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Industry 4.0: Zero Defect Manufacturing (ZDM)

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Abstract

Industry 4.0 is subset of 'forth industrial revolution' also it is now days known as 'smart manufacturing', 'industrial internet' or 'integrated industry'. This paper seeks to discuss the opportunities of Industry 4.0 in the context of zero defect manufacturing, since the implications are expected in this field. We are pursue the goal to light up the topic which is handled and still need grab more attention towards it on Industry 4.0 in the context of zero defect manufacturing, thus the following research paper approach. It addresses intelligence and sustainable production achieved through combination and integration of online predictive maintenance, monitoring of processes parameters and continuous quality controls of both input materials and output from the process.

***Keywords:** Forth industrial revolution, industrial internet, integrated industry, monitoring of processes, smart manufacturing, zero defect manufacturing*

INTRODUCTION

Most manufacturing and process industry companies want to achieve intelligence and more sustainable production system and thus move towards zero defect manufacturing/or production (ZDM) with related benefits such as: lower cost, lower energy consumption, less scrapped output and material waste, faster lead times and deliveries, increase production status overview and planning ability, production system resilience against problems and issues, and confidence in availability and output quality, etc.

This is way to stay competitive and profitable as well as reliable or trustworthy in the eyes of the costumers, as they in turn have pressed production processes and just in-time schedules.

In the phase of moving towards ZDM, there is may be need of smaller or drastic changes in the todays technologies, investment, partnership, organization, finance, and research and development activities. The ZDM required combination and integration of areas, teams, competencies, skills, data from many sources as well as data analytics, information systems. ZDM in production development needs attention in each process stage. This is a necessity since no one will make defects faster and more rapidly and for finished product with high cost and heavy workload it is crucial to do the work right at first attempt as Crosby refer to in his book "Quality is free", but he also pointed out that to do this right is not necessary cheap.

The paper addresses the combination and integration of following into ZDM approach:

- Data storage and analytics
- Re-scheduling of production
- Monitoring of process parameters
- Online predictive maintenance
- Re-configuration and re-organization of production

RELATED WORK

There is lot of existing work related to intelligent and sustainable manufacturing/production system, circular economy, predictive maintenance and quality control, zero defect manufacturing/production, etc. We consider ZDM is a part which is struggling towards industrial 4.0 and in particular through the combination and integration of many types of systems where information and knowledge flows from top to low level system and vice-versa. The advantages from ZDM are also considered with once in an ideal industry 4.0 scenario.

Concerning zero-defect manufacturing or production, Wang provides ideas about how to use product, equipment and process data in a data mining framework used to improve knowledge finding and quality of products [1]. Further, Myklebust outlines a product and plant-oriented approach with use of real-time data and knowledge feedback loops to achieve near zero defect level [2]. In addition, Teti [3] brings up signal processing and decision-making, Di Foggia and D'Addona [4] consider the need to identify critical key parameters and Ferretti et al., [5] discuss use of monitoring systems for raw materials/input, in-process and output measurements. The research brings up relevant aspects of ZDM, which according to above have been brought together into a comprehensive approach.(Fig.1).

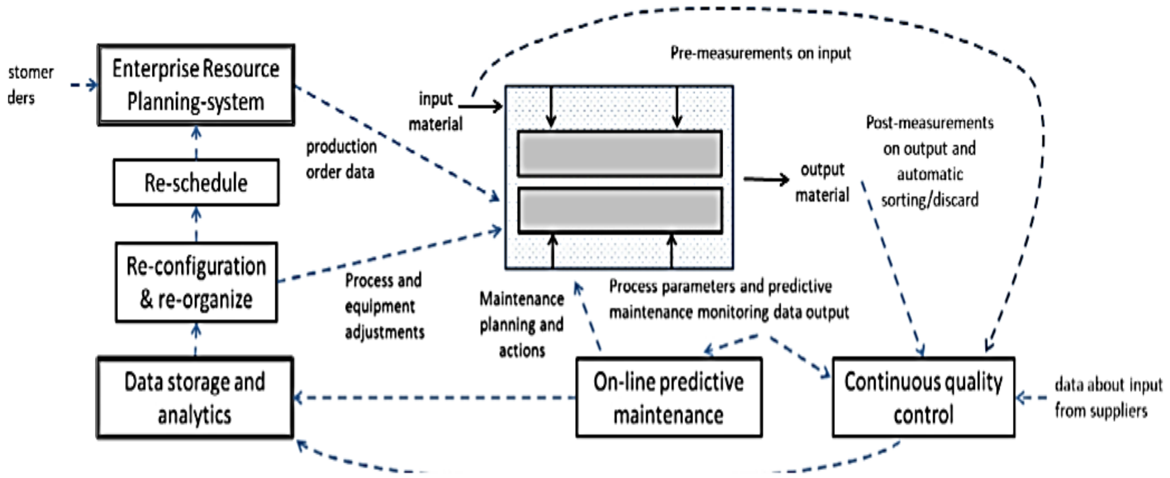

Figure 1: *ZDM approach starting to be applied at press-hardening.*

In terms of more general ZDM and Industry 4.0 challenges, for instance, Lindstorm et al.[6] assert for Industry 4.0 with service innovation/smart analytics that there are five areas not yet adequately resolved: manager and operator interaction (health condition of machine components is missing in decisions made), machine fleet (gathering information and knowledge about common design issues and errors for various contexts of use in order to find any systematic or context specific issues), product and process quality (feedback loops to the system are needed), Big Data and Cloud (cloud capabilities needed for self-awareness and self-learning machines with adaptive prognostics and health management), and, finally, sensor and controller networks (where, for instance, sensor failure and degradation can provide wrong input to prognostics and, subsequently, incorrect outcome and decisions).

