination from the production process [10]. The pillar of the autonomous maintenance described by the TPM applied in a manufacturing plant has a positive impact on the increase of the OEE of the machines [11].

Ceramics Italia is a company located in the city of Cucuta, in the Department of Norte de Santander in Colombia, which manufactures materials for floors and wall cladding. Within the framework of the TPM program, the autonomous maintenance pillar was implemented according to the guidelines of the Japanese Institute of Plant Maintenance.

II. MATERIALS AND METHODS

The production process in the plant includes several stages for the manufacture of ceramic products. The structure of the plant describes the process required for the manufacture of the ceramic product, as shown in Figure 1.

Figure 1. Description of the ceramic processing

Each stage of the process has a series of equipment that needs to be managed in order to achieve its highest performance. It is necessary to identify all the equipment to know its proper operation condition and have the ability to understand the data collected during its operation. There are eight main pillars to TPM including autonomous maintenance, planned maintenance, quality maintenance, focused improvement, equipment management, training and education, environmental health and safety, and administration [12].

The implementation of autonomous maintenance was developed in seven steps organized in three stages, as described in Figure 2. The premise of autonomous maintenance is to involve the operator in the daily maintenance activities of the equipment, with the objective of permanently diagnosing its actual condition [13]. Operators feel responsible for their machines; equipment becomes more reliable [14].

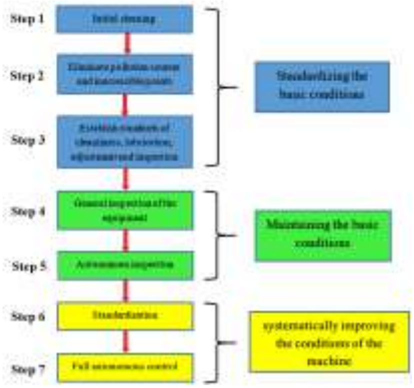

Figure 2. Three stages - seven steps for developing autonomous maintenance

To carry out the seven steps in the three stages described in the literature in order to achieve the objective of reducing contamination, the proposed methodology described in Figure 3 was applied.

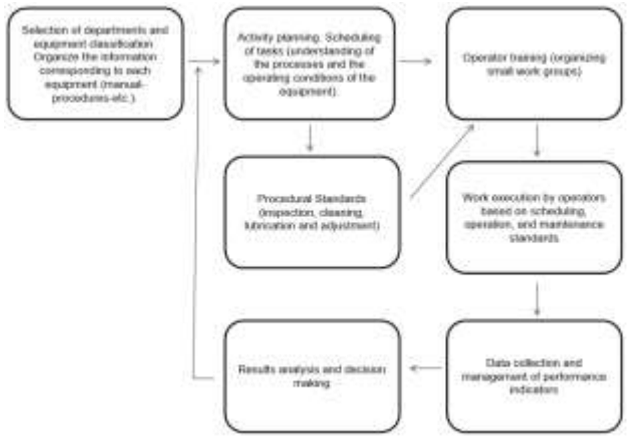

Figure 3. Proposed methodology for implementing the seven steps

The stages of the manufacturing process were organized in four specific departments (Processing lines, presses, furnaces, and sorting), as shown in Figure 4. The organization by areas seeks to structure the initial audit for the implementation process of the autonomous maintenance pillar [15].

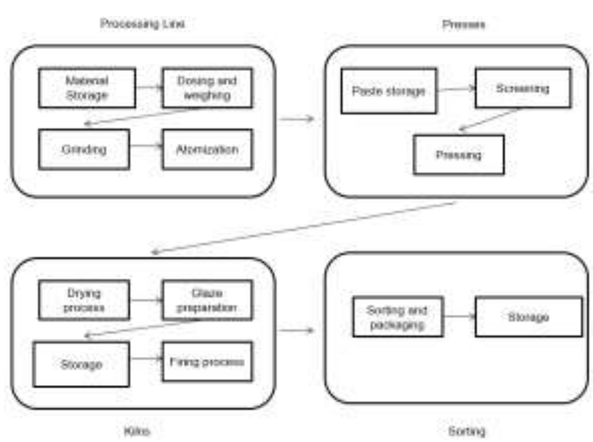

Figure 4. Organization of the process by departments for the application of the methodology

Below is a description of each of the 7 steps performed on each piece of equipment in its corresponding operating department.

2.1 Initial Cleaning –

This activity was carried out by performing a general cleaning of the equipment in the plant. The dirt, dust, and residues that had adhered to the machines over time were removed. Although it is difficult to maintain a degree of cleanliness due to the characteristics of the process with the ceramic material, this initial cleaning is the beginning of keeping the machines in good condition and avoiding their deterioration.

