MRJ Scale Model Test for Ditching Certification

Courtesy of Mitsubishi Aircraft Corporation

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The Mitsubishi Regional Jet (MRJ) is a 70–90-seat airliner intended for short- to medium-range routes. MRJ is planned to be operable on overwater flights to offer a greater variety of operational routes. To operate overwater flights, airplanes are required to be certified for ditching which is to ensure safety during a water landing. As a result, certification activities for ditching are currently in progress. The airplane behavior in a water landing was investigated and the acceleration and pressure data were acquired to ultimately demonstrate the safety of the occupants, availability of exits, and the adequacy of the flotation time for evacuation. These data will be evaluated and used to obtain ditching certification for the MRJ and future airplane programs.

1. Introduction

The long-awaited MRJ is the first domestically produced airliner in Japan since the YS-11. Currently, development has shifted from the design to manufacturing phase and various tests are being conducted to obtain an aircraft type certificate.

In addition to meeting the increased demand for regional air transportation, the MRJ is designed to operate on some of the major routes currently served by 100–170-seat airliners. In response to various requests from airlines, a choice was made to obtain ditching certification for the MRJ so that a greater variety of flight routes can be served. With ditching certification, overwater flights, on which the airplane flies a certain distance or time away from a shoreline or land suitable for an emergency landing, becomes permissible.

Ditching refers to a land-aircraft making an emergency landing on a body of water, e.g., the ocean or a river. Airliner ditching is relatively rare, but successful examples include the recent 2009 case of the A320 that landed on the Hudson River in New York, and from the 1950s, the case of a B377 that landed in the Pacific Ocean northeast of Hawaii after circling to wait for daylight.

This paper presents the MRJ scale model test conducted as part of ditching certification activities. This was the first major test in MRJ development and was conducted in the presence of representatives from the Japan Civil Aviation Bureau (JCAB) and the U.S. Federal Aviation Administration (FAA).

2. Airliner ditching conformance and purpose of ditching test

Airliner ditching situations can be categorized into two groups. The first group is called planned ditching, where an intentional water landing is made during an overwater flight as the airplane cannot return to land due to reasons such as a lack of fuel. The other group is called unplanned ditching, which encompasses all other situations of airplane entering into the water. An example of these situations is a water entry made near an airport unintentionally or without sufficient preparation time for ditching, due to any problems that might occur during take-off and landing.

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Ditching certification is for the planned ditching situations and it is necessary to demonstrate that the three elements described below are satisfied.

(1) The probability that the behavior of the airplane in ditching will cause injury to passengers and crew and impediment to escape is minimized.

(2) The airplane remains afloat for a sufficient period of time for passengers and crew to leave the airplane and enter the life rafts.

(3) The airplane is equipped with appropriate ditching equipment.

The purpose of the scale model test for ditching was, for element 1, to establish the optimum airplane attitude (pitch angle) to minimize passenger impact in ditching, and for element 2, by taking pressure data on the bottom of the fuselage, to ensure that damage resulting in rapid flooding would not occur.

This kind of ditching test is conducted by aircraft manufacturers, but not frequently. Once the test data are acquired, they are used for subsequent aircraft development for a long period of time. The MRJ ditching test was conducted because there were no prior ditching data available for the MRJ. The acquired data, like ditching test data for other aircraft, will be used over the long term.

3. MRJ ditching model test

3.1 Overview of test, facility and ditching model

The test was conducted by launching a scale model with a catapult to have the model land in a water tank. A larger scale model would simulate the actual (full-scale) airplane better and therefore provide more accurate test results, as well as have more room for instruments. On the other hand, a larger scale model would result in a higher catapult release speed and require a longer catapult rail for launch, as well as a longer water tank for landing.

Given these factors, a 1:11 scale was selected and the model was landed in an approximately 50 m long water tank. An overview of the test setup is shown in **Figure 1**. The testing was conducted with the support of TRaC Global Limited, a U.K. company with a wealth of experience in this kind of testing.

