Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 57 (2016) 247 – 252

www.elsevier.com/locate/procedia

49th CIRP Conference on Manufacturing Systems (CIRP-CMS 2016)

Situation-based Methodology for Planning the Commissioning of Special Machinery using Bayesian Networks

Sebastian Poeschl [a] *, Frank Wirth [b], Thomas Bauernhansl [c,d]

[a]*Graduate School of Excellence advanced Manufacturing Engineering – GSaME, Nobelstr. 12, 70569 Stuttgart, Germany*
[b]*TRUMPF Lasersystems for Semiconductor Manufacturing GmbH, Johann-Maus-Str. 2, 71254 Ditzingen, Germany*
[c]*Fraunhofer – Institute for Manufacturing Engineering and Automation IPA, Nobelstr. 12, 70569 Stuttgart, Germany*
[d]*Institute for Industrial Manufacturing and Management IFF, University of Stuttgart, Nobelstr. 12, 70569 Stuttgart, Germany*

* Corresponding author. Tel.: +49 (0)7516 303-32905; fax: +49 (0)7156 303-930560. *E-mail address:* sebastian.poeschl@gsame.uni-stuttgart.de

Abstract

In German mechanical engineering customized systems and integration solutions are the biggest trends which are mainly applied in special machinery. This paper shows a method to decrease test and commissioning time by using expert knowledge and by considering the risk of failing processes. In literature and practice there is a wide research on virtual commissioning. However, research on methods to optimize production is very rare for complex machinery. In the proposed method, for planning and adapting processes, the authors use heuristics because of their ability to optimize processes using expert knowledge. For the decision of the right application of a heuristic, Bayesian Networks are applied to rate and compare different alternatives. Thus, the result is a method which allows to rate the processes with the needed time and the possible risk for an elimination and a substitution of these processes. Using this method the throughput time of a laser system in production in one single commissioning process is decreased in the validation example by approximately three days.

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems

Keywords: Special Machinery; Bayesian Networks; Process Heuristics; Process Optimization

1. Introduction

The trends of customized systems and integration solutions are mainly driven by the customers demand for more complex products [1,2]. Thus, the impact of developing more and more complex products with the known methods is an efficiency loss along the product engineering process [1]. The commissioning time is about 10-25% of the throughput time of the product engineering process [3,4]. It varies because of the differing products and their complexity. Compared to serial production, special machinery requires a high engineering effort. Nevertheless, the adaption and precision of the product at the commissioning processes are not comparable to those of serial products. Consequently, efficiency losses caused by the process complexity, the human influence and the low degree of automation have to be accepted [5,6]. Those effects get more important the higher the complexity of the product is [7,1].

Working with known methods like virtual commissioning, especially with complicated products, the effort to build a model is high [8]. Thus, the efficiency of the product engineering process is affected and there is a potential to increase process efficiency.

The major source of delays in test and commissioning is the error containing definitions of upstream sectors which mainly consists of error handling times and waiting times [3].

Furthermore Fig. 1 shows the shares of processing time compared to the idle and waiting time. The processing time is divided into the planned processing time and the processing time caused by technical incidents. To shorten the processing time, caused by technical incidents, the processes with the highest risks have to be identified and dealt with.

In the next chapter an overview on special machinery, Bayesian Networks, process heuristics and risk assessment is given to describe the basics of the proposed method. Following the state of the art in commissioning in special

Peer-review under responsibility of the scientific committee of the 49th CIRP Conference on Manufacturing Systems
doi:10.1016/j.procir.2016.11.043

machinery and process planning is described. On top of that an approach in process optimization, the virtual commissioning, is explained.

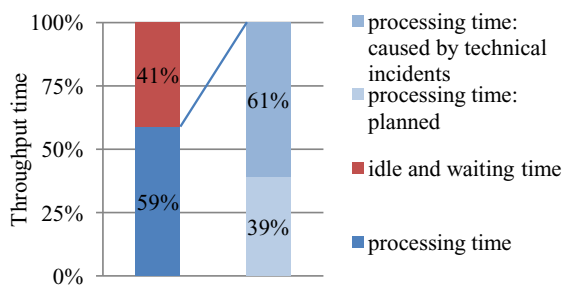

Fig. 1 Throughput time shares of a commissioning process [3]

Concerning the concept of the paper, the authors propose an approach to decrease test and commissioning time by assessing the risk and the duration of processes. To achieve this goal process heuristics to model the process adjustment are described. To combine the process model with the risk analysis and to integrate the existing expert knowledge Bayesian Networks are used.

For validation purposes, the method was applied in an industrial environment. In the evaluation the results of the validation of this case are outlined. Finally a summary, a discussion and an outlook are shown.

2. Basics

The content of this chapter is to summarize the basics which are needed to understand the concept of the production planning in special machinery with Bayesian Networks and process heuristics. Furthermore risk assessment methods are depicted.

2.1. Special Machinery

The field of special machinery can be described as a product engineering process for specialized machines with a high standard. The quantity of the produced parts is very low or even just a single machine is produced. Thus, methods of serial production have a limited application in special machinery [9].

Special Machinery can be found in all industry sectors of mechanical engineering [10]. Consequently, the produced products differ in various ways. Especially the batch size of often just one machine and the individual requirements of the customer show effects on the production and commissioning processes. Therefore, the main focus is on one customer and not on the requirements of a whole market [11]. This property influences the commissioning processes because of the low batch sizes and the missing ability to learn during ramp-up processes.

2.2. Bayesian Networks

Bayesian Networks are directed acyclic graphs which use the Bayes Rule. The prior probability $P(w)$ describes the probability of the event w. $P(w|z)$ is called the posterior probability and $P(z|w)$ is the likelihood of z in case of w [12].

$$P(z|w) = \frac{P(z)P(w|z)}{P(w)} \quad (1)$$

Bayesian Modeling involves mainly two concepts. The first one is to model the probability of certain states. The second one is the utility to calculate the possible outcome. Thus, benefits and costs can be involved into the model [12].

Bayesian Networks are graphical ways to show dependencies between variables in a model and to combine the several calculations of the Bayes Rule [13]. Therefore, they represent a way to create a model in a very wide range of applications. Bayesian Networks focus mainly on decision analysis, risk analysis and failure data analysis [14–18]. The ability to represent conditional dependencies between a set of random variables makes them a tool which can be applied in expert systems [13,19]. Bayesian Networks are able to adapt and model expert knowledge or learn from cases [20,21]. Transition phases show similar properties like the ramp-up phases. The use in transition phases was shown by Nembhard [22]. Thus, the process optimization in special machinery shows a high potential to be supported by Bayesian networks.

2.3. Process Heuristics

Heuristics are defined as a “support and guidance during the search for solution on the basis of heuristic principles” [23]. Heuristic principles are described as the optimization with limited theoretical knowledge and with, compared to other methods, less effort to achieve the goal [24]. Process heuristics are for example the elimination of activities, the combination of activities, the changing of the order of activities, outsourcing of activities, simplification of activities and the parallelization of activities [24]. Consequently, expert knowledge is important for the decision which process heuristics can be applied. The wide application possibilities of heuristics allow the combination with process landscapes to support decision finding.

2.4. Risk assessment

As methods for risk assessment mainly the Fault Tree Analysis (FTA), the Event Tree Analysis (ETA) and the Failure Mode and Effect Analysis (FMEA) are found in practice [25]. All of them are displayed in a tree structure which generates the possibility to rate the failures or risks for example with the indication of the likelihood of occurrence [24].

Those methods do make a causal dependency between events which are not quantified. Thus, the guaranty of a