Figure 5. Decoration line

2.2. Establishing cleaning, lubrication, adjustment, and inspection standards –

According to previous knowledge of the machinery, inspection, cleaning, and lubrication standards were prepared in order to maintain and establish the equipment condition. In this stage, the procedures for the equipment maintenance were designed so that each operator could carry out the basic maintenance activities according to the schedule defined in the TPM program. Routes and protocols were established for the effective lubrication of each of the components of the different equipment located at each stage of the process. Figure 6 shows the standard for inspection and general cleaning of the equipment used to apply water to the glazed tiles.

italia TPM - CHOICE OF A POINT

TOPIC: Inspection and General Cleaning NUMBER: TPM-4003

PREPARED BY: Maintenance Manager DATE: 20-10-30

CLASSIFICATION BASIC KNOWLEDGE IMPROVEMENT PROCEDURE HEAD LEADER

1. Enlistment of tools:

☐ Compressed air

2. Cleaning nozzles:

☐ Disassemble the nozzle.

3. Pump check:

DATE:		INSTRUCTOR:		COLLABORATOR:	

Figure 6. Standard procedure for inspection and cleaning of equipment used for applying water

At this stage, the type of deterioration that the equipment may suffer with the active participation of the operator was identified. The inspection standards were designed by specialists and the operators were trained to carry out these activities. The general inspection was carried out on all the plant's equipment and made possible to identify the most common problems that occur on a daily basis. Table 1 shows small malfunctions and basic conditions in the equipment that affect its maintenance and operation.

Table -1 Details of daily inconveniences that hinder autonomous maintenance

	Inconveniences	Inconvenience Details
1.	Small malfunctions	Dust, oil, dirt, waste.
1.1	By dirt	Friction, wear, corrosion, deformation.
1.2	By lubrication	Obstruction, deformation, heating, noise, vibrations.
1.3	By inspection	Scratches, crushing, deformation.
1.4	By adjustment	
2.	Basic conditions	Damage and obstruction by dirt and waste.
2.1	Cleaning	Difficulty applying lubrication, leaks due to damage.
2.2	Lubrication	Waste, lack of indicators and components.
2.3	Inspection	Misalignment, deformation by excessive force.
2.4	adjustment	
3.	Hard-to-Access Areas	Machine structure, protections, positions, space.
3.1	For cleaning	Position of the grease nozzle, height, used oil outlet
3.2	For lubrication	nozzle.
3.3	For inspection	Structure, positioning, location of measuring devices,
3.4	For adjustment	Lack of adequate indications.

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2.3. Standardization –

The standardization ensured that the cleaning, lubrication, and inspection activities designed in the program were properly assigned to the operators and that they were carried out in the shortest possible time. The standards were accompanied by one-point lessons that include the necessary information to ensure easy understanding of the operators. The objective of this stage is to improve the execution of maintenance work performed by the operator.

When carrying out this activity, the following steps were taken into account:

1. Identify the type of machine.

2. To know the operation characteristics of the machine.

3. To know the technical specifications of the machine (according to the catalog): lubricants, types of bearings, among others.

4. Exchange information with technicians, mechanics, and plant operators.

5. Taking photographs.

6. Form creation.

7. To fill out the forms.

This process involves the development of forms that show the step-by-step procedure necessary to perform the cleaning, inspection, and lubrication standards. 59 one-point lessons were made as standards to develop the autonomous maintenance activities by the operators, some of them are listed in the following Table 2.

Table -2 One-point lessons.

Lubrication of the mobile crossbeam - hydraulic press.	Mold dismantling - hydraulic press.	Lubrication of helical and chain drives - horizontal dryer.
Lubrication of columns and worm screw-hydraulic press.	Height adjustment of the shaft - hydraulic press.	Lubrication of chain drives of infeed and outfeed elevators of horizontal dryers.
Axle bearings lubrication - hydraulic press flywheel.	Mold assembly - hydraulic press.	Edge Cleaner Adjustment
Lubrication of motor bearings - hydraulic press.	Height adjustment of lower pins and plate feeder - hydraulic press.	Roller lubrication - horizontal dryer.
Extraction of lower pins - hydraulic press.	Gear lubrication - vertical dryer.	Visual control of leaks - motovariators.

Dismantling of mold box - hydraulic press.	Centering of pins - hydraulic press.	Lubrication of edge cleaners.
Mold box assembly - hydraulic press.	Cleaning of grille - hydraulic press.	Bearing Lubrication.
Dismantling of pins - hydraulic press.	Lubrication of rocker shaft bearings - vertical dryer.	General cleaning of tanks.
Assembly of lower pins - hydraulic press.	Lubrication of the drag chain joints- vertical dryer.	Revision of belts.
Inspection and general cleaning of compensators.	Inspection and general cleaning - decorating machine.	Verification and change of couplings in lateral rails.
Change of upper pins - hydraulic press.	Lubrication of shaft supports - vertical dryer.	Verification of belt tension and pulley alignment.

