Mechanism Design of a Bionic Robotic Fish

Jun ZHONG, Chun ZHAO* and Yi-fan CHEN

College of Mechanical and Electrical Engineering, Hohai University, No.200 Jin Lin Road
Changzhou 213022, Jiangsu Province, China

*Corresponding author

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Abstract. In recent years, bionic robot fish have received more and more attention and have been applied in many fields, such as underwater detection, underwater archaeology, and military field. The main reason is that the propulsion and propulsion efficiency of the bionic fish are high, and the swimming performance is excellent, which is suitable for underwater operation. This paper studies the mechanism design of bionic fish which is suitable for underwater operation. The presented robotic fish consists of the power transmission mechanism of tail and the rising-falling mechanism of chest. The swing mechanism of tail uses DC motors as driver, and the transformation mechanism is added at the tail to turn the rotary motion of motor into swing movement. The pectoral fins wobble mechanism is used as the rising and falling mechanism, which is conducive to raising the swing frequency.

Introduction

Modern underwater vehicles generally use propeller propulsion, low efficiency, energy consumption and noise, and most fish have high swimming efficiency and without sound. The development of bionic fish, which has the high energy utilization rate and fast speed and Realize long-time, large-range underwater operation, is becoming a hot spot of research and has been paid more attention than ever before. Many robotic fish have been developed in the past years [1-10]. CJ Esposito designed a robotic caudal fish with six individually moveable fin rays by reference to Lepomis macrochirus, and performed test of fin ray stiffness, frequency and motion program on the generation of thrust and lift forces [11]. J Liang proposed a robotic fish designed for application in real-world scenarios[12]. A compact parallel four-bar mechanism was adopted for propulsion and maneuvering, and motion control algorithm was programmed. AD Marchese described an autonomous soft-bodied robot by employing a compliant body with embedded actuators emulating the slender anatomical form of a fish [13]. An array of fluidic elastic actuators were used to drive the robot. V Kopman presented the design of a biomimetic robotic fish with a modular caudal fin and analyzed its performance [14]. YJ Park presented a simple method to identify the condition for maximizing the thrust generated bb a compliant fin propulsion system and focused on a particular kinematic parameter of the phase difference between the sinusoidal motion of the driving angle and the fin-bending angle [15].

This paper focuses on the design of tail driving mechanism and chest swinging mechanism. The driving mechanism and the rising and falling mechanism model are plotted respectively in the 3D drawing software, finally, the assembly is carried out to verify the reasonableness of the mechanism.

Tail Fin Mechanism Design

The design of the machine fish is mainly divided into two parts:

1) The driving mechanism of the tail. According to the swimming way of the family fishes, the propulsion force is mainly generated by the swing of the caudal fin, so the driving part is in the tail of the fish.

2) The rising and falling mechanism of chest. The rising and falling of the bionic robot fish can be realized by changing the relative angle between the pectoral fins and the fish body.
In this paper, a DC motor is selected as the output part of the tail power module, and the rotation motion is converted to swinging by designing a special organization. In the design of the mechanism, The reciprocating swing and rotation often need to be converted to each other, as well as the moving requirements of the robotic fish (keeping a straight line in the two dimensional plane). The schematic diagram of tail drive is shown in Figure 1. 1 - motor, 2 - the output shaft of motor, 3 - eccentric wheel, 4 - servo frame, 5 - tail handle.

![Figure 1. The schematic diagram of tail drive.](image1)

![Figure 2. Three dimensional model of tail structure.](image2)

The three-dimensional model is designed according to the schematic diagram of the tail structure and it is shown in Figure 2. In the model, the crank of the transmission mechanism is replaced by the eccentric wheel, so that the whole mechanism is more coordinated and compact. The motor is used as a power source, and the movement is output by the output shaft, and the motion is transmitted to the optical axis through the coupling, then the eccentric wheel is revolving, and the optical axis is supported by the bearing, the design of bearing and bearing seat can reduce the friction coefficient in the movement process and ensure the rotary precision. The cam is an innovative part of the mechanism. Its typical feature is to provide the linear motion of the anti friction surface and the rotating motion of the axial plane, which coincides with the design requirements of the design of the mechanism. In this way, the output power of the DC motor is transferred to the servo frame through the cam, and then it is straight moving, and the cam which is fixed with it swings the upper plate and finally realizes the reciprocating oscillation of the fish tail fin through the tail support frame. In order to make the whole organization run more smoothly, gap fit is applied in the following two parts: the cam and the follow-up frame, the bearing and the upper plate, this reduces friction and ensures that robotic fish can swim at high speed.

