

Ecological Floating Island Multi-specification and Multi-sample Delivery Drone

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Abstract: The exacerbation of water pollution due to industrial progress has highlighted issues of inadequate capacity, limited environmental adaptability, and subpar operational efficiency in monitoring and transportation within the intricate environment of ecological floating islands. To address these challenges, a design method for a multifunctional unmanned aerial vehicle system is proposed, emphasizing modularity and self-adaptation. The system features a six-rotor layout, a combination of a lightweight fuselage and a low power consumption power system to achieve high speed and extended endurance. It enables dynamic and precise grabbing and releasing of various sample boxes through a self-locking plug-in mechanism integrated with sensing and response capabilities at the base. Furthermore, stability in adverse weather conditions, such as strong winds, is enhanced through aerodynamic optimization and a multi-sensor fusion algorithm. Practical application demonstrates the system's effectiveness in meeting the requirements of normalized monitoring and swift sample transfer on ecological floating islands. It offers efficient technical solutions for ecological restoration and scientific research, showcasing broad environmental adaptability and potential for widespread adoption.

Keywords: Environmental Pollution; Unmanned Aerial Vehicle; Self-locking Plug-in Mechanism; Adaptability.

1. Introduction

With the increasing demand for ecological environment management, ecological floating islands are more and more widely used in water purification and ecological restoration. Ecological floating islands are distributed in the water area, so manual inspection and material transportation are inconvenient. In the process of daily maintenance and monitoring of ecological floating islands, samples of different specifications need to be transported. It may also be necessary to transport small equipment, tools and materials for the repair of floating islands and plant replanting. At the same time, traditional water transport vehicles, such as ships, are limited in some complex water environments (such as narrow channels and areas full of aquatic plants), and are slow and inflexible. The development of unmanned aerial vehicle technology makes it possible to use unmanned aerial vehicles to realize efficient transportation and flexible distribution of ecological floating islands. It can overcome the limitations of geographical conditions of water areas and quickly transport various specifications of goods to designated ecological floating islands.

In recent years, domestic and foreign research on the above problems has been carried out around two aspects of application and technology: Kang et al. proposed a control framework for transporting UAV suspended payload, and extended to UAV trajectory tracking with dynamic feedback controller [1]. Nigro M et al. proposed that because the thrust generated by the propeller is oriented along parallel axes, orthogonal to the plane of the propeller [2]. Soni S et al. proposed an algorithm that achieves the highest data rates in terms of payload delivery time, payload weight, velocity, and maximum range covered by various drones [3]. Wu K et al.

proposed that operating UAVs at variable speed can save about 21% of energy compared with constant speed operation UAVs, which has advantages in cost saving and range extension [4]. Aggarwal S et al. suggest that drone based medical delivery is time-saving, but overcoming operational challenges can provide effective long-term deployment strategies. The technical and logistical challenges associated with drones were identified as deployment of suitable drones, payload capability, operational time management, and drone transportation.[5] Jung H et al. proposed that under strong wind conditions, the proposed method based on robust optimization achieves better performance than deterministic models. Stronger winds correspond to better ones for the proposed model [6]. Liu B et al. proposed new applications of unmanned aerial vehicles (UAV) in joint cargo delivery and in situ sensing, and proposed a new algorithm for joint optimization of route and sensing mission selection to minimize UAV energy consumption, maximize its sensing reward, and ensure timely delivery [7]. Ceviz O proposed introducing a privacy-aware, decentralized intrusion detection method tailored to drone networks, making a significant contribution to drone security. Furthermore, by introducing FANET and federated learning on real datasets, our approach differs from other approaches lacking highly dynamic and 3D node movement or accurate federated data [8]. Jupriyanto proposed how drone systems can be used to generate high-resolution images that can be used to predict crops [9].

In view of the above problems, this paper adopts the concept of functional module design, designs a multifunctional UAV system with modularization and self-adaptation as the core, alleviates the limitations of traditional UAV in load capacity, environmental adaptability and

operation efficiency through structure optimization and intelligent control technology, and provides a basic technical scheme for subsequent upgrading. Principle scheme design.

