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Assessing and Improving Ramp-Up Capability

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Abstract**—**In times when product life cycles are decreasing, while market demands are increasing, manufacturing enterprises are confronted with the challenge of more frequent and more complex ramp-ups. Thus it becomes obvious that ramp-up management is going to be a topic enterprises have to focus on in the future. Since each ramp-up is unique concerning the product, the process, the technology, the circumstances and the coaction of these four factors, the knowledge of the ramp-up situation and the current ramp-up capability of the enterprise are fundamental requirements for the subsequent improvement of the ramp-up capability of the production system.

In this article a methodology is going to be presented which can be used to define typical production ramp-up situations, to identify the current ramp-up capability of a production system and to improve it with respect to a specific situation. Additionally there will be a description of the functionality of a software-tool developed based on this methodology.

Keywords**—**Assessment methodology, ramp-up, ramp-up capability, software-tool.

I. Introduction

BASED ON the current circumstances mentioned in the abstract, the research project "RampAble – Configuration of Ramp-up-viable Production Systems" was carried out at the Institute of Production Systems & Logistics at the Leibniz University of Hanover. The objective of the project was to provide small and medium-sized enterprises (SME) with a software-tool which allows them to assess and improve the ramp-up capability of their production systems with respect to a predefined ramp-up situation. The tool enables SMEs to not only identify their current ramp-up capability and to increase it according to a specific ramp-up situation, but also to plan ramp-up capable production systems by focusing ramp-up enablers during the planning phases they are defined in. In order to assure the suitability of the software-tool for practical use, it was elaborated in cooperation with seven SMEs.

As a basis for the software-tool a methodology was developed which connects certain objects using different handling methods. *Attributes*, *ramp-up-favorable measures*, *configuration elements* and *recommendations* are the four objects of the methodology. Fig. 1 shows that these objects are connected by three methods: a *morphology*, a *maturity model*s and a *portfolio*.

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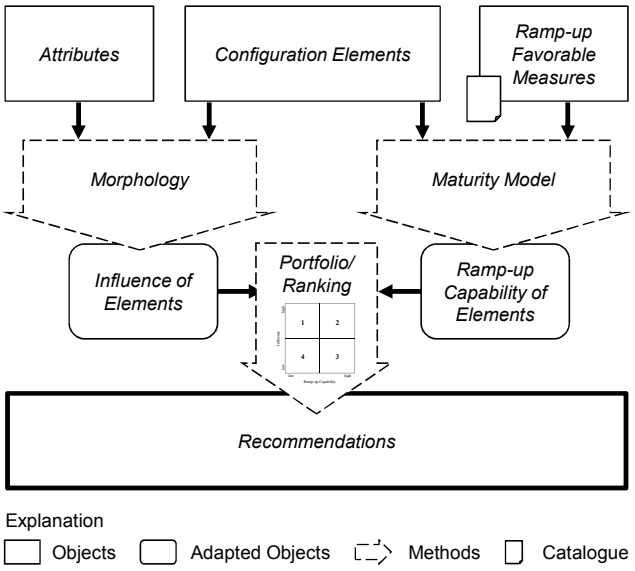

Fig. 1 Functionality of the Methodology

In the first step of the project production, systems were examined with the target of identifying the elements of production systems with the highest influence on their ramp-up capability. As a result of this step, 18 different *configuration elements* with potential to support ramp-ups were identified. In the second step of the project, *ramp-up challenges* were identified and used to derive *ramp-up favorable measures* which can be used to improve the ramp-up capability of the production system.

Whereas the *attributes* in combination with *configuration elements* serve to identify the level of influence of each *configuration element* on the ramp-up situation, the *ramp-up favorable measures* in combination with the *configuration elements* provide the possibility to identify the current ramp-up capability of each *configuration element.* Combining the influence of the *configuration elements* with their current ramp-up capability in a *portfolio* leads to *recommendations*, how to improve the ramp-up capability of the production system concerning a specific situation.

In order to not only provide a methodology to reactively identify and adjust the ramp-up capability of a production system, but also a possibility to proactively design ramp-up capable production systems, the identified *configuration elements* as well as the *ramp-up favorable measures* were implemented in the factory planning process according to VDI 5200. The description of the planning process for ramp-up capable production systems however is not part of this article.

