MM Science Journal | www.mmscience.eu
ISSN 1803-1269 (Print) | ISSN 1805-0476 (On-line)
Special Issue | TEAM 2024
Transdisciplinary and Emerging Approaches to Multidisciplinary Science
11.9.2024 – 13.9.2024, Ostrava, Czech Republic
DOI: 10.17973/MMSJ.2024_11_2024082

TEAM2024-00022

CREATION, MANAGEMENT, AND USE OF A DATABASE FOR THE MAINTENANCE PROCESS OF PRODUCTION EQUIPMENT IN AN INDUSTRIAL COMPANY

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Abstract
The paper presents the creation of a database of motion norms to support the maintenance management system in an industrial production company, implemented by a team from the Faculty of Mechanical Engineering, VSB - Technical University of Ostrava. This database is intended for filling and optimal use of maintenance modules of ERP systems and for use in the processes of preparation of maintenance and service orders. The article focuses on the methodology of creation, characteristics, use and availability of this database and its application in industrial practice.

Keywords:
Maintenance, database, information system, process management, TPM

1 CURRENT GOALS SET FOR THE MAINTENANCE SYSTEM IN INDUSTRIAL COMPANIES

The understanding of maintenance only as a system that returns objects after a malfunction or an accident to a state that fulfils their function is now generally outdated, although it is still accepted in many companies. Today, and increasingly in the future, it is necessary to focus on fault-free and reliable operation of objects with technical and economic efficiency [Necas 2013, Necas 2019, Schindlerova 2021]. This cannot be ensured otherwise than with a widely elaborated maintenance management system based on the balance of resources and results achieved [Necas 2021, Sproch 2021].

Correctly balanced preventive maintenance based on diagnosis and planning according to fixed and sliding interval should form the basic pillar of the system, only to a limited extent and due to failure supplemented by correction after the occurrence of failures and accidents. The benefit should then be the availability of the equipment without losses due to faults, the full performance of the equipment without losses due to the reduction of parameters, and the required level of quality without degraded output quality [Schindlerova 2024].

However, the achievement of the stated goals must be supported by a sufficient amount of resources of an appropriate level, regardless of whether the resources to ensure maintenance are internal (insourcing) or external (outsourcing). It is necessary that the optimally balanced structure of resources is effective and sufficiently financially secure, but without excessive burden on the corporate economy. Capacity, personnel, material, and information resources must create a whole with a synergistic effect, and each of their components must represent a high-quality and sophisticated security subsystem for the care of the company's production equipment [Novak 2012, Tomek 2017].

Maintenance Processes	Maintenance Objectives	Maintenance Resources
• Preventive maintenance ▪ planned maintenance (according to fixed and sliding interval) ▪ diagnostic maintenance • Follow-up maintenance (after failure)	• Equipment availability • Device performance • Quality of output production	• Material capacity resources • Personnel resources • Material resources • Information Sources*

Properly designed maintenance organisation and fault monitoring and prevention significantly affect the efficiency, reliability, and safety of production. In mechanical engineering, where it is an important pillar of the economy, this includes, for example, the maintenance of production machines and tools for sheet metal drawing [Cada 2021, Cada 2022, Balcerzak 2024], shearing [Cada 2021], bending [Cada 2023], material refinement [Rusz 2019, Rusz 2020, Hilser 2014, Hilser 2020, Pastrnak 2021, Bednarczyk 2024,], forging [Cada 2023].

From a maintenance point of view, the wear resistance of the forming tools [Evin 2019, Tavodova 2020] is important and affects their useful life. For forming tools, it is possible to prevent defects using nondestructive detection methods

[Stancekova 2013]. When it is necessary to produce spare parts for which the type of their material is not known, their material analysis can be performed [Kudrna 2020]. Residual stresses in components can be analysed using Barkhausen noise [Neslusan 2011].

The achievement of maximum production productivity and the elimination of waste can be achieved, for example, by using the Value Stream Mapping method [Sajdlerova 2015], which is part of Lean Management, as well as by the appropriate design of the distribution warehouse [Schindlerova 2019].

The information resources needed to manage and plan processes, identify needs, ensure implementation, and carry out analyses in the area of maintenance are still underestimated in many companies today. However, they fulfil an extraordinary role in the process of improving the quality of maintenance and can lead to significant benefits and elimination of losses.

2 IMPORTANCE OF DATA IN THE MAINTENANCE MANAGEMENT PROCESS

While human resources for maintenance (internal and external workers) must follow the path of dual education and education of quality mechatronics, managing electronic and mechanical systems, the provision of material resources is moving towards a warehouse-free system of provision of spare parts including the use of modern 3D printers, and capacity resources connect the provision of technological equipment maintenance and diagnostics, the system of ensuring and using information resources complements and connects everything into one complex and sophisticated whole.

