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Preventive maintance plan for SKF Latin Trade SAS equipment

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Abstract
This research presents the design and implementation of the preventive and predictive maintenance plan developed for the seven polishing machines of the Swedish multinational SKF, of the LSB (Large Size Bearing) line. Based on Reliability Centered Maintenance (RCM), which allows identifying the most relevant equipment for the process through a criticality analysis adopting strategies in order to eliminate the occurrence of failures. The methodology implemented in this research allowed the generation of maintenance tasks that facilitated the management and visualization of the information of each asset. The company provides maintenance services for large bearings used in cement plants, foundries and industrial material transport machines, seeking to optimize production methods and the application of this theoretical and analytical procedure allowed verifying that the conditioning services offered by the company are more efficient, demonstrating with figures the retribution of the plan.

Key words: preventive maintenance plan; predictive maintenance; maintenance tasks; failures; equipment; corrective maintenance; SKF Latin Trade SAS.

Plan de mantenimiento preventivo para los equipos de la empresa SKF Latin Trade SAS

Resumen
Esta investigación presenta el diseño e implementación del plan de mantenimiento preventivo y predictivo elaborado para las siete máquinas de pulimento de la multinacional sueca SKF, de la línea LSB (Large Size Bearing). Basado en el Mantenimiento Centrado de Confiabilidad (RCM), que permite identificar los equipos de mayor relevancia para el proceso mediante un análisis de criticidad adoptando estrategias con el fin de eliminar la ocurrencia de fallas. La metodología implementada en esta investigación permitió generar tareas de mantenimiento que facilitaron el manejo y visualización de la información de cada activo. La empresa presta servicios de mantenimiento para rodamientos de gran tamaño usados en cementeras, fundidoras y maquinas industriales de transporte de material, buscando optimizar los métodos productivos y la aplicación de este procedimiento teórico y analítico permitió verificar que los servicios de acondicionamiento ofrecidos por la empresa son más eficientes, demostrando con cifras la retribución del plan.

Palabras clave: plan de mantenimiento preventivo; predictivo; tareas de mantenimiento; fallas; equipos; mantenimiento correctivo; SKF Latin Trade SAS.

1. Introduction

The maintenance of equipment must be carried out based on its function and taking into account its design, which is why since the beginning of industrialization, maintenance has been conceived as the one in charge of the good performance of the machine. Technological advances have improved the condition and revision of equipment, which has optimized delivery times. SKF Latin Trade is the Latin American branch of a Swedish multinational company in charge of selling and reconditioning bearings, seals, calibration of high precision equipment and multiple engineering works. In Colombia, within its facilities located in Siberia (Cota, Cundinamarca), it remanufactures bearings for freight cars, conveyor belts and manages two reconditioning lines; Train Bearing Units (TBU) and Large

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Size Bearings (LSB). The LSB line uses seven pieces of equipment; horizontal polishing table, compressor, electrical distribution boards and four lathes, which are in daily use and require constant maintenance, therefore, in this research we used tools provided by Reliability Centered Maintenance (RCM) since this work philosophy has been widely accepted by large companies that require reliable monitoring of their machines [1-6]

1.1 Description of the research problem

The maintenance tasks were of low technical scope, there was no clarity for the operator and the maintenance indicators were of low reliability (criticality of 28% of maintainable items). They were not based on accurate measurements such as temperature or vibration. According to the company's maintenance reports, the machines only had monthly preventive maintenance that consisted only of reviewing wear and tear parameters and equipment cleanliness. The useful life of the serviceable parts was not considered to facilitate the calculation of the probability of failure. The most common consumable parts were drive belts, bearings, safety elements, mechanical seals. In addition to this, after the COVID-19 pandemic, the remanufacturing area decided to have an annual stock, since it had the resources and strategic planning to manage each one [7-10]