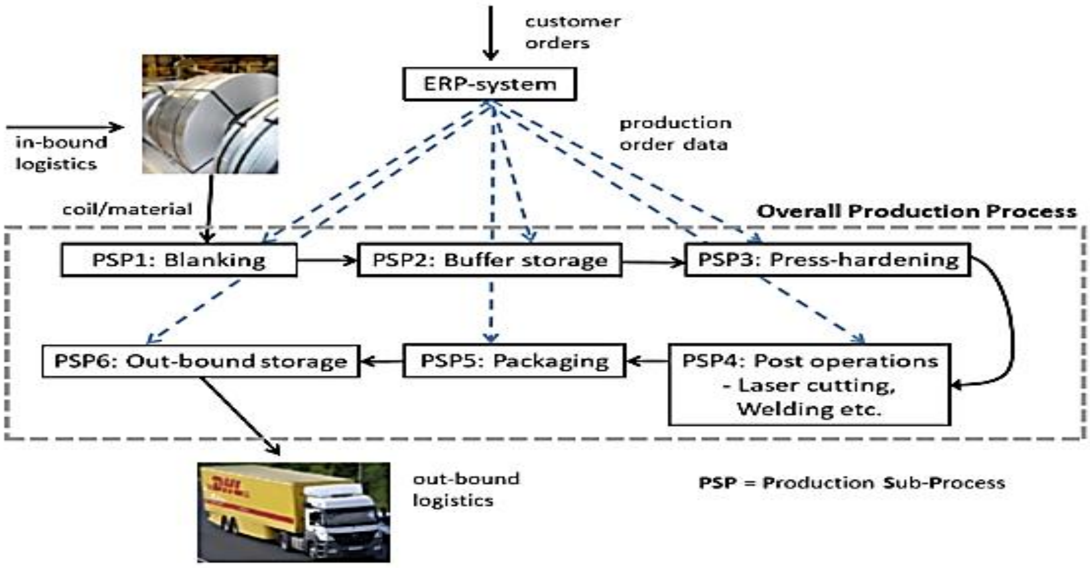

Figure 2: *Overall production process and its sub-processes.*

In Fig. 2, the ERP-system sends production order data to all sub-processes based on customer orders. During the second cycle, the focus has been on the press-hardening sub-process and how it can be improved further. The output from the first cycle, and thus the input to this cycle was, after a number of research efforts targeting various parts of the press-hardening sub-process, an improved understanding of what is required to move towards ZDM. Thus, the following ZDM approach was developed (see Fig. 1) based on those first cycle findings.

Approach Work

The approach, which is applied in a manufacturing context at the production sub-process, will be further described here below. The approach has the following main pillars:

- Monitoring of process parameters
- Collaborative manufacturing
- Continuous quality control; Measurement of input (materials) to the process (with potential discard); Measurement of output (part or product) from the process with automatic sorting and discard.
- On-line predictive maintenance
- Data storage and analytics
- Re-configuration and re-organization of production
- Re-scheduling of production

Below, each of the pillars is outlined in greater detail:

Monitoring of Process Parameters

The process is monitored using sensors and other data extracted from the production equipment and process control in order to ensure the process quality level. If the output from the process is outside of wanted specifications, a change in parameters can rectify the problem and allow manufacturing to continue uninterrupted.

Collaborative Manufacturing

Sharing of manufacturing data without media breaks along the supply chain.

Continuous Quality Control

Firstly, the input should be measured in order to verify that it meets specifications; otherwise, it should directly be discarded and taken off the manufacturing line to avoid costs without any revenue.

On-line Predictive Maintenance

Data is collected by monitoring the production equipment using sensors and other types of data extractors. The aim is to find early signs of maintenance needs or the need for replacements, etc. The use of prediction allows for planning of most maintenance actions and purchase of spares or larger components in a timely manner, thus avoiding unplanned stops, as maintenance should be done during planned maintenance stops to keep the production pace up and avoid delivery problems.

Data Storage and Analytics

In order to get control of the data and common analytics, storage and analytics need to be crafted and kept updated. Some of the data storage and analytics will be done within, for instance, the on-line predictive maintenance and continuous quality control parts, but an aggregated view and central point for distribution of the decision-making information is desirable. This also makes it easier to assess or calculate the confidence levels, etc. pertaining to the decision-making information due to the knowledge and meta-data about the collected data and which analytic methods are applied.

Re-configuration and Re-organization of Production

As mentioned above, re-configuration of the process could solve issues related to, for instance, input variations or certain output issues. If there are issues with the equipment, some of these problems can also be temporarily managed by reconfiguring process parameters until a scheduled maintenance occurs (avoiding an unplanned stop). In some cases, if problems are detected, a re-organizing of the process and equipment can help to temporarily solve the problem until it can be properly fixed.

Re-scheduling of Production

In case problems arise and it is not possible to continue with the current output/schedule, it is essential to know whether other output can still be manufactured without a maintenance stop or simply by retooling, etc. This requires that the lead times for change of order and tools, etc. are not too long. This, in combination with reconfiguration and re-scheduling, will enhance the robustness of production processes with input uncertainty as well as dynamic manufacturing steps (i.e., with process parameters varying) involving, e.g., high pressures and temperatures as well as advanced geometries.

CONCLUSION

This paper makes contribution to literature by outlining the ZDM approach which combines and integrate, monitoring of process parameters, collaborative manufacturing, continuous quality control, data storage and analytics and re-configuration or re-scheduling of manufacturing/production. The paper contributes to practice by providing sets of technical changes and additional problems that needs to be addressed in order to achieve ZDM.

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