New information technologies and the quality of available hardware (sensors, wireless transmissions, clouds, Internet of Things, etc.) enable the collection, transmission, storage, sorting, and use of a large amount of data can advance maintenance management to a previously unpredictable level. However, practice lags far behind possibilities. Consistent data analysis is not performed, diagnostics of technical condition are not connected to artificial intelligence and do not follow up on the preventive maintenance planning process, downtimes are not automatically consolidated with production management, etc.

However, it is necessary to realise that high-quality information system support, whether with software or hardware equipment, is only a prerequisite for good maintenance of information security. An extensive and high-quality database remains a necessary condition, which, according to the findings of the team at the Department of Mechanical Technology, Faculty of Mechanical Engineering, VSB – Technical University of Ostrava, was the main deficiency in all companies with which the department has cooperated so far.

It can be stated that the more extensive and complex this database is, the higher the quality of the maintenance management system supported in this way. Its construction must be long-term and detailed, so that the information can be generalised and serve as a starting point for subsequent planning, preparation, and implementation of maintenance at the level of current and future requirements.

The database must include information of a temporal, technical, dispositional, and economic nature:

- Time-related information – time of availability and time between breakdowns, inspection intervals, waiting for repairs and duration of repairs, etc.,
- Information of a technical nature – optimal and extreme data vibro-technical, thermo-technical, tribo-technical, device efficiency, voltage, current, flow, etc.,
- Dispositional information – quantitative data (e.g., equipment failure rate, availability of maintenance) and qualitative data (occurrence of poor production quality and non-conforming products, productivity and productivity related to production equipment),
- Information of an economic nature – especially cost, profitability, loss and efficiency related to maintenance, availability, and poor quality.

For the information system to maximally support the maintenance management process and for the database to be sufficiently extensive and high-quality, it is possible to introduce the connection of internal information systems to intercompany structures – the so-called data networks for maintenance processes.

In 2023, SIEMENS published a project focusing on Digital Data Chains (DDC), which deals with digital and permanent access to information about the plant and its individual components. It identified the significant time lag in finding the information needed for planning, installation, commissioning, operation, cleaning, maintenance and service as a major problem. According to the study, the online availability of this data in the digital data chain from the cloud at any location on a mobile device should be a matter of course. The creation of a common cross-enterprise platform for sharing data on all assets throughout their lifecycle and on the procedures, activities and resources required for operation, maintenance and servicing, accessible via a digital tag, is a current goal.

The solution proposed by the VSB-TUO team in the segment of determining the duration of repairs of production equipment is an innovative solution and a complement to the current research reported in this article (see section 4), which is being carried out at the Faculty of Mechanical Engineering of VSB – Technical University of Ostrava under the leadership of doc. Novák - i.e. the creation of a complex and specific database of motion norms for a set of maintenance activities on any production equipment. Increasing the efficiency of maintenance and saving costs clearly requires precise definition, traceability and transparency of processes, a high degree of automation in this area, on-line connection of maintenance managers with control systems and thus achieving high productivity of work in maintenance and service of production equipment. Thus, our research builds on and fills the gap between the development of software systems and the practical implementation of maintenance by creating a database for determining the duration of work. The proposed database is the basis for the implementation of digitalisation in manufacturing processes, including maintenance. The proposed database clearly defines maintenance activities in terms of the requirements for their performance. In particular, it concerns the supply of the process with materials, spare parts, tools and devices, the procedures required to carry out repairs, including the time values necessary for maintenance activities.

3 INFORMATION SYSTEM AND ITS MODULAR LINKS IN MAINTENANCE MANAGEMENT

A prerequisite for an excellently functioning Total Productive Maintenance (TPM) management process is its support by an appropriately designed information system with an interconnected structure of mutually complementary and well-communicating sub-modules. At the same time, it is not always necessary to comprehensively change the existing system software, but to fully engage its capabilities and connect it with new application programmes, solving other areas of maintenance processes.

A maintenance management information system that meets the requirements of TIM should support the following basic requirements and functions:
detailed records of all machines and equipment and their structural components,

- assessing the state of production equipment based on diagnostics,
- keeping a history of machines and equipment and their structural components,
- preventive maintenance planning according to fixed and sliding intervals,
- planning the purchase of optimal supplies for maintenance and repairs and monitoring their condition,
- management of the system of training and training of operators for efficient and gentle operation,
- connect the activities of operating machines and equipment with basic maintenance activities,
- coordinate and link the activities of maintenance workers, operators, toolmakers, technologists, and designers,
- maximise the possible concurrence of inspections, maintenance, repairs, and service,
- carry out analysis of maintenance activities,
- formulate measures and draw conclusions in the direction of operation, maintenance, toolmakers, technologists, and designers.

