# EMBRAER170 WING BIRD STRIKE TEST

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## Abstract

*Kawasaki Heavy Industries, Ltd. is responsible for design of wing leading edge structure of Embraer170 twin-engine commercial jet airliner. Kawasaki performed bird strike test and analysis on the wing leading edge structure of Embraer170. This paper presents the design and analysis of the protection structure in pylon area against bird strike. Bird strike analysis using LS-DYNA shows good agreement with the test results.*

## 1 Introduction

FAR 25.571 (e) requires successful flight completion after strike with a 4-pound bird on aircraft. Kawasaki performed the wing bird strike test as a certification test for the substantiation of the flight safety after bird strike on the wing structure.

In order to reduce development risk against bird strike, Kawasaki focused the design and analysis efforts on the weakest area of the structure. Improvement of the design was done after the bird strike analysis, which revealed that the preliminary design did not have enough strength against bird strike.

The bird strike test proved that the improved design has enough strength. Improvement of the bird strike analysis method was accomplished using the bird strike test results.

## 2 Design of Pylon Cover

Fig. 1 shows the wing leading edge and pylon structure of Embraer170. Interface area between the pylon upper surface and the wing leading edge is one of the critical points in the wing leading edge structure for bird strike. Beneath the pylon cover, fuel lines run to the pylon from the wing front spar. The pylon cover must withstand bird strike without tear or large deformation to protect the fuel line. The rupture of the fuel lines will result in fuel leakage and this should not happen.

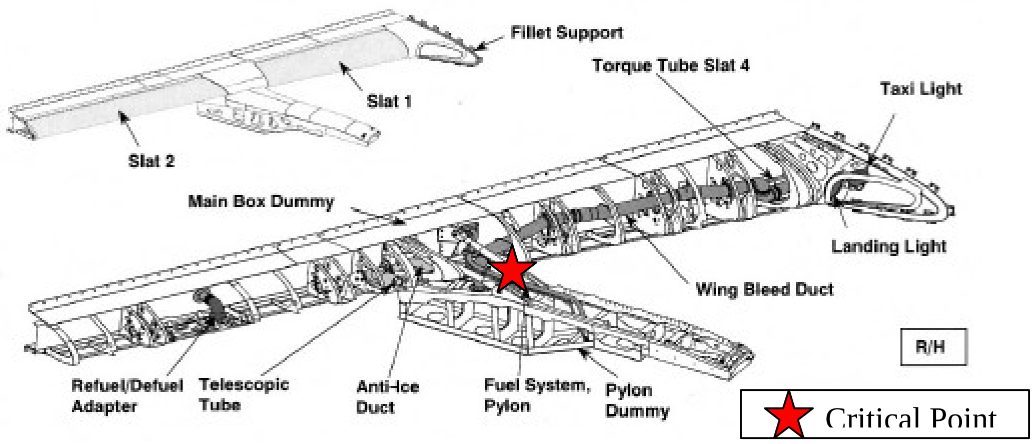



Fig.1 EMBRAER170

In the preliminary design of the pylon cover, an angle was provided in the pylon cover as a protection. As shown in Fig. 2 (a) and (b), bird strike analysis of the preliminary design revealed that the deformation of the pylon cover was large and the deformed structure hit the fuel line.

We made design improvement to avoid the excessive deformation of the pylon cover adding an H-section beam at the leading edge of the pylon cover. The H-section beam was intended to contact with two pylon link rods at the event of bird strike and the rods would support the beam. The bird strike analysis of the improved design is shown in Fig. 2 (c).

## 3 Bird Strike Test

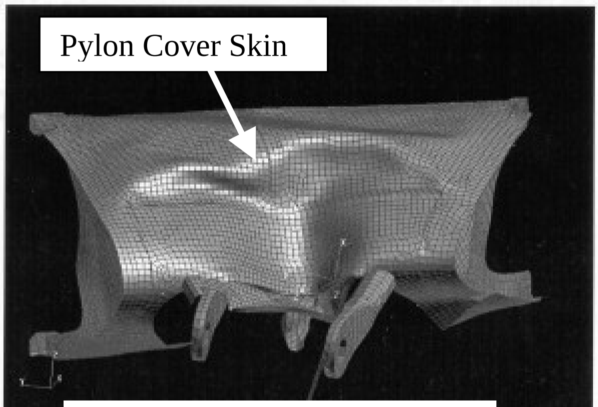
The bird strike test article of the wing leading edge is shown in Fig. 3. The test article consists of two leading edge slats, wing fixed leading edge structure with a front spar and a pylon. Dummy wing skin and ribs of the wing box structure were provided to support the front spar. The test article is mostly made of aluminum alloy. Right-hand side of the structure was used as the test article.

