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DEVELOPMENT OF A PREVENTIVE MAINTENANCE METHOD APPLICABLE TO SMALL AND MEDIUM COMPANIES

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Abstract.

This paper presents a study on maintenance, as well a generalization of a predictive maintenance system in order to evaluate a maintenance model that could be easily used in several small and medium companies that still are in developing. This model will allow the prevention of failures through parameters later studied in order to minimize the occurrence of failures and stops in the production process, so reduce the aggregate costs of maintenance and to help in the growth of these companies.

Keywords: *predictive maintenance, costs, new companies*

1. INTRODUCTION

The increasing participation of new corporate business to the market, many of these saw the need for improvements in the productive sector, in order to establish them in the competitive market. This development is not based entirely on increasing the quality of products and / or services, but also on reducing costs. In this respect, it is possible to mention the costs for maintenance, which mean a large portion of the costs of an industry.

Maintenance is an area that is directly linked to the productive sector, which means that bad planning results in loss of production due to unforeseen failures that generate a series of implications. Therefore, the result of a poorly planned maintenance, a company can realize a high rate of rework, living with chronic problems, lack of spare parts in stock, large number of unforeseen services, non - existent maintenance history or unreliable and mainly low productivity. All the features mentioned above may be present in companies and, when verified, improvements need to be made.

2. PREDICTIVE MAINTENANCE

According to ABNT (1994, page 7), predictive or controlled maintenance is maintenance that guarantees a desired quality of service, through the use of information analysis techniques obtained from the process or equipment, in order to reduce to a minimum preventive and corrective maintenance. (RODRIGUES FILHO, 2013)

Predictive maintenance is associated with the term "predict". Therefore, the general purpose of this type of maintenance is to predict failures in systems equipment through monitoring of various parameters (OTANI; MACHADO, 2009). These parameters are programmed so that the intervention only occurs in case of real need, that is, when the equipment reaches a range of predetermined degradation values. The mostly common evaluated parameters are: vibration, temperature, quality of lubricants and electrical parameters. (CAMPOS AND RODRIGUES FILHO, 2013 apud FILHO, 2006)

The correct use of this type of maintenance can ensure that the equipment works perfectly after the repairs have been made and, in this way, minimize the loss of productivity. In addition, because it acts as a preventive way, predictive maintenance acts by guiding employees with their predetermined measures, improving teamwork.

Jesus et al. (2013) show that maintenance costs can represent 15% to 30% of goods produced within an industry specifies therefore it is essential to use monitoring techniques to reduce the costs for unscheduled maintenance and this can automatically be increased the ultimate profitability, thus keeping the company competitive in the market.

2.1 Predictive Techniques Study

The predictive techniques allow the realization of interventions based on the state of the equipment, through the evaluation of the measurement results, follow - up or monitoring of performance parameters of equipment and components. (CAMPUS, ROGRIGUES FILHO, 2013 apud KARDEC, NASCIF, 2009)

In order to stimulate productivity and cost reduction, some predictive maintenance techniques characterized as Non-Destructive Testing (NDT) will be addressed. That is, the techniques that enable during operation. In addition, this type of test prevents damage to the material or equipment.

The use of NDT allows inspection of equipment and products, both during manufacturing and during its useful life, allowing better quality control, cost reduction and inspection reliability. Because it is a technique that does not damage the part to be inspected, it is gaining space in maintenance, but still presents high costs for certain uses in relation to the process, which requires the companies to study the technical and economic feasibility of using some of these tests. (Campus et al., 2013)

According to ABENDI (2012), the main non-destructive tests are:

- Parasitic chains;
- Visual assay;
- Magnetic particles;
- Acoustic emission;
- Sealing;
- Ultrasound;
- Radiography and Radioscopy;
- Penetrating liquid;
- Thermograph;
- Vibration analysis;
- Analysis of lubricants;
- Alignment of rotary machines.

3. A NEW MAINTENANCE APPROACH

3.1 RCM – Reliability-Centred Maintenance

Moubray (2000) defines Reliability-Centred Maintenance (RCM) as a process used to determine what should be done to ensure that any physical asset continues to do what its users want it to do in its operational context. In other words, it means a methodology that allows determining when an equipment will fail and, therefore, to program the stops based on this study of probabilities.

Here again, the results outweigh the costs. A good reliability study can give the system greater rationality in the application of the resources destined to the maintenance and better control of the stock of parts, the work orders and the scheduled stops. The RCM helps to optimize the level of availability of machines and costs, as it reduces the periodic interventions from 40% to 70% (Moubray, 2000).