The UAV is mainly used for the transportation of ecological floating island samples. It is mainly divided into three functional modules: flight function module, load function module, navigation and control function module. Among them, the flight function module uses motor to drive propeller to generate lift force, obtains position information based on GPS positioning system, and real-time senses flight state parameters such as attitude and speed through multi-type sensors to realize accurate flight control and dynamic adjustment; The load function relies on the adjustable lifting platform to complete multi-category sample loading, combined with the self-locking grasping mechanism at the bottom of the drone to achieve stable clamping, with the

buffer shock absorption device to ensure the safety of the sample, the integrated weighing system can verify the load weight in real time to ensure that it meets the load specifications of the drone and then start the transportation process; Navigation and control function based on GPS positioning planning optimal route[8], support operators through real-time aerial images, remote command control of unmanned aerial vehicles, ensure flexible and efficient implementation of transportation tasks. The functional breakdown of the UAV is shown in Fig. 1. Its main technical parameters: maximum flight speed $\geq 20\text{m/s}$, cruise speed $10\sim 15\text{m/s}$; endurance time ≥ 60 minutes; maximum flight altitude $\geq 100\text{m}$; wind resistance ≥ 6 ; payload $\geq 10\text{kg}$; working environment temperature $-20^{\circ}\text{C}\sim 50^{\circ}\text{C}$, humidity $0\sim 95\%\text{RH}$ (no condensation), adapt to different water ecological floating island environment.

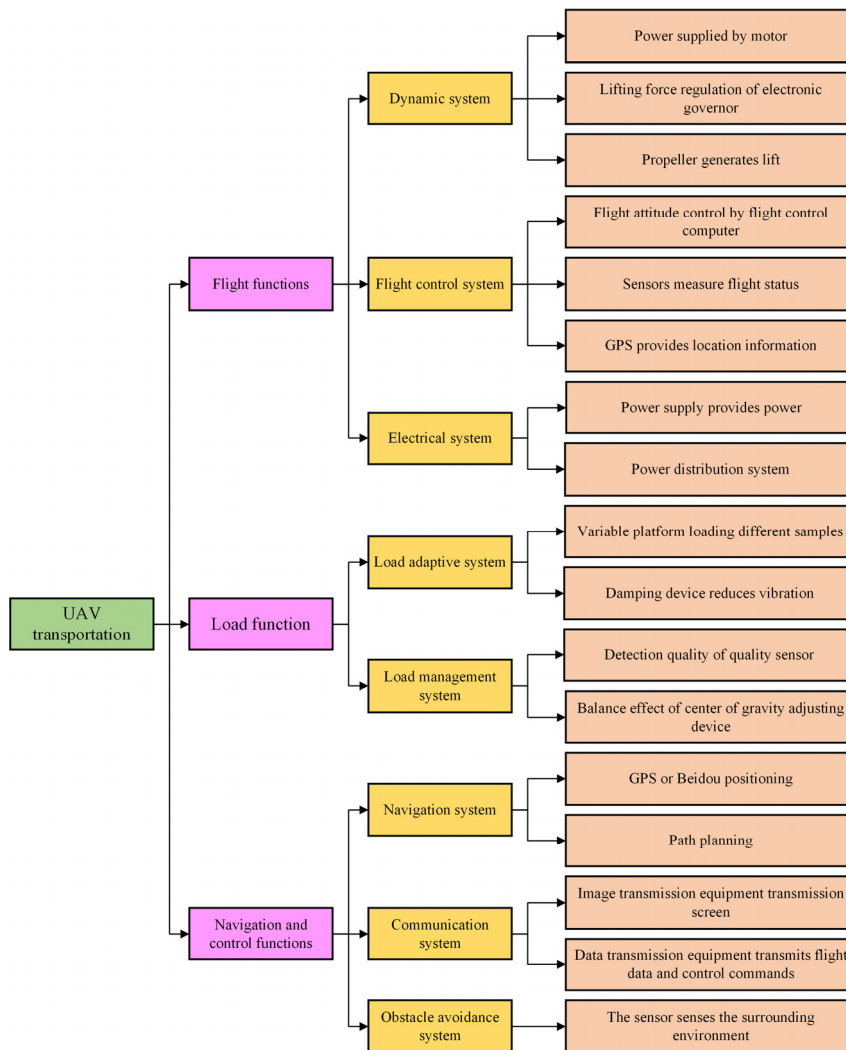


Fig 1. Functional decomposition of ecological floating island multi-specification multi-sample delivery UAV

2. Process Design

The prior art method comprises semi-automation and full-automation operation modes, wherein the semi-automation is combined with sensors such as a vision system and the like to assist the operation of a mechanical arm; although the accuracy and the efficiency are improved and the dependence on personnel is reduced, the system is complex, the cost is high, and the recognition accuracy and the reliability under special environments are limited; and the full-automation completely depends on preset programs and sensor feedback,

and the efficiency, the accuracy and the repeatability are good, but the early development cost is high, the adaptability to the environment and the target is poor, and errors are easy to occur when the preset conditions are not met. In terms of technical difficulties, the load capacity and mechanical structure strength require the robot arm to have sufficient load capacity and structural strength while being lightweight, and the material selection and structural design are difficult; in terms of accuracy and synergy, the motion accuracy and flexibility require high-precision motor drive, transmission mechanism design and advanced control algorithm, and the

synergy with UAV requires solving the cooperative control problem of self-locking plug-in mechanism and positioning and flight system. Therefore, a new design is put forward, that is, a simple device is installed at the bottom of the fuselage to realize the clamping function, and a matching box mechanism is designed. Self-locking plug-in mechanism diagram: as shown in Fig. 2, can achieve the extraction of the box.