2.4. Full autonomous control –

The trainings on the pillar of autonomous maintenance were guided by the maintenance and production department of the plant. Operators were trained to develop basic maintenance activities and were involved in the process through small group activities so that they are able to perform maintenance and solve problems, constantly improving their performance. To ensure continuous improvement, individual performance indicators were used for each operator, collective performance for group, and overall performance by department. Equation 1 was applied to calculate each operator's compliance per month.

$$C = ((M-A)/(M-D))*100\% \qquad (1)$$

Where, C: Compliance percentage, M: Number of days worked in the month, A: Number of days in which no activities were carried out, and D: Number of resting days of one operator per month.
The performance by department was also determined by applying Equation 2.

$$G = (SC)/(OP) \qquad (2)$$

Where, G: Overall compliance percentage by department, SC: Sum of the operators' particular compliance by department, and OP: Total operators per department.

III. Result

Plant contamination from dirt was reduced by applying the inspection and cleaning standards defined in the procedural standards for each piece of equipment. Likewise, the lubrication and adjustment protocols made it possible to reduce contamination due to oil leaks. In addition, noise, vibration, and heat generation levels in the equipment showed significant decreases.

The control over the performance of the operators individually and in groups allowed reducing maintenance and production costs, improving equipment performance and product quality. Figure 7 shows the performance of an operator during the first six months of application of the methodology for the implementation of autonomous maintenance.

Figure 7. Particular case of operator performance

There was an increase in performance since the implementation of the methodology and during the first three months. In the fourth month, performance decreases precipitously, although it is still a little higher than before. A similar performance was presented in all the analyzed departments, as can be seen in Figure 8 (presses), Figure 9 (processing lines), Figure 10 (kilns), and Figure 11(sorting).

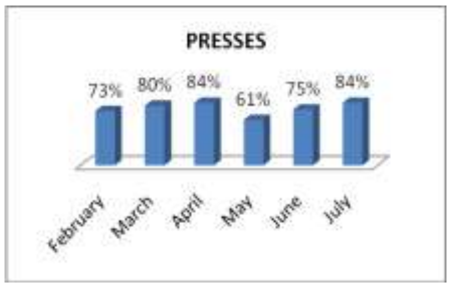

Figure 8. Particular case of operator performance

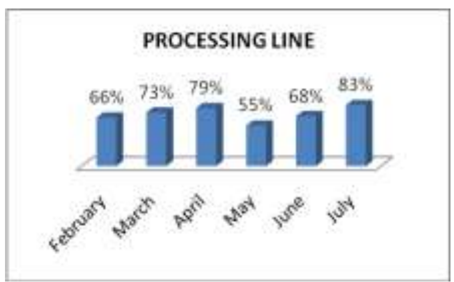

Figure 9. Overall performance of material processing line

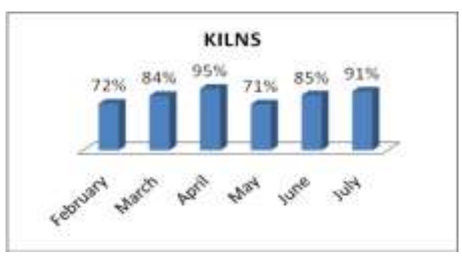

Figure 10. Overall performance of kilns department

Figure 11. Overall performance of sorting department

As can be seen in the figures, there was a notable decrease in May in the performance of autonomous maintenance activities carried out by operators, which is undoubtedly due to some administrative situation or decision that affected the work environment, as well as the motivation and interest of all operators.

IV.CONCLUSION

The process of implementing autonomous maintenance in the company was accomplished according to the objectives outlined in the proposed methodology. The autonomous maintenance becomes the pillar for the design and development of a total productive maintenance program TPM for the company, aimed at maximizing the overall equipment effectiveness in each department. In general terms, the performance of equipment operators in all departments increased by an average of 20%, resulting in a reduction in downtime and speed losses, which increases the overall equipment and plant effectiveness.

Cleaning, lubrication, and equipment adjustment activities were well executed and at a high level of performance, making production cleaner and more efficient. Also, maintenance work, consumption of inputs, and waste derived from the process were reduced. This makes possible to mitigate maintenance waste such as oils and greases, reduce fuel consumption due to incorrect operation, lower noise levels due to vibrations and misalignments, as well as lower energy losses due to friction and hot points.

The high degree of commitment reached by the operators during the process stages allowed reducing speed losses and equipment downtime, increasing their availability and improving product quality. It is necessary to analyze in greater detail the causes that generated the overall decrease in performance presented in the fourth month in all departments of the process. The performance control showed the importance of motivation and commitment of the staff in this type of processes.

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