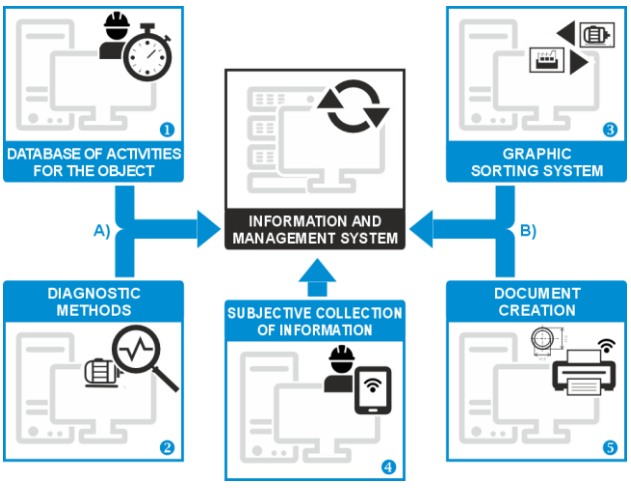

Fig. 1: Information system for maintenance processes

The complex information system for maintenance activities (see Fig. 1), as it was designed at the Department of Mechanical Technology, VSB – Technical University of Ostrava, consists of five modular units connected to the central information and management ERP software and connects the processes of managing the normative database, management of the diagnostics area, a graphic sorting system of machinery and production equipment, a system for creating documents, and a system for subjective information gathering.

Information and management system

Maintenance management information system modules provide five main areas (see Fig. 1), which can be briefly characterised by functions:

• **Database of activities for the object** ❶ – its basis is movement norms, including work and technological procedures used in maintenance during assembly and other auxiliary and service activities. Its structure has a modular character and is therefore universally usable to define all maintenance activities.

• **Diagnostic methods** ❷ – implements the results of research and development of diagnostic identification of non-standard manifestations of production equipment and signals the need for the intervention of service, maintenance or department personnel, technologists, designers, or toolmakers.

• **Graphic sorting system** ❸ – the module facilitates, shortens, and simplifies detailed records and documentation about production equipment in graphic form and in a step-by-step breakdown – parts of production equipment, parts of production equipment, production equipment, workplace, internal department, and company, or link to the supplier of production equipment device.

• **Subjective collection of information** ❹ – the module records information based on the subjective findings of cooperating department workers, identified based on experience, knowledge and practice.

• **Document creation** ❺ – a module that allows rendering or a way to secure the object you are looking for, open an existing drawing or 3D animation, send it electronically or print it.

The core of the maintenance information system is any quality ERP system of enterprise resource planning that automates processes related to the operation of the enterprise. All the information needed for maintenance management must be easily and quickly available in it, and it must also be able to communicate not only with internal departments, but also with external entities.

A. Diagnostic system and activity database

The links between the activity database system for the object ❶ and the diagnostics system ❷ (see Fig. 2) creates an interface between the measured values of vibro, thermo and tribo on the one hand and the creation, use and organisation of the activity standards database on the other.

As shown in Fig. 2, the objects are diagnosed in the system at set intervals, mainly in terms of reporting vibrations, temperatures, and the state of lubricating oils, and the measured values are assessed in terms of meeting the set range of values (yes/no). For example, you may be wondering whether the assessed component (bearing) exhibits no excessive vibrations, does not heat up excessively, or does the oil show signs of wear or contamination. The system should be able to evaluate the

development of the state of the installation or a specific measurable component and evaluate the measures necessary for more reliable and safe operation.

