Research on Civil Aircraft Emergency Evacuation Time for Ditching

Wu Yang
Aircraft Integration Department, Shanghai Aircraft Design and Research Institute
E-mail: wuyang1@comac.cc

Abstract. Emergency evacuation for ditching is an important airworthiness requirement for civil aircraft to ensure safety. However, to demonstrate the emergency evacuation for ditching of a real aircraft is a time-consuming and laborious test with significant safety risks. Based on the analysis of airworthiness clauses, this paper proposes a method for calculating and analysing the emergency evacuation time for ditching. Taking a certain type of aircraft as an example, a typical case is selected for calculation and analysis, and the evacuation time under this typical case is obtained, which provides data support for the airworthiness emergency evacuation airworthiness compliance.

Keyword: Civil aircraft, Airworthiness, Ditching, Emergency Evacuation

1. Introduction
According to CCAR25.801(d) [1], for civil aircraft, “It must be shown that, under reasonably probable water conditions, the flotation time and trim of the aeroplane will allow the occupants to leave the aeroplane and enter the life rafts required by 25.1415.” That is, the flotation time of the aeroplane must be longer than the time of the emergency evacuation of all occupants so that the occupants can safely evacuate the aircraft and enter the life rafts. However, to demonstrate the emergency evacuation for ditching of a real aircraft is a time-consuming and laborious test [2], this paper proposes a method for calculating and analysing the emergency evacuation time for ditching, and provides data support for airworthiness compliance.

2. Airworthiness requirements
According to CCAR25.803, for all newly developed aeroplanes, it must be shown that the maximum seating capacity, including the number of crew members required by the operating rules for which certification is requested, can be evacuated from the aeroplane to the ground under simulated emergency conditions within 90 seconds. To demonstrate emergency evacuation on the ground involves a wide range of personnel, professions and large funds, and for the volunteers participating in the test, it is a test of huge safety risks. It is also one of the key tests for transport forensic aircrafts to obtain the model certificate issued by the airworthiness authority.

There is no relevant requirements for emergency evacuation for ditching in CCAR25.803. All requirements for ditching are reflected in related verification tasks in CCAR25.801 (d). Therefore, the emergency evacuation for ditching does not need the real demonstration test to show conformity as emergency evacuation on the ground, but only by means of computational analysis. The ditching for
Civil aircraft is a problem of water entry impact [3]. Most of the early studies were theoretical [4], but after 1970s, it tended to solve it numerically [5].

Almost none of the transport aircraft designed independently in China has conducted systematic research on ditching [6]. Especially for large transport aircraft, there is a lack of experience in airworthiness forensics [7].

According to CCAR25.801 (d), it must be indicated that the time of the aircraft floating on water is longer than the total time spent by all members evacuating from the aircraft to the life raft, which includes the time spent by the crew taking the raft, opening the hatch, throwing the raft, inflating the raft, and evacuating. This paper decomposes the total evacuation time, measures the decomposed time by experiments, and accumulates them to provide support for measuring the total time of emergency evacuation for ditching.

3. Computational conditions
   a) Total number of evacuated passengers
      The longest evacuation time is required when the number of passengers is the largest. Therefore, the evacuation time is calculated based on the maximum seating capacity, and the number of pilots and all crew members should be added.
   b) Emergency exits arrangement
      The arrangement of emergency exits, which contains the number and location of emergency exits, has a significant impact on the emergency evacuation time. The number of emergency exits is closely related to the maximum number of passengers.
      According to CCAR25.807 (e), ditching emergency exits must be provided in accordance with the following requirements whether or not certification with ditching provisions is requested. For aeroplanes that have a passenger seating configuration of 10 seats or more, excluding pilots seats, one exit above the waterline in a side of the aeroplane, meeting at least the dimensions of a Type III exit for each unit (or part of a unit) of 35 passenger seats, but no less than two such exits in the passenger cabin, with one on each side of the aeroplane. The passenger seat/exit ratio can be increased through the use of larger exits or other means, provided it can show the evacuation capability during ditching has been improved.
   c) Life raft layout
      The layout of the life rafts (including the standard capacity of passengers of the life raft and the location of the life rafts on the aircraft) is also critical to the emergency evacuation for ditching.

