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3D Robot Model Development

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Abstract:

Modeling robots, their design and movement is an urgent task. Such modeling allows us to anticipate and solve many problems that arise both during the physical creation of the robot and during its operation. This article proposes a three-dimensional modeling of the robot – the MP-999E hand. First, the process of modeling a gear wheel is discussed in detail, and then the modeling of the robot itself.

Key words: 3D model, Robot, Prototype, Spur gear, Gear tooth

Introduction

One of the key areas of scientific development is robotics [1]-[6]. The areas of application of robots are expanding more and more. However, for the successful development of robots, preliminary 3D modeling of these devices is advisable. The relevance of such modeling is due to a number of reasons [7]-[13].

Firstly, due to the development of technology, computer power and software, it has become possible to create highly accurate and realistic models [14], [15].

Second, simulation helps optimize robot design and testing. This means that the costs of developing a real robot are reduced, since many problems can be seen and corrected already at the modeling stage. Modeling reduces prototyping costs and speeds up development.

Third, simulation makes it possible to test new ideas, algorithms, and concepts without having to build a real prototype.

Fourthly, through simulation it is possible to optimize and improve the characteristics of robots before they are manufactured. That is, the robot becomes more efficient, maneuverable and functional.

Fifthly, modeling allows us to anticipate and prevent undesirable situations in the robot's behavior. This is a consequence of the ability to study the behavior of robots in different scenarios and environments, as well as analyze their interactions with people and other robots.

This list can be continued. However, we see that the development of three-dimensional robot models is an extremely relevant and timely task.

Related works

Many scientists around the world are working on the problem of three-dimensional modeling of robots. At the same time, since the model is a certain simplification, the main emphasis is on the research objectives. Let's look at some works on this topic.

Paper [15] devoted to an ecosystem of virtual environments and tools that allows for the management of realistic virtual environments where robotic simulations can be performed. It is called Robot@VirtualHome.

In [16] scientists propose present the pipeline for realistic virtual environment generation using an adapted robot model, including lifelike map generation methods such as photogrammetry.

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Zhu, A., & et al. in [17] use prototype BIM simulation environment. They implemented multiple different robots to complete the construction of a steel frame based on the smart construction objects. Authors in [18] present and discuss a general approach for the dynamic modeling and analysis of a passive biped walking robot, with a particular focus on the feet-ground contact interaction. For a legged-wheeled hybrid robotic vehicle development [19] modeling also was used. And in paper [19] among other stages we see modeling stage.

In [20] researchers use ROS in order to analyze and compare robotic arm's responses under different algorithms and different target pose.

Uneven environment based on ACO tuned MPC controller was used to perform simulation in [21], and further, it has been validated using real-time experiments on humanoid robot NAO.

Modern robots use many sensors. And for their installation, it is also advisable to pre-simulate them to determine the necessary characteristics and production parameters [22]-[24].

Modeling a robot and especially its operation is extremely important in such a field of science as medicine. Before using the robot on real patients, its operation must be simulated first on a computer and then on a human prototype (mannequin). In [25] a minimally invasive aortic valve positioning process through a previously designed soft robot was simulated. The adoption of the weighting process for the fitting was successful, as it permitted an accurate prediction in the region of interest through models with less parameters.

In article [26] the phenomenon of impact-contact in a closed-loop robotic chain has been dynamically modeled.

During robot development [27] first of all scientists build a model that describes how the robot morphology affects performance on selected terrains.

Article [28] presents a dynamic model for the increasingly popular Panda robot by Franka Emika.

So, we see that many scientists are working on the problem of modeling for robots. It should be noted that in each specific situation, researchers need to select model parameters that influence the processes that need to be studied. Next we will look at 3D modeling of the MP-999E robot.

Design of a 3D model of a spur gear with an involute side profile

Thanks to modern methods of computer-aided design and rapid prototyping, ideas have become much easier to implement. CAD, CAM, CAE system. Unigraphics NX7.5 is a complete solution for digital product creation, offering an integrated system to perform design, engineering analysis, documentation, tooling and pre-production tasks of any complexity for all areas of industry.