In the model, another innovation is that the linear guide pair is adopted between the servo frame and the bottom plate. Its advantages are simple structure, small dynamic friction coefficient, small static friction coefficient, high positioning precision and good precision. These excellent characteristics are not comparable to the general support mechanism. All directions of the linear guide are of high rigidity. It is a standard part with interchangeability, and has the ability to adjust the heart automatically. Even if there is a deviation in the installation, it can be balanced by a line rail slider, with high motion accuracy and stable operation, which is related to its automatic heart control ability effect.

**Pelvic Fin Mechanism Design**

The movement of pectoral fins is a compound movement. On the one hand, it can do flapping wing motion, and it can do winged wing motion when needed. When the pectoral fin is parallel to the cross section of the fish body, the robotic fish moves in a two-dimensional plane, and the pectoral fins are flapping before and after. When it is necessary to rise or descend, the pectoral fin driven by the internal drive, changes the angle of the tilt which is part of the wing movement. In order to realize the linear movement of the robotic fish in the water, and realize the combination of the linear motion and the pectoral fin swing, two DOF pectoral fin oscillating mechanisms are designed to simulate the body structure of the real fish. The design of the pectoral fin oscillating mechanism is the right and left
symmetry mechanism. A single side mechanism as shown in Figure 3, 1, 2 - steering gear, 3, 4 - bevel gear, 5 - bearing block, 6 - center shaft, 7 - steering arm.

Figure 3. Schematic diagram of the pectoral fins. Figure 4. 3D model of bionic mechanical fish.

The three-dimensional model of the pectoral fin structure is as shown in Figure 4. The flap motion and the rotation around the steering wheel axis (rocking wing motion) and the compound movement of both are realized in the mechanism. The steering gear 2 is fixed to the central transmission shaft, and the steering gear 1 and 2 respectively realize the wing motion and flap movement of pectoral fins.

According to Figure 4, The steering engine 1 does not work and the steering engine 2 works. Assuming that this is the initial position, the pectoral fin only moves forward and back to assists the tail fin drive, and keeps the machine fish swimming in the two-dimensional plane. The steering engine 1 is positively rotating at a certain angle, and the output shaft drives the gear pair to move, thus driving the center shaft to rotate. The steering engine 2 also rotates due to the fixed connection between the steering gear 2 and the central shaft. Then the steering engine 2 drives the pectoral fin through the rocker arm and the sleeve. At this time the pectoral fin is no longer parallel to the cross section of the fish body, but at a certain angle. At the same time, the machine fish submerges due to the drive of the tail. The steering engine 2 keeps working, the robot fish submergence, otherwise, when the steering engine 1 rotates at a certain angle, and the steering gear 2 keeps working, the robot fish rises.

The whole structure has the following advantages:

(1) The bevel gear can realize the transmission of two vertical axes, which has the advantages of long life, high load carrying capacity, noise reduction and damping, light weight and so on, which is beneficial to reduce the weight of the machine fish as a whole, which is necessary to improve the oscillating frequency.

(2) When the propulsion device of the tail is broken down, it can still achieve reliable lifting, and the chest oscillating mechanism has two independent steering engine, which can realize the work lift under the condition of no propulsion.

(3) When the driving mechanism of tail works, bionic mechanical fish can achieve variable speed lifting by changing the frequency of swing and matching the swing of pectoral fins.

Summary
In this research, robotic fish mechanism is designed. Tail fin mechanism is realized cam transmission and bar linkages. Pelvic fin mechanism is realized by combination of steering gear and shafts. The assembled robotic fish is presented by integration of single tail fin and two pelvic fin mechanisms. In the further study, controller will be designed for the robot and experiments will be performed.

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