Development of a Methodology to assess the Capability of Production Ramp-up

Christian Krüger, Tim Klemke, Michael Heins and Peter Nyhuis

Abstract— Due to shorter product life cycles combined with an increasing product variety in the future, companies are increasingly being faced with the challenge of a manufacturing ramp-up. To perform this efficiently and effectively, it is crucial for companies to possess knowledge about the capacity of their manufacturing ramp-up. As a holistic approach to reactive and proactive capacity of manufacturing ramp-up is missing from the literature, at the Institute of Production Systems and Logistics, Leibniz University of Hanover, a research project is planned in which the desired holistic approach is to be developed. In the following article, the planned development of methodology for assessing the capability of manufacturing ramp-up is presented.

***Index Terms*— Maturity model, production management, production system, ramp-up management.**

I. Introduction

The environment in which companies operate has changed dramatically in recent years. New technologies and new products are being developed at shorter time intervals, which will be subsequently offered in the global market. As a result, products on the market become obsolete at a quicker rate and need to be replaced by newly developed products. Thus product life cycles shorten increasingly, as reflected in the increasing number of manufacturing ramp-ups being carried out. Another aspect is the diversification of customer demand and the associated increase in product variations that must be integrated as part of a ramp-up in a production system.

The start-up management is thus a key to future success in the market-operated businesses [1], [2], [3]. The term "ramp-up" in this context is understood to be the transition from product development to a mass production process [4]. In particular small and medium enterprises (SMEs) are often faced with the challenge of not having enough ramp-up experience, competencies and strategies. Overcoming ramp-up in the case of small and medium enterprises is therefore often associated with an increased effort. To conserve existing resources and thus to remain competitive, it is important particularly for SMEs to plan ramp-ups successfully. For these reasons, it is important for companies to have knowledge relating to the initial capacity of its production systems. It describes how to manage the property, production start-up in terms of quantities, delivery dates and costs. Only by knowing the initial capacity can companies plan ramp-ups in a target-oriented manner and attempt to derive measures for its improvement.

Systematic descriptions of the necessary characteristics of a production system as well as integrated models for their planning, evaluation and configuration as a link in a supply chain are not available so far. There are only individual tests, which are suitable for identification of specific weaknesses in the initial planning [4], [5], [6]. An assessment of responsiveness to unexpected problems - a necessary consequence of the hitherto unknown large number of parameters on the ramp-up – is so far insufficient. Several approaches are available though, but their focus is not on the necessary holistic, proactive identification and evaluation ramp-up-prompting properties of a production system, but only on partial areas [7], [8], [9], [10], [11].

Therefore, at the Institute of Production Systems and Logistics, at the Leibniz University of Hanover a research project is planned with the aim to develop a methodology by which it is possible to document the existing ramp-up capability of production systems and to develop measures for improving the ramp-up capability. Thereafter, the planned approach to the development of the methodology is presented. For this purpose the foundation in the areas of production planning and ramp-up management are explained initially.

II. Fundamentals

A. Production system

In existing literature there are different illustrations of a production system. In the planned research project for a production system, a definition is used as a basis, developed in the preliminary study „Wandlungsfähige Produktionssysteme“ of the Bundesministeriums für Bildung und Forschung. A production system can therefore be described as a socio-technical system that transforms “input (such as know-how, methods, materials, resources, energy) into added value (such as manufacturing or assembly) and associated processes (e.g. transport) to output (e.g. products, costs, residuals)” [12].

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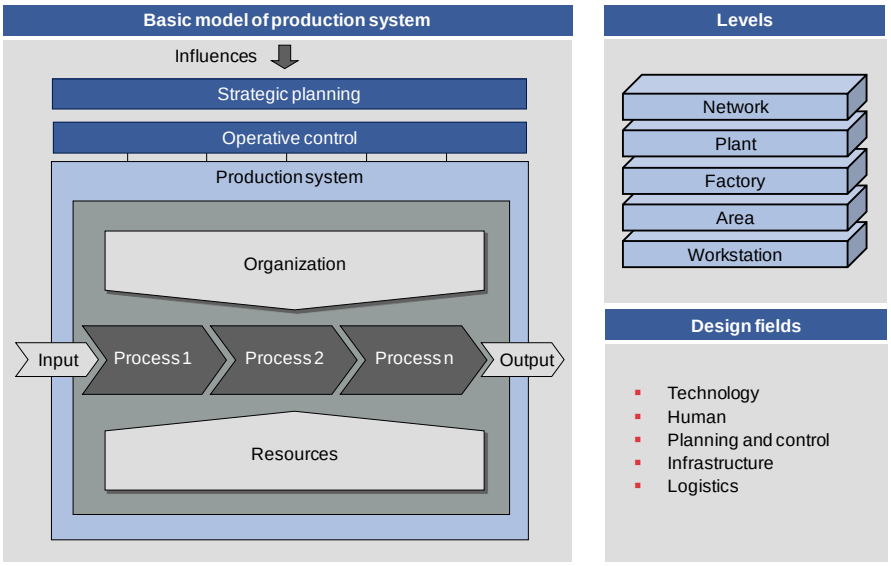

Fig. 1 Production system

By means of long-term, strategic planning and short-term, operative control, the goal to meet a production task in a flexible, cost- and time-optimal use of production factors [13] is targeted. This effect influences, for example, the economic or technical environment to a production system [14], [15]. Fig. 1 shows the basic model of a production system with its associated levels and design fields.

