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Increase of Capacity Flexibility in Manufacturing Systems by Substitution of Product Functions

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Abstract

In the current competitive market manufacturing companies are driven by significant price pressure as well as high fluctuation in demand. They are faced with the challenge of producing products cost-effectively. Especially, serial and variant manufacturers strive for high capacity utilization to prevent overcapacity and to reduce their fixed costs in production. By applying current approaches companies are able to react on market turbulences by adapting the manufacturing system in the limits of a defined flexibility corridor. However, with these the existence of overcapacity is not eliminated. In particular, an alternative approach for short and medium term adjustments in the existing manufacturing system has to be given. Consequently, the objective is the efficient use of overcapacity. For this purpose, in this article a new approach to increase the capacity flexibility in manufacturing systems is described. The core approach "Substitution of Product Functions" focuses on manufacturing two different variants of product components with the same product function simultaneously but two different product designs. One of the component designs needs a high process time with low variable costs, the other one a low process time with high variable costs. Thus, two product designs with differentiation in variable costs allow the use of the factor "manufacturing process time" as an additional control variable for increasing the capacity flexibility. The main result will be a cost-optimized and highly utilized manufacturing process. Based on previous scientific studies in this article the results of the influence on costs and capacity flexibility by variation of the product design and design of manufacturing system are presented.

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Keywords: Product Function; Flexibility; Capacity Utilisation; Manufacturing System; Cost Reduction

1. Introduction

While the world's population in 1950 only amounted to about 2.5 billion people, it has now grown to more than seven billion. McKinsey's extrapolations show that a world population of almost eight billion in 2025 is to be expected. In 1990 there were 1.2 billion people who had more than ten dollars for consumption and by 2025, every second person will be able to contribute to this consumption [1]. The strong world population growth and positive development in consumption will lead to an enormous increase in demand. Because of today's globalization, companies will also be affected by an immense boom in sales [2]. However, the opening and expansion of markets will cause an additional increase in market competitors and have a negative impact on the competitiveness of manufacturing companies [3,4].

Customers will get the opportunity to compare and to choose different offers based on their preferences. This will cause high fluctuations in demand and uncertainty in the capacity planning of manufacturing companies [2]. In Fig. 1, the fluctuation in demand is shown for the manufacturing sector. An enormous drop in incoming orders between 2007 and 2009 can be noted, which caused turbulences and economic crises such as corporate bankruptcies.

Based on this background, the decrease of predictability of markets as well as strongly fluctuating incoming orders can be regarded as the essential factors that are responsible for the occurrence of strong turbulences in the manufacturing sector. Therefore, the challenge for manufacturing companies is to find approaches to increase the capacity flexibility in their manufacturing systems, as well as to survive the dynamic and competitive market [5].

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Fig. 1. Fluctuations in demand of the manufacturing industry [6].

2. State of the art

Focus of the following sections is on the *capacity flexibility* in manufacturing systems. For this purpose, the term capacity flexibility will be defined and the benefits of capacity flexibility described. Afterwards, an explanation of the dimensions of the capacity flexibility follows. Furthermore, the procedures for determining the requested and available capacity as well as current approaches for increasing the capacity flexibility are presented.

2.1. Capacity flexibility

The term capacity flexibility is often synonymously used with *volume or quantity flexibility* [7]. Capacity flexibility is defined by SETHI & SETHI, as the ability to operate economically in a manufacturing system, at different levels of utilization [8]. TEMPELMEIER uses a similar definition and describes the capacity flexibility as the ability to operate economically, despite frequent changes in throughput [9]. In addition to the analysis of ability, SCHELLMANN observed different measures for the implementation of capacity flexibility. According to the author, capacity flexibility is the total of available measures, which allow reversible adaptions of the capacity in work stations and production systems. These measures include adaptions of the capacity of production resources, such as machines and equipment, as well as human resources [10].

Derived from the given definitions, a universal definition for the presented article can be made. Therefore, *capacity flexibility* is the ability to ensure reversible, economic capacity adjustments in a manufacturing system by using a defined bundle of measures. The bundle of measures focuses on the optimal capacity utilization of manufacturing, human and material resources.

2.2. Benefits of capacity flexibility

To represent the benefits of using approaches to increase the capacity flexibility a general definition of the benefits of flexibility will be generated. According to KALUZA, the benefit of flexibility is defined as enhanced achievement of objectives, by having the possibility to make quick adaptions in case of disturbances or market changes [11,12]. The implied benefit refers to situations of future uncertainties. Therefore, the benefit of implementing measures for capacity flexibility can only be identified right after the occurrence of a change in the manufacturing system. In general, the implementation of any flexibility measures can be compared to an investment problem with risks. Flexibility measures initially incur costs and future cash flows are uncertain [11].

The benefit of capacity flexibility is particularly evident in the increase in competitiveness. On the one hand, the advantages are in the possible manufacturing of customer demand, but on the other hand, they are evident in increase in profitability [13,14]. Increase in profitability means to make profit and is the core aim of any company. If a company is not able to make profit even in times of crises, it will not prevail over its competitors and will disappear sooner or later from the market [15].

In particular, high capacity flexibility plays an important role in corporate existence. Capacity flexibility can be the crucial factor for preventing bankruptcies in crises. According to a study of EULER HERMES, most bankruptcies (44%) are in the manufacturing industry. Based on a detailed survey of more than 125 experienced insolvency practitioners, the insufficient transparency (44%), wrong investment (42%) and inefficient production planning (41%) are the most frequent causes of bankruptcies [16].

2.3. Dimensions of capacity flexibility

In general, the dimensions of capacity flexibility are explained in the research work of ROGALSKI. In contrast to the author's breakdown of the dimensions by time, variety and cost, the breakdown by *time*, *scope* and *costs* is preferred [17]. The first dimension describes the *time for changes* in the manufacturing system. The second dimension is defined as an established *scope of action*, with flexibility potentials and the third dimension illustrates the *costs for system adaption* and *implementation* of flexibility measures.

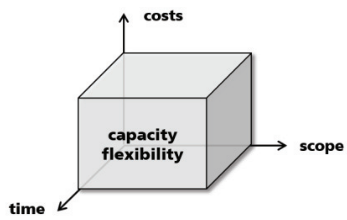

Fig. 2. Dimensions of the capacity flexibility.

In Fig. 2 it is shown that a so-called *tensor of flexibility* is created by the dimensions of flexibility. The highest impact on the capacity flexibility is given by the second dimension of the tensor (scope of action). Depending on the characteristics of one of these three dimensions, the *size of the tensor* and the *degree of capacity flexibility* for an established manufacturing system is determined.

During a change process, a temporal effort (*time*) arises. The effort is created firstly, by identifying a need for action and secondly, by applying flexibility measures in the manufacturing system [18]. The temporal components are divided into reaction time and adaption time. The response time results from the sum of time for the perception, recognition and identification of a problem. During the adaption time the