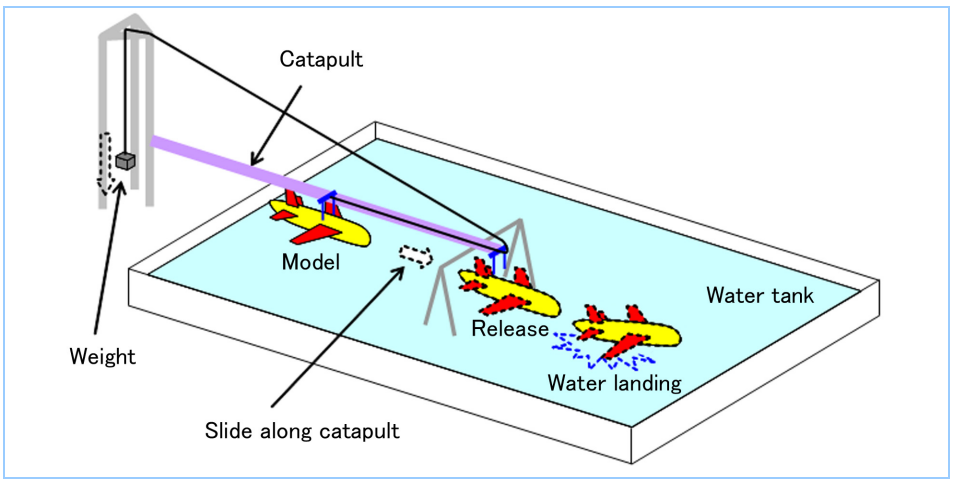


Figure 1 Overview of ditching model test setup

Because airplane behavior and the impact of ditching were to be evaluated in the ditching test, the test conditions were set so that the Froude number, which is calculated using the following formula, would be the same for the model as that of the full-scale airplane.

$$Fr = U / \sqrt{gL}$$

Where Fr is the Froude number, U is the airplane velocity (m/s), g is the gravitational acceleration (m/s^2), and L is the airframe length (m).

Testing a model at the same Froude number as the full-scale airplane meant that the effect on the latter could be inferred from the test results on the former. This principle is often used for scale model ship tests in which the water force on the model ship is measured. **Table 1** shows the parameter relationships between the model and the full-scale airplane when the Froude number remains the same. Based on these parameter relationships, the full-scale results of ditching will be predicted.

Table 1 Parameter relationships between model and full-scale airplane for testing using same Froude number as full-scale conditions (linear scale reduction: 1/N)

	Model	Actual airplane
Length	L	NL
Weight	W	N^3W
Velocity	V	$\sqrt{N}$ V
Time	t	$\sqrt{N}$ t
Acceleration	a	a
Pressure	p	Np
Force	F	N^3F

Certain parts of the airplane, such as the engines, may become detached in ditching. For those parts, the model was fabricated with scale-strength materials so that the detachment could be simulated in the test. This design would allow more accurate simulation of the airplane motion and therefore enable more accurate measurements of the forces acting on the airplane. For parts for which strength scaling is difficult, e.g., the wing-body fairing and landing-gear doors, removable designs were employed so that the detachment effect of those parts could be evaluated.

3.2 Data measurements

As shown in **Figure 2,** accelerometers were installed in three locations (near the center of gravity, cockpit and the aft pressure bulkhead), and pressure transducers were installed in the bottom of the fuselage, most of which were in the aft where the first contact with the water was expected. In addition, gyroscopes were installed to acquire attitude data, and video recordings were made to confirm the behavior of the model.

In the process of determining the measurement locations and data processing method, a study on the impact load of water landing conducted jointly by MHI and the Aviation Program Group of the Japan Aerospace Exploration Agency was consulted.

