CIRP Journal of Manufacturing Science and Technology xxx (2018) xxx–xxx

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

journal homepage: www.elsevier.com/locate/cirpj

On the future of ramp-up management

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ARTICLE INFO

Article history:
Available online xxx

Keywords:
Agility
Big data
Industrie 4.0
Internet of things
Paradigm shift
Ramp-up management

ABSTRACT

The aim of this paper is to present research hypotheses and practical implications on developing a novel ramp-up management approach facing recent challenges and trends in the field of agile production. Applying a mixed-method design based on a quantitative pre-study with 67 researchers and qualitative interviews with seven practitioners in ramp-up-relevant fields showed a consensus on the continuing importance of human factors for future ramp-up management. For managing ramp-up phases, real-time data infrastructure is central to support the learning and decision making process and thus to increase ramp-up agility. Along with this requirement, organizations are expected to have flatter hierarchical structures and be able to extend their product portfolio by implementing new technologies such as additive manufacturing.

Introduction

Nowadays, production industry faces several major challenges. Some of these have risen recently; others have been an issue for some time but intensified lately. First, globalization is still an important challenge for production industry as it offers both cheap production capabilities and new markets [1]. However, in the 20th century globalization has also resulted in a worldwide imbalance of production and consumption that has led to many social and economic unrests [2]. Then again, global competition has also intensified due to the rise of new competitors from emerging economies like China, India or Brazil [3]. This increased competition results in a strong focus on innovation within production industry [4] as, for example, China transforms its industry from parts manufacturing to value creation based on its national strategy since 2010. Second, customer individualization challenges production industry and its product development and production capabilities [5]. Therefore, companies raised their product variety in order to offer highly individualized products requested by their customers and capable to win the market competition [6]. Third, especially in developed countries the population is ageing, as life expectancy rises and birth rates decline [7]. Thus, companies are challenged to address the issue of an older workforce and changing societal needs [8].

These global challenges dramatically influence product development and production ramp-up as the fundamentals of how, what and when to develop or ramp-up new products are affected. Companies face a new situation of permanent multi-product developments and ramp-ups as they offer more individualized products, with more variants in less time [9]. This parallelization offers potential learning opportunities as ramp-up traditionally was a rare process but also increases complexity within ramp-ups [10]. As the whole production industry struggles to cope with these new challenges applying traditional methods, procedures and work concepts, several trends regarding how companies try to tackle them can be identified.

First, Industrie 4.0 is considered as one of these trends as it has a huge impact on future production industry [5]. Industrie 4.0 is a paradigm shift of the future economy: it describes the transformation of industries by the internet of things, data and services connecting people, objects and systems [11]. The Boston Consulting Group (BCG) provides a broader definition, describing Industrie 4.0 as a transformation process of production industry based on nine different technologies namely big data and analytics, autonomous robots, industrial internet of things, additive manufacturing, simulation, system integration, cloud services,

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https://doi.org/10.1016/j.cirpj.2018.03.001
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cybersecurity and augmented reality [12]. Based on this definition several technologies closely related to ramp-up management are introduced in detail.

Big data and analytics are often seen as the main enabler for Industrie 4.0 and several of its basing technologies (e.g., autonomous robots or augmented reality) specifically through the possibility to collect, analyze and use big data with a massive decrease of the required infrastructure's costs [13]. In relation to ramp-up management, big data and analytics are expected to offer several advantages. On the one hand, it is expected to improve productivity, e.g. in the field of mass customization [14]. Moreover, big data facilitates ramp-up activities induced by continuously discovering, developing, producing and delivering product features that are specifically tailored to individual users in agile product development and production processes [14]. On the other hand, big data allows for new product development and delivery approaches such as the "smart targeted customization" (STC) taking advantage of the close-loop integration of consumption, distribution and production big data in Industrie 4.0. This enables a product development deriving a better caption of customer needs reducing complexity and change management during ramp-up dramatically.

The integration of autonomous robots into production processes is another technology facilitating Industrie 4.0 although autonomous systems have existed for decades in production industry [15]. As automation technology advances, additional process steps can be automated offering opportunities for self-automated machines and factories. This improves both production productivity (to cope with competition) and integration of an older workforce (to cope with demographic changes) within ramp-up and series production [15].

