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Improvement of the Integrated System for Automated Design of Engineering and Technological Preparation of Additive Production

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ABSTRACT*:* The paper considers the improvement of the automated design system for the design and technological preparation of additive production. The software developed by the authors and the software components of the design and technological preparation of production allow for the layout of the equipment working chamber, the generation of three-dimensional modeling, and the creation of control commands in the G-code format. The possibilities of using computer modeling at the stages of manufacturing products by means of 3D printing have been determined. The similarity of technological processes makes it possible to speak of the applicability of the developed techniques for all types of additive production equipment.

KEYWORDS*:* G-code, software components, design and technological production preparation, computer-aided design systems, additive production, integrated system, STL format, 3D printer, automated processing systems**.**

I. INTRODUCTION

The main trends in the development of modern machine building are associated with the creation of an integrated computerized multinomenclature production on the basis of integrated automation of the production processes of products, from design to fabrication.

In integrated production, the process of designing a product, technology and processing system for its manufacture is the most time consuming. Therefore, the greatest efficiency is achieved in the automation of design procedures that require high costs of intellectual work. The most relevant is the development of automated processing systems (AOS), using expensive CNC equipment, automated transport and storage systems and control computers.

Automation of the design process of AOS is primarily related to the creation of a theory and formalized methodology for technological design, which is also the basis for building automated control systems for multi-product production.

The development of hardware 3D printing in recent years has caused a high interest in the topic of additive production. A wide range of materials and printing processes allow us to find applications for additive technologies in various fields of activity - from the production of souvenirs to the production of high-tech parts in the field of engineering production. The experimental work on the creation of other technologies for layer-by-layer synthesis is actively carried out [1].

A separate issue in the topic of 3D printing is the task of creating a software tool to support additive production, which takes place between the stages of designing a part and its physical printing on the device. The high resolution of modern printing devices exerts increased requirements for software components, and the complexity of technological processes imposes additional limitations. Technology determines the accuracy of geometric modeling and the requirements for resources of computing systems.

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II. MATERIAL AND METHODS

The distribution of software for additive production generally repeats the scenarios for the development of information support in other areas. There are both open source projects for automation of some technological processes, typical for low-cost popular printers (FDM), and closed, well-protected software for industrial printers of high price categories. The development of software support will be demanded steadily until technological ideas in the field of additive machine tool construction end, which, apparently, will not happen soon [2].
Understanding the process of additive production allows us to formulate the place of software for design and technological training and its main tasks (figure 1)

