International Journal of Scientific Research and Management (IJSRM)
||Volume||11||Issue||04||Pages||EC-2023-963-972||2023||
Website: www.ijsrm.in ISSN (e): 2321-3418
DOI: 10.18535/ijsrm/v11i04.ec1

Structural design and mechanics research of a bionic pelican floating object fishing device

Jie Yuan, *Hong Zhang, Ling-xia Hou, Li-hua Li, Meng-yao Liu, Xin Liu, Hong-ye Yan, Yu-bo Jiang

School of Mechanical Engineering, Yangtze University, Jingzhou, Hubei Province, 434023, China

Abstract

In order to meet the needs of surface floating objects fishing operations in small areas such as lakes and rivers, a fishing device is developed that can be used for high-intensity operations and is highly adaptable to the environment. In this paper, a water and land type bionic pelican surface floating object fishing device is developed based on the MeArm robotic arm combined with a three-degree-of-freedom linkage robotic arm using bionic principles. In order to meet the needs of the fishing function, the overall structure of the surface floating object fishing device was bionically designed by combining the large beak and flexible neck of the pelican, The innovative design of the mouth lower beak opening and closing mechanism, the lower beak gear rack lever slide mechanism, the mouth throat pouch bottom release mechanism and the neck structure are mainly carried out.The structural strength of the device under the most dangerous operating conditions was simulated using finite element analysis software for statics and dynamics simulation. The research results show that the structure of this design is reliable, and the experimental test of the prototype model verifies the validity and reliability of this design scheme, which provides the theoretical and experimental basis for the further development of the subsequent products.

Keywords: bionic pelican; floating object; fishing device; structural design; statics; dynamics

1.Introduction

Structural bionic design is the innovative design of products by summarizing the operation of the internal and external structures of living creatures in nature and imitating their functional mechanisms or modeling features[1]. The bionic pelican surface floating object fishing device mimics the pelican's appearance and feeding pattern in order to achieve the efficient and precise characteristics of pelican hunting. Domestic related industries and enterprises have been more mature in the research of linkage robot arm and hull structure.[2-4]This product is designed based on the bionics principle and combined with the characteristics of the pelican's mouth, neck and abdomen. The neck mainly adopts three-degree-of-freedom four-rod robotic arm structure, which has the advantages of large working space, flexible movement and strong bearing capacity and high precision, and the collection part adopts Catamaran structure. The research of the bionic pelican surface floating material fishing device is mainly for small waters and land surface litter cleaning and fishing operations. Traditional conventional manual fishing[5] and fishing vessels fishing[6] are difficult to operate efficiently in this environment. To this end, the paper developed a bionic pelican floating object fishing device can get rid of the traditional manual fishing safety hazards and work intensity and fishing boat fishing difficult to apply to small areas of disadvantages.

The design of the device to provide fishing power is one of the key technical issues in the research of the bionic pelican floating object fishing device. Some domestic and foreign institutions have also conducted research on such fishing power units[7-9].The structure is based on the MeArm robot arm, and the bionic principle is combined with the characteristics of the pelican's neck, and the already mature three-degree-of-freedom robot arm is used to imitate the pelican's neck, and based on the-three-degrees of freedom linkage manipulator, the length of key links is changed and innovative design is carried out. With the gradual use of modern design methods such as finite element simulation analysis and simulation design, the theory of optimal design of robots[10-12] has become more and more perfect. This paper uses Solidworks simulation to simulate the structural strength under its most hazardous operating conditions, including statics and dynamics simulation. The reliability of its strength is verified. The experimental results prove that the device is easy to operate, flexible in control, efficient in fishing, and has broad application prospects.

2 Structural design and working principle analysis

2.1 Structural design and composition

The core elements of the structural design of the Bionic Pelican floating object fishing device: By imitating the structural characteristics of the pelican in order to achieve flexible control of the device, the mechanism is dexterous and can complete the functions of fishing, storage and transportation. The overall device structure is shown in Figure 1, which consists of three parts: head, neck and hull. The head is used to complete the fishing work, the neck is used to drive the head to the appropriate position, and the hull is used to achieve the transport function.

