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PROSTHETIC HAND 3D MODEL DEVELOPMENT

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Abstract:

The development of prosthetics is an extremely pressing task in our time. Such devices are designed to improve a person's quality of life and give him opportunities that he lost either as a result of injury or illness, or at birth. However, direct physical development is preceded by three-dimensional modeling of such devices, as a result of which it becomes possible to identify and correct errors, as well as optimize the device itself. In this article, the authors provide modeling of a human hand, its assembly, as well as calculation of grip force and analysis of the choice of material in the UniGraphics NX 7.5 environment

Key words: Medicine robot, Gripper device, Assembly, UniGraphics, Simulation, Modeling.

Introduction

With the development of technology, especially IoT and AIoT, robotics is increasingly penetrating various spheres of human life [1]-[9]. Many scientists note the expansion of the areas of application of robots. Accordingly, the number of research related to robotics using a variety of sensing systems, sensors is constantly growing [10]-[14]. One such area is medicine, in which robotic devices are used to solve a wide variety of problems [15], [16].

Despite the highest level of development of science, including medicine, the number of people in need of prostheses is not decreasing, but, unfortunately, is growing. At the current stage of development of technological progress and scientific achievements, people with physical disabilities have a large selection of different opportunities and a range of products from the prosthetic industry, as well as a full range of various adaptive equipment. Moreover, despite all the variety of existing devices, each of them is not ideal, much less universal, suitable for any person who needs this type of prosthetics.

Many scientists are working on this problem, creating more and more new devices, among which robotic prostheses are becoming quite popular. It should be noted that the use of robotics in various fields of medicine is a very promising area for Research [17]-[22].

Robotic prosthetics are advanced medical devices designed to restore or improve limb function in people who have lost them due to injury, disease, or birth defect. These prosthetics are typically equipped with advanced technology, including motors, sensors and microcontrollers, that allow them to mimic natural limb movements.

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Robotic prostheses can vary in functionality and level of complexity. They can perform a wide range of movements, from simple everyday activities to more complex tasks such as skillful finger control to perform precise actions.

The technologies used in robotic prosthetics are constantly improving. Some of these include brain interfaces that allow users to control the prosthetic with thoughts, as well as sensors that can provide haptic feedback, giving users the sensation of touch and pressure.

These innovative prosthetics play an important role in improving the quality of life of people with limb loss, helping them return to daily activities and activities that may have previously been limited.

To develop robotic prostheses, it is advisable to first simulate its design in modeling environments, which also help to select the material for the device being developed. Further in the article we will consider modeling a prosthetic hand in the UniGraphics NX 7.5 environment.

Related works

The development of robotic prostheses is extremely promising due to the provision of new opportunities for people with disabilities, and is also very relevant due to the large number of people in need of prosthetics. The consequence of this is a huge number of scientific works devoted to this topic. Let's briefly look at just a few of them.

Paper [23] analyzes the state of the art of robotic prosthetic hands with particular attention to the potential and current limits of their main building blocks: the hand itself approaches to decoding voluntary commands and controlling the hand, and systems and methods for providing sensory feedback to the user.

In [24] authors consider above-knee amputees. They note the lack of sensory information, even while using most advanced prostheses. And it is necessary to restore intraneural sensory feedback results in functional and cognitive benefits.

Fleming, A. and co-authors in [25] describe robotic lower limb prosthesis control via electromyographi signals recorded from residual muscles in individuals with lower limb amputations.

Scientists [26] propose soft prosthetic hand that is able to perform all the real-world grasping tasks of the benchmark tests, showing great potential in improving life quality of individuals with upper limb loss.

Prostheses focused on people with an amputation below the elbow are considered in work [27]. It integrates different studies related to hand prosthesis, this will allow him to evaluate alternatives where he will be able to choose, analyze the study or characteristics that better contribute to his research topic.

Sun, Y., & et al. in [28] write about the robotic knee prosthesis. They distinguish such development trends bionic and lightweight structures with better mechanical performance, bionic elastic actuation with energy-saving effect, artificial intelligence-based bionic prosthetic control.

A robotic knee is also under research in [29]. Authors of this study demonstrate reinforcement learning tracking control for automatically configuring the impedance parameters of a robotic knee prosthesis.

Researchers [30] note that existing powered robotic prostheses are much heavier and bigger and have shorter battery life than conventional passive prostheses, severely limiting their clinical viability and utility in the daily life of amputees/ They propose their own lightweight robotic leg prosthesis.

This is a very small part of the research, but it gives us an idea of how comprehensive and relevant the development of robotic prosthetics is. Later in the article we will present the development of our device at the 3D modeling stage.

