ANALYSIS AND RIG TEST IN EMB170 FLAP MECHANISM DEVELOPMENT

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Keywords: kinematics, high lift device, rig test

Abstract

Kawasaki Heavy Industries, Ltd. developed flap mechanism of Embraer 170. Kinematic analysis and rig test for the flap mechanism were performed in order to reduce development risk. Basic operation tests were performed successfully before the first flight of the aircraft.

1 Introduction

Kawasaki is participating the development of Embraer 170/190 commercial jet family as a partner and responsible for development of the flap mechanism and structure.

The flap of Embraer 170 is a double-slotted type to realize high lift coefficient at landing (see figure 1). The flap mechanism is a sophisticated design with track rails, rollers and rods.

During the development phase of the flap mechanism, Kawasaki performed internal load analysis considering gaps, friction, flap panel loading, and wing deflection using the multi-body system simulation program, MSC.ADAMS.

Kawasaki also performed flap mechanism rig test for both inboard flap and outboard flap to validate the analysis. Flap panel load and wing deflection were simulated in the test.

This paper presents the overview of the kinematic analysis and the rig test of Embraer 170.

Fig.1. Embraer 170 and Flap

2 Flap Mechanism

Two track supports are attached to the trailing edge of the wing box structure to support each flap, the inboard flap and the outboard flap. Each track has two main track rails. A main carriage with four rollers follows the rails.

All flap panels are mainly made of composite material. Each main flap panel is attached to the two main carriages. Two aft track rails are extended from each main panel to support the aft panel. Four actuators at the track positions drive the mechanism through rods and bellcranks.

See figure 2 for the flap mechanism and its movement.

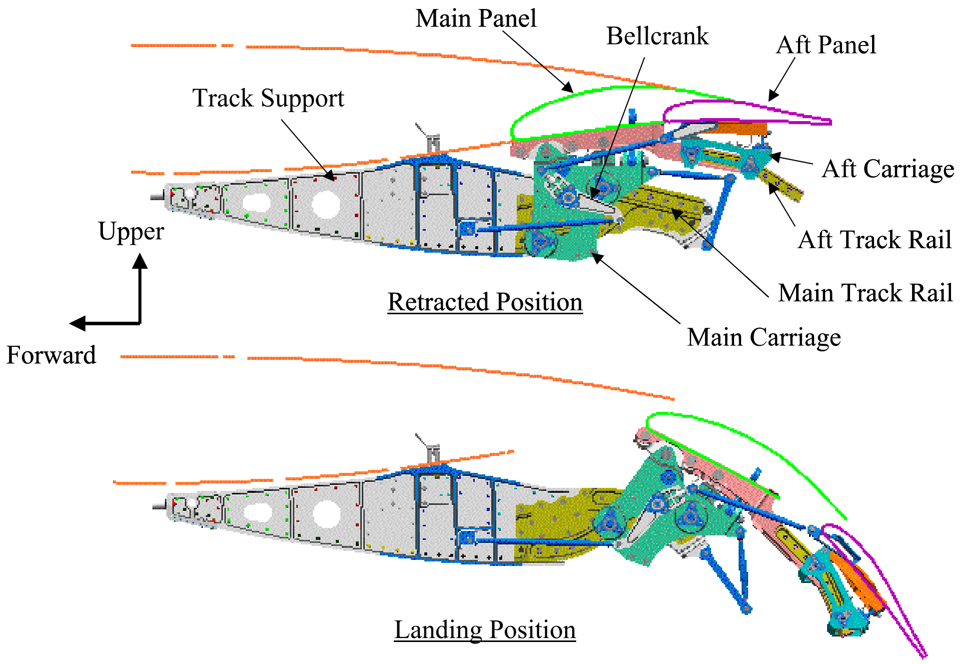

Fig. 2. Flap Mechanism

3 Analysis

Following effects should be considered in the analysis of the flap mechanism.

- Movement of the mechanism
- Friction in the rollers
- Gaps between the rollers and the rails
- Air load on the panels
- Deflection of the panels
- Deformation of the components of the mechanism

Kinematic analysis is necessary to tackle with the problem. The kinematic analysis calculates internal load to be used for stress analysis of components of the flap mechanism. Kawasaki uses MSC.ADAMS.

