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Implementing TPM supported by 5S to improve the availability of an automotive production line

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Abstract

The maintenance management is a topic of strategic importance for automotive manufacturers. In fact, an effective maintenance process and a preventive maintenance (PM) procedure can significantly reduce the risk of equipment failures that can lead to downtime on the production lines. However, due to the complexity of an automotive production system, the risk of failure on a crucial piece of the production equipment cannot be entirely avoided. The study made in this paper aims at improving the availability of a critical production line through the total productive maintenance (TPM) methodology and supported by Lean Maintenance tools. An analysis is made of the initial condition of the line where the main problems are identified by employing several tools for this purpose, such as Mean Time between Failures (MTBF), Mean Time to Repair (MTTR), Overall Equipment Efficiency (OEE) and Availability (A). In response to the identified problems, an action plan is developed and implemented in order to find the root cause of the high number of malfunctions and faults in one of the line's equipment with the use of 5S tools, visual management, and maintenance progress, as well as the development of a training program to increase operators' skills. The results of such actions were positive as the line became more organized, the value of the MTBF increased, the MTTR value decreased, and consequently the overall availability increased.

Keywords: TPM, OEE, Availability, Lean Thinking, automotive industry, 5S

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1. Introduction

The automotive industry has undergone significant changes in recent years. These changes have their origins in the competitive process that leads manufacturers to diversify their products in order to create new markets [1]. This reorganization of the automotive industry has changed the links between equipment manufacturers and builders but also more broadly the organization of the production process itself. Increasing global competition, a focus on fuel economy, rising commodity prices, electrical and smart mobility and shorter development cycles are all factors that make the automotive sector one of the most competitive industries today [2]. In this quest for diversification, the maintenance is an important factor that can ensure the sustainability of the machines and also helps to ensure the availability of the production tool [3].

Total Productive Maintenance – (TPM) is a philosophy that aims to optimize the overall performance of production equipment and ensuring their most efficient use. This method focuses on the participation of employees in the maintenance effort and the efficiency of the equipment. Maximizing efficiency and finding the optimal cost over the equipment lifecycle, the goal is to reduce costs, reduce lead times and increase product quality. This philosophy is deployed at all levels of the company and requires commitment from all employees [4]–[6].

The philosophy of the TPM is to never cease to search for the maximum productivity of the industrial system in order to obtain the maximum use of the productive potential or to come as near as possible to zero interruptions of the process. The TPM approach is an approach that focuses on two phases. The first is an analysis phase which is mainly aimed at improving the overall efficiency of the production apparatus, the second phase is an improvement phase around the concept of self-maintenance, that is, the participation of the machine operators by giving them responsibility in the operation of his equipment [7]–[9].

TPM seeks to achieve 100% availability of production equipment for production by eliminating unplanned shutdowns of equipment and stoppages, wastes caused by degraded machine performance, reduced productivity caused by a reduction of the machine speed, breaks or stops requested by low-level operators or lack of qualified personnel and a loss of valuable time when starting the equipment after a planned shutdown or not [10].

Implementing TPM brings several advantages such as an improved quality due to a better equipment stability, an improved productivity by eliminating outages, micro-shutdowns and loss of pace, an improvement of the delivery rate due to an easier schedule. A reduction of the accumulation of work in progress (WIP) at the sites provided for this purpose in order to compensate for machine stoppages and finally, it could bring an improved employee satisfaction through better results, more accountability and involvement, and richer tasks [11].

In this study it is aimed to improve the availability of a critical production line through the TPM methodology and supported by Lean Maintenance tools. An analysis is made of the initial condition of the line by employing MTBF, MTTR, OEE and A, where the main problems are identified. In response to the identified problems, a plan of actions is then developed and implemented in order to find the root cause of the high number of malfunctions and faults in one of the line's equipment with the use of 5S tools, visual management, and maintenance progress.

This paper is organized as follows. In chapter 2 the utilized indexes are presented. Chapter 3 depicts the case study and the objectives. In chapter 4 the results and their analysis is made. Finally, in chapter 5 the conclusions are given.