The purpose of planning the stock for one year was for purchasing purposes, since, from this area, the processes of quotation, acquisition and arrival of spare parts are delayed. These processes can last from two to six months, and it is critical for productivity reasons to have a machine stopped due to an unforeseen failure that works eight hours a day. Considering the 192 hours they work per month; the resource consumes about 20% per month among the total number of inspections. However, constant spare parts changes indicate a failure in the follow-up that needs to be adjusted to obtain better production performance and foresee the improvements to be made, without compromising product delivery times. The cost per inspection changes if a spare part is required; however, maintenance is normally of an autonomous type, so it does not involve external labor, although it compromises the company's productivity. Based on the above and taking into account the parameters established for the development of this project, the following question arises: How to improve the monitoring of each equipment for a timely maintenance of the LSB line in the company SKF Latin Trade SAS? [11-16]

1.2 Research justification

The company had the necessary instruments for the inspection and verification of each equipment, this was a way to evolve the processes managed without the need to resort to other equipment or suppliers in most cases. After the routine use and common wear of the machines, the company needed to standardize a predictive maintenance plan that would indicate how often they should be performed; vibration analysis, ultrasound and thermography. To evaluate the behavior of the machines without compromising their function and service delivery schedule. It is important to

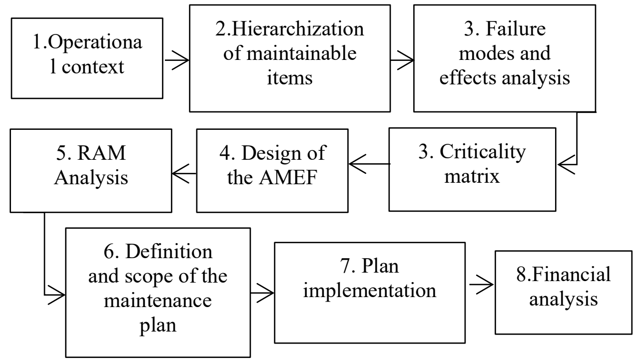

Figure 1. Project methodology.
Source: Author.

highlight the importance of this process, since it contributed to save time and money, allowing the operators to concentrate on their daily remanufacturing operations and making the work schedule where the dates were specified, being necessary the study of each asset for its analysis. The author's contribution from Mechanical Engineering in this project is the implementation of ISO 14224 and ASTM 1934-99 (Thermography analysis), D3580 (Vibration analysis), E114-10 [4] (Ultrasound test), which were to be used, also in the parameters of standardization, monitoring and support of maintenance according to workload and optimization of the current plan. All this to facilitate the tasks of the operators that will speed up delivery times, increasing production capacity in the plant [17-20]

2. Methodology

This research had a qualitative and systematic approach, to achieve the objective, information was collected from the maintenance history and the supplier manual. It was captured in the format and considered the errors that each equipment presented in the maintenance tasks of the last two years, the spare parts required in the corrective maintenance previously done and the criticality of the equipment based on its productivity, time in operation and relevance within the operation (Fig.1). The project was structured in a series of steps as follows [21-23]:

2.1 Operational context

An analysis of the workload of the line's equipment was carried out, taking into account the corrective maintenance history, the life history of each one, technical data sheets and operating manuals. In addition to the comments of the operators in charge of operating the equipment and the two people in charge of performing the weekly and monthly maintenance tasks. In order to better address the problem [24,25]

2.2 Hierarchization of maintainable items

Each piece of equipment was broken down into system, function and maintainable item, according to ISO 14224. Where we went from the most general to the most particular, from the equipment to the type of maintenance it requires to function in the best way, within the categories are included: Equipment, system, maintainable item (engines, transmissions, coolants), type of failure that could present and maintenance [26-28]

2.3 Failure modes and effects analysis

In order to identify the failure modes of each piece of equipment, a thorough preventive maintenance was carried out to note down the details of each machine and thus, together with the suggestions indicated in the manuals, adjust the failure mechanism and obtain more rigorous severity criteria. For this we reviewed the maintenance history, taking the maintenance tasks of the last two years, which for security and privacy reasons of the company is not authorized to use these documents in this article, to have a clear outline of what has happened with the machine, raise possible failure scenarios and based on that raise the necessary solutions or repairs [29-32].

