

Development of Additive Technologies in Voronezh Region Based on a Complex Regional Project

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Abstract—The article analyses the process of developing and implementing a complex regional project in Voronezh Region — the creation of the Centre for additive technologies. The implementation of the project allowed establishing the first enterprise in Russia, producing domestic additive household plants provided with domestic raw materials. The Centre for additive technologies actively implements the building processes, filling orders from third-party small and medium-sized businesses and studying the ongoing physical and chemical processes. In the course of project implementation, the idea of producing domestic analogues of raw materials for industrial additive plants, including foreign ones, was realized. Further project implementation will eliminate the dependence of additive technologies market of the Russian Federation on foreign suppliers. As of 2019, the project continues, although its opportunities are limited by the need for substantial financial investments.

Keywords—*additive technologies; regional project; interaction between an innovation centre and small business*

I. INTRODUCTION

The current status of socio-economic processes in the regions of Russia is characterized by significant, rapid, but poorly balanced changes [1], [2]. Practically all the regions set goals of developing advanced production technologies in various sectors that are likely to ensure progressive transformation of the economy. Within the implementation of regional policies in developing advanced industrial technologies, special attention is paid to additive technologies. Their development and implementation into practice requires establishing regional structures that specialize in a particular area of the additive technologies industry. In this way, it is allowed to cover the whole industry, and reduce capital intensity and unreasonable time consumption. The organization that deals with the task of developing and implementing additive technologies in Voronezh region is JSC “The Centre for technological competence of additive technologies” (hereinafter referred to as “the Centre for additive technologies” or “the Centre”), which is based on the principle of public-private partnership.

The Centre for additive technologies is a leading industrial manufacturing, whose operation is based on digital additive technologies with the use of advanced materials.

The Centre is focused on cooperation with small and medium-sized enterprises, which traditionally are state supported [3].

The term “additive technologies” applied in the article defines a class of processes that automatically create complex objects - “building” cross sections of details layer by layer, from the bottom up, until a physical prototype of the model is achieved.

II. ORGANIZATIONAL ASPECTS OF PROJECT DEVELOPMENT AND IMPLEMENTATION

The major objectives of the project include making products of high quality and with the competitive price in as short a time as possible, accelerating research and development, studying additive technologies, and developing progressive domestic samples of additive equipment.

This project represented Voronezh region and became the winner in the competition among the entities of the Russian Federation for state support subsidies for small and medium-sized businesses in 2013. This competition implied equity financing from Voronezh region on the measures of state support for small and medium-sized businesses. The authorized capital of the Centre was formed by means of “Voronezhselmash LLC” equipment and production facilities, as well as federal and regional budget. The most modern industrial additive plants, covering all commercialized additive technologies existing at that time were purchased through funds from the federal and regional budget.

In terms of organization, PJC “The Centre for technological competence of additive technologies” is a dependent company of “Voronezhselmash LLC”, which is its controlling shareholder.

Under the project, it was planned to encourage innovation in the region by means of creating a new production within the interrelated areas: design - projecting and calculating; engineering - optimizing technical solutions; production - materializing design concepts through digital technology with the use of advanced materials.

The Centre focuses on cooperation with small and medium-sized businesses through reducing research and

development time, improving the quality and technical level of products, developing new technologies and product items, and training qualified professionals.

At the stage of preparing project implementation strategy, software products, techniques, devices and equipment that met the world technical standards, were introduced. Initially high demands were made on personnel. The ability to use basic software products of solid modeling became a mandatory requirement. To large extent, the staff consisted of young specialists - postgraduate students, young scientists who were capable of working in a team. Personnel training preceded the installation and equipment development stage. The project implied close interaction with university science and specialized departments, the departments of metallurgical and material engineering, in particular. In the course of project development, in cooperation with Voronezh State University, the basic department of additive technologies was created.

III. IMPLEMENTATION OF THE PROJECT ON ADDITIVE TECHNOLOGY DEVELOPMENT

The project was implemented by stages, with each stage creating the necessary conditions for product commercialization. One of the most critical conditions was the continuity of project implementation; it was organized in such a way as to eliminate the possibility to cancel or freeze the certain stages for an extended period.

