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APPLICATION OF FMEA TOOL FOR THE ANALYSIS OF MECHANICAL FAILURE IN BEARING SUPPORTS

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Abstract. *This article reproduces a real case study of an bearing support break, whose bearing was installed in a tube transfer line. The FMEA (Failure Mode and Effect Analysis) was the tool used to provide support in the study of bearing failures. This paper shows the results of the application of an interdisciplinary project methodology, integrating the disciplines of the seventh period of the Production Engineering course, in a Brazilian university. In order to describe information interaction relations, criteria, practices and use of the data provided by the maintenance indicators, unifying comprehensively the technical information, we sought to create a greater consistency in practice of preventive maintenance management. The proper implementation of this methodology will allow industrial companies to achieve their strategic objectives, making them better prepared to deal with the constant challenges of a competitive market.*

Keywords: *FMEA; Mechanical failure detection; Tubes production; production maintenance*

1. INTRODUCTION

The FMEA method was developed by reliability engineers in the late 1950s to study problems that might arise from malfunctions of military systems. An FMEA is often the first step of a system reliability study and involves reviewing as many components, assemblies, and subsystems as possible to identify failure modes, and their causes and effects. The FMEA objective was precisely to prevent the risks of accidents due to problems that aircrafts could present. Then, chemical industries adopted this methodo dology to improve safety in the handling of substances.
According to Ferreira (2003) the objective in general lines of FMEA is to deal with the security factor, from its origin to the present day. Automotive industries are amongst the ones that mostly use this tool, especially with regard to product, process and thereof quality improvement. According to Moura (2000), the FMEA definition of customer, is not just about end customers, but all those who participate and are influenced in the productive process, such as: project and process engineers, and besides assembly, manufacture and technical assistance teams. In this paper, we applied the FMEA tool in a real case study of breaking of an axis bearing, installed in a tube transfer line in a tube manufacture process.

2. LITERATURE REVIEW

2.1. Failure Mode and Effect Analysis (FMEA)

The FMEA is a design tool used to systematically analyze component failures and identify the resultant effects on system operations. The analysis is sometimes characterized as consisting of two subanalyses, the first being the failure modes and effects analysis (FMEA), and the second, the criticality analysis (CA).

Successful development of an FMEA requires that the analyst include all significant failure modes for each contributing element or part in the system. The FMEA can be performed at the system, subsystem, assembly, subassembly or part level. It should be scheduled and completed concurrently with the design. If completed in a timely manner, the FMEA can help guide design decisions.

The usefulness of FMEA as a design tool and in the decision-making process is dependent on the effectiveness and timeliness with which design problems are identified. In the extreme case, the FMEA would be of little value to the design decision process if the analysis is performed after the hardware is built.

While the FMEA identifies all part failure modes, its primary benefit is the early identification of all critical and catastrophic subsystem or system failure modes so they can be eliminated or minimized through design modification at the earliest point in the development effort.

It should be remarked that for more complete scenario modelling another type of reliability analysis may be considered, for example the Fault Tree Analysis (FTA), a deductive (backward logic) failure analysis that may handle multiple failures within the item, including maintenance and logistics. The FTA method may use the basic failure mode FMEA records as one of its inputs, an interface hazard analysis, human error analysis and others may be added for completion in the scenario modelling.

According to Helman and Andery (1995), failure analysis and effects of failures is a quality tool used in the preparation of projects (products and processes) that can be used in the industrial, as well as in the administrative area.

The FMEA method is used to identify all possible types of failures and the effects that each failure can result in the system as a whole, through a deductive reasoning process. At first, this tool has been used for development of new product projects, but over time, it began to be used to correct flaws in existing products and processes.

According to Ferreira (2003, p. 6), the FMEA consists of a standardized method that is used to eliminate these flaws:

> Generally speaking, FMEA is a systematic brainstorming session, with the objective of identifying what can go wrong in a system (product) or a process. Essentially, for each component of a system or process, FMEA identifies all possible project failure modes. For each of these failure modes are listed the effects or consequences of these failures for the whole system or subsystem.

