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Towards autonomous control in maintenance and spare part logistics - challenges and opportunities for preacting maintenance concepts

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Abstract

Maintenance and spare part logistics often determine the life cycle costs related to the usage phase of assets. Therefore, different maintenance strategies are known from literature and adopted by enterprises in order to cut these costs. Most often these strategies face problems due to uncertainties in processes and tasks. This paper suggests an adjusted preactive maintenance concept which implements autonomous control aspects in order to plan and control personnel, equipment, resources, etc. ad hoc and without hierarchical planning instances. In doing so, different well known strategies will be kept equitable within the concept but are replenished with an overall heterachical organized planning and controlling approach. As a result, maintenance objects themselves gain the opportunity to trigger maintenance measures, no matter whether it's a case of inspection, maintenance or repair, according to their particular requirements. The paper gives a valuable insight into an effective concept of how to handle the complex situation for the operational maintenance processes as well as related spare part logistics in general and illustrates first concrete approaches.

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Keywords: Maintenance concepts; autonomous control; preactive maintenance concepts

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1. Introduction

Maintenance and in particular the repair in terms of actual physical activities that are required to reproduce the state of a machine can be seen as part of the integral logistics management [1]. Tasks like dispatching the orders and the related allocation of resources of personnel and equipment have to, in general, be fulfilled in a similar way as production environments. General inspection and maintenance as well as repair activities include resource allocation of working places and maintenance teams for queued orders. This assignment problem is referred to as a so-called "scheduling" [2] and is part of planning and control. The logistical process chain of maintenance order processing thus integrates personnel and team planning, equipment and material logistics as well as spare parts logistics. The concrete design of these processes is highly dependent on the chosen maintenance strategy [3].

Especially when pursuing a condition-based strategy, the effective integration of state information in the planning and control level is critical for the further processes [4]. A long-term maintenance planning is replaced by a medium time planning which allows relatively good state forecasts of the components and, in conclusion, a good scheduling of appropriate maintenance or repairs. However, faults which lead to a sudden failure must be scheduled as urgent jobs and initialize a rescheduling [3]. The challenge is to find an effective approach to handle the complex situation for the operational maintenance processes as well as the spare part logistics. A central information processing, planning and control system for this problem would require extensive information for each subsystem. Nevertheless, uncertain estimates cause a lack of planning reliability [5]. However, heterarchically organized objects, which follow their objectives through decentralized self- control, promise better efficiency for the overall system [6]. The general suitability of autonomous and decentralized decision-making systems for logistics planning and control processes for specific scenarios have been demonstrated already [7, 8, 9]. For spare parts logistics and maintenance processes this has not been fully investigated yet. However, condition monitoring systems and assessment methods would allow logistical objects to independently know their condition. As a result, they can be used for local decision-making and further activities, which is a precondition for autonomous structures. The planning and control by corresponding objects which negotiate the best possible behavior independently via multi-agent systems is one example. It is put onto the shortlist of suitable methods in preactive maintenance concepts [10, 11].

In the following, the paper gives a valuable insight into a modernized approach of preacting maintenance concepts through autonomous and decentralized decision-making systems with today's opportunities and tomorrow's challenges. In chapter 2, a literature review that analyzes today's state of the art is performed, followed by a methodological description of the preacting concept in chapter 3. In addition, some cases will be shown and discussed to investigate the practical eligibility following the technical approach of the concept in chapter 4. Chapter 5 gives a final conclusion and an outlook for further development and research requirements.

2. Literature review and state of the art

In general, maintenance strategies can be subdivided into two categories: on the one hand, corrective maintenance, also known as run-to-failure or reactive maintenance, and on the other hand, preventive maintenance. Corrective maintenance implies that the maintenance activities start with the detection of a failure. With this strategy, the system or the component will be maintained or even replaced after it breaks. The particular type, timing and extent of necessary repair measures are unknown and cannot be planned. In contrast, preventive maintenance strategy implies that the activities will be done as a precaution in order to avoid any possible failures. Besides this, the preventive maintenance can again be divided into two parts. One part is the time-based maintenance, which means that the maintenance measures will be carried out after a predefined operating hour's interval or after a particular time horizon. It is accepted that the lifetime is usually not completely exploited. The other part is the condition-based maintenance (CBM), which often leverages a condition monitoring system in order to observe different indicators, which can describe the condition of the considered system [12]. Hence, on a theoretical basis, the maintenance program can be planed whenever one or more indicators show that something is going to fail [13]. The basis for the strategy is that 99% of all failures are announced through measurable indicators [14].

An advancement of the main strategies is reliability centered, risk based and total productive maintenance. It should be mentioned that there are several more derivatives, which generally exist in order to address particular requirements of the overall systems [15]. The reliability centered maintenance concept focuses on cost-efficiency