Production management with the use of digital factory tools

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Abstract: Contemporary computer technologies are the basic tools of the accumulation and exchange of information in enterprises. Software of the digital factory systems is becoming more commonly used in management processes. This paper focuses on the concept of digital factory, its principles, the ways and areas of application as well as benefits for industry.

Keywords: digital factory, computer aided management systems

The activities of a company in the conditions of a free market economy make designers and managers undertake increasingly complex tasks. The consequence of this is the necessity for synchronisation of increasing quantities of technological factors. This leads to more effective methods of designing and controlling of production processes.

Using digital manufacturing, process planning can be done simultaneously to product design, shortening time to production and working towards a lean manufacturing practice. In this way, problems in the manufacturing process can be discovered and eliminated before starting production.

1. Introduction

Control of designing and production planning is one of the most important tasks of a company. The target of these activities is to manufacture the products at the planned time. Furthermore, we have to fulfil qualitative requirements, and their manufacturing costs should be as low as possible.

The introduction of computers into companies was accompanied with the development of software that aids designing, production planning and control. At the present time, this software is characterised by the possibility of integration with other computer systems and modular structure.

New tendencies within a company's organisational field, which also have an influence on computer systems, have a meaningful influence on the development of designing, production planning and control. Among them, the most important include Computer Aided Designing (CAD), Material Requirements Planning (MRP I), Manufacturing Resource Planning (MRP II), Enterprise Requirements Planning (ERP or MRP III), Just in Time (JIT), and Kanban and Optimised Production Technology (OPT).

Recently, much has been said about the digitalization of production enterprises. A lot of companies accomplish this by the implementation of integral software packages. These different modules integrate together for the various functional departments of the company. The main integrating element of such systems is the common database. This solution enables the quick and efficient design of new products [1].

The digitizing of production systems is almost connected with the entire production process, from the design a new product, through supply, manufacturing and sale. The use of computer tools in manufacturing does not only contain the planning and recording of realized works, but also the design of departments, production lines, workplaces, the analysis of executed works from point of view of ergonomics, the control of NC machines, the simulation of processes, and production management [3].

2. Digital Factory

Digital Factory entitles virtual picture of a real production. It represents the environment integrated by computer and information technologies, in which the reality is replaced by virtual computer models. Such virtual solutions enable to verify all conflict situations before real implementation and to design optimised solutions.

As defined by Alan Christman in the 2003 CIM-data report [2], digital manufacturing is "the process of using 3D CAD models and associated information for visualizing, modelling, and simulating manufacturing processes. The intent is to establish how to most effectively produce a part within resource constraints".

Digital Factory supports planning, analysis, simulation and optimisation of complex products production and simultaneously creates conditions and requires team work. Such solution enables quick feedback among designers, technologists, production systems designers and planners.

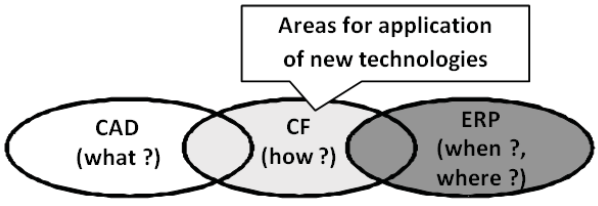

Fig. 1. The area of interest of the software related to the "digital factory"

Rys. 1. Obszary zastosowania oprogramowania związanego z „cyfrową fabryką"

Digital Factory represents integration chain between CAD systems and ERP solutions [4], as it is shown in the figure above.

One of very important properties of Digital Factory is the vision to realize process planning and product development with parallel utilisation of common data. Digital Factory principle is based on three parts:

- digital product with its static and dynamic properties,
- digital production planning,
- digital production with the possibility of utilisation of planning data for enterprise processes effectiveness growth.

It is very important to gain all required data only one time and to manage them with the uniform data control, so that all software systems will be able to utilize it. The integration is one of the main conditions for the implementation of Digital Factory.

Digital Factory is appropriate mainly as a support for the batch manufacturing of complex products, their planning, simulation and optimisation. Its main current application area is automotive industry, mechanical engineering industry, aerospace and ship building industry as well as electronics and consumer goods industries [6].

3D digital model of products (DMU – Digital Mock Up) creates currently basic object for the work in digital manufacturing environment [13]. There exists possibility to optimise products, processes and production systems even by the development phase with the utilisation of 3D visualisation and modelling techniques. Such a solution brings time to market reduction and significant cost reduction [7].

The system for the design of shop floor 3D layouts of production halls is missing in current Digital Factory solutions [10], but it is possible to create the 3D model of production hall directly in CAD systems. Such a solution is advantageous by new layouts or by new production systems designs.

In cases, when the production halls exist, it is often more effective to create 3D model of production hall with the usage of Reverse Engineering technologies and 3D scanners [8, 19] (fig. 2).

