ABSTRACT

of the dissertation work submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D070300 - Information Systems (by industry)

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Information system for modeling trajectories for constructing robotic systems for plasma spraying on implants of a complex geometric-topological structure

General characteristics of the work: the thesis is devoted to the development of an information system for modeling trajectories for the construction of robotic systems for plasma spraying on implants of a complex geometrical-topological structure. On the basis of the parametric method, the classification of implants is carried out; the trajectories of the manipulator movement were modeled on the basis of the Hermite polynomials of the third and fourth orders; a simulation program for the movement of the robot along the given coordinates at a certain speed was developed to spray the surface of the implant.

Key words: parametric classification of implants, modeling of motion trajectories, Hermite spline, plasma spraying, virtual simulator, robotic systems.

Relevance of the research. The production of titanium medical products is a higher production limit, i.e. development of technologies for the production of medical products (implants for orthopedics and traumatology) made of titanium and its alloys from domestic raw materials. Research on the manufacture of implants using the latest systems for the additive production of metal products by selective laser melting and implants using modern CNC machines is an urgent and demanded task today.

The design and manufacture of implants is a complex and time-consuming process, in addition, for the biocompatibility of implants, the application of bioactive coatings is required, which provides an increase in the percentage of implantability with human tissues. For accurate coating, robots are the optimal solution.

The relevance of this problem is due to the action of the Code of the Republic of Kazakhstan "On people's health and the health care system" (dated July 7, 2020 No. 360-VI LRK), which defines the standards for the production of medical devices, including implants and endoprostheses.

The main idea of this work is to develop an information system for modeling trajectories for the construction of robotic systems for plasma spraying on implants of a complex geometrical-topological structure. A distinctive feature of this system is the preliminary classification of implants based on certain parameters, construction of a trajectory based on distance and speed, simulation of movements in a virtual simulator for the Fanuc robot.

The object of research is robotic plasma spraying systems.

The subject of the research is the information and mathematical support of the control system for the process of plasma spraying on implants of a complex geometrical-topological structure.

Purpose of the study: modeling the trajectories of plasma spraying on implants of a complex geometrical-topological structure for robotic systems.

Research objectives:

1. To perform the classification of implants and to form a data storage;
2. To create 3d models of implants of different classes;
3. To adapt the interpolation method based on the Hermite spline for the formation of the spraying trajectory;
4. To develop software modules of spraying trajectories for a manipulation robot.

Research methods: the basis of research methods is the use of mathematical modeling, three-dimensional modeling, simulation, robotics. The development of software was carried out using web programming methods, object-oriented programming technologies were used.

Scientific provisions submitted for defense:

1. Parametric classification of implants of complex geometrical-topological structure;
2. Model of the spraying trajectory of implants of a complex geometrical-topological structure based on Hermite splines of the third and fourth orders;
3. System architecture and software modules for spraying process control for robotic plasma spraying systems.

Scientific novelty of the research:

There is proposed a model for the classification of implants of a complex geometrical-topological structure based on the parametric method, and for each class of implants, there is created a spraying trajectory based on Hermite splines of the third and fourth orders.

Scientific and practical significance of the work

The totality of the results obtained in this work made it possible to create the scientific foundations of an information system for modeling trajectories for the construction of plasma spraying robotic systems on implants of a complex geometric-topological structure. The main scientific and practical results of the dissertation work were obtained in the course of research in the framework of the program-targeted funding project "0006/PCF-2017 "Production of titanium products for further use in medicine". There were registered following computer programs: "Computer program "Information subsystem for working with the implants database" dated August 19, 2020. No. 11699", "Information system for modeling trajectories for the construction of plasma spraying robotic systems on implants of a complex geometric-topological structure" (computer program) dated February 16, 2021, No. 15189. The results of the dissertation work are promising for the creation of high-tech production, for the introduction of an information system into production formation of plasma spraying trajectories for robotic systems, which will optimize the process of plasma spraying, cost-effectively to execute the plasma spraying process.

Approbation of the work. The main results of the research are presented at following conferences:

1. International scientific conference "Intelligent decision-making systems and problems of computational intelligence (ISDMCI'2017)", 22-26 may 2017, Zaliznyi port, Ukraine;
2. XIV International Scientific and Practical Conference "Mathematical and Software for Intelligent Systems (MPZIS-2017)", 21-22 november 2017, Dnipro, Ukraine;
3. Winter InfoCom 2017: Materials of the V International scientific-practical conference, 1-2 december 2017, Kiev, Ukraine;
4. International scientific conference "Intelligent decision-making systems and problems of computational intelligence (ISDMCI'2018) », 21-27 may 2018, Kiev, Ukraine;
5. Proceedings of international educational forum" The didactic hub: Europe-Asia ", 26.04.2018, Semey, Kazakhstan;
6. International scientific-practical conference “XVIII international scientific seminar“ Modern problems of informatics in economics, management and education and overcoming the consequences of the Chernobyl disaster ", 2-8 july 2018, Svityaz, Ukraine;

International scientific-practical conference “Creativity of young scientists for the innovative development of Kazakhstan“, 11-12 april, Ust-Kamenogorsk, Kazakhstan.

Publications

Based on the research materials, there are 13 publications, of which 5 are in publications recommended by the Committee for Control in Education and Science, 1 article in a journal included in the Scopus database and 2 copyright certificates "Computer program "Information subsystem for working with implants database" dated August 19, 2020. No. 11699", "Information system for modeling trajectories for the construction of plasma spraying robotic systems on implants of a complex geometric-topological structure" (computer program) dated February 16, No. 15189. Dissertation research was carried out within the framework of the project "0006/PCF-2017 "Production of titanium products for further use in medicine”.

The structure and content of the dissertation work

The dissertation work is presented on 96 pages of a computer set, consists of an introduction, four chapters, a conclusion, a bibliography and annexes. The text is illustrated with 29 tables, 88 figures. List of sources used -100.

The first section of the dissertation presents the results of an analysis of the current state and development of technologies for creating implants for restoring lost or destroyed parts of the human skeleton. The main technical characteristics of the developed technologies are presented, the difference between their consumer properties from existing analogues. The use of microplasma spraying technology has been substantiated.

In the second section of the dissertation, as a result of the parametric classification method, there was developed a system for the classification of

implants according to their compliance with the necessary conditions for subsequent plasma spraying.

To implement the parametric classification method, 11 parameters were identified. There are 3 classes of implants defined. Three implants were selected from the first two classes of implants, which meet the limiting parameters allowed when spraying by a robot.

In the third section of the dissertation, there were created 3d models of implants, the process of spraying implants using a robotic complex was conditionally divided into five stages.

In order to simulate the trajectory of motion with the given coordinates and velocities, a spline of the third and fourth orders was used. The solution to this problem is simulated in the Matlab environment.

The fourth section of the dissertation describes the developed application "Information system for modeling trajectories for the construction of plasma spraying robotic systems on implants of a complex geometric-topological structure" for working with implants database.

A simulation model of the robot movement along the given coordinates and velocities were developed for spraying the surface of the implant.

In the final section of the dissertation, a list of the main results and conclusions of the dissertation research is given, on the basis of which, the provisions submitted for defense were confirmed, an assessment of the scientific novelty and practical significance of the research is given. Certificates of state registration of a computer program are given in the appendices.