In order to conduct the markets analysis, the quantitative methods were applied, since the purpose of the analysis was not planning the revenue, but understanding the general situation. Lists of organizations and the data from Russian National Classifier of Types of Economic Activity (OKVED) are no sensitive information and therefore were obtained from the Internet.

The purchased components account for about 20% of production costs for industrial enterprises of Voronezh region, about 50% of them - foreign-made.

The strategy of the Centre for additive technologies is founded on providing small and medium-sized businesses with exclusive discounts and benefits when ordering products. Therefore, it makes the products of the Centre cheaper for small and medium-sized businesses, but does not affect the quality, as it is not lower than that of imported components.

The Centre creates additional opportunities for small and medium-sized businesses in the use of innovative technologies, which do not require significant costs.

Due to the establishment of the Centre, small and medium businesses have been given the opportunity to create engineering samples and prototype models in as short a time as possible and in the most cost-effective manner, which contributes to the implementation of research and development and innovative ideas that require modern high precision equipment.

We enquired that financing innovative domestic developments in the field of additive technologies at the

Centre is based on a commercial activity on providing rapid prototyping services.

The choice of the financing method is conditioned by the following factors: on the one hand, it was necessary to provide services at the lowest possible prices, and on the other hand, the company is to be self-sufficient and have enough resources available to develop and create prototypes of domestic additive equipment.

Such a task requires a careful and thorough approach to price formation. This process is essential in the field of additive technologies, as there are much more variables involved, than in traditional technologies. For this reason, in order to organize the process of quickly calculating potential orders and business opportunities, the Centre has developed its own digital economic models for each additive technology located in the Centre.

Let us consider the formation of one of the models by the example of SLS EOS P395 plant, with Microsoft Office Excel as a tool.

The task is to form the most effective and reliable model of cost calculation. Modeling starts with the cost of raw materials that are bought in foreign currency and are to be used in the building process. Next, the reference information is collected, consistent with the logic of calculations. In the presented data, the cost of equipment, print speed mm/h, powder density g/cc, effective volume of the build envelope and the permissible density of components are constant due to the additive technology, process physics and actual costs.

The plant payoff period and the number of working days per year are the passport data of the business plan, funded by the state, and hence can not be changed.

The number of daily working hours is specified by the building process continuity. The equipment operator is needed at the stage of launching the building program and preparing equipment for operation. If everything has been done correctly, the building process is completed without human participation. If an error has been made, the plant will automatically be switched off at the building stage, the error corresponds to. Thus, at night, the plant works without the service of an equipment operator, whose working day is 8 hours a day.

Overhead costs are set by the managing company of the "Voronezhselmash" corporate group, taking mutual financial flows and transfer price forming into consideration.

Electricity costs are based on actual tariffs.

It has been empirically calculated that powder consumption coefficient is between 1.6 and 2 units and depends on the specific tasks and the density of filling the build envelope with products. Since we consider the technology of rapid prototyping, not mass production, the product range and their positional relationship in the build envelope differ with each launch, which means that the exact coefficient cannot be reliably predicted. That is why its average value based on equipment starts statistics is used in calculations.

Next, a data pack on the product or products to be launched for building should be formed. The initial data about the product includes its three-dimensional model. Additive plants do not work without digital starting data. A complex internal mathematical algorithm of a software product calculates the volume of a polysurface product and shows the result in the defined unit of measurement, in our case, in cm^3 . The mass of the product has no linear relation with its volume, since there are valid values for hollow or openwork products.

The cost of the material depends on its brand; therefore, the used material is indicated.

The amount of consumed powder, in grams, is calculated based on the product mass data, in grams, multiplied by the powder consumption coefficient from the block of reference information. Thus, we obtain the first part of the variable cost of building a specific product.

At this stage, the acquired data is enough for the computational part of the model:

The calculations of the production time for a product in the build envelope are based on the data on its height and the reference information on the building speed per hour. At the end of building, as a product or a group of products is created, they undergo powder bed fusion for as long as the temperature in the build envelope does not equal the exterior temperature, otherwise the product may be deformed while being removed. For this reason, the product is removed after the build envelope cools, and time for build envelope cooling is considered equal to the building time. During cooling, there is no actual wear of moving parts of the equipment, but the process of temperature reduction is a part of the building process, so, this time is also taken into account when calculating depreciation.