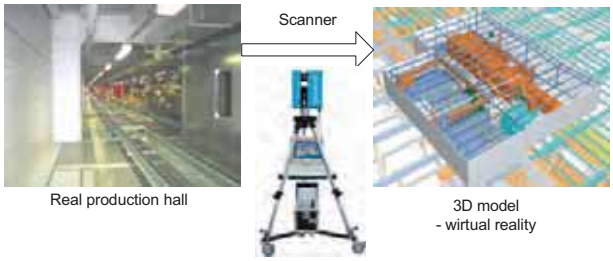

Fig. 2. Digitizing of the manufacturing system
Rys. 2. Digitalizacja systemów wytwórczych

The material flow simulation enables to optimise the movement of material, to reduce inventories and to support value added activities in internal logistics chain [15] (fig. 3).

The subsystems for effective ergonomics analysis utilise international standards as NIOSH, RULA etc., which enable right planning and verification of man-machine interactions on workplaces [17] (fig. 4).

The highest level of analysis represents computer simulation of production and robotics systems (fig. 5.), which enables optimisation of material, information, value and financial flows in the factory [18].

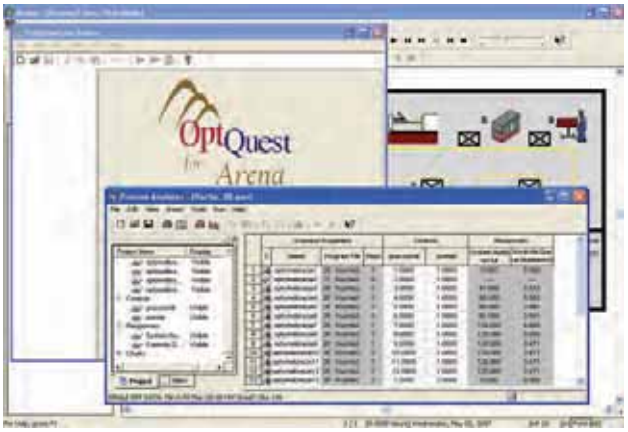

Fig. 3. Simulation and optimization of material flow
Rys. 3. Symulacja i optymalizacja przepływu materiałowego

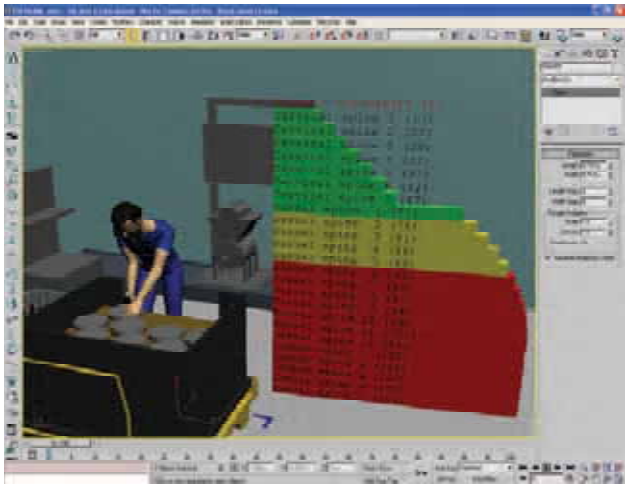

Fig. 4. Chart of the back strain by the discomfort
Rys. 4. Wykres obciążenia kręgosłupa wg dyskomfortu

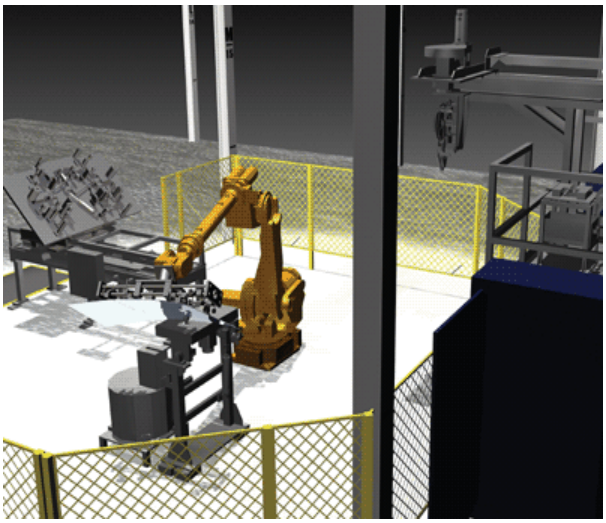

Fig. 5. Virtual scene of the robotics system in Mantra 4D [19]
Rys. 5. Wirtualna scena zrobotyzowanego systemu oprogramowanie Mantra4D [19]

3. Creation of virtual objects libraries

Any Digital Factory system hast to dispose with user libraries and databases of virtual objects representing parts, machines, robots or even manufacturing lines. These virtual objects are later used by engineers for design of virtual scenes of production halls. Chosen examples of such elements from virtual object libraries are shown in the following figures.

