e-Manufacturing: Framework for a Collaborative Distributed Manufacturing

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Abstract: In modern industry production improvement requires an environment in which relevant participants have the access to all types of digital data. Also, data acquisition from manufacturing plants is necessary, as well as their distribution via the Internet to all internal and external structures that require such data for the purpose of strategic decision making. This is the only way for participants to respond to future technological challenges and improve their efficiency in the modern business.

Applying the concept of e-Manufacturing enables distributed design, manufacturing, diagnostics and maintenance to be carried out via the Internet with the involvement of different teams of experts. In general, the concept of e-Manufacturing involves numerous information, collaborative and virtual technologies and is specifically suitable for the use in integrated collaborative CAD/CAPP/CAM environment.

Keywords: collaborative engineering, distributed manufacturing, e-Manufacturing, internet technologies

1. INTRODUCTION

In the last century mass production model was dominant with the prevalence of standardized products and processes but with reduced flexibility and customization in the fields of product design and process planning [8], Fig.1. Then, a new paradigm in manufacturing emerged which caused the transition to the era of quality management. Large manufacturing enterprises focused on reducing its internal flows by transferring support functions outside an organization’s boundaries. Manufacturing enterprises have increasingly started to rely on their supply chains with the emphasis on reducing deadlines and stock. The age of quality has led to the development of very different business and manufacturing models, as well as the modern form of enterprise integration: e-Manufacturing.

The wide application of Internet technologies and the development of e-Business have led to significant changes in the global market. In order to meet increasingly diverse and massive customer requirements, enterprises should reduce production time and batch sizes, as well as to strive towards increasing manufacturing flexibility. One way for manufacturing companies to survive in the global market is the application of internet technologies, i.e. the implementation of the concept of the e-Manufacturing control as one of the main components of the e-Business. In this way, company engineers and managers are provided with an efficient access to information.

The e-Manufacturing (e-Mfg), in broad sense, can be described as the application of the Internet to manufacturing [6]. The e-Manufacturing integrates customers, e-Commerce systems and suppliers into manufacturing process, thereby creating a strategic framework for manufacturing, which is based on internet technologies. This concept is usually applied in the high tech industry, as well as in all companies that integrate the Internet into their production processes in order to increase profitability. Modern companies use the Internet for various forms of e-Commerce and e-Business, and also to create a production environment, i.e. e-Manufacturing. The use of different internet services enables the management and control of manipulators, robots, CNC machines, as well as other, similar industrial equipment. By the synthesis of internet technologies and the concept of digital factory, frameworks for the e-Manufacturing are formed [6].

The e-Manufacturing represents the use of advanced information technologies for automated productivity optimization, which, among other things, provides [9]:

- Improved data availability to enable factory decision support,
- Improved tools and applications for data utilization in decision making for productivity optimization,
- Extended equipment control to support decision implementation,
- Increased security of communication channels outside manufacturing operations.

The core value of the e-Manufacturing is to enable decision-making in a real time in the relation between a product designer, production process and supplier. Traditionally, before the real time manufacturing, product design and process planning functions require weeks or months of analysis. Thanks to the e-Manufacturing system, in a few hours, engineers can match product attributes with real process characteristics, customer requirements, as well as the operational capability of machines and equipment. Also, an efficient data exchange and synchronization with the e-Business system are enabled.
2. STRATEGY AND IMPLEMENTATION OF e-MANUFACTURING

The e-Manufacturing strategy is based on make to order and e-Maintenance for equipment in manufacturing plant. The basis of the e-Manufacturing is the exchange of information between customers, manufacturing enterprises and suppliers. Manufacturing plant, through material management and equipment maintenance system, represents the starting level in the data collection necessary for decision-making processes. The application of internet technologies in production control and new manufacturing paradigms like Internet of Things (IoT) and Cloud manufacturing (CMfg) makes the process of collecting the required data more effective and efficient.

The path that leads to the implementation of the concept of the e-Manufacturing involves the improvement and integration of vital systems for immediate manufacturing. Following this path, it is necessary to implement and integrate systems for active process control, manufacturing execution systems, as well as automated material handling systems [1, 9], Fig. 2.

The goal of the e-Manufacturing is not to eliminate the human from the manufacturing process, but to improve human productivity, efficiency and ability for rapid and accurate realization of manufacturing activities. In this way, the participants in production process are able to focus on innovation and creativity, which is a prerequisite for increasing competitiveness.