2.4 Criticality matrix

A criticality matrix was developed together with the chief engineer, workshop chief engineer and maintenance engineer to assign values and importance to the severity criteria that took into account industrial safety, environmental impact, maintenance costs, lost production time and quality control of the finished product. Based on the company's quality and productivity parameters, the maintenance route was programmed based on the worst-case scenarios proposed by the work table created for this maintenance plan. Where the worst scenarios where it is necessary to do a corrective maintenance were classified with the letter A and the red color in the AMEF format, the scenarios where a preventive maintenance could be implemented with the letter B and the yellow color and finally the scenarios where it is only necessary to do lubrication and cleaning with the letter C and the green color [33-35].

2.5 Design of the AMEF

The FEA first prioritizes the taxonomy of the equipment, the failure modes and effects by which the equipment could fail, the severity criteria proposed with the area engineers in the criticality matrix in Table 1, the valuation obtained from the calculation of the severity criteria, which range from one to three, where one is considered non-critical, two medium critical and three very critical. Each value was recorded in the criticality matrix developed with SKF engineers (Table 1), where it is described why the value is assigned to each criterion and it is related to the failure frequency. Taking into account the value assigned for each one, a value of A, B or C is obtained, where C is not critical, B is medium critical and A is very critical. From this concept, a predictive inspection frequency calculation is made, according to the criticality level of the maintainable item. For the equipment categorized as non-critical; Horizontal Polishing Table, Medium Lathe and Large Lathe, the maintenance benefits are evaluated to define if its maintenance is essential [36,37], or on the contrary, the option that the component works until breakage is considered. The severity criteria defined determine the maintenance tasks that will be implemented for maintainable equipment and items.

After obtaining the criticality of each maintainable item, the frequency of predictive inspections is calculated, where the periodicity between each measurement is obtained to better monitor the condition of the maintainable items that require greater attention due to their use. Based on the above, maintenance tasks are proposed that lead to a better performance and extension of useful life to avoid unexpected cost overruns [38-40].

2.6 RAM analysis

2.1.1 Equations

For the reliability of the plan, five management indicators were established that will contribute to a better evaluation of the quality and reliability of the plan itself:

- **Mean time between failures:** It consists of measuring the total time of good operation of the equipment between each repair and is calculated as follows:

$$MTBF = \frac{Working\ hours\ in\ good\ condition}{Number\ of\ corrective\ interventions\ per\ year} \quad (1)$$

- **Maintainability:** Ease with which equipment returns to operations after a failure:

Table 1.
Criticality matrix.

Criticality matrix for reliability analysis								
Severity criterio: Impacts						Occurrence criterion		
Months (M), Days (D) and Hours (H)								
						Probability of failure		
Classify	safety	Environment	Maintenance	Time lost	Quality	1D < 1M	1 < 6M	> 6M
						A	B	C
A	Incapacity > 3D - Fatality	High impact - Control > 3 H	CM > 1.500.000	P > 16H	High	9	6	3
B	Incapacity 1-3D	Control < 3 H	$500,000<CM<=$1,500.000	4 H < P <= 16 H	Medium	6	4	2
C	No incapacity	No impact	CM =< $500,000	P< 4H	Low	3	2	1

Source: Author.

$$MTTR = \frac{Hours\ spent\ on\ repair}{Number\ of\ interventions\ per\ year} \quad (2)$$

- **Availability:** This indicator evaluates the condition of the equipment to fulfill its function based on the mean time between failures and maintainability as follows:

$$Availability: \frac{MTBF}{MTBF + MTTR} \quad (3)$$

- **Maintenance cost over replacement value:**

$$CPMV = \frac{Total\ maintenance\ cost}{Price\ of\ new\ equipment} X100 \quad (4)$$