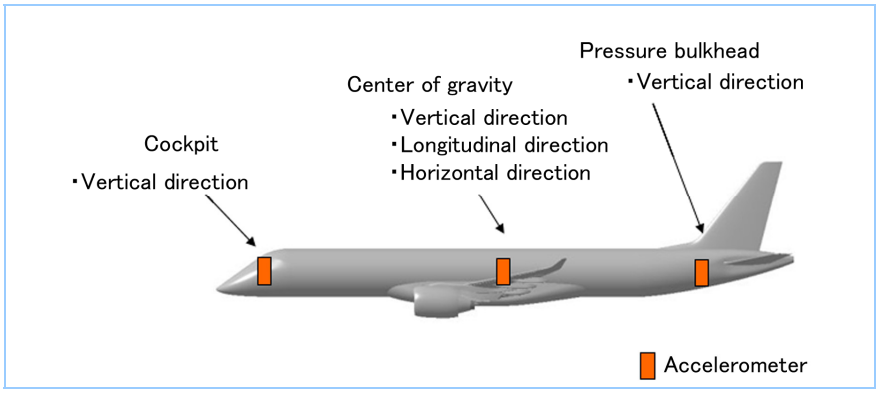


Figure 2 Accelerometer installation locations

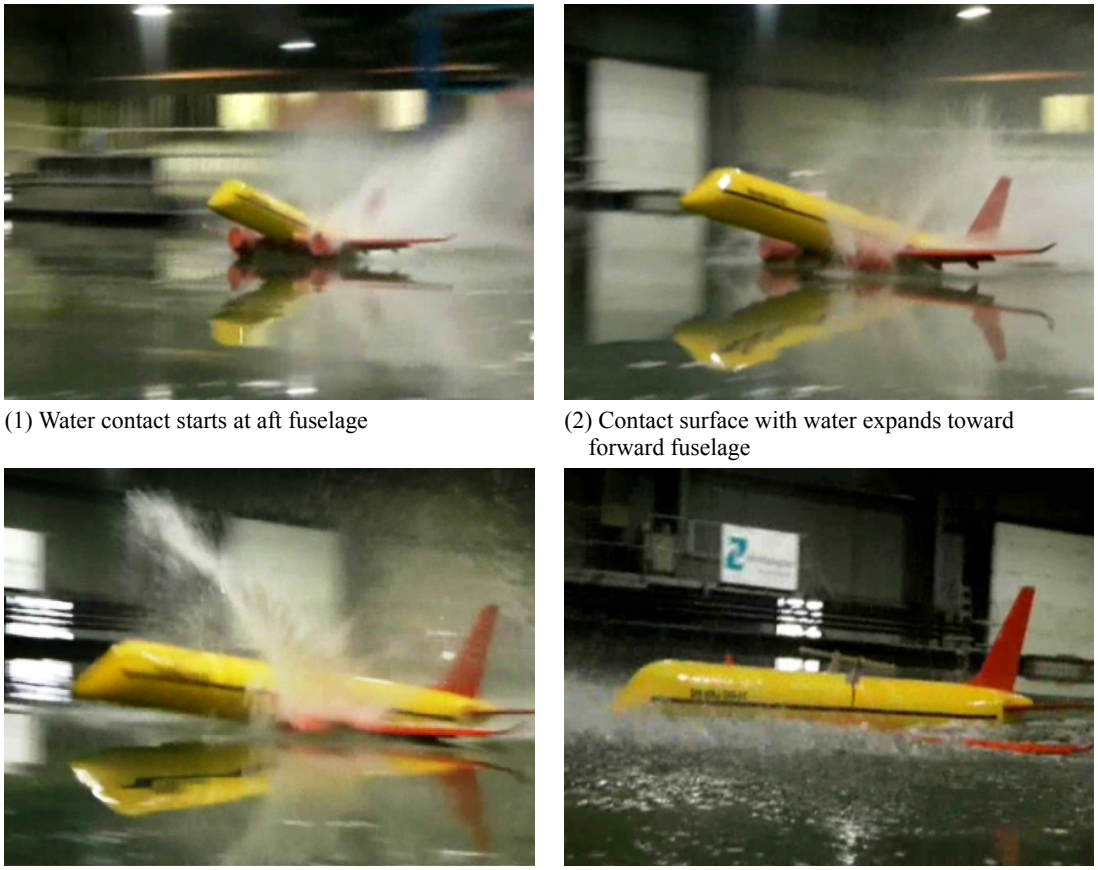
3.3 Test cases

As previously stated, the purpose of the test was to select the optimum pitch angle and obtain data to demonstrate the adequate strength of the fuselage. Therefore, the parameters of flight velocity, pitch angle, weight, center of gravity and descent rate were varied among test cases. Since the airplane is considered fully controllable when landed on water, landings with a nose down attitude or a large roll angle were excluded.

4. Test results

Figure 3 shows a typical sequence of photographs of the model landing in water.

In a water landing, suction force (negative pressure) is generated on the aft fuselage where contact with the water occurs first, causing an increase of nose-up attitude. When this increase in nose-up attitude is large, it poses a greater risk, in the following nose-down motion, such that the airplane is slammed into the water. On the other hand, landing at a very shallow angle is more likely to cause the airplane to skip or porpoise. In this ditching test, a landing attitude resulting in relatively small accelerations was found where these undesirable behaviors did not occur. It was confirmed, therefore, that the MRJ was capable of stable water landing at the optimum pitch attitude or its vicinity.



(1) Water contact starts at aft fuselage

