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An Adaptive Robot Hand with Spiral Blade Expansion Slide Tube

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***Abstract* - Robot hand has a wide range of applications in the field of robot, which is used to connect the robot and the object temporarily, and can be released at the appropriate time. The robot hand grabs the object first and then releases it. In order to reduce the cost, the general robot hand is made into two parts with relative motion in order to realize the function of grasping and releasing. There are also many structures that mimic human hands and are designed to have more fingers and several joints, but that leads to higher system complexity. In order to solve the problems of adaptability and complexity, we design an adaptive robot hand with spiral blade expansion slide tube array. The device is used to grasp objects and achieve the effect of multi-directional grasping of objects. It can provide grasping force to the object in many directions, especially has good adaptability to the top and side of the object, and adapts to the grasping of objects of different shapes and sizes. All kinds of shapes placed in different directions can be grasped effectively. In the design of the robot hand, due to the array arrangement of the sliding tube, when the sliding tube buckles to the object from top to bottom, it can first be adaptive to the object in the horizontal direction, and then the expansion of the elastic thin film tube can be adaptive to the side of the object. Combined with the ascending motion of spiral rotation, the multi-directional grasping effect is achieved. Compared with the traditional robot hand, the robot hand has higher adaptability and simpler maneuverability. In this paper, the detailed design scheme of the machine hand is given, and the feasibility of the device is verified by force analysis. After improvement, the device has a certain demand on the production line that needs to be grasped.**

Index Terms - adaptive robot hand, spiral blade extended slide tube array, multi-directional grasping.

I. INTRODUCTION

Today, with the rapid development of robots, Generally speaking, the robot hand imitates some simple actions of the human hand through the mechanism. The human controls the robot hand through the relevant instructions. The hand can realize many functions and work in the environment that the human cannot adapt to. The emergence of the robot hand greatly improves the efficiency of modern industry. In order to reduce the cost, the general robot hand is made into two parts in order to realize the function of grasping and releasing. There are also many structures that mimic human hands and are designed to have more fingers and several joints, but that leads to higher system complexity. Some robot hands are designed to look like multiple fingers by imitating the structure of the human hand, but this kind of hand has more parts and is more difficult to control.

Robot hands are divided into many kinds, and industrial grips are used the most. For example, Binary Industrial Gripper [1] this kind of robot hand can grasp objects, but it is not as flexible as human hands. One kind of hand is underdrive hands, and underdrive hands are more flexible. But the operation is more complex, such as FRH-4 Hand [2], one kind of hand is dexterous hand, this kind of hand is mainly based on spatial operation, the degree of intelligence is high, very flexible, but the system is more complicated, such as NASA Hand [3], the other is the rod cluster hand. This kind of hand has strong adaptability, such as Bernoulli Principle Gripper [4], Rock Climbing Robot [5], such as H.F Hand [6] [7] like the figure 1. This kind of hand grabs objects more efficiently and makes it more adaptive by means of centripetal convergence, such as Pin Array Gripper [8] like the figure 2. It has better adaptive effect but higher processing difficulty, while Arrays of Rotating Pins Gripper [9] and General Purpose Hands for Bin-Picking Robots [10] have less grasping power and balanced advantages and disadvantages, while Systems and methods for gravity-independent gripping and drilling [11] has multiple fingers. Its basic unit is a flexible sheet, and there are three inverted thorns on the sheet, and multiple sheets form a finger, which has good adaptability in different directions. For example, Adaptive robotic gripper [12] uses wrapped grasping, which is very creative. LLIRF soft hand [13] has good flexibility and can stably grasp smooth objects., A Vacuumdriven Origami "Magic-ball" Soft Gripper [14] is a kind of special manipulator, which has no fingers and is grasped by contraction.

Peter B. Scott in the literature （Peter B. Scott, The Omnigripper: a form of robot universal gripper, Robotica, 1985, vol. 3: pp. 153-158）introduces a kind of universal gripper Omnigripper [15], which is mechanically passive and adapted to the shape of the object. The gripper has two sets of rod clusters, each of which has a number of parallel long rods, which are driven by the object to be grasped and slide up and down freely to adapt to the shape of the object. Combined with the driver to drive the two groups of rod clusters close or leave, to achieve the grasp of the object. For example, when

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the end of a robot is directed against an object placed on a supporting surface, such as a desktop, the object presses the long rod so that it slides into the pedestal because of the large number of long rods and the finer (smaller diameter) of the long rod. Different long rods come into contact with different surface points of the object, and the sliding distance of each long rod to the palm of the hand is different, which is related to the local shape of the object. After that, the two sets of rod clusters from left to right are closed to hold the object, and the long rod is used to hold the object from the side to achieve the purpose of grasping. The shortcomings of the device are:

Fig. 1 The CTSA Hand.