3.2 TPM – Total Productive Maintenance

TPM or Total Productive Maintenance encompasses several factors such as: standalone maintenance, planned maintenance, quality maintenance and training. In general, TPM values the training of its employees, so that the operator can dedicate themselves to observation, cleaning, organization and maintenance activities of an equipment. The table below shows how a scheme of activities would be following the PMS precept, so that the elementary tasks would be left to the operators, while those responsible for the maintenance would be more focused on activities to analyze and improve the plan.

Table 1- Activity in Scheme TPM

Source: XAVIER, 1998

OPERATORS	MAINTENANCE	ENGINEERS
Perform maintenance tasks: Lubrication, regular, packing, re-tightening.	Perform tasks with a greater degree of complexity or difficulty.	Planning, design and development of equipment that does not require maintenance.

4. QUALITY TOOLS

4.1 Flowchart

A flow chart shows the flow of information, customers, equipment, or materials during the process steps and can also be known as flow diagrams, process maps, relationship maps or blueprints. In addition, flowcharts show how companies produce their products through processes and allow everyone to see the critical points between functions and departments. (FORMENTINI, 2014) Figure 7 shows an example flow chart.

In general, according to Koyano (2000), the flowchart assists the work of an organization in the survey phase, or in the planning, as follows:

- It allows to understand or to establish with clarity the relations between the units of work.
- Identifies relationships or processes that can be eliminated or that need to be changed.
- Establishes, in the two cases above, the identification of the phases of the process and the need to change its flow.
- It allows identifying and suppressing the useless movements of any element (a request or a pile of pieces, for example).

4.2 Check Sheet

Tool used to organize the process of data collection and recording, in order to contribute to optimize the subsequent analysis of the data obtained. The main features of the check sheet are: have a simplified format, collect data quickly and detect trends.

Motor Assembly Check Sheet								
Name of Data Recorder:								
Location:								
Date of Data Record:								
Defect Types/ Event Occurrence	Dates							TOTAL
	Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	
Supplied parts rusted								20
Misaligned weld								5
Inappropriate test procedure								3
Wrong part issued								7
Film on parts								0
Voids in casting								0
Wrong dimensions								2
Adhesive failure								0
Insufficient masking								1
Spray Failure								4
Total	0	10	12	11	6	4	0	

Figure 1 - Example of Check Sheet; Source: Koyano, 2000

4.3 Cause and Effect Diagram

Also known as the Fishbone Diagram (by its format) and Ishikawa Diagram (Kaoru Ishikawa - who created it), it was developed to represent the relationship between the effect and all possible "causes" that may be contributing to this effect. (KOYANO, 2000)

The Cause and Effect Diagram is shown in Figure 2 and shows how it can be developed to have clarity and separation by group of possible causes of the problem.

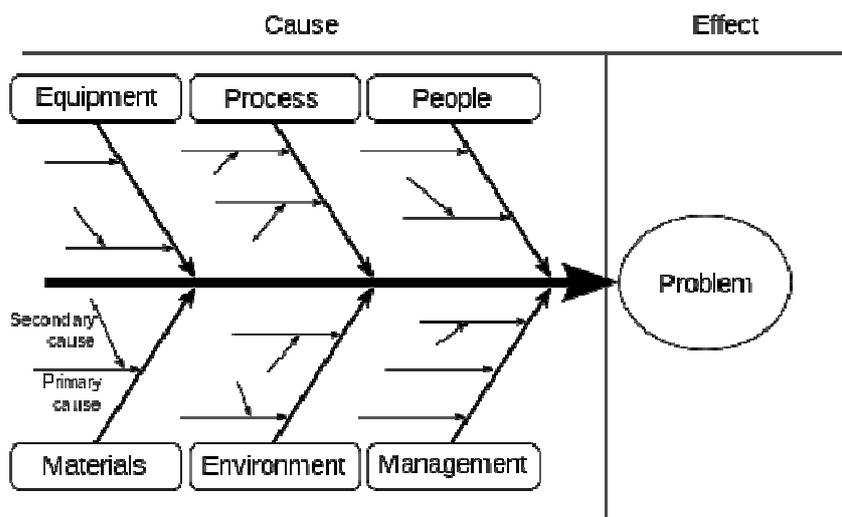


Figure 2 - Graphical cause and effect diagram representation

Source: Autor

According to Hradesky (1989), to assemble a Cause and Effect Diagram the following steps are necessary:

1. Start the meeting. Invite all people who are affected by the problem and have knowledge about it, including various levels of organization.
2. Clarify the effect. The problem must be very clear in order to define the effect correctly, this will reduce the influence of causes that do not concern the problem. If the problem is too great, it can be subdivided into smaller problems with a diagram for each.
3. Generate causes through free association of ideas. Identify the major groups of causes in the form of ramifications of the main spine, these groups can be material, method, people, machines, measures and environment.
4. Generate causes asking each of the present to point out possibilities, in order to encourage new ideas.
5. Determine the importance of causes. After two rounds have been held for each participant to present causes, a vote should be taken to choose the ten most voted causes and after a new vote to choose the main cause of the problem.
6. Check the cause. Verify that the selected cause affects the process characteristic through methods such as experimentation, data collection, and control chart.
7. Take corrective action. The cause verification method can provide adequate corrective action.

4.4 Matrix GUT

This matrix is a way of dealing with problems in order to prioritize them. After determining the causes for a given problem, the GUT matrix allows quantifying each cause according to its severity, urgency and tendency (GOMES, 2006). Each of these parameters is punctuated from 1 to 5 and after the score is calculated the result $G \times U \times T$, establishing parameters of priorities of the problems to be solved.

Causas das Listras	Gravidade				Urgência				Tendência						
	Extremamente graves	Muito graves	Graves	Pouco Graves	Sem gravidade	Ação imediata	Alguma urgência	O mais cedo possível	Pode esperar um pouco	Não tem pressa	Piorar rapidamente	Piorar em pouco tempo	Piorar em médio prazo	Piorar em longo prazo	Não vai piorar
1. Troca de bobina															
2. Falta de energia															
3. Defeito mecânico															
4. Defeito elétrico															
5. Parada programada															
6. Parada Operacional															
7. Trama enroscada															
8. Problemas de MP															

Figure 3 - Filled Matrix GUT example.

Source: MARIANI, Celso A. (2005).

5. PDCA CYCLE

The PDCA cycle is a management method, represented in the way to be followed so that the established goals can be achieved. When using the method you may need to employ a variety of quality tools, which will provide the necessary resources for the collection, processing and provision of information necessary to conduct the stage of the PDCA (CAMPOS, 2004).

Figure 6 shows a graphical representation of the phases of the PDCA, wherein the first phase corresponds to the Plan (Plan) that define the ideal targets (control items of the analysis process, establishing the methods for their achievement). The second stage comprises the DO (execution), which requires the education and training of the people involved, with the effective execution of the planned actions. At the same time, the information in the process is generated are registered (MARIANI, 2005).

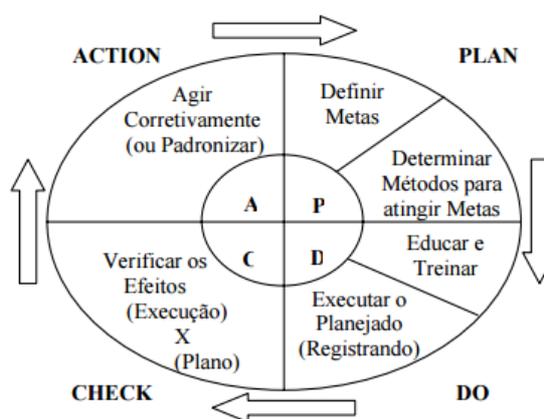


Figure 4 - PDCA Process Management Method

Source: CAMPOS, Vicente F. (1992)

The third step is composed of CHECK (check) and aims to compare execution with planning. Here it may be noted that if the results initially proposed were or were not achieved. The last and fourth stage, ACTION implies corrective actions; in this phase, from the results achieved, there are two distinct paths to follow: if the verification showed that it was not possible to reach the proposed results, one should start with the study of corrective actions and then resume the

PDCA method; but if the proposed results were achieved, then the process should be standardized, thus ensuring its continuity. (MARIANI, 2005)

6. RESULTS OBTAINED AND ANÁLISIS

The method of predictive maintenance, developed in this work, was divided into two flow charts to better functionality and understanding. Therefore, it is presented a detailed explanation of each step:

6.1 Flow chart for identification and improvement in processes in general

This first flow chart (Figure 7) is intended for company management staff in order to identify the main problems that hinder the smooth functioning and seek ways to extinguish them or mitigates them. The steps will be explained and detailed in topics.

1. Documentation research: consists of searching for reports that have occurred in the past that can make problem identification simpler. These reports should contain consistent data about a failure or problem that has already occurred, which solution was taken and should be ascertained whether the problem was resolved.