The cost of raw materials is calculated through multiplying the amount of consumed material by its cost. The formula itself is more complicated, since it takes into account the name of the material, i.e. it searches for a parameter to determine the necessary value.

Depreciation is calculated by multiplying the depreciation amount per hour, by the time of machine work, including cooling.

Energy costs do not take into account the time for cooling, since at this time no real electricity consumption takes place. Therefore, they are calculated by multiplying the kilowatt rate by the time of product building, measured in hours.

The salary does not account for the cooling time, either, because, in fact, an employee is not working at that time. In production planning, the plant is usually started at such a time that the cooling process takes place at night.

The unit cost represents the total costs of raw materials, electricity, labour and depreciation, increased by the amount of overhead costs established directly. In fact, the final calculations are similar to analogous calculations on any other industrial technology, traditional or innovative. The specificity of additive production models is about carrying

out additional computational operations to achieve the generally accepted values. Therefore, the Centre has implemented it all in the form of digital mathematical calculation models that can reduce the time to respond potential customers significantly.

In the model, we applied the financial terms accepted in the economic literature [4], [5], [6].

The analysis of the model has proved that it is not efficient to start a plant for one small product, it is necessary to fill the build envelope to the maximum. For this reason, in the Centre the orders are placed collectively, in order to make them a common process. Such organization helps to offer the best prices for the centre's services for enterprises that create the demand for rapid prototyping.

Let us consider the development processes in the field of additive technologies, performed by the Centre for additive technologies, within its competence. The first and strategically very important area of development is creating domestic additive manufacturing plants. The Centre started to develop this area, mastering the simplest FDM additive technology, and applied it to create training and household, but not industrial plants. The first working sample of the device was a simple 3D printer built up mainly of a DIY kit ordered in China. It helped to study basic physical processes and principles of building. The obtained information can be used to break the device down into components by means of components tree, and design the original device casing which would differ from the existing foreign models.

A thorough analysis of domestic analogues of components demonstrated that domestic enterprises do not produce most of the components used to build high-precision and oversized machines with numerical program control. This led to the forced need to purchase microelectronics and linear displacement systems from foreign manufacturers, which in its turn negatively affected the possibility of reducing the final product cost.

Despite a significant share of foreign components, the centre managed to locate production in Russia and acquire the status of domestic products due to over 50% of domestic components in product cost structure. The software, which is a proprietary solution of the Centre, was also a great contribution.

The introduction of the first domestic training and household 3D-printers allowed the Centre to start supplying them to educational institutions of the Russian Federation within the federal program for equipping educational institutions and providing their material and technical base.

With the money raised, the Centre for additive technologies continued developing and released an advanced version of a desktop FDM 3D printer providing the improved building process, using two materials simultaneously.

In the summer of 2015, by the efforts of the Centre's employees and talented Skolkovo students, a working prototype of a desktop 3D printer that applied an SLA building technology was developed. That fact allowed the company to secure the title of the national centre of

competence in the field of domestic additive technologies development.

The same year, a private investor addressed the Centre with a proposal to organize a line for producing polymer filament for domestic 3D printers within the enterprise, with further raw materials production and sale for devices manufactured by the Centre.

IV. CONCLUSION

Thus, due to this project implementation, the Centre for additive technologies became the first enterprise in Russia to manufacture and supply domestic additive household plants created with domestic raw materials.

In the area of commercial 3D printing, the employees of the Centre actively perform building processes, execute the orders from small and medium-sized businesses, and study the physical and chemical processes that take place while building. The obtained data served as an evidence base for the idea of producing domestic analogues of raw materials for industrial additive plants, including for foreign ones. This allows eliminating the dependence of the additive technologies market of the Russian Federation from foreign suppliers. So far, in 2019, this process is ongoing, even though it is limited by the need for substantial financial investments, which the company is unable to generate on its own.

Nevertheless, the active participation of the Centre in additive technologies development in Russia based on the unique enterprise equipment with almost all modern additive technologies, made it the centre of specialized conferences and forums for professionals in the field of additive technologies.

Since the origination of the Centre and up to the present day, the level of the country's enterprises awareness about additive technologies has significantly increased. New participants and interested individuals have appeared who carry out an independent policy and claim to play the leading role in the industry. More and more frequently, the initiatives in the field of advanced industrial technologies are condemned at the state level.

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