CAD/CAM Systems in Implant Design in Kazakhstan

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***Abstract*—It is considered in the work some problems and perspectives Delcam CAD/CAM systems applying in implant design and for its production on CNC machines.**

I. Introduction

The development and production of medical devices are among the most intensively developing areas of scientific and technical activity. They include the development of new materials, design, production and quality control technologies. In the 21st century, medical science and technology became one of the main driving forces of modern technical civilization, gradually pushing astronautics and becoming one with information technologies, intensively developing in the last 30 years. According to the forecasts of the British government, the most popular specialists until 2030 will be bioengineers, developing new medical products, and doctors using high-tech methods of treatment [1-10].

A big problem in the dental industry today in Kazakhstan is a small number of large-scale scientific researches related to the comparative analysis of whole groups of medical products that are truly independent.

Analysis of the development of the Kazakhstan market of medical products showed that the volume of the domestic market of medical products increased most intensively from 2006 to 2012, but it is significantly inferior to the markets of leading foreign countries such as Germany, Switzerland and Austria [2, 11, 12].

The main materials used for the manufacture of implants are metal alloys (titanium, cobalt, stainless steels), polymers and ceramics. Despite the intensive increase in the use of polymers and ceramic materials in implantable products, metallic materials retain their leading role (about 60% of all implants). The share of products made of titanium alloys can be estimated at about 28% [13-15].

II. The Goal of the Research

Medical implants are implanted in the body for the purpose of prosthetics of damaged organs. As a rule, the implant has a common basic construction that can be presented in the form of a discrete size series to reduce production costs, and a unique individual part whose geometry is determined by the physical features of the structure of the patient's body.

The initial data for implant design is obtained by computer tomography of the patient. Detection and analysis of violations is done by a doctor who decides on prosthetics and together with a technologist builds a 3D model of the implant in a specialized CAD system. The finished result of the design is the CAD model of the implant and the necessary tooling for its manufacture, as well as the results of CAE-calculation of the stress-strain state of the implant under the action of operational loads. This approach allows to ensure the production of a quality implant and positive results of prosthetics.

Implants are manufactured in various ways, including plastic deformation from sheet blanks. This is due to the fact that sheet constructions are easier and cheaper (although in some cases they may not be sufficiently hard). For the manufacture of implants, often use solid sheet or perforated (such as "mesh") blanks of titanium VT1-0, from which products with a complex spatial shape are obtained by means of plastic deformation.

The goal of the research was to develop a technology for designing and manufacturing implants of complex spatial shape and specialized modules of integrated CAD based on CAD / CAM / CAI Delcam systems designed for calculating and constructing parameterized die tooling, as well as designing the technology of its manufacturing on CNC machines.

III. Development of Methods for Designing and Manufacturing Implants for Maxillofacial Surgery

As a rule, the implant and technological equipment for its manufacture can be divided into two components: a universal and individual for each patient part, therefore the technology of computer-aided design should be designed for the production of both these parts. Tools can also be used in the process of manufacturing implants from sheet blanks on which the plastic deformation of the workpieces is carried out manually, by punching with polyurethane or in a combined method with manual finishing.

The model for the shaping of the implant blank by plastic deformation also consists of an individual patient shape part providing for the qualitative positioning and fixing of the implant on the jaw and a base with a uniform shape for installation in a container with polyurethane. The unfolding of the implant's blank should be located in the container and therefore determines its transverse dimensions.

Let’s consider the process of designing an implant using a specific example. The initial results of the tomography and the shape of the implant were provided by our colleagues from the Kazakh National Medical University. The CAD model of the part of the implant in place of the lost part of the bone for osteosynthesis in the maxillofacial surgery is shown in Fig. 1.

