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A Novel Underactuated Universal Gripper with Swing Rods and an Elastic Membrane for Underwater Grasp

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***Abstract* – Underwater grasping is special and different from common object grasping. Traditional gripper cannot be used in underwater environment. Underactuated gripper is simple in structure and has self-adaptive function, which is better than complex dexterous hand for underwater tasks. This paper proposes a novel underactuated universal gripper, called SREM gripper. The SREM gripper is used to grasp objects, realizes the adaptive function of the size and shape of objects by using multiple swing rods, and realizes the space envelope of objects by using an elastic membrane. The device achieves the multi-direction grasping of objects, can provide grasping force to objects in multiple directions. The device is not limited by the working environment, has simple structure and low energy consumption.**

Index Terms: robot hand, underactuated gripper, swing rod, elastic membrane

I. INTRODUCTION

Robot gripper has a wide range of applications in the field of robots. It is used to temporarily connect and fix robots and objects and releasing them at an appropriate time. The former realizes grasping objects, while the latter realizes releasing objects. In order to reduce the cost, the general robotic gripper is made into two parts with relative motion, so as to realize the function of grasping and releasing in the simplest way.

There are also many structures that imitate human grippers, designed to have more fingers and fingers with several joints, and control algorithms.

Some robotic grippers have adaptability, that is, they do not know the shape and size of the object to be grasped before grasping, nor do they detect the object to be grasped by sensors during grasping, but they can grasp it adaptively. This kind of automatic adaptability to the shape and size of the object makes the robot gripper achieve a wider grasp of different objects without increasing sensing and control.

Many robotic grippers like the structure and proportion of human hands, developed to have several fingers and several joints in each finger. The Utah/MIT Dexterous Hand [1], Gifu Hand [2-3], DLR/HIT Hand II [4], and Shadow Hand [5], etc. These dexterous grippers are complex in structure, control and sensors [6-8].

Many underactuated grippers were developed to decrease the difficulty in control and sensors. The traditional underactuated grippers are easy to control. Self-adaptive grippers are focus in research area of robot grippers, since the self-adaptive gripper do not need to previously sense the shapes, sizes and positions of the grasped objects. The grasping performance of self-adaptation for different objects of shapes and sizes will enable the gripper grasp more kinds of objects.

Traditional underactuated grippers are divided into two aspects: 1) multi-fingered grippers. Such as the FRH-4 Hand [9], the prosthetic hand [10], the GR2 Gripper [11], the tendon-mechanism hand [12], and the SDM Hand [13]. 2) special gripper. These kind gripper means there is obvious finger with joints. Such as the adaptive gripper [14], the universal gripper with a spherical structure [15-16], and the SSA Gripper [17]. These hands have self-adaptive grasping function.

Underwater grasping is special and different from common object grasping. Traditional gripper cannot be used in underwater environment. Underactuated gripper is simple in structure and has self-adaptive function, which is better than complex dexterous hand for underwater tasks. This paper proposes a novel underactuated universal gripper, called SREM gripper. The section II introduces two traditional grippers with pin array, which is the basic scheme of the improving gripper, SREM gripper. Then the structure, working process, motion and force analysis, and control system of the SREM gripper is described in latter section.

II. OMNI GRIPPER AND CTSA GRIPPER

Peter B. Scott introduced a mechanical passive universal gripper (Omni gripper) [18], shown in Fig. 1. The gripper has two sets of rod clusters, each group of rod clusters has several parallel long rods. These long rods, driven by the object to be grasped and sliding freely up and down, achieve the purpose of adapting to the shape of the object, and then combined with the driver to drive two groups of rod clusters close or leave to achieve the grasp of the object.

When the end of the robot is against an object placed on a supporting surface (such as a desktop), the object extrudes a long rod to slide into the base. Because the number of long rods is large and the length of the rod is thin (smaller diameter), different long rods touch different surface points of the object, and the sliding distance of each long rod to the palm is different, which is related to the local shape of the object. After that, two groups of rod clusters, one left and one right, are assembled to clamp the object, and the long rod is used to clamp the object

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from the side to achieve the purpose of grasping, shown in Fig. 2, Fig. 3.

