Crash of Japan Airlines B-747 at Mt. Osutaka

Dec. 8th, 1985, near the ridge of Mt. Osutaka, Ueno, Gunma Prefecture

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(Summary)

On August 12th, 1985, JAL flight 123, a B-747 bound for Osaka Airport, went out of control 12 minutes after the take-off from Haneda Tokyo International Airport, as it approached cruising height of 7,200m, because of fatigue failure of the aft bulkhead, followed by the structural failure of the vertical fin, resulting the crash at Mt. Osutaka, Ueno, Gunma Prefecture after 32 minutes of irregular flight. By this accident, 520 of the 524 passengers and crew on board were killed, making it the worst single aircraft accident in the world.

1. Component

Aft Pressure Bulkhead

2. Event

The aircraft had received large-scale repairs at the maintenance field at Haneda in June 1978, after it experienced a tail hit landing at Osaka International Airport. Fatigue failure of the aft bulkhead was due to a mistake during the repairs at that time. Figures 1~3 show the details of the riveted joint that was incorrectly repaired by the engineering staff from Boeing. The repair was not conducted in accordance to the company procedure. The repair was made using two separate splice plates instead of single plate. As a result, the entire load was transmitted through the center rivet row only, and multiple site fatigue cracks initiated from the rivet holes of the center row soon after the repair. These cracks propagated by the cyclic pressurization of the aircraft and finally caused the unstable fracture of the whole structure after a total of 12,319 cycles. The repair mistake extended across two bays, which is about one-meter in length. As this was longer than the critical length necessary for the unstable failure of the structure, the crack propagated by the interlinking of adjacent small cracks without being arrested.

As is shown in Fig. 3, as a result of the mistake in the repair, the entire membrane stress induced by internal pressure was transmitted through just the center row fastener. Therefore, it can be judged that the fundamental mechanism of load transmission was not understood at all by the maintenance engineers.

The following issues are also pointed out.

The final check of the repair work made by the Airline representatives and air transportation authority was insufficient. Even though the site of the repair mistake was covered with sealant, the check should have been able to identify the problem.

The issue of periodical maintenance and inspection over the course of the 12,319 flights conducted after the repair was also problematic, since the inspection was not conducted before accident.

3. Course

Many structural parts of the vertical fin were retrieved from Suruga Bay, where the first decompression occurred. The most of the wreckage was found at the site of crash. The wreckage of the aft fuselage was reconstructed at the Chofu Airfield, and the initial investigation focused mainly on the cause of the fracture of the aft pressure bulkhead.

4. Cause

The direct cause of the accident was the fatigue failure of the aft bulkhead as shown in Fig. 1. The central hydraulic controlling system and APU located at the back of bulkhead as well as the box-beam structure of the vertical fin were blown off by the large mass of air moving a hypersonic velocity that was induced by this breakage.

As a result of the total loss of hydraulic pressure, the aircraft went out of control and finally crashed near the ridge of Mt. Osutaka, although it was able to stay in the air for 32 minutes and avoid an immediate mid-air explosion.

5. Immediate Action

Among other investigations, the aft pressure bulkhead where the large-scale repairs had been conducted after the tail hit accident at Osaka air port seven years ago were closely examined. Detailed fractgraphy observations of the fracture surface of the fastener joint were made.

6. Countermeasure

Even though the main cause of the accident was the mistake during the repair of the pressure bulkhead conducted seven years before the accident, the direct cause that led the aircraft losing control was the loss of the hydraulic control unit and the vertical fin. The Aircraft Accident Investigation Commission advised the manufacturer and operator to reinforce the torsion box structure by installing a plate to prevent the high-speed airflow from entering the box beam in the event that the pressure bulkhead does burst. The advice was put into practice.

7. Knowledge

(1) Inspections conducted at appropriate intervals are indispensable, especially after a large-scale repair or design change has been carried out in order to ensure that the designer's intention is completely satisfied.