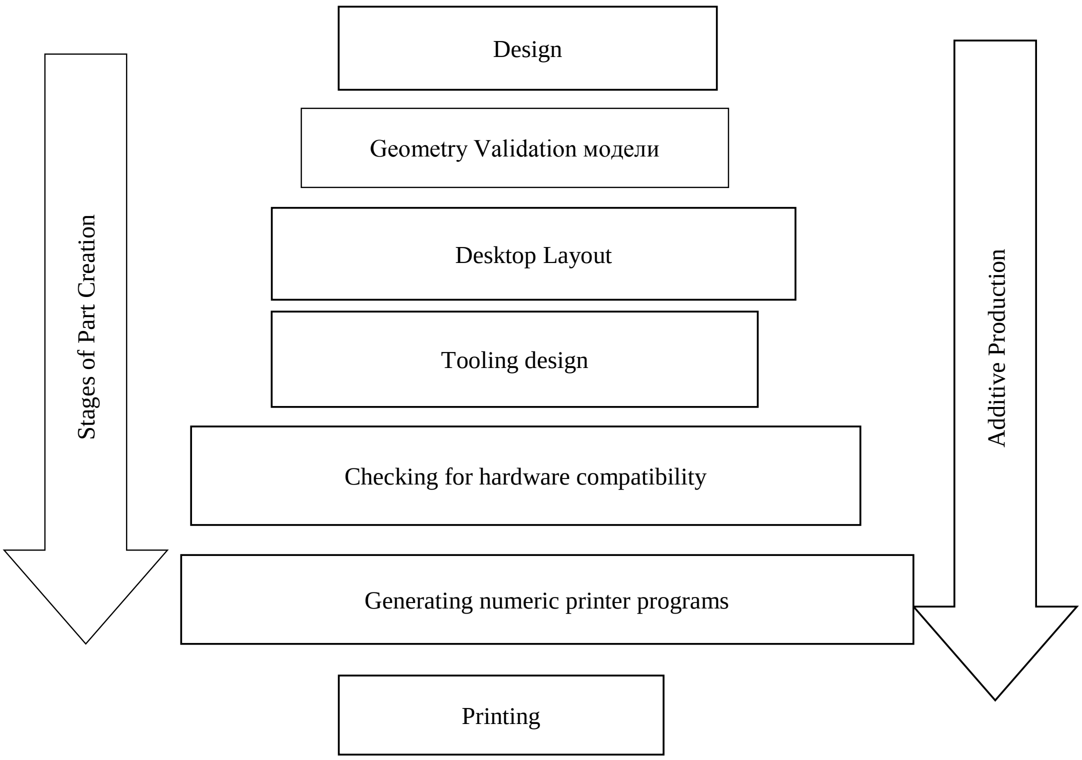

Figure 1: Algorithm for the preparation of additive production in the life cycle of creating a detail.

At each stage of preparation of production in the additive process, the automation tasks areassigned their own tasks (Table 1).

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Table 1:At each stage of preparation of production in the additive process, the automation tasks are assigned their own tasks

Stage	***Tasks***
Model geometry validation	Visual and algorithmic verification of the integrity of the geometric representation of the model, ensuring the specified technological accuracy
Desktop Layout	Import models in the specified volume and with the specified accuracy, reduction of units of measurement, positioning of models in the coordinate system of the printing device.
Tooling design	Identifying places that require the design of additional equipment or support, ensuring the filling of internal volumes.
Checking for hardware compatibility	Checking the layout of models for technological temperature limitations of the printer
Generation of numerical programs of equipment	Compilation and verification of numerical programs of equipment

Practical use (by authors) of various technologies of three-dimensional printing and various types of printing devices allowed to reveal a number of shortcomings of the available software supplied with printers, as well as to reveal a number of unsolved problems in the technological preparation of additive production.

The main drawbacks of the existing software (software) are: concealment of algorithms and calculation methods, opaque pricing mechanism, software limitations in accuracy and functionality, lack of guaranteed technical and user support and the possibility of operational improvements for potential new production tasks, inability to expand functionality for engineering calculations and the expansion of the nomenclature of printing devices. The revealed shortcomings of the existing software and production needs were the prerequisites for the development of its own software components for automating the preparation of additive production.

The goal of the development is the software components of design and technological preparation of production (SCDTPP). The following tasks were performed in the design and development of the SCDTPP:

1. Creation of the core of the system of geometric modeling, which allows to conduct hierarchical design of assemblies.
2. Ensuring the import/export of geometric models in the grid representation with a given accuracy.
3. Create a space layout tool for modeling the working area of printers.
4. Development of mathematical methods for validating the geometry of models, and the formation of a discrete, three-dimensional type of models with a given accuracy.
5. Development of tools for modeling processes and performing numerical engineering calculations, typical for selective high-temperature additive technologies.
6. Preparation of software environment for compiling control commands of perspective printing devices.

To achieve the goals set, a prototype SCDTPP is developed, which is an application for the operating system MS Windows, built on the basis of the Windows API without the use of additional software libraries. For graphics, the OpenGL standard is used. All geometry is represented by double-precision floating-point numbers of 8 bytes per number, which makes it possible to programmatically not limit the accuracy. The total number of simultaneously processed objects is limited only by the amount of computing resources used and by the size of the address space allocated by the operating system - 3 gigabytes for 32-bit applications.

