Application of digital twins in specific manufacturing processes

M Olender-Skóra
Silesian University of Technology, Faculty of Mechanical Engineering, Department of Engineering Processes Automation and Integrated Manufacturing Systems, Konarskiego 18A, 44-100 Gliwice, Poland

E-mail: malgorzata.olender-skora@polsl.pl

Abstract. Following the requirements of the modern economic environment is a challenge for entrepreneurs. The more, that there is an increasing need to manufacture product for individual customers, the so-called customization approach. As a result, the production is individualized, so that the repeatability of products and stocks is low. This forces companies to apply specific organizational development strategies such as Lean and Agile. It also forces an increase in flexibility of the implementation of individual production tasks of enterprises. Increased production flexibility, at the same time, influences a greater number of decisions made, data generation and the use of enterprise resources. For this purpose, entrepreneurs use various simulations approaches, including applications for simulation of complex production processes, but nowadays they are increasingly leaning towards the so-called digital twins. The article presents the possibility of using a digital twin and the necessary data required to make such a twin in order to reflect the actual activities carried out in production.

1. Introduction
Following the changing on the market, manufacturers are looking for solutions, that will help them achieve specific goals, not only in terms of new manufacturing perspectives, materials or business processes. Due to market dynamics and increasing customization of products, there is a need for solutions, which will also accelerate the process of task execution and analysis, but also in the decision-making process [1-4]. In order to appropriately coordinate, execute and efficiently implement processes, the concept of a digital twin is increasingly being used. With regard to this term in the first step data is required, which, in addition to appropriate IT solutions, is the basis for the realization of the digital twin [5, 6].

In the article the algorithm of creating a digital twin, the required data from different areas of the enterprise, which are the basis for the transformation into a digital twin are showed. Barriers to the implementation of such solutions are also indicated. In addition, a simulation model of the production process, which is also one of the forms of a digital twin is also showed.

2. Digital twin
Over the past few years, the definition of a digital twin has changed. However, there is still no specific constant definition for this term. Many authors have attempted to clarify and systematize this increasingly popular concept. In the table 1 are showed example of definitions of a digital twin.
Table 1. Definitions of a digital twin [7].

| Authors and (year) | Definitions |
|--------------------|-------------|
| Grieves, (2014)    | “Virtual representation of what has been produced” |
| Söderberg et al., (2017) | “Using a digital copy of the physical system to perform real-time optimization” |
| Qi and Tao, (2018) | “Virtual models of physical objects are created in a digital way to simulate their behaviors in real-world environments” |
| Kannan and Arunachalam, (2019) | “Digital representation of the physical asset, which can communicate, coordinate and cooperate the manufacturing process for an improved productivity and efficiency through knowledge sharing” |

These definitions are also changed due to the development of technology, new solutions, the ability to implement these solutions in the company, but also because of intention of the company to make changes [8-11]. However, the basis is the appropriate use of data and resources, in order to flexibly realize the production, from the stage of product design to receipt the product for customers. The implementation of a digital twin requires the merging of multiple levels in the enterprise. In the first level is data. Data, which are extracted from multiple areas of the enterprise at the same time. And accordingly, depending on, which stage will be reflected as a digital twin, the required data are changes. However levels about management, monitoring are important to, as a complete process, in which the relevant management tasks are realized and also integration of all planes of the enterprise.

Therefore, the appropriate data is needed to create a digital twin. And accordingly, depending on the area of the enterprise, different data are required. An example of the data extracted for the execution of a digital twin, as a complete enterprise are showed on figure 1.

![Figure 1. Data extracted for the creation of a digital twin.](image)

Data are the basis for creating a digital twin, however, they differ depending on whether the whole company or only a part of it, will be transformed into a digital version, e.g. production processes and the production preparation area.
The following section of the article describes the digital transformation of a selected manufacturing process in an enterprise.

3. The digital twin of the process
In connection with the creation of a digital twin for a manufacturing process, the first step requires data, which is the input data for the manufacturing process. The input data are: number of machines, routes, number of employees, warehouses, internal transport, number of robots, operation times, etc. Knowing this data, a simulation model is developed and simulations experiments are performed. An example of process simulation is showed in figure 2. The model consists of several machines (processor), operated by workers, a robot, and warehouses. To complete the items on the line, transport vehicles are used.

![Figure 2. Model of process in FlexSim.](image)

By creating a digital twin of the manufacturing process, it is possible to continuously testing, analyzing, and making improvements and retesting to get the best results. In this way, many improvements can be made without actually testing them in reality. This solution allows to save time and money, because changes on the line are implemented, when the results of simulation tests are satisfying. The output data from the simulation for example are: process bottlenecks, storage problems, transport problems between machines, idle times, productivity, lead times, machine layout, etc.

Additionally, in article, in order to illustrate the creation of a digital twin for a manufacturing process, an algorithm was developed (figure 3). This algorithm consists of several steps, that show what data are needed, what should be done, in which moment, for create a digital twin.
Figure 3. An algorithm for creating a digital twin of processes.