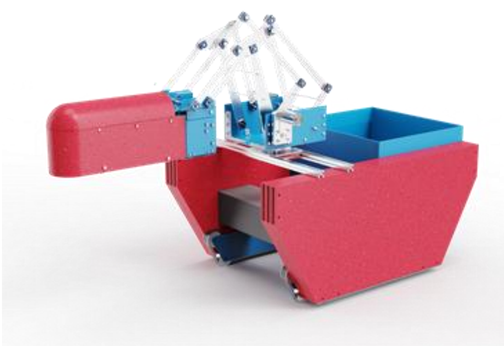
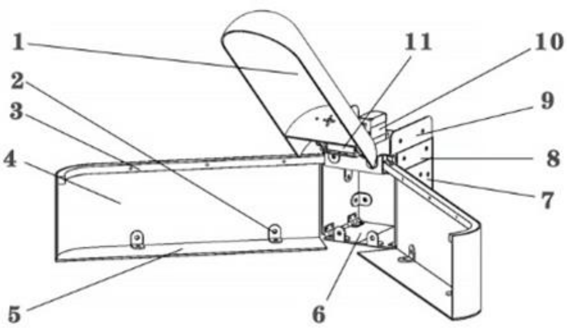


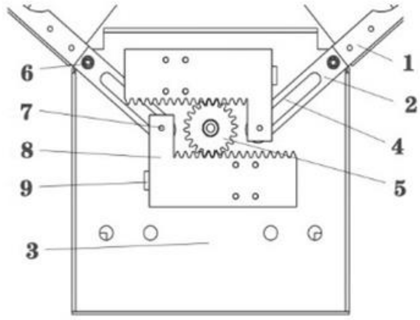
Figure 1: Overall structure of the device

The core structure of the bionic pelican floating object fishing device consists of the head and neck, which should meet the appropriate structural strength. The head consists of the mouth and the collection area, and the head is the rubbish collection device. The lower edge of the mouth adopts the opening and closing design as shown in Figure 2, which is composed of the upper jaw, the lower jaw and Servo. Servo is used as the power source for opening and closing the upper and lower jaws of the mouth. The upper beak is driven directly, and the lower beak is controlled by the gear rack lever chute mechanism, as shown in Figure 3. The design of the bottom structure of Laryngeal sac of mouth is shown in Figure 4 to complete the garbage dumping.



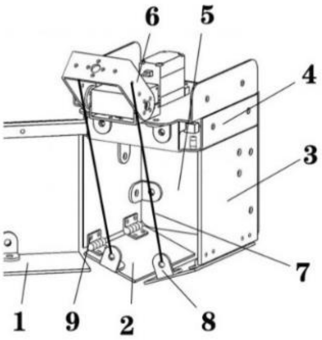
1- Upper beak; 2- Connecting angle code; 3- Lower beak skeleton; 4- Lower beak edge plate; 5- Bottom plate of lower beak; 6- Bottom lamina of laryngeal sac; 7- Throat capsule side plate; 8- Lower beak fixing plate; 9- Servo fixing plate; 10- Lower Beak Servo; 11- Upper beak servo

Figure 2: Design of the lower beak opening and closing of the mouth



1- Lower beak skeleton reinforcement plate； 2- Lower beak skeleton； 3- Lower beak fixing plate； 4- Slot； 5- Gear； 6- Rotating shaft； 7- Cylindrical pin； 8- rack； 9- Guide rail slider；

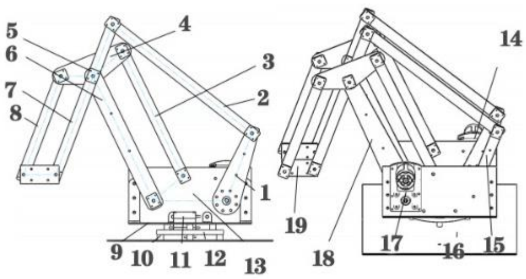
Figure 3: Lower beak gear rack lever chute mechanism



1- Lower beak base plate； 2- Bottom lamina of laryngeal sac； 3- Throat capsule side plate； 4- Lower beak fixing plate； 5- Posterior commissure of laryngeal sac； 6- Upper beak servo rotation frame； 7- Traction rope of laryngeal sac base plate； 8- Laryngeal sac base plate lock； 9- Looseleaf；

Figure 4: Bottom drop design of the mouthpiece capsule

The neck is the core component to complete the fishing operation as shown in Figure 5, need to meet the control of flexible, accurate positioning, by Servo, Cloud Terrace carrying a three-degree of freedom linkage robot arm, Servo Cloud Terracecan achieve 360 degrees rotation of the neck.