2. Utilized indexes

Several indexes are utilized in this industrial unit for assessing how effectively the maintenance operations are made. One of the used indexes is Overall Equipment Efficiency (OEE) which is a measure that conveys how well the equipment operates when compared to its full potential and it is represented as follows:

$$OEE = OA \times OP \times OQ \tag{1}$$

in which OA is Operational Availability, OP is Operational Performance and OQ is Operational Quality. The Operational Availability is expressed by the following equation:

$$OA = \frac{Operating\ Time}{Affected\ Time} \tag{2}$$

The Operational Performance is expressed as:

$$OP = \frac{Time\ of\ Correct\ Operation}{Operating\ Time} \tag{3}$$

Finally, the Operational Quality is represented as follows:

$$OQ = \frac{Conforming\ pieces}{All\ the\ produced\ pieces} \tag{4}$$

2.1. Mean Time Between Failures - MTBF

Mean Time Between Failures (MTBF) is an index that provides information regarding the reliability of an equipment or a subset [12]. It expresses the average time of conforming operation, that is, the time that elapses, on average, between two consecutive faults [13]. For one MTBF is calculated by the ratio between Operating Time and the number of faults [14]. The MTBF is expressed as:

$$MTBF = \frac{Operating\ Time}{Number\ of\ Faults} \tag{5}$$

2.2. Mean Time to Repair – MTTR

Mean Time to Repair (MTTR) is the average time required to repair a malfunction. For a given period, the MTTR is calculated through the ratio between the time used to repair the faults (TF) and the number of faults [14] at it is represented as follows:

$$MTTR = \frac{TF}{Number\ of\ Faults} \tag{6}$$

2.3. Availability

According to NP EN 13306:2007, the Availability (A) is defined as "the ability of a good to be in a position to fulfil a required function under specified conditions, at a given time or in a given time interval, assuming that the necessary external means are supplied" [15]. The expression of the availability depends on the MTTR and MTBF, already mentioned, and it can be calculated [16] as shown in the following equation:

$$A = \frac{MTBF}{MTBF + MTTR} \tag{7}$$

3. Case Study and Objectives

The first step in the development of the improving plan was the choice of the production line where this project would be carried out. For this, a study was carried out that involved the analysis of the faults registered in the equipment of the whole plant in the period between June and November of 2017. In this analysis, it was verified that the number of machines where there was at least one fault was very high and, for this reason, it was decided to select the 50 machines with more malfunctions. As some of these machines were similar it was decided to group them by families, with the intention of sorting the types of machines that are more negative.

Fig. 1 shows a Pareto diagram, where the columns represent the frequency of failures, that is, the number of faults, and the continuous line, the accumulated frequency, between the months of June and November. In this figure, for the sake of commitment to suppliers, the names of the technologies are not disclosed. It can be observed that of the 32 families of technologies identified, the most negative was technology 1 with a total of 125 failures.

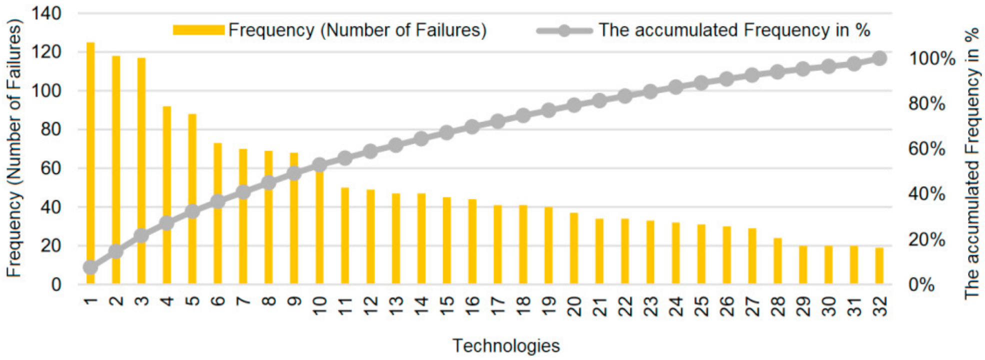

Fig. 1. Distribution of failures by equipment technologies between June and November 2017.

Five pieces of equipment of technology 1 originated the 125 malfunctions that can be seen in Fig. 1. Next, it was verified that these five pieces of equipment are all part of the same production line: the production line of the intermediate crankcase. After this, the production line of the intermediate crankcase was chosen to carry out this study. The intermediate crankcases arrive unfinished to the industrial unit where they are machined through machining processes, such as milling, drilling and turning. Subsequently, certain components are placed in already machined parts, such as balls, buffers and valves. Finally, the intermediate housings are taken to the finished product warehouse where they are shipped to the customer. In Fig. 2 it is shown the intermediate crankcase that arrives at the raw line and intermediate crankcase ready for shipment, after going through the various operations of line.