Manipulator detailed assembly development using UniGraphics NX 7.5

When developing any device, it is necessary to perform its three-dimensional modeling, as well as modeling the necessary parameters, including the strength of forces that will be used during its further operation. Many works present such modeling [31]-[33].

Most designed products are assembly units (assemblies). In fact, an assembly is a kind of hierarchical structure, at different levels of which there are components - subassemblies or parts.

Connections are used to place parts in an assembly. Assembly connections allow you to specify the relative position of the assembly components, that is, they fix the degrees of freedom. By correctly specifying all the assembly connections in the assembly, it is possible to analyze the operation of the entire mechanism. Assembly constraint is applied to component geometry (such as planar faces, edges, etc.).

Each component located in space has 6 degrees of freedom (3 linear and 3 rotational). By imposing assembly connections, certain degrees of freedom are fixed. One constraint usually limits several degrees of freedom.

The designed gripping device consists of elements such as a body and 5 fingers. This model has 4 fingers with an identical design, the assembly of which is shown in Figure 1.

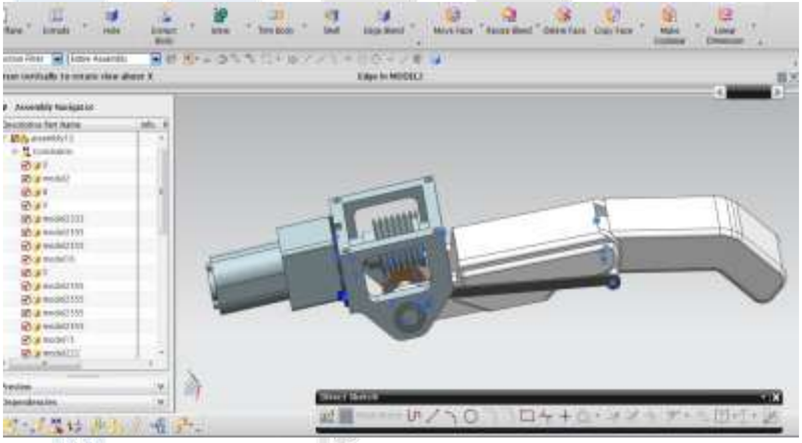

Figure 1: Gripper device finger assembly

The second design element of the manipulator is the thumb, which has a different type of assembly. Figure 2 shows the assembly of the robot's thumb.

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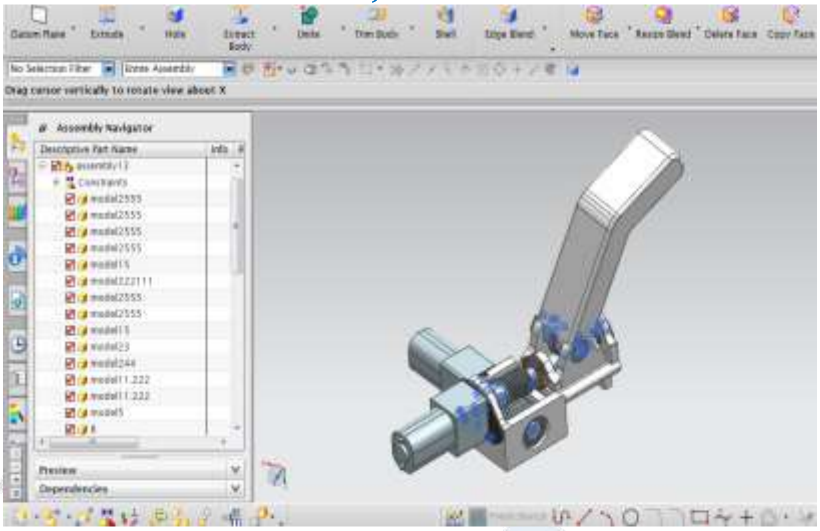

Figure 2: Gripper device thumb assembly

The final work is to assemble the manipulator hand, which consists of a body, 4 identical fingers and 1 thumb. This design is shown in Figure 3.

