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ScienceDirect

Procedia Manufacturing 13 (2017) 1128–1134

Procedia MANUFACTURING

www.elsevier.com/locate/procedia

Manufacturing Engineering Society International Conference 2017, MESIC 2017, 28-30 June 2017, Vigo (Pontevedra), Spain

Implementing autonomous maintenance in an automotive components manufacturer

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Abstract

The automotive sector constitutes one of the most demanding activities in the global market, since it requires a constant increase in productivity, both in the automobile industry as well as in the companies whose manufacture its components. This sector is currently set within an economic framework where there is a relentless search for costs reduction and an increase in productivity with minimal investment. In order to meet these requirements, companies have sought to optimise their products and processes to ensure higher profits. This study was developed with the purpose of enhancing procedures in the maintenance sector regarding a company which supplies air-conditioning tubes to the automotive sector. The main objective was to increase its machines and equipment availability through the implementation of autonomous maintenance. Due to the undertaken improvements, there was a 10% increase in the monthly indicator of equipment availability on line AA3 at the company where the study was carried out. This, in turn, resulted in an increase of 8% in OEE (Overall Equipment Effectiveness) during the same time period, which was chiefly due to a reduction both in machine breakdown rates, as well as in the MTTR (Mean Time To Repair) on the same line.

Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.

Keywords: Autonomous Maintenance; Automative Industry; TPM; Visual Management

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2351-9789
Peer-review under responsibility of the scientific committee of the Manufacturing Engineering Society International Conference 2017.
10.1016/j.promfg.2017.09.174

1. Introduction

Due to the market high demand, industry has been pressed to develop and adopt new production technologies and techniques, as well as management procedures, with no chances for failures or waste. Faced to this scenario, companies must continuously enhance their activities in order to survive in this competitive environment [1]. This demand invariably affects the maintenance sector which, together with production, must carry out their activities in such a way that these do not interfere with the course of the productive process [2]. To this end, maintenance strategies must be drawn up so that possible breakdowns on equipment are reduced to a bare minimum. Thus, the goal is to reach a level of total efficiency to ensure reliable uninterrupted production [3]. Autonomous maintenance is a tool which stems from the eight foundations of the Total Productive Maintenance structure (TPM). Its aim is to eliminate all the forms of time expenditure associated to stoppages in the productive system due to machine breakdowns, which invariably produce a direct impact on process performance [4, 5]. Autonomous Maintenance is, therefore, essential to the implementation of TPM; it enables greater production throughput and includes the support of the company's employees [6]. In order to implement these targets, greater responsibility must be given to the operators: these must be made fully aware of their role in ensuring both the quality of the end product, as well as the efficient running of machines to achieve significant improvement in equipment performance [7].

The work described in this article was developed at a company in the sector of components for the automotive industry, which is located in Porto, Portugal. Autonomous Maintenance was implemented and associated with other Lean philosophy tools (5S, TPM and Visual Management) with the purpose of improving actions in the maintenance sector of a production line, which would then reduce the stoppage rates resulting from machine breakdowns. This article is divided into five sections: section 1 consists of the introduction; section 2 presents a review of literature pertaining to the subject of maintenance optimization tools; section 3 deals with the methodology developed to carry out the work; section 4 describes the course of all the practical work involved and undertaken at the company being studied. This section also presents improvement proposals for identified problems, as well as the results obtained from their implementation. Finally, section 5 deals with the conclusions reached through this research work.

