ANALYTICAL STUDY ON HYDROSTATIC RESPONSE CHARACTERISTICS DURING WATER LANDINGS OF AMPHIBIOUS AIRCRAFT

Feng Sun[1,*], Yuhao Zheng[2], Shunshun Zhu[2]
[1]Xi'an Modern Control Technology Research Institute, Xi'an, China
[2]Northwestern Polytechnical University, Xi'an, China

Abstract

Large amphibious aircraft mainly perform sea rescue missions and fire extinguishing tasks. In recent years, many scholars have studied the strength characteristics of metal and composite materials [1,2]. At the same time, there is relatively more research on the energy state of aircraft landing on land [3], but the overload generated during water landing is an important load condition for aircraft structural strength design, which cannot be ignored for the safety of crew members and onboard equipment. Therefore, further research is needed. Landing response is a response pattern unique to seaplanes and is one of their main landing modes. Therefore, an analysis of the landing response of amphibious aircraft is necessary. In this study, the flow field mesh of the aircraft landing process was divided by ICEM software, and the entire fluid domain was meshed by non-structure. The computational fluid dynamics software FLUENT was used to calculate the landing response of the aircraft on static water, and the variation law of the maximum center of gravity overload, the pressure-time curves of multiple monitoring points at the bottom of the hull and the pitch angle of the aircraft during the landing process were given.

Keywords: amphibious aircraft; water landing test; fluid-structure interaction; hull-style fuselage

1. Calculation Method

1.1 Finite Volume Method

The basic idea of the FLUENT system is to divide the calculation area into meshes and make each grid point have a non-repeating control volume around each other, the differential equations to be solved (governing equations) are integrated for each control volume to arrive at a set of discrete equations. Based on the unstructured Euler grid format, the finite volume discretization method is used to perform numerical calculations [4].

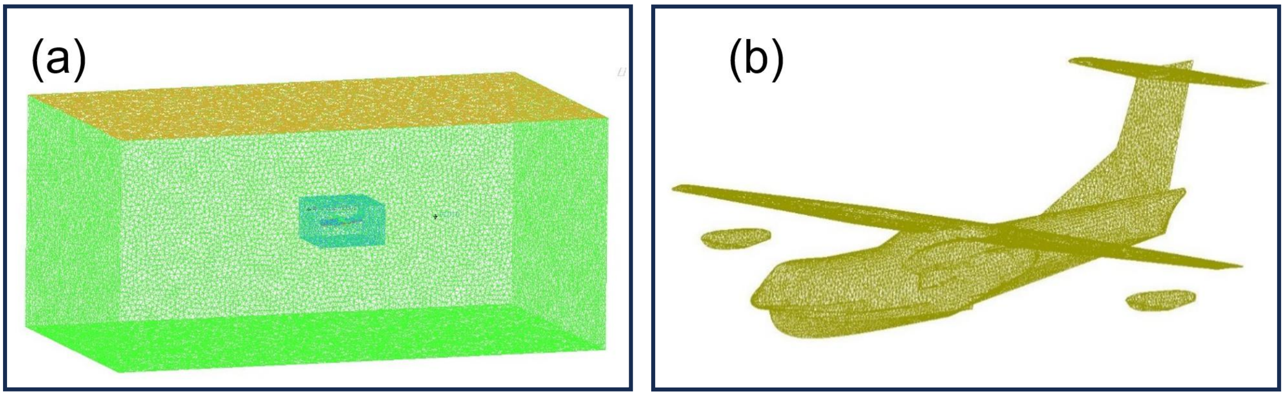
1.2 Moving Grid Method

In the calculations in this study, the amphibious aircraft landing is a rigid movement of the boundary, which causes the shape of the fluid domain to change with time, so the mesh of the fluid domain needs to be adjusted with the movement of the boundary [5]. In this study, a moving mesh model is used for mesh adjustment. The update of the grid is automatically completed by FLUENT based on the changes in the boundaries at each iteration step. During the landing process of amphibious aircraft, the distance of movement is relatively long and the attitude changes are significant, which can cause significant deformation of the mesh in the moving grid area. Therefore, the numerical calculation in this study adopts the mesh reconstruction method and elastic smoothing method.

2. Static Water Responds

2.1 Computational Models and Meshing

ICEM software was used to establish the geometry of the structure, calculate the flow field, and divide the mesh. Figure 1 shows the grid situation, and the total number of grids is 1.67 million.



(a) Schematic diagram of the flow field mesh (b) Aircraft surface grid distribution

Figure 1 – Schematic diagram of the grid distribution

2.2 Flow field initialization settings

When using other numerical methods to calculate the landing response of an aircraft, it is generally based on the ninth volume of the Aircraft Design Manual [6], where the lift experienced by the aircraft during landing is taken as 2/3 times the gravity and passed through the center of gravity. This approximation method cannot accurately reflect the actual lift experienced by the aircraft during landing, and doesn’t take the water surface effect into account before landing on water, that is, the airflow below the wing surface is compressed by the two sides of the wing and water surface, causing an increase in pressure below the wing surface. Therefore, in this report, the initialization of the flow field enables the aircraft to have lift close to the real situation when landing on water.

