

Prospects for deployment of integrated production automation systems using artificial intelligence

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Abstract. The article considers the directions of application of artificial intelligence in the deployment of integrated systems of production automation at all stages of the product life cycle: design and engineering, production, equipment control, control and monitoring during production and operation, in-process logistics and management of interaction with suppliers and customers. Three strategies for the implementation of complex production automation systems using artificial intelligence are proposed: a strategy for solving local production and technological problems, a strategy for the development of virtual reality technologies, and a strategy for comprehensive digitalization within the framework of Industry 4:0.

1 Introduction

In the context of unprecedented sanctions against the Russian economy, it is critical for defense industry enterprises to adapt to the multiplied demand for goods based on the use of their production, technological and innovation potential, technology transfer, and methods of state support. The key tasks facing the defense industry complex are not only to scale up production, but also to develop the markets for high-tech dual-use and civilian products freed up by the departure of foreign suppliers.

In the current situation, it is necessary to initiate processes in the domestic defense industrial complex:

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- reduction of time and costs for product development, production and modernization;
- rapid introduction of best practices and product samples;
- development of solutions for creating world-class high-tech products using new production technologies and cross-industry and interdisciplinary competencies of engineers and scientists;
- creation and/or development of bases for in-house R&D;
- product life cycle management.

2 Artificial intelligence in factory automation

The solution to the challenges faced by the defense industry is based on the introduction of complex production automation systems using artificial intelligence.

In general terms, a complex system of production automation is a set of mathematical methods, technical means, communication means, devices for displaying information, data transmission and organizational complexes that provide rational control of a complex object or process in accordance with a given goal [1-4]. As part of automated systems: information, mathematical, technical and software training. Complex systems of production automation have a hierarchical structure and unite in the control process subsystems of equipment control, technological processes, product parameters at different stages of its production, etc.

The level of development of modern production determines new requirements for control systems of multistage and multilevel production processes, which can be realized on the basis of artificial intelligence.

Artificial intelligence is "a direction in information technology that allows to endow machines with the ability to imitate human intellectual behavior. The ability of artificial intelligence to independently obtain knowledge in the process of work is provided by solving machine learning tasks [5].

There are two most promising directions of artificial intelligence development:

- machine vision (market forecast up to \$25 billion by 2024);
- machine learning - the ability of artificial intelligence to independently acquire knowledge in the process of work (market forecast up to \$100 billion by 2025) [6].

The development of information and communication management methods and artificial intelligence technologies allows for the introduction of machine learning mechanisms based on the results of automated data collection and processing. Introduction of artificial intelligence allows to fully automate operational management of technological processes, control of equipment operability, control and measuring devices, adjustment and correction of equipment modes, rational implementation of technological processes within the framework of technological regulations on the basis of machine learning based on the results of analysis of technological experience. Machine learning algorithms are used to process large data samples, manage inventories, in-process logistics, and maintenance processes.

The application of artificial intelligence in industry contributes to increasing the level of production automation up to the exclusion of human participation. In the process of implementation of methods and technologies of artificial intelligence, such functions as development of innovative products, research of new technological directions, provision of complete enterprise management based on data analysis and deep learning methods of networked large-scale cyber-production systems will be developed.

The introduction of artificial intelligence methods provides an increase in the accuracy of forecasting the development of production processes on the basis of solving data transformation problems. In particular, based on the application of boundary methods of calculation, equipment operation, dynamics and causes of deviations in the process of equipment functioning are analyzed, its critical states are predicted.

Artificial intelligence can be applied both at individual stages of industrial production and in general in production management, including:

- in the processes of product design and construction, including for text recognition in requirements management, document management, archiving of design documentation, creation of databases and knowledge bases;
- in the process of creating 3D models and digital doubles;
- in the process of testing individual assemblies, parts and product samples as a whole;
- in the production process as a technology for selection and optimization of technological modes and technological cycles;
- in the process of control to recognize errors and deviations from normative values of parameters, control of completeness of performed technological operations as a technology of multi-parameter control;
- in the process of equipment control for optimization of operating modes, prevention of breakdowns and determination of conditions for repair and maintenance;
- in the processes of intraproduction logistics to optimize routes;
- in the process of interaction with suppliers and customers;
- in the process of product operation, providing collection and analysis of information for the purpose of further optimization of design and technological parameters in production;
- in ensuring the safety of production processes [1, 7, 8].