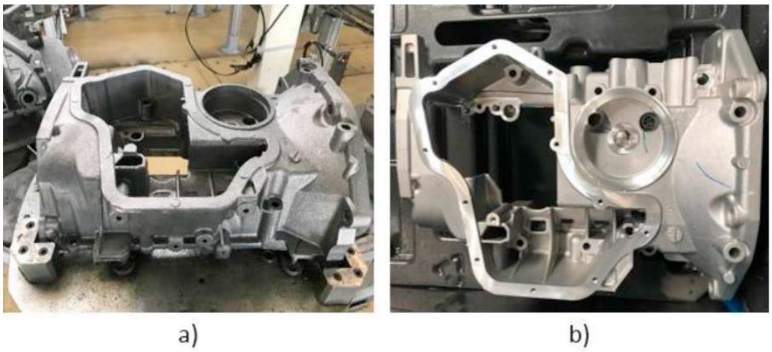

Fig. 2. Unfinished (a) and ready for dispatch (b) intermediate crankcase.

The set of machines available on this line has a production capacity of approximately 560 thousand pieces per year. In order to achieve the expected production, the line operates for seven days a week and with five different teams, three during the week and two weekend teams. Each team consists of seven operators, a line driver and the head of the line.

3.1. Used Indexes

In this section an analysis is made of the initial state of the intermediate crankcase line. In order to better perceive the state of this line, several indexes are assessed such as MTBF, MTTR, OEE and A. Next, the losses of the equipment and their respective more adverse subsets are analyzed. Also in this chapter, the main problems initially encountered in the production line are analyzed. Fig. 3 shows the monthly OEE obtained during the year 2017 in the machining of the intermediate crankcase, as well as the target OEE for the same year, represented by the continuous line. The last column refers to the average obtained for this index in the year 2017.

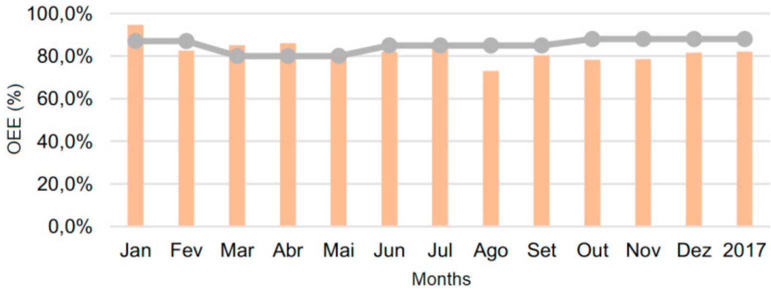

Fig. 3. Crankcase OEE (%) and the average for the year of 2017.

The OEE goal for 2017 was 88%, but the annual average shown in Fig. 3 shows that this index stood at 82.1%. It is also observed that only in the months of January, March and April the objective was reached. The lowest value obtained in the month of August are negative due to this month being a slow month with barely any order. Considering the last five months of 2017, none of them managed to reach the target OEE and, taking out September and December with 80.4% and 81.6%, respectively, no other month was able to overcome the 80% OEE barrier.

For a better understanding of the differences between the obtained OEE and the objective OEE, a Fig. 4 was obtained which shows the monthly OEE deviation from the target. By analyzing the size of the vertical bar for each point of the graph, it can be observed that the months of October and November present a deviation of approximately 5%, only surpassed by the month of August with a standard deviation of 6%. The standard deviation observed in these months shows how far they have to improve in order to reach the management target for OEE.

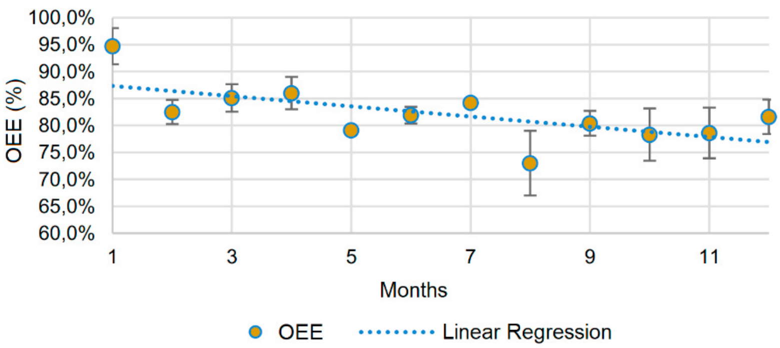

Fig. 4. Standard deviation of the actual OEE in relation to the target OEE.