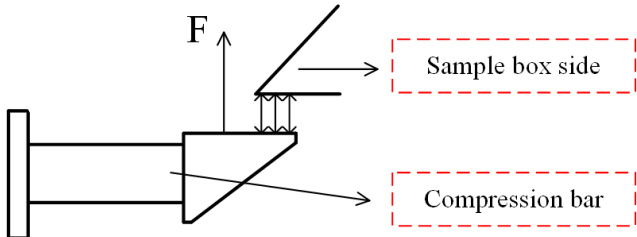


Fig 2. Schematic diagram of clamping box of self-locking plug-in mechanism

Case clamping method The case clamping mechanism is shown in Fig. 3. After the conical block structure at the lower part of the case is pressed into the clamping device by the weight of the UAV, the device is clamped by the contact extrusion between the lower surface of the clamping device and the upper surface of the conical body at the bottom of the case, so as to realize the fixation of the conical block support at the lower end of the case.

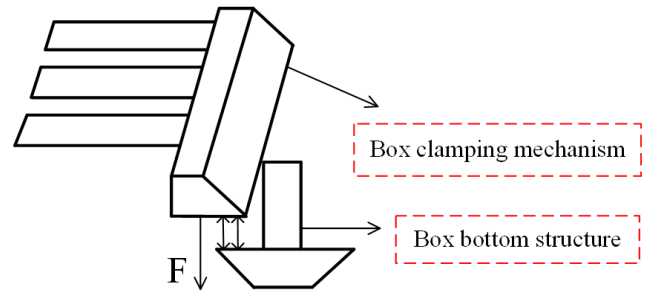


Fig 3. Box clamping mechanism

3. Mechanical System Motion Scheme Design

There are 15 synchronization points in the movement cycle Fig. 4 determined according to the waste treatment process flow. The synchronization point involves the work switching between the height vision sensor and the horizontal vision sensor, the flight height adjustment of the UAV, the action of the self-locking plug-in mechanism, etc. If the UAV flies to the horizontal flight altitude, the height vision sensor stops, the horizontal vision sensor starts; when it descends to a certain height, the self-locking plug-in mechanism is compressed, etc., and each synchronization point ensures the synchronization of the overall movement.

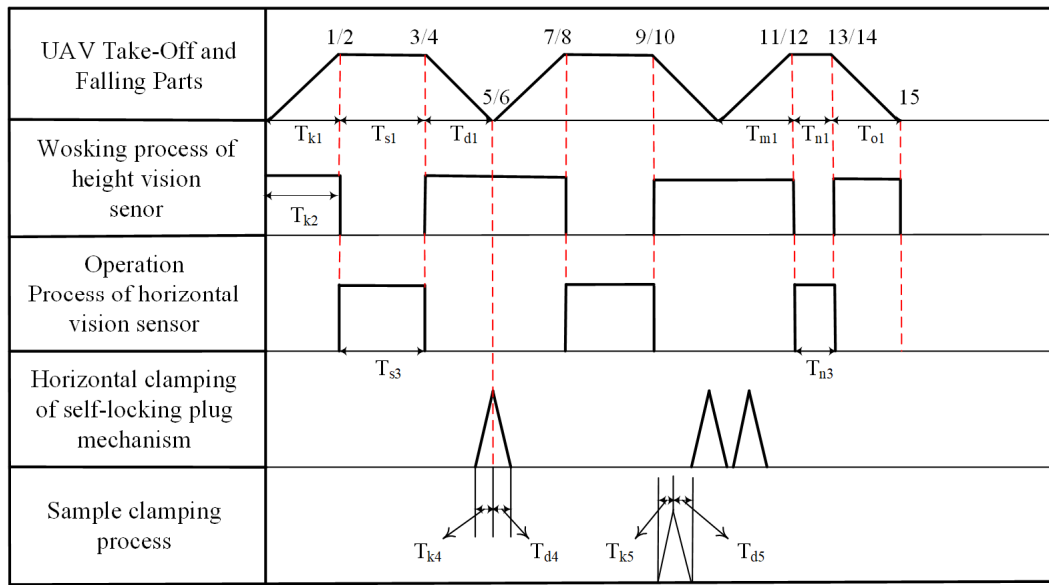


Fig 4. Ecological floating island transportation UAV transportation cycle diagram

The minimum time to complete the entire work cycle is calculated to meet the requirements of mission book endurance ≥ 60 minutes and single delivery time < 50 minutes, assuming a single complete delivery time of 50 minutes. The proportion of flight time in the air phase is the largest. Considering the parameters such as maximum flight speed, cruise speed and maximum flight altitude, assuming relevant flight time parameters, after adjustment, the total time to complete a transportation is finally determined to be 39 minutes, less than 50 minutes.

