Abstract— This article took the trevally crescent-shaped caudal fin mode fishes as bionic object, based on the biological observation and bionic research, established the fish swimming model of trevally crescent-shaped caudal fin mode, and designed the three degrees of freedom, tail-tail fins-pectoral fin, robotic fish. It detailed focuses on the fish propulsion theory and robotic fish overall design, including mechanical design, tail design, pectoral design, hardware control system design, drive system design, software design, and the selection and application of steering gear, stepper motor, and microcontroller.

Keywords— Robot fish, Structural, Control design, Caudal fin, Caudal peduncle and Pectoral fin.

I. INTRODUCTION

LOOKING forward to design a simple, practical, and efficient robotic fish, this paper combined with the caudal fin push-type of robotic fish of kinematic study design, based on the underwater experiments, motion analysis, comparative analysis [7]. There are two types of crescent-shaped caudal fin propulsion: one is the left-right motion of body and caudal fin, such as tuna swordfish and shark; another is the up and down movement of body and caudal, such as whales and dolphins. Both of them have the same principle. This design is based on the former research object.

II. THE STRUCTURAL DESIGN OF THE ROBOTIC FISH

During the designing process, the swing-translational movement should be considered firstly. The design should refer[4] to following parameters:

a) Maximum of tail fin attacking water angle \( \alpha_{\text{max}} \), \( 15^\circ < \alpha_{\text{max}} < 25^\circ \);
b) Phase of tail fin swing – translational \( \psi \), \( \psi=90^\circ \)
c) Amplitude of translational movement of caudal fin swing axis \( H \), \( H= (0.75-0.1) \text{ LB} \);
d) Maximum swing of posterior margin of caudal fin swing, \( A_{\text{Tmax}} \approx 0.1 \text{ LB} \)

III. TAIL DESIGN.

A. TAIL FIN

Tuna, sharks have very low aspect ratio of the crescent-shaped tail fins, like an intermediate angle hydrofoil with an arc-shaped leading edge and sharp trailing edge. The profile of tail fin is low resistance shape and obtuse front edge, which can produce a lot of front-end suction, which can provide a large part of the propulsion. In order to better mimic the tail fins of fish, we designed the former half of the tail fin is aluminum, rigidity is good, is conducive to swing tail fin; The latter half is silica gel, flexibility is good. This design improves propulsive efficiency and advance the speed of fish. Fig. 2.a shows a shark-shaped caudal fin with large aspect ratio.
B. Caudal peduncle

The advancement model of carangid crescent-shaped caudal fin of fish’s body has greater stiffness, which the amplitude is mainly concentrated in the body after 1/3 part. The bionics design of tail is the most important section in fish designing. As shown in Fig.2.b, the unique single-motor drive linkage of the two joints of the caudal peduncle mechanical design will be able to simulate a very good tuna tail posture.

IV. DESIGN OF PECTORAL FIN

Under high-speed swimming, the pectoral fin as the elevator controls the way of up and dive, which is able to achieve sensitive dynamic response speed and efficient performance. Pectoral fin is usually arranged near fish head, paired-like, and adjustable angle of attack. Reference [5] to the shark’s pectoral fin proportion of the total body size and shape, machine fish has a single degree of freedom of the wing pectoral fin. As shown in Fig.4.1, by a stepper motor-driven rotating rod with the angle of rotation of the two pectoral fins, pectoral fins are made of thin aluminum sheet material, which have a stronger rigidity and a small gravity.

V. CONTROL SYSTEMS DESIGN.

A. CONTROL SYSTEM

To ensure the reliability of system development, the modular and top-down idea is used in machine fish designing [2]. System function modules are designed separately, through the interface modules combined into the overall control system block diagram shown in Fig.4

1) Voltage Transformation Module

In only one case of power supply, it transforms the large power into the required power supply for motors, wireless receiver modular and MCU part, respectively.

2) Communication module

To achieve serial communication between the upper PC and the lower MCU, and correct communication between wireless modular and MCU

3) DC Motor Driver Module

Using the counter PCA of MCU to generate PWM signal to control the motion of machine tail rotation

4) Stepper motor drive module

In order to achieve the control of pectoral fin, the MCU I/O port is used to generate pulse signal to drive stepper motor.
B. DRIVE CIRCUIT DESIGN OF TAIL JOINT DC

Tail fin is replaced with tail joint DC to generate propulsion force. In this paper, the implementation of robotic fish is, actually, the control of the tail DC motor. The selection is the generic motor AE037090150-01A, using fixed frequency PWM and micro-chip. Figure. 6 are a single chip and power amplifier driver interface circuit; it is a unipolar-driven DC motor system is not reversible. Eccentric wheel mechanism is used the tail part. It requires only one-way rotating DC motor to achieve the swing of tail fin. This design is to avoid the motor, reverse switch back and forth between the motor windings interrupted to bring too much, increasing the motor life, but also ensure the stability of the whole system work [3].

C. DRIVE CIRCUIT DESIGN OF PECTORAL JOINT DC

The up/down action is done by a stepper motor inside the fish head, and the pectoral fin is driven by DC motor. While upping/downing, there is a certain angle between pectoral fin and fish body, which is kept same. As moving forward, there is a recovering trend to zero of the angle. Thus, it needs to maintain a certain torque. And stepper motor is with large torque, enough to make pectoral fins positioned in the desired position. Therefore we chose the stepper motor as the drive motor of pectoral fin. The up/down action is actually the control of the pectoral fin joint of stepper motor. Stepper motor control system driving circuit shown in Fig.7.
**D. Function of Control System Software.**

1) Generation of PWM square wave

Through two timers of MCU, the PWM signal is generated to control the DC motor. After setting up the relevant register, PWM wave is generated by the hardware rather than MCU.

2) Stepper motor pulse and direction signal generation

There is a timing issue.

3) Wireless remote communication

To achieve the wireless remote control of machine fish, through a predetermined transmission protocol, MCU processes the remote control signal and takes the appropriate action in the interruption.

**VI. Conclusions**

In accordance with crescent-shaped tail fin fish and on the basis of bionic research, the idea of bio-mimetic robot fish body is proposed, and we design a single-motor drive linkage of the two joints to promote bio-mimetic robot fish tail fin, as shown in Fig.8, with the stepper motor of pectoral as a fish elevator to achieve the machine fish upping and diving.

![Real robotic fish](image)

**Fig. 8 Real robotic fish**

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**Reference**


