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# Structural Design Study of Air-Dropped Unmanned Maritime Mobile Search and Rescue Platforms

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**Abstract:** In order to improve the efficiency and safety of search and rescue (SAR) at sea, this paper proposes a kind of emergency rapid rescue unmanned craft (air-dropped unmanned maritime motorized search and rescue platform) that can be delivered by a large transport aircraft. This paper studies the structural design scheme of the platform, and the main scale of the platform, the choice of power system and the impact resistance performance are considered in the design process to ensure its rapid response and effective rescue capability under complex sea conditions. Simulation results show that the platform can withstand the impact of air injection into the water and the shipboard equipment can operate normally under the impact load, thus verifying the feasibility and safety of the design. This study serves to improve the maritime search and rescue system and enhance the oceanic emergency response capability.

**Keywords:** Maritime search and rescue; Unmanned maritime platform; Maritime airdrop; Impact resistance simulation

## 1. Introduction

Maritime search and rescue (SAR) plays a critical role in protecting the lives of individuals at sea and ensuring the safety of the marine environment. As the marine economy continues to develop, the frequency and complexity of maritime emergencies increase, necessitating enhanced maritime emergency response SAR capabilities. The existing sea and air search and rescue system mainly consists of an air-drop rescue kit. The main body of the kit is an inflatable soft life raft that cannot maneuver independently after air-dropping into the water. In a rescue operation, it is necessary to first locate the victims and then perform a precise drop. This necessitates prolonged carrier airtime and precise airdrop accuracy. Enhancing the maritime SAR system entails innovating related technologies and equipment to effectively address complex situations.

The airdrop unmanned maritime mobile SAR platform represents a novel SAR method utilizing rigid search and rescue boats, delivered via airdrop from large transport aircraft. This approach combines the timely response capability of air-sea-linked SAR systems with the durability of ship-based SAR platforms. Integrating unmanned technology with airdrop rescue boat technology reduces risks for search and rescue personnel and lessens the need for extended airtime of the carrier. This innovation enhances rapid response and effective rescue capabilities for sudden maritime accidents in complex oceanic environments with imprecise positioning.

## 2. Air-dropped offshore mobile platform design

### 2.1. Platform scale design

The airdrop unmanned rescue boat needs to quickly arrive at the rescue area far from the coast. To achieve this, the platform needs to be transportable by fixed-wing aircraft and deployed via airdrop to the target zone. The former Soviet Union developed 14010 manned lifeboats along with supporting IL-76 large transport aircraft. For example, a lifeboat measuring 12.4 meters in length and 3.2 meters in width successfully underwent physical sea drop experiments (refer to **Figure 1**). Thus, designing a large parachute platform for sea drop rescue operations is considered feasible.

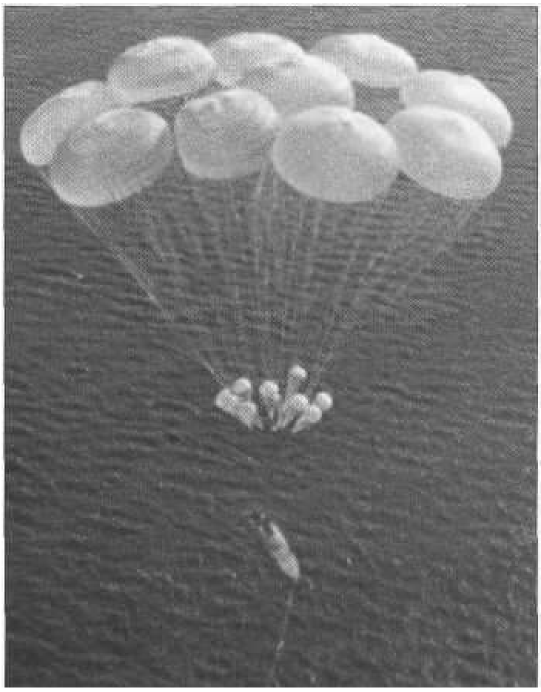
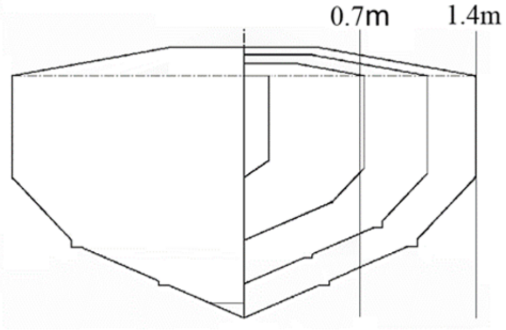