2.3 Pressure Monitoring Point Setting

In order to monitor the pressure at the bottom of the hull when the amphibious aircraft lands on the water, 10 pressure monitoring points P_1 to P_{10} are set on the bottom surface, as shown in Figure 2.

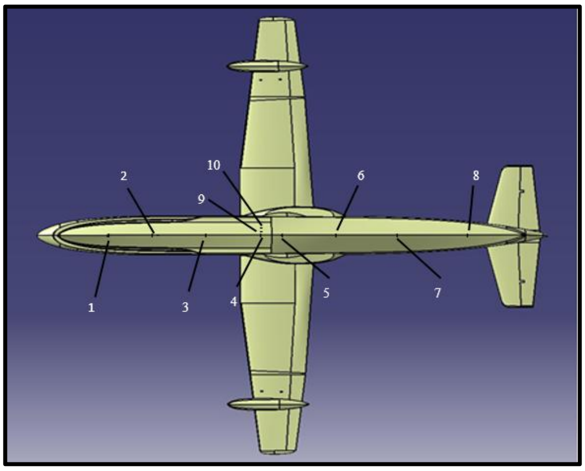


Figure 2 – Distribution of pressure monitoring points

2.4 Static Water Landing Conditions

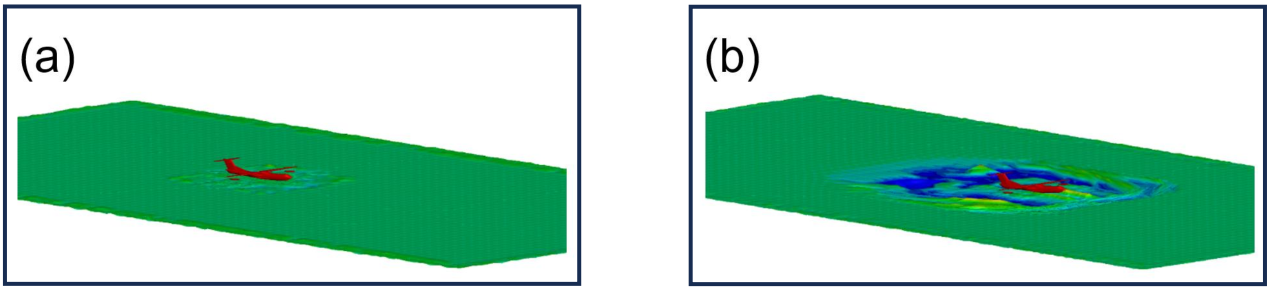
When the amphibious aircraft lands on the water, the influence of the pitch angle and the landing speed on the landing response is mainly considered, the vertical descent speed of the aircraft is 0~3m/s, and the descent speed of 3m/s is considered as the serious landing condition in the normal landing mode, the pitch angle under the normal landing condition is 5°~6°, in summary, 6 landing conditions as shown in Table 1 are selected for calculation.

Table 1 – Amphibious aircraft landing conditions

Landing conditions	Pitch angle	Forward flight speed(m/s)	Descent speed(m/s)
1	5°	41.67	1
2	5°	41.67	2
3	5°	41.67	3
4	6°	41.67	1
5	6°	41.67	2
6	6°	41.67	3