Fig. 2 The Slidable Pin Array Self-adaptive Robot Hand.

(1) It is impossible to achieve multi-directional grasp. When the device exerts a grasping force on the target object, the grasping force can only be closed along the direction of the two sets of rod clusters, which is equivalent to the two-finger gripper, which produces only one-dimensional clamping mode, and the clamping effect is poor.

(2) The grasping failure of a long strip object placed in a particular direction. When the target object is parallel to the direction and the target object is longer than the device in this direction, the target object will not be grasped by the closure of two sets of telescopic rods, such as grasping a long strip object.

(3) The grasping stability needs to be improved. The grasping force of the device to the target object is only generated by the combination of two sets of rod clusters, and can only use the force of grasping force to close and grasp the object, but lacks a better enveloping closed grasping effect, because, Force closed grasping objects may not necessarily produce shape closed grasping, but shape closed grasping must include force closed grasping, so the grasping stability has reached the shape closed is the best.

II. Design of SBESTAA Hand

A. Design concept

The purpose of the invention is to overcome the shortcomings of the existing technology, and to provide a spiral blade expansion sliding tube array adaptive robot hand device, referred to as SBESTAA Hand. The device has the following advantages in grasping objects well at the same time:

(1) It can provide grasping force to the object in many directions, especially for the top and side of the object, and can adapt to the grasping of objects of different shapes and sizes.

(2) It can effectively grasp all kinds of shapes (including strips) placed in different directions.

(3) It has the advantages of simple structure, low energy consumption, fast grasping, short grasping time and stable grasping.

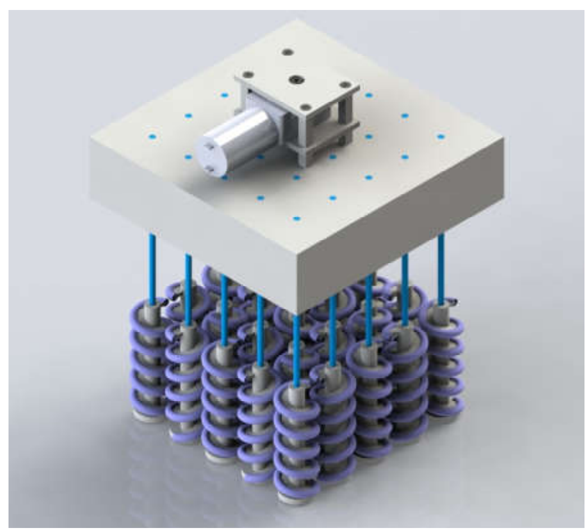


Fig. 3 The SBESTAA hand.

B. Structure of SBESTAA hand

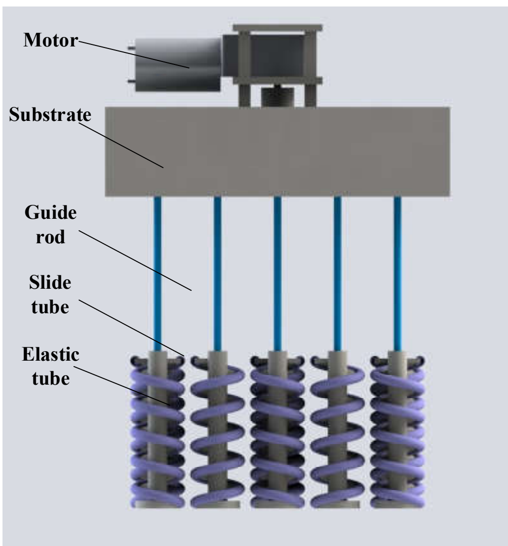
The internal structure of the manipulator studied in this project mainly has two parts: the slide tube assembly and the transmission part.

1) Slide tube assembly.