**Figure 1.** Soviet manned lifeboat 14010 air-drop test

Considering the demand for airdrops using large transport aircraft, the main scale of the platform and the design of ship parameters should take into account the limitation of cabin space and maximize the carrying capacity under the premise of safeguarding maneuverability and safety. Due to the intense impact and complete submersion during the airdrop process, a double-layer fully enclosed shell is essential to ensure anti-submergence protection. The superstructure is streamlined, and external equipment is designed with folding stowage to enhance impact resistance. To safeguard the rescue object's safety, self-inflating D-type airbags surround the ship's side, providing protection and improving navigational performance in high sea conditions, while also offering additional buoyancy reserves.

Considering the carrying capacity of the existing large transport aircraft, the navigational performance of the unmanned boat platform, the stability and safety of the airdrop, and the working environment of the boat equipment, the main scale parameters of the airdrop unmanned maritime motorized search and rescue platform of this design scheme and the type line diagram are shown in **Figure 2**, where L is the length, B is the width, D is the depth, D1 is the fully loaded draught, D2 is the unloaded draught, and θ is the angle of slanting rise.

| Main scale parameters | |
|---|---|
| L | 11m |
| B | 2.8m(Main scale parameters)/<br>3.5m(Airbag inflation) |
| D | 1.6m |
| D1 | 0.9m |
| D2 | 0.45m |
| $\theta$ | 23° |



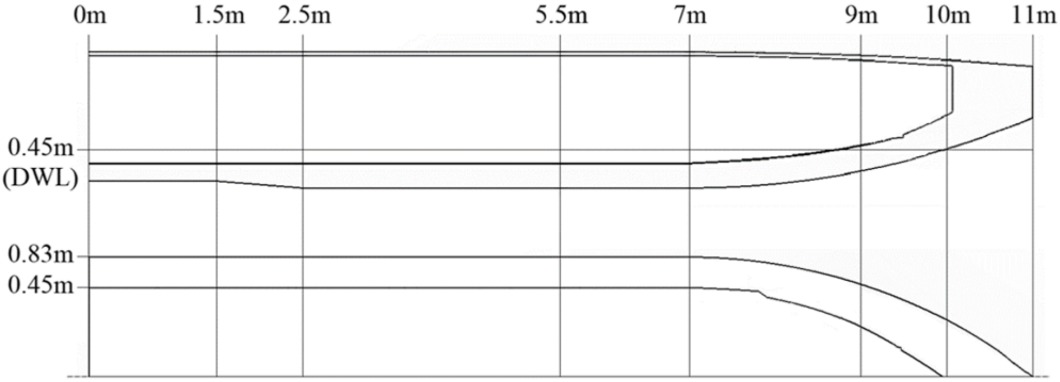


**Figure 2** Main scale parameters and profiles of the platform

## 2.2. Power system program selection

Compared with the drop-type lifeboat, the air-dropped maritime unmanned aerial SAR platform needs to emphasize more on maneuverability. Besides, the balance between the maximum speed and the endurance is also taken into account. In addition, the propulsion system needs to be impact-resistant and people-friendly to prevent harming the victims.

Water jet propulsion offers speed advantages over propellers and higher propulsion efficiency at high speeds [1]. The stator of a water jet propeller reduces the rotational energy loss in the propeller wake and the conduit reduces the rotor lobe slipstream loss and increases the effective thrust, thus increasing the propulsive efficiency for better range.