The SCDTPPs are built on a modular basis using an object-oriented approach. The structure of the SCDTPP contains the core of the system, the database of objects, the user interface, the calculated subroutines. The polymorphism inherent in the design of the system allows you to work with different types of objects: c models loaded with grids, with parametrized internal objects, discrete objects of the three-dimensional type. The use of the component approach in the design of the SCDTPP allows the functionality of the system to be expanded by integrating the new code without performing a rebuild of the main modules of the entire system [3].

To export models from CAD systems, the STL format is used (figure 2). The downloaded objects are arranged in a hierarchical structure.

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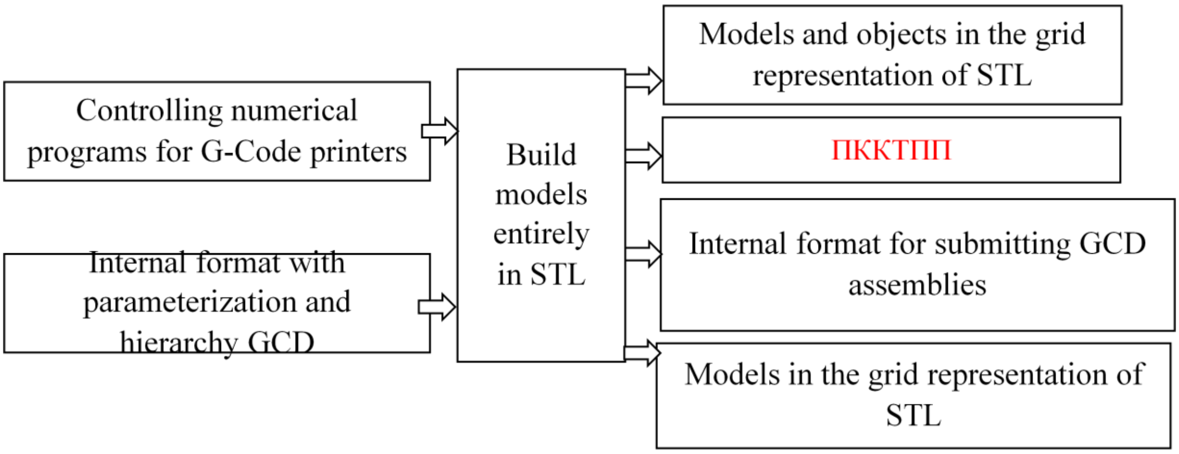

Figure.2. Scheme of organization of I / O control of information in the SCDTPP

III. SIMULATION&RESULTS

One of the tasks of the design and technological preparation of production is the layout of the camera of the printing device. The SCPPP allows you to interactively perform linear transformations of loaded models for their arrangement in the area of the printing device. It is possible to save the linked camera in the internal format of the SCDTPP and export models taking into account the made spatial transformations in the STL format in the coordinate system of the printing device.

One of the fundamental concepts in additive production due to technological features is the three-dimensional modeling of the working area of the printing device. SCDTPP allows you to create three-dimensional modeling of any range of the working area of the machine with any precision. The mathematical apparatus for calculating three-dimensional modeling is based on trace algorithms.

In the mathematical support of the SCDTPP, programs that form the structure of the system being designed are represented in the form of a multidimensional object at the input of which the vector of input variables $\vec{x}(\tau)$:acts:

$$\vec{x}(\tau) = [x_1(\tau), x_2(\tau), \dots, x_n(\tau)],$$

where $x_1(\tau), x_2(\tau), \dots, x_n(\tau)$- are the components of the vector $\vec{x}(\tau)$, they characterize, first of all, the full set of properties of blanks and semifinished products (dimensions and their deviations, roughness and microhardness of surfaces, structural parameters, etc.) used in this object.

The output variables describe the vector $\vec{y}(\tau)$:

$$\vec{y}(\tau) = [y_1(\tau), y_2(\tau), \dots, y_n(\tau)],$$

where $y_1(\tau), y_2(\tau), \dots, y_n(\tau)$- are the components of the vector y ⃗ (τ), they characterize the properties of the finished part (accuracy of dimensions, shape and relative position of surfaces, surface roughness etc.).