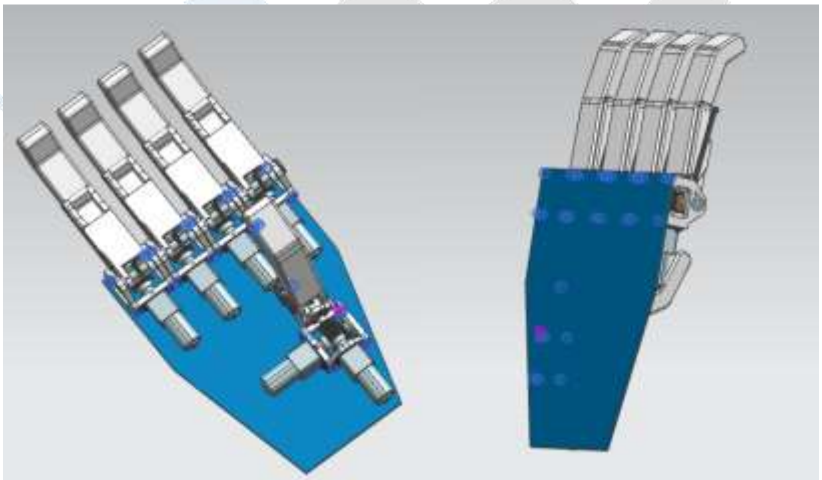

Figure 3: Robot hand assembly

The force applied to the manipulator body modeling

For a preliminary assessment of a structure strength and performance, an engineering approach is used, which mainly consists of representing the structure in the form of simple units and elements, for which there are analytical estimates for searching for the stress-strain state. Such estimates include the use of simple formulas for searching for stresses in beams during tension, bending or torsion, searching for relative elongation, moments of inertia, reaction forces, etc.

The basic principle underlying analysis based on the finite element method is to split the mathematical model of the area under consideration into non-overlapping subdomains (finite elements) and solve the problem at each element. The set of elements, their properties, and boundary conditions is called a finite element model. The behavior of each element is described

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by a certain finite number of degrees of freedom, which together determine the number of degrees of freedom of the finite element model. The main steps of the finite element method: idealization, sampling, solution of a system of differential equations. By idealization we mean the transition from a real physical model to a simplified (modified) mathematical one. However, mathematical models have an infinite number of degrees of freedom, which entails the practical impossibility of solving the problem using a complex mathematical model. Limiting the number of degrees of freedom of a model is called sampling, and the model is called a discrete model. Each stage of numerical modeling introduces one or another error into the calculation result. Particular attention should be paid to two stages:

- idealization – at this stage the transition to a mathematical model is carried out, which can introduce a significant error or even a cardinal error in the result;

- sampling – at this stage it is necessary to check the convergence of the numerical solution to the correct one, and as the number of degrees of freedom increases to infinity, the discretization error tends to zero.

Engineering analysis "NX Advanced Simulation" allows you to evaluate the accuracy of calculations to increase grip force. By simulating grip compression, an gripper device finite element model was created. When creating a finite element model, the program automatically creates an idealized gripping device model by simplifying the model geometry and checking nodes and structural elements.

For the engineering calculation of the force applied to the rack in “NX advanced simulation” the following operations were performed:

- creation of a geometric model (or assembly) representing an accurate digital model of the object being analyzed;

- performing numerical engineering analysis;

- stage of idealization of the model. At this stage, geometry is simplified, midsurfaces are highlighted, and bodies are divided for additional local control of the mesh quality;

- construction of a finite element mesh taking into account condensations in the zones of the greatest gradients, properties and materials, fastenings and loads are specified;

- launching the model for calculation;

- obtaining and analyzing post-processing results will allow for a detailed visual and quantitative analysis of the results.

NX's mathematical and engineering calculations provide us with maximum risk reduction when performing modifications to increase the gripping force of the gripper and release the finished product. Figure 4 shows the modeling of the gripping force

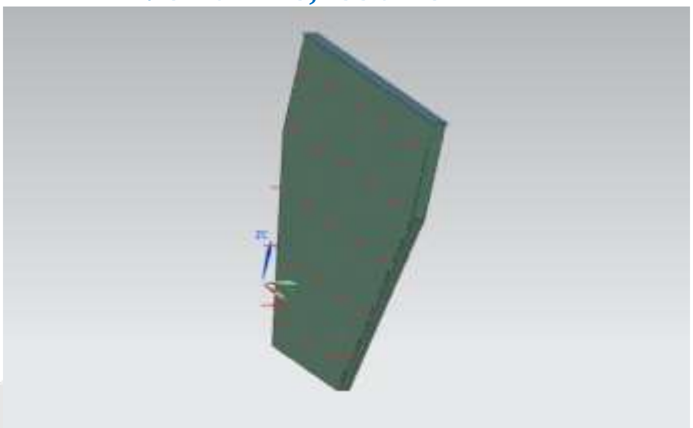

Figure 4: Grip force simulation

When modeling the manipulator body, it was proposed to assign 3 selected materials: Titanium-Annealed, Polypropylene and Iron_40.

The first material chosen is Titanium-Annealed. Based on the analysis, we can see the results presented in Figure 5.

