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A holistic approach for quality oriented maintenance planning supported by data mining methods

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Abstract

Appropriate maintenance measures, which are carried out at the right time are a key factor to secure plant availability, product quality and process efficiency in modern manufacturing systems. Established maintenance strategies oftentimes lack in combining these strongly related aspects. They are not capable to anticipate in a holistic way and therefore lead to unnecessarily high maintenance efforts, wasted resources and the occurrence of quality and availability impairments.
In order to realize a holistic and anticipatory approach for maintenance planning, a methodology which consistently compiles and correlates various data via "cause and effect" coherences is depicted. By breaking down the production facilities on component level a basis is set to link condition monitoring data, wear data, quality and production data by using data mining methods. This framework enables the identification of maintenance-critical conditions and the prediction of failure moments and quality deviations.

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Keywords: Maintenance, Predictive Model, Quality,Data Mining, Manufacturing system

1. Introduction

Quality management, maintenance and production control are essential functions in manufacturing systems for achieving desired production targets [1]. The field of maintenance plays an important role to raise the potential of "Industrie 4.0" [2, 3]. In this light the volume of created data and the need of data processing is going to increase considerably within the near future [4]. Therefore, a successful maintenance planning needs to be able to handle this amount of data and at the same time link it with the implicit knowledge of employees.

The main task of maintenance is to preserve the function and performance of a machine or a system. Due to increasing complexity of production, handling and transport facilities as well as increasing automation the role of maintenance is gaining more importance [5].

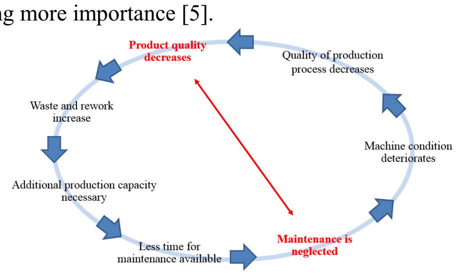

Figure 1. Sphere model of maintenance and product quality [6]

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An equally important role of maintenance is the assurance of product quality by providing an optimal machine status to eliminate system-related loss of quality during production. Thus, there is a causal relationship between maintenance and product quality, as illustrated in the sphere model (fig. 1) [6].

In the area of conflict between economy, safety and availability, decisions have to be made which simultaneously achieve a minimization of costs, a maximization of equipment availability and increased product quality. These measures will lead to an improvement in the system's productivity.

2. Maintenance strategies and approaches

Due to increasing demand for higher quality and more efficient production processes, holistic concepts have to be developed, in addition to the three basic maintenance strategies, failure oriented maintenance, periodic maintenance and condition-based maintenance.

In the context of large-scale production with constant machine loads, conventional maintenance strategies can be applied, whereas in customer order driven production processes, current approaches of preventive maintenance fail as they are not responding to specific load spectrums.

Especially in flexible production systems with a high variation of the production mix and no fixed load spectrum there is a need for anticipative and holistic maintenance strategies (Fig. 2), that jointly consider sensor signals from condition monitoring systems, quality and machine data as well as historical information regarding the failure behavior. [1,7].

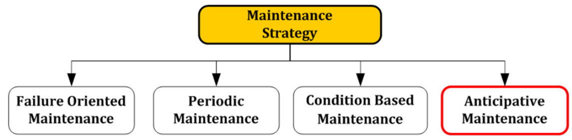

Figure 2 Maintenance Strategies [5]

Predicting the degradation and its effects on the manufacturing process is a central issue within maintenance planning approaches. Most existing models, used to predict machine failures, are based on historical data or data from long term studies about the condition of the machine or its components. Probability models like the Weibull distribution, which describe typical degradation processes of components, are derived from these data sets [7].

Traditional quality management methods use product- and process data for gaining conclusions concerning product quality, which subsequently (after a data analysis) trigger a re-adjustment of the production process, if a deviation from the defined specifications is detected. However, neither machine data, nor production planning and control data are included in this approach.

Different aspects regarding quality control (product, process and production infrastructure) are already covered by existing methods (Fig. 3). Quality oriented maintenance strategies, combining product and machine level by linking the product quality with failure effects of certain components, are provided in the literature. Consequently, a coherence between the degrading machine system and the quality relevant characteristics can be derived [8]. Load oriented maintenance strategies statistically determine the remaining life time by using external measurement parameters. In order to schedule maintenance intervals, machine- and process perspective are combined by linking the production program and failure effects of components [9]. Using a load spectrum dependent service life model allows for aligning operating resources in terms of economical organizational and technological aspects [10].

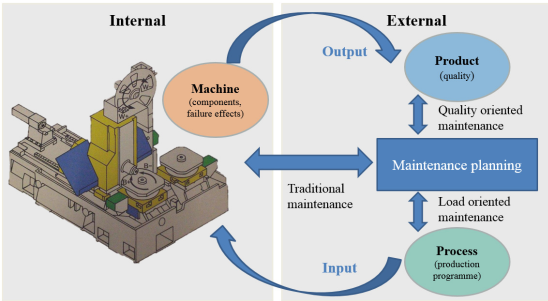

Figure 3. Interactions of maintenance related perspectives

However, even though certain maintenance strategies combine different perspectives, a holistic maintenance strategy, which takes product, process and machine perspective into account, is neither applied in the industrial practice nor published in literature.

3. Current Challenges of Maintenance planning

Increasing cost pressure, individual customer requirements, company internal and external dynamics and therefore increasing market volatility are shaping the field of maintenance [11].

For different reasons it becomes more and more difficult for classical maintenance strategies to derive a minimum between maintenance cost and system-wide downtime costs:

- In case quality of maintenance relevant data is often unsatisfactory, system-wide standards are missing or the same data sets are processed in different systems within the period between failures, it is not possible to derive a significant correlation and analysis of the failure behavior.
- Since information regarding the machine status is incomplete or provided to late, an exact and wear optimized replacement of components is not possible in time.
- Because the applied loads do typically vary from the theoretical load profiles, calculations of lifetime for plant components lose explanatory power.

Therefore, maintenance measures are either carried out at a wrong or unfavorable time. Thus, it is not likely to achieve a replacement of components that is aligned with the present production status and the required product quality. Classical maintenance strategies are buying improved plant availability with increasing maintenance cost due to waste of resources.

For that reason, existing planning tools are facing little acceptance. This fact leads to inconsequent data recording and data maintenance in dedicated systems. As a result the quality of the maintenance planning decreases even further.

However, in the light of "Industrie 4.0" it is foreseeable that