The components of both input and output vectors can be not only constructive and technological properties of blanks, parts, assembly units, but also quantities reflecting the technical and economic indicators of the SCDTPP.

Parameters characterizing the flow conditions of the SCDTPP are described by the vector$\vec{z}(\tau)$:

$$\vec{z}(\tau) = [z_1(\tau), z_2(\tau), \dots, z_n(\tau)],$$

where$z_1(\tau), z_2(\tau), \dots, (\tau)$-are the components of the vector$\vec{z}(\tau)$,for example, temperature, pressure, feed, rotation frequency, and factors that have a destabilizing effect on the course SCDTPP.

The dimension of the vectors$\vec{x}(\tau), \vec{y}(\tau), \vec{z}(\tau)$for real processes is very large, and it is impossible to take into account all their components, some of the components are considered as random functions.

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Three-dimensional modeling (figure 3) can be considered as a generalization of the discrete representation in order to save computing resources while accompanying additive production. Using a discrete representation allows you to more fully judge the geometry of the part and its topology.

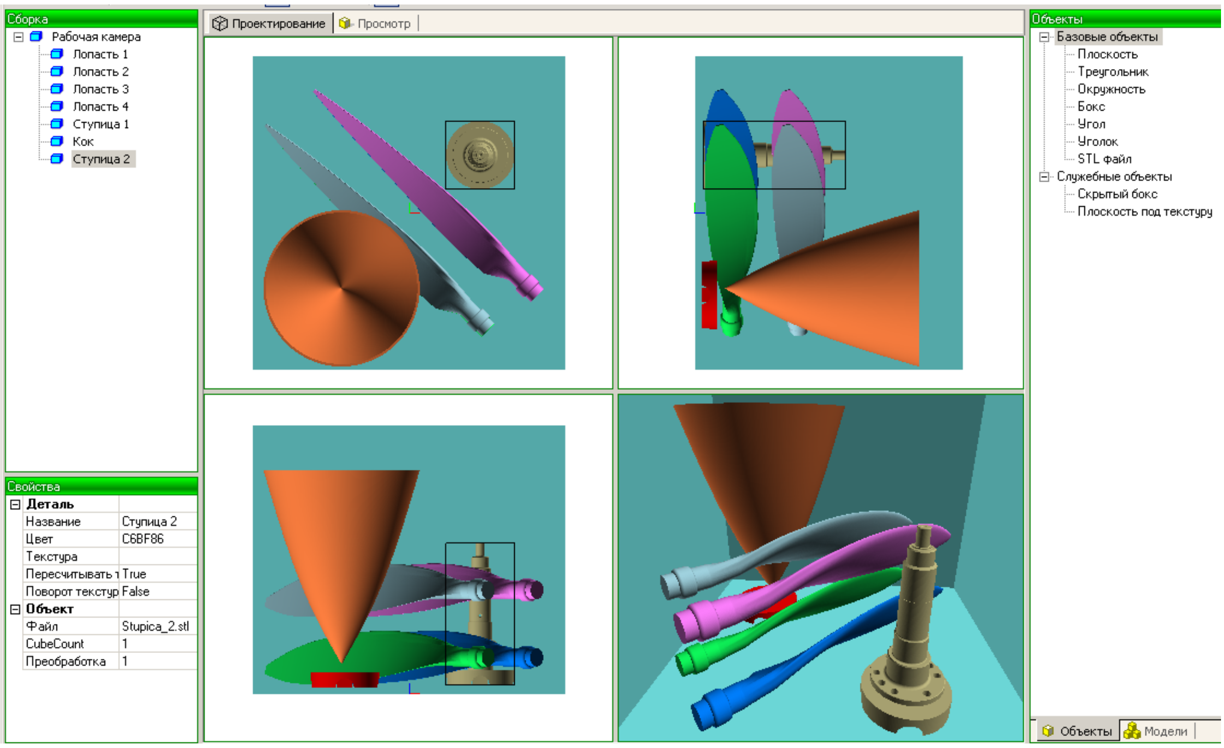

Figure 3:Three-dimensional modelling with the mapping of layers of given ranges

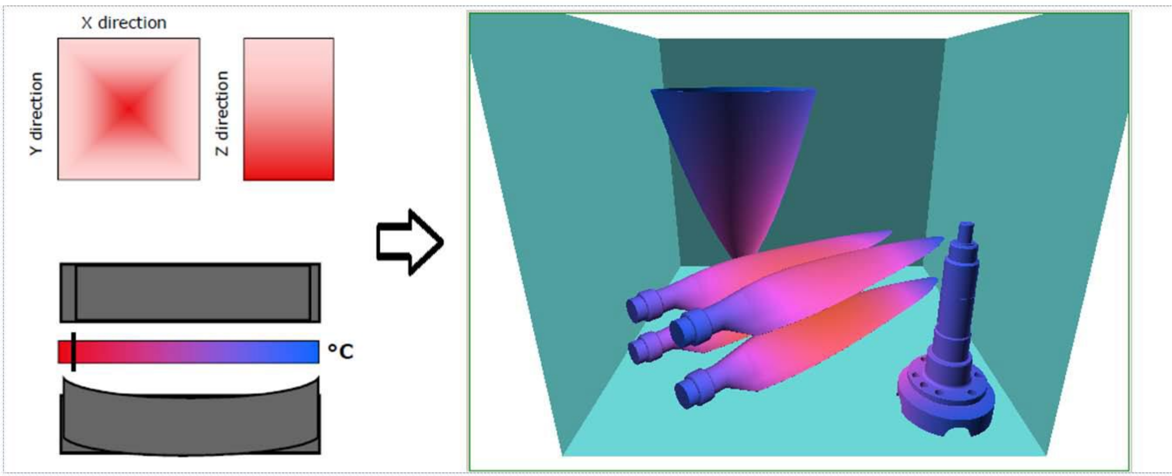

Figure 4. The display on the temperature distribution indicator in the EOS INT P 395 3 D machine chamber and the fan blade heating in the SCDTPP

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IV. DISCUSSIONS

According to experts, the world market of products and services related to additive technologies in 2012 increased by 28.3% and amounted to 2.2 billion US dollars. In 2013 - 3.07 billion dollars. According to forecasts, by 2015 the market will double, in 2017it will be estimated at 6 billion dollars, and in 2020 - at 10.8 billion dollars. [5].
The volume of sales of industrial 3D printers (from $ 5,000 per unit) in 2012 amounted to 7.8 thousand units, printers for home use (from $ 1,500 per piece), about 70 thousand pieces. [6].