2. Literature review

The industrial sector has indeed become more robust over the years. As a result, there has been an increasingly important need to hone processes so as to meet the challenges of product diversification and the context of growing competition amongst rival companies [8]. In order to excel in this scenario, many have resorted to the use of improvement techniques ensuing from Lean philosophy to reduce waste and eliminate activities which add no value to the process [9]. The LCM process (Lean Centered Maintenance) thus emerged from the attempt to connect these concepts with other areas. It consists of Lean tools applied to the maintenance sector which, through the implementation of their principles and ensuing results, aim to support decision-making in companies, reduce waste and achieve constant improvement in the efficiency of equipment and machines [10]. In order to clarify the meaning of "maintenance", this can be understood as a set of techniques and tools that ensure the quality and reliability of the machines, equipment and facilities found in an industry, so that there are no unexpected interruptions in the system [11, 12]. Deriving from Lean philosophy, one of the tools used in maintenance processes is TPM, which consists of a set of techniques to address the optimisation of maintenance processes. When implemented, it results in the reduction of waste and a significant increase in productivity for the company involved [10]. The concept behind the TPM process is well defined: in order to ensure its successful application, the optimisation of the productive process must include the reduction of machine breakdowns, thus minimising waste and the consumption of products during the process [13]. The implementation of TPM requires setting up eight support pillars, one of which is autonomous maintenance. This is defined as a set of preventive and predictive maintenance activities carried out by the operator, who is involved in machine manufacturing functions and is thus responsible for its maintenance and working order [14]. By taking on this responsibility, the operator is fully autonomous: the worker can request the support of a maintenance team when intervention on the machine is necessary, or when assistance is needed, without interfering in the productive process [15, 16]. The use of this tool is not restricted to the automotive sector, and its application can also be found in other sectors such as: Telecommunications [14], Agriculture [17] and in the area of Metallurgy [18]. One can thus conclude that the application of autonomous maintenance is of crucial importance to a corporation: its use provides great support in the improvement of results and reduction of waste, as well as in ensuring a greater quality of its products and services [17]. In order to be able to demonstrate the effectiveness of the autonomous maintenance implementation, one resorted to OEE as a tool to indicate the machines and equipment performance [19]. This indicator is used worldwide by several industries to demonstrate the percentage of productive time of equipment. Through autonomous maintenance, it is thus possible to identify an increase in the equipment availability [20].

3. Methodology

The research methodology adopted to undertake this work was developed in four stages. The first of these consisted of a bibliographical review of the analysis and optimisation tools used in the maintenance sector, which is supported by theoretical concepts drawn from scientific articles and published books. During the second stage, one proceeded with the mapping of the company's maintenance process, in which the current scenario, as well as the main problems and improvement potential of the process, were analysed for this sector. The third stage consisted of implementing autonomous maintenance on the company's production line, as well as detecting critical points on machines to decide on a corrective action, with the purpose of optimising the company's maintenance process. Finally, the fourth and last stage comprised an analysis of the results obtained through the implementation of autonomous maintenance on the production line of the company involved in this study.

4. Analysis and optimisation of a productive line for the manufacture of air-conditioning tubes

The assembly line used as case study for this work was chosen because it presents the greatest machinery diversity into the company. Furthermore, it was also being subjected to a standardisation process at the time, which made it easier to implement maintenance optimisation tools. This context will also facilitate future applications of this type to other lines at the company. The line selected is denominated as AA3 and produces air-conditioning tubes for the automotive sector. This production line is divided into two areas: one of these manufactures high-pressure tubes and the other low-pressure ones. The nomenclature used for each area refers to the tube's resistance to the pressure exerted upon it when in operation in a vehicle.

4.1. Mapping of the maintenance sector

A company's maintenance sector is defined as an area which executes improvements and repairs on machines and equipment, thus ensuring a standard of reliability and preventing interruptions in production. In order to achieve this goal, maintenance can be undertaken in two ways: one is reactive, in which the immediate repair of breakdowns is carried out; the other is proactive, so that intervention takes place before breakdowns. The company subjected to study currently applies both of these maintenance models. The first is used in a curative manner and the second is divided into preventive and 1st level maintenance actions (see Fig. 1).

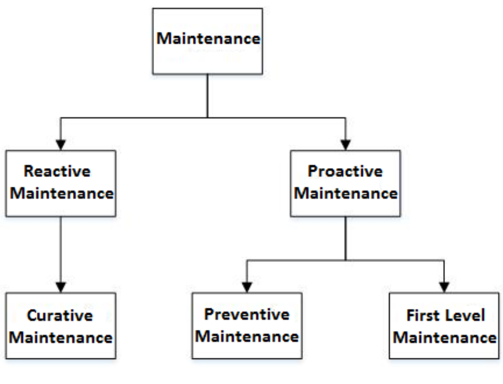

Fig. 1. Flowchart of the maintenance actions used in the company studied.