3.1. Take-off and Descent Mechanism

The sample transportation of ecological floating island is only related to water level and sample box size due to height, and each flight journey is similar, as shown in Fig. 5. It is divided into 9 sections: T1 section motor starts to drive UAV to take off; T2 section motor power decreases, lift and fuselage

weight balance realize horizontal movement; T3 section motor power gradually decreases to 0, UAV lands to clamp sample box; T4 to T6 stages repeat T1, T2 and T3 processes respectively but with heavy objects; T7 section motor starts to disengage clamping device; T8 section flies to charging point; T9 segment motor stops UAV landing and completes transportation.

3.2. Self-locking plug-in Mechanism

After the UAV arrives above the sample box, the motor stops rotating and lands, and the self-locking plug-in mechanism is pushed by its own weight. T0 stage mechanism no action; The T1 stage is a compressed state, when the drone lands, the wedge block and the cone block interact and separate, and the spring compresses; after the cone block comes into contact with the wedge block in the T2 stage, the spring rebounds to reset the wedge block; the wedge block in

the T3 stage lifts the cone block, and the drone flies; in the T4 stage, the drone drops and places the box, and the wedge block acts separately from the second part of the cone block; in the T5 stage, the pressure rod is compressed first and then relaxed, the process is the same as that of T1 and T2; in the

T6 stage, the sample box bottom is counter-clamped by the clamping device; T7 stage wedge block and the second part of the cone block compression; T8 stage and the first part of the cone block action, pressure rod relaxation, complete the release of the box. The motion cycle is shown in Fig. 6.

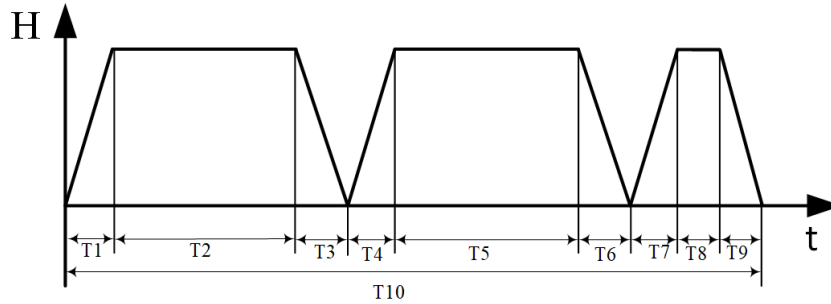


Fig 5. Cycle diagram of takeoff motion

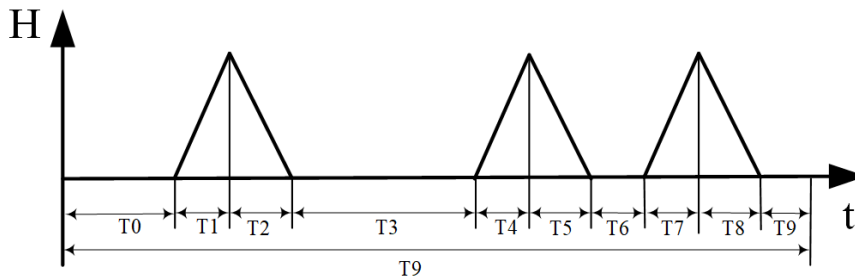


Fig 6. Cycle diagram of compression and relaxation clamping motion of compression rod