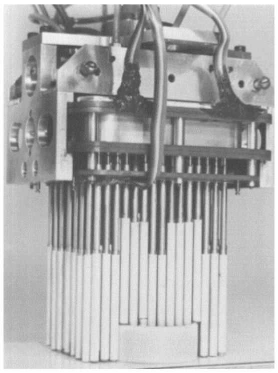
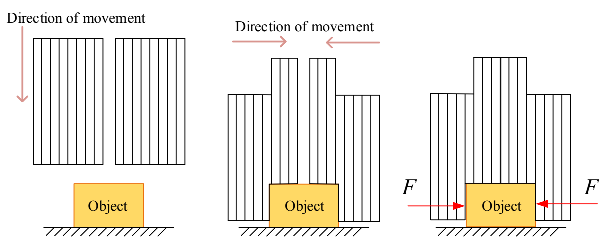


Fig. 1. The Omnigripper.



(a) (b) (c)

Fig. 2. The principle of Omnigripper

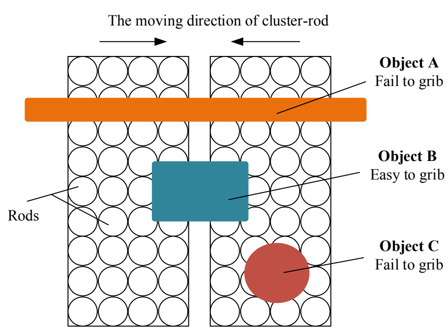


Fig. 3. The grasp range of the Omnigripper.

The disadvantages of the device is that:

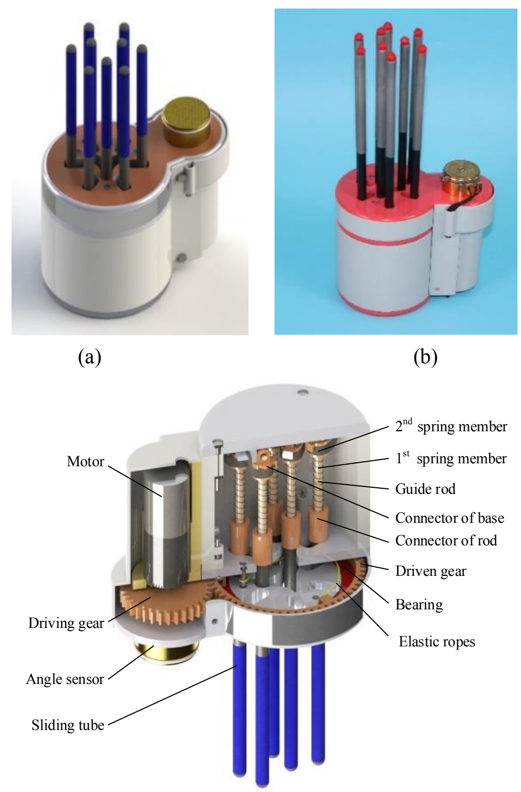
(1) It is impossible to grasp in multiple directions. When the device exerts a grasping force on the target object, the grasping force can only follow the direction of the two groups of rod clusters, which is equivalent to a two-finger gripper, and produces only one-dimensional gripping mode, and the gripping effect is poor.

(2) Grasping failure of long strip objects placed in a specific 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 two groups of telescopic rods, such as grasping a long strip of object.

(3) Complex structure and high energy consumption. The device has two sets of rod clusters. It needs two movable supports (or moving base), a set of linear guides, two sliders, actuators, transmission mechanism and so on. Its structure is more complex, and it is more energy-consuming to make a clump of heavy rods with many long rods move together.

(4) Grasp stability needs to be improved. The grasping force of the device to the target object is only produced by the combination of two groups of rod clusters. The grasping force can only be used to close the grasping object, but there is no good envelope closed grasping effect. Because the force closed grasping object may not necessarily produce the shape closed grasping, but the shape closed grasping must include the force closed grasping, so the grasping stability has reached the best shape closed grasping.