The fixed twin propulsion system has no rudder mechanism, does not require a pod design, and removes the guide nozzles and reversing devices that are exposed on the outside of the hull aft of a conventional water jet propeller [2]. This design, with no exposed moving components, reduces the probability of damage to the powertrain during empty launching and ensures that there will be no secondary damage to persons in distress during rescue and salvage.

## 2.3. Passive rocking stabilization device

Various passive rocking reduction solutions are available for small unmanned vessels. One such solution involves a hull stabilizing device comprising a bilge keel set and rocking fins. The bilge keel set is affixed to the bottom of the hull, while the rocking fins are rotatable and connectable to the hull. When the rocking fins are rotated and distributed at an angle to each other with respect to the hull, the damping effect of the hull is improved, thereby stabilizing it. Conversely, when the rocking fins are rotated and secured inside the hull, the hull’s travel resistance is reduced [3]. The bilge fins and bilge keel design used in this platform are shown in **Figure 3**.

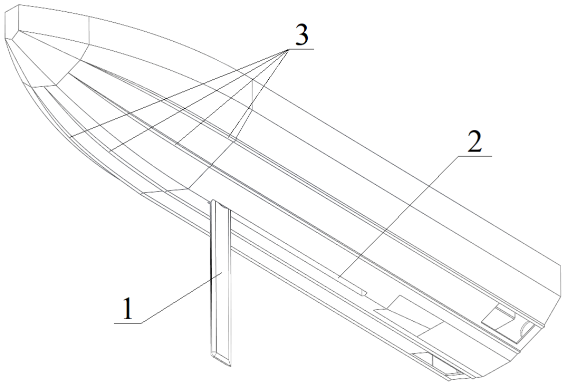


**Figure 3.** (1) Shock absorbing fins, (2) stowage slot, and (3) bilge keel

## 3. Simulation of platform impact resistance

### 3.1. Simulation model establishment

The simulation is conducted based on the parameters of the self-designed air-dropped maritime unmanned aerial search and rescue platform, which is geometrically modeled using SolidWorks software. Following the design steps, the D-shaped airbag remains uninflated during the platform's airdrop into the water, and the surface search system is not extended from the hull. Therefore, only the hull part is simulated and analyzed in this study.

The platform design is created using SolidWorks software and then imported into Ansys software for subsequent meshing. The quality of the final simulation is closely linked to the fineness of the meshing. It is generally required that the cells are predominantly in the form of positive or orthogonal polygons, ensuring smooth transitions between the meshes. This is crucial because distorted meshes can lead to inaccurate simulation results. In this finite element model, the mesh is divided according to the criteria outlined in Table 1.

**Table 1.** Meshing criteria

| Indicator item | Standard value |
|---|---|
| Slenderness ratio | < 3 |
| Warpage | < 10 |
| Jacobi coefficient | > 0.8 |
| Twist | < 15 |
| Maximum internal angle of quadrilateral | < 120 |
| Minimum internal angle of quadrilateral | > 60 |
| Maximum internal angle of triangle | < 150 |
| Minimum interior angle of a triangle | > 30 |

The specifics of mesh division are shown in the table below. The symmetric division operation is carried out for the platform hull to ensure that the simulation results satisfy the symmetry of the hull and reduce the consumption of computational resources. The mesh refinement operation is adopted for the structure with concentrated stress and large stress gradient in the model, while a slightly larger mesh size is adopted for the part with small changes in stress gradient and simple structure in the model in order to reduce the amount of computation. In addition, special interfaces, such as geometrically mutated parts, are set as mesh boundaries.