3.3. Clamping Mechanism

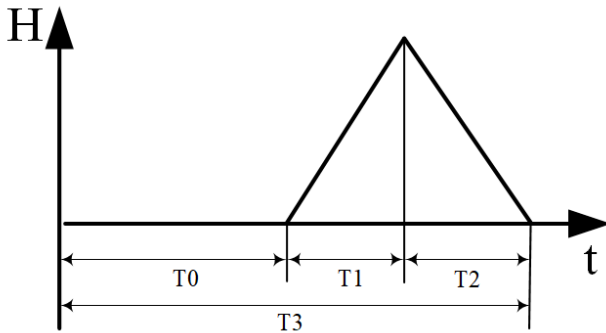


Fig 7. Cycle diagram of clamping motion of base

The unmanned aerial vehicle carries the sample box to the upper part of the clamp body, the motor stops rotating, and the self-locking mechanism is pressed down by gravity. At this time, the force of the pressure rod is decomposed into downward force and horizontal force, and the horizontal force pushes the rod to move to both sides, and the upper surface of

the box base contacts and extrudes the lower surface of the wedge block at the head of the pressure rod to complete the clamping of the box body. The whole process is divided into three stages: T0 stage is the process of UAV box transportation; T1 stage is the compression stage of the pressure rod; T2 stage The upper surface of the box base crosses the lower surface of the pressure rod, the pressure disappears, and the spring relaxes to make the wedge block relatively tighten, completing a movement cycle. The movement cycle diagram is shown in Fig. 7.

3.4. Highly Visual Mechanism

The height vision sensor senses the height of the fuselage and the ground during takeoff, ensuring accurate sample picking and release. The movement cycle is divided into six stages: T0 is the takeoff stage; T1 is the flight to the sample box stage; T2 covers the falling, clamping and lifting process; T3 is the flight to the storage place with the sample box; T4 is the flight to the clamping device with the sample box and the takeoff stage; T5 is the flight to the charging place in the air; T6 is the falling stage to the charging place. The movement cycle diagram is shown in Fig. 8.

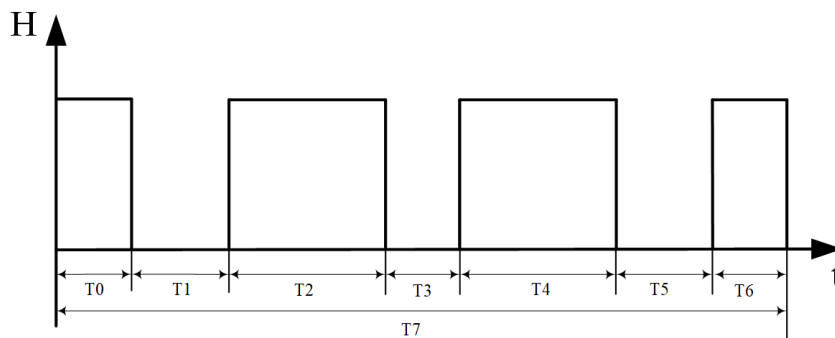


Fig 8. Motion cycle diagram of altitude vision sensor

4. Structural Scheme Design

According to the use conditions and scenarios, an ecological floating island multi-specification multi-sample

delivery UAV is designed, and its assembly diagram is shown in Fig. 9.

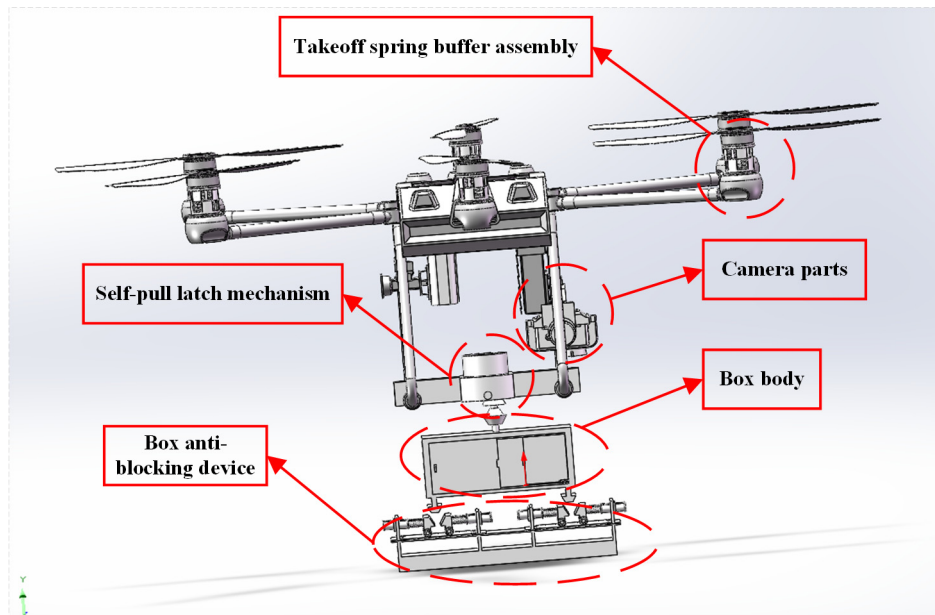


Fig 9. Assembly drawing of UAV and supporting box clamping device

4.1. Camera Sensor Assembly

The device is installed at the side of the UAV, and the connection between the camera body and the handle is connected by a rotatable shaft. The transmitted image information can be changed by adjusting the rotation angle of the shaft. The structure diagram is shown in Fig. 10.