Hong Fu et al. proposed a novel robot gripper (Cluster-tube Self-adaptive Robot Hand, CTSA hand) in order to overcome disadvantages of the traditional Omnigripper, as shown in Fig. 4. However, this gripper cannot grasp small animal in underwater environment.



(a) (b)

(c)

Fig. 4. CTSA gripper.

III. Structure Principle of The SREM Gripper

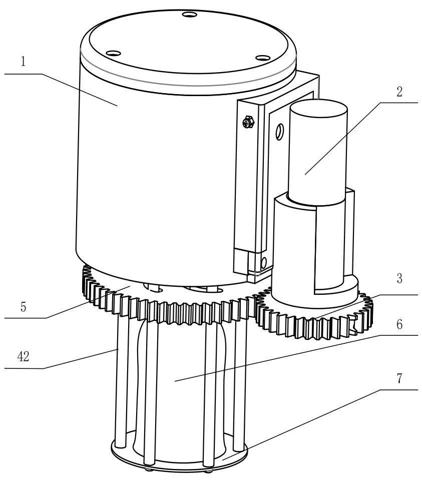
In order to overcome the shortcomings of the above devices, a new type of robot gripper, flexible adaptive Swing-rod robot gripper, was designed in this paper.

4.1 Structure of the SREM gripper

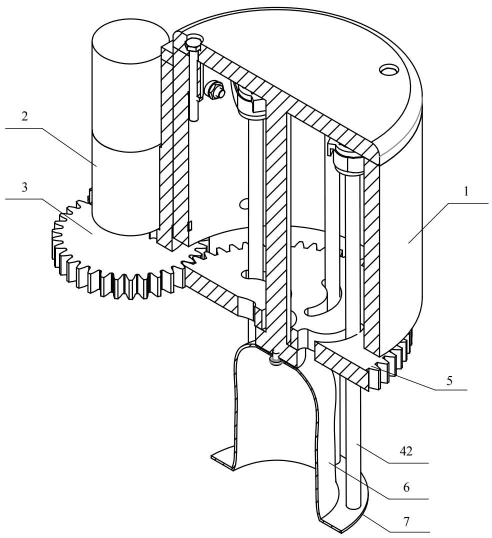
The SREM gripper proposed comprises a base, a sliding groove plate, a driver, a transmission mechanism and K swing-rod components, shown in Fig. 5.

1) chute plate

The chute plate is the core control mechanism of the device, which is connected with the output end of the transmission mechanism; K semicircular chutes are arranged on the chute plate; the K semicircular chutes are uniformly distributed around the geometric center of the chute plate; each swing rod slides in a semicircular chute.



(a)



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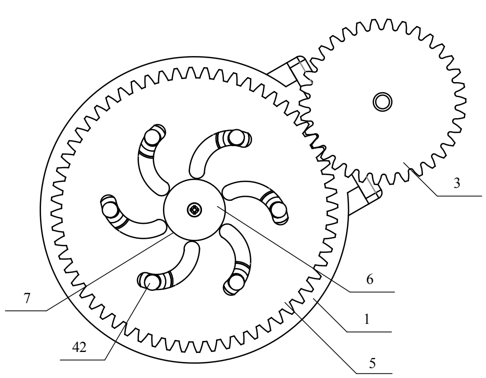

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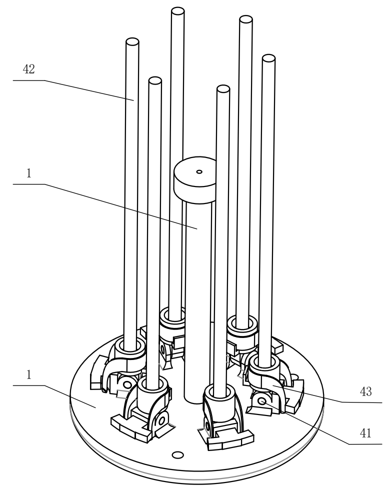


