FLOWCHART IDENTIFICATION IN THE CASE OF MAINTENANCE PROCESS MANAGEMENT

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ABSTRACT

The implementation of an integrated management system in industrial companies involves identifying the processes needed and associated performance indicators. The complete and accurate definition of performance indicators plays an important role in both process performance monitoring and in identifying the impact of the process on company results. Considering the maintenance of the machine tools as one of the main support processes for manufacturing, it is important to analyze, identify, and solve the maintenance problems as fast as possible. The definition and implementation of maintenance programs require some resources to prevent the machine tools downtime. Taking into consideration the importance of machine tools availability, it is necessary to define and validate a method for data collection and analyse the machine tools' performance in terms of available time usage. In the present paper, a case study is conducted using a database including data collected from industrial environment, in the case of the manufacturing process of bearing components. An integrative method for the identification, control, and optimization of total defect time was defined and validated, with the main objective of establishing a flowchart for data collection, analysis, and database updating.

1. INTRODUCTION

In the actual economic context, using the resources at their maximum capacity requires rigorous planning in all sectors of a company. Combining all resources in an integrated manner is a good strategy to ensure the continuity and sustainability of a business.

Machines and equipment are among the important resources for any company. Maintaining the machine tools in function plays a key role in resuming and keeping regular operational capabilities [1] at both the designed production capacity and resources consumption. Considering the maintenance process as an essential strategic element for achieving business objectives [2], all aspects that could impact business operations and results should be identified. The maintenance system can be influenced by a series of technical, economic, and organizational factors [3].

The strategies used in industrial companies, related to the management of maintenance systems and activities, could be classified as:
- Management of the maintenance activities in an integrated manner, using its own qualified human resources,
- Outsourcing of the maintenance activities, considering that the entire responsibility is assumed by the supplier, and

– The mix of the strategies from above.

In the predictive maintenance case, a series of parameters are measured in order to identify the potential defects of one or more components [4]. In the specific case of grinding machine tools used in bearings components manufacturing, the heat release by the electrical panels and the vibration level are monitored.

The identification of all variables that influence the performance of a machine tool may become a difficult job for process engineers. The implementation of a performance maintenance system requires the identification of all variables, in terms of input data, resources needed, responsibilities, expected results, specific activities, and control issues.

To obtain realistic information and data related to the machines' operation, different types of software were developed and validated. Considering the important impact of the machine tool status on the quality of the produced goods, the parameter "Expected level of quality" should be considered as an auxiliary input data. Some maintenance interventions should be performed when quality deviations are registered. Quality deviations can be defined either as out-of-specification products or as deviations from the set-up parameters. Such deviations may lead to productivity losses due to the need for unplanned and frequent adjustments of the set-up. These unplanned activities could have an important impact on operations performance in terms of lead time, rate of rejection, and scrap ratio. The impact of unplanned activities on lead time may result in delays in deliveries to both the next process and the end customer.

The planned maintenance system [5] has an important role in preventing production stops and also in preventing potential accidents due to possible defects of the spare parts. The main activities developed in planned maintenance may be:
- Change the spare parts according to the producer's recommendation,
- Identification and prediction regarding the occurrence of potential defects, based on

some dedicated models and algorithms, which impact the safety of the operator, the product quality, and the environment.

The planning of maintenance becomes a difficult job for maintenance engineers, which must use both historical data and their knowledge to specify the moment when a machine should be stopped and repaired. The repairs can be classified as:
- Technical revisions,
- Current repair class 1,
- Current repair class 2, and
- Capital repair.

Some accidental defects could occur during the predicted normal functioning time. In these cases, quick intervention is required to minimize production losses. Additionally, it is necessary to reduce delays, first for the next process and ultimately for deliveries to the end customers. As an end customer, a distributor, an integrator, or an OEM (Original Equipment Manufacturer) may be comprised. Blocking an assembly line at the customer (OEM) can lead to a lot of damage in the product logistic flow and also to the other related supply chains.

Different studies [6, 7] have been conducted to identify the most suitable maintenance system for implementation in different companies operating in the current economic context. In [8], a model was developed to predict the time required for machine replacement, taking into account the entire life cycle and repair cycles.

