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An approach for the integration of anticipative maintenance strategies within a production planning and control model

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Abstract

Current production planning and control systems of manufacturing companies do not include future-oriented maintenance strategies that allow the precise prediction of maintenance tasks. This results in inefficient production processes due to unforeseeable machine downtimes, fluctuating lead times and a high number of rush orders. An approach for the integration of anticipative maintenance strategies within a production planning and control model is developed in order to increase the flexibility and quality of production planning. Based on an anticipative maintenance strategy, the model derives measures for minimizing the overall production costs as well as maintenance related costs over a finite planning horizon.

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Keywords: Maintenance;Production planning and control; Predictive model; Integrated planning models

1. Introduction

Today's companies face the challenge to model their production processes flexible, versatile and customer oriented, in order to stay competitive. This leads to challenges, like the increasing of facility complexity, decreasing of lead time, higher variance of production and assembly processes, rising claims regarding quality as well as cost pressure [1]. Especially the decrease of lead times causes an increasing of capacity and flexibility demands in production [2]. Beside the quality of products, customers begin to perceive logistics performance measures, like the adherence of delivery dates or lead time, as a criterion for decision making. 67% of enterprises prioritize lead time already as the most important target dimension [3].

Even though the strong interaction between production planning and control (PPC), maintenance and quality management is scientifically proven [4,5] and its influence on the above described challenges is undisputed, current planning processes are conducted without a holistic approach that considers all three areas. This results in non-aligned maintenance and production plans. Wrongly picked maintenance dates influence the productivity of a production system significantly. An ideal trade-off between maintenance- and production related costs cannot be found. Beside choosing inefficient moments for planned maintenance measures, short-term changes of during the production processes represent main reasons for turbulences on the shopfloor. As an example, the average planning reliability of SMUs specialized on mechanical engineering, averages 25% after only three days [6]. A big stake of those changes result from unplanned facility downtimes, which restrict the demanded flexibility of a production system significantly. Hence delays emerge which are difficult to compensate and cause additional costs (e.g. due to bad product quality or avoidable overtime)

Furthermore, the ability of employees, to act and react on those unexpected occurrences, is often limited. Decision-making that is not based on a reliable data basis leads to uncoordinated manual interventions and therefore inefficiencies, undefined and not manageable processes.

The depicted difficulties on the shopfloor-level (Fig. 1) lead to an increase of urgent orders and high deviations in

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lead time. If the quantity of urgent orders increases by 35%, the processing time of normal orders, rises up to 40%, depending on the stock level [7].

In the long term, a significant decline in delivery dates is the consequence. An often-used approach is to compensate this effect with earlier order releases. However, this kind of countermeasure leads to a rising stock level, an overstressing of resource capacities and an increasing of lead-time due to longer queues in front of machines. The internal dynamic increases and the effect amplifies additionally. The trend of declining delivery dates, is hence not stopped, but contrary enhanced. The production performance is declining exponentially [8].

2. State-of-the-Art on integrated planning models

The overall performance of a production system depends significantly on effective planning and process design on the shop floor-level [5,9].The essentially influencing factors on among others are production planning and control, maintenance and quality management. Many literature sources prove the strong interaction of these disciplines with regard to productivity, product quality and aggregated costs of a production system [10].

During the past years different problem-solving approaches were developed, which aim to support production planning and control in terms of various target values. Hadidi et al. distinguishes currently existing models in two groups [11]:

1) Interacting models: These models aim on optimization of a defined function under the consideration of other functions. The requirements of other functions constitute restrictions for the model.
2) Integrated models (Fig. 2): These models aim on the optimization of two or even more elements at the same time.

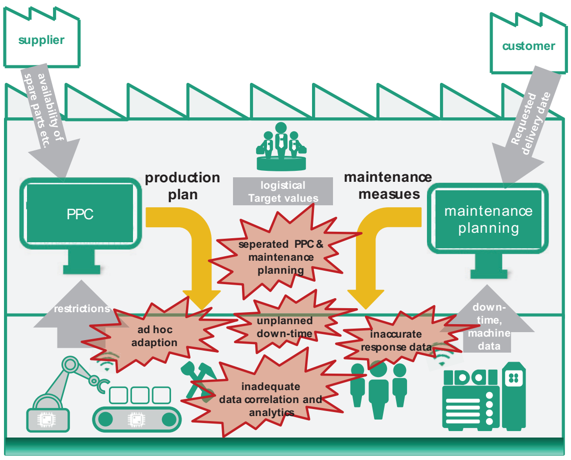

Fig. 1. Current difficulties caused by a lack of integrated PPC & maintenance planning.

Fig. 2. Interaction of relevant functions to plan and control production.

2.1 Interacting models in area I (production planning and maintenance)

Zhou et al. present a dynamic-opportunistic maintenance model for a multi-component system, were the maintenance planning is able to react on short-term changes in production order sequences. Short-term alterations in the production schedule are inevitable due to market fluctuations and can therefore lead to prioritization or deferring, of preventive maintenance operations. The components of the system interact respectively support each other, with the result that a preventive maintenance operation causes a shutdown of the whole system. Once this condition occurs, the model will suggest additional necessary maintenance operations on the system, to guarantee that the opportunity costs, caused by maintenance operations, are as low as possible [12].

Aghezzaf et al. attend to solve the problem of incomplete maintenance operations by using a non-linear mixed-integral optimization model. Therefore, a single machine, on which corrective and preventive maintenance operations are carried out, is observed. It is assumed, that the condition of the machine is stochastically determinable and hence the number of necessary maintenance operations within a planning period, can be calculated based on the system's age. The model considers the number of necessary maintenance operations as well as the condition of the machine in terms of the system's reliability, as additional restrictions in production planning and control. Furthermore Aghezzaf et al. provide a tool to measure the performance of this heuristic approach. This is especially interesting for an integration into an ERP system of a company [10].

Wong et al. contemplate a production process with heterogeneous machines, which place distinct requirements on maintenance operations: The machines demand different maintenance measures, which cause diverse downtime. Furthermore, the chronology between measures varies from machine to machine. With the aid of a genetic algorithm, this difficulty is depicted and the cycle-time is minimized. The model assumes that maintenance operations are "perfect", which means that the condition of the machine is set "new" after a conducted maintenance measure [13].

Xiao et al. draft an optimization model, which particularly focuses on the difficulties of interlinked facilities: If a facility is down due to a preventive maintenance operation, the whole