II. Objects of the Methodology

A. Attributes

Morphology systematically compares characteristic attributes or alternative solutions of issues in order to simplify their descriptions [1], [2]. Whereas the ramp-up situation basically is determined by the product and the company's situation and only influenced by the corporate strategy and the market situation [3]-[5], attributes were identified with a focus on the identification and description of product changes and the company's situation during ramp-ups. The eight attributes *complexity of product, complexity of technology, complexity of process, variants, suppliers, personnel, degree of automation* and *environment* were identified to describe the examined ramp-up situation in a preferably exact way.

B. Ramp-Up Favorable Measures

According to [6] the ramp-up capability of a production system is defined by the number of ramp-up supporting features of the system. In analogy to the four enablers of changeability, the features *convertibility, reactivity, availability* and *transparency* were chosen as *ramp-up enablers* [7]. By opposing these four *ramp-up enablers* to the 18 *configuration elements,* 72 fields for the allocation and identification of *ramp-up favorable measures* were defined.

Using this structure, a catalogue for *ramp-up favorable measures* was developed which allows the allocation of each *ramp-up favorable measure* to a combination of a *ramp-up enabler* and a *configuration element.* The catalogue contains measures from literature but also best-practices from industry. In order to keep this catalogue up to date, the possibility to add newly identified measures is provided.

C. Configuration Elements

According to system theory a production system can be described by a certain amount of elements which are put in a defined order by the relations between them. Thus they serve as a mean of transformation of input into output factors [8], [9]. In order to identify the elements of a production system with influence on its ramp-up capability, the production system was divided into the five levels *network, site, factory, system* and *workstation* [10]. Since the improvement of a system takes place within certain fields, the four configuration fields *technology, logistics, organization* and *personnel* were selected [6]. By opposing the levels of a production system to the configuration fields, a scheme was given to systematically identify elements of a production system. The eighteen elements with the highest influence on the configuration of ramp-up capable production systems were derived and defined as *configuration elements.*

D. Recommendations

Whereas *attributes, configuration elements* and *ramp-up favorable measures* are the three objects serving as input for the methodology, *recommendations* are the final output. *Recommendations* are the measures with the highest potential to improve the ramp-up capability of a production system concerning a specific situation.

The comparison of the ramp-up capability of the 18 *configuration elements* and their influence on a specific ramp-up situation identifies the *configuration elements* with the strongest influence on and thus with the highest potential for the improvement of the current ramp-up situation. Recommendations are directly allocated to these high potential *configuration elements.*

III. Methods of the Methodology

A. Morphology

Since the ramp-up capability of a production system is strongly related to a specific situation, this situation needs to be identified and described systematically in a preferably detailed way. In order to simplify the description of this situation, morphology was developed which identifies the different influences of the 18 *configuration elements* on the ramp-up situation by systematically comparing ramp-up characteristic attributes [1], [2].

The developed *morphology* serves to define the ramp-up situation by specifying the eight different attributes and results in a ranking of the 18 *configuration elements.* In order to describe the ramp-up situation, the developed *morphology* not only uses quantitative numbers, but also qualitative descriptions for the specification of the eight attributes.

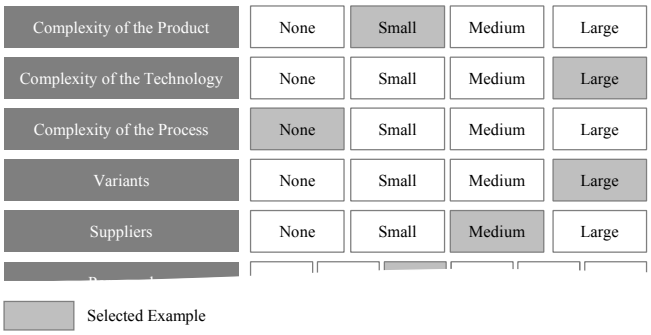

Fig. 2 Functionality of the Methodology

An example of the *morphology* is shown in Fig. 2. In this example the ramp-up situation is mainly characterized by:

- a small change in the *complexity of the product*, e.g. the face-lift of the VW Golf,
- a big change in the *complexity of the technology*, e.g. the change from welding to bonding technology,
- no change in the *complexity of the process*, i.e. no change in the sequence of the production steps,
- a large number of *variants*, which can lead to different manufacturing parameters for the machines and
- a medium number of *suppliers.*

It becomes obvious that most of the attributes are not meant to be specified by absolute numbers. Because the developed software-tool, and thus the methodology, was intended to be applicable in SMEs of any size, a scale with absolute numbers

would lead to wrong results. For one enterprise 20 suppliers which have to be considered during ramp-up would already be a large number, whereas for another enterprise 20 suppliers are just a very small number. As the intention of the software-tool is to give the enterprise applying it a preferably exact hint on how to improve their ramp-up capability, a morphology using qualified specifications for its attributes was developed.

The result of the definition of the ramp-up situation is a prioritization of the 18 *configuration element*s. Thus a first indication to the most influential *configuration elements* for the investigated ramp-up situation is provided.

B. Maturity Model

Whereas morphology serves to systematically describe a certain situation - in the described methodology by identifying the different influences of the 18 *configuration elements* - a *maturity model* provides the possibility of assessing the capability of a production system [11].

The developed *maturity model* uses the *ramp-up favorable measures* – allocated to the *configuration elements* – to describe the current ramp-up capability of each of the 18 *configuration elements* and thus of the entire production system.

The ramp-up capability of a *configuration element* is defined by the relevance and the execution status of the *ramp-up favorable measures* allocated to this element. Fig. 3 shows the scheme provided to define the relevance and the execution status of a *ramp-up favorable measure.*

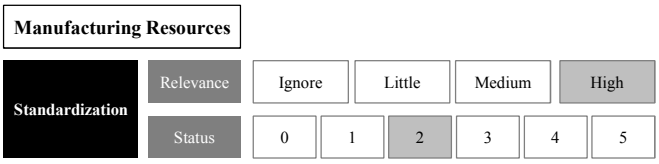

Fig. 3 Scheme to define relevance and status of measures

In this example the *ramp-up favorable measure* standardization allocated to the *configuration element* manufacturing resources is shown. Fig. 2 already indicates a change in the production technology. According to this change the relevance of the standardization of manufacturing resources is selected as high, whereas the execution status is rated with 2 out of 5.

In analogy to this example the relevance and the execution status of each of the *ramp-up favorable measures* is defined. Thus the current ramp-up capability of each of the *configuration elements* can be identified. Because the allocated number of *ramp-up favorable measures* to each *configuration element* depends on the current content of the catalogue, the ramp-up capability of a *configuration element* relates to the current number of allocated *measures.* Fig. 4 shows an excerpt of the scheme to define the ramp-up capability of the *element* manufacturing resources.

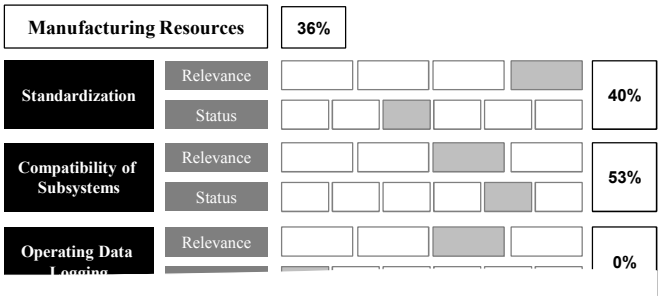

Fig. 4 Scheme to define the ramp-up capability of an element

In the example given in Fig. 4 the different relevance of the *ramp-up favorable measures* as well as the different execution status are shown. It becomes obvious that the current ramp-up capability of the manufacturing resources is defined by a factor including the relevance and the execution status of each *ramp-up favorable measure* of the *element.*

C. Portfolio

In order to be able to not only connect the results of the *morphology* and the *maturity model*, but also to visualize them in a comprehendible way, a portfolio was developed. After identifying the influence of each *configuration element* by using the *morphology* and the ramp-up capability by using the *maturity model*, all 18 *elements* can be located in the portfolio. As depicted in Fig. 5, the portfolio opposes the influence of the *configuration elements* to their ramp-up capability and thus is divided into four quadrants. In order to derive *recommendations* from the portfolio, these four quadrants were named and, according to their potential for the ramp-up, for each of them a generalized strategy was developed.

