Digital Transformation of Manufacturing Towards Industry 4.0 Concept

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Abstract. Markets are nowadays oriented towards high quality products that are produced in small series production with fast delivery dates. Therefore, manufacturing companies are forced to adapt their production processes and make them more flexible and efficient. In that sense, this paper presents digital transformation of manufacturing as a concept of product innovations in which conventional methods and models are replaced by digital ones through all stages of product lifecycle. Digital transformation or digitalization of manufacturing refers to the interaction between physical and digital models within the production process. That is the crucial step towards the implementation of the Industry 4.0 concept which is fully focused on the integration of manufacturing with information technologies and digital services.

1. Introduction
Reduction of product lifecycle and changes resulting from frequent modifications in production program, increase requirements for much faster and more efficient transfer of information between engineers as well as other participants involved in planning and manufacturing processes. Application of the concept of digital factory, in other words, digital manufacturing, facilitates transfer of information which also leads to faster reduction of new product development time. Complete digitalization of manufacturing represents the framework for the implementation of novel technologies such as Smart Factory and Industry 4.0 concept [1, 3].

In recent years, implementation of information and internet technologies has accelerated the integration of engineering activities, equipment and all other components involved in planning and manufacturing. Digitalization has brought many innovations in the fields of product development and production preparation.

2. Digital engineering
Digital engineering accelerates the product development cycle, from design to its use, thereby increasing efficiency of engineering processes through the integration of CAX and PLM systems. Efficient exchange of digital information within the engineering processes is achieved in this way, figure 1.

Modern software tools enable the cooperation among project teams based on the exchange of digital information which ensures greater innovation and better quality, while reducing the new product cost and time to market. Frequent product changes result in the occurrence of multiple product
variants and digital engineering brings new tools and methods for efficient work administration during all stages of product lifecycle for various product variants and customer needs, figure 2.

By applying engineering information in a digital form, an analysis and evaluation of products, its functions and manufacturing conditions can be performed. In doing so, starting parameters include targeting cost, expected sale, possible prices as well as required resources for the planned product. In this way, planned costs are defined in the earliest stage of production planning.

Stages that follow are product design, including various engineering analyses of future product’s characteristics, then definition of process plans and planning of direct manufacturing processes. Management of digital information also involves sales analysis, maintenance as well as recycling of end-to-life products. Efficient analysis of all stages with product lifecycle also includes continuous collaborative work among all subjects involved in digital engineering processes.

The digital engineering framework contributes to the efficient solving of engineering tasks and provides:

- Reduction of planning errors,
- Increase in productivity,
- Reduction of time losses,
- Reliability of products,
- Introduction of innovations etc.

Digital manufacturing is a universal concept for the entire network of digital models, methods and tools, including simulation and 3D visualization, integrated with a continuous data management system. Digital manufacturing represents the integration of virtual and real manufacturing, figure 3.
Therefore, the concept of digital manufacturing is considered as an integrated concept aimed at improvement of products and engineering activities with production process and simulation. Different forms of simulation can be applied in virtual models on different levels of planning in order to improve products and manufacturing processes. Thus, digital manufacturing represents the simulation of all activities in the field of research and development as well as in the field of production processes.

Vision of the concept of digital manufacturing focuses on the integration of available methods and tools for design and control of products at different levels of manufacturing and operational control with the company. Consequently, the concept of digital manufacturing integrates the following elements [1, 5]:

- Product development, testing and optimization,
- Development and optimization of process plans,
- Production system planning and improvement and
- Operational production planning and control.

Digital transformation of manufacturing can also be viewed as the information strategy of a company for improvement and collaboration of production processes in global environment [2, 7]. The concept of digital manufacturing includes modelling of products, processes and resources on the basis of real data. Planned products as well their processes are intensively verified and enhanced using virtual models until they are fully developed [6]. When all potential errors are eliminated, then the models can be applied in real manufacturing.