In order to simulate the effect of flexibility of the parts, the major structural elements were modeled as “flex parts.” The same models as used in the stress analysis (MSC.NASTRAN) were used in the MSC.ADAMS analysis. The friction coefficients were tuned by using the data obtained in the rig test. Figures 3 to 5 shows ADAMS model for outboard flap mechanism.

Both normal operation and failure cases were analyzed. Failure cases include jamming of rollers, system failures, failure of structural parts, etc. Total of over 6,000 cases were analyzed.

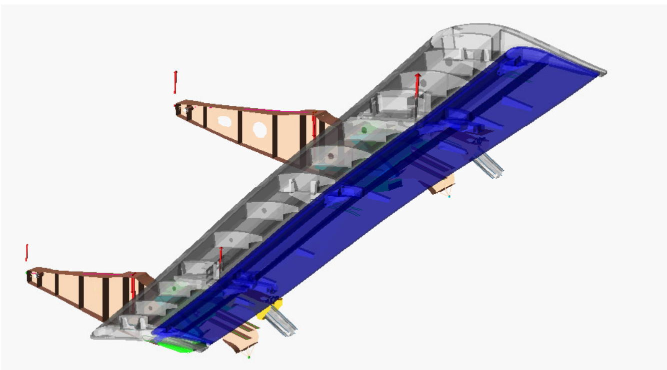

Fig. 3. ADAMS Model –
Outboard Flap, Retracted Position

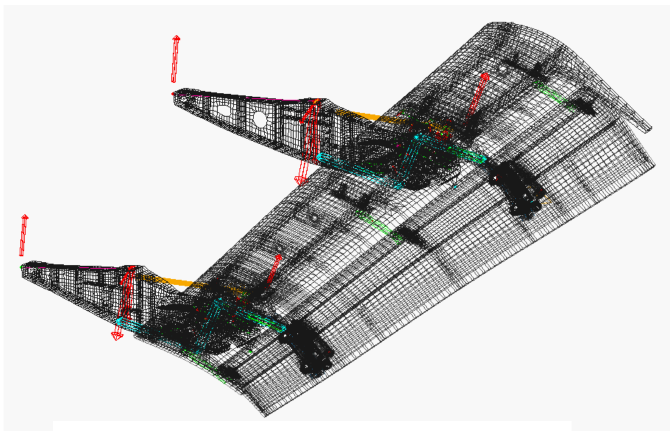

Fig. 4. ADAMS Model –
Outboard Flap, Take-off Position

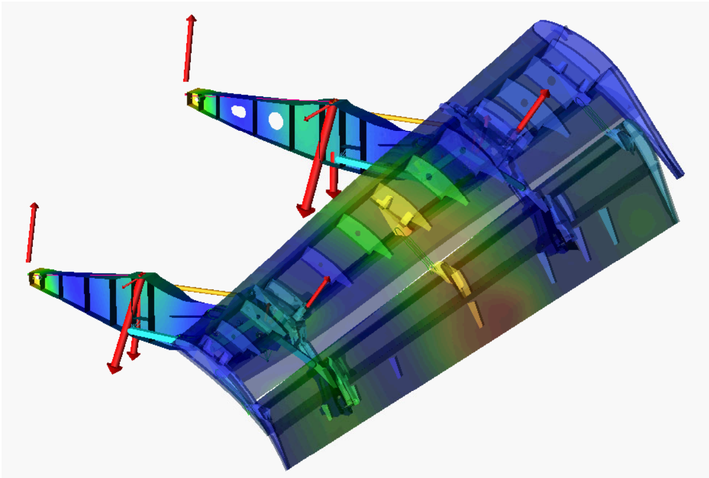

Fig. 5. ADAMS Model –
Outboard Flap, Landing Position

4 Rig Test

4.1 Test Objective

The objective of the flap mechanism rig test is as follows.

- To demonstrate smooth operation of the mechanism under realistic condition before the first flight.
- To obtain internal load data in normal operations and failure conditions for validation of analysis.
- To obtain endurance data of moving components of the mechanism.

4.2 Test Articles and Test Equipment

Both inboard flap and outboard flap were tested in the separate test fixtures.

In order to simulate the actual condition as much as possible, the following actual parts were used in the test articles.