In the paper [9], a new approach to aid maintenance managers in the difficult task of selecting relevant KPI-s for measuring the performance of maintenance services is presented. The proposed methodology allows the ranking of KPI-s, according to the decision makers' preferences.

In dedicated literature, few studies were developed considering an integrative approach to the maintenance process [10] and objectives.

In the present study, a database was built with information collected from the industrial environment. The main data collected concerns:

- The types of defects (mechanical or electrical),
- The type of symptom on one side and the history of repairs on the other side,
- The normal working time before a planned intervention, and
- The estimated cost of the planned intervention.

A flowchart for the maintenance process control was defined based on data concerning the past performed activities and achieved results.

The paper is structured in four sections, including this introduction. Section II develops and validates a flowchart, which can be used to create a database and then to use the data to identify and predict as quickly as possible the repair parameters (time, cost, necessary spare parts, and other resources). Section III develops a case study to identify a set of parameters that can be used to predict the „total defect time", while Section IV presents the main conclusions and discussions related to the presented study.

2. METHOD FOR IDENTIFYING THE "TOTAL DEFECT TIME" PARAMETER

The machines tools are used in manufacturing processes to implement, at different stages, one or more process phases, according to operation plans or technical specifications, using dedicated tools, devices, and checkers. To achieve the production targets, in terms of quality level, quantity level, and processing time, the machines should work at their nominal capacity. A lot of jobs should also be done to maintain the machines' operational capacity, such as: surface cleaning, ensuring oil for greasing the components, planning and implementing maintenance activities according to the recommendations of the producers.

Collecting information related to the maintenance process can be a challenging task for the processes managers. Quickly repairing a machine tool, even during an accidental defect, may become a hard job for the

maintenance personnel, technicians, or engineers. The finding of an alternative production flow using similar machines also becomes an important job for production engineers. A method to identify the alternative production flow using the multicriterial optimization method based on industrial data collected from a bearing manufacturing company was developed in study [11]. Using the proposed method, the decision-makers could accurately and rapidly decide which machine tool is the most appropriate and also available from a maintenance and production point of view to be set up and then used to continue the production process. Based on the main potential consequences of an accidental defect, a flowchart that can be used to create a database and then to use the data to identify and predict as quick as possible the intervention parameters (time, cost, necessary spare parts, and other resources) is developed and validated in this case study. The flowchart is built by considering the history of planned and unplanned repairs on the same machine or on similar machines at similar defects.

Based on the previously described situation, this paper presents an integrated methodology designed to assist the process manager in improving operational processes.

The usage of the proposed flow of activities also helps in resources allocation activity, to estimate the intervention parameters, time and cost, in the case of an accidental defect, and to improve the parameter named ***total defect time*** (Tdt).

The parameter ***total defect time*** is assumed as *the period of time between the moment of defect identification by operators and the moment when the machine restarts production in normal conditions*.

Schematically, the main components of the parameter ***total defect time*** are identified and presented in Figure 1.
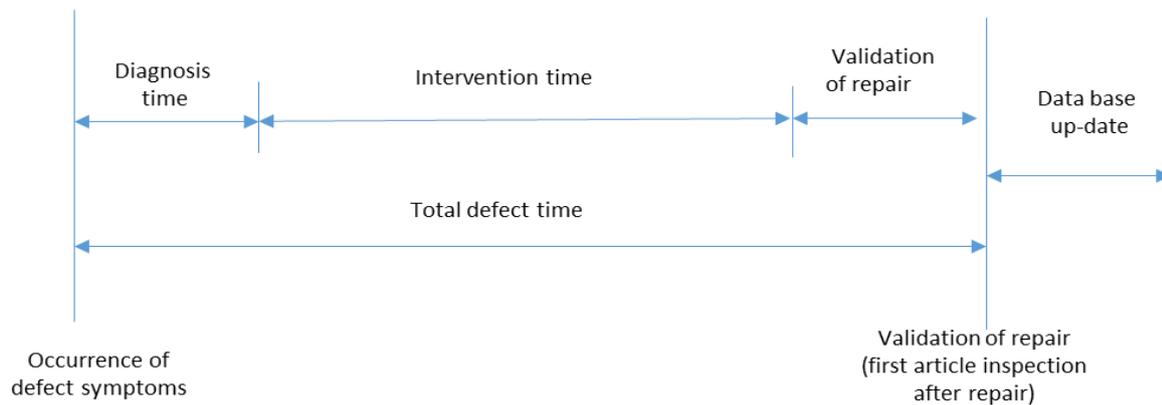
Fig. 1. *The "Total defect time" components*

The prediction of intervention costs can help companies in planning maintenance activities on one side and in optimizing the total defect time on the other side.