A vertical division of production can be approached via five hierarchical levels. The level of detail increases from top-level network to the levels of plant, factory, area and to the lowest level workstation. A higher level always includes the lower levels [12], [16]. At the highest level network, for example, the relations of the company and its customers and suppliers are considered. The design fields in a production system include technology, the human with its skills and abilities, planning and control, infrastructure and logistics. The basic model described incorporates the essential physical elements of a production system and is thus suitable for the comprehensive description of the ramp-up capability.

B. Ramp-up management

The ramp-up management of a mass product includes “all activities and measures for planning, management and implementation of startup with the related production systems, from the release of the pre-series, up to a planned production, including upstream processes and downstream processes in terms of measurable suitability of the product - and process maturity" [17]. The essential task of ramp-up management is the target-oriented coordination of all necessary tasks, so that the timely and quantity relative availability of parts is guaranteed at the production points. Through effective management, therefore, the lead time can be shorted, costs can be reduced and operations as a whole can be more transparently designed [18], [19], [20]. A common tool for planning the start is the start-up curve, which is affected by the starting dates and volume management. Basic elements of the ramp-up management are for [21] to determine the starting strategy, the choice of process management, personnel or organizational strategy and procurement management.

The assessment of startups is treated in the literature compared to the development of solutions for ramp-up support so far only in a subordinate manner. Ramp-up assessment, is considered to be both the downstream, reactive evaluation of the startup sequence as well as the proactive assessment of the proposed ramp-up with regard to the pursued objectives. In the following some selected approaches are mentioned.

WILDEMANN uses a modified form of the FMEA (Failure Mode and Effects Analysis) that can be used to help examine ramp-ups in advance for their specific risks [10]. ZÄH and MÖLLER place risk assessment as the initial focus of their considerations [11]. This approach is designed to proactively identify risk takers and risk factors to determine the interaction between them and estimate the impact on ramp-up targets.

SCHUH developed a ramp-up tomogram that forms the basis of the ramp-up planning [22]. The tomogram includes the characteristics of the design quantities, equipment and tools, raw materials and purchased parts, direct staff and production processes under the aspects of novelty, availability, robustness, and learns effects as well as workload at specific startup dates. LAICK created a reference object and a reference process model for the start-up [23]. Detailing of the objects and application process modules produces a model from which an identification code and target system is derived. LANZA established a process for combined simulation of time-variant quality parameters on production process level and time-varying degrees of availability and performance on resource level [5].

The various approaches have in common that the evaluation of the ramp-up capability of a production system within the meaning of the research so far is not holistic. Only partial aspects of start-management are seen, the focus is not a holistic evaluation of the initial capacity.

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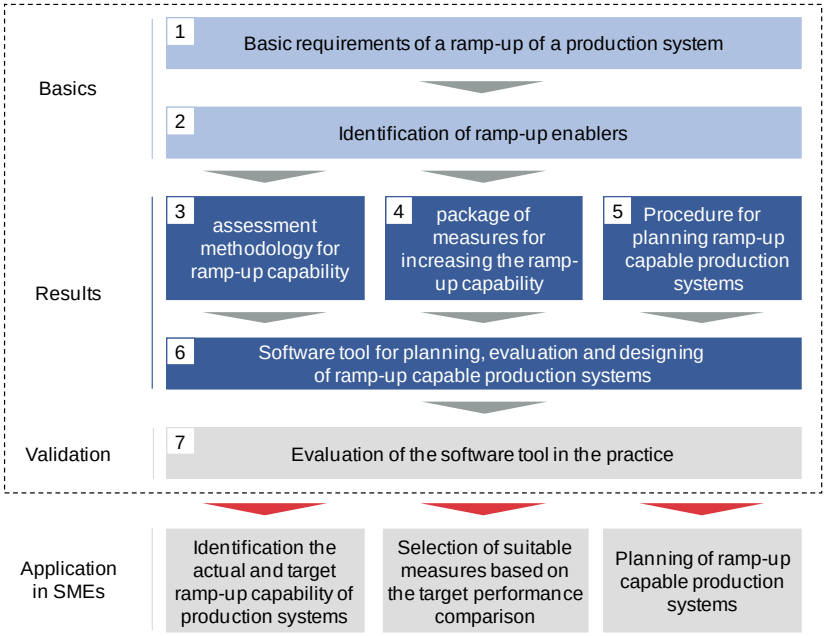

