PAPER • OPEN ACCESS

The use of digital twin in the industrial sector

To cite this article: A P Rozhok *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **815** 012032

The use of digital twin in the industrial sector

A P Rozhok[1,2 *], K I Zykova[1, **], S P Suschev[1] and R Revetria[2]

[1] Department of ecology and industrial safety, Bauman Moscow State Technical University, 5/1, 2ya Baumanskaya st., Moscow, 105005, Russia
[2] Department of mechanical, energy, logistics engineering management, University of Genoa, Genova, 16126, Italy

* rozhok_anastasiya@mail.ru
** zykova.ki@bmstu.ru

Abstract. The paper discusses one of the most active areas of production digitalization, capable of reducing the risks of environmental pollution - a solution for the virtual representation of the real static and dynamic characteristics of a technological system, briefly called “Digital Twin”. The concept and classification of Digital Twin are described. The application of Digital Twins is also considered, starting with the analysis of the work of smart products in real operating conditions and ending with the creation of a fully digital robot factory.

Currently, industrial enterprises rely on highly sophisticated machine tools consisting of several hundred components that must be monitored and maintained to avoid unexpected failures. To solve this problem and protect the production line from stopping, it is necessary to have information on the technical condition of each production resource and its components [1]. In the end, this information allowing to choose the right maintenance planning. As the technology of machine servicing appeared, diagnostics gradually appear in all areas of mechanical engineering [2, 3].

This technology is Digital Twin – these are digital representations of physical objects or environments that exist in the real world. Digital Twins are becoming indispensable in the industry for a variety of reasons. Using Digital Twins, operators can better understand their systems – from measuring wear levels in equipment to analyzing traffic flows in smart city road networks, and assessment of its impact on the environmental situation [4] When it is necessary to make changes, those responsible for such systems can also the first experiment with the Digital Twin, without risking unplanned downtime or disruption of the real-world model [5-6].

The application of the Digital Twin in industry solves the issues of safety, labor protection, environmental safety, and economic efficiency. The Digital Twin makes it possible to design and operate industrial production with full control of compliance with technological regimes and environmental factors. As a result of the application of Digital Twin technology in the industry we get production in which the minimum load on nature is provided, the probability of various technogenic accidents is reduced many times. It is an opportunity to conduct certain production and technological experiments not on expensive equipment, sacrificing precious time resources, but in a virtual digital environment, negating the risks associated with damage and downtime of equipment, threats to human health and the environment."

Digital Twin products include [7]:

- geometric and structural model of the object;

- a set of calculated data on parts, nodes, and products in general;
- mathematical models describing all physical processes occurring in the product;
- information on technological processes of manufacturing and assembly of individual elements and the product as a whole;
- product lifecycle management system.

Digital Twin is used at all stages of the product life cycle, including design, manufacturing, operation, and disposal [8-10].

At the stage of preliminary design: variants of a computer model of the product being developed are created to evaluate and select possible technical solutions.

At the stage of technical design: the variant selected at the previous stage is finalized and refined using element models. The resulting product model allowing to take into account and optimize the interaction of all elements, taking into account operating modes and environmental influences, which can already be called the Digital Twin of the product being developed.

At the manufacturing stage: the developed model helps to determine the required manufacturing tolerances to achieve the required characteristics and ensure a trouble-free operation of the product throughout the entire service life, as well as allowing to quickly identify the causes of malfunctions during the testing process.

At the operational stage: The Digital Twin model can be finalized and used to implement feedback to adjust the development and manufacture of products, diagnostics, and prediction of malfunctions, increase work efficiency, to identify new consumer requests.

Let us consider in more detail the various classifications of Digital Twins. Michael Grieves in his work identified three types of Digital Twins (Figure 1): DTP - Digital Twin Prototype, DTI – Digital Twin Instance, and DTA – Digital Twin Aggregate. Next, we consider each of these twins in more detail [4, 11].

