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Towards intelligent and sustainable production: combining and integrating online predictive maintenance and continuous quality control

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Abstract

The paper addresses intelligent and sustainable production in the sense of combining and integrating online predictive maintenance and continuous quality control. The rationale for combining and integrating them is that continuous quality control can provide input to the online predictive maintenance in cases where no signs of maintenance issues have been indicated and inadequate output is produced (and the process parameters cannot be adjusted in order to meet the output specifications). The paper outlines the first part of an action research effort at Gestamp HardTech AB in Sweden, whose objective is to keep its position as a world-leading provider of press-hardened vehicle parts. The first initial design criteria concerned with simplicity and low-cost was changed after learning more details and what can be accomplished, and the updated first design criteria focused instead on robustness, high-quality output and future-proofing. The intermediary result is an action plan for the technical change, whereas the organizational change will be addressed later during the action research effort.

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1. Introduction

The paper concerns the first phase and part of the second phase, i.e., diagnosing and planning action, of an action research effort at a manufacturing company, Gestamp HardTech AB, which produces advanced and complex press-hardened components for the vehicle industry.

In order to increase competitiveness and economic as well as environmental sustainability, new and innovative ways need to be tried and implemented when successfully verified. However, all such ways do not need to be disruptive but can involve combination and integration of existing concepts that together will create more value than when used separately. This paper concerns two such concepts: online predictive maintenance of production equipment and continuous quality control of production process parameters as well as the output from the production process. **Online predictive maintenance** entails, in this paper, using sensors and other means to online monitor and collect data pertaining to an asset and its operational activities, output and condition. This does not

mean that all collected data are stored; thus, data that are to be used and stored must be actively selected. The data, or rather various parameters, must be modeled in order to find thresholds and relations in between parameters that can be used to indicate potential problems arising (i.e., diagnostics) and maintenance need (i.e., prognostics). Thus, modeling and the analytics, as well as the ability to quickly traverse and mine large amounts of various data, are key. During the analytics, data from other complementary sources such as meta-data, vendor databases or historic data, etc., can be combined and mined together with the data passing by online as well as recent data stored. Subsequently, analytic results derived (e.g., prognostics and asset degradations) need to be presented and visualized adequately in order to support decision-making processes. In addition, in case the analytics reveal signs of immediate failure within the asset monitored, notifications/warnings for reactive maintenance, as well as emergency shutdowns or graceful degradation schemes, can be issued. **Continuous quality control** encompasses, in this paper, online monitoring and collection of production process

parameters as well as measurements of the output from the production process. As in the online predictive maintenance described above, the data or parameters need to be modeled in order to find which ranges, thresholds and relations in between parameters can lead to diagnosis and reveal arising or actual quality problems – which will render output that does not meet the specifications.

The rationale for **combining and integrating** these are that if the online predictive maintenance does not indicate a need for maintenance and the production process parameters look adequate, but the production process output is not adequate, this is an indication that maintenance is needed now or soon (i.e., reactive) if the process cannot be adjusted by changing the production parameters to restore the output quality wanted. Thus, the continuous quality control can be used as an additional indicator for maintenance need, which may also involve a check-up and verification of the monitoring sensors and their function. Further, these two concepts can be integrated into the same data collection/monitoring/analytics platform, as they are both based on using sensor data combined with additional data, which is modeled in order to obtain input for decisions (suitably visualized to be understandable) and to enable warnings/notification as well as potentially automatic shutdowns or graceful degradation schemes in case serious problems occur but are not adequately predicted.

This paper addresses the question as to whether combining and integrating online predictive maintenance and continuous quality control can lead towards intelligent and sustainable production within the manufacturing industry. Further, the purpose is to make senior management teams and R&D managers aware of the potential of this approach and how it can be addressed. In addition, besides providing vehicle components, Gestamp HardTech AB is interested in providing “soft parts” and production equipment (mainly press-hardening equipment) as integrated product-service offerings or as Product-Service Systems (PSS) [1-2] or Functional Products (FP) [3-4]. This paper concerns an important aspect of achieving this.

The paper is organized such that the research approach follows the introduction and related work. This is followed by the result section including an analysis and, finally, the discussion and conclusions section.

2. Related work

There is a lot of existing work pertaining to predictive maintenance and quality control, and an open search using Google Scholar with the search string “predictive maintenance”+“quality control” limiting results to after year 2000 renders approximately 2470 hits. Limiting the same search to results after year 2010 renders approximately 1500 hits, and thus it is hard to assess if all relevant literature has been covered in the literature review. However, Lee et al. [5] posit that for service innovation and smart analytics, within the frame of Industry 4.0, there are 5 issues not yet adequately resolved: *manager and operator interaction* (where the health condition of machine components is missing), *machine fleet* (and gathering information/knowledge about all instances),

product and process quality (feedback loops to the system are required), *Big Data and Cloud* (cloud capabilities required for self-awareness and self-learning machines with adaptive prognostics and health management), and, finally, *sensor and controller network* (where sensor failure/degradation can lead to wrong input to prognostics and, subsequently, incorrect outcome and decisions). This paper attempts to address all five of these issues; however, the last one to a lesser extent. The issues are addressed by outlining a scalable and generalizable online predictive maintenance and continuous quality control approach for production processes and equipment by collecting, modeling and analysing data originating from sensors or other data extractors, and also involving cloud solutions to support decision-making. Other research of interest includes: Cassady et al.’s [6] initial work on predictive maintenance and quality control, Lee et al.’s [7] conceptual work on intelligent prognostic tools and e-Maintenance (including proactive maintenance), Deloux et al.’s [8] outline of a predictive maintenance policy based on combining statistical process control and condition-based maintenance, and Duffuaa et al.’s [9] proposed conceptual simulation model for maintenance systems. The majority of the research listed is conceptual and only some of it is verified in industrial settings. Further, additional work of interest includes Koc et al.’s [10] introduction to e-Manufacturing including intelligent maintenance systems and e-Maintenance, Choudhary et al.’s [11] work on data mining in manufacturing, which includes both maintenance and quality, and Löfstrand et al.’s [12-13] and Reed et al.’s [14-15] work on simulation of maintenance, service and availability. This set of research brings in other areas of concern for predictive maintenance and continuous quality control and, in some cases, the latter are relevant to the other areas as well.

3. Research approach

The research approach employed in this study has been based on an indepth qualitative study using action research with a manufacturing company, Gestamp HardTech AB, located in northern Sweden. However, it would also have been possible to use a spiral model with gradual refinement for the research as well. Gestamp HardTech AB is part of the global Gestamp Group, which produces parts for vehicles and is active in 20 countries with 12 R&D centers, approximately 100 production plants and 32,000 employees. Gestamp HardTech AB has an R&D center, press-hardening tool development and manufacturing, as well as a production plant. The research targeted in this paper is the first phase and part of the second phase, i.e., diagnosing and planning action, of an action research [16] effort where the researchers have had the roles of external expert/consultant and internal expert. A literature review was part of the first phase and its result was used as input to the diagnosis. Action research has been defined as “*a participatory, democratic process concerned with developing practical knowing in the pursuit of worthwhile human purposes, grounded in a participatory worldview which we believe is emerging at this historical moment. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit*”

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