Birds of 4-pound weight were shot from the air gun (Fig. 4) at the cruise speed of the airplane. Total of 9 shots were performed in the test. The shots were selected to evaluate the weakest area for bird strike and one of them is the pylon cover area. High-speed video camera was used to record damage process and to measure the actual bird strike speed.

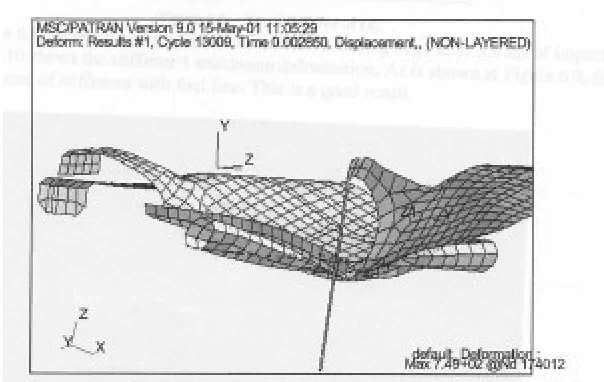
Embraer170 Wing leading edge structure withstood all 9 shots without any serious damage. In this paper, we discuss bird strike on the pylon cover.

## 4 Bird Strike Analysis – After Test

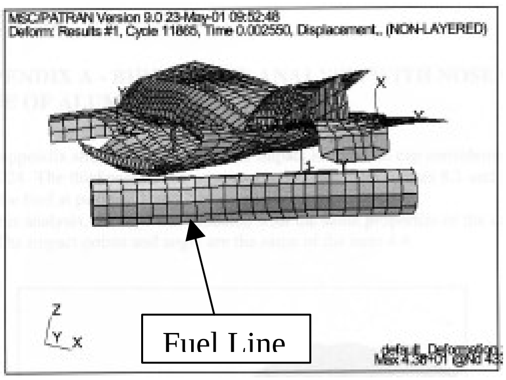
To establish analytical method to predict damage of structure in bird strike, we tried to simulate the phenomenon after the test using LS-DYNA. The model of structure was build up with elasto-plastic shell elements. To simulate tearing, eroding technique was used in which




(a) Deflection (Preliminary Design)




(b) Deflection around Fuel Pipe (Preliminary Design)




(c) Deflection around Fuel Pipe (Improved Design)

Fig.2 Analytical Results (Design Phase)

