Design of various parts of multi-joint bionic fish equipment

Qingli Shang

Haidu College of Qingdao Agricultural University, No. 11, Wenhua Road, Laiyang City, Shandong Province 265200, China
Email: shangqingli@hdxy.edu.cn

Abstract. The multi-joint bionic fish has a convenient and stable structure, small size, and can be used in different occasions. At present, it can be used in normal underwater activities and can effectively solve the difficult problem of underwater exploration. The equipment consists of six parts in total: fish wing forward device, fish wing movement linkage device, single joint connection device, fish tail stabilization device, fish body bending and direction changing device, and driving device. Satisfying the basic requirements can solve the problem of underwater operations.

1. Introduction
The multi-joint bionic fish adopts a modular design. After designing a single joint, it can be assembled, and the number of joints can be increased or decreased according to the situation. At the same time, the adopted single-chip microcomputer is used to control the speed of three motors and two power driving devices to realize intelligence. It is divided into six parts, and finally assembled together. (Fish wing forward device, fish wing motion linkage device, single joint connection device, fish tail stabilization device, and drive device) The assembly sequence of each module is reasonably scheduled, so that the entire equipment achieves the perfect expected effect. The structure is simple, and the machine is stable as a whole, which meets the needs of exploration and operation of the ocean.

2. Overall design
The specification of this design is that each single joint is 260mm long and 1500mm wide. When adding 5 sections according to the normal standard, the overall length of the device is 1870mm wide and 260mm. When in use, the length of the side wings and the number of joints can be changed according to the size of the working space to change the overall device Specifications (Fig.1).
Model each part first, then assemble the parts, and finally put several large modules in the assembly environment for assembly, and simulate and analyze the functions of each module[1].

The working method of the multi-joint bionic fish: Fish-wing forward device: A crank mechanism is used to control the sliding rod to swing back and forth through a pair of bevel gears. The other end of the sliding rod is connected to two fins like a hinge mechanism. When the slider rotates, it opens and closes to drain the water backward. Motion linkage device: There is a cylindrical gear at the other end of the slide bar. There are two cylindrical gears at each single joint. They are located at both ends of the motor that provides power. The cylindrical gears of each single joint are linked by a conveyor belt to achieve each joint provides power, and when the main drive motor is lost, a backup motor can be used to provide the power of the fish-wing forward device. Fin stabilizing device: through the coordination of three bevel gears, a large cone at the bottom drives the small bevel gears on both sides to move, so that the bevel gears on both sides turn in opposite directions, thereby driving the two fish tails to move up and down in a staggered manner. Single joint connection device: The single joint connection device strengthens the bearing strength of the front, middle and back joints in the design of ordinary cylindrical connection. Fish body bending direction changing device: adopts a parallelogram design[2]. One diagonal is the diameter of a turntable, and the other diagonal connects the fish head and tail. When the turntable rotates, the two unilateral angles are controlled. Change the length of the diagonal line connecting the head and tail of the fish to compress or stretch the body of the fish, thereby realizing the bending of the fish body. Drive device: use a single-chip microcomputer to control three motors, of which there are two servo motors and a three-phase asynchronous motor, the servo motor controls the fish wing movement in the fish wing forward device to move the whole forward, and the three-phase asynchronous motor controls The bevel gear at the bottom of the fish tail stabilization device achieves forward and reverse rotation, so that the two fish tails reciprocate up and down, and the program control is used to achieve precise coordination of each part when swimming.

3. The design of each part of the multi-joint bionic fish equipment

3.1 Design of fish wing forward device
The fish-wing forward device is composed of cylindrical gears, sliding rods, rotating parts, large pulleys, side slurry, streamlined heads, bearings and bolts. During the design process, the left and right side slurry should be symmetrical. The diameter of the sliding rod must be smaller than the diameter of the through hole of the rotating part handle. The threaded hole is drilled at the end and fixed with a bolt. After calculation, it should be exactly at the position of the sliding rod to ensure that the sliding rod moves linearly in the through hole of the rotating part handle. The rotating part should be added with a bearing. The diameter of the rotating part must be calculated to match the flange linear bearing. Afterwards, the conical gear is matched and assembled in sequence, and finally the through hole of the sliding rod rotating rod handle is ensured. The cylindrical gear and the motor are exactly in a straight line.
3.2 Design of fish-wing motion linkage device
The fish-wing motion linkage device is composed of two parts: one is the connecting shaft and the other is the cylindrical gear of each single joint through a conveyor belt. The first part is composed of connecting shafts, bearing supports, and bearings, and the other part is composed of conveyor belts and cylindrical gears similarly (Fig.2). When designing, it is necessary to consider the length of the conveyor belt and the axis distance of the cylindrical gears of all joints, and leave a certain gap. Because the temperature cannot be controlled due to the depth in the water flow, it is necessary to leave a certain width, roughly the same width. It is 30mm to ensure thermal expansion and contraction, and there must be fish-wing motion linkage devices at both ends of the machine to ensure that the two are simultaneously restrained to maintain overall stability[3].

![Fig.2 Fish-wing motion linkage device](image)

The connecting shaft has been improved. First, the bottom surface of the keyway is designed on a flat surface to facilitate the processing cost. When the various levels are separated, the gears are distinguished and the finishing surface is reduced.

The power mechanism (Fig.3) is used to provide power for a single joint. There is such a device in each joint, but only the two single joints at the two ends have a motor in the middle. One is used to provide power, the other is Reserves are reserved, and the joints can only be increased or decreased from the middle to ensure that the weight of the two ends is the same, to prevent the heaviness of the whole, and the serious sinking of each part.