Fig. 2 Project steps

III. OBJECTIVE, PROCEDURE AND CONCLUSIONS OF THE PLANNED RESEARCH PROJECT

The aim of the research project is therefore to develop a methodology, by which SMEs holistically assess the ramp-up capability of their production process both proactively and reactively. In addition, economic solutions to increase the ramp-up capability will be needed to attempt to make ramp-ups in the future more controllable. To achieve this goal, a seven-step comprehensive project approach was developed by the Institute of Production Systems and Logistics, Leibniz University of Hanover, which is to be presented as follows. As a result of the proposed research project, a software tool for planning, evaluation and designing ramp-up capable production systems is expected, which can be applied user friendly for different tasks in SMEs.

The project steps listed in Fig. 2 are processed sequentially, so that the project begins with step one "basic requirements of a ramp-up of a production system" and the project ends after completion of project step seven "evaluation of the software tool in the practice". The results worked out for each project step are included in at least one succeeding step of the project. For example, the results from step two to are included in steps three and four (see Fig. 2).

In the first step of the project, different types of ramp-up situations are included. These may be, for example, a series ramp-up of a new product or the resumption of production under a structural change of the production system. The identified types are then classified according to their essential distinctions. That is, it will address the question of which characteristics (e.g. number of participants, degree of novelty of the product) distinguish the different ramp-up situations. To create the foundations for a successful development of an evaluation methodology for the start of production systems, based in this, requirements are identified the production must meet in order to support the practice-relevant ramp-up types. For this purpose, the production system is considered in terms of levels and design fields as described in Fig. 1.

Step two of the project will be developed based on the identified needs of production ramp-ups at first as a precise, operational definition of the ramp-up capability, which forms later the foundation for the determination of universal properties of production ramp-up capability. With ramp-up capability features the core capabilities and attributes of a production system are named, that promises in its existence, the greatest success in the realization of a ramp-up. Furthermore, generally applicable properties of production ramp-up capability, i.e. the ramp-up promoting characteristics of a production system are identified and their dependence investigated. The identified properties are then clustered to ramp-up enablers.

With the help of a maturity model in step three the ramp-up of production capacity should be made measurable. The origin of this type of model is located in the U.S., where it is related to the use of the term of maturity by the "Capability Maturity Model" (CMM), has gained popularity [24]. The purpose of a maturity model is to be able to determine the deviation from the ideal means of characteristics. With regard to the use in the research project there are two main steps to take for the development of a maturity model. First, all design objects in a production system must be defined. A design object is created here by the comparison of each level and design field of a production system. For example, from the comparison of the level "work station" and the design field "technology" the design object "means of production" results (see Fig. 4). When all design objects of a production system have been identified, a reflection of the design objects to ramp-up enablers from step two ensues, to derive characteristics and scale to rate the ramp-up capability. Thus the design object "means of production" shown in Fig. 4 has among other things, the characteristics "identification of means of production" and "variant flexibility of production resources" and a scale value in percent per feature. The total value of ramp-up capability regarding a design object is then obtained from the average of percentages of individual

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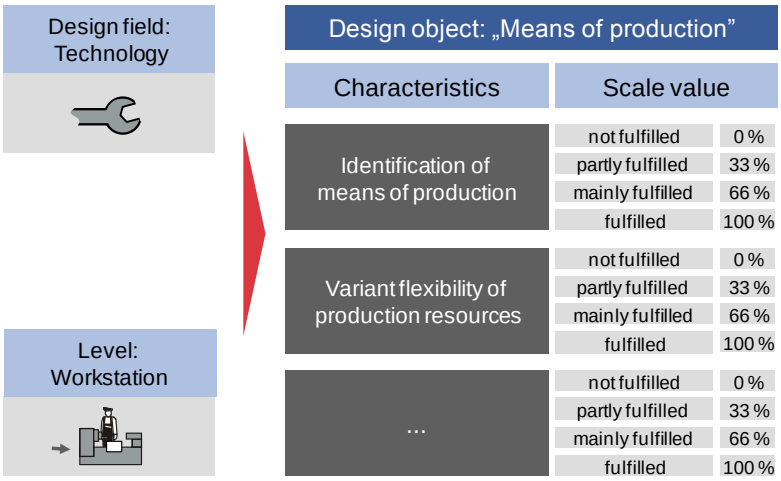

Fig. 3 Design object "means of production"

characteristics. In order to set situation- and strategy-specific target values for the ramp-up capability all design objects, the main types of start-up situations and the basic types of start-up strategies are juxtaposed. Dependencies and interactions between the design objects are taken into account. In this way, overall strategy and situation-specific target values of the initial capacity will be established. The evaluation of the ramp-up capability of production systems should ultimately be made using the maturity model based on four steps (see Fig. 3). These are the "analysis of the production system," the "determination of the actual degree of maturity", the "identification of target-maturity" and the "deductions from action potentials". By means of comparison of the expected and actual values a requirement for action, if necessary for each individual design object is then derived.

