Crashworthiness Research on Cabin Structure at JAXA

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What is JAXA?

JAXA : Japan Aerospace Exploration Agency

Aims : JAXA will promote research and development in aerospace, deepen its intelligence, and contribute to achieving a safe and prosperous society.

Three Japanese organizations that had previously promoted separate research and development in aerospace were merged as JAXA on October 1, 2003. Through the merger of the Institute of Space and Astronautical Science (ISAS), the National Aerospace Laboratory of Japan (NAL), and the National Space Development Agency of Japan (NASDA) into a core space agency, JAXA will comprehensively promote all space development, from basic research to development and utilization.

Organization:

Program Office
- Aviation Program Systems Engineering Office
- Safety and Quality Assurance Office

Civil Transport Team
- Clean Engine Team
- Supersonic Transport Team

Operations and Safety Technology Team
- Unmanned and Innovative Aircraft Team

Crashworthiness Section

JAXA
- Office of Space Flight and Operation
- Office of Space Applications
- Institute of Aerospace Technology
- Institute of Space and Astronautical Science
- Aviation Program Group
Philosophy: To nurture the growth of the aviation industry and lay the groundwork for breakthrough for the future of air transport.

Two Basic Policies:

1. Responding to requests from society as a core organization in the aviation circles of Japan
2. Opening up the next generation through advanced technology development projects
Objectives of Crashworthiness Section

- Establish crash simulation technique on aircraft crashworthiness in Japan
- Improve cabin safety to improve survivability at crash accidents
The more impact energy can be absorbed, the more cabin safety and survivability can be improved.
Our Research History

- Shock absorbing device research (1993-)
- Scale model of fuselage under-floor structure research (1998-2000, 2004-)
- YS-11 airliner fuselage section drop tests
- Seat test in ATR42-300 drop test - Jul. 2003
- MH2000 Helicopter full-scale crash test - Feb. 2004
- Retired YS-11 airliner fuselage section drop tests
  (Now we are planning)
Substructure(1)

Underfloor Scale Structure Model

Built underfloor analytical model verified by real drop tests with underfloor scale model

Experiment

Analysis

Expanded

Fuselage Section
Structure Scale Analytical Model
Governed impact failure mode changes with components stiffness distribution

Frames absorb larger impact energy than other components

Angle of attitude at the contact with ground has effects on crush results largely
Scale model fuselage section drop tests and analysis (1)

Seat and passengers substituted by corresponding weights.

These articles simulated conventional fuselage structure, not a specified aircraft.
Procedures of Test and Analysis

1. Pre-Analysis

2. Test of Basic-type Article
   - Drop Height: 3.2m Impact Velocity: 7.9m/s (26fps)
   - Acc: 65, Strain: 63, High-speed Video: 3, VHS: 2

3. Improve simulation model of improved-type article with the test results of the basic-type test

4. Test of Improved-type Article
   - Drop Height: 1.9m Impact Velocity: 6.1m/s (20fps)
   - Acc: 65, Strain: 63, High-speed Video: 3, VHS: 2

5. Post-Analysis for improvement accuracy
Scale model fuselage section drop tests and analysis (3)

Pre-Analysis

Basic-type Test

Drop Height: 3.2m  Impact Velocity: 7.9m/s (26fps)
Scale model fuselage section drop tests and analysis (4)

**Improve simulation model**
**Improved-type Model**

**Improved-type test**

**Drop Height: 1.9m**  **Impact Velocity: 6.1m/s (20fps)**
Improved-type test

Post Analysis

Drop Height: 1.9m  Impact Velocity: 6.1m/s (20fps)
Comparing accelerations between test and analysis

Pre-test

Improved after 1st test

Post Test

Compare accelerations on Weight

In graphs, blue lines: test, red lines: analysis
Rivet Modeling

Make a Rivet Model for Crash Simulation with LS-DYNA in order to improve accuracy of simulation.