The use of a set of parameters included in a dedicated database to predict maintenance activities parameters helps the decision-makers to identify the way of acting in the case of a defect occurrence, and also to replan the activities to achieve the expected results of a manufacturing process. Expected results may mean downtime, productivity, on-time delivery, achieving the level of orders, quality of products, level of scrap, and rejection rate.

As an effect parameter, the ***total defect time*** has an important impact on the organization's results. The management strategy of the maintenance process should consider the approach of the ***total defect time*** parameter from the following points of view:

– The production results: productivity, OEE, and usage of resources in a sustainable manner.
– Measurement of the performance of the maintenance activity, and
– Reference for a randomly occurring defect.

3. FLOWCHART FOR DATA COLLECTION & DATABASE CREATION

In this chapter, a case study was developed to identify a set of parameters that can be used to predict the ***total defect time.*** The improvement of this parameter leads to an improvement in resources usage and planning of the maintenance process. Many companies consider the production processes as the most important during the business planning phase, but at the same time, the maintenance is considered as a support-process that consumes important resources and could be performed only in the event of an occurrence.

This approach was recently improved by using the methods and models for maintenance planning. Maintenance planning should consider a set of key factors such as:
- Status of the machine tool – history of repairs,
- Working time,
- Available resources: financial, material, and human and
- Allocated budget.

A database was created by considering the registered information collected in a company involved in the bearing manufacturing industry. The defects were registered and classified as electric and mechanical for each machine. An application was defined using this data to help maintenance engineers predict intervention costs by considering past jobs.

The data consisting of downtime values was registered by the employees based on the internal applicable work instructions. The results obtained from database interrogation could be used to predict the cost to solve a defect (considering past solved cases) on one side, and to identify the activity due-time on the other side. The necessary steps are integrated in the proposed flowchart for database creation and usage. They are schematically presented in Figure 2.
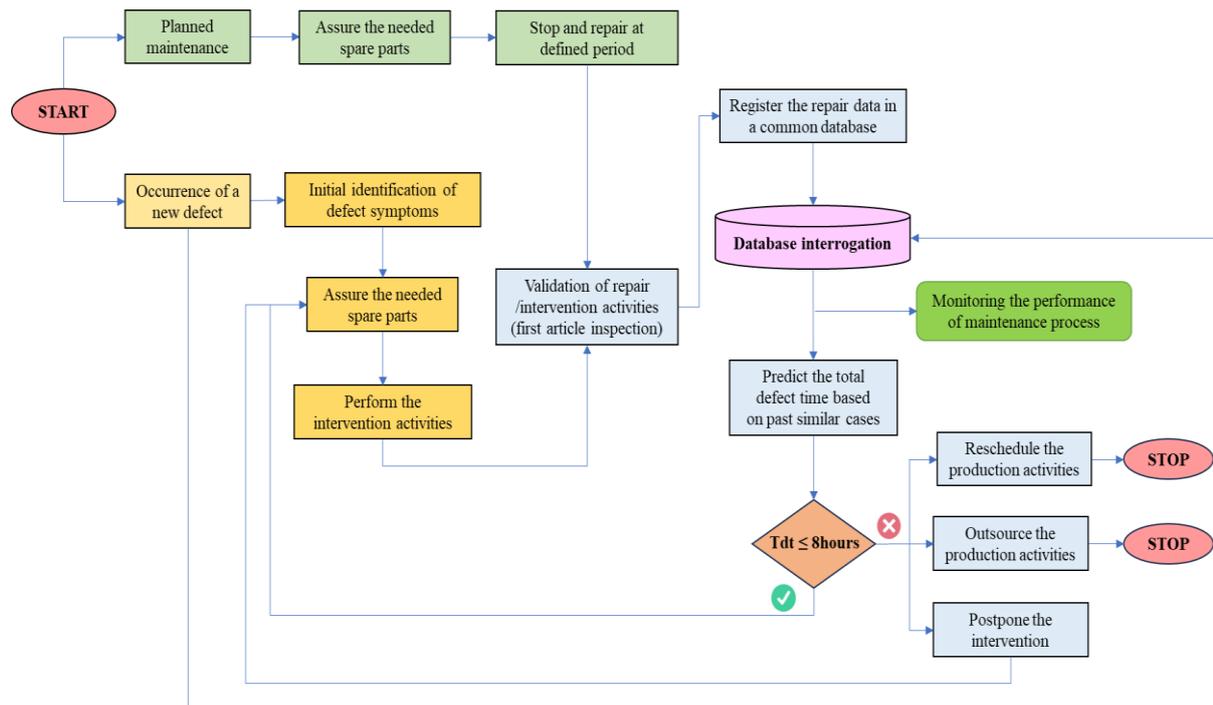
Fig. 2. *Flowchart for data collection and database creation*

