Anthropomorphic gripping device for an industrial robot: design and calculation of parameters

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Abstract

The article presents a fundamentally new design of an anthropomorphic gripping device for an industrial robot for service objects, the shape and position of which are unknown a priori. The novelty of the proposed design from the known devices lies in the fact that each phalanx of the fingers of the gripping device is made in the form of four corrugated pneumatic chambers mounted on spherical hinges. This design allows you to capture objects in the angular coordinate system, which is typical of the human hand. Analytical dependences for calculating the geometric and force parameters of an elastic gripping device are given. The results of mathematical modeling and recommendations for the development of such anthropomorphic captures for robots are given.

Keywords Industrial robots · Mechanical grippers of robots · Robot finger · Technological devices of robots

1 Introduction

There are many designs of gripping devices for industrial robots, among which the most well-known are mechanical, vacuum, electromagnetic and combined devices for capturing industrial objects. As a rule, these devices have a special purpose, which is determined by the shape, physical and mechanical properties of production objects. For example, mechanical gripping devices are used mainly for cylindrical and body parts, vacuum devices are used to capture fragile and thin-walled products, and electromagnetic devices are used for flat parts, but only for those that possess ferromagnetic properties [1]. For the creation of anthropomorphic gripping devices, the paper [2] is interesting, in which a pneumatic manual system from the subsystems of control and teleoperation is proposed. These systems allow for muscle modeling and can be used as didactic tools. Also, the effective use of teleoperations for controlling manipulators was proposed in [3]. The proposed technical solutions are ideally suited for training

and management, but cannot be applied directly in the industry to perform technological operations.

In each of these applications, the gripping devices satisfy the tasks of the technological process and are successfully operated. However, there are areas of activity in which the special functions of the gripping devices are not enough. Such applications of gripping devices include objects whose shape and position are not known a priori. The article [4] is devoted to solving this problem, in which an intelligent method of capturing unknown objects based on hierarchical models of the coordinates of objects points using a sensor of vision is proposed. The use of intelligent systems for the recognition of unknown objects to capture them, of course, is a promising development of robotics. However, in this article there are no designs themselves gripping devices for industrial robots.

The efficiency of the process of capturing objects for assembly robots is facilitated by the methods of automatic programming proposed in [5]. Also in article [6], an adaptive control scheme of robotic systems is presented that capture and manipulates unknown objects. These works

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are of interest to improve the automatic control of the process of capturing objects, the shape and position of which are a priori unknown. However, as in previous works, in these studies there are no recommendations or technical solutions for the actual designs of gripping devices for robots. At the same time, to capture various objects with an indefinite form, universal gripping devices are needed, which can work in the angular coordinate system inherent to the human hand.

As examples of service objects with an uncertain form, one can cite agricultural products: vegetables, fruits and berries. Another, fundamentally different field of application of gripping devices, are objects of jewelry production, in which the shape and size of the billet of minerals and precious products are also not previously known. In similar and other applications of robot grippers, anthropomorphic devices are most effective, namely, structures close to the human hand. Therefore, the task of synthesizing anthropomorphic gripping devices for robots is relevant in the field of operation of industrial robots.

2 Prerequisites and means for solving the problem

Currently, in the field of robotics, quite effective anthropomorphic exciting devices for industrial robots have been created. These devices can be used to perform various technological operations that require degrees of mobility close to the human hand. An effective example of such a device is interconnected phalanges for robotics gripping [7], in which the interconnected phalanges of the robot's grip are connected by hinges and can be rotated by gears. Thanks to the swivel of the phalanges, the device allows you to hold objects of different shapes. However, all the fingers of this device work in 2D space, which limits its technological capabilities.

Another equally effective device is the anthropomorphic prosthesis brush [8], which contains fingers in the form of five mechanical links, which are part of each finger and are connected by an elastic plate. The location of the fingers must be accurately calculated so that the object is securely held in the grip and that the balance of forces is maintained at the point where the fingers touch the production object. Due to the fact that the fingers of this grip are made in the form of flat mechanical links, they move only in a 2D plane, and not in 3D space.

Also known is the robot's hand of soft silicone rubber [9], in which the fingers are connected to the engines by means of tendons. This technical solution can be used to build anthropomorphic robots suitable for the consumer market. However, in this robot brush, each of the fingers is also bent only in one of the 2D planes. In other words,

each of the fingers of the device is deprived of the ability to perform operations in 3D space, for example, in a spherical or angular coordinate system, in which the human hand works.