In step four a package of measures is developed, showing the general and industry-specific solutions and best-practice examples. From the list of measures, companies can select alternative actions to respond to the detected action potentials (see project step three). Therefore a systematic and standardized method is developed which supports derivation and implementation measures. The method is based on the ramp-up enablers identified in step two. These are compared to the design objects (see step three), for which action requirement during the assessment of ramp-up ability has been identified. Thus, case-specific measures are derived and their interactions using a function analysis are investigated. The measures derived are included in the catalog which is expanded steadily. In the course of the research project developed solutions will be processed and categorized. An extension of the catalog is provided over the life of the project and beyond the end of the project. From the list of measures, companies can select appropriate solutions and ultimately may make modifications to increase its ramp-up capability.

In the fifth step of the project a procedure is to be developed which allows the planning of phase based ramp-up capable production systems. Based on existing factory planning models an explicit listing of the necessary steps regarding the planning of ramp-up capable production systems is to be integrated into a planning procedure. For this purpose it is planned to go through three stages. At the beginning there is a summary and categorization of the ramp-up ability characteristics of the design objects from step three and measures from step four. As an intermediate result is then a comprehensive collection of ramp-up capability relevant features and the derived measures. In step two these are assigned to the stages of factory planning. They are recorded in that phase, in which first information is required for the design of objects in the planning. In the last section, planning content will be assigned to other necessary information. It is described, e.g. which input is required for the planning of specific objects and which output is generated.

In step six, the developed evaluation methodology, the planning of measures and planning procedure are incorporated in a software tool. The tool should have a clear and concise structure to ensure the necessary user-friendliness.

Finally, in step seven both the developed methods and the developed software tool are to be evaluated using case studies and interviews at short intervals with several project

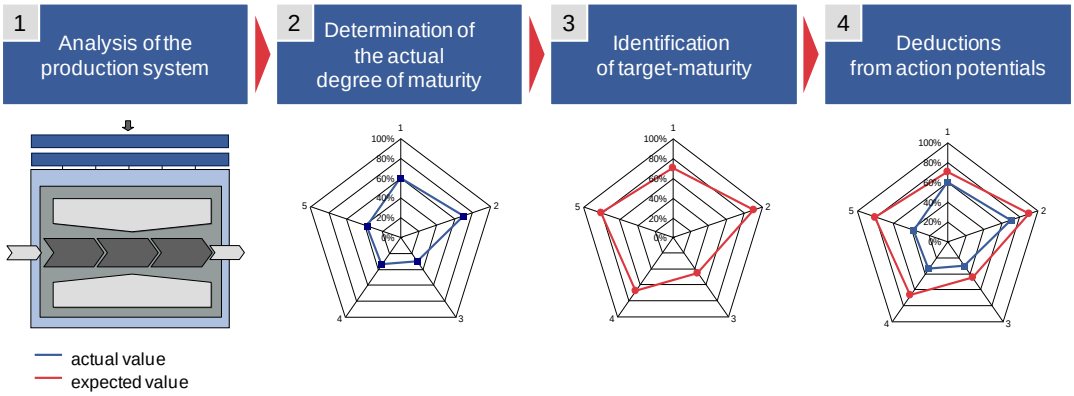

Fig. 4 Methodology to assess the capability of production ramp-up

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participants, mostly SMEs. Here the applicability is tested using various starting situations. This means that the ramp-up capacity of production is assessed both in the course of a ramp-up as well as, e.g. at re-start due to conversions. Thus, the change in the ramp-up capacity due to accordingly introduced adjustment is reviewed.

IV. Summary and Conclusion

Due to an increased number of product variants and shorter product life cycles, companies need to integrate an ever wider variety of products in shorter intervals, in their production systems. Consequently, the importance of production ramp-ups increases and the ramp-up management is today a key competency of manufacturing companies in order to be successful on the market. To plan ramp-ups successfully, it is important for companies to possess knowledge about the ramp-up capability of their production systems. As existing approaches do not yet allow comprehensive evaluation of ramp-up capability of production systems, at the Institute of Production Systems and Logistics, Leibniz University of Hanover, a procedure has been developed, with the aim to develop a methodology for precisely this form of assessment. Upon completion of the planned research, therefore, a methodology for the holistic assessment of the ramp-up of production systems is expected.

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