Curative maintenance is used more frequently since preventive measures are only carried out at the weekends. During normal workdays, the maintenance technicians are only available for curative actions, due to the number of breakdown events on machines. Fig. 2 shows the relation between these two types of maintenance activities by presenting the data gathered for the number of events in each of the last 3 years (2014, 2015 and 2016).

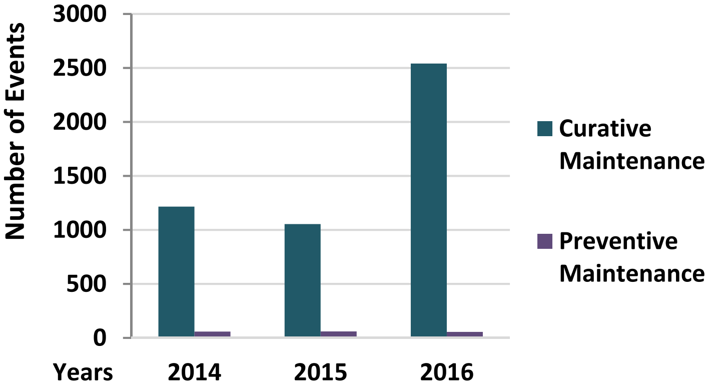

Fig. 2. Relation between curative and preventive maintenance events.

In the case of 1st level maintenance, which should be carried out weekly by line operators, this has proved to be ineffective. The reason for this is that the usage instructions are somewhat confusing and generic. Furthermore, there is a lack of control over the actions themselves, so that they are often not performed correctly by the operators.

4.2. Problems identified/opportunities for improvement

Once the analysis of processes used in the company was carried out, one proceeded to identify the main problems detected in this sector, whose are presented in Table 1. Initially, line AA3 presented overall equipment effectiveness (OEE) of 74%, regarding 75% of equipment availability.

Table 1. Description of the identified problems.

Problem	Description
High incidence of breakdowns	High incidence of breakdowns caused by lack of preventive maintenance measures.
Low incidence of preventive maintenance	Maintenance technicians are unavailable for preventive actions.
Machines and equipment availability	Low machine availability rates due to frequent breakdown events.
1st level maintenance	Timely preventive action not undertaken or incorrectly undertaken by the operators.
Repair time	Long periods of time spent by maintenance technicians to repair machines and equipment.

The purpose of this work is to reduce the number of curative maintenance actions on line AA3, subsequently redirecting these time-savings to increase the number of preventive actions. Greater availability on the OEE line would thus be achieved by optimising the 1st level maintenance process to the equipment autonomous maintenance.

4.3. Solutions proposal

Table 2 presents proposals for the improvement of the identified problems. Through the maintenance sector optimisation, the productivity and efficiency of the line studied will thus be increased.

Table 2. Description of proposals for improvement.

Problem	Proposals for improvement
High incidence of breakdowns	Define preventive measures to minimise breakdown rates.
Low incidence of preventive maintenance	Redistribute maintenance technicians' tasks and redirect the time spent on curative actions to preventive ones.
Machines and equipment availability	Carry out daily cleaning and checks on machines and equipment to ensure they are in working order.
1st level maintenance	Redesign the current 1st level maintenance model to make it faster and more efficient to perform.
Repair time	Use visual management techniques to facilitate the detection of breakdown points.

In order to solve the abovementioned problems and apply the improvement actions whose were subsequently defined, one selected the improvement tool of autonomous maintenance to optimise these processes and achieve the expected results. The seven stages were thus followed to carry out the implementation and conclude its application (see Table 3). Each of the stages in this process, as well as the undertaken actions, have been identified.

Table 3. Description of stages in the implementation of autonomous maintenance.

