JOURNAL OF UNIVERSAL SCIENCE RESEARCH

ISSN (E): 2181-4570 ResearchBib Impact Factor: 6,4 / 2023 SJIF(2023)-3,778 Volume-2, Issue-1

Gripping Device Development: Some Aspects

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Abstract:

Grippers give robots flexibility and functionality, allowing them to effectively perform a variety of tasks depending on the application context. Among other things, they allow robots to solve the following tasks: capturing objects; moving objects; assembly and installation; work in hazardous environments; maintenance and repair; medical surgery; research in science and engineering, etc. In this article, the authors propose the gripper kinematic diagram development, calculation of the compression force, as well as modeling of the gripping device.

Key words: Robot, Gripping device, Gripper, Kinematic diagram, 3D modeling.

Introduction

Many modern robots are equipped with gripping devices. Robot grippers have many uses and serve different purposes depending on the specific task and application [1]-[16].

For material handling tasks, robots equipped with grippers can perform material handling tasks such as sorting, packaging, assembly, welding and cutting. Grippers allow robots to manipulate objects of various shapes and sizes.

In industrial automation, robots are often used to automate production processes. Grippers in this context enable robots to efficiently handle and move objects on a production line [17].

Robots with grippers can perform assembly and assembly tasks on production lines, speeding up processes and increasing accuracy [18].

In a number of industries, such as energy, telecommunications or even medicine, robots with grippers can be used to maintain and repair equipment in hard-to-reach or dangerous areas.

Robots with gripping devices are used in surgery to perform precise and low-traumatic manipulations during operations [19].

Robots can be used to explore and perform tasks in environments that are dangerous or harmful to humans, for example, at the bottom of the sea, in the area of nuclear accidents, man-made disasters, etc. [20], [21].

Gripper robots are widely used in automated warehouse systems to move, sort and pack goods [22], [23].

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Grippers make robots versatile tools capable of performing a variety of tasks in a variety of applications. Thus, the topic of work related to some stages of the development of a gripping device is relevant.

Related works

The gripper provides the robot with the ability to perform various tasks related to grasping, holding and manipulating objects in the environment. It is quite natural that many scientists are working on the problem of developing such devices. Let's look at some works on this topic.

Article [24] proposes an adaptive gripping device of an industrial robot, which combines functions of capturing different-shape manipulation objects with control of deviations from the shape of these objects.

Takács, K. and co-authors in [25] present a systematic review of the state-of-the-art robotic soft object gripping solutions aimed for the food-industry, focusing on red meat handling.

In [26] authors present a soft gripper with variable effective lengths that is achieved by rapidly softening selective shape memory polymer sections (within 0.6 s) via a flexible heater.

Researchers in [27] proposed a bionic flexible gripper that was inspired by octopus grasp. It had the advantages of being lightweight, and having good cushioning, low driving air pressure, and a strong grasping force.

Paper [28] proposes a dual-mode soft gripper made of rubber material that can grasp and suck different types of objects.

In [29] scientists propose a circular shell gripper that consists of a rigid external shell and four soft internal air chambers. The soft chambers can be pneumatically inflated, thereby enabling it to grasp an object with a large contact area. The rigid shell allows the gripper to generate a large grasping force, while providing rigidity.

A soft gripper with multiple grasping modes is proposed in [30]. The gripper consists of four modular soft fingers integrated with layer jamming structure and tendon-driven mechanism. Each finger's rotating shaft of the base uses a torsional spring to decouple the bending deformation and relative rotation. An octopus-mimicking vacuum sucker is installed in the fingertip to generate suction.

Study [31] presents in this paper a novel soft-rigid gripper that exploits the combination of specialized fingertips with a passively compliant structure.

Thongking, W., & et al. in [32] focus on dielectric elastomer actuator applications and propose a technology to expand the applicability of a soft gripper.

Scientists in [33] note that grippers are widely used for the gripping, manipulation, and assembly of objects with a wide range of scales, shapes, and quantities in research, industry, and our daily lives. They propose to utilize a simple shape memory polymer block.

A gripping device kinematic model development

When designing robots, much attention is paid to gripping mechanisms. Typically, interchangeable gripper designs are used for workpieces of various shapes. The choice of gripping mechanism is determined by the shape and weight of the product. The grip must hold the part and at the same time not cause damage to it. During moving device development it is necessary to develop a kinematic diagram [34]. Figure 1 shows

ISSN (E): 2181-4570 ResearchBib Impact Factor: 6,4 / 2023 SJIF(2023)-3,778 Volume-2, Issue-1

a kinematic diagram of the developed universal gripper designed to grip various objects weighing no more than 0.2 kg, which will be the basis for modeling a 3-dimensional model.