![Fig.3 Power mechanism](image)

3.3 Design of single joint connection device
The single-joint connection device (Fig.4) is composed of an articulated plate, a connecting piece, a bearing, and a connecting shaft. When the connecting shaft is connected from the connecting rod of the joint plate through the connecting column welded on the joint plate, when the connecting rod is not connected When connecting directly through the connecting column, the connecting column may not be
firmly welded to the joint plate. When the water pressure is too high, the joint plate and the connecting column may break, or the joint plate may break in the middle. When joining the connection, when using a rod, the connecting rod will share most of the pressure on the joint plate, and use the front and rear joints to connect to prevent breakage, just like a human bone.

3.4 Design of fish tail stabilization device
The function of the fishtail stabilizer is to maintain the overall balance. The fishtail stabilizer is composed of a three-phase asynchronous motor, a connecting shaft, a direction changing box, a tail wing, a motor support, a bevel gear, and a bearing. The reversing box is equipped with 4 bevel gears, one on the bottom and three on the four sides. One of them is connected to the three-phase asynchronous motor through the connecting shaft and coupling to provide power. When the power is transmitted from the front side bevel gear to the bottom cone, the bottom bevel gear will be provided to the bevel gears on both sides. The diameter of the bottom bevel gear must be larger than the other three bevel gears to withstand enough torque, and the diameter of the other three bevel gears must be the same. Control the three connecting shafts on the same plane. When the bottom bevel gear rotates, it drives the symmetrical bevel gears on both sides to rotate. Because they are in a symmetrical position, the bevel gears on both sides turn in opposite directions, and the bevel gears on both sides drive their respective connecting shafts. The tail wing swings up and down, so that the two tail fins are up and down, so that the water flows out from the body stably, ensuring the overall stability[4].

When the fishtail stabilization device is working, the two tail fins can move in two directions simultaneously through one motor, and the tail can be controlled to swing up and down through the three-phase asynchronous motor. Because the tail swing needs to be regular, when one tail fin reaches the uppermost limit, the other tail should reach the lowest limit, so the angle of the keyway of the two bevel gears should be controlled to 0°. On a plane, swing the tail as much as possible to play the role of the fishtail stabilizer.

3.5 Structural design of driving mechanism
To ensure that the multi-joint bionic fish moves forward steadily, it is necessary to coordinate the driving speed with the speed of the tail and flanks to achieve the desired effect. The servo motors and three-phase asynchronous motors of the two mechanisms are controlled by a single-chip microcomputer, and the desired functions can be realized by designing simple programs[5].

The diameter of the gear connected to the servo motor on the drive device should be 2/3 of the diameter of the gear connected to the connecting shaft, which is a pair of reduction gears. When the fish-wing forward device calculated by the servo motor speed as a whole is 0.05m/s, the equipment's forward speed should also be 0.05m/s, so as to ensure that when the equipment advances at a constant speed, the side wings can pass through the water evenly. Resistance moves forward steadily. At this time, the three-phase asynchronous motor in the fishtail stabilization device needs to set a speed of 1/4 times the forward speed 0.0125mm/s. The tail should mainly play a stabilizing role, and the role of pushing the overall forward is only an auxiliary.
4. Animation simulation and interference analysis of each component

In order to verify whether the six mechanisms can be assembled together to achieve the desired purpose, use the 3D software SolidWork to assemble the models together, as shown in Fig.6, and then use the plug-in SolidWorks motion in the software to analyze its movement. Whether there is interference.

First find that the two parts of the drive motor and the three-phase asynchronous motor linear motor belong to the original moving parts. The forward motion and the stable tail motion of the equipment are driven by these two motors. Add a simulated motor to the two motors in the motion analysis module. The motion mode of the motor driven in the device is rotary motion. Therefore, the rotary motor simulation is used when the motor is added. The forward speed calculated in section 2.5 is 2.5mm/s, so the rotating motor speed is also set to 2.5mm/s, and the direction is counterclockwise (Fig.7)
Then configure the motor of the drive motor. The drive motor drives the movement of the forward device. The speed is also 0.2mm/s, and the direction is parallel to the right as shown in Fig.8. After the motor is configured, start to run and turn on the interference detection. After a few seconds of motion simulation, no interference was found, so the designed structure and scheme have reached the basic requirements.

![Fig.8 Configuration of linear motor](image)

5. Conclusion
The innovative points of the multi-joint bionic fish designed in this design are as follows:

1. In this design, the mechanism is optimized. As long as the program controls the motors of the two parts to perform their own functions, it is convenient to write.

2. The single joint of the multi-joint bionic fish can be replaced at will. When one of the joints has a problem, it can be replaced and modified at will. The number of joints can be added or subtracted freely according to the work needs to adapt to various working situations. The usability of the device is more powerful.

3. The multi joint bionic fish equipment is symmetrical about the middle and bears a sheet as a whole, but the forward mode will not be affected by the up and down pressure, and this design will greatly reduce the impact on the overall stability of the device due to special factors, and the overall stability is increased to a certain extent through the tail wing stabilization device at the tail.

References
[1] Cai Zixing. Principles and Applications of Robots[M]. Changsha: Central South University of Technology Press, 1998.
[2] Song Weigang. Mechanical Parts Design Manual (Third Edition) [M]. Beijing: Metallurgical Industry Press, 1994.
[3] Yang Jiajun. Mechanical system innovation design M]. Wuhan: Huazhong University of Science and Technology Press, 1999.
[4] Hua Danian. Design of connecting rod mechanism [M]. Shanghai: Shanghai Science and Technology Press 1995.
[5] Luo Zhenbi, Zhu Yaoxiang. Modern Manufacturing System [M]. Beijing: Mechanical Industry Press, 1995.