The first step requires data, related to the preparation of production processes, resources, equipment. These data are usually in ERP/MRP systems (Enterprise Resources Planning/Material Resources Planning). But for the needs of the twin, these data must be available in databases for: data analysis, corrections, data about suppliers, dates of orders, periods of cooperation. And in future, these database will be necessary. With a digital twin, this data also becomes more available for decision making person from any place, which simplifies and speeds up the implementation of decision making
processes in this area. Then, on these data, appropriate simulations are created, both of production processes, as in the article, but also for analysis of individual components and models in CAD programs. These documents also are transferred to the database for further analysis and interpretation. The advantage of the digital twin of such documentation is the fact, that employee have access to the developed documents and models at any time. This is particularly important at the time of flexible production and small series, repeated from time to time, which is characteristic for the so-called customization of products. This is also intended for introduce certain standards both in terms of product performance, but also in terms of how the company operates, when production are changed. Then, having the input data, including the routes, the production schedules are also developed. By making them in digital version, the required changes can be made at any time. The last and most important factor is to have digital equivalents, on which analyses and tests are performed, which are constantly monitored. So changes are made faster because the decision makers have access to them all the time and not only by the one person. Transparency of data and analysis results also allows for make more effective strategic and tactical decisions, that influence on the functioning of the whole enterprise.

The benefits of introducing a digital twin are significant, however, there are also some barriers to implement these solutions, that keep manufacturers from introducing them into enterprises.

4. Barriers for creating a digital twin

4.1. Required data
Under creating a digital twin, exist a few main concerns, that make manufacturers afraid of this type of solution. The first barrier is the production data which are processed. This data are often the basic data, on which the functionality of not only the production process, but also the entire enterprise is based. In this area there are data about suppliers, lead times, costs, set of machines, employees, failures, etc. In addition, this area includes also all documentation, i.e. CAD drawings, standardization cards, quality cards, machine breakdown cards, results from analyses and simulations, etc. With such a wide range of data, manufacturers are afraid, that by creating a digital twin of the documentation and this data, the data will leak.

4.2. Simulation of manufacturing processes
Due to the implementation of the digital twin in this area, the most common problem for manufacturers, especially for small manufacturers is the problem of access to appropriate software. The second problem is the results of the analyses and simulations, that are made, as well as the improvements made in the simulations.

4.3. Reading data from machines and robots
In this area, the problem connected is to generate data from multiple machines, equipment and robots at one time and in a real time. This is a large amount of data that, in order to be used as a digital twin, must be properly stored. Appropriate databases and folders must be available to store them, because these data are also analyzed. Also, improvements and changes are made based on them. Reading of data from machines and equipment is realized by PLC, HMI panels integrated with code scanner or other sensors. This also involves a high level of integration of the company's IT systems.

4.4. Standardization
Realization of manufacturing requires many tasks to be performed at the same time. However, at each level of production, realization must be at the highest level of quality. For this purpose, standards are introduced for the implementation of individual production tasks, so that each shift of employees make products, that have to fulfill specific standards. Also, in this aspect, thru creating a digital twin, all standardization cards, instructions and procedures for the implementation of work, should be available in digital version in the databases of the enterprise, so that every employee could have access to them.
But a barrier in this area is also access to the database for every production worker and the reluctance of workers to use such solutions.

4.5. Appropriate IT infrastructure
In terms of IT infrastructure, the biggest problem with the digital twin is building the right databases to store the data, and the servers. Currently, mostly databases are created in the cloud. However, a large number of manufacturers are afraid of data leakage and loss of all sensitive data.

4.6. Data security
Due to the collection of large set of data, enterprises are increasingly deciding to store them in the cloud. This is a flexible solution, in which dedicated people have access to data from any place. However, data leakage is a problem. Losing data can cost a company huge money, because some of this data is confidential. In this area, it is necessary to monitor movements on servers, but also to implement appropriate security solutions.

5. Conclusions
Changing customer requirements and a changes in the market are also visible in functioning of enterprises. These enterprises are looking for solutions, that will support them in the implementation of the required tasks, especially since production takes place under a specific customer, so-called customization. Combined with available technologies, to better organize planning and management, enterprises are increasingly taking advantage of the ability to create a digital twin, both in production processes and the entire enterprise.

In the article describes the definition of a digital twin. The possibility of its, creation on the basis of an exemplary production process is indicated. An algorithm for creating a digital twin has also been developed. In addition, in the article points out the barriers, that hold back individual manufacturers from introducing digital solutions in enterprises.

6. References
[1] Foit K, Golda G, Kampa A 2020 Processes 8 1648 (doi:10.3390/pr8121648).
[2] Sekala A, Gwiazda A, Kost G and Banas W 2018 IOP Conf. Ser.: Mater. Sci. Eng. 400 052009 (doi:10.1088/1757-899X/400/5/052009).
[3] Olender M 2020 IOP Conf. Ser.: Mater. Sci. Eng. 916 012079 (doi:10.1088/1757-899X/916/1/012079).
[4] Krenczyk D, Olender M 2018 IOP Conf. Ser.: Mater. Sci. Eng. 400 022036 (doi:10.1088/1757-899X/400/2/022036).
[5] Kannan K, Arunachalam N 2019 J. Manuf. Sci. Eng. 141(2) 021015 (doi:10.1115/1.4042076).
[6] Yan Hong Lim K, Zheng P, Chen Ch-H, Huang L 2020 J. Manuf. Syst. 57 82-93.
[7] Lim KYH, Zheng P and Chen C 2020 J. Intell. Manuf. 31 (doi:10.1007/s10845-019-01512-w)
[8] Valilai OF, Houshmand M 2013 Robot. Comp. Integ. Manuf. 29(1) 110-127.
[9] Krenczyk D, Kalinowski K, Ćwikła G, Kempa W, Grabowik C, Papiroca I 2020 Inter. J. Mod. Manuf. Techn. XII(3) 65-71.
[10] Liu J, Zhou H, Tian G, Liu X and Jing X 2018 Int. J. Adv. Manuf. Tech. 100(5-8) 1619-1634.
[11] Olender M, Kalinowski K, Grabowik C 2019 Intel. Sys. Prod. Eng. Maint. 835 (doi:10.1007/978-3-319-97490-3_38).