2. Data collection: can be done in two ways.

2.1 Brainstorming: meeting with all employees regarding problems in the process. Seek through a conversation the opinion of the majority about what would be the biggest problem in the process.

2.2 Checklist: Data record form. Many companies do not keep track of past failures. So it is so important to keep a file of the present moment about the current situation of the company (faults, problems, solutions) so that, if in the future a problem reappears, just consult these records of the old / current direction.

3. Analysis of the data: analyze the data obtained from the collection (item 2).

4. Prioritize the problems: GUT prepare a prioritization matrix that organizes problems according to their severity, urgency and trend.

5. Identification of the causes: from the identification of the problems and the choice of the critical problems must be found the fundamental causes, that is, what triggered the origin of these problems. This can be done through the Ishikawa Diagram.

6. Suggestions for improvement: correspond the possible solutions found for the causes of the problems.

7. Implement controls for management of production processes: these are measures that tend to improve management but may change in relation to the problem to be addressed. In general I have suggested the following drivers:

7.1 Loss control;

7.2 Production schedule (production scheduling);

7.3 Inventory management.

7.4 Prepare flowchart for processes: Example maintenance flowchart (Appendix C).

7.5 Staff training: many of the failures are due to lack of training into employee. In some cases, a quick training provided by the company can yield great results.

7.6 Others.

8. Consistent Proposal? If proposals presented by management are consistent and appear to generate good results, these proposals for improvement should be applied (item 9). In case the proposals are not sufficient, it is necessary to return to item 2 to restart the identification of the problems.

9. Apply proposals.

10. End.

The quantification of the improvements was not proposed due to the main focus of the work that aims at predictive maintenance. In this way, means of improving the management of these companies were mentioned, since poor management can lead to losses in maintaining it.



Figure 7 - Flowchart for identification and improvement of processes in general

6.2 Flowchart of implementing Predictive Maintenance

This second flow chart for the industrial production and manufacturing sector corresponds to the steps for implementing predictive maintenance. It is worth mentioning that many companies do not have maintenance plans and only use corrective maintenance. The flowchart can be found in Annex C.

1. Plan the maintenance cycle
2. Prior definition of basic inputs: which materials should always be available during the process.
3. Resources: define the material, financial, human resources necessary for the execution of the process.
4. Structure: check the company's policies regarding maintenance, what types of maintenance the company is already adept, what forms of action.
5. Corrective maintenance: consists of emergency repairs without quality control and specialized personnel. Check for this type of maintenance.
 - 5.1 Verify data sheet: document that has information of operation information by the manufacturer.
 - 5.1.1 Check the working hours of each equipment until failure.
 - 5.2 Check sheets: Make a check sheet for each piece of equipment. The data of fatigue, corrosion, abrasion, erosion, lubrication and dirt failures should be noted. Rupture, disassembly or loosening.
 - 5.2.1 Can it be computerized? Give preference to computerized systems to already be registered the data immediately after the conference. If this is not possible, scan the information weekly.
6. Store fault information: There must always be a fault record or an equipment situation for any adversity.
7. Identify the causes of faults: from the fault history, the manufacturer's technical data sheet can predict or identify the main causes of faults.
8. Define the techniques to be performed before faults in each equipment: lubrication, stops for exchange of damaged parts, packing, vibration and thermal tests. Even personal training can be a way to reduce failures.
9. Define regular stops: give preference to stop dates and forward to employees.
10. Effect the techniques and final stops.
11. Was there a decrease in failures? If there was no decrease, we must go back to item 7, because there must have been some error in identifying the causes of the failures. If yes, go to item 12.
12. Measure the effectiveness and effectiveness of services performed: improvements can be quantified by observing the reduction of costs by unscheduled outages, prolonging the life of equipment.
13. Indicators: always keep indicators checking if the process is working properly after the improvements.
14. Results: store the good results for use later and analyze the indicators.
15. End.

