CIRP Journal of Manufacturing Science and Technology 10 (2015) 1–15

Contents lists available at ScienceDirect

CIRP Journal of Manufacturing Science and Technology

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

Review

Complexity-oriented ramp-up of assembly systems

Günther Schuh, Thomas Gartzen *, Johannes Wagner

Production Engineering, Laboratory for Machine Tools and Production Engineering (WZL) of RWTH Aachen University, Steinbachstr. 19, D-52074 Aachen, NRW, Germany

ARTICLE INFO

Article history:
Available online 26 June 2015

Keywords:
Ramp-up management
Complexity management
Assembly systems
Discreet migration
Production management

ABSTRACT

Challenges in assembly system ramp-up include singularity of each assembly system, high complexity and resulting instable system behavior, frequently leading to losses. The planning of a dedicatedly staged assembly system ramp-up allows for successful dealing with complexity and thus limits instabilities, as is shown in this paper. It provides a newly-developed assembly system ramp-up approach which addresses key challenges of ramp-up situations and allows for higher migration stability and eventually shorter time-to-volume. Along with the proposed planning methodology, a newly developed ramp-up control method is confirmed by industry experts to contribute to time-to-volume and ramp-up cost reductions. An exemplary case study validates the approach and illustrates practical implications for the manufacturing industry.

Contents

Introduction . . . 1
Challenges in assembly system ramp-up . . . 2
  Singularity of each assembly system ramp-up . . . 2
  Complexity in assembly system ramp-up . . . 2
  Instable system behavior during ramp-up . . . 2
Research methodology . . . 2
New approach for assembly system ramp-up . . . 2
  Characterization of the assembly system . . . 3
  Effect model of complexity drivers and generic ramp-up stages . . . 3
  Choice of ramp-up measures and planning of migration path . . . 5
  Steering and control of ramp-up . . . 6
Application case . . . 7
Summary and conclusions . . . 14
Acknowledgements . . . 14
References . . . 15

Introduction

Ramp-up in an assembly context must be understood as the launch of a complete assembly system in which the assembly system is transformed from a state of prototype production to volume production [19]. It is characterized as a situation in which unplanned changes, errors and delays frequently occur, posing challenges to the management of a ramp-up [1,17]. At the same time, a fast ramp-up is important to reach a short time-to-volume, a decisive factor for the profitability of any manufacturing company [2,3].

Assembly systems have the objective of assembling products from parts or sub-assemblies. To enable this function, human assembly operators as well as certain forms of tools or machinery are required. Thus, assembly systems are to be considered

* Corresponding author. Tel.: +49 241 8028193.
E-mail addresses: G.Schuh@wzl.rwth-aachen.de (G. Schuh), T.Gartzen@wzl.rwth-aachen.de (T. Gartzen), Jo.Wagner@wzl.rwth-aachen.de (J. Wagner).

http://dx.doi.org/10.1016/j.cirpj.2015.05.007
1755-5817/

'socio-technical systems', because they consist of human and technical elements which interact [4]. As the number of elements and their interrelations, notably in the case of advanced technological products, can grow high, such systems tend to be complicated. Especially in a ramp-up situation, where the system condition changes dramatically over time, an assembly system is perceived as complex [5,6]. Complexity in a manufacturing context has been analyzed and defined mathematically in various publications [7,8]. It can cause overstraining of decision-makers [9], especially in a ramp-up situation due to a lack of stability which expresses itself in unpredictable system behavior. As a consequence, striking gaps between planned and actual ramp-up curves occur and customer requirements cannot be met as desired.

It becomes evident that a systematic approach is required to ensure the stable transfer from prototype production to serial production in order to avoid the aforementioned problems.

Existing ramp-up approaches predominantly focus on the launch of new products, while the production processes and systems are often neglected [5]. The product launch is important and well-researched from a marketing perspective. However, existing approaches are not sufficient when planning the implementation of a complex production system.

A number of challenges need to be met in order to close the gap between theory, which mainly provides product launch approaches, and practice, which requires dedicated ramp-up strategies when it comes to production system ramp-ups.