4. Calculation
   4.1. Analysis of typical experiments
      According to the calculation results of the aircraft waterline and the location of the emergency exits, as well as the situation that the emergency exit may be unable to open due to the ditching, this paper analyses the unusable conditions that may occur in all the emergency exits of the aircraft, and finds out the most typical case for consideration and analysis. For example, all exits can be used, one emergency exit on the wing cannot be used, and two exits on the rear cannot be used, and so on.
      Considering that one or several life rafts are not working properly when ditching, it is necessary to analyse the most typical situation that life rafts cannot be used according to the location and the actual seating capacity of life rafts. For example, the life raft with the maximum seating capacity cannot be used, the life raft nearest to the emergency exit cannot be used, and the life raft most convenient to use cannot be used.
      Combine the situation the emergency exit cannot be opened and the life raft cannot be used to find out the most typical situation or the most critical time of emergency evacuation time, and carry out comprehensive experimental analysis.
4.2 Experimentation time
According to the experiment process of the emergency evacuation for ditching and the need of calculation and analysis, the whole experimental process is decomposed step by step and the time of each step is measured by experiment. Specific time decomposition may include:

- t1: The time taken by the attendant to unlock the seat belt and stand up from the seat;
- t2: The time taken by the attendant to run from the attendant seat to the life raft storage, take out the life raft and get the life raft out to the ready handling state with the help of two designated passengers (for each life raft, there will be a corresponding t2);
- t3: The time taken by the two designated passengers to move the life raft packages taken off and ready for handling to the available emergency exit (according to the combination of the life raft and emergency exit, there will be a corresponding t3);
- t4: The time taken by the attendant to open the hatch (there will be a corresponding t4 for each hatch);
- t5: Total time for n (which represents the number of people participating in the experiment) crew members to jump from emergency exit to the life raft, which is the total evacuation time.
- t6: The total time taken by the n crew members to run at a specified distance in the cabin.

4.3 Calculating time
According to the above experimental time, the time of each analysis item can be calculated. Specifically include:

- T1: The time taken by the attendant to unfasten the seat belt and stand up. In the calculation analysis, the average t1 of all records is T1.
- T2: The time taken by the attendant to run to the life raft, take the life raft out of the storage and move it to the emergency exit with the help of the designated passengers. The combination of the measured t2 and t3 is T2. For different emergency exits and life raft storage locations, there will be a variety of situations of T2.
- T3: The time taken by the attendant to run from one emergency exit to another. The corresponding t3 multiply the coefficient C, which is the distance from one emergency exit to another divided by the distance from the life raft to the emergency exit in the experiment, is T3.
- T4: The time taken by the attendant to open the cabin door. Different hatch opening times can be obtained by averaging t4 measured at the hatch, taking the maximum value as T4.
- T5: The average time taken by the crew to jump from the hatch to the raft. T5=t5/n.
- T6: The time taken by the crew to move from one emergency exit to another. The average time of T6 measured multiply the coefficient C, which is got through the distance from one emergency exit to another emergency exit divided by the distance running in the experiment, is T6.
- T7: The time taken by the attendant to tie the life raft to a fixed rope, throw the life raft out of the door and pull the inflatable rope.
- T8: Inflation time of life raft. Due to the high cost of dumping and retracting life rafts, T7 can be estimated from competing aircraft of the same kind, and T8 can be provided by life raft suppliers.
- T9: The time, which is not counted in the above time measurement process, contains the time to judge the internal and external conditions of the aircraft after confirming the aircraft has stopped, and the clearance time of the attendant. The delay time T9 caused by the confusion can be estimated by referring to the experimental data of the competition aircraft.

5. Case analysis
This chapter takes a certain type of aircraft as an example, selects a typical case, performs calculation and analysis, and obtains the evacuation time in this typical case.

a) Total number of evacuees
When a type of aircraft makes emergency evacuation for ditching, the total number of evacuees includes 90 passengers, 2 pilots and 2 crew members, for a total of 94. The detailed cabin layout is shown in Figure 1.
b) Emergency exit arrangement
There are 4 emergency exits for a type of aircraft (shown in figure 2). All 4 doors are type I.

c) Life raft layout
A type of aircraft is equipped with three 38-seat (standard capacity) life rafts, whose overload capacity is 1.5 times of the standard capacity, that is, 57 seats. The three life rafts are arranged as follows: one is in the first suitcase on the left side of the cabin, another is in the second suitcase on the right side, and the third one is in the storage room behind the aircraft.

d) Test and Data Processing
Through experiments, the measured data are shown in Table 1 below.

Table 1. Time Data Processing Table

| step | Test measurement items                                      | Average value of measurement (s) |
|------|-------------------------------------------------------------|---------------------------------|
| t1   | the attendant unfastens the seat belt and stands up         | 1.62                            |
| t2   | time for passengers to pick up rafts at the life raft storage area | 3.51                            |
|      | raft fetching in front suitcase                             |                                 |
|      | raft fetching in rear storage room                          | 9.36                            |
| t3   | time for passengers moving rafts to corresponding emergency exits | 11.03                           |
|      | From the front suitcase to the front emergency exit         |                                 |
|      | From the rear storage room to the front emergency exit      | 9.42                            |
|      | From the rear storage room to the rear emergency exit       | 20.01                           |
|      | From the rear storage room to the front emergency exit      | 7.01                            |
| t4   | Time for opening the cabin door                             | 6.35                            |
|      | The front emergency exit                                    |                                 |
|      | The rear emergency exit                                     | 3.01                            |
| t5   | Total evacuation time of 16 passengers                      | 28.44                           |
| t6   | Running time of 16 passengers at specified distances in the cabin | 17.12                           |
The experimental process is shown in Figure 3 below.