(d)

Fig. 5. The proposed robotic gripper

1-Base, 2-Driver, 3-Drive, 4-Swing Rod Component, 41-Swing Rotary Shaft 42-Swing Rod 43-Spring 5-Slot Plate, 6-ElasticFilm 7-Elastomer

The edge of an elastic membrane is fixed at the end of the swing rod and the geometry of an elastic membrane is fixed in the geometry of the swing rod. The center is fixed to the geometric center of the chute plate, the elastic part is fixed to the edge of an elastic membrane, and K is a natural number greater than 3.

2) An elastic membrane

An elastic membrane is an adaptive means of the device. The edge of the module is fixed at the end of the swing rod, the geometric center of an elastic membrane is fixed with the geometric center of the slide plate, and the elastic part is fixed with the edge of an elastic membrane, where K is the natural number greater than 3.

3) Flexible Fixers and Swing Rods

Each swing rod assembly comprises a swing rod, a swing rod rotating shaft and a spring; K rotating axles are respectively sleeved in the base, and K rotating axles are uniformly distributed in the circumference; one end of the spring in each swing rod assembly is connected with the base, and the other end of the spring is connected with the swing rod. Each spring is one or more of the torsion springs, the pull spring, the rubber band and the elastic rope.

4) Transmission mechanism

The drive mechanism of the device is connected with the output end of the driver, and the driver is fixed on the base. Both of them achieve deceleration effect through gear speed ratio

4.2 Working process of the SREM gripper

The device has two states, the first state is open state and the second state is convergent state.

The gathering state of the device is shown in fig. 6. At this time, the six pendulum rods 42 move inward along the sliding groove to the inner end of the sliding groove under the rotation of the sliding groove plate 5. The six pendulum rods 42 end are close together. Because of the pre-tightening force of the elastic part 7, the end of an elastic membrane is tightened, and an elastic membrane forms a complete envelope state.

The opening state of the device is shown in Fig. 6a-6d. All swing rods 42 are located at the outermost end of the chute, and the spring is not pulled near under its preload, thus making all swing rod components 4 in a vertical state. This state has a larger tension force than the state of convergence.

The switch between the opening state and the closing state of the device is realized by the drive 1 driving the rotation of the chute plate 5 through the drive mechanism 2.

Therefore, the device is in an open state when it is not working.

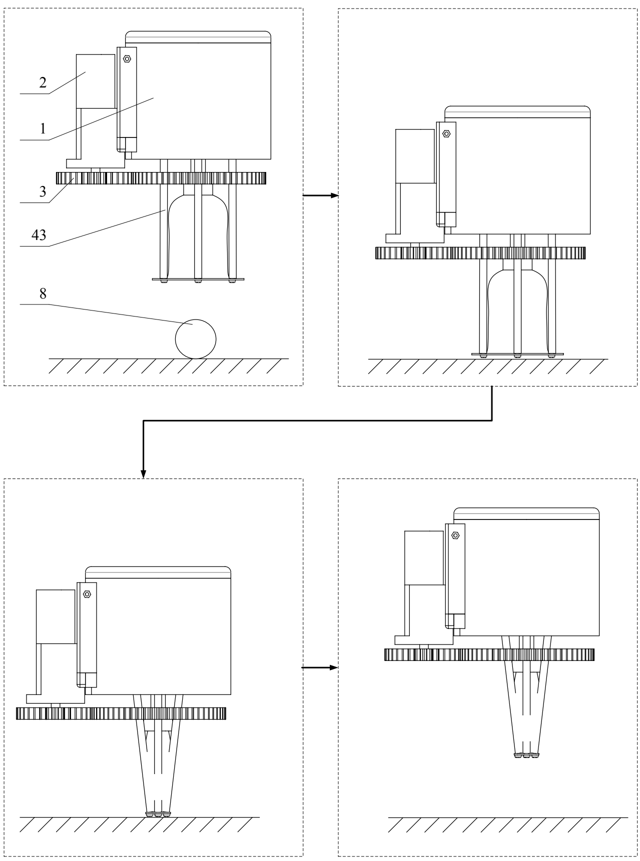


Fig. 6. Working process of the robotic gripper.