**Table 2.** Meshing units parameters

| Structure | Unit type | Unit size | Number of units |
|---|---|---|---|
| Hull | Lagrange quadrilateral | 0.1 m | 5712 |
| Water | Rhombohedron | 0.1 m | 90000 |
| Airspace | Rhombohedron | 0.1 m | 81000 |

## 3.2. Analysis of the airdrop of the platform into the water

The air-dropped maritime unmanned aerial SAR platform is thrown from a high altitude, and finally adjusted to the hull of the ship and the water surface at an angle of 45 ° attitude, and enters the water at an impact speed of 10m/s. At this stage, the bottom of the bow touches the water surface, and after the impact, the stern starts to rotate downwards until the hull is flush with the water surface. The motion process can be described by the following equations:

Force in the horizontal direction:

$$m\ddot{x} = F_n \sin\theta + F_n \cos\theta - f_n \sin\theta - f_n \cos\theta$$

Force in the vertical direction:

$$m\ddot{z} = F_n \cos\theta + F_a \sin\theta - G + F_b$$

Moment applied:

$$I\ddot{\theta} = -M_n - M_{f_n} - M_b$$

In these equations, *F* refers to the hydrodynamic force on the hull, *f* refers to the fluid resistance on the hull, *M* refers to the moment on the hull, and *G* refer $m\ddot{x} = F_n sin\theta + F_a cos\theta + f_n sin\theta - f_a cos\theta$s to the gravitational force on the hull. The subscript *n* refers to the normal direction, the subscript *a* refers to the axial direction, and the subscript *b* refers to the buoyancy force.

## 3.3. Simulation conditions and parameter settings

The simulation involves the process of hulling from air into water. Given the substantial dimensions of the actual air and water domains, a 1:1 reduction is impractical. Therefore, the simulation employs a water domain with dimensions of 30 m*60 m*10 m and an air domain with dimensions of 30 m*60 m*9 m. The boundaries of both the water and air domains are set as non-reflective boundaries to more accurately reflect real-world water and air scales. The parameters of the hull material (FRP) are set as follows (Table 3):

**Table 3.** Parameters of the hull material (FRP)

| | |
|---|---|
| Density (kg/m$^3$) | 1700 |
| Tensile strength (MPa) | 160–320 |
| Tensile modulus of elasticity (MPa) | 7000 |
| Poisson's ratio | 0.22 |

The parameters for the air domain and water domain are set as follows (Table 4):

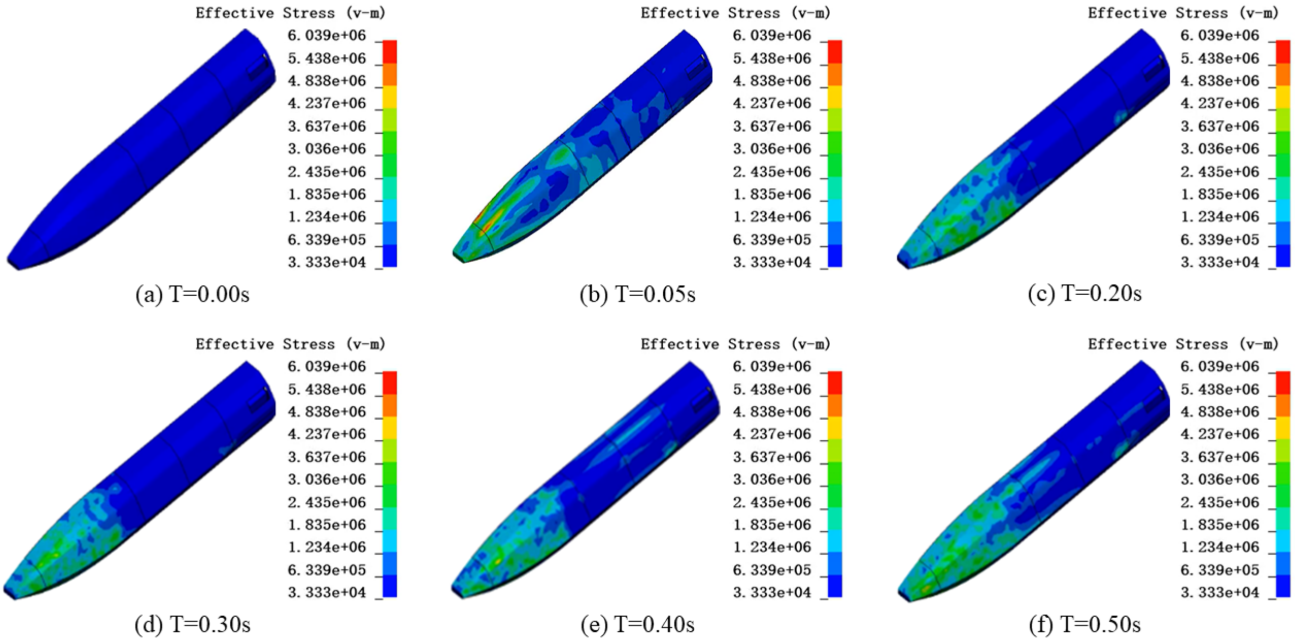
**Table 4.** Parameters for the air domain and water domain