**Figure 3.** Experimental process diagram

e) Typical case calculation

Typical cases are selected as follows: if a life raft in the front of a certain type of aircraft is found to be unusable, and two emergency exits in back cannot be used, all the crew members evacuate from the boarding gate and service gate.

In this typical case, the evacuation method will be carried out according to Figure 4.

![Evacuation Method](image)

**Figure 4.** Evacuation Method

The calculation results are shown in Table 2 and Figure 5:

**Table 2.** Computational Decomposition

| step | action | Time item | Time(s) |
|------|--------|-----------|---------|
| 1    | the attendant unfastens the seat belt and stands up the attendant runs to the life raft, with the help of the designated passengers takes the life raft out of the storage and moves it to the emergency exit | T<sub>1</sub> | 1.62 |
| 2    | the attendant opens the cabin door the attendant ties the raft to a fixed rope, throws the raft out of the door and pulls the inflatable rope | T<sub>4</sub> | 6.36 |
| 3    | Inflating life raft | T<sub>7</sub> | 45.00 |
| 4    | The time taken by 47 crew members to board the life raft and each person costs T0 (the front life raft can contain a maximum of 47 people) | T<sub>47</sub> | 83.90 |
| 5    | the latter attendant finds one of the front life raft cannot be used and move the latter life raft to the other side of the front emergency exit | T<sub>10</sub> | 25.47 |
| 6    | 47 crew members board the life raft at T0 per person | T<sub>47</sub> | 83.90 |
| 7    | the delay and confusion time | T<sub>9</sub> | 52.50 |
| 8    | total evacuation time | T | 332.76 |

5
In this case, while the former attendant open the front door of the aircraft, the latter attendant finds that the latter emergency exit cannot be opened. After the evacuation of the front passengers, the latter flight attendants move to the front and the remaining passengers evacuate.

So the total evacuation time: \( T = T_1 + T_2 + T_4 + T_7 + T_8 + T_{47} + T_{10} + T_{47} + T_9 \).

\( T_1 \), \( T_2 \) and \( T_4 \) can be measured directly through experiments. \( T_7 \) can be estimated by reference to similar competing models. \( T_8 \) can be provided by life raft suppliers.

\( T_{47} = 47 \times T_0 \).

\( T_{10} \) can be calculated from test data.

\( T_9 \) is confusion and delay time, and can be estimated by competing models.

The total evacuation time is 332.76 seconds. This time is much shorter than the floating time of a certain type of aircraft.

It can be concluded that the aircraft meets the relevant airworthiness requirements of emergency evacuation for ditching.

6. Conclusion

This paper analyses the airworthiness clauses of emergency evacuation for ditching firstly, and concludes that the emergency evacuation for ditching does not need real demonstration test to show conformity, so as to avoid the real verification test which involves a wide range of personnel, a large number of professions, a large amount of funds and a huge safety risk to the volunteers. On this basis, a method for calculating the emergency evacuation time for ditching is proposed, which is to decompose the total evacuation time for ditching of the aircraft's crew, and measure the decomposition time step by step through experiments, and then accumulate it to get the total evacuation time. Finally, taking a civil aircraft as an example, a typical case is selected for calculation and analysis, and the total evacuation time for ditching under this typical case is obtained, which provides data support for the airworthiness of emergency evacuation for ditching.

References

[1] Civil Aviation Regulation of China (CCAR), Part 25-Airworthiness Standards: Transport Category Airplanes. R4.

[2] Li Dan, Civil Aircraft Numerical Simulation Technology Based on CCAR25 Ditching Regulation, 2016.09, China Science and Technology Information, 43-44.
[3] Zhang Tao, Li Shu, Jiang Xiang, and Zhao Jinqiang. Analysis model and numerical simulation for civil aircraft ditching. 2010.03. *Journal of Nanjing University of Aeronautics & Astronautics*, 392-394.

[4] Von Karman T. The impact on seaplane floats during landing [R]. *NACA-TN-321*, 1929.

[5] Miloh T. On the oblique water entry problem of a rigid sphere [J]. J Eng Math, 1991, 25(1): 77-92.

[6] Li Bin, Yang Zhichun. Research progress on ditching of large transport aircraft. *High-level Forum on Key Technologies of Large Aircraft and (Shenzhen Guangdong China: 2007 Annual Academic Conference of China Aviation Society)*. 200-209.

[7] Jin Lei, Liu Youdan. Research on ditching Airworthiness Technology of Civil Aircraft. 2012.03. *Aeronautic Standardization & Quality*, 29-32.