The determination of the critical level of failure modes is carried out on the basis of three indices, as shown below: a) the severity index of the failure modes effects; b) the occurrence index of the failure modes causes and c) the the detection index of the failure modes causes, as shown in Tables 1 to 3 (LEAL; PINHO; ALMEIDA, 2006).

Using the traditional methodology, the multiplication of these three indices, that have scales of 1 to 10, will result in the Risk Priority Number (RPN), which is responsible for the failure ranking (FERREIRA, 2003; PALADY, 2004).

Table 1 Severity Range (Source: adapted from Palady, 2004)

Scale of severity of the effects of failure modes	Severity Index
effect not perceived by customers	1
insignficante effect perceived by 25% of customers	2
insignificant effect perceived by 50% of customers	3
moderate effect perceived by 50% of customers	4
pretty critical effect perceived by customers	5
pretty critical effect that upsets customers	6
critical effect that let customers somewhat dissatisfied	7
critical effect that let clients considerably dissatisfied	8
critical effect that let customers completely dissatisfied	9
dangerous effect that threatens the life of the customer	10

Table 2: Occurrence range (source: Palady, 2004)

Scale of severity of the effects of failure modes	Occurence Index
extremely remote, highly unlikely	1
remote, unlikely	2
small chance of occurrence	3

casual occasional failures number	4
moderate occurrence	5
frequent occurrence	6
high occurrence	7
very high occurrence	8
certainty of occurrence	9
extremely remote, highly unlikely	10

Table 3: Detection range (source: Palady, 2004)

Scale of severity of the effects of failure modes	Detection Index
Is almost certain to be detected	1
Very high probability of detection	2
High probability of detection	3
Moderate chance of detection	4
Average chance of detection	5
Any probability of detection	6
Low probability of detection	7
Very low probability of detection	8
Remote detection probability	9
Detection nearly impossible	10

2.1.1. FMEA Models

Since its emergence, there has been two distinct types of FMEA, project (DFMEA) – Design Failure Modes and Effects Analysis and process FMEA (PFMEA) – Process Failure Modes and Effects Analysys. The difference between both FMEA types is based on the intended objectives, being applied, in this case, as a FMEA process.

2.1.2. FMEA Models

When working with the FMEA analysis a company tends to: perform a production process with higher quality; to work with greater reliability and safety; to work with lower cost and smaller malfunctions and to decrease the likelihood of failures in processes and products.

In this context FMEA can be considered an analytical technique used by a team of people as a way of ensuring that, to the extent possible, the potential failure modes and their associated causes/mechanisms have been considered and located. At its most rigorous, the FMEA is a summary of the knowledge of people (including an examination of items that could fail based on experience and past issues) of how a product or a process is developed. Thus, it is essential that the people that makes up the team is qualified and the most diverse possible.

As a result, the FMEA directly impacts on the company's financial return, reducing or eliminating failures and developing actions and procedures to deal with the risks envolved. From the point of view of the employees of a company, FMEA is a tool that encourages teamwork, providing motivational gains.

2.2 Bearing Support

A bearing is a device that allows the controlled relative motion between two or more parties, comprising the socalled rolling elements, like balls, rollers, etc, which constitute the so called scrolling tracks/rails and the house interposed between the rings. All these elements are made up of steel-chromium alloy and its dimensions are subjected to a system of standardization.

There are several types of bearings, such as: angular contact ball bearings, roller bearings and needle roller bearings. These bearings range from open bearings, ie those not retaining the entire grease, metal sealed , plastic or rubber seal sealed bearings, which in turn have greater retention of greases, gradually increasing their useful life, as well as providing a low noise level, which nowadays make much difference in the workplace environment.

