Status and perspectives for the use of additive technologies in various branches of Russian industry

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Status and perspectives for the use of additive technologies in various branches of Russian industry

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Abstract: The article analyses the state and perspectives of the use of additive technologies in the Russian industry. The authors emphasise that additive technologies not only changed the process of product design, but also modernised the process of value creation. In Russia, additive technologies are developing slowly due to the lack of qualified personnel, the high cost of technology and the underdevelopment of the necessary infrastructure.

Introduction

Global digitalisation and informatisation of all spheres of human life take place in modern conditions. Thanks to this phenomenon, it becomes possible to use a large number of innovations, without which it is increasingly difficult to imagine modern life. So in the industry, the leading sector of the economy, additive technologies that change the algorithm of manufacturing goods/products began to be actively introduced.

Additive manufacturing (referred to as AM - additive manufacturing) is regarded as a class of advanced technologies for the customised production of parts of complex shape on a three-dimensional computer model by successive application of the material (mostly often layer-by-layer) - in contrast to the subtractive production (for example, traditional mechanical processing) [2].

Such production involves the following value creation algorithm:

1. Preparation of CAD-model (computer-aided design model).
2. Creation of an STL-file that contains a 3D model.
3. Virtual separation of the 3D model into layers.
4. Transfer of this file to the AP-system for the layer-by-layer formation of the final product.
5. Finishing treatment.
6. Release of the finished product (for use).

Each company independently decides what kind of additive technologies to use in manufacturing their products. The specifics of the company's business, the available funding, the necessary resources, including staff and other factors, are taken into account.

The aim of this work is to assess the state and perspectives of the additive technology development in the Russian industry, as well as to identify the main obstacles to their spread.

1. Research Materials and Methods

Implementation of research tasks was achieved on the basis of analysis of statistical data and experience of enterprises of the Russian industry, comparative analysis, content analysis and survey of top managers of leading Russian enterprises.

2. Findings

The originator of the additive manufacturing industry is the founder of 3D Systems Charles W. Hull. In 1986, he made a proposal regarding the method of layer-by-layer synthesis (the use of ultraviolet

radiation focused on a thin layer of photopolymer resin). It was he who introduced the term "stereolithography". In the same year, the engineer assembled the world's first stereolithographic 3D printer-SLA (Stereolithography Apparatus), which enabled digital technologies to get ahead. Almost at the same time, the founder of the company, Stratasys, invented the first FDM-device. After that, the market of 3D printing began to grow rapidly and replenished with the latest modifications of unique printing equipment [5].

Since 2016, additive technologies have become more actively used in the industry, mainly due to such advantages of AP [2] as: reduction of the time and cost of launching the product into production; the possibility and economic feasibility of small-scale production; timely changes in the project at the production stage; functional optimisation of products; economic feasibility of production of customised products; reduction of costs and production waste; simplification of logistics, reduction of delivery time, reduction of inventory; personalised design.

These technologies have changed the processes of design and construction of products, as a result of which they have become continuous product creation processes. At the moment, modern design and production of products are unthinkable without additive technologies. For example, in the West, 3D printers are common along with conventional computers and are used in the manufacture of fabrics, shoes, food and even the cultivation of living human organs.

Despite the obvious advantages of AP technologies, they have their limitations and drawbacks. For example, the high cost of industrial printers and consumables, the lack of manufacturers of such equipment, the lack of appropriate knowledge of the staff, the problem of protection of intellectual property rights of the patent holder of AM technology, etc. All the above-given factors impede the widespread use of these technologies.

However, this did not prevent the world market of additive technologies from growing. According to the forecasts of the consulting firm Frost & Sullivan, the market volume will increase from $ 5.31 billion in 2018 up to $ 21.5 billion in 2025. By 2025, AP technologies will be globally applied in the following industries: automotive, architecture, aviation and aerospace, consumer electronics, medicine and others [3].

In 2018, the largest consumers of additive technologies in the world are North American countries. The increase in the North American market by 2025 is estimated at $ 7.65 billion. The second largest market is in Europe and the Middle East, which could increase to $ 7.18 billion by 2025.

It is worth highlighting the rapidly growing market in the Asia-Pacific region. It will reach $ 5.56 billion in 2025. At the same time, China will take a large share - 70%.

