Modelling Dynamic Production Systems with a Special Focus on Dynamic Bottlenecks

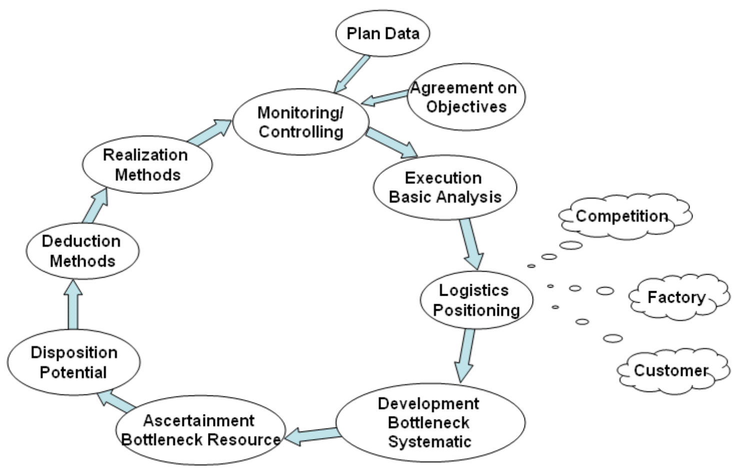
Bottlenecks play the key role in determining overall performance of manufacturing systems. Improving the performance of bottlenecks may lead to low inventory, appropriate utilization, short lead time and low schedule deviation. Therefore, consideration of bottlenecks is of prime importance at all levels of decision-making in production management practice (e.g. Production Planning and Control) and even in decision-making for strategic investments (e.g. process improving projects, new facility purchases, etc). Although bottlenecks have been a subject of study for more than ten years, current work still produces promising results; especially new and enhanced features for bottleneck-oriented Production Planning and Control methods are still required. The bottlenecks of a system may vary from different perspectives. From the view of logistical objectives in manufacturing, bottlenecks are categorised into inventory, utilization, lead time and schedule deviation bottlenecks. In terms of research subjects, bottlenecks can also be classified into resource, order and product bottleneck. Based on the bottleneck appearance cycle, we can categorize bottlenecks into static and dynamic bottlenecks. From the point of view of production logistics, several shortcomings of conventional bottleneck research have been pointed out.

Research Problems

First of all, in previous research on bottlenecks, bottlenecks are usually evaluated using single or only few logistical objectives (e.g. utilisation). However, logistical objectives might be distinct due to the different manufacturing situation of manufacturers and various requirements of customers. To meet this demand from factory and market, the systematic and alterable logistical objectives should be considered during the process of analysing bottlenecks.

Secondly, most previous studies devoted themselves to the analysis and methods of reducing or avoiding bottleneck resource, bottleneck orders and products (logistic items in production systems) have not been researched separately. Therefore, the analysis results are not accurate enough to find suitable methods to reduce bottlenecks.

Finally, previous studies are mainly focused on static bottleneck analysis and treatment methods. During the process, the dynamic characteristics of bottlenecks are ignored; therefore deduced methods can not efficiently handle bottleneck problems. In some cases, the derived methods are carried out on the wrong subjects (i.e. resources, orders or products) or at the wrong time and even worse performance of production logistics systems.



Approaches

The above mentioned shortcomings of conventional development create the need for novel manufacturing control systems that are able to efficiently reduce dynamic bottlenecks which caused by environmental change (e.g. external customer demand change, raw materials failure etc.) and production disturbances (e.g. machine

