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A TASK-DRIVEN FLEXIBLE MANUFACTURING SYSTEM FOR MAJOR INDUSTRIAL APPLICATIONS

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Abstract: *Highly flexible and adaptive manufacturing systems are urgently required to meet the challenges of the upcoming demand of the industry. However, many traditional industries are hesitating to introduce sophisticated approaches which require a complete re-organization of the production organization. This paper presents an approach of a task-driven manufacturing system which can be smoothly integrated into traditional factory organization systems. Thus, barriers of introducing innovative solutions in production are significantly reduced.*

Key words: *adaptiveness, flexibility, Manufactron, manufacturing, task-driven*

1. INTRODUCTION

Today's production faces various challenges: One of the most important aspects is to increase adaptivity and flexibility of production. This is due to the increasing demand of customer-tailored products, decreasing lot sizes down to lot size 1 as well as mass customization.

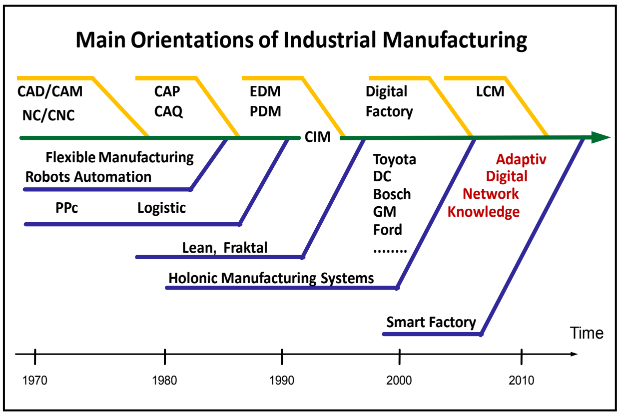

Fig. 1. Manufacturing main orientations (Manufuture, 2004)

To meet the resulting requirements the traditional resource-based manufacturing systems have to shift to innovative, knowledge-based production systems (***, 2004). Accoring to figure 1, these systems are adaptive, digital, networked and knowledge-based. This results in a benefit for the entire chain of production processes: Planning of production shall be supported by simulations which can also be coupled with real production data for planning improvements. The ramp-up time of production gear shall be reduced by knowledge-based approaches instead of classical production recipes. Finally, production execution shall be improved by flexible and reliable production equipment.

2. APPROACHES FOR FLEXIBLE PRODUCTION

Following the classical Computer Integrated Manufacturing since the early 1990s, scientific approaches of self-organisation have been investigated which are mostly based on multi-agent systems (MAS). A further development of MAS are the "Holonic Manufacturing Systems" (HMS) which have been developed under the Intelligent Manufacturing Initiative.. Holons are defined as an "autonomous and co-operative building block of a manufacturing system for transforming, transporting, storing and/or validating information and physical objects". HMS combine the best of hierarchical and heterarchical control (***** ,**1996). However, most research and development activities within the holonic initiative concentrated on heterarchical control structures.

In contrast to these approaches, the PADABIS project kept the traditional hierarchical factory organization of Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) and field level. It demonstrated the advantages of mobile agents compared to classical Manufacturing Execution System (MES) and Supervisory Control and Acquisition (SCADA) (*******, 2008). Concerning the field level, only fundamental concepts in PADABIS exist.

In order to react most flexibly on disturbances, Buchmeister et al. recommend heterarchical control structures rather than hierarchical ones. They propose to organize manufacturing systems to respond on disturbances and changes in the production environment (Buchmeister et al., 2010).

The importance of knowledge in general as well as the actual transformation of a technology and information based society towards a knowledge-based society and its impact on the education of people and also on the organization of manufacturing systems is impressively illustrated in (Katalinic, 2010). According to this, knowledge is seen as "key resource for economic growth".

3. TASK-ORIENTED PRODUCTION

3.1 Background

Having a look at the nowadays situation in real production facilities, in traditional industry branches, planners and machine operators hesitate to introduce the newest generations of production systems due to several reasons: Besides the cost these are resitrictions in terms of complexity, scalability, disturbance handling, etc. for innovative MAS (Almeida et al., 2010).