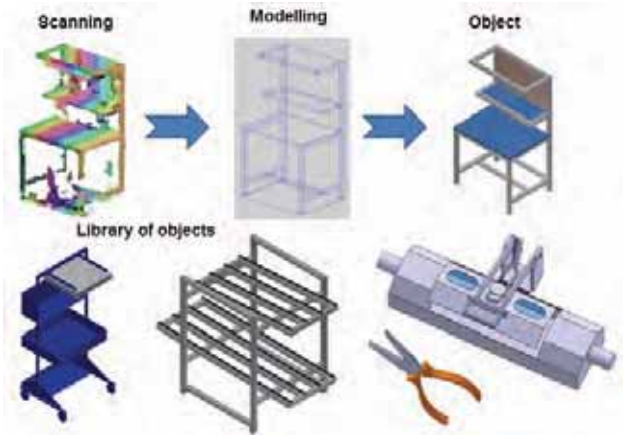

Fig. 6. Virtual objects library
Rys. 6. Biblioteka wirtualnych obiektów

4. Digital Factory benefits for industry

Digital Factory implementation results directly in economic as well as production indicators improvement. Any slight saving realised in design and planning phase can bring huge cost reduction in production operation phase. Thanks to this, payback period by investment in Digital Factory is very short.

Digital Factory advantages [5]:

- reduction of risk,
- processes verification before start of production,
- possibility of virtual checking of production halls,
- validation of designed production concept,
- optimisation of production equipment allocation,
- reduction in required area,
- bottlenecks and collisions analysis,
- fast changes,
- better utilization of existing resources,
- machines and equipment off line programming saving time a resources,
- reduction or full elimination of prototypes,
- ergonomics analyses, etc.

Digital Factory enables to test and reveal all possible production problems and shortages before start of production.

Any year automotive exhibitions show new models, merry-go-round of innovations turns faster and faster. Original Equipment Manufacturers (OEMs) introduce any two to three months new models what very often requires changes of production processes. Extremely short innovation cycles and products customisation significantly change all industries. The innovation is successful only in case, that it is quickly launched on market. The collaboration of single partners is very important not only in product development but in production planning and control too. There exists a lot of chaos and supplementary costs by the launching of new products. These supplementary costs achieve often millions of Euro [14].

The following figure shows the benefits from Digital Factory introduced by Toyota. It emphasizes mainly time factor influence by the new product launching and the possible cost reduction resulted from it.

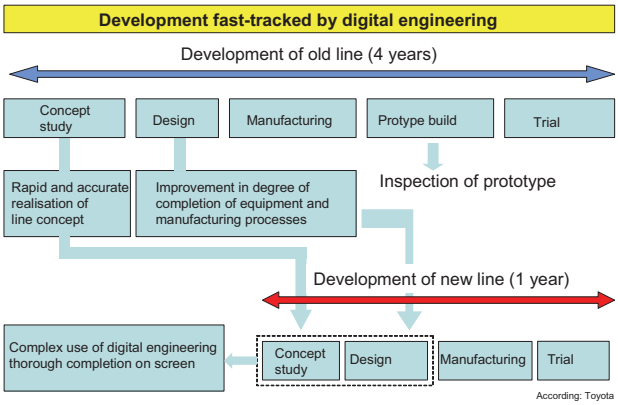

Fig. 7. Time to market shortening
Rys. 7. Skrócenie czas dostarczenia wyrobu na rynek

The highest potentials for high quality and low costs of products are in product development and production planning phases. The statistics show that product design and production planning influence about 80 % of production costs. Digital Factory enables product launching time reduction up to 25 to 50 %. Estimated cost savings are supposed from 15 to 25 %. According to some studies done in industry, using digital manufacturing techniques, twice the amount of design iterations can be processed in 25 % of the time [11–12].

The current production equipment is often inflexible by quick changes. That is why the designers of such equipment are looking for new solutions (automatic reconfiguration of production machines) with fully automated control systems, which will be able to find optimized production process and parameters after production task definition.

According to CIMdata report [2], Digital Factory enables to achieve following financial savings:

- Cost savings by assets reduction about 10 %,
- Area savings by layout optimisation about 25 %,
- Cost savings by better utilisation of resources about 30 %,
- Cost savings by material flows optimisation about 35 %,
- Reduction in number of machines, tools, workplaces about 40 %,
- Total cost reduction about 13 %,
- Production volumes growth about 15 %,
- Time to market reduction about 30 %.