Of particular interest is the gripping device for the robot [10] with fingers in the form of rotational kinematic links combined by a cable. This device provides reliable retention of objects with a complex surface geometry, but, as in the previous case, each of the gripping fingers is bent only in the plane. This property limits the functions of the robot arm with respect to movement in a spherical coordinate system. Combined capture [11] manufactured by Simrit (Germany) has broader functions. This robot grip contains fingers in the form of elastic corrugated pneumatic shells that span the curved surface of the product. Thanks to this technical solution, the pneumatic gripper adapts to the curved surface of industrial products. However, as well as the analogues discussed above, the capture is also deprived of the possibility of movement in 3D space.

In addition to the technical solutions described above, theoretical studies and mathematical models of anthropomorphic grips for robots are known [12]. These mathematical models allow us to determine the optimal number of capture points for production facilities and the conditions for their reliable transportation in the technological space.

The simulation of the anthropomorphic capture device Federica Hand is presented in the study [13]. This model allows you to make changes to the design to provide the required degree of adaptation to the captured object, as well as displays the movements and characteristics of an anthropomorphic gripping device and service object in the Matlab Simulink program. Similar, quite effective studies of the kinematics of an anthropomorphic gripping device with the determination of the optimal location of contact points of interaction between a mechanical drive and a phalanx of gripping were proposed in [14]. However, these mathematical models do not contain methods for calculating the mechanical strength of an anthropomorphic gripping device necessary for their engineering design.

Methods for calculating the parameters of various mechanical gripping devices for robots are described in [15], but these techniques provide classical technical solutions for gripping devices whose fingers move only in 2D space and not in 3D space of a spherical or angular coordinate system, which is characteristic of a human hand.

All the designs of gripping devices discussed above do not have the ability to work in an angular coordinate system in 3D space, which is characteristic of the human hand. This means that the above designs of grippers do not provide the universality of the process of capturing objects with an indefinite shape.

The above analysis of mathematical methods for calculating parameters of gripping devices shows their applicability only for classical mechanical structures of grippers. At the same time, there are no methods for calculating the parameters of anthropomorphic captures.

Based on the above analysis of research, it can be argued that the task of creating an anthropomorphic gripping device for a robot remains relevant. Therefore, in this article, the author proposes a new design of an anthropomorphic gripping device in the form of a set of corrugated pneumatic chambers. This design provides independent movement of each finger. To enable the design of such devices, an engineering method for calculating the deformations of corrugated pneumatic chambers, as well as analytical dependencies for determining the forces and stresses acting on the fingers of an anthropomorphic device, are proposed below. And the design of the gripping device and the method of calculating its parameters are proposed for the first time.

3 Formulation of the problem

The purpose of these studies is to expand the technological capabilities of mechanical gripping devices for robots, namely, ensuring the movement of each finger of an anthropomorphic gripping device of a robot in the 3D technological space of Cartesian, spherical or angular coordinate system. It should be noted here that the angular coordinate system is a kind of spherical coordinate system and is distinguished by the absence of kinematic links of translational motion, and contains only links of angular movements that are characteristic of the human hand. In addition, for the engineering calculation of the parameters of an anthropomorphic gripping device of a robot, it is necessary to obtain analytical dependences of the geometric and power characteristics of such a device.

4 Solution of the problem under consideration

The goal of the research was achieved in three successive stages: at the first stage, a fundamentally new design of an anthropomorphic capture device was created; at the second stage, a mathematical model was developed for calculating the geometric and power parameters of this device, and at the third stage, the analytical relationships of the device parameters were modeled.

4.1 The design of the anthropomorphic device

For a better understanding of the analytical model of an anthropomorphic capture device, we first consider its construction. Like a human hand, the gripping device (Fig. 1) contains five fingers attached to the flange, which is placed on the hinge of the robot arm. The thumb consists of two phalanges, and the rest of the fingers: the index finger, middle finger, ring finger, and little finger each contain three phalanges, like the fingers of a person's hand [16].

Fragment "A" Fig. 1 is shown in more detail in Fig. 2. Each finger (except the thumb) has three phalanges: the big phalanx, middle and small phalanx. The end of the finger is a soft tip for contact with the production object.