(2) Fundamental training and education in areas such as the mechanics of materials should be provided in detail even for the engineers at the site.

(3) The people who are responsible for signing the document of approval of repairs should check the site carefully to assure that those repairs were conducted as desired.

8. Background

The system for ensuring the structural integrity after a large-scale repair was inadequate. At JAL, the concept of making frequent inspections that is essential for ensuring the integrity of the structures, especially when a large-scale repair was conducted as the present case, did not exist.

9. Sequel

The fast and unstable fracture of the pressure bulkhead of the jumbo jet aircraft was the result of the propagation and linking up of multiple site cracks that emanated from the rivet holes. Figure 6 shows the behaviors of these cracks at the location L18 of the fastener joint. Because of the mistake in the repair of the bulkhead, the load was transmitted through the center row fastener only. Because the stress became highly concentrated there, multiple-site cracks started from many of the fastener holes, and those cracks linked-up to became long enough after 12,300 pressurization cycles to cause the fracture. In fact, it was reported that fatigue cracks were observed at more than 30 of the 50 fastener holes in the repaired area, and total length of the cracks was more than 270 mm. These damages led to the fatigue failure of the bulkhead in the last flight.

One reason why multiple-site cracks occurred is that the old rivet holes were used again at the repair without resizing the holes. The JAL accident showed the potential danger of multiple-site cracks.

Three years later, on April 4th, 1988, another accident caused by multi-site damage occurred in Hawaii.

This time a large part of the fuselage structure of a B-737 operated by Aloha Airlines was blown off while cruising. These two accident cases that were caused by multiple-site damage (MSD) and multiple-element damage (MED) showed that the damage tolerant design concept based on the behavior of a single crack is insufficient for such cases.

Since the accident of Comet-I, disasters caused by fatigue failure was repeated after 31 years. The cause of the Comet accident was a design problem that was common to the entire fleet, while in the case of the JAL accident the problem was in the repair and therefore was an individual matter. By tracing the history of fatigue related accidents, one can suggest the direction of future research on this subject.

10. On the Side

In 1989, a similar accident occurred in the USA. A DC-10 operated by United Airlines lost control when the entire hydraulic system was totally damaged because of the failure of the compressor fan disk of the first stage in the second engine located at the empennage. However, in contrast to the JAL case where the cockpit crew did not recognize the severity of the situation and insisted on returning to the original airport, the crew of DC-10 correctly understood that the engine controlling the hydraulic unit was fractured. Therefore they tried to land at the nearest airstrip as soon as possible. Although they were forced to make crash landing and a fire broke out soon after the touch down, more than 60% of the people on-board survived.

If the pilot is able to correctly assess what is occurring on the aircraft and operate according to that assessment, the worst results can always be avoided. In the case of the JAL accident, the pilot thought that he could return safely because he thought that only the rear cargo door (R 5 Door) was fractured, even though there had been time to understand the facts of the situation correctly with the support of other aircraft, as the aircraft was able to stay in the air for 32 minutes.

11. Social Impact

As the accident involved a Jumbo Jet that is used all over the world, much concern was raised just after the tragedy as to whether or not the accident cause was common to the fleet.

The accident was long talked about as a tragedy, because so many people were killed. JAL, the biggest airline in Japan, lost much of its credibility, and it took long time to regain consumer trust in the company and restore the number of air travelers in Japan.

12. Information Source

(1) Aircraft Accident Investigation Report 62-2 (1987), Aircraft Accident Investigation Commission, Ministry of Transportation of Japan.

(2) H. Kobayashi, Safety Engineering, 26-338 (1987).