In order to study the reliability of the equipment of the intermediate crankcase production line, the monthly MTBF was calculated over the year 2017. Knowing that the MTBF represents the mean time between failures, it is intended to identify the time that elapses between consecutive failures in this set of equipment.

By analyzing Fig. 5, it can be stated that the month of March was the one that had more failures since this represents the lowest value of the MTBF with a mean time between failures of 91.45 hours. This means that, on average, for every 91.45 hours a failures occurred in one piece of equipment on this line.

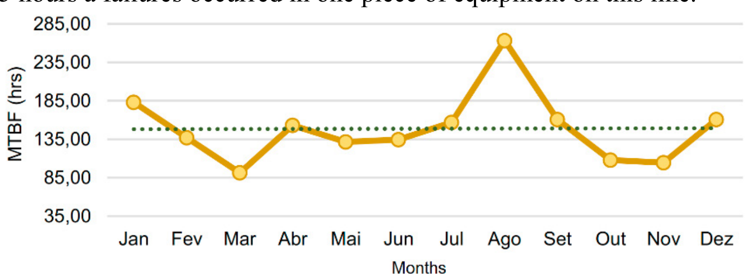

Fig. 5. MTBF of the intermediate crankcase in hrs.

In order to study the maintainability of the equipment of the intermediate crankcase it was necessary to calculate the MTTR. This index tells the average time that a malfunction takes to be repaired. Therefore, the lower the MTTR, the better.

By analyzing Fig. 6, it can be stated that the MTTR shows a positive trend, which in the case of this index represents a negative result for maintenance management since the positive trend indicates that the repair time of the equipment has been increasing during the year 2017. The month where the average repair time was highest was December with an average of 6 hours to repair a downtime of the equipment. On the other hand, the month of April was the one where the time needed to repair a malfunction was lower, with an average of 1.65 hours. High MTTR values can have a number of causes, such as the complexity of the malfunction, the lack of knowledge of the maintenance technicians, the lack of human resources and the lack of material.

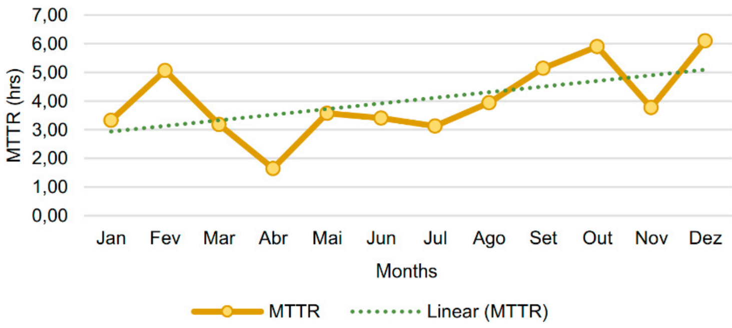

Fig. 6. MTTR of the intermediate crankcase in hrs.

In a perfect scenario, where it was possible to perform all the repairs of the failures outside the scheduled hours of operation, the availability of any equipment or set of equipment was 100%, but this is not what happens in reality. Taking into account the previously calculated MTTR and MTBF, the equipment availability in the year 2017, shown in Fig. 7, was calculated.

Through the observation of Figure 6, it is verified that the availability shows a negative trend throughout the year 2017. The month of April was the month where the availability obtained the highest value, with around 98.9%. On the other hand, the month of October represents the month with a lower availability, with around 94.8%. This value is related to the high MTTR obtained for the month of October, since the availability is related to this index.

