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ScienceDirect

Procedia CIRP 52 (2016) 262 – 267

www.elsevier.com/locate/procedia

Changeable, Agile, Reconfigurable & Virtual Production

Procedure for defining the system of objectives in the initial phase of an industry 4.0 project focusing on intelligent quality control systems

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Abstract

Industry 4.0 describes the fourth industrial revolution, which leads to an intelligent, connected and decentralized production. A core aspect is a continuous communication between humans, machines and products during the production process enabled by cyber physical production systems (CPPS). The overall aim is to increase cost- and time-efficiency, and improve product quality, which requires a broad understanding of the enabling technologies as well as methods and tools. Within this paper, one production process (spring coiling) with three different involved value adding companies is analyzed to identify quality related production issues that shall be addressed with an intelligent condition monitoring based quality control system. The research addresses both machine related and organizational process analysis. Therefore, a comprehensive descriptive model has been developed to represent the relevant systems, their interfaces, interdependencies and influence parameters. This paper presents the procedure to develop the descriptive model, including other generated documents to define the system of objectives incorporating the technical and the value adding partners' requirements.

Peer-review under responsibility of the scientific committee of the Changeable, Agile, Reconfigurable & Virtual Production Conference 2016

Keywords: Industry 4.0, Quality control system, Condition monitoring, System of objectives

1. Introduction

Industry 4.0 describes the fourth industrial revolution, which leads to an intelligent, connected and decentralized production. A core aspect is a continuous communication between humans, machines and products during the production process enabled by cyber physical production systems (CPPS). The overall aim is to increase cost- and time-efficiency, and improve product quality, which requires a broad understanding of the enabling technologies as well as methods and tools.

Many SMCs - which are small and medium-sized companies with less than 250 employees and a turnover less than 50 million/year - in Germany face difficulties concerning adaption and application of the necessary tools and technologies of Industry 4.0 due to knowledge and organizational barriers. Therefore, there is an increasing need for supporting processes and models. This article focuses on the initial development phase of an intelligent quality control system, incorporating the analysis of the current state of quality control systems and the definition of targets and requirements for the system as well as the project stakeholders. As a primal result of the currently running three-year research project "IQ 4.0 – Introduction of intelligent quality control systems through connected value creation", the authors introduce a procedure including methods and tools that is intended to support the project core team during this initial phase.

2. State of the Art

Industry 4.0 stands for a new level of organization and regulation of a product's entire value chain over its life-cycle [1]. The development of Industry 4.0 comes along with a remarkable increase of performance. Studies show an increase of productivity up to 50 % [2] and more than 80 % of the examined companies that use Industry 4.0 technologies indicate an increase of efficiency [3]. More than 45 % point

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doi:10.1016/j.procir.2016.07.067

out, that the customers' satisfaction is rising and that they experience a decrease of product defects [3]. Due to a rising demand on high quality machines and products, in the next few years about 100.000 new jobs could be provided only in SMCs within Germany [4].

In practice though, the potentials of Industry 4.0 cannot be used by many SMCs because they do not know how to adapt new technology and how to find the right requirements within their company [5]. Furthermore, missing concepts for a connection with extern value adding partners prevent SMCs from using these potentials [6]. Therefore, they face the risk of falling behind the technological progress and losing competitive ability [7].

Currently, there are many concepts describing information layers (FDT, EDD, eCl@ss, IEC 61360 Series/ISO13584-42), communication layers (OPC UA: Basis IEC 62541), realization of functional layers (FDI) and consistent engineering (AutomationML, ProSTEP iViP,) which are helping companies to organize their data and information flow [8]. RAMI4.0 extends these concepts to a reference architecture-model describing lifecycles and value chains [8], but there is still a lack of research results regarding a procedure of current state analysis and definition of targets and requirements within single companies and value adding partners [10].

For an objective and automated evaluation of product and process quality as a basic element of quality control, quality describing conditions have to be monitored with measurement technologies. Often, it is impossible to monitor these conditions directly within the manufacturing-process. That is why measurable indicators have to be identified which allow a conclusion to the quality state [9]. The advantages of quality control using indicators haven't arrived in practice yet. Main reasons are the inevitable adjustments of the sensors to the specific applications as well as the complex selection and application of suitable analyzing methods to create appropriate indicators [11].

Classical database systems can be overstrained if all measured data is saved and forwarded to following levels of a quality monitoring system. In context of Industry 4.0, a decentralized, machine-oriented preprocessing of data is suggested to reduce the data quantity [12]. Big-data-solutions based on sensor raw-data accordingly lead to immense and (in parts) worthless amounts of data that necessitates further invests to the data-infrastructure [13].

The functionality of systems like Manufacturing Execution System (MES), Computer-aided Quality (CAQ), Enterprise-Resource-Planning (ERP) or workflow-systems developed strongly in the past few years. However, these systems neither include an intelligent, decentral decision logic, nor automated process-support by actuators [14]. For reasons of safety and effort, software solutions like Enterprise Application Integration or service-based system architectures haven't arrived in most companies yet, even though they are an important step to increase transparency and productivity by accomplishing a connected adding value. [15]

The increasing use of sensors extends the possibilities of gathering production data [16]. This data plays a decisive role in the context of developing innovative industrial services like predictive maintenance. New services result from the aggregation and intelligent analysis of applied machine- and environmental data [6]. However, at current state this data is hardly used [17]. The development fails at insufficient data exchange between machine manufacturer and machine user. To date, concerns regarding potential attacks to sensible data, loss of data or its misuse prevent a more intense exchange of data [18].

Looking on the before mentioned context of Industry 4.0, a central problem becomes visible: In general, Industry 4.0 solutions afford a comprehensive approach both on technical and on organizational/processual level. Usually, one single manufacturing company cannot establish new solutions due to knowledge and accessibility barriers on either technical or processual level.

In research and practice, a systematic approach for enabling Industry 4.0 solutions for SMCs – comprising manufacturer, machine developer and software supplier – is not known neither from literature nor from application. As a first step, a formalized method for the current state analysis of involved value added partners is needed to define the starting point and target state for a new Industry 4.0 quality control.

3. Method and Approach

The following case serves as an application example for the deduction of the process: A manufacturer of technical springs aims to improve the effectivity (availability, performance and quality) of the production system through intelligent quality control and services. The corresponding machine developer on the other hand aims to establish predictive maintenance services. A secondary target is to improve the future product generations by adapting the machine design to the real load spectrum of the production process. The software developer provides both database, data processing and interfaces to acquire, store and evaluate the sensor data. Figure 1 explains the example use-case in further detail: The quality control system is not only established within one single company, it is regarded as a cooperative process between machine user and producer.

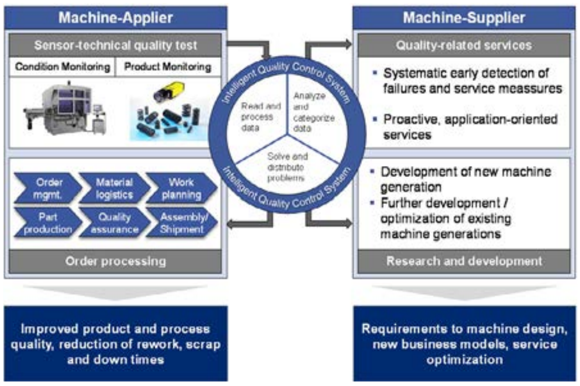

Figure 1: Example use-case with machine applier (manufacturer) and machine supplier

Within the overall project, the example case is just one of three main use cases. Both the methods and the processes for