Computer-aided manufacturing: Industry 4.0

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Abstract. The modernization of the Russian economy and its transition to an innovative development path are inextricably linked with the renewal of production and its material and technical base. In recent years, there has been a tendency to increase the economic potential of highly developed countries through scientific, technological and technological innovations, with the State playing an active role. There is a trend towards a digital industry based on the so-called Industry 4.0. This leads to massive implementations of cyber physical systems in production, to the automation of most production processes, the endowment of devices with artificial intelligence and the introduction of many other modern technologies. All this has a significant impact on increasing productivity and reducing the cost of production.

1. Introduction
The concepts of Industry 4.0, the fourth industrial revolution are becoming increasingly popular, and they are becoming more than just words, behind them are real projects that come into our lives. The fourth industrial revolution is a combination of industry and digital technologies, leading to the creation of digital industries or smart factories and factories where all devices, machines, products and people communicate with each other through digital technologies and the Internet. In fact, Industry 4.0 is an industry connection to the Internet.

At the same time, the market becomes personalized, that is the development and production of products individually for each person becomes a priority. Industry 4.0 allows you to create mass production of individual orders, while the price of products will be lower.

2. History of transition to the fourth industrial revolution: Industry 4.0
The movement towards the fourth industrial revolution in the historical context is shown in figure 1. The first industrial revolution was the invention of a steam engine in the second half of the 17th century in Great Britain. But the period of revolution covers the XVIII-XIX centuries, in different countries the revolution did not take place simultaneously. Steam engines were used in pumps, then in locomotives, steamboats, as well as in production. Steam power has influenced the development of metallurgy, mechanical engineering, transport and other industries. There was a transition from manual to mechanical labor and a sharp increase in productivity was observed.

The second industrial revolution is associated with the invention of the conveyor by Henry Ford and in-line production. The period covers the times from the second half of the XIX to the beginning of the XX centuries. During this period, many other inventions were also born, the Bessemer method of steel smelting, as the first inexpensive method of producing high-quality steel, electric energy, widespread use of chemicals, telephone, telegraph, etc. Division of labor possible owl production using electricity.

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The third industrial revolution or «Digital revolution» took place at the end of the 20th century (since 1970) and is associated with the development of electronics, digitalization, computerization, information systems, as well as the invention of a robot. Electronics and information technologies have led to further automation of industrial production.

The fourth industrial revolution originates in 2011 [1] as the German public-private Industrie 4.0 program within which the German companies with assistance of the federal government in the form of grants create digital, clever productions which devices and products interact with each other and provide the personalized production. The concept of the fourth industrial revolution was formulated in 2011 by Claus Schwab — the president of the World economic forum in Davos. Claus Schwab in the fourth industrial revolution has seen global changes of mankind, in this revolution not products, and people and respectively the whole world will change more. Germany had to play the leading role through the strengthened integration of «cyberphysical systems», or CSP, factory processes. CSP is in fact the comprehensive term which is used in talk about integration of the small cars connected to the Internet and human work. For speedup of internetization of factory machines and machines the strategy of development of the industry «the Platform of the Industry 4.0» and the state program «the Industry 4.0» has been developed.

What distinguishes the fourth industrial revolution is the speed at which it can realize its potential for a significant and long-term impact on the economy, on inequality between developing and developed countries, on the labor force, on the price of products and on our societies. It is possible that when the automation process itself becomes automated thanks to technologies such as artificial intelligence, changes will accelerate to unprecedented rates.

![Figure 1. Transition to Industry 4.0.](image)

Today, it is Germany that leads in the pace of development of Industry 4.0. But similar programs are implemented in other countries, for example, in China – «Made in China 2025», in Japan – «Connected Facts» connecting factories to the network, in the USA – Industrial Internet, etc. In 2012, the non-profit Coalition of smart manufacturing leaders was created in the United States. It includes industrialists, suppliers, IT companies, government agencies, universities and laboratories. The goal of the organization is to create an open, smart platform for industrial IT applications. These programs will dramatically increase the competitiveness of data producers and they will become market leaders.
3. **Industry 4.0 principles**

In Germany, some principles of Industry 4.0 were formulated:

- **Compatibility**: all devices and machines must be able to communicate with each other in the same language through the Internet of Things, i.e. they must be compatible.
- **Transparency**: the creation of a digital copy of the product, the collection of data from microarrays and sensors through which devices communicate. As a result, the most complete information is accumulated about all processes that occur with equipment, smart products, production in general, and so on.
- **Technical support**: the software collects, analyzes, systematizes, visualizes sensor data and helps a person make a decision or make it automatically, thereby freeing up human resources. This support can also consist in the complete replacement of people with machines during dangerous or routine operations.
- **Decentralization of management decisions**: automation of various solutions by systems, maximum human replacement. Employees are assigned the role of supervisors who can connect in emergency and non-standard situations.