The figure illustrates a comprehensive workflow for data collection and database creation within the equipment maintenance process. It integrates both planned and unplanned maintenance activities, showing how defect detection, repair interventions, and spare-part management are interconnected.

The flow begins with either scheduled maintenance or the occurrence of a new defect, followed by the initial identification of symptoms and the allocation of necessary spare parts. After the intervention is performed, the repair data is validated and recorded in a centralized database, enabling subsequent analysis and monitoring.

A key component of the diagram is the decision block that evaluates whether the total defect time (*Tdt*) exceeds 8 hours. Based on this assessment, the system proposes several operational responses, such as rescheduling production activities, outsourcing the intervention, or postponing the repair. These decision paths support efficient planning and contribute to minimizing downtime while maintaining equipment reliability.

Overall, the flowchart provides a structured view of the maintenance process, emphasizing the importance of data-driven decisions and historical data analysis in improving maintenance performance.

The original database concerning the equipment maintenance was built by considering the following issues: *i) intervention time*, meaning the total defect time – the diagnosis time, *ii) equipment type* - key equipment or back-up equipment, *iii) working time* from last planned maintenance (capital repair, current I, current II or technical revision), iv) *Mean time between failure* - MTBF, *v) frequency index*, meaning no accidental defects /year, vi) *total working time*, meaning the number of working years for each machine, *vii) total working time* from the last unplanned intervention, *viii) working regime* (1 - rough turning, 2 -semi-finishing turning, 3 - finishing turning), and *ix) maximum cutting time*.

4. RESULTS AND DISCUSSIONS

The maintenance process requires dedicated resources to be efficient and to help companies achieve their goals related to production levels and customer satisfaction.

Based on the company's strategies, maintenance processes should be considered

one of the most important processes, and it requires a dedicated budget and specific human and material resources.

The proposed flowchart for data collection and database creation can help the maintenance staff optimize intervention time and related activities, on one side, and support the management team in identifying the most feasible strategy in terms of defect-solving decisions, on the other side. Regarding the decision point, a total defect time higher than one production shift involves a series of activities to be performed as:

- Reschedule the production activities – this decision is feasible in case an alternative technological and economical solution is available and the delivery to the customer is not affected. At this point, it should be also considered the setup time for the proposed alternative and the availability of the devices needed.
- Outsource the production activities – in this situation a series of conditions must be considered: available and qualified supplier, delivery time, and other logistics details.
- Postpone the intervention – in this case, the activities can be planned, and the needed spare parts can be assured in a planned manner.

In all proposed decisions, the management team should first consider the impact on customers' activities and inform them according to the applicable agreements and rules.

The measurement of the process performance shows that the resource consumption increases in time due to the wear of the machines, on one side, and also due to the new production capacities acquisitions, (meaning supplementary allocation of human and material resources), on the other side.

Considering the maintenance process as a component of the management system, it directly follows that the performance of the company is significantly influenced by the maintenance activities.

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