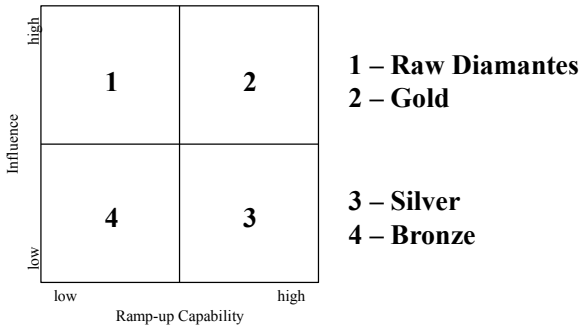

Fig. 5 Portfolio for the identification of high potential elements

Configuration elements located in the quadrant *Raw Diamantes* have the highest potential to improve the ramp-up capability of the production system. Whereas they are having a high influence due to the ramp-up situation, the ramp-up capability of the *Raw Diamantes* still is low. In order to improve the ramp-up capability of the entire production system these *elements* should be focused and their allocated *measures* should be realized.

Configuration elements located in the quadrant *Gold* have a lower potential than *Raw Diamantes.* They are having a high influence on the ramp-up while having a high ramp-up

capability at the same time. These *elements* are the ones facilitating the ramp-up. They need to be controlled, but do not have to be improved further.

Configuration elements located in the quadrant *Silver* have a low potential for the ramp-up. Their influence on the ramp-up situation is low, whereas their ramp-up capability is high. They provide the production system with a certain ramp-up capability but are not as powerful as *Gold elements.* They do not have to be focused nor improved.

Configuration elements located in the quadrant *Bronze* have the lowest potential to improve the ramp-up capability of the production system. They are having low influence on the ramp-up situation while having low ramp-up capability at the same time. Due to their low influence they do not have to be focused and should only be improved, if no *Raw Diamantes* are left and the ramp-up capability of the production system still is too low.

IV. Functioning of the Methodology

When using the software-tool three basic steps have to be executed. Firstly the ramp-up situation has to be characterized; secondly the current ramp-up capability has to be identified and finally the ramp-up capability of the production system has to be improved.

The first step when using the software-tool consists of the characterization of the ramp-up situation the enterprise is facing. The user is lead form one attribute of the morphology to the next until all eight attributes are specified.

The second step when using the software-tool consists of the identification of the current ramp-up capability of the production system. The user is lead through the entire catalogue of *ramp-up favorable measures* until the relevance and the execution status for each of the *measures* is identified. This step also serves as a controlling tool to track the development of the ramp-up capability of the production system. The identified ramp-up capability can be saved and compared to earlier results. *Measures* which are not relevant for the enterprise can be ignored and are not provided the following time the ramp-up capability is identified.

The third step when using the software-tool consists of the improvement of the current ramp-up capability of the production system. After accomplishing the first two steps, the software-tool generates a *portfolio* which displays the different potential of the 18 *configuration elements* to improve the ramp-up capability of the production system. Thus *configuration elements* with high potential can be focused and *measures* with high influence can be taken. A ranking of the *configuration elements* concerning their potential and a ranking of *ramp-up favorable measures* concerning their influence on the *configuration elements* and thus on the production system is additionally provided.

V. Summary and Outlook

Today's high frequency and growing complexity of production ramp-ups lead to recurring challenges for SMEs. Most SMEs neither possess the necessary know-how of how to deal with ramp-ups nor the capacity to manage them. Therefore a software-tool was developed at the Institute of Production Systems and Logistics within the research project "RampAble - Configuration of Ramp-up-viable Production Systems". This tool allows SMEs to assess their ramp-up capability concerning specific situations and configure their production systems in a way which facilitates further ramp-ups. This article describes the methodology, the software-tool is based on.

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