Digital Factory and Agent Based Manufacturing Execution System – An Approach for a Combined Planning and Control System for Complex Manufacturing Logistics

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Summary: The increasing variety of products associated with a reduction of lot sizes leads to a growing complexitiy of logistics at small and medium-sized businesses. Nevertheless those companies want to maintain their flexibility and adaptability of their manufacturing systems. The creation of a flexible and versatile manufacturing logistics system for small and medium-sized businesses is thus investigated within the scope of a research project at the Leibniz Universität Hannover. Key component of the approach is a Digital Factory model as basis for the production planning. Within this model the entire production of a exemplary scenario including the required information flows are simulated. The simulation was furthermore used to enable the development of an optimal and realistic configuration of the manufacturing system on basis of different scenarios. Conducted studies affected both the planned implementation of RFID technology for the monotoring of movement data and the application of lean methods in the production process. In order to control the material flow within the real production process a Manufacturing Execution System (MES) was developed. This system is composed of software agents to reach a maximum degree of flexibility with regard to the application situation. These agents process information autonomously and share those with each other. Within this system the movement of parts is monitored and are compared to the specifications of the Digital Factory model. If deviations of from scheduled to real production processes occur, the staff is informed systematically and measures to counteract are taken.

Keywords: Agent, Simulation, Production Planning, Manufacturing System

1. Introduction

Many small and medium-sized entreprises (SME) with job shop production experience a permanently increasing variety of their offered products which results in a diminishing lot size of each manufactured variant [1]. Thus, high demands on the mutability and flexibility of the affected manufacturing systems are made. In order to reach a high degree of flexibility the complexity of manufacturing logistics increases and thereby becomes a critical competitive factor. Because of the cost-intensive tansport of components as well as the increasing level of coordination, logistics are becoming a bottleneck in the process chain und thereby determine the overall efficiency of manufacturing systems [2].

The development of a Digital Factory model is a way to regard the dynamics of manufacturing logistics in order to increase the predictability of job shop manufacturing [3]. The reproduction of the material flow enables the comfiguration of a realistic simulation model. Thus it is possible to find the optimal configuration for Manufacturing Execution Systems (MES) in the examined period through different scenarios without affecting the real production.

The manufacturing control can be realized through manufacturing execution systems (MES) based on the requirements of the Digital Factory. However, these have to be adjusted to the particular application scenario whereby their implementation leads to high startup costs due to the high development efforts. Alternatively, MES which are prefabricated and available on the market form an insufficient adaption to the particular manufacturing scenario [4]. The following approach introduces an approach which allows the development of a prefabricated MES with maximum adaptability to a production situation by its breakdown into software agents based on information from the Digital Factory. These software agents are autonomous, interacting modules, which can be combined as desired so that a maximum level of flexibility is achieved. Thus adjustments to an application scenario can be made with minimal development effort.

Therefore, within the framework of a research project at the Leibniz Universität Hannover and its cooperation partners a flexible and reactive logistics system for the production in SMEs is developed. The system is based on the combination of the Digital Factory with an Agent-based Manufacturing Execution System (A-MES). Input data for both the Digital Factory and the A-MES is the acquisition of the material flow by means of RFID technology.

2. Application scenario and concept

The application scenario for the development of the planning systems involves the machining of structural components with a large number of variants in a job shop production. The transport between work stations is carried out via transport carts. Routes through production differ depending on the part transported. Furthermore, parts are subject to different machining times at the work stations. The developed concept focuses on two key components: a Digital Factory model and an agent-based MES which are described in the following section.

3. Digital Factory as basis for production planning

Digital Factory models are often applied to serial productions with a high degree of automation, e. g. the automotive industry. These models are suitable particularly for the assessment and optimization of strategical (e. g. dimensioning of transport technology, layout analysis) as well as operative (e. g. testing of limit loads, evaluation of batch size and job sequencing) planning [5, 6].

In the first step, the application scenario, which is based on a job floor production, was transformed into a virtual process chain simulation via the software Tecnomatix Plant Simulation® [7]. The model contains the layout of the regarded production including work stations as well as transport routes, carriers, production tools and transport carts (Fig. 1).