On the levers of each phalanx of the finger there are articulated joints. The first large phalanx is fixed on the levers with the possibility of rotation around the axes mounted on the flange. In Fig. 3 the design of one of the phalanges is shown. The remaining phalanges have the same design and differ only in smaller sizes. As stated above, each phalanx contains four pneumatic corrugated chambers. These chambers are formed by large and small corrugated shells made of elastic material, for example, from high-strength polyvinyl chloride.

The beginning of each chamber is fixed on the levers with the ability to rotate around the axes of the flange. The ends of the chambers are fixed on the cross, which is mounted on the pivot with the possibility of sliding. At the beginning and at the end of each phalanx there are articulations that allow the phalanges to make corner turns relative to each other.

Fig. 1 Anthropomorphic gripper for industrial robot

Fig. 2 Finger design for gripping device

Fig. 3 The design of the phalanx of the finger

The pneumatic control circuit of the corrugated phalanges of the fingers is shown in Fig. 4. A pneumatic compressor creates a stream of compressed air, which, according to a predetermined control algorithm, is distributed by automatic pneumatic valves to the corrugated chambers. The pressure of the compressed air in the chambers is set by pressure regulators, and the rate of entry of compressed air into the chambers is regulated by throttles with non-return valves.

In the initial position, as shown in Fig. 4, with equal pressures $p_1 = p_2 = p_3 = p_4$, the phalanx takes a straight position along the Y axis. But depending on the pressure

Fig. 4 Pneumatic phalanx control circuit

difference p_1 and p_2 in the respective corrugated chambers, the phalanx is bent through an angle $\pm \alpha$ around the X axis, and under the condition of pressure difference p_2 and p_3 of the phalanx, is bent through an angle of $\pm \beta$ around the Z axis. These bends of the corrugated pneumatic chambers are accompanied by translational movement $\pm \Delta y$ along the Y axis in the XYZ coordinate system. Corner bends of corrugated chambers occur due to the difference of the areas of the large and small corrugated shell of each chamber. According to this algorithm, all the phalanges of the fingers of the gripping device work.

As can be seen from Fig. 5, the implementation of the indicated pressure combinations in the corrugated phalangeal shells allows the fingers to be oriented both in Cartesian XYZ and in the angular coordinate system R, β, γ (where R is the radius of the sphere, β, γ —respectively, the bending angles of the fingers). The angle α defines the service area of the fingers of an anthropomorphic gripping device in an angular coordinate system R, β, γ .

As examples, Fig. 6 shows possible applications of an anthropomorphic gripping device for a robot to capture various fruits, for example, apples, lemons, or vegetables: tomatoes, peppers, and other agricultural products. Similar applications of an anthropomorphic capture device are also possible in industrial fields, for example, for jewelry or for instrument manufacturing.

Fig. 5 Variants of the position of anthropomorphic fingers in the angular coordinate system

Fig. 6 Examples of finger positions grabbing fruits and vegetables

4.2 Mathematical model for calculating device parameters

The main element of the fingers of an anthropomorphic gripping device is corrugated pneumatic chambers operating under pressure. The chambers of all phalanges

are identical and differ only in their size, which decreases from large to small phalanx of each finger. Figure 7 shows the design diagram of the main structural element of the pneumatic chamber, namely the scheme of the corrugated shell that forms the chamber.

Pneumatic corrugated chamber is under pressure “ p ” of compressed air. This pressure causes the action of the force F at the point “ c ”—the center of mass of the end cap of the chamber. From Fig. 7a it can be seen that the area “ A ” of the end cap is the area of the circular sector with radius R_1 with central angle α and radius R_2 :

$$A = \frac{1}{2} \alpha (R_1^2 - R_2^2). \quad (1)$$

According to the scheme, the distance from the center “ O ” to the center of weight of the end cap “ c ”:

$$OC = \frac{4}{3} \frac{\sin(\alpha/2)}{\alpha} \frac{R_1^3 - R_2^3}{R_1^2 - R_2^2}. \quad (2)$$

Due to the pneumatic pressure p , acts on the end cover of the chamber the force F .

$$F = pA = \frac{1}{2} p \alpha (R_1^2 - R_2^2). \quad (3)$$

This force is distributed into two components N_1 and N_2 , which stretch the large and small corrugated chambers. The values of these forces can be determined from the equilibrium equations:

Fig. 7 Design scheme of the corrugated shell **a** scheme stub; **b** shell scheme

$$\begin{aligned} N_1 + N_2 &= F \\ FOC - N_1 R_1 - N_2 R_2 &= 0 \end{aligned} \quad (4)$$