2.5 Calculation Results

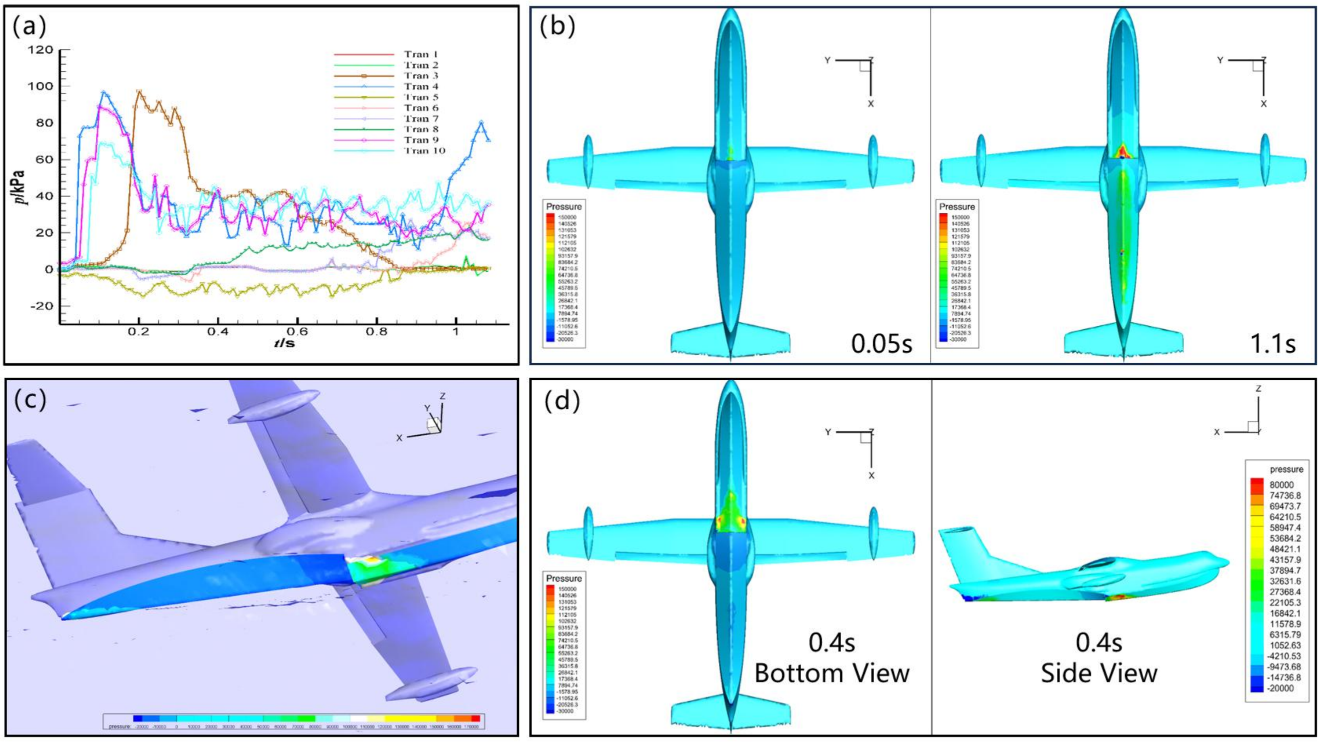
FLUENT computational fluid dynamics software was used to simulate the landing response of amphibious aircraft. According to the calculated landing conditions shown in Table 1, the overload of the center of gravity and the change of the position of the center of gravity, the change of velocity, the change of fuselage pitch angle, the change of pitching moment and the pressure distribution of the bottom of the ship are given when the aircraft lands on the water. The process of water landing is shown in Figure 3.



(a) 0.05s after contact with the water surface (b) 1.1s after contact with the water surface

Figure 3 – FLUENT water response simulation

Take the bottom pressure distribution and the time mileage of the pressure monitoring point under condition 5 as an example, as shown in Figure 4.



(a) The pressure changes at each point in condition 5

(b) 0.05s and 1.1s bottom pressure distribution

(c) 0.4s bottom pressure distribution (underwater perspective)

(d) Bottom view and side view of 0.4s pressure distribution

Figure 4 – The time history of each pressure monitoring point and the pressure distribution at the bottom of the ship under condition 5

3. Conclusion

Through the simulation analysis of the hydrostatic landing response of large amphibious aircraft, the following conclusions are drawn:

(1) The initial landing attitude angle has a great influence on the aircraft's landing response. Through the calculation and analysis of six landing conditions, when the initial angle of attack for landing is selected at 6 °, the center of gravity overload and peak pitch angle of the aircraft during landing are less than 5 °, which is more conducive to maintaining the aircraft attitude, protecting the safety of aircraft equipment and personnel.

(2) The descent speed of the aircraft when it hits the water has a great influence on the overload of the center of gravity, the impact pressure on the bottom of the fuselage, and the change of pitch attitude. As the descent speed decreases, the maximum center of gravity overload of the aircraft gradually decreases, and the peak value of the pressure monitoring points at the bottom of the hull also gradually decreases. The pitch torque generated by the positive and negative pressure zones at the bottom of the ship also decreases, thereby reducing the change in pitch attitude. Therefore, the aircraft should minimize its descent speed when landing on water to minimize the impact on the aircraft structure and ensure stable attitude.

(3) During the landing process of the aircraft, the positive pressure zone appears in the front of the step, and the negative pressure zone appears in the rear of the step and at the trailing edge of the hull. The maximum pressure peak occurs at monitoring P_4 or monitoring P_3, and during the landing process, monitoring P_3, P_4, P_9, and P_{10} have been subjected to significant water pressure, which means that the front part of the hull and ship bottom will bear greater pressure when landing. The pressure at monitoring P_5, P_6, and P_7 after step interruption is very low or even negative, this indicates that the bottom of the ship has a good role in separating the flow, which greatly relieves the water pressure of the hull at the rear of the broken step.

4. Contact Author Email Address

The contact author email address: fengsun@mail.nwpu.edu.cn.

5. Copyright Statemen

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