ISSN No:-2456-2165

Underwater Stingray Mechanism Bot

Vedant Umbrajkar, Tanaya Deshpande, Parth Joshi, Prof. A. D. Zope
Pune Vidyarthi Griha's College of Engineering and Technology, Pune

Abstract:- The paper deals with the design and development of an underwater stingray mechanism bot. In this study, a unique underwater propulsion system based on stingray biomimicry is proposed. The device's flexible and streamlined motion is modelled after a Skotch-Yoke mechanism coated in a silicon rubber sheet. The main goal of this project is to create an economical, effective, and environmentally friendly underwater propulsion system that can be applied to a variety of tasks such as underwater surveillance, marine research, and ocean exploration. Traditional underwater propulsion systems may be expensive and detrimental to the marine environment; the suggested mechanism offers a less expensive and more environmentally friendly substitute. Flexible, long-lasting, and resistant to a variety of external variables are made possible by the employment of silicone rubber sheet and acrylic sheet material in the mechanism design. Experimental testing of the suggested underwater propulsion system based on stingray biomimicry has yielded excellent results, suggesting potential for usage in a variety of underwater applications.

***Keywords*:--** *Biomimicry, Stingray, Skotch Yoke Mechanism, Toroidal Propellers.*

I. INTRODUCTION

An underwater stingray mechanism bot mimics the undulations of a stingray fish. Due to the absence of conventional propellers, this robot moves through the water with ease while producing far less noise than its natural counterpart. A stingray bot is a vital tool for marine exploration and study since it can travel undetectably through the water because of its adaptive camouflage. Due to its ability to blend in with its surroundings, it is also a prime contender for covert and stealthy activities like surveillance and reconnaissance.

The mechanism used in recreating the motion of this fish is 'Skotch Yoke Mechanism'. Skotch Yoke Mechanism is a mechanism used to convert rotary motion into reciprocating motion. The mechanism consists of a slotted yoke that is connected to a rotating shaft, and a pin or slider that moves back and forth in the slot. As the shaft rotates, the pin or slider moves along the slot, causing the yoke to move back and forth in a linear motion.

Toroidal propellers are used for the propulsion of the bot. These propellers are also used for balancing so that the bot movement is steady. A significant advantage of toroidal propellers is their ability to operate quietly, which is particularly important in underwater applications. The reduced turbulence and drag result in a smoother and quieter operation, which is less disruptive to aquatic life and allows for more accurate sonar readings.

Silicone rubber sheet is used to enclose this bot. One of the primary advantages of silicone rubber sheets is their flexibility. This property allows them to conform to complex shapes and surfaces, making them ideal for use in applications that require precise molding. In the case of the underwater stingray mechanism, the silicon rubber sheet is used to mimic the flexible and streamlined movement of stingrays, enabling smooth and efficient underwater propulsion.

Acrylic material is used for the fins in the mechanism, as it is lightweight, which can be beneficial in applications where weight is a critical factor, such as in unmanned aerial or underwater vehicles. Additionally, acrylic sheet material is easy to machine, fabricate, and join, making it a versatile and useful material for rapid prototyping and custom design.

II. BIOMIMICRY

Biomimicry is the practice of studying and imitating natural systems, processes, and designs to solve human problems and create innovative solutions. It involves using nature as a model, a measure, and a mentor to design sustainable and efficient systems. Biomimicry has already yielded numerous innovative solutions in a wide range of fields.

In this project, the mechanism of a stingray fish that uses undulating motion of the fins for propulsion and better maneuverability is proposed. There are various types of mechanical systems that can be used to mimic this undulating motion, and this paper proposes the use of Skotch Yoke mechanism for the same. Toroidal propellers are also included in the design for gliding and balancing the bot while underwater.

III. METHODOLOGY

A. Design

The most important aspect of this bot is its design, which is inspired by the stingray fish. The tapering fins and the aerodynamic body are what make its locomotion efficient. The density of the bot (excluding the weight of the electronic components) is the most important design consideration as it affects locomotion and maneuvering control. Designing the bot with minimum weight and maximum volume is a challenge as both increase on adding features, but a balance needs to be maintained. The aspect ratio between the length and width of the fin bones is another

ISSN No:-2456-2165

crucial consideration while designing the bot, as it contributes the most to the weight and volume of the bot in addition to varying the velocity of the bot.

