Robotic system development using CAD/CAM/CAE of NX

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Abstract. The article proposes a design technique of a 6DoF robotic system for processing complex-shaped parts containing a base and a module for installing a tool and a module for processing parts made in the form of parallel structure mechanisms using the CAD / CAM / CAE of NX system controlled by PLM management of Teamcenter system. In order to create a digital model of the system, a control structure was developed, which allowed creating the design using the “Bottom-Up” method in the course of the assembly. The control structure reduces the time of the creation of a model. The constructed model of the system will be used in the future for engineering calculations and mathematical analysis, as well as for obtaining all the necessary design documentation.

1. Introduction
Nowadays the design of any products is carried out using computer-added design (CAD) systems. At the software market there is a large number of software systems for design automation. The NX CAD / CAM / CAE system, which most effectively operates under the control of the Teamcenter PLM system, occupies the leading position in this area. Teamcenter is a universal platform for integration with heterogeneous applications, which provides round-the-clock work on the product and on-line access of various remote designers to implementing project [1]. This system allows performing various tasks on product support at all stages of the life cycle. Teamcenter includes a large number of applications used at certain stages of the product life cycle of any complexity. The “Structure Manager” application, which is a part of the Teamcenter system, allows creating a single universal structure for the future product. Thus, when setting the task of designing a new product with high precision of performance and minimization of implementation timeframe, the best option is to use CAD / CAM / CAE NX system under the control of PLM management of Teamcenter system.

2. Development of robotic system
The electronic composition of a robotic system based on the use of parallel structure mechanisms was developed taking into account the technical specification and draft documentation of engineering and design, as well as of the kinematic and static calculations [2-7].

Figure 1 shows the kinematic structure of the system. The mechanism contains a module for the installation of the tool 1 and a module for the installation of the processed part 2 on the basis of tripods. The upper module can rotate around the horizontal axes X and Y, as well as move progressively along
the vertical axis Z. The lower module can move along the horizontal axes X and Y, as well as rotate around the vertical axis Z.

![Kinematic scheme of robotic system](image)

**Figure 1.** Kinematic scheme of robotic system

After the preparation of the composition of a product and preservation of it, it is necessary to select the top level of the assembly and to push the NX – “Start / Open in NX” button on the “Structure Manager” toolbar.

In order to add further products that make up the structure of the robotic system, the context command “Control components in standby mode (Teamcenter)” is used.

For each product a manager can appoint a performer who, using round-the-clock access to Teamcenter, can perform design work at any time and in any place where there is access to the Internet. A manager creates a composition, differentiates the rights of users, thereby assigning responsibility for each product, which makes it possible to precisely control the process of working on the project and monitor the activities of each participant.

In the course of designing a new product, it is most beneficial to use the “Bottom-Up” method [8]. This method gives a designer a general idea of developed product. During this method a product design is carried out in the course of the assembly. This method is best used in the design of new products or for draft documentation with the appropriate technical specifications. If the task is to reproduce the product according to drawings, for digitizing or subsequent upgrading, then a “Bottom-Up” method should be used, in which all the parts are created first and then the main assembly is performed. The use of a combined approach is also possible when the finished products and the control structure are used for designing new products.

In order to facilitate the work in accordance with the composition of a product, a control structure of the assembly is developed. It is a set of construction geometry, arranged relative each other in a specific way. The presence of the control structure in the assembly reduces the time of the creation of a model.
In the future, the structure will be used to create a geometry located in the plane of a structure. In this case, according to the draft design, the planes are positioned in the places where the main assembly elements are joined. Thus, with the help of construction geometry at the preparatory stage, the overall dimensions of the future product are also determined. Figure 2 shows that the planes limiting the overall dimensions of the frame are located relative to each other at a distance of 1039 mm from each other. During the simulation of solids, it is important to understand that the main purpose is to create a precise geometric representation of a designed product [9].

The plane of a desktop for the installation of the part is located from the plane of the base at a height of 203 mm. The distance between the plane of the base and the upper plane of the frame is 890 mm. The plane of a desktop for the installation of the tool is located at a distance of 368 mm from the upper plane of the frame. The next step is to create the geometry of each unit of the robotic system. At the beginning, the frame of the system is designed; on its basis, it is possible to start the creation of a module for installing a part located in the “Lower Module” assembly. In order to create the geometry of the lower module, it is necessary to determine the position of the schematic design. For this purpose, the module plane is selected as the plane of schematic design from the control structure (Fig. 3).