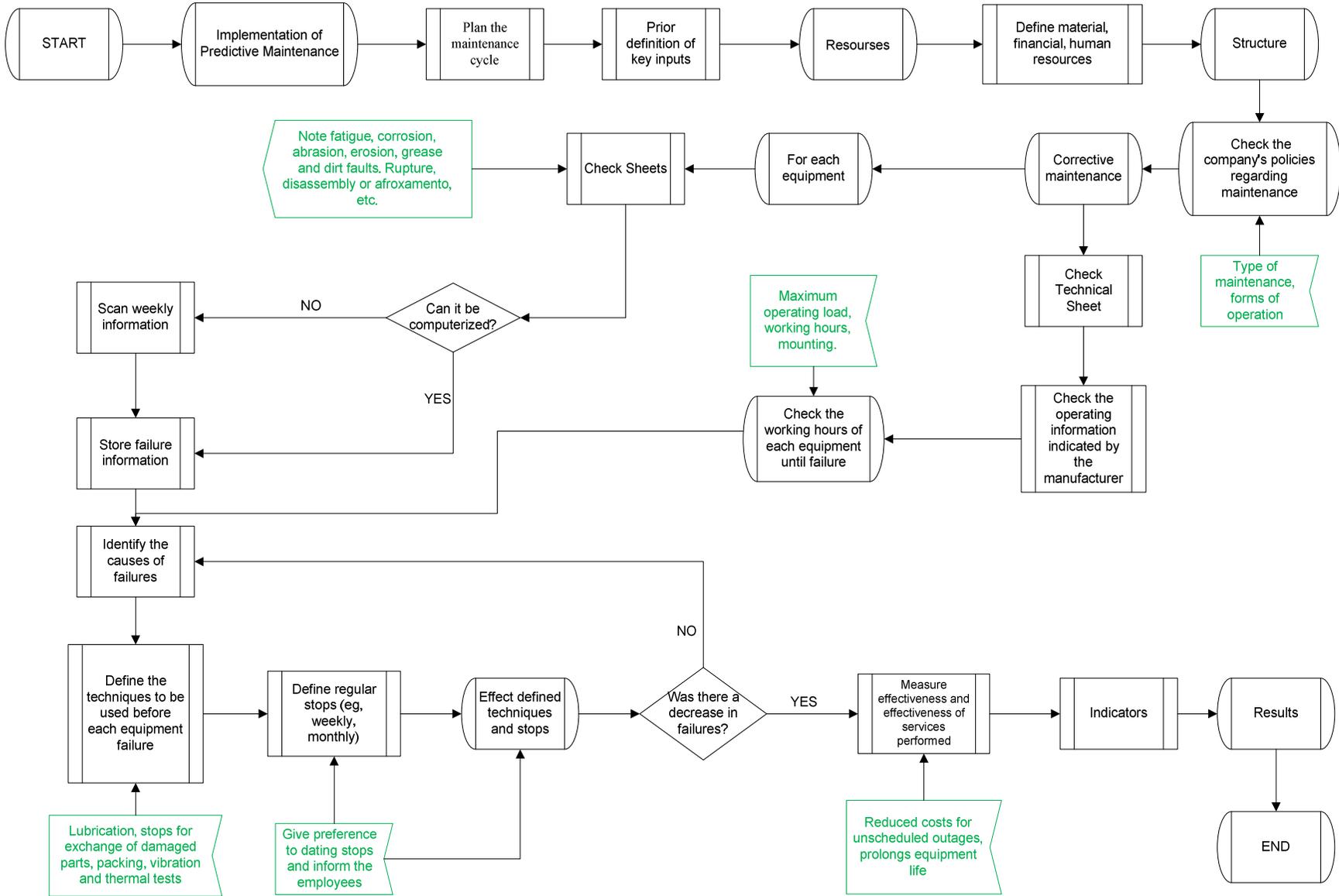


Figure 8 - Predictive Maintenance Flowchart

7. CONCLUSIONS

The study of the current situation of maintenance following the fault line in the productive processes and including the costs involved in the use of corrective maintenance, provided information of the precariousness in this sector. The basis of this was found in the analysis of production processes, where it was verified that the cost to the detriment of corrective maintenance is twice as great as the process implemented in preventive maintenance.

It is possible to say that even the cost of implementing a predictive system can overcome the losses of the lack of investment in equipment, use of new materials and even qualification of maintenance and operation labor. In addition, it is worth saying that in the long term, this investment will be reversed in reducing process failures and lower operating costs.

The development of a predictive maintenance method through the use of flowcharts process is extremely functional and dynamic. The first flowchart that deals with the identification and improvement in the processes in general presents activities and means that can improve the administration of companies in a way that makes the management a necessary factor for the good management of the maintenance. Added to this is the second implementation of the flowchart describes the Predictive Maintenance industry and manufacturing as predictive maintenance to be implemented, that is which the procedures necessary for their realization describing the techniques to be used. Thus, failures, both in management and technical, will be properly treated, making the company to use this method is virtually immune to recurrence of such failures.

The next goal is to carry out more applied study in companies in the field of Mechanical Engineering so that results can be verified that are more quantitative than qualitative.

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