3. Goals of digital transformation of manufacturing
Digital manufacturing is a technology or a discipline that provides a strategic approach for development, implementation and optimization of all elements of a production process. The concept of digital manufacturing covers a network of digital models and methods used for defining all aspects of a production process in companies of the future [4]. Digital manufacturing environment represents the combination of a digital product and digital processes and resources. That means the framework that integrates a virtual manufacturing model with real physical model.

Digital transformation of manufacturing includes the following aspects:

- Process definition,
- Process planning,
- Modelling of production system,
- Visualization,
- Simulation of operations,
- Analysis of ergonomics,
- Study of manufacturing time,
- Study of productivity,
- Balancing of production lines,
- Analysis of alternative resources,
• Automation of manufacturing and
• Programming of control structures.

The concept of digital manufacturing starts with defining and planning of manufacturing processes, then managing information on manufacturing processes which serves as a condition for efficient collaboration, figure 4.

Figure 4. Framework for manufacturing process control using digital manufacturing

Simultaneous product design and process planning is the principle applied in concurrent engineering. In this way, process planning is carried out not only to define product shape and its functional criteria, but to simultaneously determine manufacturing and technological criteria as well. Different simulations and engineering analyses result in the optimal product design and optimal process plan and after validation, the adopted solution is applied in a real manufacturing system. Results of manufacturing operations are further analysed and they represent useful information within the digital reengineering of products and manufacturing operations. Also, digital manufacturing includes integration with equipment for direct manufacturing and control, systems for enterprise resource planning, supply chains and other relevant factors that have an impact on the production plan, Figure 5.

Figure 5. Digital manufacturing-synthesis of process planning and production execution
Digital transformation of manufacturing is an integrated solution package for planning of production processes and visualization using tools for virtual simulation which enables engineers to optimize production processes.

Therefore, this concept integrates various tools for:
- Product design,
- Engineering analysis,
- Process planning,
- Control of machining systems,
- Time management and business applications,
- Planning the allocation of production processes,
- Ergonomics,
- Robot work simulation,
- Production planning,
- Product lifecycle management,
- Simulation of production processes,

4. Digital manufacturing and Industry 4.0

Digital manufacturing plays a crucial role in the development of enterprises on the principles of Industry 4.0 concept, as it supports innovations and improvements of product development [3]. This technology provides shorter time to market and reduces development and manufacturing costs.

Application of digital manufacturing opens the possibility of efficient monitoring and improvement of a production process by using and controlling data related to the development, planning and validation of production resources. The goal is to integrate data from different areas in the domain of product design and production, Figure 6.

**Figure 6.** Integration of processes from the domain of product design and the domain of production

The starting point in the application of Industry 4.0 is the application of the concept of digital manufacturing as it provides the following [5]:
- Definition of logistical standards that can be applied to different products,
- Time saving for correction of possible errors in process and production planning,
- Optimization of logistics planning,
- Standardization of assembly processes,
- Optimization of planned time norms in all stages of production and
- Efficient collaborative data management in the domain of product design and production planning.
Information exchange and engineering collaborative processes are crucial in digital manufacturing and the implementation of Industry 4.0 technologies [3,7], Figure 7.

![INDUSTRY 4.0](image)

**Figure 7.** Industry 4.0 technologies and tools based on the digital transformation of manufacturing

5. **Conclusions**

Digitalization of manufacturing is a critical step towards the application of novel technologies that are presented within the Industry 4.0 concept. It is necessary to digitize not only physical models of complex products, but also production processes, systems, resources and other elements that are a part of product lifecycle. That is the only way for manufacturing companies to respond to future technological challenges and improve their efficiency in modern business. One of the important reasons for digital transformation of manufacturing is efficient communication between the experts responsible for solving common problems and successful achievement of common goals. That primarily relates to the optimization of products and processes which leads to significant reduction in development and manufacturing costs.

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