Stage	Description	Action undertaken
1	Initial cleaning	
2	Elimination of dirt sources, and areas of difficult access	Cleaning Instructions implementation (drawing up of a page for each machine of the line, providing support to the operator clean the machine).
3	Standardisation of cleaning and inspection	Use of 5S philosophy (helps to eliminate dirt, keeping the surroundings clean and the tools close to the area where they are needed).
4	General inspection of equipment	Use of 1st level maintenance to identify machine problems (improvement of the previously used model).
5	Overall Inspection of the process	Use of visual management techniques with the objective of facilitating the detection by operators and maintenance technicians regarding machine problems.
6	Systemic autonomous maintenance	Cards implementation to report abnormalities or safety, maintenance and production improvements. The purpose is to develop a sense of autonomy in workers so that, when necessary, they feel free to express their ideas.
7	Autonomous management	Check-sheets drafting of for 1st level maintenance, as well as for cleaning actions, to serve as a control method in the application of these activities. Training of operators and staff responsible for the AA3 line carried out, as well as preparation of the team and maintenance technicians, aiming to demonstrate the importance and results of this implementation.

The implementation of autonomous maintenance was thus carried out by following these stages: cleaning actions, machines and equipment inspection, line organisation and its activities standardisation. These stages ensured the achievement of the proposed goals and reduced the problems of interference caused by breakdowns in the process.

4.4. Analysis of the obtained results

After the implementation and execution of the seven stages of autonomous maintenance, a reduction in breakdowns was observed on line AA3. Table 4 presents the number of interventions carried out by the maintenance technicians before and after the applied improvements.

Table 4. Number of interventions on line AA3 in 2017.

	Before Improvements		After Improvements	
Year 2017	January	February	March	April
Number of Interventions	127	134	120	97

Consequently, one also saw an increase of 10% (from 75% to 85%) in the availability rate of the machines on line AA3 from January to April 2017 (see Table 5). As a result of this factor, there was a significant increase of 8% (from 74% to 82%) in OEE during the same time period, which directly impacted on the line AA3 production efficiency.

Table 5. OEE results before and after the implementation of autonomous maintenance.

	Before Improvements		After Improvements	
Year 2017	January	February	March	April
Availability (A)	75%	74%	80%	85%
Quality (Q)	99%	97%	99%	98%
Performance (P)	99%	98%	98%	98%
OEE = A x Q x P	74%	70%	78%	82%

In addition to these improvements, there was an increase in the Mean Time Between Fails (MTBF) of the machines on line AA3, as well as a reduction in the time spent by maintenance technicians on breakdowns repairs. All this was due to the visual management techniques applied to the line machines, which enabled the maintenance technician and operator to rapidly detect the malfunction. In order to calculate these data, one recorded the average, in hours, of the MTBF and MTTR (Mean Time To Repair) on all the line's machines for each month (see Table 6).

Table 6. MTBF and MTTR data for line AA3 in 2017.

	Before Improvements		After Improvements	
Year 2017	January	February	March	April
MTBF (h)	267,25	227,65	278,34	300,05
MTTR (h)	0,71	0,75	0,68	0,63

5. Conclusions

This article was developed aiming to implement the autonomous maintenance function on air-conditioning tubes manufacturing line for the automotive sector. One also aimed to reduce the stoppage rates on machines ensuing from breakdowns. The main objective was achieved through the application of the seven stages of autonomous maintenance. By following these, operators were able to develop the responsibility to autonomously carry out activities related to cleaning actions, organisation and daily checks of the critical points at the workstation, thus ensuring that their machines and equipment were in good working order. This project resulted in a significant decrease in the number of interventions on the line, and thus contributed greatly to the 10% increase in the monthly rate of machine availability, as well as 8% in OEE during the same period of time. Simultaneously, and as a consequence of these applications, there was also an increase in MTBF, as well as a reduction in MTTR due to the use of visual management practices. These enabled both the operators and maintenance technicians to easily detect a problem on the machines. Solutions were provided for the problems identified and, owing to these results, the company plans to extend the implementation of this improvement technique to other lines. All this was achieved through the use of techniques which directly tackle various types of waste and provide support in the continuous improvement of the process.

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