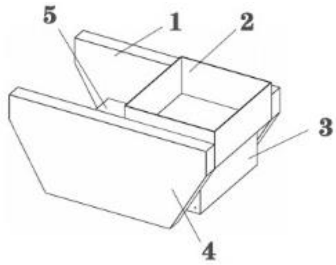


1- Active Master Rod 3； 2- Main Rod 2 Linkage； 3- Triangulated parts connecting rod； 4- Triangles； 5- Bearing Housing； 6- Slave master 1； 7- Main Rod 2； 8- Mouth linkage； 9- Head Servo Cloud Terracecan fixing plate； 10- Turntable bearing support column； 11- Head Servo Cloud Terracecan； 12- Turntable bearings； 13- Neck servo fixing plate； 14- Active Main Rod 3 Control Servo； 15- Slave master 3； 16- Neck fixation plate； 17- Active main lever 1 controls the servo； 18- Active Main Rod 1； 19- Neck-mouth connection plate；

Figure 5: Neck structure design

The neck and beak structure of the bionic pelican floating object fishing device is the core part of the control system to achieve precise attitude control and high-precision positioning function. The control program is written in C language and the Arduino is used as a carrier to control the servo and brushless motor to accomplish the intended movements of the mouth, neck and chassis of the bionic pelican floating object salvaging device. The motion parameters are calculated with the aid of MATLAB, and the motion parameters of the three-degree-of-freedom robotic arm of the neck are mainly calculated.

The hull is the support component of the bionic pelican floating object fishing device to complete the fishing and dumping process as shown in Figure 6, which should have a strong load-bearing capacity and consists of tracks, track motors, double hull structure and underwater thrusters. Tracks are available for the unit to travel on land and use underwater thrusters to provide power for surface navigation. The dual hulls work more reliably and operate stably, while the fishing unit is easier to install.



1- Monohull (right); 2- Storage baskets; 3- Rear floating block; 4- Monohull (left); 5- Front floating block;

Figure 6: Hull structure composition

2.2 Working Principle

The bionic pelican floating object fishing device is designed to bionic the structural characteristics of the pelican to achieve the device's functions of salvaging water objects, storage and transportation. When the device is operating on the water, the power is transmitted from the engine power output shaft, and the power is absorbed by the underwater thruster to generate thrust and push the device forward. When it reaches the garbage fishing position, it stops moving forward. The salvaging device consists of a servo head carrying a three-degree-of-freedom linkage mechanical arm and a mouth part. The three-degree-of-freedom linkage mechanical arm is mainly used to imitate the movement of the pelican neck and change the position of the mouth part, and the mouth part is a garbage collection device. The servo controls the robot arm and the mouth together to move above the sump floating storage area, and controls the opening and closing of the mouth to realize the garbage picking work. After picking up the garbage, the servo controls the three-degree-of-freedom robot arm movement of the neck of the device to realize the lifting of the neck of the device. The neck and mouth are rotated together by the head to the top of the garbage storage basket, the mouth opens and the garbage falls into the basket, completing the garbage retrieval, dumping and storage functions. The fishing state is shown in Figure 7, and the dumping state is shown in Figure 8. The device uses Arduino as the control system language, which can not only complete the automatic control, but also realize the manual operation, and realize the coordination of mechatronics through computer programming. Modifying the programming data and language can change the overall motion trajectory of the bionic pelican floating object salvaging device. The use of microcontroller microcomputer system to control the device to complete a series of fishing functions.