3D-printing is a third promising technology to address various challenges within the context of Industrie 4.0 [16]. 3D-printing describes the production of goods based on a CAD model through additive manufacturing [17]. As a technology, it enables fast prototyping in product development and ramp-up. For customers a personal 3D-printer offers the possibility to print products individually at home diminishing the need for traditional manufacturing completely [16]. However, additive manufacturing is currently limited to a small range of materials and applications. Therefore, the replacement of traditional ramp-up through 3D-printing is not expected in the near future.

Overall, in relation to ramp-up as the connecting phase between product development and series production, Industrie 4.0 shows tremendous effects. Important examples might be the integration of automated (self-) learning systems into ramp-up management, of software ramp-up and digitalization into physical ramp-up, or of 3D-printing steps into prototyping.

Second, agility concepts for ramp-up as well as product development are considered as another trend to cope with the challenges in production industry. Agility concepts were originally introduced for software development and are based on the Agile Manifesto [18]. The Agile Manifesto consists of four basic principles [19] which result in several agile methods applied e.g. scrum or feature-driven development that have been transferred to physical product development and ramp-up recently [20]. Although primarily focusing on product development, agile principles are expected to enhance customer integration and prototyping and thus, reducing complexity within ramp-up management.

As stated before, global challenges and trends induce radical changes in ramp-up and its management. However, models from traditional research are incapable of dealing with these changes as the fundamentals of ramp-up management are quickly evolving. This results in a need for new approaches in order to better support ramp-up management in the future.

Whereas quite some literature deals with vast challenges of traditional ramp-up management (see Refs. [21,22,10] for reviews), research on the future of ramp-up management dealing with the integration and adaption of global trends like Industrie 4.0 or agility concepts is still scarce.

Against this background, the aim of this article is to derive research hypotheses and future directions on the development of novel ramp-up management approaches incorporating global challenges and trends. To achieve this objective a two-staged mixed research method is applied. It combines a quantitative pre-study with qualitative interviews to gain insights into the reasoning and mindsets of future trends in the context of ramp-up management.

The remainder of this article is structured as follows. Section "Theoretical background on ramp-up management" provides a common theoretical basis on ramp-up management, its traditional phases and challenges. Data and research method used in our research are presented in Section "Research data and methods" followed by results of the case study and expert interviews in Section "Results". In Section "Discussion" the combined results are discussed, their implications for future research and practice are derived and the study's limitations are outlined.

Theoretical background on ramp-up management

In literature, ramp-up is described as a value-creation phase starting with the completion of both product and process design and ending with the achievement of the full production capacity of the production system at the point of transition to series production [23]. Beyond that, the term ramp-up management can represent a wider understanding to include all activities and measures necessary for planning, controlling and executing the ramp-up in the corresponding production system. This also covers upstream and downstream processes necessary for ensuring an adequate product and process maturity [24]. In this section, different aspects within the field of ramp-up management are dealt with including the process and structural organization, ramp-up curve typologies, ramp-up management models and the target-system with associated conflicts.

Process organization

A major differentiation regarding process organization is found between product- and process-focused perspectives. The former perspective is the most widely spread in literature [25–30]. On the product side, ramp-up is the transition from the development to the production phase [31–33]. It starts with the approval of the pre-series production followed by a so-called *'zero series production'*. Pre-series production is characterized as the first production of a larger number of prototypes [34]. The pre-series is mainly used for teaching the employees new processes [35]. Furthermore, last errors occurring on both product and production side are intended to be identified and solved here [36]. The zero series is the first production phase under serial conditions, usually performing only a small output quantity. After pre-series and zero series, the start of production (SOP) is reached. Here, the regular production of final products for sale is launched and the production volume is scaled up [37]. Reaching the maximum productivity of the system marks the end of the ramp-up and is followed by regular production [34,30].

From a process-focused view, the ramp-up phase includes the final phases of the realization phase and the first steps of the use phase. It is primary defined by the commissioning and ramp-up of the production system: after plant planning, production and assembly of the individual system, the ramp-up phase starts with

Please cite this article in press as: R. Schmitt, et al., On the future of ramp-up management, NULL (2018), https://doi.org/10.1016/j.cirpj.2018.03.001