When compared with angular contact ball bearings, rollers bearings with the same dimensions, ball bearings feature a lower friction resistence and a lower variation of rotation than roller bearings. This makes them more suitable for use in applications that require high rotation, high precision, low torque and low vibration.

Conversely, the roller bearings have a higher load capacity, which makes them more suitable for applications requiring long life and resistance to high loads and shocks. There are several types of roller bearings available on the market, each with its specific application: the bearing can be axial or radial depending on the load guidence it admits.

Bearing supports are machine elements that serve as seat for the bearings (housing) and also as support elements. They are usually bearing supports made of cast, steel or brass, where are coupled lubrication systems and protection of bearings, following a specific pattern of dimensional tolerance.

2.3 Selection and Recommendations for Maintenance Policy

To choose an appropriate maintenance policy to an equipment, we have to define a decision-making process and indicate the recommended maintenance practices, in accordance with the characteristics of the failure modes and the own maintenance practices used in the equipment and systems. For critical components, we must perform a selection of maintenance tasks, developing maintenance policies based on decision diagrams employed by the reliability-centered maintenance (Moubray, 2000).

To apply the decision diagram is necessary to carry out the components failures classification, depending on the consequences of these operational performance. From the point of view of decision making in maintenance, the failures can be classified as functional or poten tial.

Functional failure is defined as the inability of an element or component of an equipment to satisfy a desired default operation. The potential failure is represented by the presence of a physical evidence that a deterioration process of a component is occuring which will culminate with a functional failure.

Authors such as Slack et al. (1997), in turn, note that the term ‘maintenance' is used to describe the way in which organizations try to avoid faults, taking care of its physical facilities.

This approach emphasizes prevention and failure recovery, an important maintenance area. Generally speaking, it can be affirmed that the causes and effects of failures deserve special and permanent attention, as well as the development of proactive actions, in order to minimize the occurrence and consequences of faults.

2.3.1 Reliability-centered maintenance (RCM)

RCM is a process to ensure that maintenance systems continue to do what their users require in their present operating context. It is generally used to achieve improvements in fields such as the establishment of safe minimum levels of maintenance. Successful implementation of RCM will lead to increase in cost effectiveness, reliability, machine uptime, and a greater understanding of the level of risk that the organization is taking. It is defined by the technical standard JA1011 SAE, Evaluation Criteria for RCM Processes (Article 5277).

This process finds its origin in the international commercial aviation industry, driven by the need to improve their reliability; the industry has developed a broad process to decide which maintenance work is required to keep an aircraft flying (Pinto, 1998).

This process has evolved continuously since its inception in 1960 (Moubray, 2000). A broader definition of RCM could be "a process that one uses to determine what must be done to ensure that a physical element continues performing the desired functions one wants in the curent operating context. It should be said that the main objective of the RCM is to reduce maintenance cost, focusing on the most important functions of the system and avoiding maintenance actions that are not strictly necessary. If a maintenance program already exists, the result of a RCM analysis will often eliminate ineffective preventive maintenance tasks. Deploying a RCM program involves a series of steps and activities in sequence:

a) System definition and collection of data and information;

b) Functional description and elaborarion of the Functional Tree

c) Analysis of failure Modes and Effects (FMEA) and determination of the functional system failures associated with the failure of each of the components;

d) Identification of critical components;

e) Selection of maintenance policies for critical components;

f) Evaluation of the implementation results of these policy.

In Figure 1 is shown the block diagram of the Reliability- centered maintenance process and its stages.

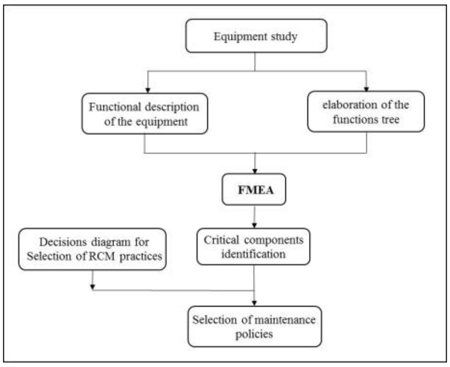

Figure 1. Diagram of RCM process

3. METHODOLOGY

For the purpose of this research, an exhaustive and systematic search of the literature related to FMEA, Reliability-centered maintenance and maintenance performance measurement was conducted from the time frame 2003 to 2014. This literature search was conducted using, among others, the following electronic databases: Emerald, ScienceDirect, and SpringerLink.