B. Amplitude Enveloping

The velocity of the bot is determined by the water displaced by the fins, which depends on the amplitude of oscillation of the fin bones. This amplitude of oscillation is defined by using an equation of fin displacement. [1] There are 4 main ways/methods/equations of amplitude enveloping, that are implemented to achieve the desired resulting propulsion:

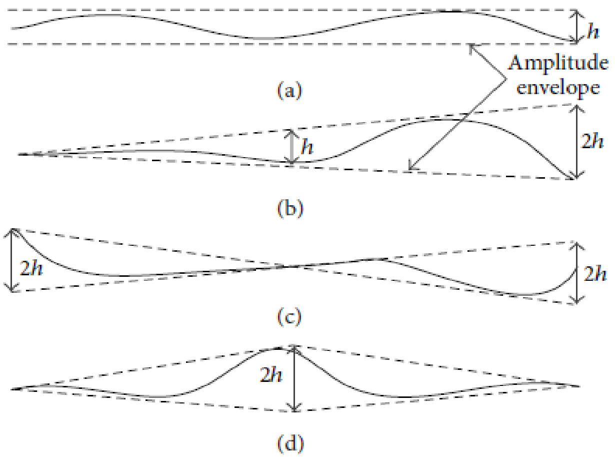

Fig 1 Types of amplitude envelopes

(a) The amplitude envelope is constant along the fins
(b)The amplitude envelope gradually increased from the anterior part to the posterior
(c)The amplitude envelope decreases from the anterior part to the mid part and increases toward the posterior
(d)The amplitude envelope increases from the anterior part to the mid part and decreases toward the posterior [2]

Determination of the right equation of amplitude enveloping is necessary as it will affect the maneuvering and control of the bot along with the change in electronics that are used. The type of amplitude envelope is decided upon their efficiency. [1] The most efficient method of amplitude enveloping is method (b), and the same is applied to our bot.

The amplitude of every point along the fin is determined by the equation:

$$A(x) = 2xh/L$$

Where, A(x) is a function of amplitude with respect to the distance of the points from the start of the fin, h= amplitude of the center of the fin and L is the length of the fin. [1]

C. Toroidal propellers

Toroidal propellers, also known as cycloidal propellers or omnidirectional propellers, are used in marine applications. Unlike traditional propellers that rely on a rotating shaft with fixed blades, toroidal propellers use a circular array of individually rotating blades arranged around a central hub. These blades rotate independently, allowing for omnidirectional thrust and enhanced maneuverability. Here are some advantages of toroidal propellers:

- Omnidirectional thrust
- Enhanced manoeuvrability
- Increased efficiency
- Reduced noise and vibration
- Robust and compact design

D. Silicon Rubber Sheet

The silicon rubber sheets are used to mimic the stingray's fins and for insulating the bot's body. The high range of temperature resistance allows the bot to be used in varying depths of water. The flexibility and elasticity of silicone rubber is important to mimic the roughness of the stingray's surface. It also ensures a smooth wave formation for efficient propulsion. It also makes an excellent electrical insulant to help prevent electrical leakage.

E. Skotch Yoke Mechanism

The Scotch yoke mechanism consists of four main components: a circular disk or crank, a connecting rod, a slider or yoke, and a guide. The circular disk or crank is connected to the source of rotary motion, usually a motor, and rotates in a circular path. The connecting rod is connected to the crankshaft and the slider or yoke, and converts the rotary motion of the crankshaft into linear motion of the slider or yoke. The guide provides support and guidance for the slider or yoke as it moves back and forth.

As the crankshaft rotates, the connecting rod moves the slider or yoke back and forth along a straight line, with the speed and direction of motion determined by the rotation speed and direction of the crankshaft. The linear motion of the slider or yoke can be used to drive other mechanical components, such as a piston, to generate work.

The Scotch yoke mechanism is commonly used in applications that require precise linear motion, such as in engines, pumps, and compressors. It is also used in some types of reciprocating saws and shapers. The main advantage of the Scotch yoke mechanism is its simplicity and reliability, as it has fewer moving parts than other types of mechanisms. It consists of just a few components, such as the crank, connecting rod, slider, and guide, which results in a simpler and more compact design. This simplicity contributes to the reliability of the mechanism, as there are fewer parts that can fail or require maintenance.

F. Electronics

- *ESP32 development board*

This microcontroller is used as a supervisory control module for sending the motor control commands, connecting with the control interface (explained in the next section), and communicating with the BMS of the battery to ensure proper functioning and overall safety of the system.

- *L298N Motor Driver*

The L289N is a dual H-bridge motor driver that can provide speed and direction control for two motors simultaneously. The module can drive DC motors that have voltages between 5 and 35V, with a peak current up to 2A.