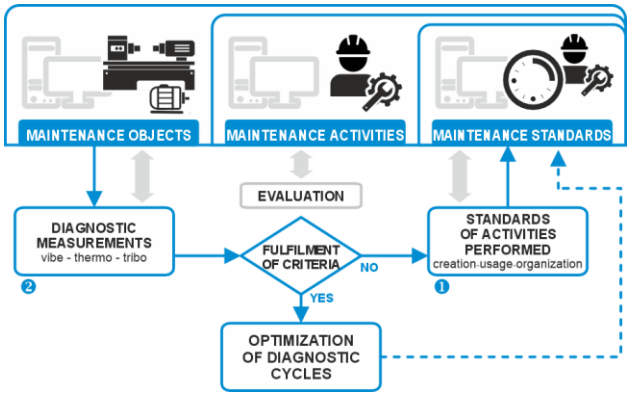

Fig. 2: Connections of diagnostics interface and activity standards

Based on the overall evaluation of the development and condition at the time of the measurement, a decision can be made to optimise the diagnostic measurement cycle, e.g. extending or shortening the interval for performing this check, and it is necessary to adjust the cycles in the maintenance standards module or include additional diagnostic measurements according to the evaluation of the equipment condition. If the diagnostic measurement shows values that no longer guarantee safe and reliable operation of the equipment or the measured values are close to the limit state, this is an instruction to carry out the appropriate maintenance intervention. In the maintenance module in the ERP system, a request is registered for the relevant maintenance work. The work and technological procedure, activity times, requirements for material and equipment of the maintenance worker are assigned to them, all according to the defined activity standards in the activity database module for the given object.

B. Graphic sorting system and document creation

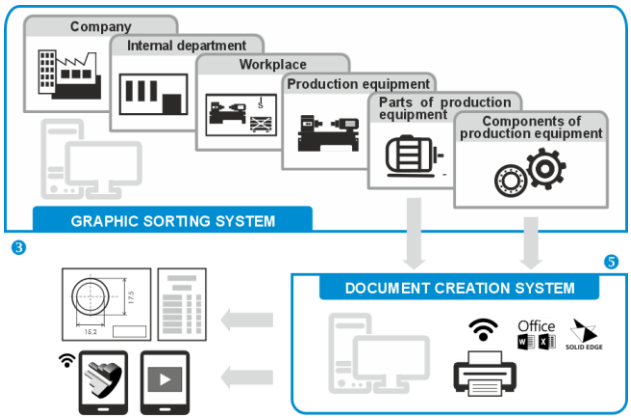

Fig. 3: Graphic sorting system and document creation

Maintenance and repair of machines and equipment are very often related to the replacement of partial components and thus to the availability of spare parts, including the necessary tools and equipment. This phase is significantly facilitated, simplified, and accelerated by the graphic sorting system ❸ (see Fig. 3). This module keeps detailed records of all objects, machines, and equipment in graphic form. At the same time, this system allows you to manage a database about the company and store new information, quickly access the archive of drawings and construction bill of materials divided by objects, and finally modify technical documentation.

In conjunction with the document creation module ❺ (see Fig. 3), it enables integration into CAD systems, Solid Edge, Microsoft Office, and others, and prints drawing documentation of production equipment and its components. It can also transmit 3D animations and sequences of disassembly and assembly of production equipment to mobile devices via wireless communication.

4 SECURITY OF THE MAINTENANCE SYSTEM WITH A DATABASE

The creation of the database for the maintenance system is a long-term and thorough work of the doc. Josef Novak, CSc. team at the Faculty of Mechanical Engineering, VSB – Technical University of Ostrava. The result of this work is an extensive set of data and procedures of maintenance activities for various devices and their structural units of the given production system, including time evaluation.

The originality of the created database lies in the methodology of its creation and thus in the high level of accuracy and precision of the created data set. The creation of the database is based on the needs of practice and incorporates all the scientific research known to date in the field of maintenance, extending and deepening these methods.

The productivity of maintenance activities in current practice is inadequate. The economic efficiency of process management in this area can be achieved through a number of measures. The main aspect of the database project is to solve maintenance problems comprehensively, i.e. in terms of process optimisation, time consumption and quality material and personnel support. The solution incorporates previously introduced trends in predictive or proactive maintenance, which it not only deepens but also significantly expands and improves.

Objectivity, detail, and completeness of the data contained in the system are prerequisites for the quality functioning of maintenance management support systems. Only such information can contribute to the effective management of the maintenance process, its planning, implementation, and evaluation. The optimal application of the database of maintenance activities for the object is conditioned by the following main factors:

- if possible, applying standard methods of carrying out maintenance work,
- sufficient security by workers in the required quantity and with appropriate qualifications,
- provision of necessary spare parts and tools.

The database, as the primary source of information for maintenance management activities, must not only be well created, continuously optimised, but also constantly supplemented. Maintenance work is specific in many ways. Especially with it's irregularly repeated occurrence of identical or similar activities in unequal conditions:

- disassembly and assembly of the same parts can be of different difficulty,
- accessibility to components may be different,

- tolerance and difference of parts, their relative position, etc.,
- the occurrence of unexpected malfunctions and accidents.