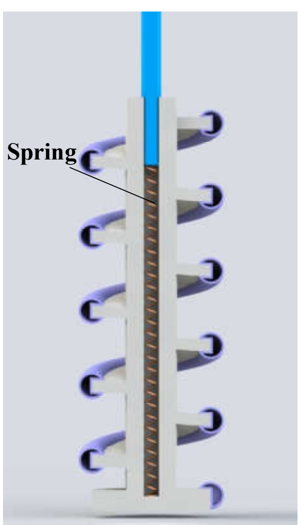
As shown in the figure 3 and the figure 4, each slide tube assembly consists of a slide tube, a slide pipe limit block, a pressure spring, a spiral blade, an elastic film tube, and a slide tube bottom plate. Among them, the Megan catheter is connected with a guide rod, which can slide in the direction of the guide rod, the slide pipe limit block can slide in the slide pipe limit groove, the spiral blade is spirally wound around the slide tube, and the surface of the spiral blade is wrapped with an elastic film tube. The slide tube bottom plate and the limit block are connected with a pressure spring, under the action of the pressure spring, the slide tube assembly can return to the original position when it is not working.

2) Transmission part.

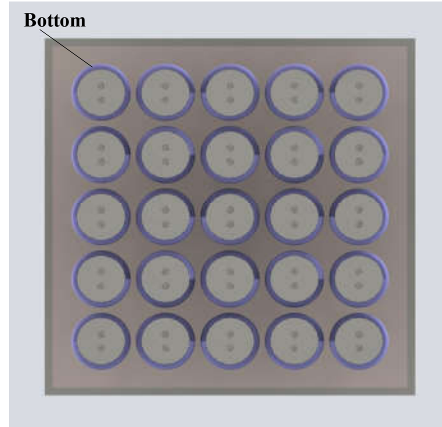
The transmission part is mainly composed of the motor and the gear. The function of the transmission part is to drive the rotation of the gear through the rotation of the motor, and then drive the rotation of the guide rod and the sliding pipe. The spiral blade on the slide tube then rotates so that the object intensifies and rises or falls.



a) Frontal sectional view



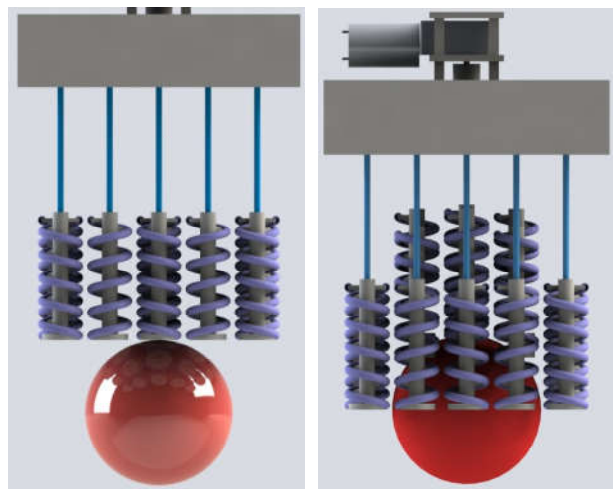
b) Unit Structure View



c) Upward view

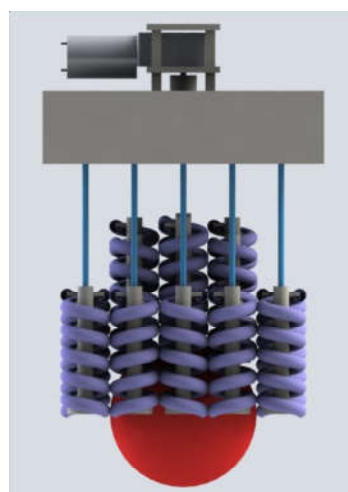
Fig. 4 The SBESTAA hand illustration.

III. Working Principle of SBESTAA Hand



a) Before grasping

b) In the process of grasping.



c) Complete the capture of the object

Fig. 5 Illustration of SBESTAA hand grabbing an object

The initial position of the device is shown as the figure 5 and the figure 6. When the object needs to be grasped, the object is on the worktable, the device buckles from top to bottom to the object, the object extrudes the bottom of the slide tube, the sliding tube in contact with the object moves upward, and the spring is deformed, which adapts to the upper shape of the object. Achieve the adaptive effect of the top, and the object is enveloped with the slide tubes.