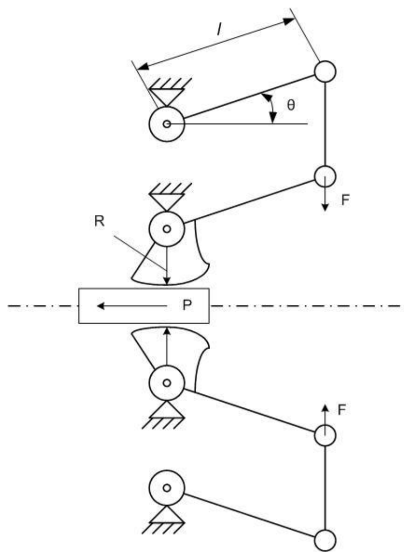

Figure 1: Gripping device kinematic diagram

The kinematic diagram of a pincer-type gripping device with a rack and pinion transmission mechanism consists of two jaws, gears, rigidly connected to the pins and rotated using a rack connected to the electric motor gear.

Gripping device works in next way: when the electric drive gear rotates, a toothed rack is set in motion, turning the gears, this causes the jaws to come together, resulting in the object being grabbed. When the gear rotates in reverse, the jaws unclench and the object is released.

Gripper forces calculation

When designing the most universal gripping devices for robots, it is necessary to take into account the specific type of part and group of parts, their shape and forces arising in the gripper. Important criteria in this case are the accuracy of holding the part and the permissible force on the jaws. Based on this, a large number of different grips have been developed, which differ in kinematic diagram and other design parameters. The force of the clamp must correspond to one of the values of the Ra10 series within the range of 1 – 8000 N. The gripper must provide a large range of movements. We take the developed kinematic diagram in Figure 1 as the basis for the design and subsequent calculation of the acting forces.

Based on the kinematic model and the existing gearbox, modification will be made by increasing the gripping force. At this stage, the required gripping force was calculated using the example of a pincer-type gripper, using the method of analyzing the acting forces, for a part weighing 0.2 kg with two types of movements.

For vertical linear movement:

JOURNAL OF UNIVERSAL SCIENCE RESEARCH

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$$F = G\frac{K}{\mu}\left(1+\frac{a_B}{g}\right), \quad (1)$$

where μ – friction coefficient;

a_B – vertical acceleration;

K – safety factor (K=1,5 - 2,0);

g – acceleration of gravity.

$$F = 0{,}2\frac{1{,}5}{0{,}13}\left(\frac{0{,}6}{9{,}8}\right) = 2{,}438H$$

For horizontal linear movement:

$$F = G\left(\frac{K}{\mu}+\frac{a_\Gamma}{g}tga\right), \quad (2)$$

where a_Γ - horizontal acceleration;

a – jaw bevel angle;

$$F = 0{,}2\left(\frac{1{,}5}{0{,}13}+\frac{0{,}47}{9{,}8}\right) = 2{,}3H$$

Let's calculate the force that the power drive must develop to securely fasten a part weighing 0.2 kg, according to the diagram shown in Figure 1.

The calculation of the drive force P is calculated from the relationship between the required holding force F (the largest value is taken), the length of the levers *l*, the angle of their movement θ and the radius of the gear transmission *R*. The drive force is calculated using the formula:

EMBED Equation.3

To modify the gripper in order to increase the gripping force and the ability to hold and move a part weighing 0.2 kg, it is necessary to install an electric drive that develops a force equal to 4.8 N.

Gripper development

The design sequence of a pincer-type gripping device consists of the following steps:

a) at the first stage, the initial data necessary for the design of the gripper was collected and processed, including:

1) construction of the trajectory of the movable item movements;

2) assessment of the movement speed of the manipulator final link;

3) assessment of the permissible positioning error of the manipulator final link;

4) assessment of the permissible rigidity and compliance of the industrial robot manipulator;

5) choosing a method for capturing and holding the movable item;

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b) based on the technical specifications and the assigned task, an analysis of the external forces acting on the gripper and its structural elements was carried out;

c) a kinematic diagram for the clamping gripper device was constructed and the directions of the forces of influence on the gripping object were determined;

d) the clamping or holding force of the movable item was calculated on the basis of which the gripping device was modified;

e) based on the 3D model, an analysis of the structural elements of the grip for strength was performed;

f) the force that the drive for the mechanical gripper should develop is calculated;

g) electric drive type is selected;

h) geometric parameters were determined, including a 3D model of the profile of the clamping jaws and the entire clamping gripper mechanism was designed;

i) formulation and justification of technical requirements for the design (including information support and equipment);

j) finite-elements analysis of the 3D model of the gripper.

Using modern CAE technologies, the ability to solve various engineering problems: calculation, analysis and simulation of physical processes, creating three-dimensional models of products and their parts have become much easier. When designing the gripper, a 3D model of each element was created using custom elements.