The main regulatory and legal documents that define and regulate artificial intelligence in Russia include:

- Decree of the President of the Russian Federation dated 10.10.2019 № 490 "On the development of artificial intelligence in the Russian Federation";
- GOST P 59277-2020. Classification of artificial intelligence systems.

3 Artificial intelligence implementation strategy

Analysis of various sources allows us to propose three strategies for the implementation of complex systems of production automation using artificial intelligence:

- Strategy for solving local production and technological tasks, which include reverse engineering tasks, tasks of digitalization of individual technological processes.
- Strategy of 3D modeling development, implementation of virtual reality technologies, additive technologies, industrial Internet of Things.
- Strategy of digital transformation, implementation of Industry 4.0 technologies.

Within the strategy of reverse engineering, as an element of solving local production and technological problems, copying and modernization of products, units and parts of equipment, analysis of the reasons for failure of products are carried out.

Reverse engineering is the development of design documentation on the basis of an existing finished product or part. The result of this process is a 3D model, on the basis of which strength and other calculations are made, technical characteristics are determined and design documentation is created. All this is important when it is necessary to modernize or recreate technical objects in the absence of design documentation for them [5].

The strategy is used when it is necessary to ensure the production of foreign analogs of products, imitation of manufactured products, reduction of import dependence, as a way to create a base for conducting own R&D.

The positive effect of development within this strategy is the possibility of development of additive technologies, 3D-modeling, accumulation of experience in digitalization of production processes.

Reverse engineering uses software that allows to form libraries of unified assemblies and standard parts and their elements, 3D models and digital twins of products.

Reverse engineering involves the use of the following methods:

- allocation and description of individual elements and assemblies of the product;
- establishment of interrelationships between the elements;
- identification of interrelated and independent groups of elements;
- determination and description of input and output characteristics of the product components;
- use of requirements matrices for individual elements and the product as a whole.

The advantage of this strategy is the accumulation of knowledge and the formation of production and technological potential for the intensification of the enterprise's own innovation activities and the introduction of elements of digitalization of production and management.

The disadvantage of this strategy is the fragmented nature of reverse engineering, which implies the coverage of individual local production tasks.

In the process of implementing the strategy of 3D-modeling, virtual reality technologies, additive technologies, industrial Internet of Things development, there is an expansion of spheres of implementation of 3D-modeling and 3D-scanning methods, virtual reality technologies and work with big data at the enterprise.

This strategy promotes the involvement of the equipment management sphere in the processes of digitalization through the introduction of industrial Internet of Things methods, which makes it possible to provide a set of digital solutions in the sphere of managing the efficiency of product design, development and production. Based on the use of big data on changes in product characteristics in the course of its operation, optimization of product parameters (changes in design, materials, modes of operation, etc.) takes place.

From the point of view of formation of market competencies of the enterprise, this strategy is based on providing conditions for satisfaction of individual characteristics of consumers' needs in conditions of preservation of mass production trends (customization). The strategy allows to expand the range of manufactured products without resorting to expensive production methods, using additive ones. Digitization of physical objects within the framework of the strategy contributes to the improvement of production efficiency, development of digital production management methods, increasing its flexibility.

The advantage of this strategy is, on the one hand, to increase the efficiency of product development and production (cost and time reduction), and on the other hand, to expand and deepen markets through product differentiation and the creation of new product lines. The result is a clearer positioning on the markets, formation of segment strategies, increasing customer focus and competitiveness of the enterprise.