13. Primary Scenario

01. Ignorance
02. Insufficient Knowledge
03. Lack of Learning
04. Carelessness
05. Insufficient Precaution
06. Carelessness of Worker
07. Misjudgment
08. Misperception
0 9. Misapprehension/Misread
10. Ignorance of Procedure
11. Insufficient Communication
12. Lack of Confirmation
13. Usage
14. Maintenance/Repair
15. Change of Components
16. Pressure Bulkhead
17. Usage
18. Maintenance/Repair
19. Poor Inspection
20. Failure
21. Fracture/Damage
22. Fatigue
23. Unstable Fracture of Bulkhead
24. Failure
25. Fracture/Damage

26. Fracture of Vertical Fin
27. Non-Regular Action
28. Emergency Action
29. Stricture of Judgment
30. Malfunction
31. Poor Hardware
32. Malfunction of Control System
33. Failure
34. Large-Scale Damage
35. Crashes
36. Damage to Society
37. Change in Perception
38. Distrust to Enterprise and Authority
39. Decrease in Customers

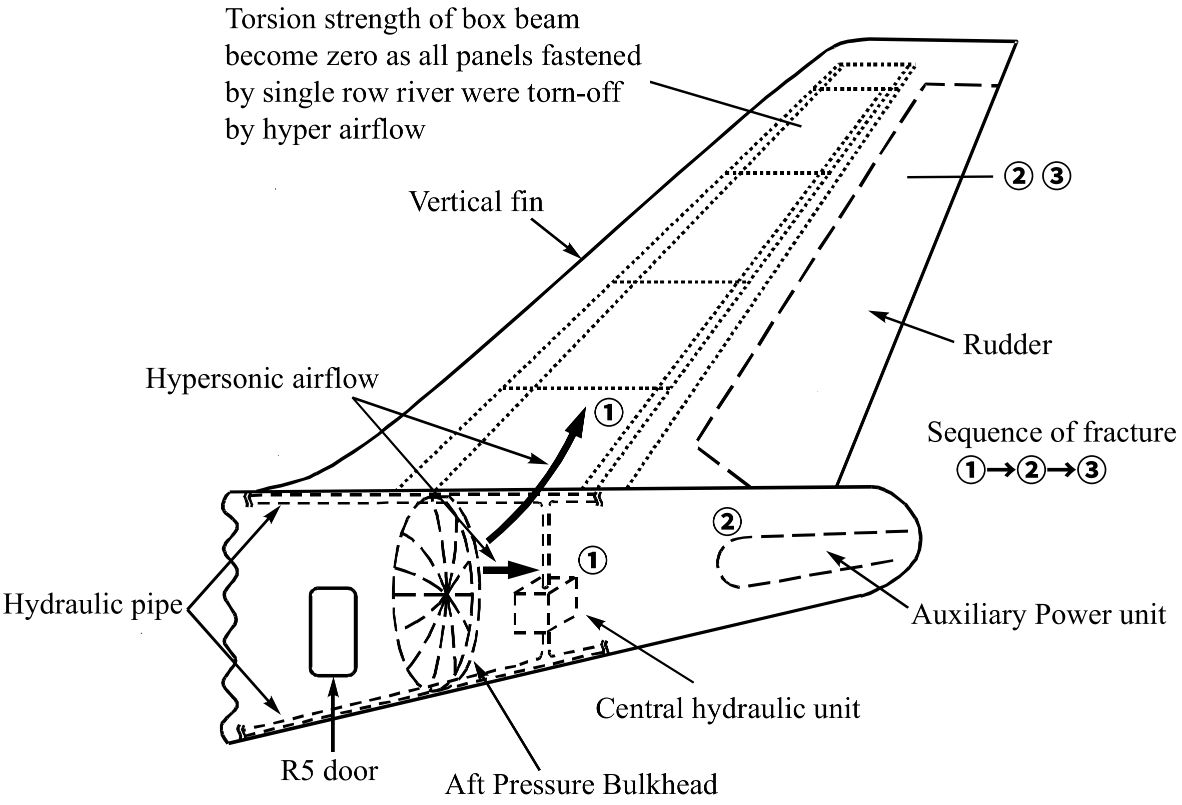


Fig. 1 Structure near the Empennage.