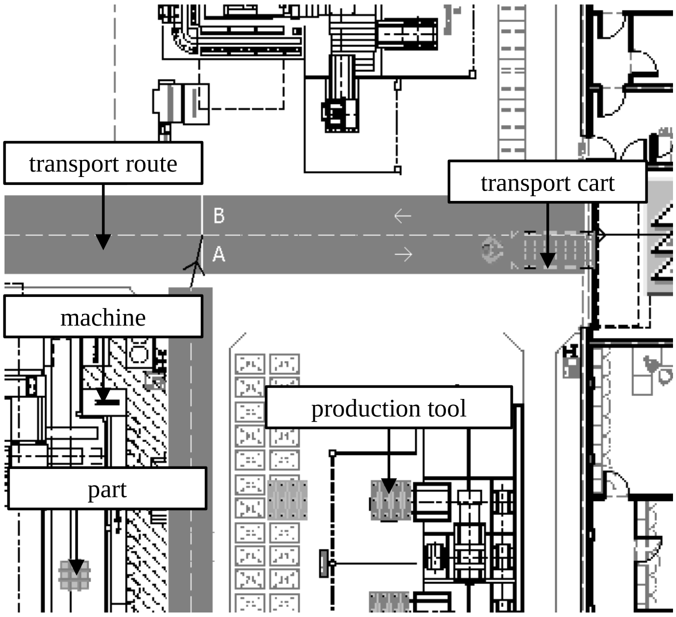

Figure 1. Representation of the digital factory model.

Based on the model several scenarios for the planning of production operations have been performed. These simulations affected several aspects of planning. Within the szenarios several parameters like the implementation of new machine tools as well as the implementation of lean methods were tested. In addition an approach for an economic use of RFID technology was being developed using the model to get a maximum of information at minimum cost with the required accuracy.

For this purpose, the entire information flow is represented within the model next to manufacturing logistic aspects. This provides a basis for the identification of the required interfaces for information processing. Thus, it is possible to identify which information is required for the monitoring of parts and in which places this information is gathered. On the one hand, this supports the planning during the compilation of specifications for transmission protocols between information-processing points. On the other hand it supports the configuration of safety measures like firewalls.

The second step includes the implementation of RFID sensors at suitable positions in the model and the implementation of RFID tags on the monitored parts. These actions enable to either identify which objects have to be recorded in the application scenario with RFID or which information has to be stored on the RFID tags. In the next step it is possible to plan and optimize the positions of the RFID scanners for the collection of required information at minimum cost and maximum benefit. Thus, a concept for each material movement can be established in order to influence the material flow up to a desired level of accuracy. These studies were conducted assuming a trouble-free operation of RFID technology.

However, errors may occur during the application of the technology which influence the production process and thereby productivity. Thus, in the third step it is on the basis of possible fault scenarios examined how the system reacts on disturbances like the breakdown of RFID tags or scanners and which possibilities can be depolyed for trouble-shooting. Additionally, organizational problems, such as merging and splitting of orders on several transport carts are examined. These studies allow a maximum adjustment of information processing of all instances to the real occurent production process. The goal is to achieve a maximum automization of data collection and to eliminate manual revisions of data stock.

Depending on the conducted studies the model provides different key performance indicators for the analysis of the production process on hand. The results of the studies are used to manually initialize the MES.

4. A-MES for production control

The more flexible a production is set up, so as to insert rush jobs or to manufacture different products in the smallest lot sizes efficiently, the more challenging the planning of material, machines and staff deployment gets. Disturbances like unscheduled rejections, supply bottlenecks or machine breakdowns and staff shortages have to be corrected as quickly as possible. For this purpose, it has to be known at all times which products are processed on which machines or on which transport routes they are [1]. For temporary deposited material it is also necessary to know the unloading time and place. A deviation of the scheduled and real material flow has to be reported and serves as basis for controlling measures. If the material monitoring is realized with help of RFID technology, there is a need for a efficient controlling software for logistic systems with high complexity. An opportunity is the developent of a decentralized production control system.