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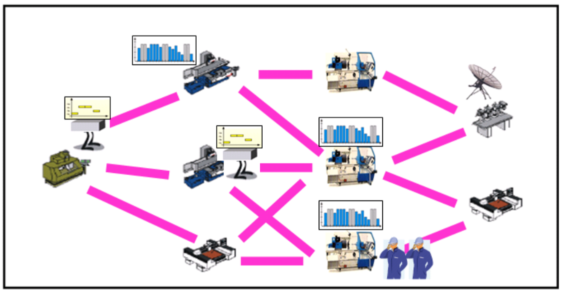
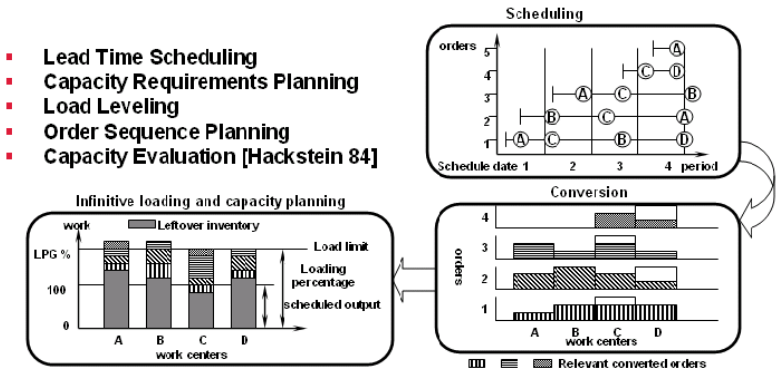
Finished in December 2011

breakdown, non-scheduled maintenance etc.). In order to cope with dynamic bottleneck problems, the ongoing paradigm shift from a centralised control of “non-intelligent” items in hierarchical structures towards a decentralised control of “intelligent” items in heterarchical structures in shop floor control. However, neither fully hierarchical, nor fully heterarchical control structures can deal with dynamic bottlenecks in a way that achieves satisfying system performance. To meet these new requirements, a number of novel concepts for the control system have been proposed and partly realized in the last two decades. The most popular ones are the Holonic Manufacturing System (HMS), the Genetic Manufacturing System and the Biological Manufacturing System.



The proposed research attempts to develop a manufacturing model where all dynamic bottlenecks are categorized and taken into account within the decision making process in HMS architecture. The architecture consists of three types of basic holons: resource holons, product holons and order holons. Every basic holon type focuses on different responsibilities of the manufacturing system. The holons exchange process knowledge, production knowledge, and process execution knowledge respectively. Aggregation is used to focus on different levels of holons. Specialisation is used to focus on different functionalities of holons. The concept of staff holons allows for the presence of centralised elements and functionality in the architecture. However, staff holons do not introduce a hierarchical rigidity into the system, since the final decision is still to be taken by the basic holons. In fact, the concept of basic holons, enhanced with staff holons giving advice, decouples robustness and agility from system optimisation. Due to its distributed basic architecture, the HMS delivers robustness and agility and is simple to extend and reconfigure. When staff holons are added, the basic holons will follow this advice as well as possible. Due to environmental change and production disturbances, the hierarchical staff holons perform badly; the advice may be ignored by the basic holons, which again take autonomous actions to do their work.

In our case, the basic holons will deviate from the plan if any dynamic bottlenecks appear; the centralised production planning will be conducted later again with regard to deviation from reality. On the other hand, when disturbances are absent, an HMS can be configured so that the basic holons follow the advice of the staff holons.



Expected Results

Simulation experiments will be constructed using eMplant 7.6 (a discrete, event-oriented simulation program) to visualize dynamic bottlenecks and assess the influence of proposed methods on logistic objectives. The configu-ration of the manufacturing system model is based on a real hanger manufacturer in Germany. The model comprises 196 workstations grouped into 32 station families, and 4,000 products composed of 360,000 orders. By applying the empirical simulation data which are exported from FAST/Pro (an infinitive daily Production Planning and Control program) in a simulation process, dynamic bottlenecks information will be derived from comparison of planning and actual data. The proposed research will reduce dynamic bottlenecks in manufacturing systems and thereby improve performance of manu-facturing systems through reducing deviation of logistical objectives and mean values. The results of research may be integrated within traditional central Production Planning systems to realize effective shop floor control in the future.

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