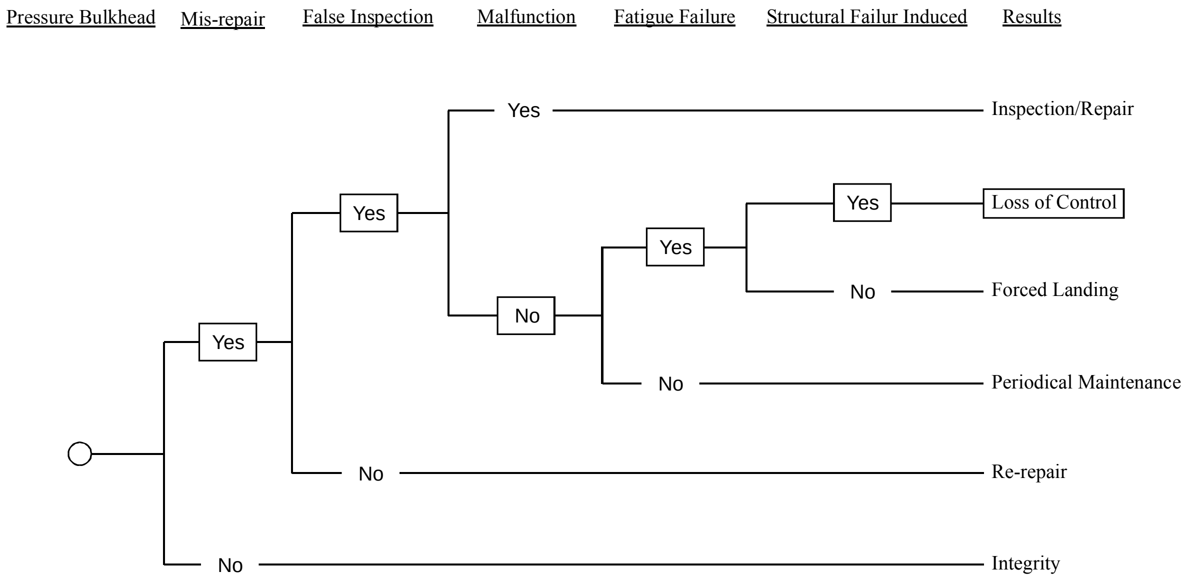


Fig. 2 Event Tree Analysis of JAL Accident Caused by Miss-repair of AFT Pressure.