After analysing the global market for additive technologies, Frost & Sullivan noted such key trends as [3]:

- continuous growth in the number of parts, in the manufacture of which additive technologies were used;
-development of 3D printing technologies at a rapid pace, reducing the time and cost of production through the use of heterogeneous materials;
- growth in the introduction of 3D printing technologies in various industries;
- the use of 3D printing in order to create a rapidly changeable production;
- increase in R & D (Research and Development) financing for additive manufacturing;
- market consolidation through the creation of consortia;
- formation of special institutions to unite the efforts of companies and scientific groups engaged in the development of solutions in the field of additive manufacturing;
- gradual reduction of production costs by reducing the cost of equipment and increasing the availability of technologies.

According to Frost & Sullivan, the leaders of AP-production include: 3D Systems (USA); EOS Gmbh (Germany), SLM Solutions (Germany) Stratasys (US); Objet Geometries (USA-Israel); Envisiontec (USA-Germany (DLP); ExOne (USA); Voxeljet (Germany); Arcam AB (Sweden).

Up to the present time in Russia the technology of additive manufacturing (design and implementation) developed very slowly. The country almost did not participate in the international organisations that were engaged in the development of AP-technologies in the world; it had neither the appropriate equipment and machinery, providing high-quality products, nor materials and raw materials for 3D-devices. There was also a lack of highly qualified, specially trained staff. In General, Russia has not created the 3D-environment infrastructure necessary for additive manufacturing.

Therefore, now Russia is among the Laggards in such areas as the creation of equipment for 3D printing, production of raw materials and auxiliary materials, etc. As of February 2018, the share of Russia in the structure of the world market of additive production is only 1% [3].

However, domestic companies are expanding the base of production of 3D printers and actively use the additive equipment. They are used in those areas where the need for products of complex geometry is high and allow to establish their production on their own sites without intermediaries, suppliers, delivery risks, reducing production costs.

There are examples of effective implementation of 3D printing in the country. For example, the All-Russian Research Institute of Aviation Materials is engaged in serious research projects, including the production of consumables for three-dimensional equipment. The great interest is demonstrated by the enterprises of metallurgy, aviation, space industry and the military-industrial complex, which use 3D printing mostly for prototyping parts, not end products [7].

Tikhvin Freight Car Building Plant (UWC - United Wagon Company) was the first to implement the project of application of additive technologies in production. At the enterprise with the help of 3D-printer elements of foundry model tooling are created. The technique provides high-quality printing - the thickness of the layer is 0.05-0.15 mm (depending on the settings). And the weight of this product can reach up to 150 kg. This technology gave the opportunity to produce components of complex configuration (with a length of up to 3 metres) for one week with the immediate start of production of pilot castings. Moreover, the equipment has good indicators of energy efficiency and ensures economical consumption of material [7].

STL files for printing are created on computers with standard software. Investments in the project amounted to about 60 million rubles.

Perm Motor Plant “Aviadvigatel” uses selective laser sintering technology (SLS) for the production of cast parts on the burned-out models; for the repair of parts it uses the method of laser cladding (LMD); for the cultivation of metal parts - selective laser melting technology (SLM). The motor plant purchased the equipment within the framework of the program of technical re-equipment of the enterprises of the United Engine-Building Company. Additive technologies are also used in fine-tuning of parts for ground-based engines such as gas turbines and power plants.

At the first conference on additive technologies, the “Luch” Design Bureau presented an unmanned aircraft. The design was carried out on a computer using a special program. Then within 30 hours all the components and parts of the aircraft were printed on the 3D-printer. Assembly of the device was carried out by personnel. The production took two months, and it used to take several years.

Federal State Unitary Enterprise All-Russian Research Institute of Aviation Materials (FSUE VIAM), which is a big powder producer, also uses additive technologies. Activities for the production of powders in VIAM arose from the need to organise the production of solders, which are mainly produced in the form of powders for high-temperature vacuum soldering. The requirements for these powders are the same as the requirements for metal powder compositions in additive technologies. In this regard, the Institute, using the company PSI (England), produced an atomiser, an apparatus that allows obtaining the necessary powders in a fairly narrow range of time. However, since atomisers have two purposes, VIAM began to investigate the method of independent design and production of the apparatus [2]. In addition to its main activities, VIAM takes part in the creation of specialised equipment and technologies for additive manufacturing and software, conducted by the St. Petersburg Polytechnic University.

