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Proactive Management of Production Technologies: A Conceptual Framework

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Abstract

To gain competitive advantages within the growing challenges of the dynamic market environment producing companies must be agile, anticipative and adaptive. Current and future manufacturing requirements need to be fulfilled in the best manner. Consequently, the appropriateness of the applied production technologies has to be analyzed continuously. In order to identify technological need for action timely the interdependencies of temporally and structurally recurring patterns (defined as cycles) within the production environment have to be contemplated. Modeling and analyzing these cycles (e.g. technology lifecycle, manufacturing resource lifecycle) facilitates a proactive planning and an evaluation approach of production technologies. Therefore, this paper presents a conceptual framework supporting the timely adequate identification and evaluation of alternative production technologies to enhance the performance of producing companies.

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Keywords: Manufacturing process; Production planning; Technological modernization; Cycle management

1. Introduction and Definitions

Decreasing profit margins [1], growing customer demands, shortened product lifecycles [2] and accelerating rates of technological change [2, 3] are key challenges for today's manufacturing companies. Zaeh et al. ([2] based on [3]) divided the factors influencing decisions and processes of a producing company into external (e.g., new products and substitutes, political and social impacts) and internal factors (e.g., production resources and established technologies). Especially production technologies are seen as the key driver for cost reduction [1] and efficiency [4] in manufacturing.

In order to assure enduring competitiveness [5] it is essential to continuously detect whether the established technologies will fulfil current and future requirements or if promising alternatives exist [6]. Since the development of requirements resulting from the production environment is hardly predictable investments in suitable technologies in terms of effort and time is a complex and uncertain task [7]. These investments are necessary from a company's perspective if there is a technological need for action. In this context, technological need for action (also referred to as technological modernization activities) is defined as the demand for the replacement of a production technology due to a decline in its suitability (properties deficit), wear out of manufacturing resources (substitution need) as well as progressed technology's maturity (substitution potential).

The term "technology" denotes all emerging and established manufacturing processes that are required to produce a product [8]. Technologies are generally based on theories consisting of valid findings of scientific research describing causes and their effects [9]. For real life application of technologies, they are embedded in manufacturing resources (cf. Figure 1). Subsequently, technologies and the underlying manufacturing resources are focus of this work and are referred to as production technologies in the following.

To remain competitive manufacturers have to monitor and anticipate external and internal influencing factors to be able to act appropriately [10]. Some factors are predictable while others are not [2]. Lifecycle models support the forecast of predictable factors. Cycles are temporally and structurally recurring patterns that can be separated in defined phases.

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These are determined by triggers, duration, repetition and effects [11]. The management of interdependencies of multiple cycles in terms of planning, modelling, organizing and monitoring is understood as cycle management [11].

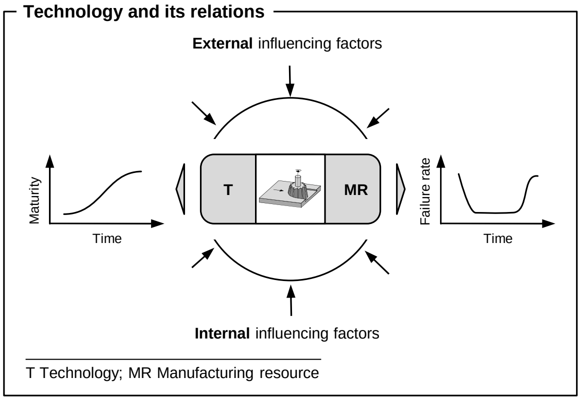

Fig. 1. Internal and external influencing factors

2. Cycle Management in Manufacturing

The understanding and use of singular cycles in the context of manufacturing is already established, whereby the product, technology and manufacturing resource lifecycle and their interactions, as shown in Figure 2, are almost regarded [12]. Subsequently, relevant lifecycle concepts and methods dealing with the cycle-oriented planning of technologies are analyzed to derive shortcomings.

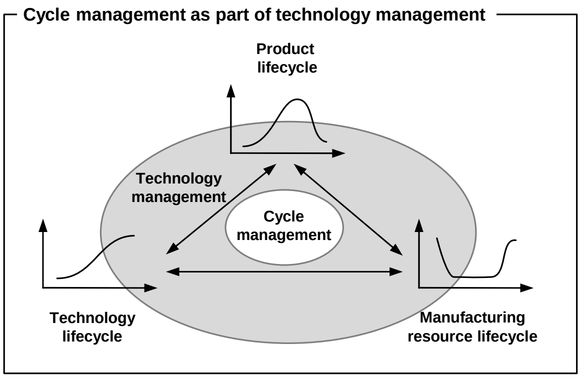

Fig. 2. Cycle Management in the context of technology management

2.1. Production-related lifecycle concepts

The concept of the product lifecycle [13, 14] for strategic decision-making is well established in industry (cf. e.g. [11, 15, 16]). Each stage of the lifecycle (introduction, growth, maturity and decline [17]) was already studied in detail. Besides, this lifecycle concept was empirically analyzed (cf. [18]). Furthermore, it was noted that the manufacturing processes have to be in line with the corresponding challenges of each product lifecycle stage [19].

The technology lifecycle [20] can be visualized using the bell-shaped curve [21] or the S-curve model [22]. Thereby, production technologies pass through an evolutionary development, which can be separated into several stages of maturity qualitatively (e.g. [21, 22]) or quantitatively using questionnaires (e.g. [23, 24]) and patent data (e.g. [25]). Depending on the lifecycle stage (innovation, key, standard, displaced technology), the production technology provides varying competitive potential [10].

Another well-accepted tool concerning the lifecycle management of manufacturing resources is the bathtub curve [12, 26]. The curve represents the idea that the operation period of simple machines or devices comprises three distinct phases (early failure, random and wear out period) [27]. However, modern manufacturing equipment is more complex, which results in changes of failure patterns over the lifetime. Moubray [26] developed six patterns of failure for describing the manufacturing resource lifecycle.

On a more abstract level, special attention was paid to the concept of the factory lifecycle developed by Schmenner [28] as well as the production system lifecycle (cf. [29]). The core idea of these concepts is that production facilities are long life products, which need to be adapted continuously to changing market environments [30].

The dynamics of process and product innovation were examined on a conceptual level. This resulted in a consistent pattern of variables, which will change due to the company's product or process development [31]. But the various characteristics of cycles in manufacturing increase the complexity of harmonizing those [10].

To deal with the complexity of cycles, especially their interdependencies and dynamics in a production environment, Stahl et al. [32] used transition adaptive recurrent Fuzzy Systems. Therefore, a rule base and a simulation scenario were developed visualizing the ideal type of behavior of relevant influencing factors.

Based on a System Dynamics model Plehn et al. [33] developed a dynamic cycle network focusing on change-relevant influences on manufacturing systems. As a result, quantitative relationships between the modelled elements have been analyzed.

The presented concepts focus the strategic management of a producing company and are often not related to specific parts of a production system (e.g. manufacturing resources). Supporting the deduction of concrete need for action to improve the competitiveness of a producing company requires a higher degree of details.

2.2. Cycle-oriented planning of production technologies

The suitability of a technology to fulfil a specific production task is changing over time [34]. Furthermore, some manufacturing resources are always in need of replacement due to obsolescence, wear-out or breakdown [35]. Although the need for continuous assessment and technological modernization of established production technologies is mentioned in literature (cf. [34, 35]) only few methods consider this fact. The majority of approaches for planning production