One of the important components of the digital industry is not product, but data. Digitalization of production is associated with data, large arrays of data that need to be read, collected, analyzed, systematized, processed, stored, transmitted, presented in the right form and much more. This requires appropriate information systems, software, wireless data transfer tools, cloud services for data exchange and storage.

Industry 4.0 covers all kinds of areas and technologies.

Industry 4.0 Technologies: additive technologies, 3D printing; modeling and visualization; integration of systems; internet of things; cyber security; cloud services; augmented reality and virtual reality [2]; autonomous robots, robotics; online planning and analysis; artificial intelligence; energy-efficient technologies; alternative energy; big data and analytics [3] remote maintenance.

Projects are born one after another, the field of activity is extensive, but the most famous of them, and which have already stated themselves can be cited as an example of Industry 4.0.

1. **Augmented reality glasses**. The worker, wearing these glasses, sees all the necessary instructions for his work. So at aircraft factories, glasses help recognize wires in aircraft and make the right connections for electricians.
2. **Simulation and visualization module**. When designing part processing in the CAM system, the programmer can simulate part processing on a virtual machine and make sure that there are no collisions of machine elements and gouging of the part.
3. **Software that allows you to connect machines to one network**. All information from the machines flows into this software, which systematizes the data, as well as signals about various events (simple, overheating, vibration, wear of nodes, operating time, etc.).
4. **Self-healing equipment**. When some wear of the machine parts is achieved, the machine will inform the mechanics about this and order the spare part itself at the manufacturer's factory or in the supply service of the enterprise, and also warn of imminent repair. It is implemented using special sensors on the machine. Breakage of the machine will no longer be a surprise, which will exclude equipment downtime.
5. **Automatic ordering of components**. The assembly of the product is guaranteed to receive all the necessary components and in the required quantity, since when receiving an order for the manufacture of the product, the system itself will check their availability in the warehouse and make an order of everything necessary in advance.
6. **The machine communicates with the workpiece and other objects**. The machine reads the necessary data from the microchip on the workpiece, how it needs to be processed, what tools it performs this processing.
7. Digital copy of the product. The electronic clone is endowed with all the characteristics of the physical product, which allows a more accurate analysis of the design.

8. Single digital space of industry.

9. Remotely set up equipment for smart products.

10. Monitor all production, process and other processes. For example, monitor product delivery from the manufacturer to the end user.

11. Internal movement of parts without human involvement.

4. Negative impact of Industry 4.0

There is also a negative side of the Industry 4.0 medal [4]. Mass robotization and automation will lead to the liberation of jobs, a large number of people may be left without work, retraining of specialists to other professions will be required, but many new professions will also appear.

The value of low- and middle-skilled labor will be drastically reduced, which can lead to a decrease in income and material benefits of the middle class. The transition to highly skilled labor is quite difficult and will not be available to everyone. The middle class is a broad segment of the country's population and a decline in middle-class incomes can lead to a collapse of the political system in the country.

There is also a premise that the low purchasing power of the population caused by Industry 4.0 will lead to low demand for products, and the profitability of many enterprises producing non-vital products will be in question.

There will be a sharp difference between countries that have successfully introduced Industry 4.0 and lagging countries in this regard. World wealth will be concentrated in the countries of winners, since they will be an order of magnitude more competitive. Many enterprises that will not be able to transform will close, regardless of their fame and long success before Industry 4.0.

Due to the fact that the fourth industrial revolution is associated with data, the Internet, digital technologies, there is also a threat to information security, the threat of hacker attacks, the breakdown of equipment, the theft of classified information of military industries, as well as information possessing a commercial secret enterprise. Therefore, the implementation of information security tools and antivirus software is required.

It is also a danger that automation will replace the mental and physical activities of people, production workers will only observe robots, and thus people can atrophy memory and other brain functions. It is necessary to involve people in various tasks for universal development.

5. Industry 4.0 implementation examples

Let us give examples of the main directions of implementation of Industry 4.0 [5]. IoT, or the internet of things provides industry (IoT) interconnection and collaboration of data, machines and people in the production process. In fact, this technology simultaneously uses sensors, robots and data to interact with each other during the manufacture of products.

The leaders in this area are Microsoft, GE, PTC and Siemens. Microsoft is developing solutions for IoT platforms that are closely related to the infrastructure (IaaS + PaaS) that is, operating on the basis of the IaaS server of the cloud provider. The technology is already being used by BJC HealthCare, a health care provider that manages 15 hospitals in Missouri and Illinois. The company uses an IoT platform to save in the supply chain.