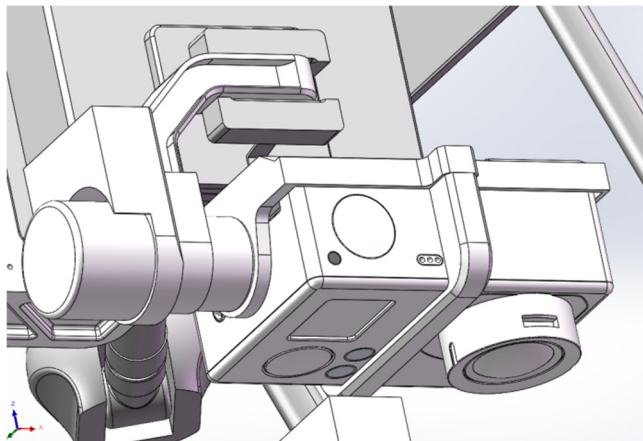


Fig 10. Camera head components

4.2. Spring Damping Member

The spring buffer component is installed under the motor to relieve the bump caused by braking, and its structure is shown in Fig. 11.

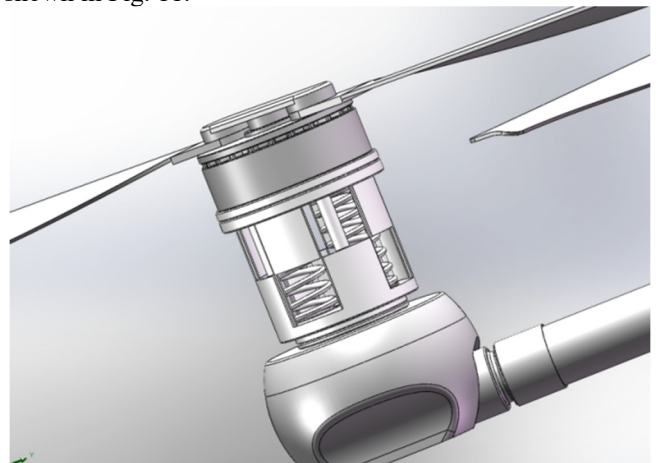


Fig 11. Structure diagram of spring buffer component

5. Mechanical Structure Analysis

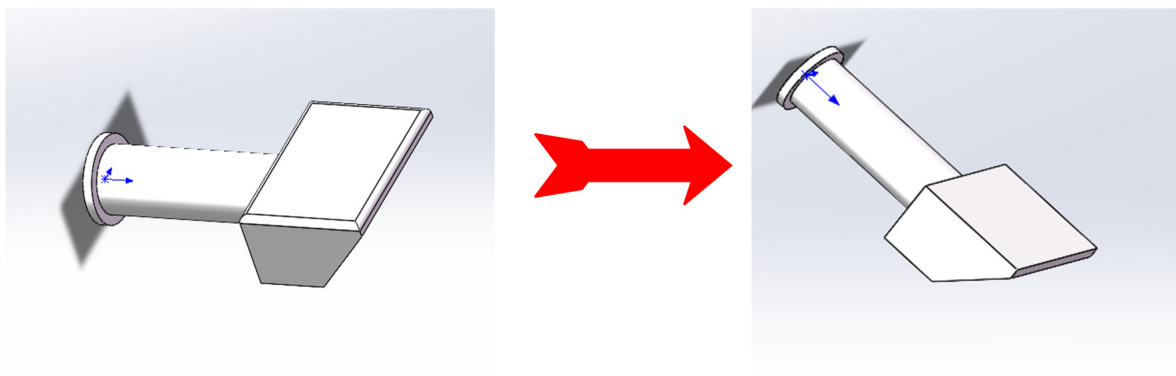


Fig 12. Comparison of simplified models

The compression bar structure is the most effective part of the entire mechanism. The rationality of the design is verified by analyzing the results of the changes in stress, displacement and strain of the compression bar after being subjected to force. The detailed process is as follows:

(1) The model is simplified to avoid increasing the

calculation amount and improve the calculation speed of finite element method under the condition of ensuring reliability and analysis accuracy. A simplified model is shown in Fig. 12.

(2) The material used to define the compression bar model is cast alloy steel, and its parameters are shown in Table 1.