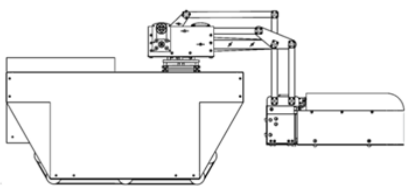


Figure 7: Bionic pelican fishing status

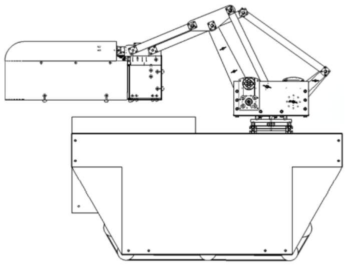


Figure 8: Bionic pelican tipping state

2.3 Functional Analysis
The Bionic Pelican floating object fishing device meets the fishing function of traditional fishing methods while having:
1、Autonomous completion of the fishing work function: under the control of the program and machinery to achieve autonomous fishing, by controlling the neck of the parallel four-bar mechanism, so that the neck of the device can drive the mouth to complete up and down, left and right movement and complete rotation and other actions. When the neck drives the mouth part to run above the sump floating storage area, the upper beak of the mouth part is lifted upward by the tiller control device, and rack and pinion lever slide mechanism is controlled to open and close the lower beak to fishing the garbage.2、Transportation and storage functions: The catamaran type structure is used to ensure the balance and stability of the device, while the garbage storage basket is set in the middle, which can hold the garbage fishingd after it is salvaged, and the device is installed with underwater thrusters and tracks to realize the water transportation and land transportation functions of the device.3、Intelligent function: Using remote control, artificial intelligence, machine vision and Internet of Things to improve the efficiency of water surface garbage cleaning devices, reduce labor costs, and thus improve the safety of water surface garbage cleaning.

3 Statics simulation analysis
3.1 Core power neck model simplification and mechanical analysis
The statics simulation mainly determines the deformation and stress distribution of the bionic pelican floating object fishing device under the action of external forces. The mechanism that cooperates with the completion of the core fishing operation is the neck structure, and this paper is directed at the analysis of this structure. Due to the large number of parts and complex shapes, the structure needs to be simplified to avoid generating a large number of cells and nodes, which is not conducive to the computational efficiency of the finite element analysis and avoid affecting the accuracy of the computational results. Necessary simplification of the model, ignoring some of the screw holes, pin holes, external wires of the neck and other features and components that do not have a significant impact on the calculation and analysis, and the integration of the rigid connection of the same material in the structure. [13]According to the structural characteristics of the neck of the bionic pelican floating object retrieval device and the actual working situation, we simplified some parts of its composition structure. The 3D model of SolidWorks software is imported into Simulation plug-in, and cell type selection and meshing are performed.

Bionic pelican floating object fishing device to complete the main fishing operation is the mouth end actuator initially pick up the fishing target, the work process by adjusting the movement of the neck linkage joint to control the position of the mouth, in the fishing process, the neck base is fixed to the head servo, can control the overall rotation of the neck, the body structure is stationary, only the end actuator mouth is subject to vertical downward uniform load. A comprehensive analysis of the posture and position of the bionic pelican floating object retrieval device at work shows that it is in the most dangerous condition when the beak is just about to be lifted, as shown in Figure 5.At this time, the moment generated by the gravity and load of the bionic pelican floating object fishing device is the largest.Under this condition the displacement of the end-effector component, i.e., the mouth, directly determines the repetitive positioning accuracy of the bionic pelican surface floating object retrieval device, so this attitude was chosen for the analysis.
3.2 Material selection and meshing
The Bionic Pelican floating object fishing device mainly uses materials such as cast aluminum and malleable cast iron. The base and each connecting rod are made of malleable cast iron. In order to reduce the specification

of the neck rudder, the mouth should be designed to reduce the weight as much as possible and choose the lighter cast aluminum material. The characteristic parameters are shown in Table 1, and the material properties are assigned to the corresponding parts in Solidworks Simulation finite element analysis software.

Table 1: Material Properties

Materials	Density/(kg·mm^{-1})	ElasticModulus /MPa	Poisson ratio
Cast aluminum	2.83 x10^{-6}	7.1 x10^{4}	0.33
Malleable Iron	7.03 x10^{-6}	1.9 x10^{5}	0.29

The grid division uses the default software division mode, that is, the choice of ten-node tetrahedral solid 187 cells, the cell type can be a good simulation of the irregular model, the grid division, the grid cell quality is good, to a certain extent to ensure the reliability of the analysis. The grid division results are shown in Figure 9.