Let's look at the method of constructing a gear using an involute curve in the Unigraphics NX 7.5 system.

To construct a curve according to the law, we will use a mathematically accurate method for creating a side profile. The NX modeling environment has a special expression engine that will be used to set the main control variables and dependencies. Gear construction is a precise process, so all constructions will be based on the values calculated by the engine.

Construction will take place in the following stages:

a) creating basic control variables and dependencies;

b) construction of the main diameters of the gear wheel, limiting the ring gear;

c) constructing a tooth profile as a curve according to the law in accordance with the parametric form of the involute given below;

d) deposition of the width of the tooth and construction of its axis of symmetry;

e) reflection of the involute relative to the constructed axis of symmetry of the tooth;

f) construction of all z teeth of the gear wheel;

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The dimensions of teeth with an involute profile determine the parameters characterizing the position of any point of the involute. An involute is a development of the main circle in the form of a trajectory of a straight line point that rolls without sliding along this circle.

The initial data for calculating both the involute and the gear are the following parameters: *m* - module - part of the diameter of the pitch circle per tooth. The module is a standard value and is determined from reference books. z is the number of wheel teeth. α is the profile angle of the original contour. The angle is a standard value and equal to 20°. As well as the diameter of the pitch circle *d*, the diameter of the circle of the depressions *df* and the diameter of the circle of the vertices *da*.

For a parametrically defined curve, the involute equation has the form:

$$x = (d\_main/2)(cos(t) + t\,sin(t)), \tag{1}$$

$$y = (d\_main/2)(sin(t) - t\,cos(t)), \tag{2}$$

where *t* – evolute angle;
d_main – diameter of the main circle (evolute).
All gear parameters will be calculated using the following formulas:
Pitch circle diameter:

$$d = m \cdot z, \tag{3}$$

where *m* – tooth module;
z – number of teeth.
Vertex circle diameter:

$$da = d + 2 \cdot m, \tag{4}$$

where *d* – pitch diameter;
m – tooth module.
Diameter of the circle of the depressions:

$$df = d - 2.5 \cdot m, \tag{5}$$

where *d*- pitch diameter;
m – tooth module.
Base circle diameter:

$$d\_main = d \cdot \cos(20), \tag{6}$$

where *d*- pitch diameter.

We sequentially add variables that determine the parameters of the gear wheel. The construction of circles *d_main*, *d*, *da*, *df*, is presented in Figure 1.

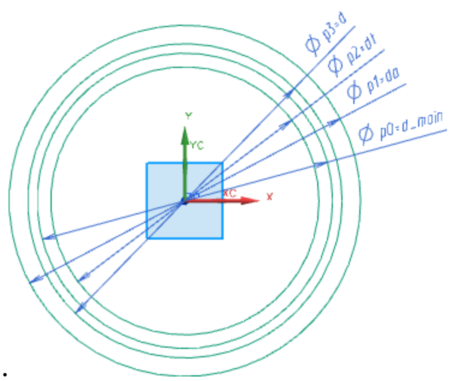

Figure 1: Circles for constructing a gear wheel

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Completion of the sketch creation and the transition to the creation of an involute is carried out by the command “Insert - Curves - Curve according to the law”. A given expression is selected as a function of the law.

After this, the variables (t, xt, yt, zt) are indicated, on the basis of which the involute curve is constructed (Figure 2).

In accordance with the parameter values t=0..1 NX creates a curve according to the law in space. Since the parameter $zt = 0$, our curve is located in the plane.

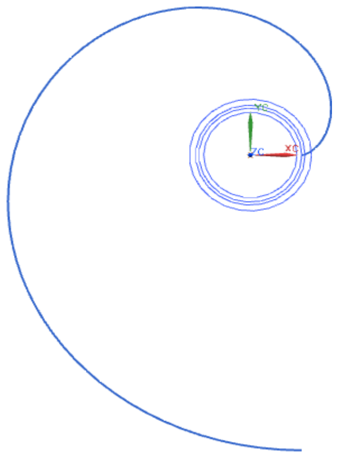

Figure 2: Involute in the construction plane

The construction of the tooth along the created line, limiting the cavities and apexes of the tooth, is its lateral surface.