Table 1. Parameters of cast alloy steel ZG1Cr13

| Material | Density/(g/cm ³) | Elastic Modulus/(GPa) | Yield strength/(MPa) | Poisson's ratio | Tensile strength | Elongation |
|----------|------------------------------|-----------------------|----------------------|-----------------|------------------|------------|
| ZG1Cr13 | 7.75 | 200 | ≥345 | 0.26-0.28 | ≥585 | ≥18% |

(3) Mesh division, mesh quality and density directly affect and restrict the accuracy of calculation results in Simulation software.

(4) Under the condition of fixed constraint, rigid constraint boundary is formed at the contact position between the circular rod segment and the vessel, and the wedge compression region bears vertical downward load. Based on

this stress state, bending stress occurs in the circular rod due to eccentric compression. As shown in Fig. 13, the constraint conditions in the finite element model are applied to the contact interface between the circular rod and the container, and the load is applied perpendicularly to the top surface of the wedge block, so as to simulate the mechanical behavior under actual working conditions.

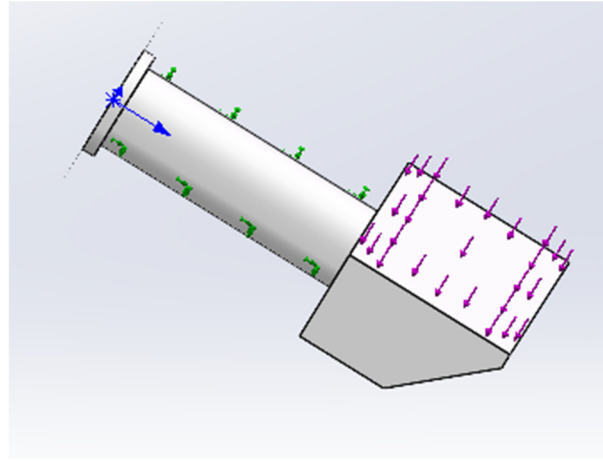


Fig 13. Finite element constraint positions

(5) For safety reasons, a force is applied to the upper surface of the wedge block in the most dangerous case. It is known that the caster is subjected to a downward force of 100N and a gravity of 9.81 m/s² in the vertical direction of the sample box in the stationary state.

(6) After completing the above modeling and boundary condition setting, the finite element analysis can be started. After calculation, stress nephogram of compression bar structure is shown in Fig. 14, displacement nephogram is shown in Fig. 15, strain nephogram is shown in Fig. 16.