Combining IoT and big data [6] is a «recipe» that Bosch uses to transform digital technologies at its Bosch Automotive Diesel System plant in Wuxi, China. The company connects its equipment to control the entire production process to a single distribution center of the plant. To do this, sensors are installed on all machines of the factory, which are used to collect data on the state of the machines and their time of operation. The company BoschRexroth equipped equipment for the production of valves (and the valves themselves) with special radio frequency identification (RFID), so that the working equipment "understands" what steps need to be performed and how to adapt each individual operation.

With the advent of IoT and Industry 4.0, companies began to generate data at a stunning speed this made it impossible to process it manually and created the need for an infrastructure that can store and
manage this data more efficiently in cloud computing technologies. One of the first among automakers to implement this technology was Volkswagen together with Microsoft, the company developed the Volkswagen Automotive Cloud cloud network. The technology will allow you to connect the car with a smart house, personal voice assistant, a service for predicting breakdowns and malfunctions in the car, as well as ensure the transfer of streaming multimedia content and updates to the operating system of the on-board computer.

Along with robotics and intelligent systems, additive manufacturing, or 3D printing, is a key technology that stimulates the development of the 4.0 Industry. One of the World economic forum's best intelligent factories in the world, Fast Radius, uses its own technology platform for 3D printing. The system collects data on the manufacture of a part from the Fast Radius virtual warehouse (cloud storage for 3D models), and then finds the best way to manufacture it and the equipment on which it can be created. 3D printing is already used for some aircraft components: for example, Arconic, an Airbus supplier, produces a titanium bracket for serial Airbus aircraft by 3D printing.

Despite widespread use in consumer applications, manufacturing is just beginning to explore the benefits of augmented reality (AR) technology. Augmented reality eliminates the gap between the digital and physical worlds by overlaying virtual images or data on a physical object. The development of this area, among others, is being carried out by General Electric, the company launched a pilot project for the use of industrial AR headsets at its jet engine plant in Cincinnati. Using augmented reality glasses, mechanics can also contact experts in real time for urgent assistance.

Virtual modeling of products, materials and processes is already being applied at the stage of engineering development, in the future its application will be expanded to simulate the full cycle of operational and production processes. These models will extract data in real time to create a virtual copy of real production involving machines, products and employees. This allows operators to test and optimize hardware settings using a virtual model before making a change directly in physical production. An example is Siemens PLM Software's Tecnomatix, a family of software products designed to automate production preparation and optimization tasks.

A digital clone is a model of a real product (for example, a car, processor or chip) that can be superimposed on products right during production. This allows companies to better analyze and optimize their production processes. For example, to accelerate the development of racing cars, Penske Truck Leasing has partnered with Siemens to use digital part clone technology. The model allowed engineers to conduct virtual tests of new parts and optimize the characteristics of the car even before its manufacture. The digital two-seater racing car was created on the basis of sensors mounted on a real car.

Siemens has developed and used virtual and augmented reality capabilities to develop a virtual training module for its Comos software. Using a 3D model and augmented reality glasses, the module helps staff cope with emergencies in virtual simulation mode. In this virtual world, operators learn to interact with equipment using a digital presentation, change equipment parameters and display operating indicators and repair instructions.

Machine learning [7] is a deep data analysis technology using neural networks, which allows improving the capabilities of algorithms for controlling machines in production or performing other tasks. The Japanese company Fanuc uses this technology to train industrial robots to perform new tasks on their own. Devices perform the same task time and time again until high accuracy is achieved. Partnership with NVidia allows the company to teach several robots at the same time what one robot can learn in eight hours, eight cars can learn in an hour. This system reduces hardware downtime and allows you to work with more diverse products in a single enterprise.

6. Conclusions
As a result of the fourth industrial revolution, almost all spheres of human life will be covered by fundamental changes. The following probable consequences of Industry 4.0 development are highlighted: exemption from routine, decrease of significance and gradual disappearance of physical labor; the fundamental transformation of the economy, the predominant development of sectors of the
economy that have access to large amounts of data; the growth of social stratification due to the disappearance of the importance of a huge number of professions, intellectual and creative opportunities will become the main value in the labor market; The disappearance of routine and standard tasks due to the automation of the vast majority of such processes; transparency of the world due to the interpenetration of the real and digital environment, new opportunities for digital control of undesirable social phenomena and events.

How the fourth industrial revolution will be realized is not really known. But one thing can be said with certainty: Industry 4.0 is slowly but surely entering our world. Industry 4.0 will make it possible to reach a new level of human development and quality of life. It will change the attitude of people and people themselves.

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