The Internet and modern information and communication technologies provide the efficient access to all types of information that are in any manner associated with the manufacturing. The traditional one-way information flows are transformed into the two-way communication channels that integrate all the factors of the e-Manufacturing [8], Fig. 3.

Fig. 3. Information flows before (a) and after (b) implementing of the e-Manufacturing

3. COMPONENTS AND HIERARCHICAL LEVELS

In general, the e-Manufacturing includes four basic components [7], which are: products, processes, manufacturing and information technology. As shown in Fig. 4., each of these components means the use of various subsystems, standards, technologies, process and manufacturing equipment.

Fig. 4. Components of the e-Manufacturing
The e-Manufacturing is a manufacturing model that optimizes the use of manufacturing resources on the basis of the exchange of information from raw material warehouse, then manufacturing, up to supply chain. The exchange of information in this model is realized on the basis of the complete electronic, i.e. computer integration of all factory components, using industry standards and protocols. The employee structure is changed from operators to technicians, engineers and managers.

One of the main tasks of the application of e-Manufacturing is the quick response to market demands. In that aspect, it is necessary to integrate business systems from higher-level enterprises, and manufacturing and processing equipment from lower-levels. Intermediate, or integration level is consisted of various management systems, manufacturing automation and monitoring systems, engineering equipment and other factory systems [1, 9], Fig.5.

Looking at the global hierarchical levels within the concept of the e-Manufacturing, two primary groups of activities can be noticed - engineering and manufacturing [9], Fig 6. The engineering aspect on the inter-company level involves so-called engineering chain (EC) which enables the realization of anticipated engineering tasks. The engineering chain represents a network of engineering objects and services that allow the realization of product design and process planning on the basis of valid engineering data. It also enables the monitoring of production process by applying the equipment engineering system (EES) and manufacturing execution system (MES).

The equipment engineering systems thoroughly monitor the settings and behaviour of manufacturing equipment and also detect, predict, classify and eliminate errors. The functionality and efficiency of engineering equipment has a direct impact on the progress of realization of the planned production process, some of its phases and manufacturing operations, as well as the final product quality. The manufacturing execution systems provide information which is applied in the realization of manufacturing operations until the final product is obtained. On the basis of updated and accurate data, these systems run and lead activities in manufacturing plant and provide adequate reports on the results of those activities. The supply chain (SC) is a component on the inter-company level which is related to the production preparation.

These systems can be regarded as the information systems within manufacturing plant that represent the link between the higher-level planning systems and the systems for direct automated industrial process control.

4. COLLABORATIVE e-MANUFACTURING

e-Manufacturing is specifically suitable for the use in integrated and collaborative CAD/CAPP/CAM environment. In general, e-Manufacturing includes a number of information, collaborative and virtual technologies. Besides, according to [2], the efficiency of e-Manufacturing largely depends on the efficiency of collaborative processes in human-human and human-system relations.

The application of collaborative systems within the e-Manufacturing has enabled the realization of distributed process planning and manufacturing via the Internet with the involvement of different teams of experts [3]. Thereby, the expert knowledge used in process planning and production process is controlled and shared [4], Fig.7.
The goal of such a methodology is to develop an adequate framework and collaborative model for virtual manufacturing in the global supply chain conditions through the shared virtual workspace [5]. This framework allows the members of distributed engineering team to work together regardless of geographical dislocation. This platform provides the conditions for faster, easier, secure and efficient collaboration in order to realize the manufacturing itself. Special attention is paid to the aspects of security and safety of collaborative virtual manufacturing, so that the environment includes developed protection mechanisms for virtual manufacturing network.

The represented framework provides:

- Development and implementation of a secure network that provides the possibility of cooperation via the Internet for different levels of collaboration to manufacturing partners regardless of their location, and
- A solution prototype for defining the mechanisms of automated security levels in order to obtain mutual trust between parties involved in the collaborative work.

The framework can be improved by developing functions for collaborative work in the area of e-Business, or e-Commerce, where high levels of safety, security and trust are also required.

5. CONCLUSION

In modern industry collaborative processes and production improvement require an environment in which relevant participants have the access to all types of data. Also, data acquisition from manufacturing plants is necessary, as well as their distribution via the Internet to all internal and external structures that require such data for the purpose of strategic decision making. This is the only way for participants to respond to future technological challenges and improve their efficiency in the modern business. e-Manufacturing provides an environment that includes implicit e-Collaboration and data exchange in a real time. One of the important reasons for applying this concept is the reduction in time required for communication between the experts responsible for solving a common problem.

REFERENCES


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