Thus, in modern conditions when working with innovative production technologies it is important to take full advantage of the opportunities provided by equipment. It is necessary not only to effectively use the supplied software, but also to be able to quickly adapt it for new production tasks or for new types of printing devices.
Advantages of additive technology developed by the software are:
- the terms of design and technological preparation with the help of additive technologies in production are reduced to 70% in comparison with traditional methods. However, analytically, this figure applied to machine building amounted to about 40-50%;
- the operating personnel of the equipment working on additive technologies, in comparison with the traditional ones, decreases 1.5-2 times. Consumables are also significantly reduced (up to 30-60%) due to the application of the developed SCDTPP;
- In 3D printing, the term "quality" is based on the resolution of the print. The print resolution, in a general sense, means the minimum allowable height of the material layer with which a particular 3D printer can print. For example, when using the method of layer-by-layer fusing, the thickness of the layer is from 120 to 330 microns. When printing from metal powder, the precision of manufacturing parts reaches 100 microns.

V. CONCLUSION

As a result of conducting research and creating a mathematical model of the process of obtaining products by additive technologies, the list of products and the range of services of machine-building enterprises can be expanded.
Practical use of the software of the SCDTPP in the full cycle of technological preparation, from the design model to the "printing" of the detail, shows the reliability of the selected techniques and software solutions. The similarity of technological processes developed for additive production technologies allows us to talk about the applicability of the developed software components for other, including additive, technologies for layer-by-layer synthesis.

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