| Parameter | Air area | Water area |
|---|---|---|
| Fluid density, $\rho$ (kg/m$^3$) | 1.2 | 1025 |
| Speed of sound, $C$ (m/s) | 344 | 1650 |
| S1 | 0 | 1.92 |
| S2 | 0 | -0.096 |
| S3 | 0 | 0 |
| GAMA0 | 1.4 | 0.35 |

Note: S1, S2, S3, and GAMAO are dimensionless parameters that facilitate the use of the GRUNEISEN equation to describe the pressure of compressible materials.

## 3.4. Analysis of simulation results

The impact resistance of the hull can be measured by the integrity of the hull structure during the hull entering the water. This is mainly reflected in the comparison between the maximum impact on each part of the hull and the yield stress of the hull material, and the method is that the simulation analysis focuses on the maximum stress and its distribution at each time on the hull structure. In addition, it is also necessary to consider whether the electronic equipment carried by the platform can withstand the impact of the impact of entering the water, which can be judged by analyzing the acceleration of the equipment installation location. Existing research results show that the moment when the hull is most affected by the impact is usually the moment when the top part of the bow region comes into positive contact with seawater [4]. Therefore, in this paper, only the impacted condition in 0–0.5s after contacting the water surface is simulated and calculated.



(a) T=0.00s (b) T=0.05s (c) T=0.20s

(d) T=0.30s (e) T=0.40s (f) T=0.50s

**Figure 4.** Hull structure stress distribution cloud (0–0.5s)

As shown in **Figure 4**, when the ship hull enters the water, the stress in the bow, which is the first to bear the impact, increases dramatically. As the hull enters the water, the stress value of the bow rises rapidly, and its strain increases to the maximum value first and transmits to the whole hull, and then decreases gradually and tends to stabilize. The maximum stress and strain curves of the hull during this process are shown in **Figures 5** and **6**.