5. Key enterprise processes

Digital Factory concept prioritizes the six most significant areas, according to their influence on production process

flow. Any area covers the set of tolls which all together integrate the whole production process, from product design to its production:

- product designing (modelling and simulation),
- process planning (treatment plans, assembly plans, work standardization, value analysis, cost analysis, etc.),
- production process designing and validation (NC production process simulation, assembly, inspection, maintenance, production operations etc.),
- production engineering (complex production scenarios, layout, industrial engineering, time analysis, ergonomics analysis, design and analysis of production and assembly systems, loading of machines, determination and optimisation of workers loading, etc.),
- production planning and control (ERP planning systems, scheduling, pull control, leveled production, mixed production, etc.),
- automation and process control (automatic generation of control programmes for control and monitoring of automated production systems, PLC, industrial robots, etc.).

6. Digital Factory software and his implementation methodology

The example of the digital factory system is DELMIA from Dassault Systemes. Users of DELMIA benefit from a 3D collaborative innovation and production experience for all actors in the manufacturing lifecycle such as virtual process and system definition, workcell set-up, optimization, scheduling, and operation, to maintenance of real-time production systems [16, 19–20].

DELMIA allows manufacturers in any industry to virtually define, plan, create, monitor, and control all production processes. It provides an array of dedicated applications for industries, combined with an environment for knowledge-sharing, process and resource management, and the ability to capture and implement best practices for manufacturing.

DELMIA PLM technology allows manufacturers to interact with factory processes early in the design stage and months before actual production commitment. Engineers, management, and stakeholders can have a 3D visualization of the real world with the ability to evaluate "what-if scenarios," make changes, optimize shop floor operations, and identify and eliminate costly errors and design mistakes. This allows any enterprise to facilitate higher quality and foster greater innovation. DELMIA also extends its PLM technology to smaller businesses within the supply chain to allow smaller companies to better connect and collaborate with larger manufacturers.

DELMIA offers on market the most comprehensive set of 3D digital solutions for production area including fuel engines production, final assembly, body welding in automotive industry, airplanes assembly, etc.

Dassault has integrated CATIA with DELMIA toolpath verification and machine tool simulation and the ENOVIA PDM product to manage the data.

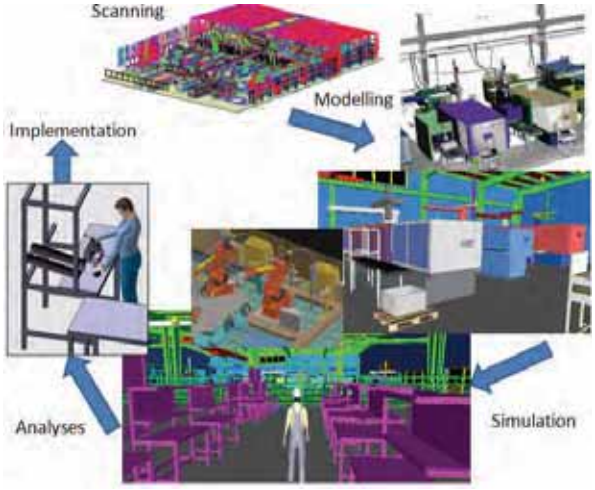

Fig. 8. Digital Factory functioning
Rys. 8. Funkcjonowanie cyfrowej fabryki

Rough procedure of Digital Factory implementation is as follows:

- definition of total standards and production principles for entire planning operations, creation of 3D objects and customer databases,
- first data collection and organisation with the utilisation of data management system; all responsible persons have direct access to the date, their addition, inspection and changes,
- in the third phase, Digital Factory system improves co-ordination and synchronisation of individual production processes,
- in the fourth phase, Digital Factory system takes automatically some routine activities, which are very time consuming.

7. Conclusions

The future outlook shows that digital manufacturing can benefit next generation products. Current research requires huge investment. Our industry requires above presented solutions. The common intention of the research centres is establishment of fully integrated system for the design of complex production. Such system should enable to bring new technologies into industry as well as into education.

Such solution will support the education of future designers, designers of manufacturing systems, technologists and managers. Any university is obliged to educate students who will be able to design competitive products and production systems by the application of advanced information technologies.

The dynamic development currently undergoes in the companies running business in the HighTech sphere application of Digital Factory systems. Some years ago we have started, University of Bielsko-Biała with University of Zilina, and now we continue research connected with building of such complex Digital Factory systems [6, 9, 13].

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Zarządzanie produkcją z wykorzystaniem narzędzi cyfrowej fabryki

Streszczenie: Współczesne technologie informatyczne są podstawowymi narzędziami gromadzenia i wymiany informacji w przedsiębiorstwach. Oprogramowanie „cyfrowej fabryki" jest coraz częściej stosowane w procesach zarządzania. W artykule przedstawiono koncepcję cyfrowej fabryki, zasady, sposoby i obszary jej stosowania, oraz korzyści dla przemysłu.

Słowa kluczowe: cyfrowa fabryka, komputerowe systemy wspomagania zarządzania

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