IV. Analysis of The SREM Gripper

In Fig. 7,

z_1 : The number of teeth of the driving gear, rad/s ;

z_2 : The number of teeth of driven gear, rad/s ;

ω_1 : The angular velocity of the driving gear, rad/s ;

ω_2 : The angular velocity of driven gear, rad/s ;

T_1 : Torque of driving gear, $\mathrm{N \cdot mm}$;

T_2 : Torque of driven gear, $\mathrm{N \cdot mm}$;

f_1 : The force of the driven gear to the swing rod, N ;

f_2 : The force distribution of the pendulum rod along the normal line of the chute, N ;

f_3 : The tangential force of the pendulum rod along the chute, N ;

r_d : The radius of the pendulum rod, mm ;

r_2 : The radius of the chute, mm ;

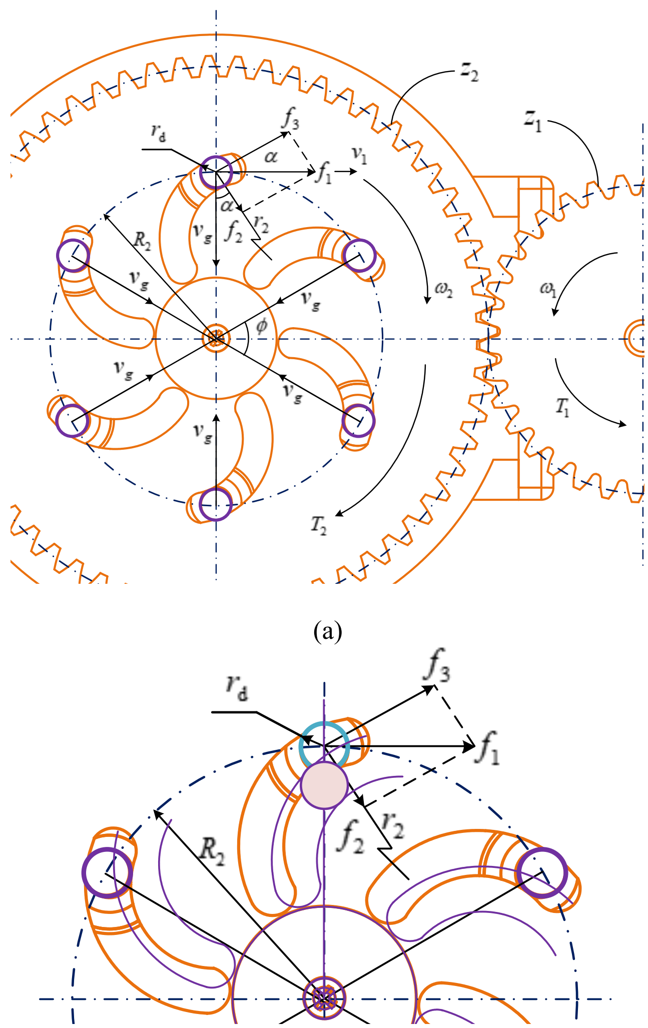
R : The radius of the distribution circle where the pendulum rod was located at that time, mm ;

α : Pressure angle, that is, the angle between the direction of force and the direction of motion, rad ;

ϕ : The pendulum rod has uniform distribution angle, rad ;

v_1 : The linear velocity of the driven gear at the swing rod, mm/s ;

v_g : The linear velocity at which the pendulum rod converges to the center at the intersection of the driven gear, mm/s .



(b)

Fig. 7. Motion and forces analysis of the SREM gripper.

As the main guiding device of the manipulator, angle and length of the chute plate determine the smooth operation of the cluster rod device. According to the pressure angle theorem and the Chinese standard for the pressure angles, the pressure angle of the cluster rod at any point of the chute plate should be less than 20 degrees.