Use Modified ARCAN method like ONERA method.

\[
\left( \frac{|f_n|}{S_n} \right)^a + \left( \frac{|f_s|}{S_s} \right)^b \geq 1
\]
Specifications

Fuselage Diameter : 2.88 m
Max.T/O Weight : 24.5 ton
Passengers : Max. 64
Wing Span : 32.0 m
Overall Length : 26.3 m
Tail Height : 9.0 m
Cruising Speed : 450 km/h
First Flight : 8/30/1962
### Fuselage sections for vertical drop tests

<table>
<thead>
<tr>
<th>Test article</th>
<th>FWD Section(2nd)</th>
<th>AFT Section(1st)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Longitudinal Length</strong></td>
<td>3.13 m</td>
<td>3.36 m</td>
</tr>
<tr>
<td><strong>Weight (incl. ATDs)</strong></td>
<td>1600 kg</td>
<td>1510 kg</td>
</tr>
<tr>
<td><strong>Number of Seats</strong></td>
<td>6 twin-seats</td>
<td>4 twin-seats and 2 Equiv. Weights</td>
</tr>
<tr>
<td><strong>Passenger Dummies</strong></td>
<td>12 by ATDs</td>
<td>8 by ATDs and 4 by Equiv. Weights</td>
</tr>
<tr>
<td><strong>Impact Velocity</strong></td>
<td>7.4 m/s (25 ft/s)</td>
<td>6.1 m/s (20 ft/s)</td>
</tr>
<tr>
<td><strong>Impact Energy</strong></td>
<td>47 kJ</td>
<td>28 kJ</td>
</tr>
<tr>
<td><strong>Test Date</strong></td>
<td>Jul. 5th, 2002</td>
<td>Dec. 20th, 2001</td>
</tr>
</tbody>
</table>
Fuselage Section of YS-11 Drop Tests (3)

(a) FWD Section
2002.7.5

(b) AFT Section
2001.12.20

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Although impact energy of the FWD test was 1.7 times as much as that of the AFT test, the peak acceleration of the FWD test was 1.2 times as much as that of the AFT test.

If underfloor structure absorbs large impact energy, the accelerations on the floor can be reduced.
Fuselage Section of YS-11 Drop Tests (5)

Simulation Results
Forward Section

25 ft/s impact velocity
Full-Scale Crash Test of MH2000 Helicopter (1)

Overview Video Picture of the Crash Test


Offered by MHI
Full-Scale Crash Test of MH2000 Helicopter (2)

Simulation Result of Crash Test as of now

Numerical Simulation with LS-DYNA
Results: Acceleration responses (Left keel beam)

- Cargo
- Front of the co-pilot seat
- Rear of the third seat row
- Front of the second seat row

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Objects of Research with Retired YS-11

Type: YS-11A-500
First FLT March 12th 1973
Total FLT Hour 57,002 Hour
Total FLT Cycle 57,273 Cycle

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Value</th>
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<tbody>
<tr>
<td>Length</td>
<td>26.3m</td>
</tr>
<tr>
<td>Width</td>
<td>32.0m</td>
</tr>
<tr>
<td>Height</td>
<td>8.98m</td>
</tr>
<tr>
<td>Main Wing Area</td>
<td>95.0m²</td>
</tr>
<tr>
<td>Aspect Ratio</td>
<td>10.8</td>
</tr>
<tr>
<td>External Diameter of Fuselage</td>
<td>2.88m</td>
</tr>
<tr>
<td>Max. Taking off Weight</td>
<td>25,000kg</td>
</tr>
<tr>
<td>Max. Landing Weight</td>
<td>24,500kg</td>
</tr>
<tr>
<td>Max. Payload</td>
<td>7,038kg</td>
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<tr>
<td>Passengers Max.</td>
<td>64</td>
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<tr>
<td>Cruising Velocity</td>
<td>472km/h</td>
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<tr>
<td>Range</td>
<td>2,242km</td>
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Objects

- Acquisition of fatigue data for design of new transport and improvement of continuing aviation safety
- Research for application of new composite material to new transport
- Verification Test of impact simulation of bird striking and tire bursting

And…
Crashworthiness Research on Retired YS-11

Retrofit under floor structure of fuselage section

Vertical Drop Test

Verification

Target:
Components (Shock Absorbing Devices), Structural Configuration, Composite Materials, Shock Absorbing Materials, etc.

Schedule:

<table>
<thead>
<tr>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
</tr>
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<tbody>
<tr>
<td>Preparation &amp; Pre-Analysis</td>
<td></td>
<td></td>
<td></td>
<td>Verification &amp; Post-Analysis</td>
<td>Test</td>
<td></td>
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Proposition:
Test bed for crashworthiness test in cooperation research with domestic and overseas universities and research institutes.
Summary

◆ Introduce crashworthiness research activities of our section

◆ Propose cooperation research by using the retired YS-11 fuselage sections

If anyone is interested in cooperation research with us by using the retired YS-11 articles, please contact me. shouji@chofu.jaxa.jp

Thank you for your attention!