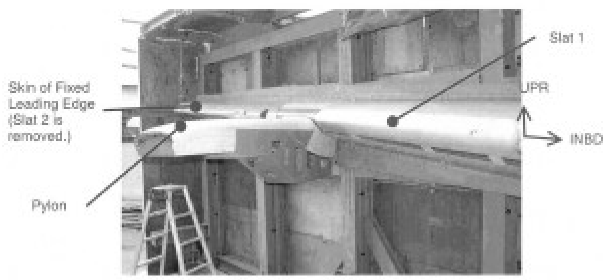



Fig.3 Test Model

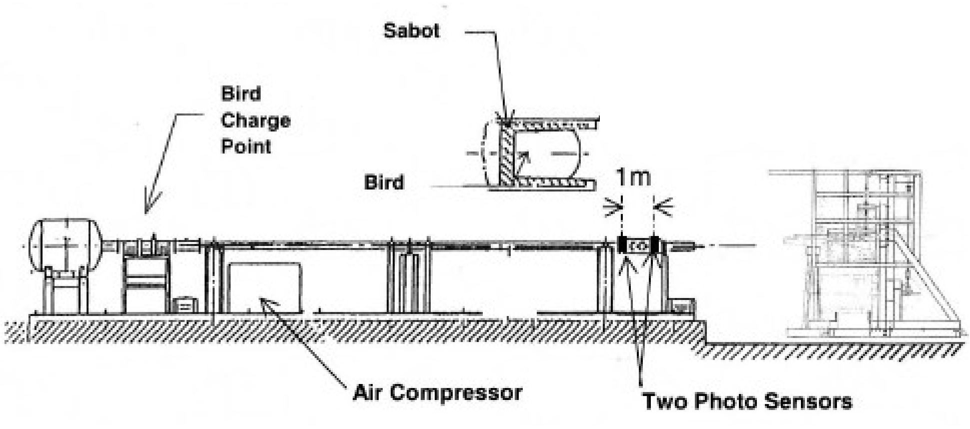
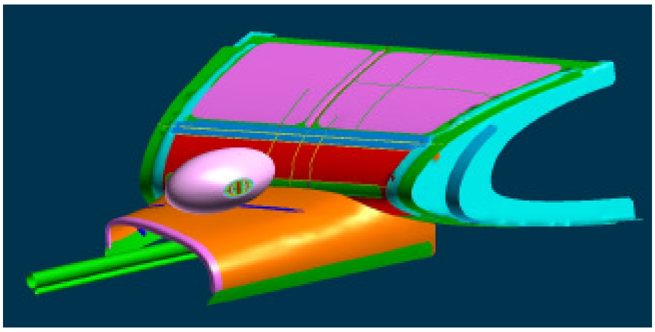


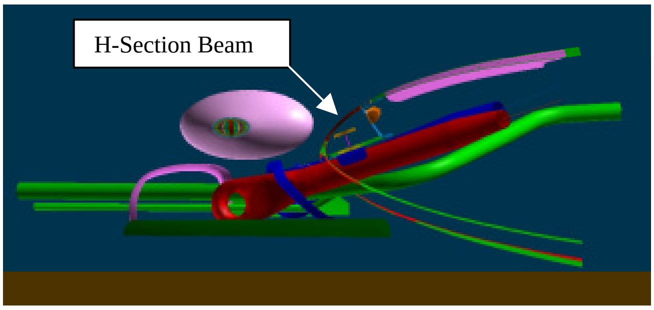

Fig.4 Equipment of Bird Strike

highly stressed elements are deleted. The model parts, which seemed to break, were divided in fine mesh.

Bird was modeled as an oval liquid body with viscosity. To simulate breaking phenomenon of bird, eroding technique was also used.



(a) Pylon Cover




(b) Side View (Inside)

Fig. 5 Analytical Model

## 5 Damage Comparison

### 5.1 Results of Bird Strike Test

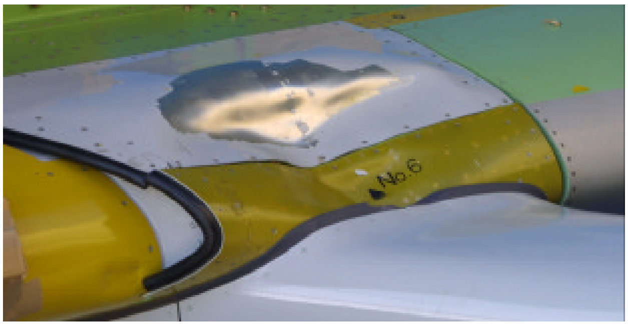
Bird strike damage of the pylon cover area observed in the test is shown in figure 6. The skin of the pylon cover was deformed, but the skin was not torn. The cover reflected the bird upward and prevented the bird from entering the structure. A stiffener riveted inside of the cover skin was heavily deformed and cracked along the corner of the stiffener.

The H-section beam was also deformed, but the link rods supported the deformed beam as shown in figure 6 (d). The fuel line was hit by the deformed beam, but rupture of the fuel line did not occur. This test result proved that the improved design worked.

### 5.2 Results of Bird Strike Analysis

We conducted bird strike analysis of the pylon cover in the same condition as the test and compared it with the test result. The results of the analysis shows good agreement with the test result. Difference between the analysis and the test result is discussed in this section.