After that, the fluid source starts, more flow is injected through the catheter, the elastic thin film tube expands, part of the elastic thin film tube contacts the object, and the surface of the elastic thin film tube is deformed to a certain extent. The base, guide rod, slide tube, spiral blade, fluid and expansion deformation of the elastic film tube have a comprehensive grasping force on the object, at this time, stop the fluid source and maintain the pressure of the fluid. The pressure in the film generates the grasping force of the object.

Then, the motor starts, drives a gear to rotate through the input transmission mechanism, the gears mesh with each other, all the gears rotate separately, driving the guide rod to rotate separately, half rotates counterclockwise, half rotates clockwise. Because half of the spiral blade is left-handed thread and the other half is right-handed thread, the part of the contact object produces upward motion, thus keeping the object close to the pedestal. At this time, the motor is stopped to rotate to realize the function of grasping the object, so the whole grabbing process is completed.

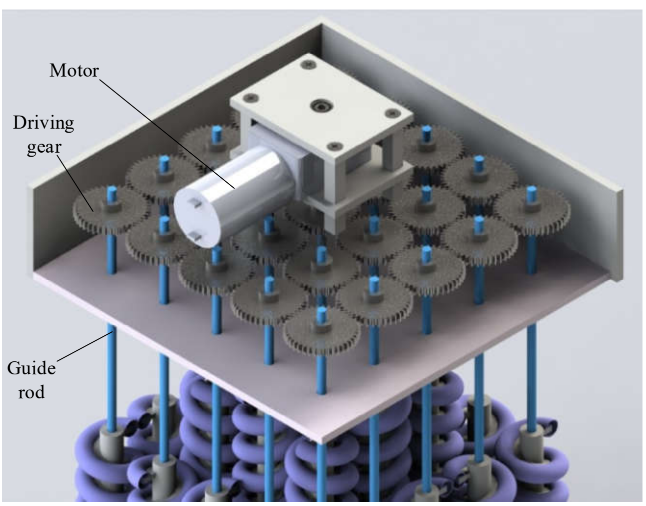


Fig. 6 Illustration of SBESTAA hand grabbing an object

IV. Contact Force Analysis

In order to evaluate the grasping characteristics of the SBESTAA robot hand, the mechanical characteristics of the SBESTAA robot hand in the grasping process will be analyzed based on the principle of virtual work. The pressure in the film generates the grasping force of the object. When a SBESTAA robot hand grabs an object, the force analysis diagram is as follows:

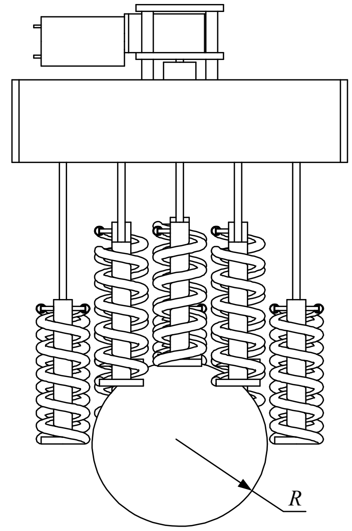


Fig. 7 Force analysis of SBESTAA hand

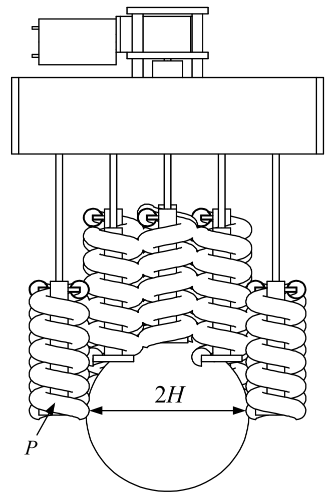


Fig. 8 Force analysis of SBESTAA hand

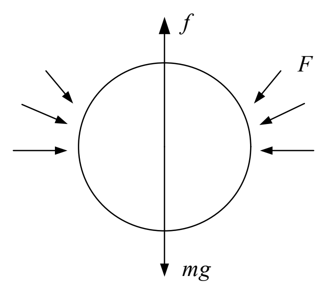


Fig. 9 Force analysis of the object

The parameters in the force analysis are as follows:

R --- Radius of a spherical object, mm;
$2H$ --- Spacing of expanded elastic thin film tubes, mm;
P--- Air pressure in elastic film tube during expansion, Pa;
f --- Friction force of elastic thin film tube to object, N;
μ--- Friction coefficient of elastic thin film tubes
m--- The mass of the object caught, kg;
s--- Contact area between elastic thin film tube and object, mm^2;

n --- Number of contact surfaces;