This strategy develops the processes of convergence of digital processes of enterprise management in general and production management, allows to identify the problems of ensuring the coordinated use of technologies of digitalization of production, management of marketing, financial and logistics activities of the enterprise, making management decisions of strategic nature.

This strategy also includes digitalization of interactions with suppliers, buyers and consumers of products.

The strategy of digital transformation, implementation of Industry 4.0 technologies is based on the idea of combining physical production with virtual development in real time. This strategy is considered in the conditions of increasing the efficiency of production and enterprise management as a whole, formation of models of production and business processes. The objects of digitalization are not only production processes and design, but also all management processes, management processes of interaction with customers and

suppliers. The integration of end-to-end digital technologies and sub-technologies is taking place, and a new level of sustainable digital development is being formed.

The advantages of this strategy include the possibility of digitalization of product lifecycle management (from design to operation and maintenance), the ability to manage interactions with suppliers and consumers, and the formation of flexibility and adaptation of the enterprise to changing external conditions.

The proposed strategies can be used sequentially as digital competencies are introduced at defense industry enterprises and as enterprises accumulate experience in digitalization Figure 1.

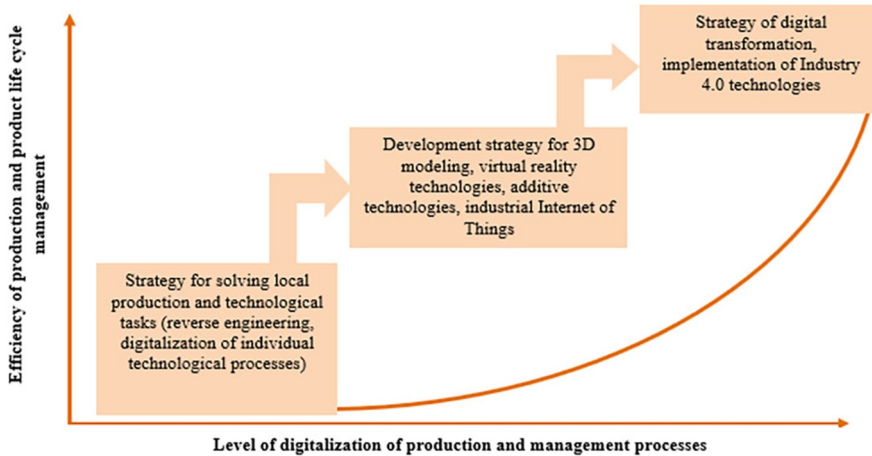


Fig. 1. Implementation strategies for integrated production automation systems using artificial intelligence.

4 Conclusion

Permanent introduction and implementation of strategies for the introduction of complex production automation systems using artificial intelligence will contribute to the creation and distribution of domestic product life cycle management systems supporting all stages - from concept creation to production, maintenance and utilization of products, the formation of digital platforms for the development of digital twins, providing, among other things, intellectual property management, expert support and product certification.

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References

1. N. Voenkova, *Ekonomicheskie strategii* **8**, 74-77 (2015)
2. I. Trauschweizer, *Journal of Military History* **80(1)**, 296-298 (2016)
3. I.A. Vdovin, A.D. Podzorov, *Business. Society. Power* **2-3(44-45)**, 22-32 (2022)
4. I. Kartsan, A. Zhukov, S. Pronichkin, *E3S Web of Conferences* **389**, 090056 (2023). <https://doi.org/10.1051/e3sconf/202338909056>

5. N.V. Cherepanov, S.P. Buslaev, *Innovations and Investments* **7**, 175-179 (2021)
6. A. Zhukov, A. Zaverzaev, G. Sozinov, I. Kartsan, *AIP Conference Proceedings* **246722**, 020025 (2021). <https://www.doi.org/10.1063/5.0092533>
7. A.I. Stankevich, *Volga region. Physico-mathematical sciences* **1(9)**, 134-138 (2009)
8. S.A. Tolkachev, *Economic Revival of Russia* **3(61)**, 127-145 (2019)