To reduce the complexity of design, a modification was made to the existing pincer-type gripping device by increasing the gripping force. Using the Siemens Unigraphics NX 7.5 engineering simulation environment, a 3D model was created for subsequent verification of the obtained data using NX “advanced simulation”. The modeling of a pincer-type grip went through 2 main stages.

Modeling of the elements was carried out based on the dimensions of the prototype of the storage unit; in the process, 16 custom elements were modeled from which a 3-dimensional detailed model was assembled, taking into account the parameters specified in the technical specifications. An exploded view of the gripper is shown in Figure 2.

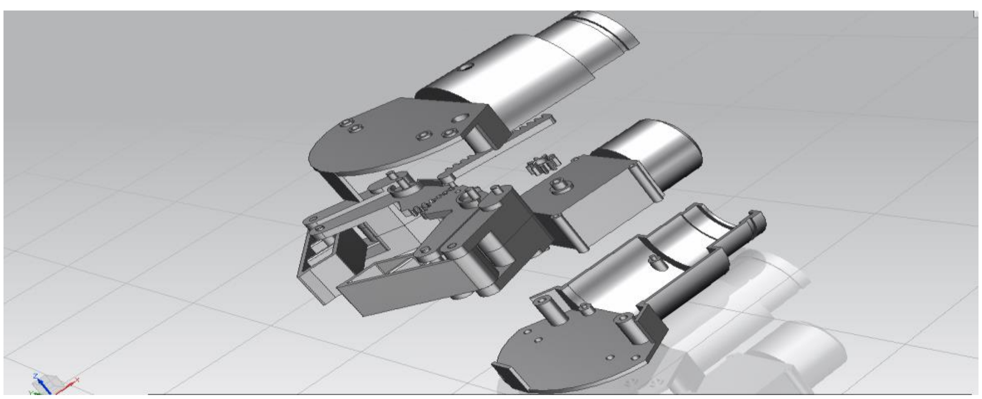

Figure 2: 3D gripper model exploded view

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The assembly of gripper elements is carried out in NX Assembly, which has its own means of monitoring the intersections of parts and calculating the mass-inertial characteristics of assembly units. All elements of the gripper were assembled, the conformity of the dimensions and the accuracy of all gripper elements construction were assessed. The program automatically checks for the absence of intersections between the assembly and modeling elements. The gripper assembly is shown in Figure 3

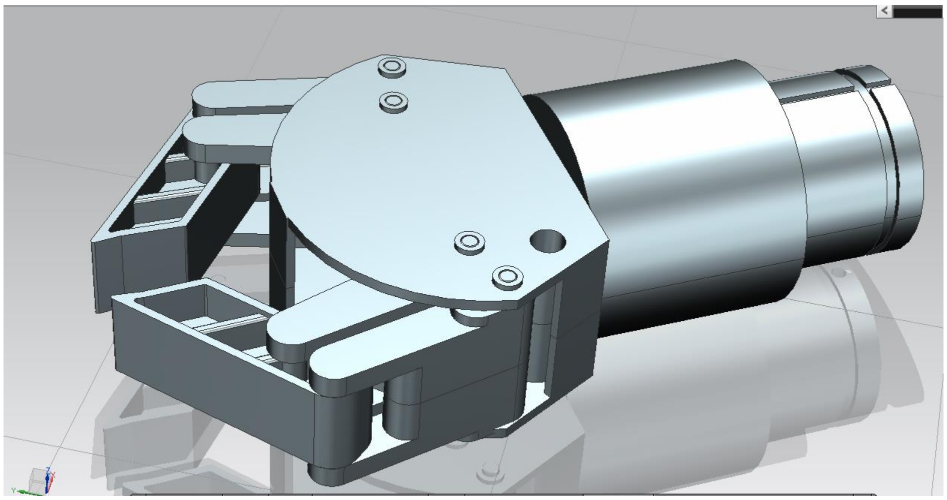

Figure 3: Gripper 3D model

The relationship between the objects of the 3-dimensional model is specified by conjugation, based on the kinematic relationships of the gripper elements. The exact specification of kinematic units is the most important factor for carrying out an engineering analysis of the gripping force and carrying out modification of the gripper.

Conclusion

A robot's gripper is typically a mechanism that a robot uses to grasp, move, or interact with objects in the environment. Grippers can take different forms and functions depending on the specific tasks the robot is intended to perform.

To select the optimal gripper, it is necessary to take into account the specific requirements of the task, the properties of the objects and the environment in which the robot will work.

In this work a pincer-type gripping device was considered.

In the article a kinematic diagram of a pincer-type gripping device has been developed.

Based on the kinematic model, the compression force was calculated. It was determined that to modify the gripper in order to increase the gripping force and the ability to hold and move a part weighing 0.2 kg, it is necessary to install an electric drive that develops a force equal to 4.8 N.

There is also a 3D gripper model exploded view and a Gripper 3D model in Unigraphics NX 7.5

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