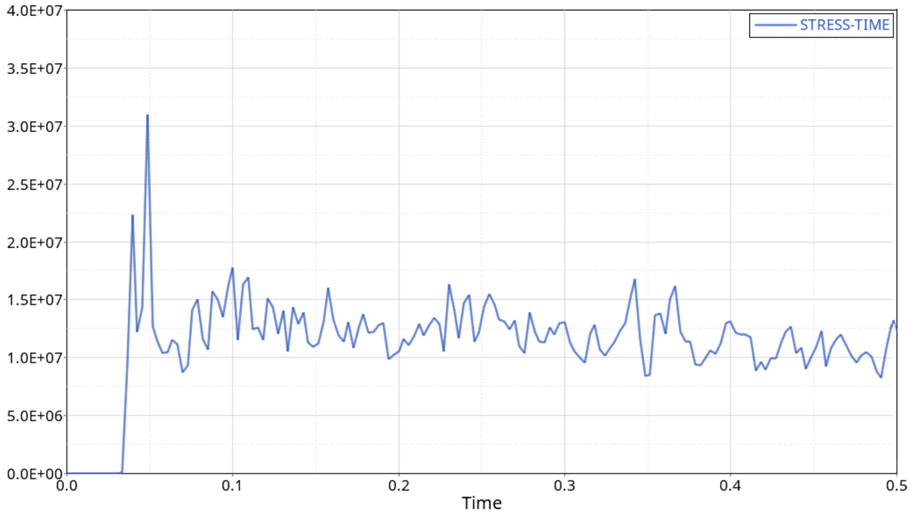


**Figure 5.** Maximum stress values on the hull (0-0.5s)

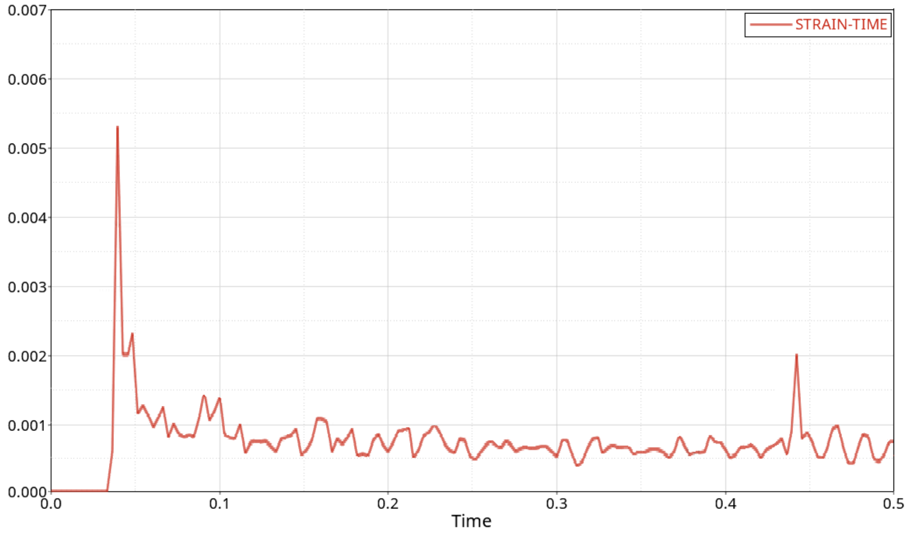


**Figure 6.** Maximum strain rate of the hull (0-0.5s)

The maximum value of the stress in the hull during the whole process is about 31 MPa, which is much lower than the maximum safe stress of FRP material (170 MPa). This indicates that the hull structure can maintain its integrity during the process of the hull entering the water. The maximum stress in the hull appears around 0.05 s, indicating that the hull was subjected to the maximum impact stress when the top part of the bow region came into frontal contact with seawater, and this result is also in line with the conclusions of the existing studies.

When the hull has a frontal impact with seawater, different accelerations will be generated at different locations, and the magnitude of the acceleration is related to whether the boat-carried equipment can operate normally. In this section, the equipment installation location located at the stern of the boat is selected to analyze the impact loads received during the water-entry impact (**Figure 7**), and the raw data are filtered using a Butterworth low-pass filter (**Figure 8**), with a filter cutoff frequency of 5 Hz [4].