Digital Twin Prototypes contain the information needed to describe and create physical versions of product instances. This information includes geometric and structural models, technical requirements and conditions; cost model, settlement (design), and technological model of the product. DTP can be considered a conditionally constant virtual product model.

Digital Twin Instance describes the specific physical instance of the product with which the twin remains connected throughout its life. Twins of this type are created based on the DTP-twin and additionally contain production and operational models, which include the history of the manufacture of the product, the applicability of materials and components, as well as statistics on failures, repairs, replacement of components and assemblies, etc. Thus, the DTI-twin of the product is exposed to changes by changes in the physical instance during its operation.

Digital Twin Aggregate is defined as an information management system for a physical instance of a product family that has access to all of their digital twins.

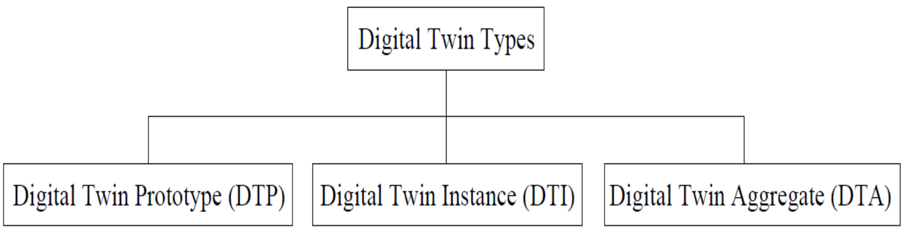

Figure 1. The types of "Digital Twins" according to Grieves.

Classification of production system Digital Twins [12-13]:

- Digital Twin of the entire production system (PS);
- Digital Twin of the production line;
- Digital Twin of a specific asset in the production line.

IOP Conf. Series: Earth and Environmental Science **815** (2021) 012032 doi:10.1088/1755-1315/815/1/012032

Digital Twin of PS includes:

1. The PS engineering model, which contains a digital description of the enterprise's resources, the structure of production assets, technological equipment, product range, and manufacturing technology, and a system for collecting information about the current state of equipment.
2. The PS operating model, which is a digital platform for describing the enterprise's logistic structure, creating production schedules, inter-workshop and external cooperation, including technical maintenance and equipment repair regulations. The dynamics of intra-workshop material flows are also subject to mathematical description, based on digitalization of which optimal production schedules of work performed are formed.

The most difficult for practical implementation is the operational model of Digital Twin PS, which, in particular, has the following functions [14]:

- to make the necessary calculations for making management decisions;
- to display in real-time the production processes taking place in the production system;
- to conduct various experiments of «what-if» scenarios by mathematical modeling of production processes.

An important task of the operational model of the Digital Twin production system is to minimize possible failures of technological equipment due to timely maintenance and repair (M&R). One of the most advanced types of maintenance is predictive maintenance. It allows to make repairs not according to a pre-drawn-up plan but when it becomes necessary. This implies not the elimination of a malfunction that has already occurred but the prevention of equipment failures by interactively evaluating its technical condition from the totality of data from the sensors and determining the optimal timing for repair work [15,16].

Digital Twin can serve as one of the predictive maintenance tools, which allows simulating various options for complete and partial failures, the operation of devices taking into account their operating modes, environmental influences, and various degrees of wear of parts. Digital Twins allowing repair crews to be well informed and arrive at the place of work already with all the necessary spare parts, tools, and instructions necessary for maintenance [17, 18].

At the level of the operational model of Digital Twin PS, M&R functions are taken into account as additional operations optimized in the operational production plan so that they minimize the speed of the processed products through the production assets of the enterprise. This task is performed by software designed for operational production scheduling.

If in the West the use of Digital Twins is already becoming the standard in the industrial field, in Russia they have not yet become widespread. Nevertheless, the country's leading companies in various industries have already adopted new technology.