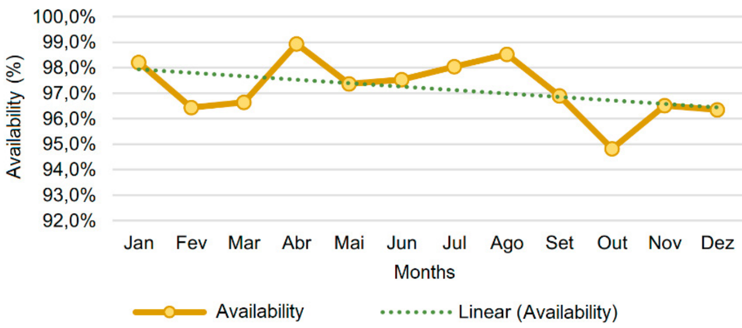

Fig. 7. The availability of the intermediate crankcase in hrs.

4. Results and Result Analysis

4.1. Maintenance improvement plan

As discussed in the previous chapter, through an analysis of the initial state of the production line of the intermediate crankcase, several problems and opportunities for improvement were identified. Therefore, it was necessary to develop and implement improvement proposals that would reverse the found situation and, consequently, contribute to improving the availability of the production line under study. In this way, this section presents a set of improvement proposals as well as a description and explanation of their implementation.

With the autonomous maintenance plan upgrade it was possible to reduce the total annual load by 236 hours, since the old autonomous maintenance plan had approximately 310 hours and the revised plan has only about 68 hours of annual load. This drastic decrease is mainly due to the change in the forecasted times for the verification tasks that were necessary to carry out by all the teams. While in the old autonomous maintenance plan these represented circa 214 hours, in the revised only represent 24 hours. The daily tasks also decreased the expected time of completion in approximately 44 hours, at the end of one year.

4.2. The impact of 5S

The benefits of this organization are more noticeable in the closet of the pieces of wear since this is constituted by numerous pieces that result in a high search time, however, with the application of the 5S and the visual management, the employees happened to take much less time to find a particular piece. Previously, the collaborators had no way of knowing where the piece they were looking for was, since even with the experience of some, the pieces were often moved and placed where there was an empty box. The identification of the parts and the placement of colors by operation makes the operators know more easily where the piece they are looking for, saving time in something that does not add value. In Fig. 8 it is possible to observe this type of improvement for the oil closet.

a) b)

Fig. 8. The oil closet before and after the 5S intervention.

4.3. Index Result

Table 1 shows the average values of MTBF, MTTR and availability for the last quarter of 2017 and for the first quarter of 2018. It can be observed that the average MTBF increased by 31 hours, that is, in the last quarter of 2017 the equipment in the studied production line had an average downtime in every 124 hours. However, in the first quarter of 2018 the equipment had, on average, a downtime in every 155 hours. It can be concluded that the measures taken have contributed to the reduction of the number of failures, compared to the last half of 2017, since the MTBF increased.

The MTTR average values for the first quarter of 2018 decreased compared to the last quarter of 2017 as the mean time to failure went from 5.26 hours to 4.56 hours. This positive result demonstrates that maintenance technicians have given less time to solve a malfunction.

The availability in the last quarter of 2018 averaged 95.9% while in the first quarter of 2018 the average availability reached 97.1%. Although the availability value increased considerably by 1.2%, it was not possible to achieve the target value of at least 98% availability. However, it can be considered a positive result since it was obtained as the availability increased considerably. In this way it can be affirmed that the implemented actions were successful since they contributed to the increase of the availability.

Table 1. A comparison between MTBF, MTTR and Availability.

	MTBF (hrs)	MTTR (hrs)	Availability (%)
Average of the last 2017 trimester	124	5.26	95.9 %
Average of the first 2018 trimester	155	4.56	97.1 %

5. Conclusions

In this paper an improvement of the availability of a critical production line through TPM methodology and supported by Lean Maintenance tools was proposed. The industrial unit in which this study was made produces intermediate crankcases for the automotive industry. An overall analysis was made of the initial condition of the production line, where the main problems are identified by employing several tools for this purpose - MTBF, MTTR, OEE and Availability. In response to the identified problems, an actions plan was developed and implemented in order to find the root cause of the existing high number of failures observed in one of the line's equipment with the use of 5S tools, visual management, and maintenance progress, as well as the development of a training program to increase skills of the employees. Several improvements were made and the results have shown that this production line has become more organized and the value of the MTBF increased, the MTTR decreased, and consequently the overall availability increased. Therefore, the implemented actions were successful and the tendency to improve even further the reliability of this line is tangible.

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