- Flap mechanisms
- Track supports and track rails
- Actuators
- Drive lines
- Flap panels

The test fixture can simulate:

- Air load on the flap panels.
  Magnitude and direction of the air load can vary in accordance with flap position. See figure 6 for the concept of flap panel load application. Two actuators for each panel are used and the actuator loads are distributed on the panel with a set of whiffletree.
- Wing deflection.
  The position of the track supports deflect due to the wing deflection. See figure 7 for simulation of wing deflection. One of the support fixtures is fixed and another support fixture can be moved with three screw jacks.

Instrumentation for internal load data acquisition was provided.

- Strain gages in major load paths
- Special instrumented bolts in connection points of mechanism

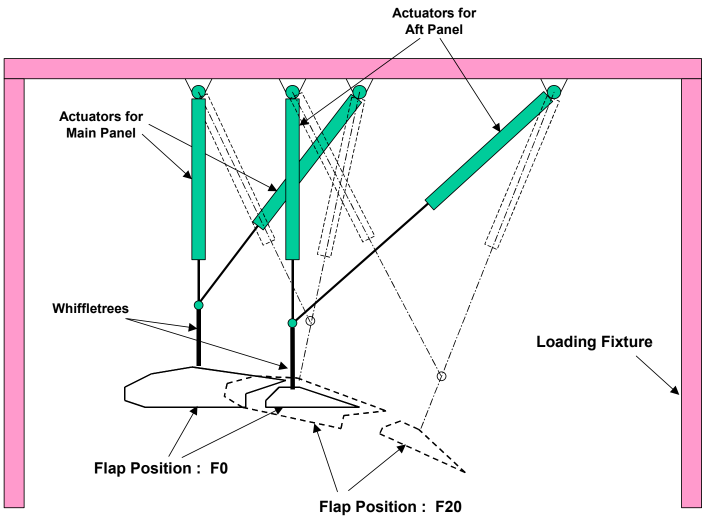

Fig. 6. Panel Loading Concept

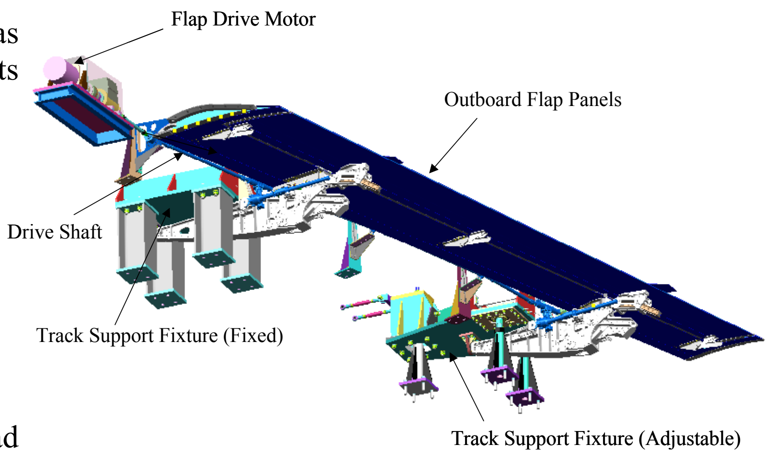

Fig. 7. Test Fixture – Outboard Flap

4.3 Test Results

Normal operation tests, failure tests and endurance test were performed at Kawasaki facility.

Normal flap operation patterns (taxing, take-off and landing) under simulated air load and wing deflection were applied to the rig. Internal load data was obtained in the tests. Figure 8 shows an example of the normal operation test pattern. Figures 9 and 10 show normal operation test of inboard flap and outboard flap. Normal operation tests of basic conditions had been successfully completed before the first flight.

Failure tests simulated failure of components and roller jamming in the mechanism. The actuators were operated with the failure or the jamming imposed. Behavior of the mechanism was closely observed and internal loads were measured in the failure tests.

Over 200 cases were tested in the normal operation tests and the failure tests. No adverse behavior was observed in the tests.

5,000 flight cycles of endurance test was performed for both inboard flap and outboard flap. No major abrasion problems were observed.

