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CONDITION-BASED MAINTENANCE OF MACHINE TOOLS

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Abstract: Condition-based maintenance is getting more and more popularity in the machine tool industry to ensure high availability and a cost-efficient operation. Scope of the research project “Make-it”, funded by the German ministry for education and research (BMFe), is to develop new systems to measure the wear of machine tool components, to calculate their remaining service life and to derive cost-optimal maintenance dates to replace them. The developed systems are integrated and tested in a novel machine tool for the simultaneous milling of ball hubs.

Key words: machine tools, condition monitoring, maintenance planning, availability, cmms

1. INTRODUCTION

Due to the tough competitive situation, producing companies are forced to manufacture cost-efficient. Their extensively automated and highly productive industrial facilities have to be intensively used to refine the acquisition cost. Normally, this requires a multi-shift operation and a high availability of the facilities (Eti et al., 2006). The safeguarding of this availability is business of the maintenance departments. In contrast, these departments are subjected to an intense cost pressure. For that reason, companies are relying on efficient Computerised Maintenance Management Systems (CMMS), modern maintenance strategies like condition-based maintenance and co-operations with maintenance service providers (Moore et al., 2006 & Kans, 2007). Furthermore, life cycle cost gain in importance regarding the procurement which is a big support for the reduction of maintenance cost (Conley et al., 2007). Within the research project „Make-it – Maschinenzustandsbasierte Verfügbarkeitsdienstleistungen für hochproduktive Fertigungsanlagen“ (condition-based availability services for highly productive machines), funded by the German ministry for education and research, different approaches for the cost-efficient availability improvement of machine tools are developed and presented in the following.

2. CONDITION MONITORING

In the majority of cases the maintenance strategies practiced in industry are reactive or periodic preventive. In the interval of maintenance recommended by the manufacturer, specified activities are accomplished and worn out parts are replaced if necessary. An example is the maintenance of the drive belt of feed axis. In the provided documentation the manufacturer refers to inspect the drive belt every 2000 operating hours. In doing so the drive belt is checked concerning damages, wear and prestress by qualified personal. If an unexpected breakdown occurs previous to the expected end of the maintenance interval, this can lead to machine failure or to a stop of a whole production line according to the level of linking. Approaches for the forecast of failures or critical system conditions are predominantly researched (Dietmair et al., 2006 & Saravanan et al., 2006). Basis of actual activities in the field of condition-based maintenance is the development of a comprehensive and robust condition monitoring. In doing so information of the machine control (NC, PLC) as well as signals of sensors integrated in machine components are used. The signals captured by the machine control, for example positions, motor currents and drive temperatures, pressure of pneumatic and coolant aggregate as well as diagnosis signals of control, drive and field bus components, often only show a general error. The possibility to deduce the actual cause of error by these signals is limited. Within the research project “Make-it”, sensory machine components are developed as well as a multi-criteria condition monitoring system which allows a cause-and-effect analysis. For the detection of condition-changes models are developed to characterise the wear and availability of components and the whole machine. The parameterisation of the models is realised by the use of test sequences. In a next step the models for condition monitoring are used for the detection of malfunctions and the localisation of the failure cause. By comparing the conditions of the machine tool with the model, which has been parameterized in error-free state, changes of attributes can be determined. After fault localization and identification of the error cause the prognosis of the remaining service life is executed. The approach that is used for this task is based on an analysis of the wear development. Under consideration of the future load situation the wear progress is extrapolated. The knowledge of the remaining service life as well as the redundant design of the machine tool demonstrator shown in Figure 1 enable the operator either to determine the optimal date for a maintenance measure and/or to use strategies for emergency operation. Strategies such as operating with modified process parameters in order to reduce machine load or milling with only one spindle engaged are possible.

Fig. 1. Machine tool demonstrator

3. MAINTENANCE PLANNING

At present, different kinds of commercial CMMS are offered on the German market. These systems comprise key features such as the illustration of machine and personal data and the administration of maintenance requests and spare parts. Main distinctions between different CMMS refer to differing graphical user interfaces (GUI), potential features for the analysis and the visualisation of data and interfaces towards other in-house management systems as ERP or MES (Peter,
Some of these CMMS have the ability to trigger manufacturing tasks based on machine condition data. This requires a coupling to the machine control or a separate system for condition monitoring. The release of maintenance tasks is carried out either when an error from the machine tool is reported or when one or more signals ascertained within the machine condition monitoring exceed a threshold value. Hence, these systems indeed generate maintenance tasks by analyzing the condition of the considered machine part, but the exact date has to be manually determined by the user of the CMMS. Thus, the user has the option either to stop and recondition the machine right away or to postpone the maintenance date until the following weekend for example. Moreover, the user has to decide which personal resource (employee of the in-house maintenance department, service of the machine manufacturer or employee of a maintenance service provider) has to carry out the maintenance task. Therefore, within the research project „Make-it” a novel CMMS has been developed, which actively supports the CMMS user carrying out these tasks. This system executes a dynamic cost calculation of different maintenance dates. Besides maintenance cost, this system also comprises cost occurring with the machine having a breakdown and the uncertainty of machine monitoring and rest lifetime prognosis. Figure 2 depicts the fact that when having chosen a later maintenance date lower maintenance and spare parts cost occur.

The machine breakdown cost caused by maintenance actions decrease likewise due to the fact, that with regard to the entire lifecycle of a machine, altogether less maintenance tasks have to be carried out. In contrast, the risk of a breakdown and the potential cost occurring with the machine having a breakdown increase. The risk of a breakdown can be described by a predicted breakdown density function, which is regarded as the output quantity of the rest lifetime prognosis. The novel CMMS is able to determine an optimal maintenance date characterised by the minimum sum of maintenance cost and potential cost of a production stop. Moreover, the CMMS considers the availability, qualification and different cost rates of several potential maintenance groups. For this reason, the CMMS is built on Microsoft Active Server Pages and designed as a web-based system. In Figure 3, the utilisation of the novel CMMS is depicted. While employees of the plant operator have full access to the condition of the considered machine part, but the exact date for an upcoming maintenance task. Therefore, within the research project „Make-it” a novel CMMS has been developed, which actively supports the CMMS user carrying out these tasks. This system executes a dynamic cost calculation of different maintenance dates. Besides maintenance cost, this system also comprises cost occurring with the machine having a breakdown and the uncertainty of machine monitoring and rest lifetime prognosis. Figure 2 depicts the fact that when having chosen a later maintenance date lower maintenance and spare parts cost occur.

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![Fig. 2. Cost comparison of different maintenance dates](image-url)

**Caption:** Cost →
Cost for repeated replacement of a component after a certain service life within a given period
Potential cost of production downtimes
- Sum with point of minimal cost
- Feasible dates for maintenance activities
- Predicted date of breakdown

4. CONCLUSION

In this paper, approaches and systems of the research project „Make-it” for condition-based maintenance of machine tools are presented. They range from sensors at the machine over a rest lifetime prognosis for components to a web-based system for condition-oriented maintenance planning. The presented systems display a big potential to further improve the availability of machine tools and their cost-efficient maintenance. But there are still challenges and limitations which justify further studies: The future development of condition-based maintenance is strongly affected by the robustness of the condition monitoring systems and the accuracy of failure predictions. Moreover, in order to be able to determine optimal maintenance dates, CMMS afford further development potential regarding the dynamic prognosis of changing machine wear caused by alternating workloads.

5. REFERENCES