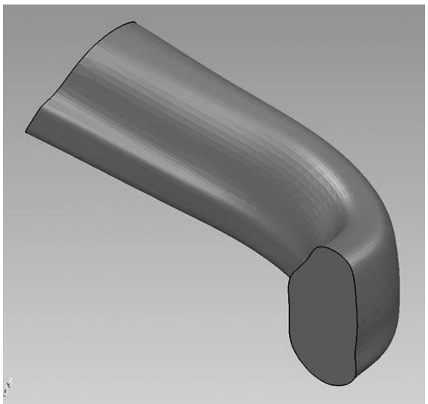

Figure 1. The CAD model

The method of constructing the surface of the implant should be universal and allows for the possibility of adjusting the shape. We developed a generalized algorithm using secant planes, which makes it possible to obtain an array of implant cross sections by planes perpendicular to its generatrix. The number of cutting planes depends on the accuracy of the design, but too many of them can lead to a decrease in computer performance. The presence of sections provides the possibility of correcting the profile of the implant with the subsequent construction of its surfaces, taking into account the shape of the jaw bones and the thickness of the sheet blank, as well as the surface of the template for its preparation. It should also be noted that the surface of the template differs from the desired shape of the implant due to the fact that in the process of spatial deformation, the titanium blank is springing.

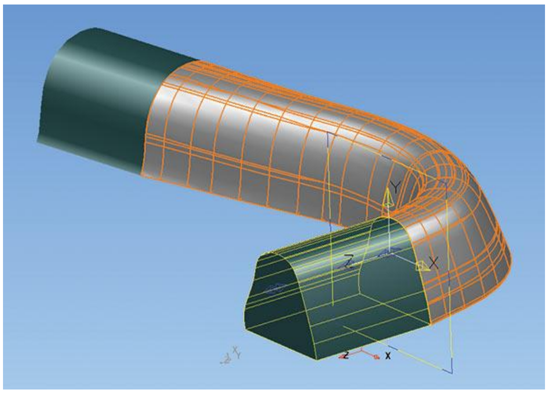

Figure 2. 3D model

Implant construction begins with the initial model obtained as a result of processing the patient's tomogram importing into the CAD system of PowerSHAPE. The resulting CAD model is a copy of the original 3D model and is suitable for further technological development. Then, on the jaw, parts of the surfaces are identified, to which the surfaces of the leaf implant will adhere when it is installed. The edges of the implant must therefore conform to the surfaces for the secure attachment of the implant to the bones of the jaw. It is necessary to add supplements both the ends along the length and the lateral generatrix of the implant to design contiguous surfaces. The first constructive supplement along the length ensures the placement of the implant over fragments of the bone for fastening with screws, and the second is needed for designing the model to avoid overhanging the workpiece over its end edges. Subsequently, the technological allowance along the lateral generatrix of the workpiece is cut off during the finishing of the product.

At the next stage, a set (array) of cutting planes is built along the entire body of the implant, and one of the lateral generatrixes of the implant base is used as the guiding curve for their construction (Fig. 3).

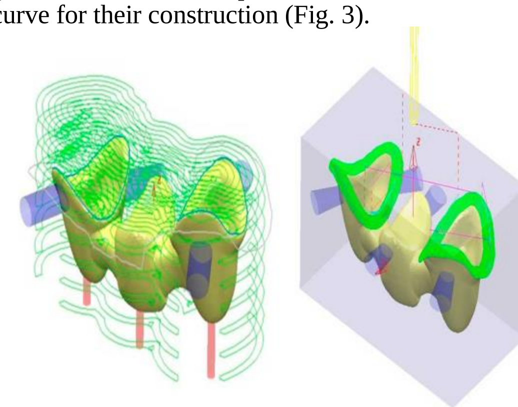

Figure 3. A set (array) of cutting planes is built along the entire body of the implant

The surface of the implant is displaced equidistantly to take into account the thickness of the sheet. In addition to adjusting the shape of the implant, the use of cross-sections makes it possible to calculate a sweep to obtain the shape of a flat sheet blank (Fig. 4). By adjusting the array of sections of the template, it is also possible to compensate for the spring of the workpiece during the stamping process.

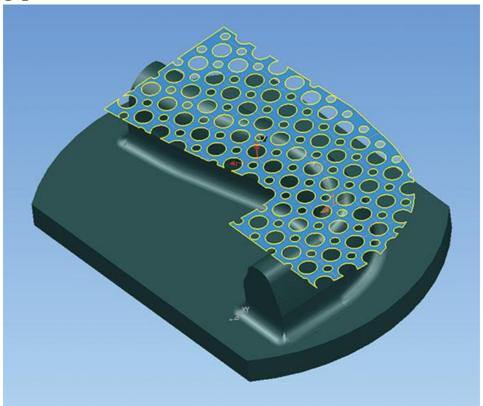

Figure 4. The surface of the implant

The process of punching a sheet blank also requires the creation of a transitional section with a round at the base on the model. As a result, we designed a ready-made model for the manufacture of a sheet implant, the base of which is designed for a universal container for the formation of a polyurethane implant.