Tooth thickness is calculated using the formula:

$$s = m \cdot \pi / 2 \tag{7}$$

where m – tooth module.

The length of the created arc s is equal to the thickness of the tooth, relative to which a line of symmetry of the tooth is constructed as a segment between the center of the circle and the middle of the arc, which will be the basis for the mirror construction of the involute (Figure 3).

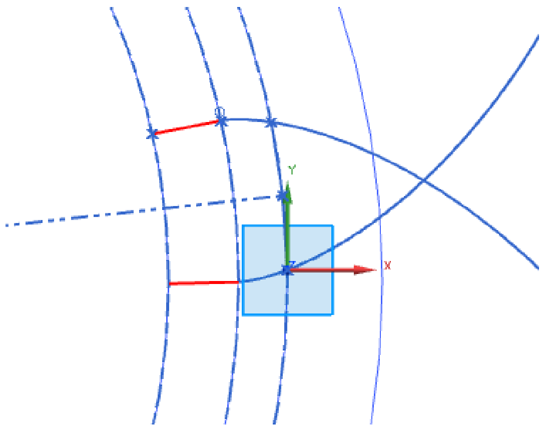

Figure 3: Construction of an involute side profile

The creation of a 3D model is based on a drawing of the contour of a gear wheel (Figure 4). Because the gear contour has a self-intersection, the body of the gear and the tooth are modeled separately from each other.

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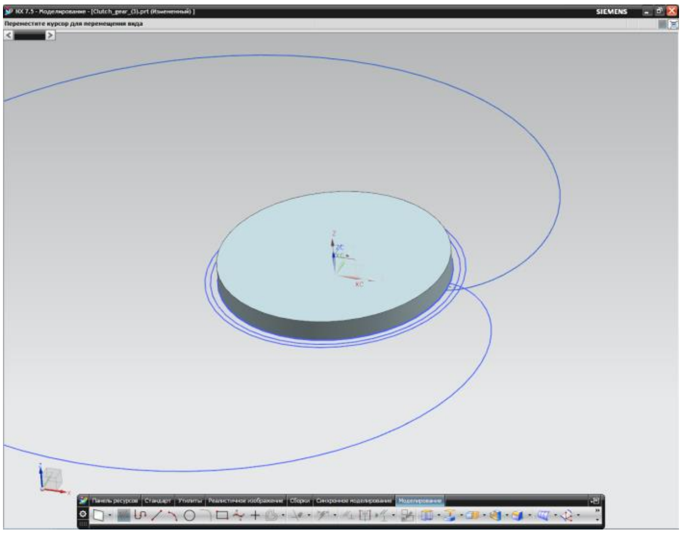

Figure 4: Gear Base Modeling

The construction of a tooth according to given curves is shown in Figure 5. When selecting a curve, the system offers a choice of segments between the intersection points. As soon as the contour is closed, NX offers to extrude the solid body.

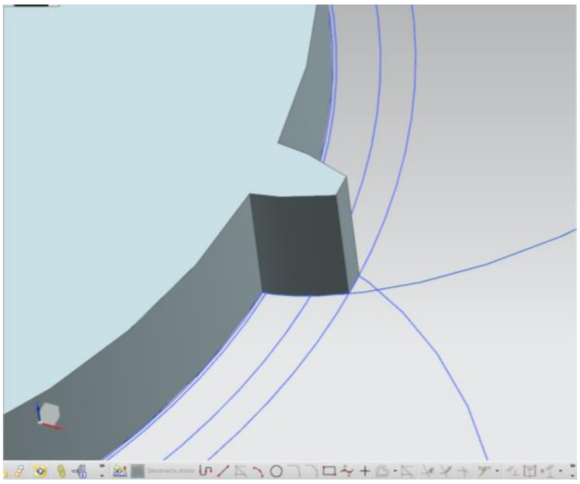

Figure 5: Constructing a gear tooth

To construct z teeth of a gear wheel, we will use the command “Insert - Associative copy - Array element”

As a base element for a circular array, we select a construction element that corresponds to the constructed tooth.