- **Cost of maintenance over billing:**

$$CMF = \frac{Total\ maintenance\ cost}{Gross\ invoicing} \quad (5)$$

To find the criticality value, the failure modes and effects were taken and assigned a value in each box of the severity criteria. A value between one and three was assigned as indicated in the criticality matrix and, within the equipment evaluation, the severity of the failure was calculated from the criteria and the probability of failure. Thus, the equation was obtained:

$$Severity = (IS * 0.25) + (EI * 0.2) + (MC * 0.1) + (TLP * 0.25) + (QC * 0.2) \quad (6)$$

Where:
IS: Industrial Safety
EI: Environmental impact
MC: Maintenance cost
TLP: Time lost in production
QC: Quality control

Now, the probability of failure was also assigned a range between 1 and 3, where 1 meant likely to fail in 6 months or more and 3 meant likely to fail between 1 day and one month, as indicated in the criticality matrix. This value was assigned based on the corrective history of the equipment, multiplied by the severity equation (Equation 1) and the severity rating of the equipment failure was obtained, as indicated below:

$$Classification = Severity * Probabilty\ of\ failure\ occurrence \quad (7)$$

Finally, the FEA format was programmed with conditionals to obtain the criticality as follows:

$$If\ Classification \leq 3\ put\ C$$
$$If\ Classification \leq 6\ put\ B$$
$$If\ Classification \geq 6.1\ put\ A$$

The matrix is required to quantify and explain on what basis each value is assigned according to the failure method. For this, the following values are assigned:
A: Highly critical
B: Average criticism
C: Non-critical

2.7 *Definition and scope of the maintenance plan*

Based on the modes and effects of the AMEF, the maintenance tasks were proposed, taking into account the assessment obtained and the severity criteria proposed for each failure mode in order to act correctly in the intervention of the assets. Failure modes and actions prior to corrective maintenance were raised at the maintenance plan creation meeting together with the other three engineers in charge. The comments and suggestions of the operators were taken into account in order to have a complete scheme and not to omit any possible failure mode [41,42].

2.8 *Plan implementation*

The plan is standardized and programmed through the maintenance software used by the company, leaving two monthly tasks for each piece of equipment and a weekly task for the compressor oil level. The tasks have a schedule to be updated based on the comments of the operator who performed the maintenance. Since, it is necessary to take into account whether to avoid corrective maintenance, it is necessary to change a machine element such as gears, belts, bearings, among others, that could generate a massive failure in the production line and generate cost overruns [43,44].

2.9 *Financial analysis*

Finally, a financial analysis was performed in order to evaluate the cost-benefit of the plan for the company. With the calculation of ROI (Return on Investment). It was found that the maintenance plan gives a clearer idea about the budget that must be had per semester, the machine elements that can be easily purchased and replaced, as well as those that require to be imported and if it is necessary to dismantle the complete equipment to replace it. Besides, the maintenance history is required to specify which parts were replaced, which elements were used and with this the budget, the downtime of the machine in production and the delivery times of the product [45,46]

3. Results

When making the calculation for each of the seven pieces of equipment, it was found that four of them; parallel lathe, small lathe, compressor and electrical distribution, are moderately critical, therefore, they require specific maintenance in the failure modes and effects that yielded this result.

The AMEF format indicates that four of the seven pieces of equipment in the line are of medium criticality. Taking into account that they will be treated as if they were of high criticality, a specific follow-up is made to maintainable items such as: motor, mobile elements, electrical connectivity and mobile elements that require greater lubrication, revision due to aging and wear according to their use.

Table 2.
Classification for each team.