Figure 9: Meshing model

3.3 Boundary conditions and loads

The neck of the bionic pelican floating object fishing device is fixed to the base head servo, and the structure is set with the connection plate and base as a fixed constraint to adjust the neck linkage of the bionic pelican floating object fishing device to the fishing attitude when the beak is just about to be lifted. The loads on the neck of the bionic pelican floating object fishing device are mainly self-gravity and the applied load on the beak. Applying a gravitational acceleration of 1g to the device as a whole is equivalent to assigning gravitational properties to the components of the Bionic Pelican floating object fishing device. The calculation will be equivalent to the gravity of the device itself. A 50N vertical downward uniform load is applied at the end bar to simulate the extreme working conditions of the bionic pelican in operation.

3.4 Solution and Analysis

As shown in Figure 10, the combined displacement cloud of the neck of the bionic pelican floating object fishing device can be seen that its maximum displacement occurs at the topmost linkage bolt connection mechanism. The size was 2.641 mm, much smaller than the estimated value of 3 mm for the bionic pelican floating object retrieval device. At the same time, the equivalent force cloud of the surface floating object fishing device of the bionic pelican is shown in Figure 11, and its maximum stress occurs at the bolt connection of the base plate. The stress magnitude is 220.6 MPa, which is much less than the yield limit of 300 MPa of malleable cast iron, then it indicates that it meets the stiffness strength requirement during the working process. As can be seen in Figure 12 of the equivariance cloud, no red area is found, indicating that the maximum equivariance exists at the distortion point and should be ignored. The analysis shows that all meet the requirements of the device and no damage will occur.

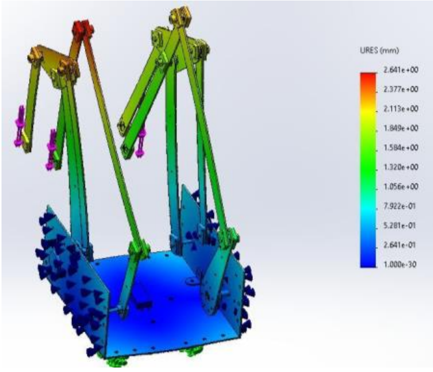


Figure 10: Combined displacement cloud map

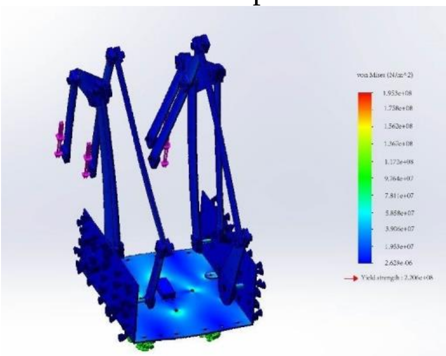


Figure 11: Equivalent effect force cloud

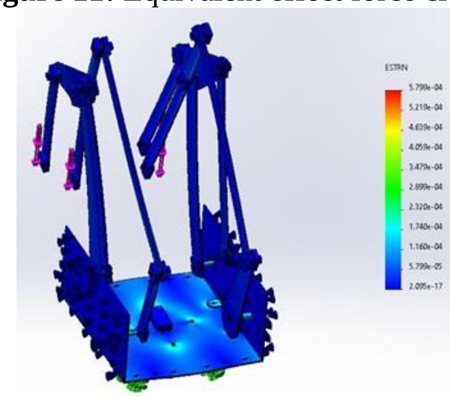
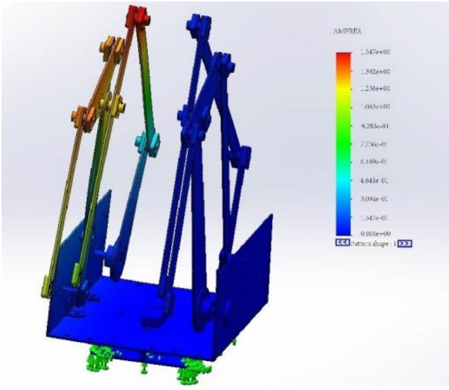