As the number of teeth we indicate the variable z - the number of teeth of the gear, and as the angle between the elements – 360/z.

Specifies the method for defining the center of a circular array and the axis around which the elements rotate. As a result, we obtain a completed gear, shown in Figure 6.

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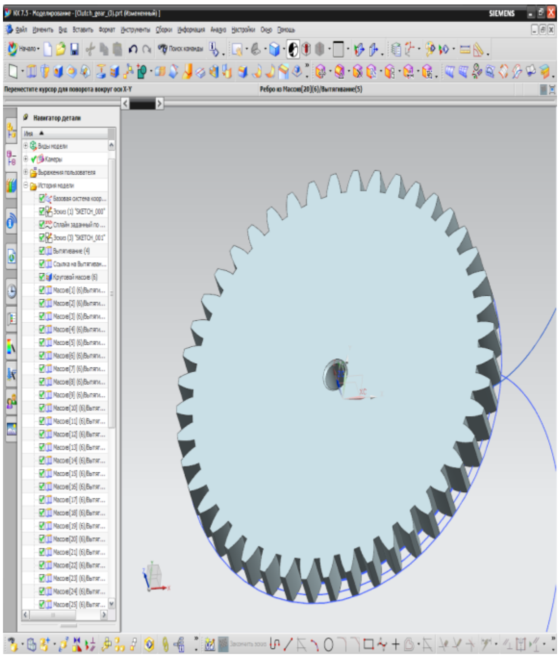

Figure 6: 3D model of a gear

Development of a 3-dimensional model of the manipulator

The construction of a three-dimensional model of the robot manipulator MR-999E (Figure 7) with maximum detail of all elements is carried out in the Siemens NX 7.5 software.

Figure 7: Robot MR – 999E

There are many methods, approaches and sequences for modeling parts and assemblies, which the designer chooses at his own discretion. The basis for the construction of each element was the drawing from which the 3D model of the element was built (Figure 8).

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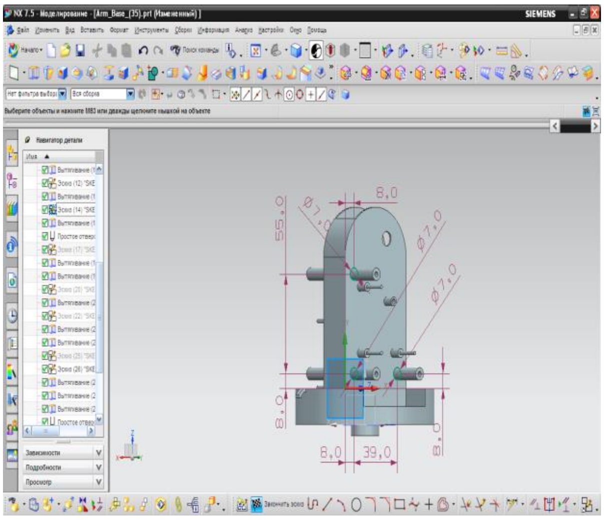

Figure 8: Creating a drawing on the 3D model plane

When developing each part, the parallel modeling method was used. The main concept of the method is the verification of all specified dimensions by parallel creation of an assembly of elements and the ability to monitor in real time inaccuracies in the modeling of individual elements and instantly eliminate them (Figure 9).