Among the first, the oil and gas sector began to show interest in it - advanced technologies were always introduced in this industry, and in addition, it was stimulated by current oil prices and increasing competition from alternative energy sources [19]. For example, ROSATOM announced plans to create digital nuclear power plants that will repeat real-life stations one by one. This will allow not only collecting and effectively applying data on the operation of each individual piece of equipment but will also create opportunities for modeling and predicting the operation of objects in various conditions and modes.

The course on digitalization also holds the mechanical engineering sector. So, in 2017, automobile corporation KAMAZ entered into a partnership agreement with Siemens to transition to digitalization and introduce Industry 4.0 solutions into production processes. At the moment, as a result of cooperation, 3D models of 20 universal machines, 28 numerically controlled machines, and several dozen pieces of equipment, including robots, tilters, manipulators, roller tables, etc., have already been developed. KAMAZ uses them to simulate assembly, machining, and other technological processes.

The technology for creating virtual twins also formed the basis of the Russian Railways «Digital Railroad» project, which organized the work of a data processing and analysis center responsible for the diagnostics and maintenance of "Lastochka" trains from "Ural Locomotives".

For the Digital Twin to perform its intended functions correctly, it is necessary to keep it up to date, which is achieved through the implementation of the Digital Twin's direct relationship with production assets, also taking into account the current state of manufactured products. To solve the problem of constant updating of Digital Twin, the technology of the Industrial Internet of things (IIoT) is used. With its help, sensors and other data acquisition equipment are connected with existing production control systems and with the operational model of Digital Twin PS. The installation of sensors on a real device is carried out in the process of implementation IIoT at the enterprise [20].

It should be noted that without the creation of Digital Twins of manufactured products, it is impossible to introduce modern Product Lifecycle Management technology (PLM). IIoT and PLM are integral attributes of a «smart factory». Its characteristic feature is the formation and use of a digital model of material flows, i.e. Digital Twin is no longer a separate product but a production system [21].

The results of a literature review are the following eight identified advantages of Digital Twin.

1. Remote monitoring and control in real-time. As a rule, it is practically impossible to get a detailed idea of a very large system physically in real-time. Digital Twin, by its very nature, can be accessed anywhere. System performance can be remotely monitored using feedback mechanisms.
2. Improving efficiency and safety. It is assumed that digital backup will provide greater autonomy in the cycle as needed. This will ensure the distribution of dangerous tasks for robots, and people will control them remotely.
3. Predictable maintenance and planning: comprehensive digital backup ensures that multiple sensors that track physical assets generate real-time big data. Thanks to data mining, faults in the system can be detected well in advance. This will improve service planning.
4. Scenario and risk assessment: Digital Twins will allow the analysis of what-if scenarios, which will lead to a better risk assessment. It will be possible to outrage the system to synthesize unexpected scenarios and examine the system's response, as well as appropriate mitigation strategies. This analysis, without prejudice to a real asset, is only possible with Digital Twin.
5. Improving interaction within and between teams: with greater autonomy and all information at the fingertips, teams can better use their time to improve interaction and collaboration, which leads to increased productivity.
6. A more efficient and informed decision support system. The availability of quantitative data and advanced analytics in real-time will help in making more informed and quick decisions.
7. Personalization of products and services. Given the detailed historical requirements, preferences of various stakeholders and changing trends, and competitors in the market, the demand for individual products and services will inevitably increase. The Digital Twin in the factories of the future will allow faster and smoother gear shifts to meet changing needs.
8. Better documentation and communication: readily available, real-time information combined with automated reporting will help inform stakeholders, thereby improving transparency.

The results of the literature review confirm real objects, for example, a pilot project to create a fully digital robot factory, where the application of the points obtained in our study will allow the company to reduce costs, increase process efficiency, and rebuild the business process so that the system processes the information practically instantly, which will lead to improved interaction within and between teams.