With these specifics in mind, it is also necessary to approach the creation and implementation of a database of labour consumption standards. Each database has its own specific structure, which is based on the type and nature of the activity, the complexity and difficulty of the given work, its repetition, and other factors.

From the point of view of detail, the elements of the database are broken down into individual movements and actions, or, on the contrary, accumulated into stable operations and sets of activities. It is advisable to maintain certain rules that allow the insertion of new data and sets of new activities on a modular basis.

For the creation of the database of each company, it is possible to use the elements of the universal database which have been processed differently regarding the organisation and technologies that exist in different production systems.

The principle of creating a database

Creating a database is an extremely demanding and laborious activity. It requires knowledge of equipment and knowledge of performing its repairs, both in terms of technological and work procedures and assembly mechanisms, as well as in terms of used tools, tools, aids, and other necessary equipment needed to carry out the given repair (scaffolding, forklift, etc.). Methodical approach to creating a database by a team led by doc. Ing. Josef Novak, CSc. consisted of the following steps:

- the method of movement norms was chosen for the creation of time values of the work performed,
- using this method, basic and higher-level data were gradually, and logically created, and aggregated data was created from them in a modular fashion,
- from the basic data system of all levels of the association, data were created for individual operations occurring in maintenance, assembly, and other activities,
- the operations required to perform the entire complex of maintenance and assembly work were compiled into complete technological procedures of the equipment parts,
- compendiums of data and maintenance information for specific types of equipment, machines, production lines etc. were compiled from the complete technological procedures of parts of the equipment.

For the database to be used in different organisations regardless of the nature and type of production, its creators were based on the realistic assumption that every device or machine consists of structural components and parts that are identical or similar, and their occurrence is determined by the function of the machine.

The structural parts in the database include, for example, gearboxes, couplings, bearings, electric motors, etc. To ensure the objectivity and professional level of the database, experts from various companies and organisations from the Czech and Slovak Republics were invited to its creation and gradual verification. They were experts from the maintenance operations of large and important engineering, metallurgical, and electrotechnical enterprises. The procedures and data listed in the database were also consulted with other specialists who in practice participate in the complex repair or maintenance of the given equipment.

The universal database created in this way should undoubtedly be an important tool for the creation of databases of any company, regardless of the type and nature of production. It is also suitable for creating data in assembly and other manual activities. The inspiration for the creation of the normative base was the well-known principle "What I don't measure, I don't manage".

Currently, the digitisation of all activities, including the digitisation of factory management, is being widely discussed. However, if digital management is to be successful, it cannot do so without, if possible, objective data. In many cases, the database data can be supplemented or verified by collecting data directly from the manufacturing process or for maintenance processes.

The created universal database is currently in paper form. However, a programme was also created to process and create data with the help of computer technology. However, to create a digital maintenance module as part of the digitisation of company management, it will be necessary to fill the software module with data from the document database and integrate the module with production management modules, and others. In the future, the subsequent research and development necessary for the introduction of digitisation of management in companies must go in this direction.

Availability of databases for maintenance management

According to the theory of management and practical experience, the system of technical and economic standards is the basis for efficient and effective management. The level and effectiveness of management is determined by the quality of the input information that is the basis of the management system. However, such information databases are not, in the vast majority, part of the software programmes provided. At the same time, an objective database is the key to effective management, and it is necessary to pay the necessary attention to this issue. Filling software programmes with data is mostly the task of business professionals. The created universal database provides information that can facilitate and speed up this work.

Universal data files processed by the team of doc. Ing. Josef Novak, CSc. at the VSB – Technical University of Ostrava can be the basis for the creation of a database of specific companies and the starting point for expanding the data needed for managing maintenance and assembly in a specific company.

5 SUMMARY

With awareness of the goals that the creation of the database aims to achieve in the field of quality management of maintenance processes, with respect for the complexity of all areas that make up the maintenance system and with knowledge of the principles of the functioning of software tools for management, a wide-ranging and objectively formed database for major maintenance activities. These universal collections of norms are now available to fill the

databases of maintenance modules of information systems in industrial companies.

It is essential to continuously monitor developments in machine and plant design, to generate new data and procedures based on this, and to focus on the continuous integration of the database into a comprehensive risk management system.

Future research must focus on the design of new machinery and equipment, improving maintenance procedures and thereby extending or optimising the lifetime of machinery and production equipment.

6 ACKNOWLEDGMENTS

This work was supported by the SP2024/049 specific research project with the name 'Research and Innovation in Engineering Technologies and Their Effective Management' solved at the Faculty of Mechanical Engineering of VSB – Technical University of Ostrava.

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