The adopted methodology concerns a case study, which according to Yin (2014), are "analyses of persons, events, decisions, periods, projects, policies, institutions, or other systems that are studied holistically by one or more method". The research that this paper refers is based on actual case study of breakings of a bearing support to an axis installed in a tube of a transfer line for moving pipes in a pipe forming industry. The scope of the project as said before, was to analyze the bearing support breaking situation and to apply the knowledge acquired to solve this type of failure and to act over the failure causes. The proposed method to solve failures, was the FMEA method.

Salomon (2001) mention that while quantitative data of a survey are used to describe a variable as their central tendency and its frequency, qualitative data are basically useful for anyone seeking to understand the context in which some phenomenon occurs.

According to Yin (2005, p. 33), the investigation of case study faces “a situation technically only where there will be a lot more variables of interest than only isolated dots, and, as a result, is based on multiple sources of evidence, with the data needing to converge in a triangle format, and, as a result, benefits from the prior development of theoretical propositions to lead to the collection and analysis of data”.

With regard to the collection of secondary data, it was verified through FMEA analyses, that certain information would be better collected, if obtained directly through suppliers catalogues.

There is a need for caution as some information obtained from secondary data, hence the need to use other sources to better ensure decisions taken, especially of literature, research and expert opinion. In addition to the information provided by the company researched, in a data collection process, a visit to the plat was made. In Figure 2, is represented the image of the roller systems researched.

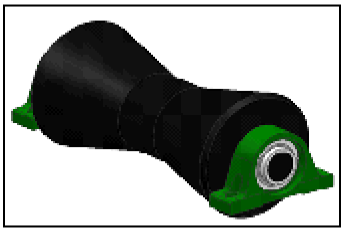

Figure 2. The Roller system studied

We highlight the importance of implementation of detailed functional analysis of the system studied, especially through the elaboration of a functional tree, which allowed to relate the functions of the different system components and the application of the 5Why’s tool, which served as the basis for the FMEA execution.

An exemple of the application of the 5 why’s tool:

Why did the Bearing support break?
Answer 1: because there was a lock between the bearing and the roller.

Why did they lock?

Answer 2: they locked because of excessive stress on the set of gear

Why there was an excessive stress?
Answer 3: It happened due to a lack of lubrication on the bearing assembly.

Why there was a lack of lubrication?
Answer 4: It happened due to a lack of preventive maintenance.

Why there was not a preventative maintenance?
Answer 5: It was due to the lack of a prevention plan.

Based on the above answers and information, a FMEA matrix was drafted, where it was evidenced by the calculation of a risk priority coefficient R, where the cause "lack of lubrication" reached the highest R value, or 540.

4. CONCLUSION

The results found with the analysis of the breaking of bearing supports by means of a FMEA and a 5 Why's tool, has shown that the source of the problem began on lack of preventive maintenance, lack of a correct analysis of the process and lack of a lubrication plan, according to manufacturer's guidelines.

In order to increase the service life of bearings, we proposed improvements as predictive vibration monitoring of biannual frequency, temperature inspection through Pyrometer, maintenance plan and procedures for lubrication of bearings, as indicated by manufacturer.

The result of the FMEA analysis has identified the critical components, i.e. those whose failure cause a system hang or damages operational performance, where it was evidenced by calculation of the risk priority coefficient (R), whereby the cause "lack of lubrication" has reached the greatest R value (540). The realization of the learning project by integrating the disciplines of Production Engineering course was very positive making possible the application of the FMEA concept in this case study.

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