From these equations, we obtain the values of the forces N_1 and N_2 :

$$\begin{aligned} N_1 &= \frac{1}{2} p \alpha (OC - R_2)(R_1 + R_2); \\ N_2 &= F \frac{R_1 - OC}{R_1 - R_2} = \frac{1}{2} p \alpha (R_1 - OC)(R_1 + R_2). \end{aligned} \quad (5)$$

We define the relationship between the forces of N_1 i N_2 and the elongation of the corrugated pneumatic chambers. We assume that the elongation occurs only due to the stretching of the corrugated shells. Consider one element of a large corrugated shell of length t_1 with radius r_1 in Fig. 7b. Under the action of force N_1 , the element is extended by the value of dt_1 , and the arc of a circle of radius r_1 goes into an arc of a circle of radius R_{b1} , while the arcs do not change their length. From the scheme of Fig. 7b it is easy to establish the following relations:

$$\begin{aligned} \alpha_1 &= 2 \arcsin \left(\frac{t_1}{2r_1} \right); \quad R_{b1} = \frac{r_1 \alpha_1}{\beta_1}; \\ R_{b1} \psi &= r_1 \varphi; \quad 0 \leq \varphi \leq \alpha_1; \quad 0 \leq \psi \leq \beta_1; \\ \Delta t_1 &= 2 \frac{r_1 \alpha_1}{\beta_1} \sin(\beta_1/2) - t_1, \end{aligned} \quad (6)$$

where φ , ψ are the current angles of the sectors (see Fig. 7b), which correspond to the elongation of the corrugated shell.

Similar relationships will also take place for the bottom small corrugated chamber:

$$\begin{aligned} \alpha_2 &= 2 \arcsin \left(\frac{t_2}{2r_2} \right); \quad R_{b2} = \frac{r_2 \alpha_2}{\beta_2}; \\ R_{b2} \psi &= r_2 \varphi; \quad 0 \leq \varphi \leq \alpha_2; \quad 0 \leq \psi \leq \beta_2; \\ \Delta t_2 &= 2 \frac{r_2 \alpha_2}{\beta_2} \sin(\beta_2/2) - t_2. \end{aligned} \quad (7)$$

To control the position of the fingers of an anthropomorphic gripping device, it is necessary to know the analytical relationships between the power load and the amount of elongation of the corrugated pneumatic chambers. The change in length Δt_1 (see Fig. 7b) of the upper large corrugated shell is determined using the well-known Mohr integral:

$$\Delta t_1 = \int_0^{\alpha_1} \frac{M_p \bar{M} r_1 d\varphi}{E J_1} + \int_0^{\alpha_1} \frac{N_p \bar{N} r_1 d\varphi}{E h_1 R_1 \alpha}, \quad (8)$$

where h_1 is the thickness of the material of a large corrugated shell; $J_1 = \frac{\alpha R_1 h_1^3}{12}$ —axial moment of inertia of the cross section of the shell; E —Young's modulus of the material of the corrugated shell; M_p , N_p —bending moment and longitudinal force from a given load. In this case:

$$\begin{aligned} N_p &= N_1 \cos(\beta_1 \varphi / \alpha_1 - \beta_1 / 2); \\ M_p &= N_1 \frac{r_1 \alpha_1}{\beta_1} (\cos(\beta_1 \varphi / \alpha_1 - \beta_1 / 2) - \cos(\beta_1 / 2)), \end{aligned} \quad (9)$$

and also in the formula (8)—the bending moment and the longitudinal force from the applied unitary dimensionless force. In our case:

$$\begin{aligned} \bar{N} &= \cos(\beta_1 \varphi / \alpha_1 - \beta_1 / 2); \\ \bar{M} &= \frac{r_1 \alpha_1}{\beta_1} (\cos(\beta_1 \varphi / \alpha_1 - \beta_1 / 2) - \cos(\beta_1 / 2)). \end{aligned} \quad (10)$$

Substituting the expression of the force factors (9) and (10) into formula (8), after integration, we obtain the change in the length Δt_1 of the large corrugated shell:

$$\begin{aligned} \Delta t_1 &= \frac{r_1 \alpha_1 p k_1}{E} \left(\frac{1}{J_1} \left(\frac{\alpha_1 r_1}{\beta_1} \right)^2 \left(\frac{1}{2} + \cos^2 \left(\frac{\beta_1}{2} \right) - \frac{3 \sin \beta_1}{2 \beta_1} \right) \right. \\ &\quad \left. + \frac{1}{2 h_1 R_1 \alpha} \left(1 + \frac{\sin \beta_1}{\beta_1} \right) \right), \end{aligned} \quad (11)$$

where $k_1 = \frac{1}{2} \alpha (OC - R_2)(R_1 + R_2)$.