However, probably the most important barrier is the need for complete factory re-organizsation while introducing innovative MAS. The requirement analysis process for a new MAS for the traditional-oriented industry branches automotive, aeronautics and machine building pointed out the wish to keep the classical three-level approach for factory organization with Enterprise Resource Planning (ERP), Manufacturing Execution System (MES) and Shop Floor Level. However, within the classical layer structure, flexibility in terms of machines (various product variants shall be produced on one machine) and routing (process steps shall be dynamically executed at different machines) is requested. In addition to that, 100% traceability, assessment as well as documentation of quality for each product instance is required (XPRESS, 2007). Quality feedback loops are used for process and product optimization in the production phase and even in the design phase of the products and production lines of the next generation.

3.2 Concept

As shown in chapter 2, existing MAS do not cover all required features in traditionally oriented factories. For that, new approach is proposed which overcomes the the major barriers for the introduction of the newest generation of MAS. The concept is built on co-ordinated teams of specialised autonomous objects ("Manufactrons"), each knowing how to execute a certain process optimally under given conditions. Manufactrons are a combination of different classical hardware and software components of assembly processes with an advanced knowledge system. They use high performance algorithms for a flexible situation analysis and an on-line quality control. The intelligence to choose the best known production parameters for a given task is achieved by the implementation of a task-to-method transformation. For trans-sectoral process learning, Manufactrons are integrated in knowledge networks.

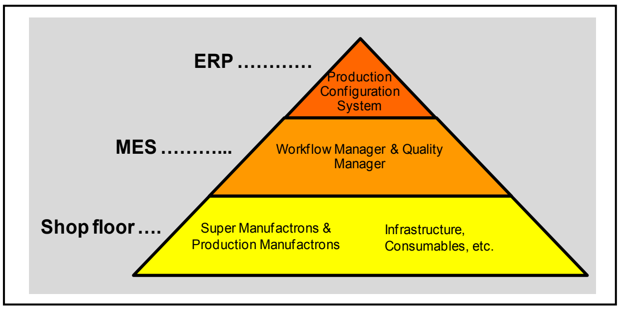

Fig. 2. Hierachical organization

The proposed approach meets the challenge to integrate intelligence and flexibility at the "highest" level of the production control system as well as at the "lowest" level of the singular machine (Fig. 2). The Production Configuration System on ERP level issues distributed simulation jobs to the underlying production entities in order to find best production layouts. The Workflow Managers are responsible for dynamic routing of production jobs to the production devices while the Quality Managers gather quality information coming from the production devices for 100% quality assessment and documentation of production. On shop floor level, the Production Manufactrons are responsible for performing the production jobs (assembling, handling, etc.). Super Manufactrons are used to coordinate Production Manufactrons and to decrease the complexity of production tasks by hierarchical abstraction.

All communication is done via the exchange of standardized documents (Hoffmeister, 2011). Task Description Documents (TDD) are used to communicate production jobs to the respective Manufactrons on the shop floor. The TDDs only contain the information what to do. It is in the responsibility of the Manufactron, to find the best fitting method for the job (how to do the job). After executing a production job (or after performing a job simulation respectively), the Manufactron issues a Quality Result Document (QRD) in which all information on the result of the performed job is collected. The third document type is the Manufactron Self Description (MSD) in which a Manufactron describes its own capabilities. The MSD is used to identify the right Manufactrons for performing simulations and job executions.

3.3 Applications

This new approach for an intelligent and flexible manufacturing system has successfully been demonstrated in five industrial applicatons in automotive, aeronautics and electrical industry. It has been shown, that the efforts for production planning and ramp-up could significantly reduced by the help of the Production Configuration System. During the execution phase, machine and routing flexibility is significalty improved by the Manufactrons and the Workflow Managers.

4. CONCLUSION

Flexible manufacturing systems are highly required to meet the challenges of future demands. One major challenge is the development of manufacturing systems for direct implementation in industry while minimizing the re-organization efforts in the factories.

The proposed approach has successfully been demonstrated in three representative industrial applications of traditionally-oriented industries. Only minor efforts had been spent for its integration in existing production setups and organizations. The advantages for production planning, ramp-up and execution have been shown. Thus, the feasibility of the approach for a flexible manufacturing system could impressively been shown for the applications under investigation.

Future research work in the approach for task-driven manufacturing will concentrate on the improvement of the task-to-method transformation approach and its adaption to further manufacturing processes. Furthermore, the implementation of the approach in further industry branches is envisaged. Other investigations will be done in the automatic generation of Task Description Documents based on the Manufactron Self Description and in utilizing the in- and out-properties of the TDDs for global, factory-wide process optimization.

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