The factory will operate without human intervention on remote monitoring, which will increase efficiency and safety; artificial intelligence developing new products and a transportation system that independently manages shipments. This is not about the distant future. Soon, a similar picture can be observed on the bitumen assets of “Gazprom Neft”. They should become the platform for working out the elements of the digital transformation of the company.

The system itself will compose a scenario and evaluate the risk, which will avoid future damage to the company and will also predict maintenance and planning, thanks to intelligent analysis. However, it will not be possible to limit only to developing the software part. If we take as an example one of the most, at first glance, simple elements of the logistic scheme – the movement of a single bitumen truck - then here the task is much more complicated than it seems. To build the optimal route and precisely observe the traffic schedule, it is important to know everything to the smallest detail: when the car arrived at the factory, through which security checkpoint passed, how fast did it go to the loading riser, what load was at that moment on the loading riser, what actual volume was loaded into the tank when the car left the checkpoint. Modern means allowing not only to track but also to calculate the full path of vehicles from the moment of appointment to unloading. However, for this it is necessary to use a huge set of electronic devices, allowing at any time to assess the state of a process. That is, we are talking about the introduction of automated monitoring systems in all parts of the logistics scheme, which characterizes the eighth point.

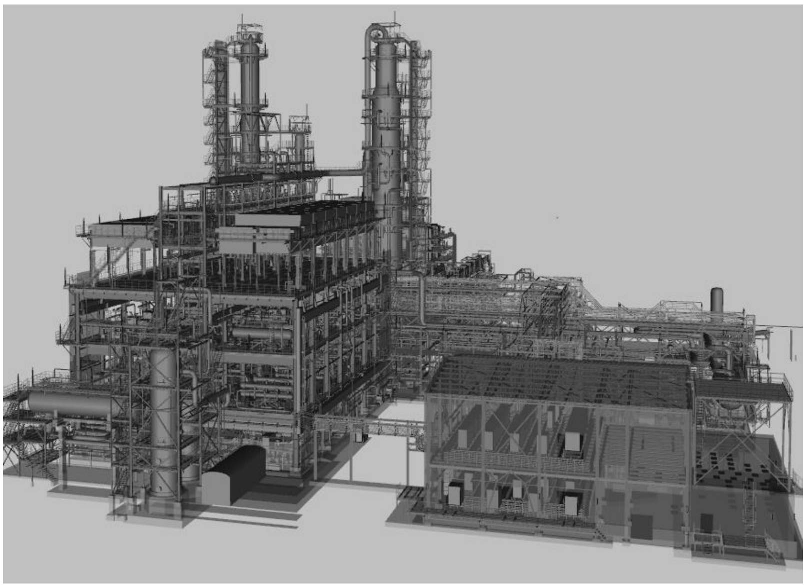

Figure 2. A pilot project to create a fully digital robot factory [22].

Given the urgency and increasing number of cases with severe environmental consequences arising from accidents at oil pipelines and refineries [23], the need to improve the reliability of these facilities is increasing, “Gazprom Neft” decided to robotize bitumen production, which, in fact, can be considered a mini-copy of the oil refinery factory but with fewer complex processes and technological risks.

A pilot project to create a fully digital robot factory will be implemented at one of the company's bitumen assets (Figure 2).

We believe that the implementation of all eight points identified above will have a beneficial effect on the further development of the Digital Twins market and increase the responsibility of developers and operators.

Digital Twins can significantly enhance the ability of enterprises to make proactive decisions based on big data, increase their efficiency and eliminate potential problems. They can also provide an opportunity to work out “what-if” scenarios in a safe and economical way, that is, in essence, experimenting with the future. The areas of the most intensive growth in the use of Digital Twins are resource-intensive industries such as industrial production, the oil and gas industry, aerospace and automotive industries, Digital Twin of which should contain a detailed description of physical and chemical processes, processes of energy consumption and production, parameters of input raw materials and manufacturing products. It is obvious that the implementation in the industrial field of the eight components of the Digital Twin competitive advantages we have identified is an urgent technical task.