The presented approach therefore applies an agent-based Manufacturing Execution System which exchanges data with the Digital Factory. Within the project the term software agent stands for lean software modules which perform certain tasks autonomously and communicate with each other. For instance, agents could be work stations in a manufacturing system which inform their predecessors and successors about their current operating status. Thus, occurring problems at a work station, such as breakdowns, are instantly known at all work stations also affected by the failure and the staff is able to react accordingly.

The focus of the A-MES lays on the control of the material flow within the production system. The main objective is to minimize lead time and inventory buffers. A concept for permanent synchronization of system data and events measured in the production was pursued during the development of the system. The approach provides the highest degree of overview on all production processes. The responsible staff thereby is informed systematically about deviations between planning and real production processes. For the exchange of data the A-MES is connected to the Enterprise Resource Planning System or works self-sufficient with job data. The graphical user interface for A-MES is shown in Figure 2.

Figure 2. A-MES Graphical User Interface.

The design provides the A-MES system with a high flexibility level concerning its applicability since any prefabricated modules can be combined. The high flexibility also reduces the implementation costs because of reduced development efforts und makes the A-MES affordable for small and medium-sized businesses. Furthermore, it is possible to adjust the system to changes of production requirements because of its modular composition.

Hence the A-MES merges the advantages of maximum adaptability of an in-house developed software solution with the advantages of low implementation costs of a prefabricated solution. It is thereby perfectly suited for small and medium-sizes businesses with a high level of production complexity.

5. Summary and Conclusion

The increasing range of variants associated with a reduction of batch sizes imposes high demands on the flexibility and mutability of manufacturing systems. A flexible and versatile production for small and medium-sized businesses was created within the scope of a research project to meet the growing complexity for the associated manufacturing logistics system.

Basis for the production planning of the approach is a Digital Factory model which represents the production with the required dynamics. With the help of the model the application of the required RFID technology for the surveillance of material flow was carried out next to the actual production process surveillance. The realization of orders according to the schedule was enabled by the development of a A-MES which controls the material flow within the production and is designed to minimize lead times and inventory buffer. The system is divided into so called agents which autonomously perform tasks and share information with each other.

The combination of both aspects in connection with the applied RFID sensor system creates a cost-efficient planning method for small and medium-sized businesses with a high level of production complexity.

6. Outlook

Within continuative research activities the simulation results will be evaluated on the basis of a pilot project at the application partner. The obtained findings will then be implemented in the Digital Factory to enhance the precision of the simulation results. Additionally, the agent-based MES will be developed further and the adaptability will be promoted by the development of more modules.

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References

[1] Kleinert, A., Sontow, K., 2010, MES Lösungen – Ersatz oder Ergänzung von ERP / PPS-Systemen?, in Producivity Management – Zeitschrift Kompetenz in Produktion und Logistik, 2/2010, GITO-Verlag.
[2] Arnold, D., Isermann, H., Kuhn, A., Tempelmeier H., Furmans, K., 2008, Handbuch Logistik: Prozessorientierte Sichtweise in Produktion und Logistik, Springer
[3] Schuh, G., Gottschalk, S., 2008, Production engineering for self-organizing complex systems, Production Engineering, 2/4:431-435.
[4] Schuh, G., Sticht, V., Brosze, T., Fuchs, S., Pulz, C., Quick, J., Schürmeyer, M., Bauhoff, f., 2011, High resolution supply chain management: optimized processes based on self-optimizing control loops and real time data, Production Engineering, 5/4:433-442.
[5] Verein Deutscher Ingenieure, 2010, Simulation von Logistik-, Materialfluss-, und Produktionssystemen Grundlagen, VDI Richtlinien VDI 3633 Blatt 1, Düsseldorf:2-5.
[6] Wenzel, S., Weiß, M., Collisi-Böhmer, S., Pitsch H., Rose, O., 2010, Qualitätskriterien für die Simulation in Produktion und Logistik, Springer, 2/4:20-24.
[7] Bangsow, S., 2010, Manufacturing Simulation with Plant Simulation and Simtalk, Springer, 1/12:1-6.