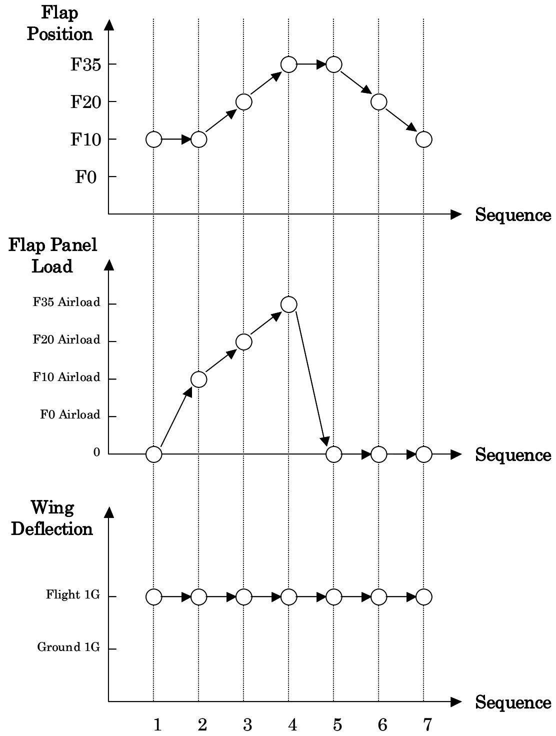

Fig. 8. Example of Normal Operation Test Pattern

5 Conclusions

The flap mechanism of Embraer 170 is a complex system and it was necessary for Kawasaki to perform intensive analysis and the rig test to reduce the development risk. The efforts resulted in the maturity of the flap mechanism design. We have had virtually no design problems in the flap mechanism in two years of the flight test.

The sophisticated kinematic analysis methodology of the flap mechanism has been established and validated in the program.

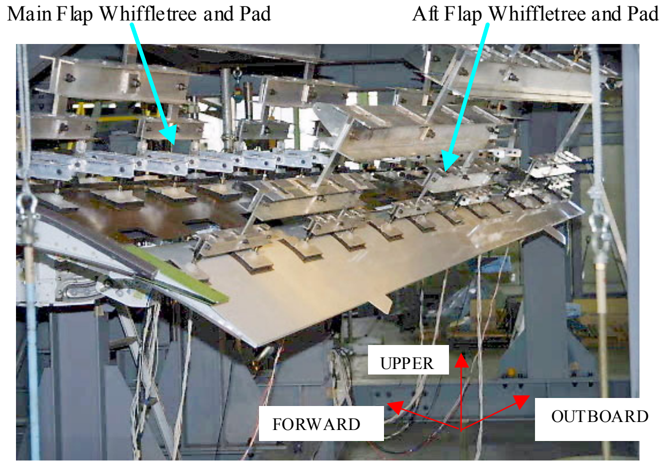

Fig. 9. Normal Operation Test – Outboard Flap

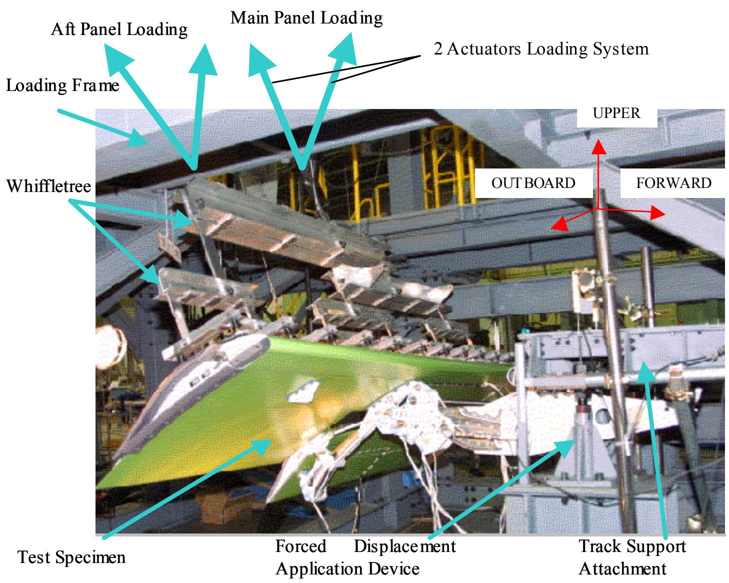

Fig. 10. Normal Operation Test – Inboard Flap