- *5V relay module*
  The relay module is used as a switch to open or close the electrical circuit.

- *12V 3600 mAh Li-ion rechargeable Battery*
  The rechargeable battery pack contains 6 Li-ion cells in a 3s2p configuration with a nominal voltage of 12.6V and an energy capacity of 3600 mAh. It also contains a built-in BMS (battery management system) to protect the battery from excessive current and short circuit.

- *12V DC motors*
  There are a total of three DC motors, two of which are used for balancing the bot, and one for the propulsion. Two of these are 1000-rpm motors that are used for balancing, while the propulsion motor is rated at 500 rpm. All three come with an attached gearbox that can be used for adjusting the torque and speed requirements.

The image below contains the electrical circuit as connected within the bot:

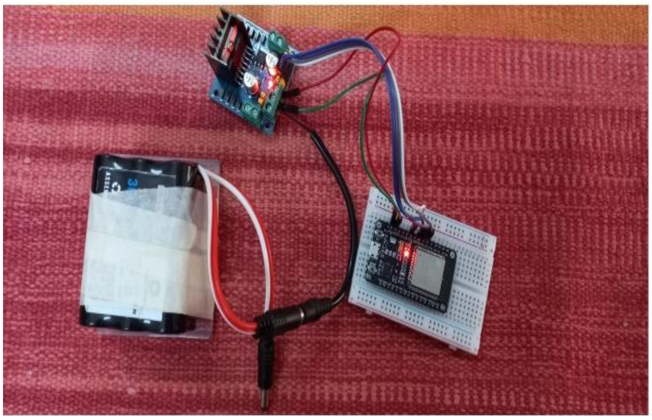

Fig 2 Electrical Circuit

G. Bluetooth Powered Control Interface

The motors that are used for the propulsion and balancing are controlled using the motor driver. The commands for this motor driver are sent using a Bluetooth module from a control interface that is designed using HTML-CSS code. The locomotion and balancing commands to control the motor are included in a C++ program using Arduino libraries.

The control interface has a button for connecting the motor driver via Bluetooth. It also contains buttons to switch the system on and off, and one button each for the forward, reverse, left, right, and stop commands. The image below shows a screenshot of this interface:

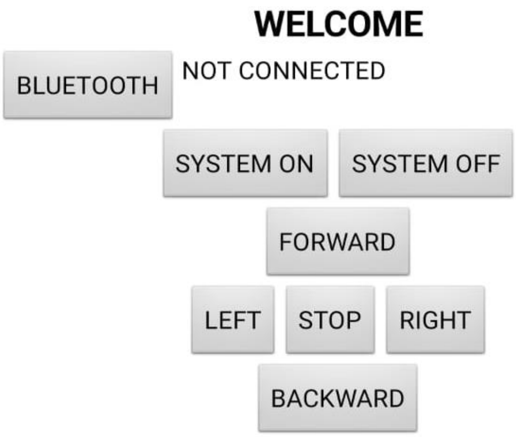

Fig 3 Screenshot of this Interface

IV. CONCLUSION

A hydrodynamic, silent and deep-diving capable underwater vehicle inspired from the stingray fish was successfully designed, modelled using computer-aided designing software and mathematically modelled to verify and analyses the final product.

ACKNOWLEDGEMENT

It gives an immense pleasure to submit the Seminar report entitled “Underwater Stingray Mechanism Bot”. We have tried our levels best to perform and present this topic to the point framework. We take this opportunity to express a word of gratitude towards all of them who have guided and helped us in completing this project work We thank Prof. A.D. Zope our project guide who has always encouraged us and given freedom to bring out maximum and best possible results from us. we also thank our Head of the Department, Prof. Dr. M. M .Bhoomkar for extending helping hand towards us. We would also like to thank all those who have directly or indirectly helped us in completion of this project. Lastly, we would like to say that this project is our sincere effort to present our skills, ability and talent to the world.

REFERENCES

[1]. Y. hua Zhang, L. bing Jia, S. wu Zhang, J. Yang, And K. H. Low, “Computational Research on Modular Undulating Fin for Biorobotic Underwater Propulsor,” J. Bionic Eng., vol. 4, no. 1, pp. 25–32, 2007, doi: 10.1016/S1672-6529(07)60009-2.

[2]. J. He and Y. Zhang, “Development and Motion Testing of a Robotic Ray,” J. Robot., vol. 2015,2015,doi: 10.1155/2015/791865