Cable robot design method using the NX CAD / CAM / CAE system

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Abstract. The article describes a method for designing a cable robot used for moving goods under special conditions. It is a parallel structure mechanism using the NX CAD / CAM / CAE system controlled by the Teamcenter PLM system. The mechanism is a rigidly fixed frame connected by tensioned ropes to a platform containing an axial displacement device. The diagram of the device is presented. To develop an electronic-digital model of the robot, the control structure that allowed for designing using the “Top-Down” method was built. The control structure reduces time required to develop a model. The spatial parameters of the device were determined. The product concept was developed.

1. Introduction
Currently, when developing a new product, it is necessary to ensure its high quality, low economic costs of manufacturing, high strength characteristics, compliance with customer requirements, etc. To solve engineering problems and achieve required quality, the NX CAD / CAM / CAE system controlled by the Teamcenter PLM system which allows for achieving the set goal and maximum efficiency is used [1, 2].

The use of the NX CAD / CAM / CAE-system can reduce the cost of the product, improve quality and reduce the time of launching it into the market. The Teamcenter PLM-system ensures interaction of all participants in the workflow in a single information space that provides each user with real-time access to product development. The integration of the NX CAD / CAM / CAE and PLM-systems allows you to cover all stages of the product life cycle [3, 4].

2. Development of a cable robot
Based on the terms of reference and outline documents, the electronic structure of the cable robot of a parallel structure was developed in the Teamcenter PLM system application “Structure Manager”.

Cable robots are a special kinematic structure, consisting of a working body connected to a fixed base platform using cables [5–8]. Unlike the known parallel robots [9–10], cable robots use cables instead of extension rods to control the position of the output link. In these mechanisms, the position of the output link is controlled by changing the length of the cables. Cables are usually wound around coils attached to the base and driven by a rotating motor.

The kinematic structure of the robot is shown in Figure 1. The cable robot is designed to move goods in special conditions and contains electric motors 1, 2, 3, 4, each of which includes a device for laying cables and a gearbox. The electric motors are rotated by control device 5. The electric motor reducers 1, 2, 3, 4 are connected to cables 6, 7, 8, 9 to move the load in the horizontal plane through
rollers 10, 11, 12, 13. Rollers 10, 11, 12, 13 are located on frame 14. The gripping device is movable platform 15 connected to cables 6, 7, 8, 9. On movable platform 15, there is output link 18, on one end of which actuator 17 is located. It can perform axial movements. Drive 17 is a direct current motor kinematically connected with a gear rack. The gear rack is at the end of the output link. At the opposite end of the output link, the drive is rigidly fixed. Its output shaft is equipped with adjustable grip 16.

When motors 1, 2, 3, 4 rotate with cable laying devices and gearboxes, the length of cables 6, 7, 8, 9 changes. As a result, the gripper moves to the desired point in space. It is assumed that cables 6, 7, 8, 9 are able to move the gripper due to output link 18 which can perform axial movements by means of axial displacement actuator 17 connected to the rack mounted on platform 15 in a horizontal plane; the drive consisting of an electric motor and a kinematic transition node ensures the conversion of rotational motion into reciprocating and adjusts the size of capture 16.

The Teamcenter “Structure Manager” application provides an ability to work with the product throughout the entire life cycle. It also allows you to download revisions and manage variant conditions. The structure manager works with revisions of elements. When creating the structure of the load moving device, a mixed approach is used to develop the structure, that is, the design engineer develops the structure of the top-level product elements, and then the product composition can be supplemented from the NX CAD / CAM / CAE system [1] (Figure 2).
After saving the composition of the new product to fill the datasets with geometry, you need to select the top assembly level and click the button "Run / Open in NX".

NX offers to select a template file in which the geometry will be created: "Assembly unit". Only the top level of the assembly is reflected in the assembly navigator. To add datasets, you need to right-click the top assembly level and select "Manage components in standby mode (Teamcenter)."

The Top-Down method was used. To facilitate the work after the composition of the product is formed, a control structure of the assembly is created in the NX CAD / CAM / CAE-system "Modeling". The control structure of the product is a special approach to the design of a new product, which allows for collective work, reduces the time of designing and making changes. The control structure is a set of geometric objects – axes, coordinate planes located relative to each other.

In the NX CAD / CAM / CAE-system "Modeling", using the “Expressions” command located on the “Tools” toolbar, the variables are created for constructing and managing the control structure (Figure 3). The variables entered in the future will be associated with dimensions of the control structure and used to simplify the editing process of the assembly. This is due to the fact that the geometry and the variable of the control structure will not be responsible for the location of the components.

Using the "Coordinate plane" command, the support tower base plane is created parallel to the XC-YC plane (Figure 4).

The planes are created parallel to the ZC-XC and ZC-YC planes that limit the length and width of the product being developed (Figure 5). The platform plane of the load handling device is created. Ultimately, the control structure includes 3 horizontal planes and 4 vertical ones. The plane of the platform is located at a distance of 700 mm from the plane of the base of the support towers, and the plane limiting the overall size in height is located at a distance of 1700 mm. The planes parallel to the
ZC-YC planes are located at a distance of 2000 mm from each other, and the planes parallel to the ZC-XC planes are located at a distance of 1500 mm from each other. Figure 6 shows the control structure.

When the control structure is ready, the geometry of the model is created. The frame consists of several elements: a vertical strut, lower profiles 1 and 2, upper profiles 1 and 2, OB-4545L-BP-1655. Profile 1 is the first one to be designed.

Using the “Sketch” command, the section of the profile located on a plane parallel to the ZC-YC plane is constructed, then the sketch is completely limited (Figure 7).

When the profile sketch is completed, a solid body is built using the “Pull” command (Figure 8). The cut is made in the cylindrical sections of the profile using the commands “Sketch” and “Pull” (Figure 9).

Using the “Slope” command, trim the right end face at an angle of 45 degrees (Figure 10). The left end trim is constructed in the same way. The last element is the rounding of the ribs of the vertical strut using the command "Rib rounding " (Figure 11).
After constructing the lower profile, the remaining frame elements are constructed. Using the commands located on the "Assemblies" toolbar, the frame assembly model is created (Figure 12). When designing products using the control structure, the main components of the assembly are mated with elements of the control structure. In this case, using the “Mates” command, the lower profile is mated with planes parallel to the ZC-XC and ZC-YC planes (Figure 13). Then, the remaining components of the top-level assembly are added to the upper assembly level.

The geometric model of the platform on which the axial displacement drive and the output link with the gripper will be located is created (Figure 14).
After all the components have been built, fasteners are added to the frame assembly. To do this, the Teamcenter Classifier PLM system is used or fasteners from the NX CAD / CAM / CAE reuse library are added.

In the assembly of the cable robot, the cables are constructed in a simplified representation supporting the platform to provide information about their position in the assembly. Figure 15 shows the assembly model of a cable robot with a movable gripper for moving goods in special conditions.

3. Conclusion

Thus, using the NX CAD / CAM / CAE system controlled by the Teamcenter PLM system, it is possible to design new products and carry out outline designing. The use of the control structure ensures accurate control of the assembly, as a result of which the change in the size of the control structure allows you to increase or decrease the size of the working area.

![Figure 14. Building of the platform](image1)

![Figure 15. Cable robot for moving goods](image2)

Based on the preliminary design, a detailed study of the components and details of the cable robot can be carried out. The CAD / CAM / CAE-system NX controlled by the PLM-system Teamcenter reduces the time for implementing the outline design and changing the structure.

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