Figure 12: Equivalent effect variation cloud diagram

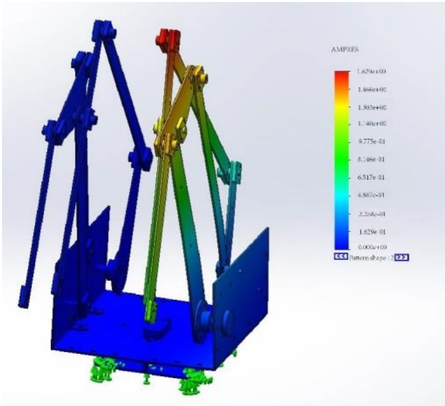
4 Dynamics simulation analysis

According to the finite element static analysis of the bionic pelican floating object fishing device, it is known that the design strength requirements are satisfied. For a more comprehensive study and analysis of the bionic pelican floating object fishing device, an analysis of its modalities is required. The modal analysis can determine the inherent frequency, vibration pattern and relative deformation of the structure of the bionic pelican floating object fishing device, and the inherent frequency is an important index to evaluate the dynamic characteristics of the mechanism. Solidworks simulation was used for dynamics simulation analysis, but only the lower order modes play a major role in the dynamic characteristics of the bionic pelican floating object fishing device, so the first eight order modes were selected for simulation analysis.

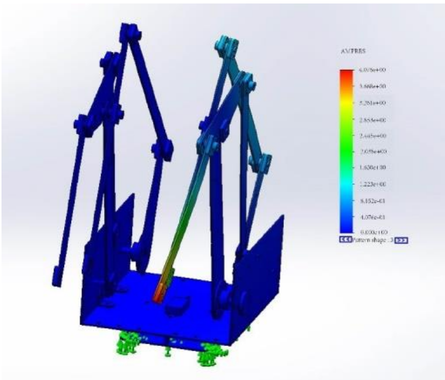
Solidworks simulation calculates the first eight orders of mode corresponding to the intrinsic frequency and vibration description as shown in Table 2, limited to the space to list only the first four orders, as shown in Figure 13.



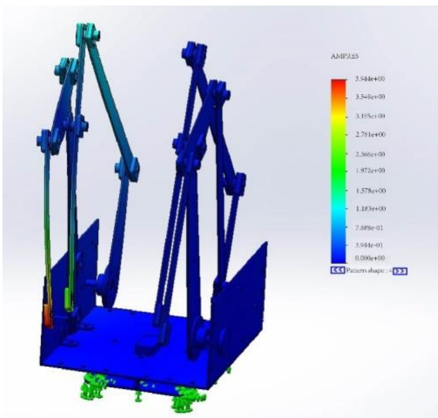
(a) First order



(b) Second order



(c) Third order



(d) Fourth order

Figure 13: First fourth order modal vibration pattern

Table 2: Description of the first four orders of intrinsic frequencies and vibration patterns

Modal order	Inherent frequency/Hz	Description of vibration type
1	10.112	Left arm swing
2	10.309	Right arm swing
3	18.95	Right arm deformation
4	19.171	Left arm deformation

As shown in Table 2, the first-order mode has the lowest frequency as the structural fundamental frequency, and the modal frequency increases gradually with the increase of the modal order, and the low-order intrinsic frequency reaches a high level, which shows that the main body neck of the bionic pelican floating object fishing device has good rigidity to complete the fishing operation, and the structure of the bionic pelican floating object fishing device can be preliminarily determined to be reasonably designed, and no resonance damage will occur.

5 Experimental analysis

According to the design drawings of the bionic pelican floating object fishing device, we fabricated and assembled the bionic pelican floating object fishing device as shown in the figure according to the model for commissioning. After the working test of the prototype model, it is practically known from the experimental results that the device has good design strength and stiffness, and the inherent frequency also meets the design requirements. Overall, the operation has good fishing accuracy and response speed.

Figure 14: Physical model drawing

6 Conclusion

The article focuses on the design and research of the structure of the bionic pelican floating object fishing device. The overall structure design of the bionic pelican floating object fishing device is carried out, and its structure, function and principle are analyzed, and the 3D geometric model of the robot is established and the virtual prototype is assembled using the 3D design software Solidworks. Using finite element statics simulation of the bionic pelican floating object fishing device in extreme operating conditions to ensure good strength and stiffness of normal operation. The dynamics simulation shows that its fundamental frequency is good, its rigidity is good, and the structural structure. The content and process discussed in the article provide an important guideline for the practical application of the bionic pelican floating object fishing device, which can meet the small-area area garbage cleaning and fishing operations with strong environmental adaptability. The device is flexible in control, efficient in fishing, and low in cost and easy in operation. It has greater practical engineering significance.