(2) Contact surface with water expands toward forward fuselage

(3) Water contact further progresses and extends to engine nacelles

(4) Fuselage completely contacts with water from nose to tail; deceleration subsides

Figure 3 Typical behavior of MRJ in water landing

Figure 4 shows a sample of the data acquired during this test. Although the details are omitted here, it shows that both vertical acceleration and longitudinal deceleration reached peak values shortly after the initial contact with the water and then diminished. These data will be presented in the compliance document for the certification and reviewed by the authorities upon submittal. The desired data of pressure, primarily on the bottom of the aft fuselage, were acquired, and the loads on the fuselage were confirmed.

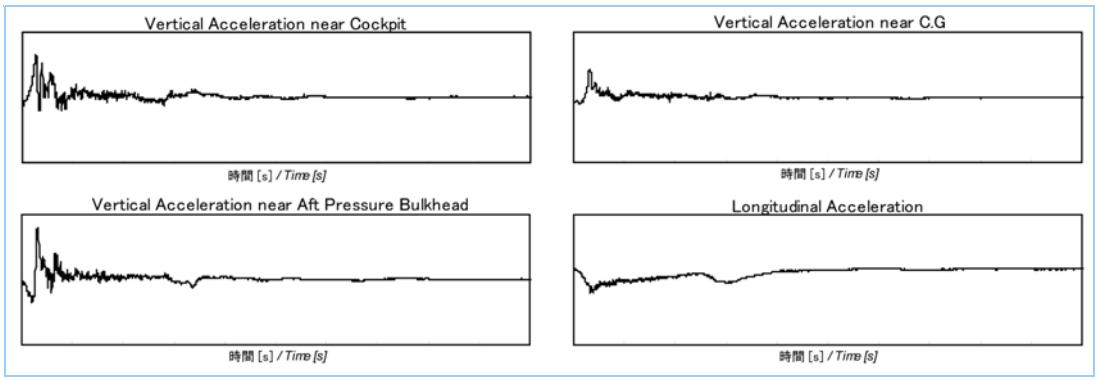


Figure 4 Examples of acceleration data acquired in ditching test

5. Conclusion

From this ditching model test, the basic data were successfully acquired to demonstrate that the probability of injuries to passengers and crew and impediment to escape is minimized, and the flotation time is sufficient to allow occupants to evacuate the airplane. The next step is to evaluate the effect of each parameter. With a ditching procedure in which the evaluation results are reflected, along with the results of the strength analysis, it is our aim to obtain ditching certification for the MRJ.