Experimental Study on the Attitude of Civil Aircraft Ditching with High Horizontal Tail Configuration

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Abstract. The airplane must meet the airworthiness requirements if certification with ditching provisions is requested. The probable behavior of the airplane ditching must be investigated by model tests or by comparison with airplanes of similar configuration. In this paper, aircraft with high horizontal tail configuration is considered as a research object, then the attitudes of civil aircraft in ditching is studied through a scaled model verification experiment. On this basis, this paper researches the effects of different parameters after ditching into the water, such as initial pitch angle, flap slat configuration and sinking speed. The research results in this paper can help to determine the ditching attitudes and parameters and thus develop strategies for ditching.

Keyword: Civil aircraft, Airworthiness, Ditching, Pitch attitude

1. Introduction
According to the requirements of CCAR25.801 (c) [1], this paper studies on the possible motion and states of the civil aircraft with high horizontal tail after entering into the water through the scaled model verification experiment. There have been many scaled model verification experiments on ditching[2][3]. Meanwhile, the influence factors on the attitude of the aircraft after entering into the water are studied in this paper, such as initial pitch angle, flap deflection and sinking speed. The experiment results can be used as a reference for the ditching procedure in the flight manual.

2. Experimental Equipment
The experiment of ditching was carried out in the high-speed towing tank laboratory. The experimental equipment includes high-speed trailer, delivery bracket, electromagnetic launcher, vertical motion mechanism, motion control system, camera system, gyroscope and collector installed in the model.

The aircraft model is fixed on the trailer through a bracket. During the experiment, the trailer accelerates to a preset speed and then the model is delivered after the speed is stable. The schematic diagram of the experimental equipment is shown in Figure 1.
3. Experimental Model

In the process of aircraft ditching, the motion of aircraft are mainly controlled by gravity (mass force), and the influence of viscous force is secondary. Therefore, the model experiment is organized according to the Froude similarity (Fr) criterion. Therefore, the design, manufacture and test of the experiment model meet the following similar conditions:

1) Geometric similarity:
The corresponding length of the model and the real aircraft is in the same proportion, and the corresponding angle is equal;

2) Motion similarity:
In the geometric similarity system, the velocity direction is the same and the size is in the same proportion at the corresponding instantaneous point. In the flow around the object, the streamline is similar and the acceleration distribution is similar.

3) Dynamic similarity:
In the motion similarity system, the direction of the force at the corresponding instantaneous point is the same, and the magnitude has the same proportion. If the forces are decomposed into inertial forces, mass forces, surface pressure forces and surface viscous forces, the polygonal geometry of the forces on the corresponding points of the two systems is similar.

The experiment model is composed of fuselage, wing, horizontal tail, vertical tail, nacelle and other parts, in which the flap deflection, horizontal tail and elevator deflection are adjustable.
4. Selection of Test Conditions
In order to obtain the most likely attitude when the aircraft lands into water and analyze the influence of the aircraft's attitude, the following tests are carried out:
   a) The initial pitching attitude angles are set to 7°, 9°, 12°;
   b) The slats are all extended and flaps are set to 15°, 25°, 41.5°;
   c) The sinking speed of the aircraft model is set to 0.3m/s, 0.6m/s and 0.95m/s.

5. Attitude Analysis of ditching into water
After the ditching, the typical pitching attitude of the aircraft model is shown in Figure 2. The experiment results show that the aircraft model will produce a moment of lift up after entering into the water, which makes the aircraft lift up obviously, thus producing a large attitude angle, which is caused by a suction force on the lower surface of the aircraft tail.

However, in a NACA research memorandum [4], the author did not find this phenomenon when the Boeing 707 model ditched, and the configuration of the 707’s fuselage tail is similar to this aircraft. We believe that this is due to the configuration of the horizontal tail. The horizontal tail configuration of the Boeing 707 is conventional. When the aircraft enters into the water at a certain angle of attack, the horizontal tail will also enter into the water. At this time, the horizontal tail will produce a lift which is acted by the hydrodynamic force. This lift will provide the pitch down moment, so as to offset the lift up moment caused by the suction of the lower surface of the fuselage tail. In this experiment, the aircraft model adopts T-shaped horizontal tail. So when the fuselage tail enters into the water, the horizontal tail has not entered into the water. At this time, the influence of hydrodynamic force is far more than the influence of aerodynamic force. Therefore, the suction force of the lower surface of the fuselage tail causes the aircraft to lift up. In article [5], which researches the influence of the rear fuselage’s shape on the ditching, the aircraft model similar to this model (fuselage structure and T-tail) also show obvious lift-up after entering into the water.

6. Analysis of The Influence of Different Parameters on The Attitude after Ditching

6.1. The influence of initial pitch angle on attitude after ditching
The change of aircraft attitude angle under three different initial attitude angles with 41.5°flap deflection and 0.3m/s sinking speed is shown in Figure 3. It can be seen that the aircraft model can reach to the maximum pitch angle after entering into the water at 12°pitch angle. And when the model enter into the water at 7° and 9°pitch angle, the pitch angle is similar after a little time. If considering the increase of pitch angle, the increase of pitch angle at 7°pitch angle is the largest, and the increase
of pitch angle at 9° and 12° pitch angle is similar. We think that this is because the smaller the pitch angle is, the more obvious the raise of tail’s lower surface is relative to the water flow, resulting in greater suction force.

Figure 3. The Pitch Angle of Aircraft in Different Initial Attitude States

6.2. The influence of different flap deflections on the attitude after ditching

Figure 4 shows the change of aircraft pitch angle under three different flap deflections at the initial 12° pitch angle and 0.6 m/s sinking speed. It can be seen that the flap deflection has no effect on the aircraft motion attitude during the whole process of nose up after the aircraft enters into the water. This is because the suction force generated by the hydrodynamic force at the tail of the fuselage is far greater than the aerodynamic force acting on the flaps. In the later stage of the whole movement, the attitude of the model in 25° and 41.5° flap deflection are somewhat different from 15° flap deflection. It is also because when the pitch angle of aircraft model becomes smaller, the flaps of 25° and 41.5° have entered into the water and are affected by the hydrodynamic force while the flaps of 15° have not been affected by the hydrodynamic force. It results in the difference of later movement attitudes.

Figure 4. The Pitch Angle of Aircraft under Different Flap Deflection
6.3. Influence of different sinking speeds on attitude after ditching
The change of aircraft pitch angle under three different flap deflections at 12°initial pitch angle and 15°flap deflection is shown in Figure 5. It can be seen that the maximum pitch angle that the model can reach gradually decreases with the increase of the sinking speed. We think that under the condition of a certain horizontal forward speed, the greater the sinking speed means that the angle of attack of the model is larger relative to the water flow when entering into the water, and the suction force generated by the tail part of the fuselage is smaller.

![Figure 5. The Pitch Angle of Aircraft under Different Sinking Speeds](image)

7. Conclusion
This paper analyses the attitude of a typical high horizontal tail aircraft after ditching into the water through the verification experiment with a scaled model. On this basis, this paper researches the effects of different parameters after ditching into the water, such as initial pitch angle, flap slat configuration and sinking speed. The conclusions are as follows:

a) When the aircraft model with high horizontal tail is ditched into the water, it will produce an obvious nose up moment due to the influence of suction force in the tail;

b) A smaller attitude angle when entering into the water results in a larger increment of pitch angle;

c) The configuration of flap and slat has little effect on the attitude of the aircraft model after entering into the water;

d) The smaller the sinking speed is, the larger the maximum pitch angle the model can reach after entering into the water.

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