Classification for each equipment				
Equipment	**System**	**Maintainable item**	**Failure**	**Maintance**
Parallel and Small lathes	Transmission	Electric motor	Excess vibration	Lubrication and vibration analysis
		Transmission box	Transmission case misadjusment	Lubrication and vibration analysis
Compressor	Dryer	Refrigeration	Hoses are cristallized	Replace hoses and oil leveling
Electric distribution	Distribution board	Damage to contactors	Short circuit	Change of terminals

Source: Author.

For a better analysis, the equipment with medium criticality was taken to classify the maintainable items by the type of probable failure they may present and to obtain a model where the maintenance tasks are adapted to the specific needs of each equipment, as shown in Table 2.

4. Analysis of results

Taking a percentage of this equipment out of a total of 25 maintainable items, of which 7 are critical and correspond to the line (motors, control boxes, heat exchanger, dryer), the criticality percentage is twenty-eight percent (28%) (see Fig. 2).

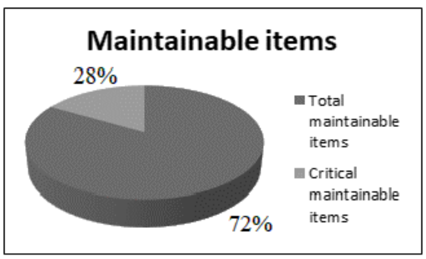

Figure 2. Maintainable items.
Source: Author.

Based on the results of the total number of maintainable elements and the criticality matrix, if one of them fails, maintenance tasks are issued for each piece of equipment according to the criticality of its components:

Table 3.
Maintenance tasks.

Maintance tasks	
Smal lathe	Spindle and clamping cup adjustment Gear lubrication Brake check
Parllel lathe	Gear cleaning and lubrication Adjustment of the spindle and clamping cup Cleaning of the banacada
Compressor	General compressor cleaning Cubicle cleaning Exchanger cleaning Checking for air and oil leaks Dryer cleaning Data collection (Amperages, temperatures and pressures)
Electrical distribution	Data collection (Amperages, temperatures and pressures) Cleaning of connections and aging check

Source: Author.

Preventive maintenance had an improvement with the creation of this plan, since the monthly routes now have a specific date of the month so that the operator can take the time to do the autonomous maintenance in the best way. Predictive maintenance is applied quarterly to the routes of each equipment such as; vibration analysis based on physical accessibility to take the collection of inspections of the same. This inspection interval is calculated through the AMEF format, facilitating the follow-up of the condition of the maintainable items to avoid unplanned shutdowns and expenses in spare parts above what was planned. Similarly, when an equipment shows very high measurements, we consult with the engineers in charge of the plant to evaluate if a replacement of the machine is required in order to cancel the machine and start the management of quotation, purchase and delivery time of the new equipment. This facilitates the acquisition of good equipment at a not very high price, since it can be purchased or imported from one of SKF's global branches (see Table 3) [47,48].

5. Conclusions

The contribution of this maintenance plan to the company was the collection and organization of data, valuable information that was archived without being registered for two years. From a research and qualification point of view, the most relevant data was corrective maintenance history, maintenance periodicity, and creation of predictive maintenance for the bearing market leader. The proposal of new preventive and predictive maintenance routes, taxonomy, technical sheets and resumes for each piece of equipment that had not been worked on before and are an essential part of good equipment monitoring. They are an essential input to prioritize and classify the line according to the requirements of the ISO 14224 standard.

The evaluation of the equipment based on the ISO 14224 standard contributed to the easy preparation of a standard maintenance plan and greater clarity for the support engineers to implement it together with the operators in charge. The equipment severity and taxonomy criteria under the ISO 14224 scheme were necessary to classify the severity of each equipment, giving rise to a more detailed analysis of each item based on the calculation of the monitoring cost based on the operator's rate and the maintenance. Preventive and predictive tasks for the design of a preventive and predictive maintenance plan that ensures that each piece of equipment is correctly monitored to reduce the risk of unexpected line stops, which affects delivery times, maintenance budget and quality. of each product.

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