Ethics approval and consent to participate

Not applicable.

Data Availability

The authors confirm that the data supporting the findings of this study are available within the article [and/or its supplementary materials].

Conflicts of Interest
The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.

Funding Statement
Fund project: "A bionic pelican floating object fishing device", The 15th Innovation and Entrepreneurship Training Program for Students of Yangtze University.

Item Number: Yz2022127.

Authors' contributions
Everyone was involved in the structural design.J,Yuan mainly did the design and analysis of the structure, static and dynamic simulation analysis, performed the analysis, research and writing of the entire article content, and was the main contributor in writing the manuscript.H,Zhang supervised the whole research work and thesis writing.L.X,Hou guided the related structural design.L.H,Li was involved in the hydrostatic analysis.M.Y,Liu and X,Liu were involved in the modelling.Y.B,Jiang and H.Y,Yan were involved in the processing of the images.All authors read and approved the final manuscript.

References

1. H.M,Jin. 2014,Study on bionic design of product modelling. Machine Design,31(01):123-125.
2. L.Q,Liu.,Y.J,Li.,&C.G,Bu.2022,Modeling and simulation of Five degree-of-freedom Robotic Arms. Science Technology and Engineering,22(29):12841-12847.
3. J,Deng.C.Li.,&Y,Bai.2018,Modular Combined Design Method of Mechanical Arm of serial Industrial Robot. Science Technology and Engineering,18(22):66-71.
4. K,Wang.,&Y.F,Guan.2008,Study on the Finite Element Analysis of 42m Inland River Minitype Dry Cargo Ship Structure. Science Technology and Engineering,(07):1917-1920.
5. Z.F,Fang.,H,Xu.,T,Tan.,K.D,He.,Z.W,Ma.,&X.G,Xie.2017,Design and Research of Bionic Fishing Hood and Unpowered Capture Device. Mechanical Design and Research,33(01):54-57+62.
6. X.X,Li.2018,The Dynamic Modeling and Simulation of the Garbage Collection Mechanism for River Cleaning Robot. Machine Design and Manufacture,(01):239-241.
7. Z.F,Fang.,B.F,Xiang.,H.P,Xiao.,K.D,He.,&J.F,Liu.2013,Dynamic and Control Strategy of Launch and Recovery Device in Harsh Sea Conditions. Journal of Mechanical Engineering,49(15):88-95.
8. Y.Z,Chang.,Y,Zhang.,F.Y,Zheng.,Z.Q,Zheng.,&J.L,Wang.2020,Research Progress of Underwater Vehicle-manipulator Systems: Configuration, Modeling and Control. Journal of Mechanical Engineering,56(19):53-69.
9. L.Q,Wang.,P,Li.,J.H,Han.,&Q.X,Meng.2004 Analysis of Kinematics of 3-Finger Underwater Manipulator. China Mechanical Engineering,(07):7-9.
10. P.E,Feng.,Q.Y,Qiu.,S.X.Pan.,Z.Y,Qian.,&J.W,Wu.2000,Theoretical Framework of the Generalized Optimization for Mechanical Product . China Mechanical Engineering,(Z1):135-138+185+6.
11. H,Song.,X,H.Xue.,&Z.Q,Yu.2016Statics and Dynamics Analysis and Topology Optimization for A Six- DOF Welding Robot SR3-600. Mechanical Design and Research,32(04):50-53.
12. Z.L,Lou.,S.L,Zhang.,&G.Y,Wang.2018, Study and Application of the Method Multi-Objective Optimization With Robust Design. Mechanical Design and Research,34(05):17-19+25.
13. X.W,Li.,F.G,Wang.,&P,Zhang.2014, FEA analysis and optimization of the palletizing robot. Machine Design,31(07):29-32.DOI:10.13841/j.cnki.jxsj.2014.07.007.