Challenges in assembly system ramp-up

Singularity of each assembly system ramp-up

Existing ramp-up approaches may fail if they describe a standard procedure regardless of the actual assembly system design and requirements [5]. Since most assembly systems differ in their design and functionalities, a ramp-up approach must take the actual assembly system into consideration.

Complexity in assembly system ramp-up

A large number of researchers have described the assembly system ramp-up as a complex process or even as one of the most complex processes in a manufacturing company [10,11]. At the same time, a plethora of definitions and descriptions of complexity exists [12]. Since the inherent complexity is described as the major challenge during assembly system-ramp ups, a ramp-up approach must assess complexity to adequately deal with it.

Instable system behavior during ramp-up

The ramp-up phase is characterized as instable [18]. While a certain degree of system instability is pivotal to change the system condition [13] and hence enable the increasing production output per time unit, the instability often overstrains the capabilities of the assembly system staff and management, leading to short-falls of the target achievement. A successful ramp-up approach should therefore ensure a largely stable, controlled ramp-up [5].

A literature review shows that until now, no assembly system ramp-up approach exists which meets all the described challenges. Thus, a research motivation exists to design a new approach ensuring a complexity-oriented, stable assembly system ramp-up. The initial research idea here is a deliberate staging of the assembly system ramp-up by means of discreet migration stages to limit the instability at any point of time to an amount which the ramp-up team is still able to successfully cope with.

Research methodology

As a methodological framework for the design of the new ramp-up approach, the explorative research methodology according to Tomczak [14] was chosen. This approach considers research to be an iterative learning process with a tentative heuristic reference framework as a starting point. The heuristic framework bases on the previous knowledge of the researchers from manufacturing industry consulting projects and previous research activities. In the course of research, existing literature in the fields of ramp-up management, complexity management and systems theory was analyzed. Additionally, empirical social research methods were applied and the continuous interaction with industry experts and fellow researchers in a university graduate training program allowed for a critical reflection and sophistication of the heuristic framework that poses the scientific backbone of the new approach. Finally, the new approach was validated in an exemplary application case in the manufacturing industry.

New approach for assembly system ramp-up

Following, the new approach for assembly system ramp-up is presented in form of a user-oriented overview over the steps of the approach, as Fig. 1 illustrates. The single steps and the scientific models behind them will then be demonstrated in more detail in the Characterization of the assembly system, Effect model of complexity drivers and generic ramp-up stages, Choice of ramp-up measures and planning of migration path, Steering and control of ramp-up sections. An exemplary case study follows in the Application case section.

As a starting point for the planning of the ramp-up, the assembly system to be implemented is analyzed in detail in order to fully consider the singularity of the assembly system (section Characterization of the assembly system). The factors which may create high complexity during ramp-up ('complexity drivers') are studied along the following dimensions: product, process, network and organization. Equally, the 'complexity enablers', the skills and resources which allow a company to deal with the complexity posed by a ramp-up situation, are analyzed with a focus on the organization and the personnel.

A well-researched phenomenon in ramp-up theory is that in different phases of an assembly system ramp-up, the targets and focus of attention differ as well [15]. Generic ramp-up phases include a first, product quality-oriented phase, a second phase, in which the output quantity is increased and a third and final phase, in which cost-efficiency is the goal. The aforementioned complexity drivers were assigned to the three ramp-up phases based on an original empirical study in Germany and Austria. According to the criticality of the complexity drivers for a specific company and ramp-up situation, the most critical complexity drivers are prioritized in each phase (section Effect model of complexity drivers and generic ramp-up stages).

At this point, the specific complexity drivers of the ramp-up to be managed are known. These are supposed to be the source of potential instability and consequent assembly disruptions during ramp-up. As increasing the stability of the ramp-up is the declared goal of this piece of research, actual measures to reach this goal must be defined. The new approach provides a catalogue of ramp-up measures based on an extensive literature review and discussions with industry experts. A comparison of the complexity drivers and complexity enablers reveals capability gaps to then choose the most adequate ramp-up measures (section Choice of ramp-up measures and planning of migration path). These constitute the 'migration basis'. Starting from the migration basis, the planning of the ramp-up in form of a discreet migration path is enabled.