The contact phenomenon gotten by the analysis is shown in Fig. 7. It should be noticed that the analysis shows left-hand wing while the bird strike test was done using right-hand wing. As shown in the figure, bird smashed on pylon cover and became flat shape changing flying




(a) Deformation of Pylon Cover

(b) Inside of Pylon Cover and Stiffener


(c) H-Section Beam

(d) Fuel Pipe

Fig.6 Results of the Test

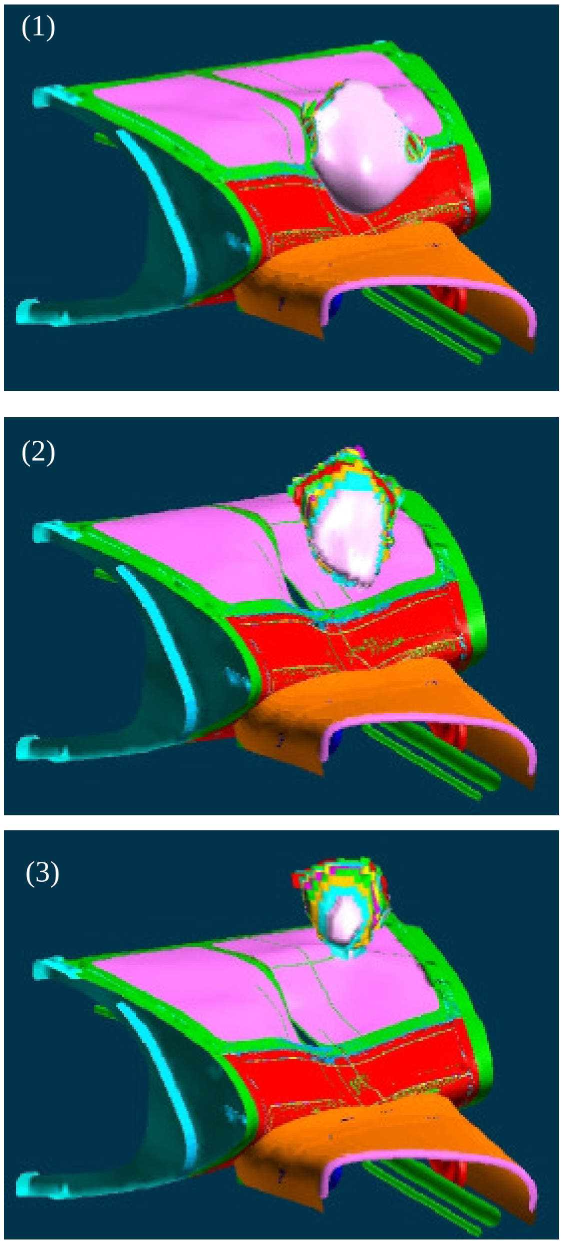
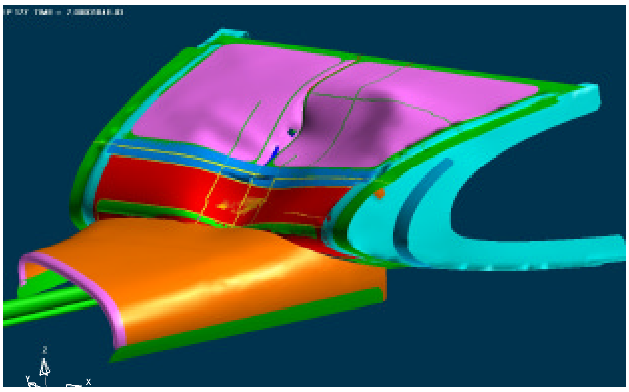


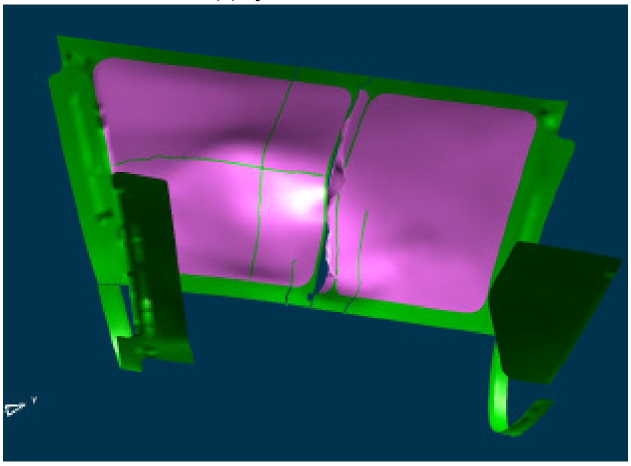

Fig. 7 Results of the Analysis
(Contact Event in a few milliseconds)

course upward. After the first contact, pressure in the forward part of the bird became lower than the atmosphere, and the eroding function began deleting these elements to simulate breaking.