It was modeled in the CAE system of Abaqus Student Edition to determine the loads acting on the implant during operation (during chewing). We used elements of the linear order type C3D8H contained in the standard library, from the category of 3D Stress to sample the volume and calculations that is working in all three directions in terms of their volume in a hybrid formulation. The mesh was uniform in length and thickness of the plate. Several variants of external loads have been modeled, including loads that arise when chewing both the intact and the prosthetic side of the jaw. Numerical analysis showed that the equivalent stresses arising in the implant in the places of its fixation with screws are close to the ultimate strength of the titanium alloy. The increase in the number of points of attachment of the implant due to the addition of a second row of screws allowed to reduce the load to acceptable levels for bone and implant material.

IV. Development of CAD hardware for the manufacture of implants by plastic deformation on the basis of the CAD-system PowerSHAPE

It has been developed CAD KazImplant in C # .NET language to automate the construction of stamp equipment, which is integrated with the CAD system of PowerSHAPE and performs 3D-constructions in it on the base of parametric models of stamp details. Integration is provided by using the library of API functions. It was also additionally used the specially developed library of functions, which is a superstructure over macros and implements work with objects in PowerSHAPE to build 3D models of stamp details. The main window of the developed CAD KazImplant is shown in Fig. 5.

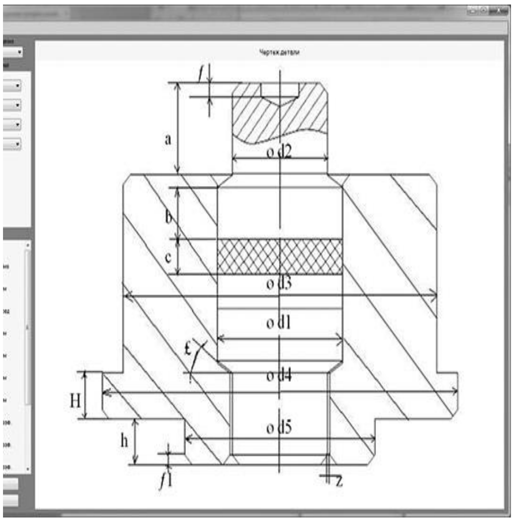

Figure 5. The main window of the developed CAD KazImplant

The parametric model of the tooling allows to arbitrarily changing the dimensions of the elements, preserving the configuration and integrity of the design by specifying the dimensional relationships (dependencies) of the variable parameters from several basic ones. The values of the basic and variable parameters can be stored in the database or set during the construction process by the user.

The details of the parts are stored in the database. The peculiarity of the application is that the user interface is dynamically formed depending on the type of product that we want to design, so it must be selected before working with the application, after that the user interface will show a drawing of the longitudinal section of the die tooling, as well as lists of parts and their parameters. Lists of details, parameters, as well as a list of types of projected products, are downloaded from the database. After setting the values of all necessary (basic) parameters and clicking the Build button, the algorithm for calculating the geometric dimensions of the parts is started, and the application builds the product in the PowerSHAPE environment in the automatic mode. The results of the CAD KazImplant are shown in Fig. 6.

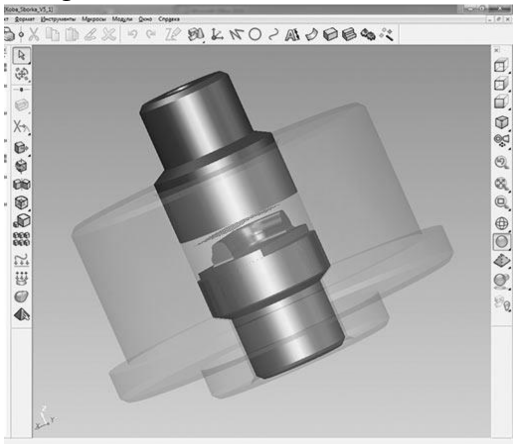

Figure 6. The results of the CAD KazImplant

We demonstrate the capabilities of the impCAD module in the example of manufacturing a designed model (a deforming tool for die tools) for the manufacture of implants.