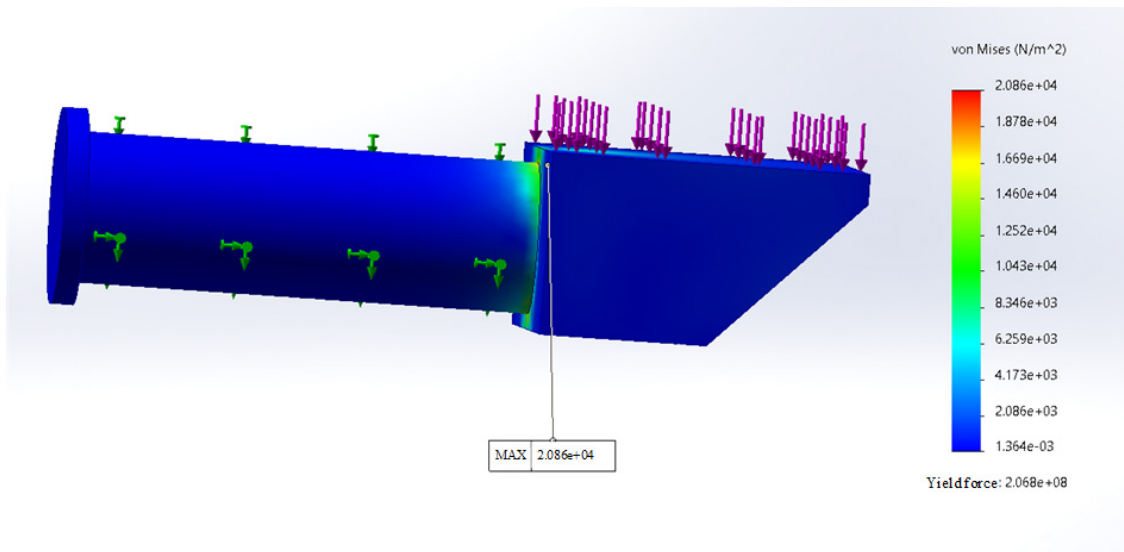


Fig 14. Stress nephogram

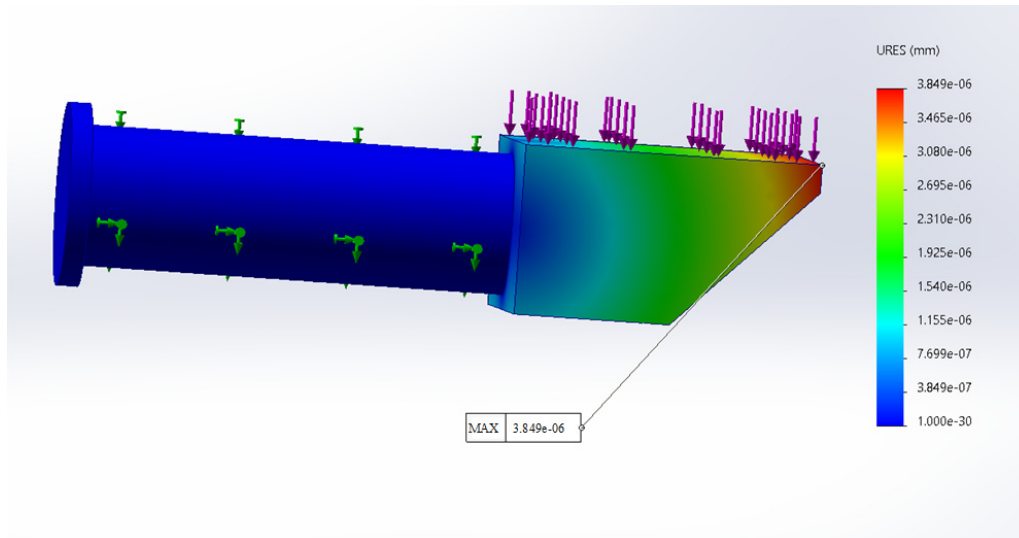


Fig 15. Displacement cloud map

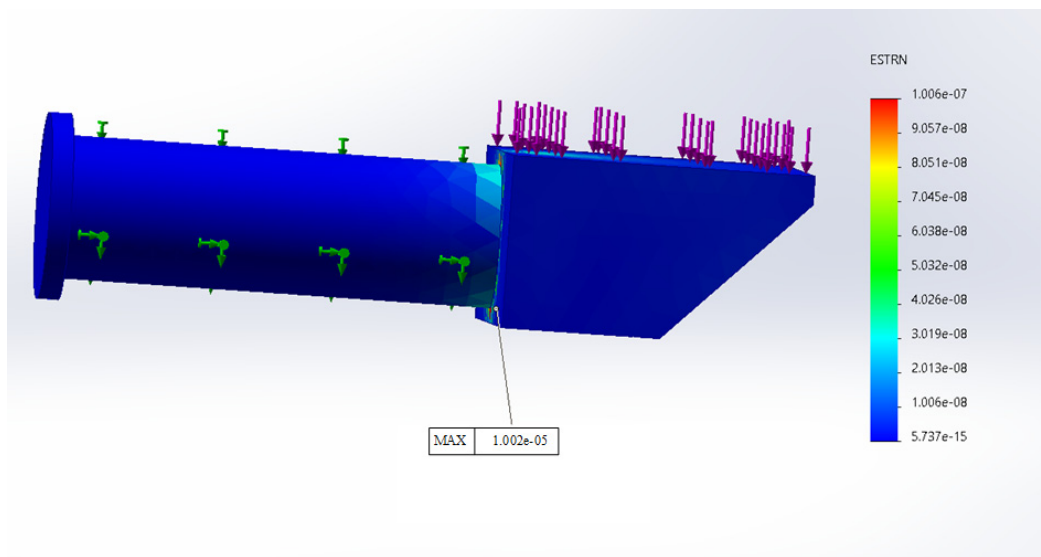


Fig 16. Strain nephogram

It can be seen from the above figure that the maximum stress received by the compression rod is $2.0868 \times 10^5 \text{N/m}^2$, which is far less than the yield force of the material; the maximum displacement is $3.849 \times 10^{-5} \text{mm}$ at the outermost end of the compression rod part, and the maximum strain is $1.006 \times 10^{-6} \text{mm}$ at the junction of the wedge block part and the round rod part, which meets the design requirements.

6. Conclusion

Aiming at the problem of water pollution caused by industrial development, and the challenges of insufficient load, weak environmental adaptability and low operation efficiency faced by monitoring and transportation in complex environment of ecological floating island, a multifunctional UAV system with modularization and self-adaptation as its core is designed in this study. Through the integration of flight function module, load function module and navigation and control function module, the efficient and stable transportation of multi-specification sample boxes in complex environments such as islands is realized, the timeliness of ecological monitoring and the reliability of sample transfer are improved, advanced technical support is provided for ecological restoration engineering and scientific research data collection, and extensive environmental

adaptability and engineering popularization value are demonstrated.

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