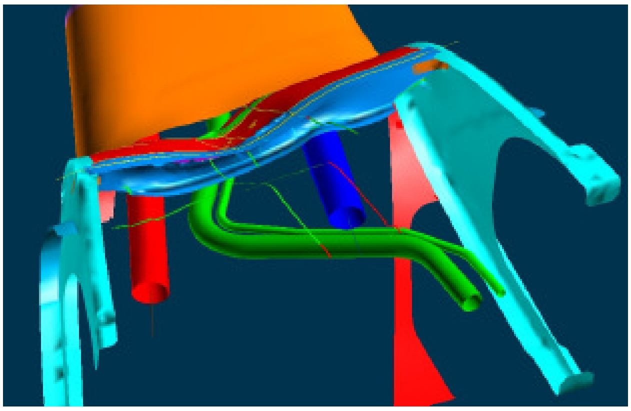
The deformation of the structure after contact event is shown in Fig. 8. In the analysis crack occurred in pylon cover skin along the stiffener while there was no crack in the test. One of the reasons of this difference is that the actual stiffener is riveted to the pylon cover skin, but in the analysis stiffener is integrated to the



(a)Pylon Cover



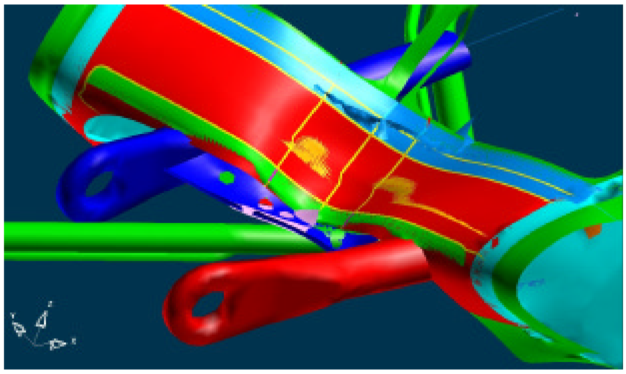
(b)Inside of Pylon Cover and Stiffener



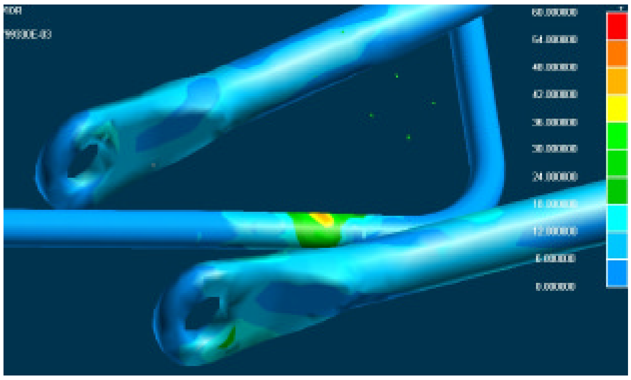
(c)H-Section Beam

Fig.8  Results of the Analysis

skin. In the latter case, the integrated parts are thicker than the ordinary parts, so high stress is produced in the ordinary parts along the border between these two parts. The deformation of the H-section beam is nearly the same as that observed in the test. The contact situation of the



(a)Contact Condition



(b)Mises Stress Intesity

Fig.9  Results of the Analysis

fuel line with other parts is shown in Fig. 9 (a), and the stress distribution (Mises stress intensity) in the fuel line is shown in Fig.9 (b). In the analysis, the deformed beam contacts with the fuel line and the stress level in the fuel line is about 90% of the yield stress.

## 7 Conclusions

Embraer170 Wing leading edge structure withstood all 9 shots without any serious damage.

Design improvement of the pylon cover against bird strike was performed using bird strike analysis. The bird strike test proved that the design worked as predicted.

Refinement of the bird strike analysis was performed after the bird strike test. The damage predicted by the analysis shows good agreement with the damage observed in the test.