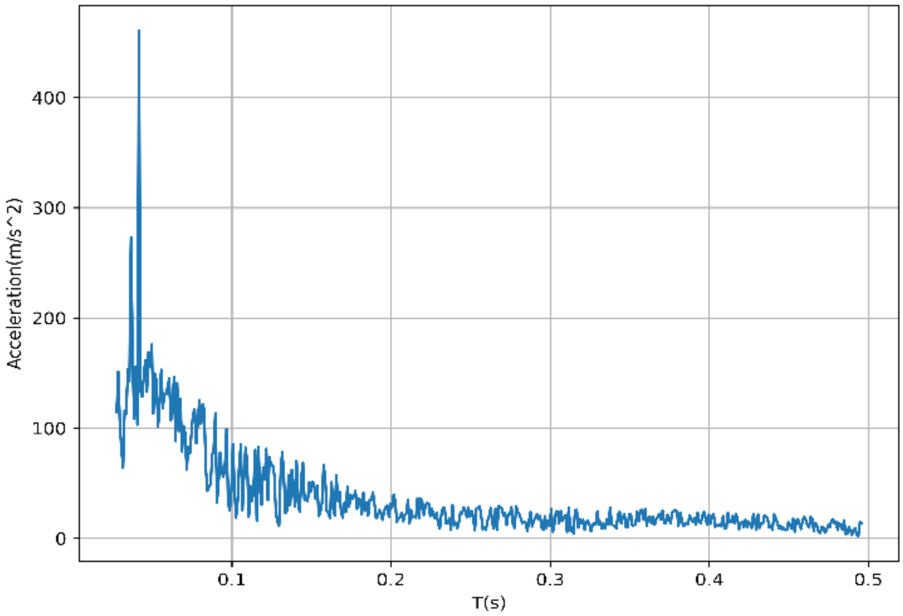


**Figure 7.** Shock acceleration at equipment installation (0–0.5s)

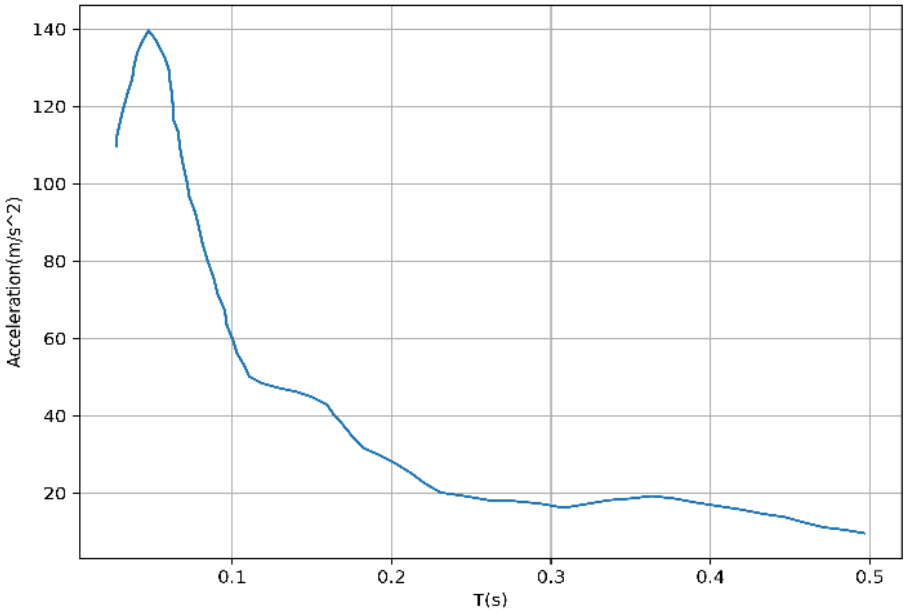


**Figure 8.** Filtered shock acceleration (0–0.5s)

The filtered data shows that the maximum shock acceleration at the equipment installation is about 14G, and the following table shows the acceleration condition limits for the main equipment installed at this location (**Table 5**).

**Table 5.** Equipment acceleration conditions limitations

| Device name | Maximum acceleration limit |
|---|---|
| Rotary structure | 20G |
| Photoelectric sensor | 170G |
| Power supply | 100G |

The maximum acceleration at the location where the shipboard equipment is installed is less than the maximum acceleration limit for the above equipment. Therefore, the in-water impact does not cause damage to the installed equipment.

In general, after simulation, the stress and strain at each place of the hull structure are maintained within a safe range, and the maximum acceleration at the installation position of the shipboard equipment is less than the working condition limit of the relevant equipment. Therefore, it can be concluded that the shock-resistant design of the platform can meet the needs of carrying out sea airdrop deployment.

## 4. Conclusion

This paper explores the structural design scheme of an air-dropped unmanned maritime motorized search and rescue platform. By integrating unmanned marine vehicle technology with air-dropped rescue boat technology, the platform offers a novel technical solution for maritime SAR, enhancing response speed and effective rescue capabilities. Simulation results demonstrate that the platform’s impact-resistant design meets the requirements for airdrop deployment at sea. Future endeavors will focus on refining design details and enhancing the workflow and algorithms of associated SAR equipment, enabling the platform to effectively handle complex maritime rescue missions.

## Disclosure statement

The authors declare no conflict of interest.

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