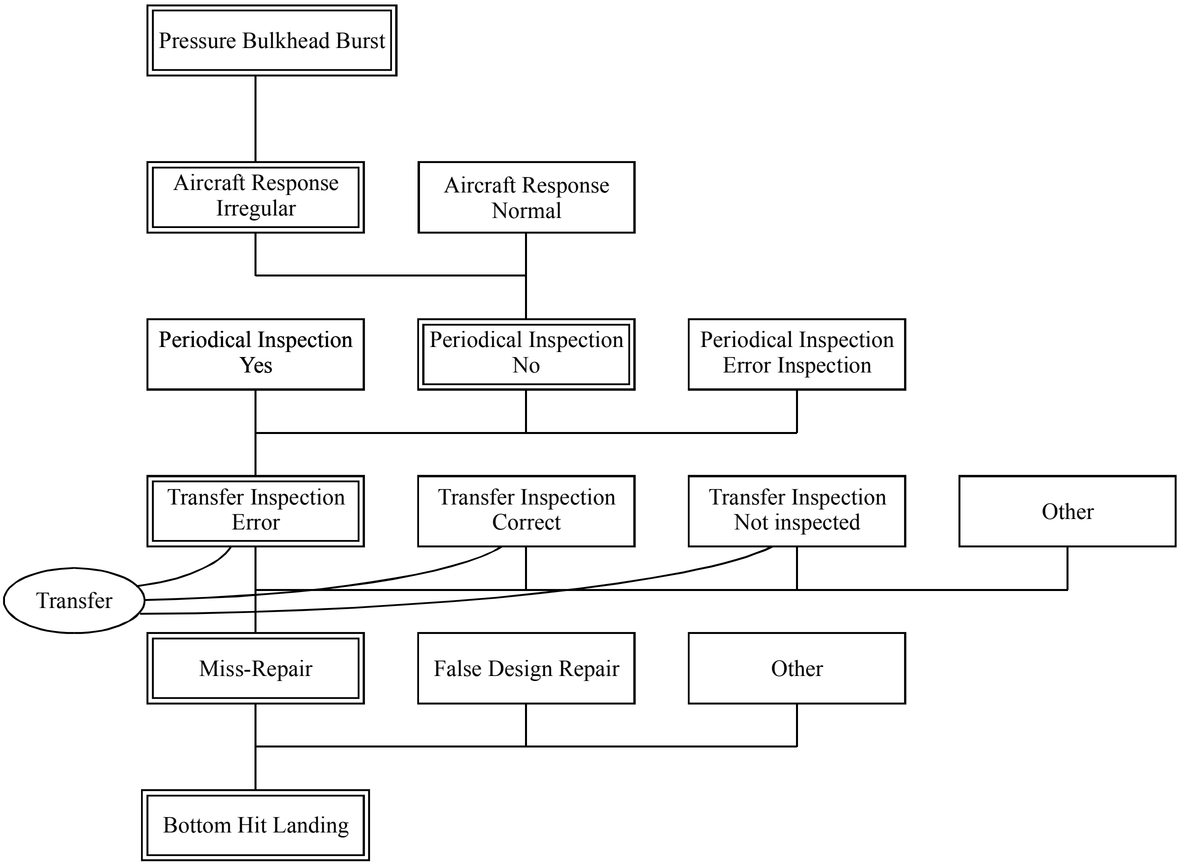
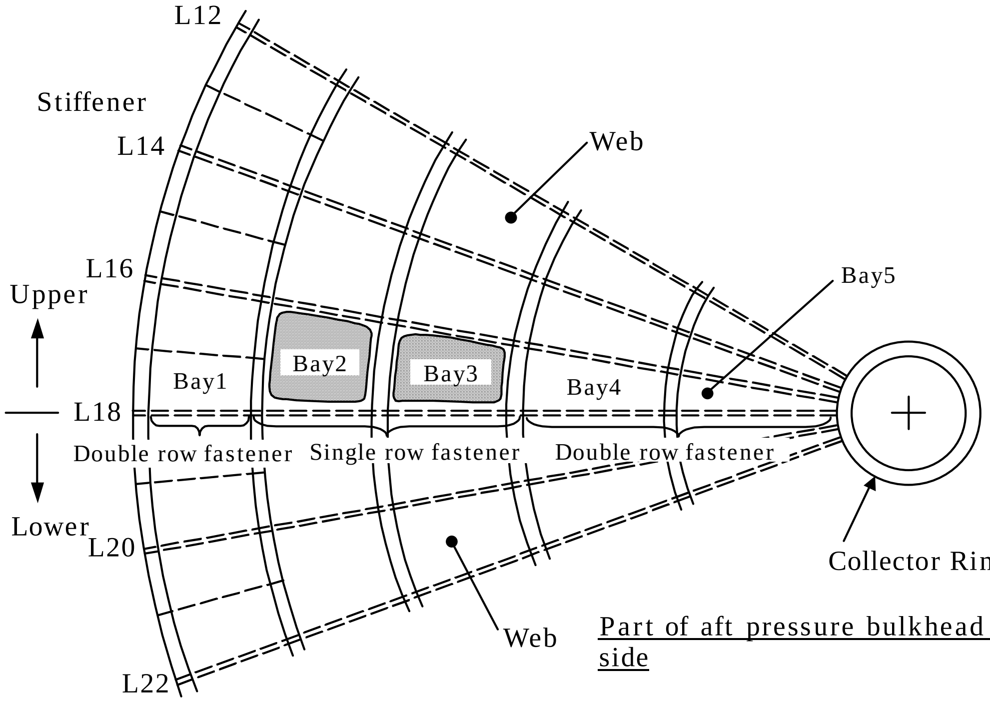


Fig. 3　Fault Tree Analysis of JAL Accident Caused by Miss-repair of Aft Pressure.