According to the equilateral triangle theorem and arc theorem, on a base with radius R, an arc with an angle of 80 degrees should be tangent to the base, as shown in Fig. 7. The purpose of doing this is to make the cluster rod achieve the best grasping efficiency under the circumstances that it is possible to be smooth.

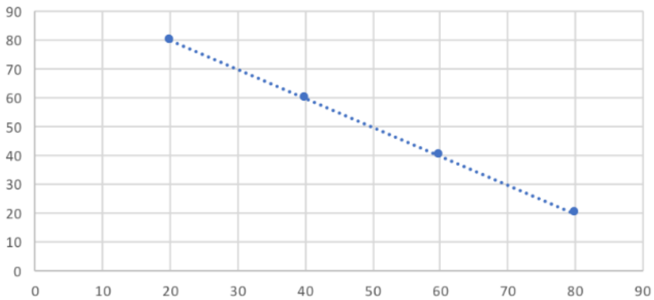


Fig. 8. The relationships between the arc angles and the pressure angles.

As shown in the fig. 7, the left circle is the base with radius R, and the sector part of the right circle tangential to the left circle is the best model of the chute plate. Fig. 8 shows the pressure angles at different arc angles in order to verify that the arc has both the grasp rate and the smoothness of the cluster rod movement.

Thus, the most appropriate length of the chute should be 80 degrees. Thus, in this kind of sliding groove cluster rod manipulator, the circle with an angle of 80 degrees is the most efficient design.

V. Control of The SREM Gripper

This gripper is easy to control without complex control scheme. The control circuit is shown in Fig. 9. There is an Arduino UNO micro-controller, one L298 motor driving circuit module.

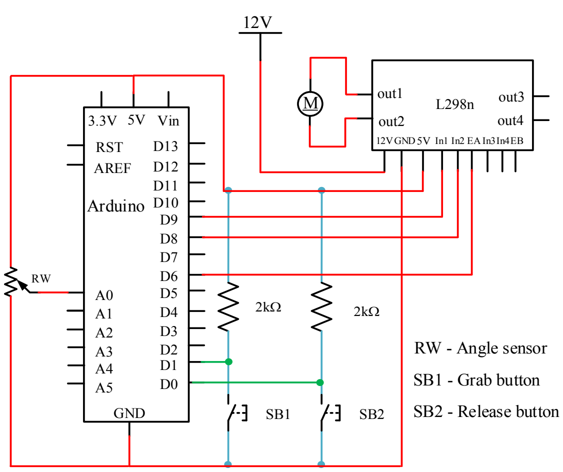


Fig. 9. The control circuit of SREM gripper.

The control method is as follows:

The driving gear is detected by an angle sensor, which will sensor the output velocity of the gear. When angular velocity decreases to a previous certain value, which means the SREM gripper is coming to stop status, at this time, the controller let the motor stop. It is used to grasp objects, realizes continuous discrete adaptive grasping function, realizes the adaptive function of size and shape of objects by using multiple pendulum components, and realizes the space envelope of objects by using an elastic membrane and elastic parts.

The device achieves the multi-direction grasping effect of objects, can provide grasping force to objects in many directions, and can be applied to objects of various shapes placed in different directions. The device is not limited by the working environment, has simple structure and low energy consumption. It is suitable for all kinds of robots that need general grasping, especially for flexible adaptive envelope grasping.

VI. Conclusion

This paper proposes a novel underactuated gripper for underwater grasp, called SREM gripper. The SREM gripper consists of a base, a motor, a transmission mechanism, multiple swing rods and elastic membrane. The gripper has self-adaptive grasping function for catching creatures. The SREM gripper has the features of self-adaption and large grasping force. The SREM gripper is easy control, simple structure, low cost and high reliability of grasping for underwater grasp. The SREM has the potential value for huge range of applications, such as the fields of service robotics, industrial applications and research of robotics. The further studies should be made to improve the accuracy and the reliability of the gripper.

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