Similarly to the above procedure (8)–(11), which for brevity will not be repeated, we obtain the change in the length Δt_2 of the lower small corrugated shell:

$$\begin{aligned} \Delta t_2 &= \frac{r_2 \alpha_2 p k_2}{E} \left(\frac{1}{J_2} \left(\frac{\alpha_2 r_2}{\beta_2} \right)^2 \left(\frac{1}{2} + \cos^2 \left(\frac{\beta_2}{2} \right) - \frac{3 \sin \beta_2}{2 \beta_2} \right) \right. \\ &\quad \left. + \frac{1}{2 h_2 R_2 \alpha} \left(1 + \frac{\sin \beta_2}{\beta_2} \right) \right), \end{aligned} \quad (12)$$

where $k_2 = \frac{1}{2} \alpha (R_1 - OC)(R_1 + R_2)$. The names of all parameters (12) are the same as in formula (11) and differ in the "2" index, which corresponds to the parameters of small corrugated shell.

Solving the system of Eqs. (6) and (11), as well as (7) and (12) numerically in the MATLAB environment, it is easy to find changes in the length of the large and small corrugated shells and the angles β_1 , β_2 of their bending depending on the pressure p of compressed air.

Full lengthening of the phalanges of the fingers can be found by the formulas:

$$dL_1 = \frac{L}{t_1} \Delta t_1; \quad dL_2 = \frac{L}{t_2} \Delta t_2, \quad (13)$$

where L is the length of the corrugated shell of the phalanx of each finger.

Now you can determine the bend angle φ in degrees and the average radius R_{aver} of curvature of the corrugated shell:

$$\varphi = \frac{dL_1 - dL_2}{R_1 - R_2} \frac{180}{\pi};$$

$$R_{aver} = \frac{(R_1 - R_2)(L_1 + L_2 + dL_1 + dL_2)}{2(dL_1 - dL_2)}. \quad (14)$$

As noted above, Eqs. (11) and (12) are necessary to control the position of each phalanx of the fingers of the anthropomorphic capture of an industrial robot. However, for engineering calculations of the strength of fingers of a device, are also needed formulas to calculate the maximum stresses σ_{M1} , σ_{M2} , σ_{N1} , σ_{N2} arising in the material of small and large corrugated shells depending on the forces and moments (5), (9) and (10). We suggest calculating maximum stresses from bending moments and longitudinal forces using the formulas:

$$\sigma_{M1} = \frac{M_1^{\max}}{J_1} \frac{h_1}{2} = \frac{pk_1 r_1 \alpha_1}{\beta_1} (1 - \cos \beta_1);$$

$$\sigma_{M2} = \frac{M_2^{\max}}{J_2} \frac{h_2}{2} = \frac{pk_2 r_2 \alpha_2}{\beta_2} (1 - \cos \beta_2); \quad (15)$$

$$\sigma_{N1} = \frac{N_1^{\max}}{\alpha R_1 h_1} = \frac{pk_1}{\alpha R_1 h_1}; \quad \sigma_{N2} = \frac{N_2^{\max}}{\alpha R_2 h_2} = \frac{pk_2}{\alpha R_2 h_2}.$$

4.3 Simulation results

According to the above theoretical model, the simulation of the corrugated shells of an anthropomorphic gripping device was performed. For the material of the shells was selected polyvinyl chloride with a thickness of $h_1 = 0.003$ (m) with the following characteristics: the density is $1.35 \times 10^3 \dots 1.43 \times 10^3$ (kg/m³); ultimate tensile strength $4 \times 10^7 \dots 7 \times 10^7$ (Pa); flexural strength $8 \times 10^7 \dots 12 \times 10^7$ (Pa); Young's modulus $2.6 \times 10^9 \dots 4.0 \times 10^9$ (Pa). The length of the corrugated phalanx chamber is $L = 0.1$ (m), the radius corrugation for a large chamber is $r_1 = 0.01$ (m); for a small chamber, $r_1 = 0.08$ (m). The range of pressure values in the chambers is $p = 1 \times 10^5 \dots 10 \times 10^5$ (Pa).