Part of aft pressure bulkhead seen from Tail side

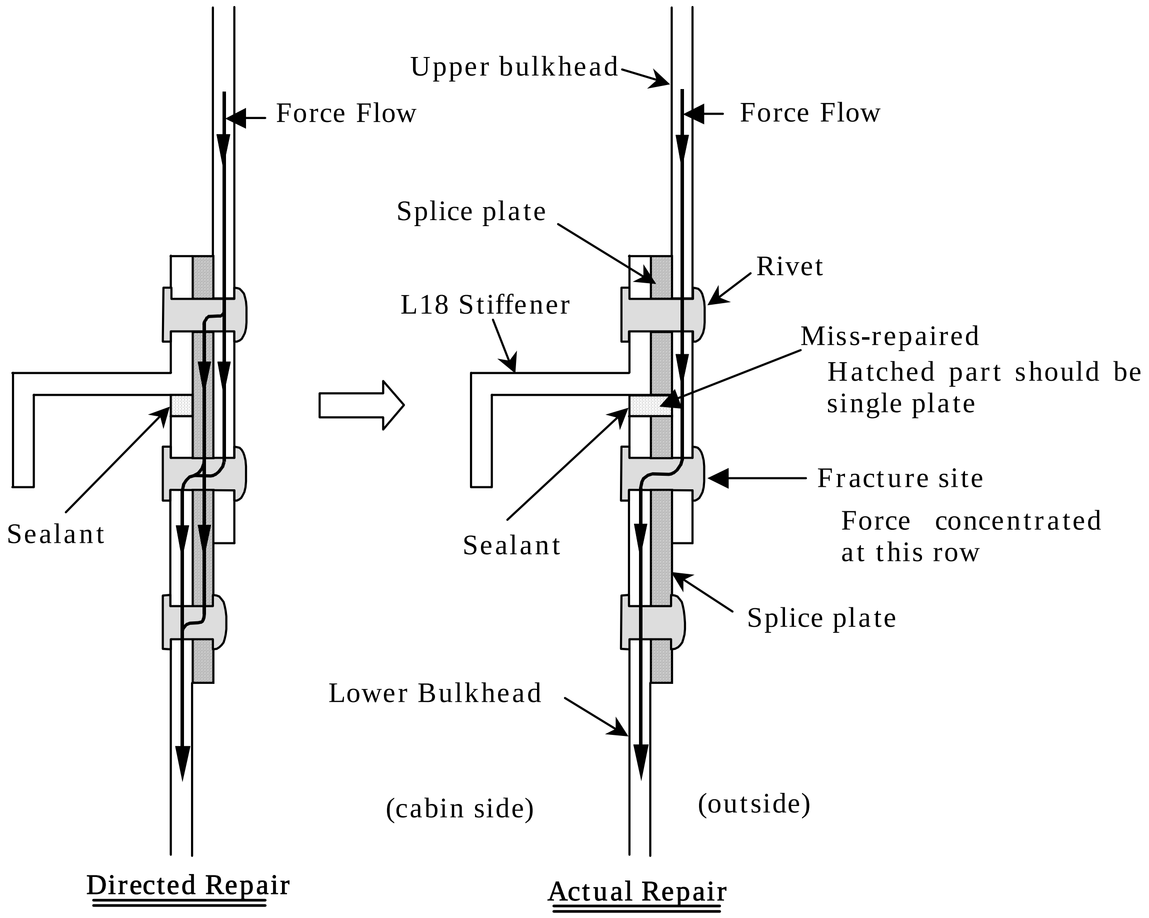


Fig. 4 The Aspect of Aft Bulkhead Repair.