Then, the next plane is created. It is located at a specified distance, for convenient creation of subsequent elements. The creation of construction geometry is an important component of any designed product. Proper formation of support planes can significantly accelerate the process of designing products of various complexities. In addition, the construction geometry in the assembly structure provides an understanding of the future product design without additional schematic design. When designing, it may be necessary to construct schematic design placed on reference planes. When working with assemblies, it is much easier to work at the expense of a correctly selected basic product in a unit or the assembly. The base body is selected according to the design features of the assembly or assembly as a whole. For more convenience in the course of geometry binding, the frame of a robotic body is determined to the upper level of the assembly. This makes it possible to interact with it in the course of the assembly or to hide it, if necessary. Thus, for example, it is possible to hide the frame structure and use only the reference plane to build the bottom of a robotic system.

During the construction of the geometry of products relative to other components of the assembly, it is possible to rely not only on construction geometry, but on the geometry of top-level models for more precise positioning in space. This method makes it possible to build, for example, a desktop model. At the same time, when a desktop model is ready, it is fixed for convenient creation and placement of subsequent models relative to the main one. The “Fixation” interface is superimposed as one of the
conditions for constraining the desktop in the working area (Fig. 4). Setting constraints allows defining the interaction of components in the assembly. For more flexible assembly control, it is best to use one “Fixation” interface per one basic part of the assembly or main assembly. Depending on the contact points and the way of interaction, additional interfaces are superimposed on the other components.

![Desktop unit](image1)

**Figure 4. Desktop unit**

In the course of the assembly apart from reference planes the axes are created along which the lower module moves. It allows controlling the position of products of the lower module relative to the selected axis with adjustable speed. Placing the drive models with respect to the axes when creating interfaces, the possibility of their movement is taken into account. Then, the additional elements in the form of support bearings for fixing the devices on the frame of the system are added (Fig. 5).

![Creation of bearing unit](image2)

**Figure 5. Creation of bearing unit**

After the creation of the lower unit, the remaining components are completed, located in the upper level of the assembly. Now it is possible to turn on the upper and lower levels of the assemblies in order to display the result obtained and continue creation in the upper part of the assembly (Fig. 6).

During the creation of the top module, a desktop is built on the basis of a predetermined plane in the control structure at a given height. Then, the construction of the upper module on the selected assembly plane is performed (Fig. 7). Reference planes allow precise designing new geometry, based on the bindings.
After the creation of a model, the ready model of the desktop for the installation of the tool, shown in Figure 8 is obtained. In similar way, the construction of subsequent parts and units of the upper module is performed.

During the course of the creation of assembly model, it is necessary to perform an assembly [10]. Gap analysis is used to check the presence of intersection of the components of the assembly and, accordingly, to ensure that the assembly is correctly constructed. The “Gap View” window displays all the intersections between assembly components. Those components without any intersection of geometry are defined as “Touching”. If during the design an error was made and intersections between the components of the assembly were detected, their state is defined as “Hard”. After analyzing the gaps, the geometry of the conflicting components is either corrected if it is an intersection between parts or units, or the intersections are added to exceptions, if it is intersection geometry in threaded joints.

Other models in the assembly are also positioned and fixed on the frame of the robotic system. Ultimately, the assembly consists of three assembly units: “Module for installation of the part”, “Module for installation of the tool”, and “Frame”; as well as fixing elements. Overall dimensions: length - 1220 mm, width - 1200 mm, height - 1045 mm (Fig. 9).
3. Conclusions
After the construction of a digital model of a robotic system, using the NX system applications, the static strength calculations, the kinematic analysis of moving parts of the system are carried out, and project documentation is issued in the form of general drawings, assembly units, and parts.
It can be concluded that the ability to create products using the “Top-Down” method and the control structure allows creating a digital model of a robotic system faster by increasing the speed of assembly and design of new products. It also simplifies the procedure of introduction of changes, since the work is carried out with a single composition of a product. During the operation of computer-aided design system, there is no need to design similar details each time, which significantly saves time and money on product development and design documentation release.

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