Another powder producer is the Research Center for Powder Materials Science (RCPM) at Perm Polytechnic University. The research center has a German laboratory unit ALD VIGA-2B, which

produces metal powders and alloys by a gas-dynamic spray. The purpose of the AM-machine is to research and obtain small experimental batches. The maximum melting point of the unit is 1.7 thousand C°.

Penza Research and Production Enterprise "Rubin" also joined the development of digital technologies in production. Design engineers of the enterprise create three-dimensional drawings with the help of computer-aided design (CAD), followed by the production of prototypes on 3D printers.

ZAO "Promtractor-Wagon" also included 3D-printers in its arsenal of technical means. At first, the technology was used to print parts of the rail-truck "33", which are copies on a smaller scale, which became useful in the development of assembly algorithms and testing for the collection of innovative rail trucks. In addition to the truck "33", the company, using additive technologies, manufactures components and parts of the forklift [7].

Well-known large corporations such as "Roscosmos", "Rostekh", "Rosatom" are seriously engaged in the promotion of additive technologies. The management of these corporations is aimed at mastering all the elements of "digital production", from the development of materials to the creation of products. For this reason, the program is implemented on additive technologies, consisting of the following sections: technology, raw materials, equipment, standardisation.

In the structure of "Rosatom", additive technologies are developing in the fuel company "TVEL", which actively cooperates with the regional engineering centre established at UrFU, working on the creation of a Russian 3D printer.

In the scientific and educational centre "Modern production technologies" of Tomsk Polytechnic University there is a printer of electron-beam fusion; laser printer; printers that print with reinforced composites, as well as ultrasonic tomography, carrying out at the machine strict control of finished products. Employees of the centre create AM-apparatus and the corresponding software to them and also plan to advance further [7].

The whole production cycle - from the idea to the implementation of the finished product is set up in the centre of additive technologies of Tomsk Polytechnic University. There is an opportunity to create and test details for the covering of spaceships, implants for craniofacial surgery, products of a sophisticated form for the aircraft industry and others, and also to create cutting-edge digital devices.

Thus, although Russia lags behind the leading countries in the field of additive manufacturing, the beginning of the development of AP technologies is laid and already developed unique technologies are proof of this. The innovative products presented above are able to create import-substituting products that are much cheaper than imported analogues and are not inferior to them in quality. So the existing design can make a good competition with foreign manufacturers.

Experts predict the development of additive manufacturing in Russia in the following areas [13]:

- the use of granules and powder materials in 3D printing will help to get rid of the use of triangular and cylindrical shapes in the manufacture of products;
- the use of carbon (graphite) fiber and metal powders will improve the properties of products;
- development of solutions for 3D printing will reduce the error in the manufacture of products and increase the accuracy of production;
- optimisation of performance and development of additive technologies will increase the accuracy, speed and quality of 3D printing;
- service development, that is 3D-printer leasing;
- development of production of 3D-printers will allow creating large-size products with high accuracy;
- the use of the material "graphene" for the production of metal fibers and batteries.

Analysts argue that the stimulation of development in the field of additive manufacturing in Russia should be supported by state subsidies and through direct investment. For example, the Industrial Development Fund provides financial support to projects in this area.

In order to increase the number of qualified specialists in the field of AP-production in the country, experts see the need to develop new professional standards and qualification requirements. Here we are talking about cooperation and the emergence of completely different formats of interaction

between Federal Executive bodies, state corporations, high-tech industries, universities and scientific organisations. At the moment the Order of the Ministry of Education and Science of Russia of 22.12.2015 No. 1506 according to which the Federal State Educational Standard of Secondary Professional Education in the specialty 15.02.09 “Additive technologies” is approved. Graduates of this direction will be involved in the organisation and management of the technological process for the manufacture of products on the apparatus for additive production [11].

3. Conclusion

Additive manufacturing marked the beginning of a real industrial revolution in the design and manufacture of certain products. The use of new methods of layer-by-layer synthesis of parts has repeatedly reduced the time to create products. The potential of such production is huge: from the transformation of ways to solve many technological problems that appear in the production process of almost any product, to the creation of new industries. However, there are challenges and difficulties in the implementation and use of these technologies. Recently, there has been a growing interest in the new format technologies from domestic manufacturers, which can be the key to the active development of the AP-technologies market in the future.

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