By using Digital Twin methods, it is possible to reduce by an order of magnitude the number of full-scale tests, the number of attempts to work out technological processes, all those actions that are associated with the manufacture of real material part and its tests, which cost is much higher than the cost of mathematical modeling while reducing the risks caused by pollution of the environment, the impact on human health.

IOP Conf. Series: Earth and Environmental Science **815** (2021) 012032 doi:10.1088/1755-1315/815/1/012032

References

[1] Grieves M 2014 *White paper* 1-7

[2] Shchurov I A 2018 Discrete Solid Modeling as Basis of Technological Systems Digital Doubles *IEEE 2018 Global Smart Industry Conference* 1-8

[3] Zainullin A M, Khusainov R M and Khusainova E R 2020 *Actual Problems of Science and Technology* 375-78

[4] Solyashinova O A and Maslova O A 2018 *Modern problems of life safety: intelligent transport systems and situational centers* 427-32

[5] Kostkova P 2018 *Life sciences, society and policy* **14** 16

[6] Huang X Liu, Q, Liu, H, Zhang, P, Pan, S, Zhang, X and Fang, J 2018 *Tunnelling and Underground Space Technology* **81** 187-208

[7] Zhu, S, Wang, M, Zhai, W, Cai, C, Zhao, C, Zeng, D, and Zhang, J 2018 *Construction and Building Materials* **187** 460-73

[8] Naveen K P and Sundaresan R 2018 *International Symposium on Modeling and Optimization in Mobile, Ad Hoc, and Wireless Networks (WiOpt)* 1-8

[9] Vlasov A I, Shakhnov V A, Filin S S and Krivoshein A I 2019 *Entrepreneurship and Sustainability Issues* **6** 1975-86

[10] Tarassov V B 2018 *Springer Cham International Conference on Intelligent Information Technologies for Industry* 26-40

[11] Michael W 2014 Grieves Digital Twin: Manufacturing Excellence through Virtual Factory Replication LLC, 7

[12] Vlasov A I, Berdyugina O N and Krivoshein A I 2018 *Global Smart Industry Conference (GloSIC)* 1-7

[13] Akberdina V, Kalinina A and Vlasov A 2018 *Problems and Perspectives in Management* **16** 201

[14] Frivaldsky M, Cuntala J, Spanik P and Kanovsky A 2018 *Electrical Engineering* **100** 11-25

[15] Carpentieri M, Tomasello R, Vergura S, Garesci F, Siracusano G, d'Aquino M and Finocchio G 2018 *Magnetics Letters* **9** 1-5

[16] Munteshari O, Lau J, Krishnan A, Dunn B and Pilon L 2018 *Journal of Power Sources* **374** 257-68

[17] Li Z, Du Y, Abu-Siada A, Bao G, Yu J, Hu T and Zhang T 2018 An Online Calibration System for Digital Input Electricity Meters Based on Improved Nuttall Window *IEEE Access* **6** 71262-70

[18] Rai J N, Jahangir A and Hoque I 2017 *Uttar Pradesh Section International Conference on Electrical, Computer and Electronics* 91-96

[19] Guan B, Yao L, Liu H and Shang Y 2017 *Optik* **131** 724-32

[20] Hall C A, Ignjatovic A, Jiang Y, Burr P A and Lennon A 2019 *Journal of Electroanalytical Chemistry* 1-5

[21] Adarsh C S D, Lakshmi T V and Kamaraju M 2017 *International conference of Electronics, Communication and Aerospace Technology* **2** 323-328

[22] https://www.gazprom-neft.ru/press-center/sibneft-online/archive/2018-september-projects/1863687/ Application date: 10.04.2021.

[23] Sredzhaddinova I Z and Solyashinova O A 2019 *Economic development in the XXI century: trends, challenges, prospects* 369-73