Figure 8 shows the simulation results of the process of elongation dL of small and large corrugated shells, and Fig. 9 shows the change in angle β of the bend of the phalanx of the fingers depending on the pressure in the corrugated pneumatic chamber. These charts are recommended as diagrams for controlling the position of the fingers of the gripping device.

Fig. 8 Elongation of large dL_1 and small dL_2 corrugated shells, depending on pressure p in corrugated chambers

Fig. 9 Changes in the bending angles β_1 and β_2 of the large and small corrugated phalanx shell

For the design of fingers of an anthropomorphic gripping device, it is recommended to use the graphs of Figs. 10 and 11, which show the change in bending moments M_1 , M_2 and the longitudinal forces N_1 , N_2 depending on the pressure p in the corrugated shells of the fingers. If during the design of the gripping device, a different material is used, other than polyvinyl chloride and with other characteristics, then the values of M_1 , M_2 , N_1 , N_2 can be calculated using formulas (9) and (10).

The simulation results of the stress variation σ_{M1} , σ_{M2} due to the action of the bending moments M_1 , M_2 in the corrugated shells and the stresses σ_{N1} , σ_{N2} from the longitudinal forces N_1 , N_2 are shown in Fig. 12. These graphs should be used when calculating the strength of the

Fig. 10 Change of bending moments of large M_1 and small M_2 of corrugated shells depending on the pressure p of the pneumatic chamber

Fig. 11 Change in the longitudinal forces N_1 and N_2 in the large and small corrugated shells depending on the pressure p

fingers of a gripping device, taking into account the allowable stress for the material from which the corrugated shells are made.

For this case, when polyvinyl chloride is used as a material for corrugated chambers, the values indicated in Fig. 12 should not exceed the characteristics of the material, namely: tensile strength $4 \times 10^7 \dots 7 \times 10^7$ (Pa) and flexural strength $8 \times 10^7 \dots 12 \times 10^7$ (Pa). For other elastic materials, restrictions should be imposed that correspond to their limit values for allowable stresses. The maximum stresses from bending moments and longitudinal forces, which we propose to calculate using

Fig. 12 The values of maximum stresses due to bending moments σ_{M1} , σ_{M2} and longitudinal forces σ_{N1} , σ_{N2} in small and large corrugated shells when fingers are bent

formulas (15), should not exceed the values of permissible stresses, which are characteristic of the material used.

5 Results and discussion

The new design of an anthropomorphic gripping device for service objects, the shape and position of which are unknown a priori, presented in the article can be used to expand the technological capabilities of industrial robots for various purposes.

The proposed pneumatic drive of the gripping device is optional. For heavy-duty gripping devices, you can use a hydraulic drive that has more power. Replacing a pneumatic drive with a hydraulic drive does not change the basic design of the device and its control system, but only requires the use of more durable materials and equipment for hydraulic automation.

The proposed mathematical model of the elastic gripping device and analytical dependences for the calculation of geometric and force parameters are recommended for the design of universal gripping devices. The results of mathematical modeling are a theoretical justification of the industrial feasibility of using anthropomorphic grips for the hands of robots.

6 Conclusion

The novelty of the proposed design from the known devices lies in the fact that each phalanx of the fingers of the gripping device is made in the form of four corrugated

pneumatic chambers mounted on spherical hinges. This design allows you to capture objects in the angular coordinate system, which is typical of the human hand. The maximum possible approximation of the design of the gripping device to the structure of the human hand can significantly expand the technological capabilities of the gripping devices of industrial robots. This property is the main result of this article.

Expansion of the technological capabilities of the gripping device, namely the ability to capture and hold objects of various shapes, is achieved by independent movements of each finger of the robot's hand in the 3D technological space. The possibility of independent movement of each finger of the gripping device is a distinctive feature of the proposed design from the previously known designs of the technological equipment of industrial robots.

Creating a design model of a new anthropomorphic capture of an industrial robot is the first stage of research. However, already at this stage, the results of the above simulation allow the use of analytical dependencies [6, 7]...[11–15] together with diagrams for the experimental design of anthropomorphic gripping devices. The plan for the next research involves the manufacture of a prototype of a gripping device and the testing of its technological capabilities. The author will be happy to share with the scientific community the results of experimental research in the next publication.

Compliance with ethical standards

Conflict of interest The author states that he has no conflict of interest.

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