The process of designing a product processing technology in the CAM system is based on the use of a universal visual interface and macros. The purpose of this work was to simplify the interaction of the technologist with the CAM-system and save his time in performing the same procedures by creating a specialized visual interface directly for this type of parts.

The created impCAD module can directly access the CAM API of the PowerMILL system and, with the help of macros, perform the necessary work on the development of control programs for CNC machines (Fig. 7).

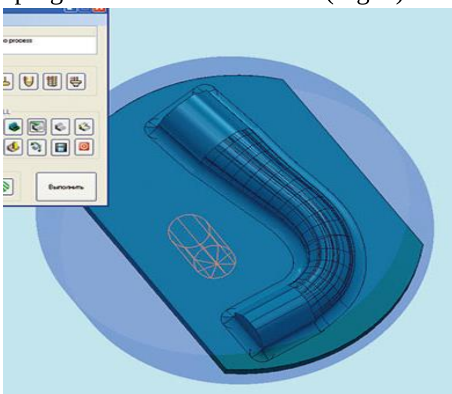

Figure 7. The results of the CAD KazImplant

The advantage of impCAD is the ability to transfer technological data, in particular tool parameters, data on processing modes, workpieces, surfaces, etc., to an external database. With this approach, CAD can become a part of an enterprise PDM-system, which also includes an expert system.

Integration with the CAM system of PowerMILL was realized with the help of the PowerSolution DOTNetOLE.dll. Macros were used to invoke PowerMILL functions, as well as PowerMILL dialog boxes. The structure of an external database for storing technological information has been developed and partially implemented. The application is written in VB.NET.

The control program can be transferred to the CNC machine after the process is formed in the impCAD module.

The working tool-model, the manufacturing technique of which was developed in CAD on the basis of PowerMILL, is made of fluoroplastic on the machine tool with CNC HERMLE C40U. The rest of the parts are made on a lathe. The matrix is made of polyurethane.

The manufactured universal die tooling for manufacturing implants from sheet blanks by plastic deformation with polyurethane was installed on a hydraulic press with a force of 20 MN (Fig. 8). In the container was placed the lower punch, polyurethane matrix, on which the workpiece cut out along the contour was installed, the model and the upper punch were placed on top. Then the upper punch was loaded with a technological force and deformed the workpiece with polyurethane on the model. Since the model was made of fluoroplastic, to reduce the workloads while working out the technology of obtaining the implant model, we used billets of sheet copper M1 0.2 mm thick, and as an elastic matrix - foamed polyurethane. The obtained samples are shown in Fig. 8.

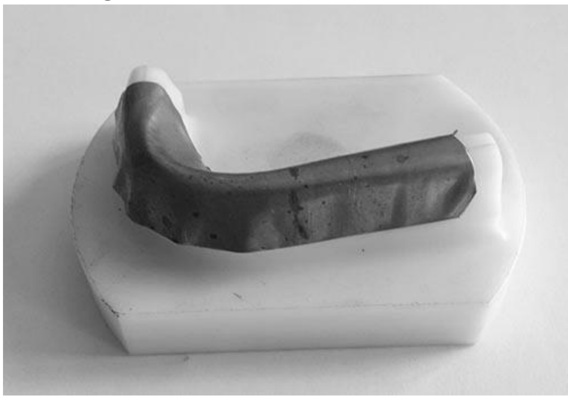

Figure 8. The obtained samples

The experiments showed that the inner surface of the implant fully corresponds to the model, while the outer one requires manual adjustment or correction of the deformation scheme. In general, this technology can be used to produce sheet implants with a complex spatial shape.

V. CONCLUSION

Thus, based on Delcam's PowerSHAPE and PowerMILL products, the technological process of designing and manufacturing implants from sheet blanks was developed and experimentally tested. This process is promising for expanding the nomenclature of implants from sheet blanks with increased mechanical properties and thickness to provide a more rigid structure for connecting damaged bone sites. Preliminary preparation of such implants will significantly reduce the time of the operation. At the same time, design automation makes it possible to more accurately and quickly design and manufacture implants of the required spatial shape. An organized treatment conditions based on the clinical conditions and desires of the patient is very important to achieve predictable results with implantable prosthesis.

Saving the natural teeth and fabricating application. The dental surgeon must familiarize himself with precision.

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