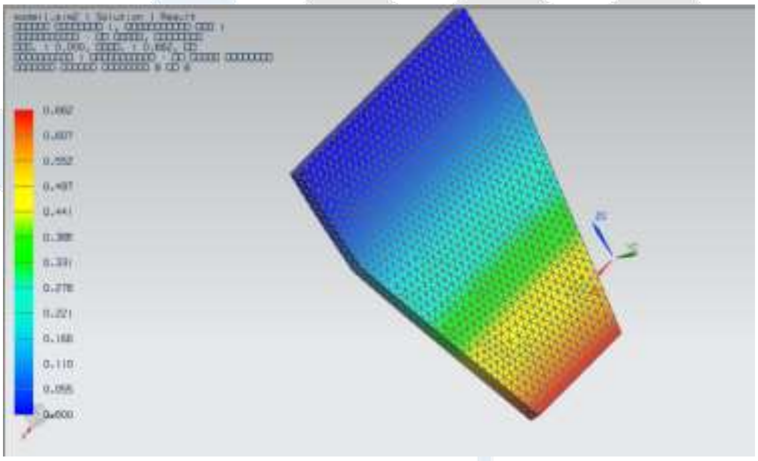

Figure 5: Titanium-Annealed material

The second material chosen is Polypropylene. The results are presented in Figure 6.

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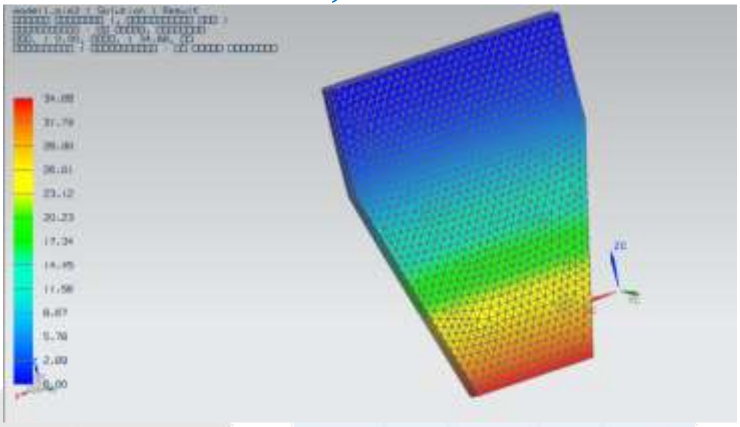

Figure 6: Polypropylene material

The third material selected is Iron_40. The results are presented in Figure 7

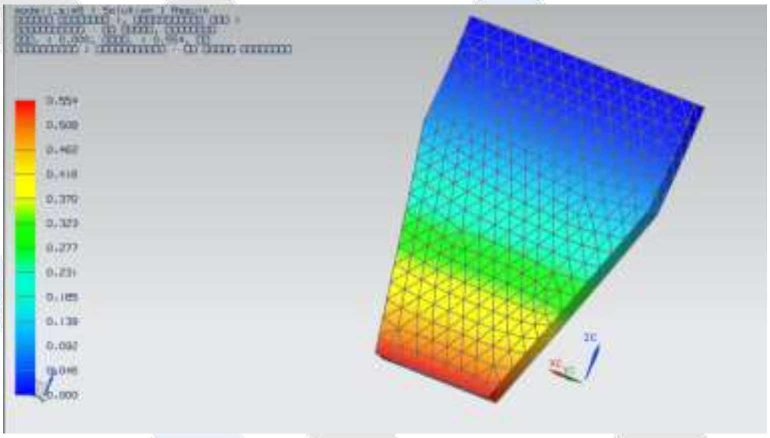

Figure 7: Iron_40 material

Conclusion

Thanks to this study, using a clear example, it is possible to select the optimal structural elements for a humanoid-type manipulator. Since it is important to understand the fact that when making a manipulator for a person with disabilities, it is necessary to take into account his individual characteristics and needs.

The work contains experimental data in the form of a strength study when choosing a material for the manipulator body. Three types of material are presented: iron, titanium and polypropylene. After completing the experiment, we can conclude that the most durable material is iron, but it has its drawback - large mass, so this material is not suitable for every person. Titanium is in second place; it should be said that this material is more practical and convenient to use for this manipulator. Since titanium does not have a large mass, it is at the same time a durable metal alloy that is not harmful to human health. Polypropylene, based on experiment, is less durable than the two previous materials, but at the same time has the smallest mass. When choosing a material, the main selection criteria are the purposes for which the manipulator will be used; you should pay attention to the height, weight, gender and age of the person for whom it is intended.

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During the research process, the Pololu 30:1 Micro Metal Gearmotor HP metal gearmotor was selected, which consists of a reliable high-power motor with a 30:1 metal gearbox. This geared motor has one, no less important, criterion - small size and weight, since for this manipulator these factors are among the main ones.

Currently, there are many devices that make modern medicine more effective, and in this work, an example of such a device was considered - a humanoid-type manipulator. Medicine is in constant development, so the introduction of robots in this area is a promising activity.

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