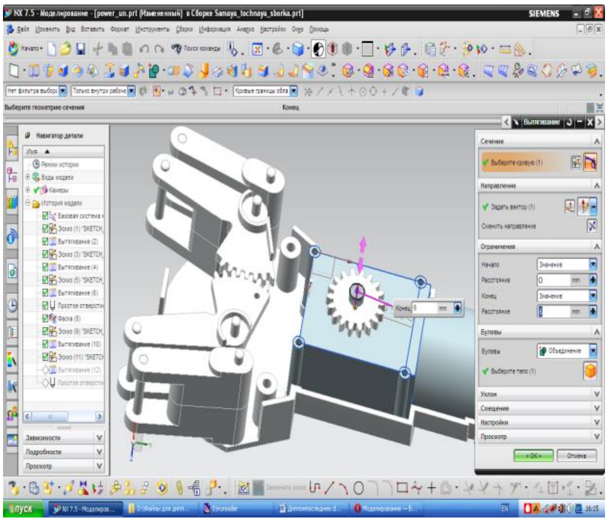

Figure 9: Editing an Assembly Feature

This reduces design time and human labor costs. The design is carried out according to a certain hierarchy of a given robot design, starting with the gripper and ending with the base. This hierarchy formed the basis for assembling the robot. The assembly of three-dimensional models into a single whole product is carried out in a special editor “NX assembly”. To assemble all the elements into a single product model, it is necessary to mate the connections between each element of the assembly. When specifying concentricity, tangent alignment and fixation mates, it is necessary in accordance with the type of node (Figure 10).

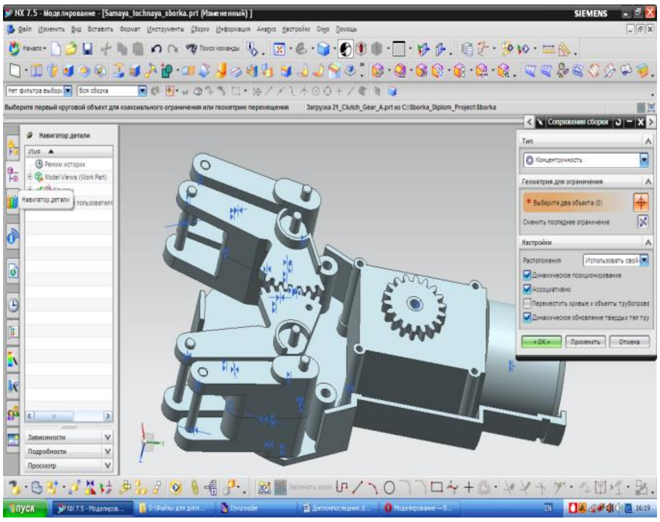

Figure 10: Assembly Mates

By setting the correct relationships between assembly elements, we will be able to set kinematic relationships and precise engineering analysis of individual joints or the entire product. After modeling all elements and assembly operations, we have a ready-made 3-dimensional model shown in Figure 11.

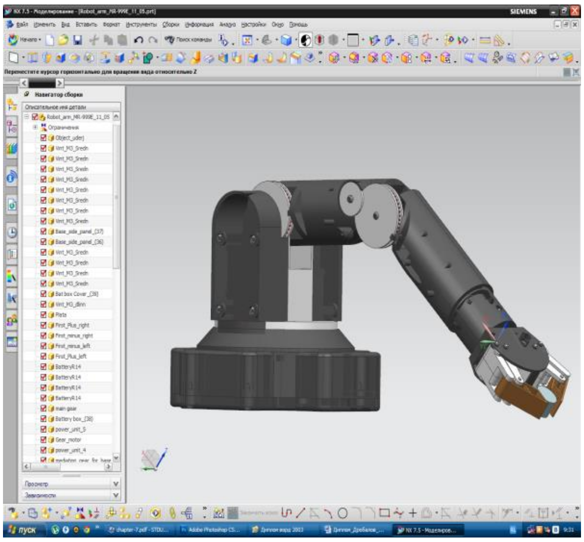

Figure 11: 3D model of the robot MR - 999E

Conclusion

This paper examines the problem of three-dimensional modeling of a robot. The result is the creation of a detailed model of the MP-999E robot.

In the future, it is planned to analyze the design and kinematics of this robot to identify potential problems both in the design and in its movement.

It is also planned to conduct various tests and simulations of the robot's operation before its physical creation. This will help determine the effectiveness of parts, prevent design errors and reduce the risk of possible problems during operation.

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Thus, the use of 3D models speeds up the design and development process, as it allows errors to be identified and corrected more quickly, as well as design improvements and optimizations.

3D robot modeling is an important tool that helps engineers create more efficient, functional and safe robotic systems.

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