η --- Effective coefficient of contact area;

F --- Pressure between elastic thin film tube and object, N;

Assume that the grabbing object is a sphere, the Figure 7 shows the state when the object is not grabbed, and the Figure 8 shows the state when the object is grabbed. From the analysis of the whole force of the object, the following formula can be obtained:

First, we analyze the pressure between the object and the elastic film tube:

$$F = P\int\int ds \tag{1}$$

$$F = PR\int_0^{2\pi} d\theta \int_{R-H}^{R} \frac{rdr}{\sqrt{R^2 - r^2}} dr \tag{2}$$

$$F = P\pi R\sqrt{H(2R-H)} \tag{3}$$

From the relationship between pressure and pressure we can get:

$$f = \mu F\int_{-\theta}^{\theta} \cos\theta d\theta \tag{4}$$

$$f = 2\mu F\sin\theta \tag{5}$$

From the Figure 9, we can analyze the whole formula to get the following formula:

$$mg = \eta\sum_{i=1}^{n} f \tag{6}$$

Therefore, by combining the (3)(5)(6) formula, we can get the following formula:

$$mg = 2\eta\sum_{i=1}^{n} \mu P\pi R\sqrt{H(2R\text{-}H)}\sin\theta \tag{7}$$

According to the actual dimension of SBESTAA hand, some value of can be measured as follows: μ=0.3, P=20000Pa and η=0.5 and we substitute these parameter values into it.

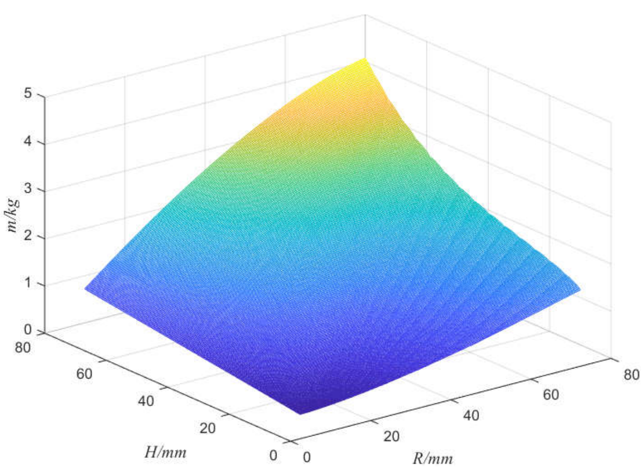


Fig. 10 Parameter diagram

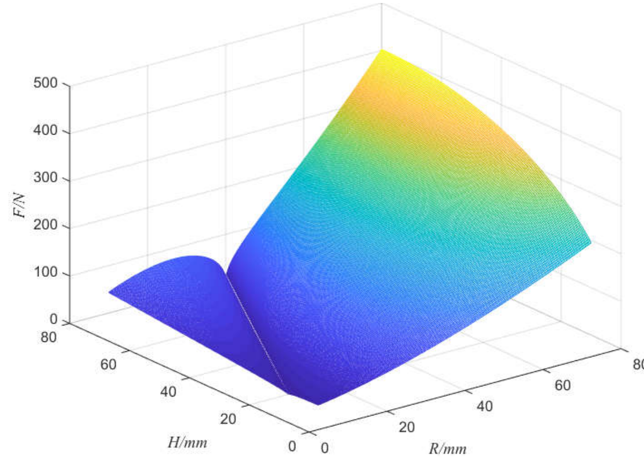


Fig. 11 Parameter diagram

By bringing the values of these parameters into the equation, the formulas of F and m of H and R variables can be obtained. Figs. 10 and 11 show the variation of F and m values with variables H and R.

Therefore, we find that the values of F and m decrease with the increase of H and increase with the increase of R.

Therefore, in order to grasp the heavier object, we can appropriately reduce the pitch or increase the value of dynamic friction coefficient and pressure.

Ⅴ. CONCLUSION

This paper proposes a new type of gripping device. This new gripping device is simple in structure and easy to operate. It is suitable for grasping objects of different sizes, shapes and directions and has strong adaptability (both on the top and side of the object), high stability, fast grip, etc., through the force analysis to verify its gripping feasibility, SBESTAA hand through the adaptive object, elastic film tube expansion, motor drive gear and then the sliding tube to achieve Grab, can be widely used in various crawling scenes.

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